Oracle® Database

Security Guide

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Oracle Database Security Guide 11*g* Release 2 (11.2)

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Preface

Welcome to *Oracle Database Security Guide*. This guide describes how you can configure security for Oracle Database by using the default database features.

This preface contains these topics:

Audience

Oracle Database Security Guide is intended for database administrators (DBAs), security administrators, application developers, and others tasked with performing the following operations securely and efficiently:

- Designing and implementing security policies to protect the data of an organization, users, and applications from accidental, inappropriate, or unauthorized actions
- Creating and enforcing policies and practices of auditing and accountability for inappropriate or unauthorized actions
- Creating, maintaining, and terminating user accounts, passwords, roles, and privileges
- Developing applications that provide desired services securely in a variety of computational models, leveraging database and directory services to maximize both efficiency and ease of use

To use this document, you need a basic understanding of how and why a database is used, and basic familiarity with SQL.

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visit http://www.oracle.com/pls/topic/lookup?ctx=acc&id=trs if you are hearing impaired.

Related Documents

For more security-related information, see these Oracle resources:

- *Oracle Database Administrator's Guide*
- *Oracle Database 2 Day DBA*
- *Oracle Database 2 Day + Security Guide*
- *Oracle Database Concepts*
- *Oracle Database Reference*
- *Oracle Database Vault Administrator's Guide*

Many of the examples in this guide use the sample schemas of the seed database, which you can create when you install Oracle Database. See *Oracle Database Sample Schemas* for information about how these schemas were created and how you can use them yourself.

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Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

What's New in Oracle Database Security?

The Oracle Database 11*g* Release 2 (11.2) security features and enhancements described in this section comprise the overall effort to provide superior access control, privacy, and accountability with this release of Oracle Database.

The following sections describe new security features of Oracle Database 11*g* Release 2 (11.2) and provide pointers to additional information:

- Oracle Database 11g Release 2 (11.2.0.2) New Security Features
- Oracle Database 11g Release 2 (11.2.0.1) New Security Features
- Oracle Database 11g Release 1 (11.1) New Security Features

Oracle Database 11*g* Release 2 (11.2.0.2) New Security Features

This section contains:

- Enhancements to Fine-Grained Access to External Services and Wallets
- Support for MERGE INTO Statements for Virtual Private Database Policies
- BY ACCESS Audit Trail Option Now the Default for AUDIT Statements
- Enhancements for the UTL_SMTP PL/SQL Package
- New DBMS_SCHEDULER PL/SQL Package Global Scheduler Attributes
- Change to the UNLIMITED TABLESPACE System Privilege

Enhancements to Fine-Grained Access to External Services and Wallets

In this release, when you use fine-grained access control to configure external network services and wallets, you now can control access to the `DBMS_LDAP` PL/SQL package. In a default database installation, this package is created with the `EXECUTE` privilege granted to `PUBLIC` users. This release enhances the security of this package by enabling you to control access to applications in the database that use this package. As part of this enhancement, the `DBMS_LDAP` package is now an invoker's rights package. Before a user can connect to a remote network host, he or she must be granted the `connect` privilege in the access control list that was assigned to the remote network host.

See *Oracle Database PL/SQL Packages and Types Reference* for more information about the `DBMS_LDAP` package.

Support for MERGE INTO Statements for Virtual Private Database Policies

In previous releases of Oracle Database, when you created an Oracle Virtual Private Database policy on an application that included the `MERGE INTO` statement, the `MERGE INTO` statement would be prevented with an `ORA-28132: Merge into syntax does`

not support security policies error, due to the presence of the Virtual Private Database policy. In this release, you can create policies on applications that include MERGE INTO operations. To do so, in the DBMS_RLS.ADD_POLICY statement_types parameter, include the INSERT, UPDATE, and DELETE statements, or just omit the statement_types parameter altogether.

See "Enforcing Policies on Specific SQL Statement Types" on page 7-7 for more information.

BY ACCESS Audit Trail Option Now the Default for AUDIT Statements

Starting with this release, the standard audit records will by default be generated using the BY ACCESS clause functionality of the AUDIT statement. Both the BY ACCESS and BY SESSION clauses write an individual audit record for each audited event, but BY ACCESS captures more detail about the audited event.

See "Benefits of Using the BY ACCESS Clause in the AUDIT Statement" on page 9-22 for more information.

Enhancements for the UTL_SMTP PL/SQL Package

Starting with this release, the UTL_SMTP PL/SQL package has the following new functionality:

- You now can configure the UTL_SMTP PL/SQL package for use on both Transport Layer Security (TLS) and Secure Sockets Layer (SSL) servers.
- UTL_SMTP now provides support for the PLAIN, LOGON and CRAM_MD5 password authentication schemes.

See *Oracle Database PL/SQL Packages and Types Reference* for more information about the UTL_SMTP package.

New DBMS_SCHEDULER PL/SQL Package Global Scheduler Attributes

The DBMS_SCHEDULER PL/SQL package the following two new global scheduler attributes, which are used to control encryption for connections to a mail server:

- email_server_credential, which enables you to specify the schema and name of an existing credential object on which user SYS has the EXECUTE object privilege
- email_server_encryption, which enables you to set one of three encryption settings for your mail server:
  - ssl_tls, which uses SSL or TLS to encrypt the connection to the mail server form the beginning of the connection
  - starttls, in which the connection to the mail server starts as unencrypted but switches to an encrypted connection
  - none, in which no encryption is used to connect to the mail server

See *Oracle Database Administrator's Guide* for more information about Scheduler preferences.

Change to the UNLIMITED TABLESPACE System Privilege

In previous releases, when you revoked the UNLIMITED TABLESPACE system privilege from users, then the explicit quotas again took effect. Starting with this release, after you revoke the UNLIMITED TABLESPACE system privilege, you must explicitly grant quotas to individual tablespaces.

See "Granting Users the UNLIMITED TABLESPACE System Privilege" on page 2-5 for more information about the UNLIMITED TABLESPACE system privilege.

Oracle Database 11*g* Release 2 (11.2.0.1) New Security Features

This section contains:

Enhancements to Fine-Grained Access to External Services and Wallets

The previous release of Oracle Database introduced the ability to create fine-grained access control to external network services and wallets. In this release, the following enhancements are available:

- **Updates to the UTL_HTTP PL/SQL package.** You now can configure network services to use the Amazon Simple Storage Service (S3) scheme, which configures access to the Amazon.com Web site. In addition, an individual application can make HTTP requests by using its private wallet and HTTP cookie table that will not be shared with other applications in the same database session. This feature also offers protection of the wallet using the access control list (ACL) privileges in place of the password credential.
- **Support for IP Version 6 (IPv6) addresses.** The `DBMS_NETWORK_ACL_ADMIN` and `DBMS_NETWORK_ACL_UTILTIY` packages, and the PL/SQL network utility packages (such as `UTL_TCP`, `UTL_SMTP`, `UTL_MAIL`, `UTL_HTTP`, and `UTL_INADDR`), now support both IP Version 4 (IPv4) and IPv6 addresses.

See "Managing Fine-Grained Access in PL/SQL Packages and Types" on page 4-49 for more information.

Global Application Contexts Available Across Oracle RAC Instances

In this release, changes to global application context values are automatically accessible across all Oracle Real Application Clusters (Oracle RAC) instances.

See "Using Global Application Contexts" on page 6-22 for more information about creating a global application context.

Secure Sockets Layer (SSL) Version 2 Support Change

Starting with Oracle Database 11*g* Release 2 (11.2), SSL version 2 is no longer included in the default list of default supported protocols. If your applications must use SSL version 2, then you can do so by explicitly setting SSL version 2 while maintaining the connection.

See *Oracle Database Advanced Security Administrator's Guide* for more information.

Enhancements to Directory Objects

This section contains:

- Ability to Audit Directory Objects

EXECUTE Privilege Available for Directory Objects

You now can grant users the `EXECUTE` privilege on directory objects that contain a user-supplied preprocessor program for use by the `ORACLE_LOADER` access driver. This prevents the user from accidentally or maliciously corrupting the preprocessor program. The SQL statements that are affected by the `EXECUTE` privilege are `GRANT` and `REVOKE`. The `ORACLE_LOADER` access parameters now include the `PREPROCESSOR` clause, which you can use to specify the name and location of a preprocessor program that modifies the contents of a data file so that the `ORACLE_LOADER` access driver can read it.

For more information about using the `ORACLE_LOADER` access driver preprocessor, see the following:

- *Oracle Database Utilities* for more information about the `ORACLE_LOADER` access driver
- "Granting System Privileges and Roles" on page 4-37 for the syntax of granting the `EXECUTE` privilege for a directory object
- "Guidelines for Securing the ORACLE_LOADER Access Driver" on page 10-11
- *Oracle Database SQL Language Reference* for updates to the `GRANT` and `REVOKE` SQL statements

Ability to Audit Directory Objects

You now can audit the `EXECUTE` privilege on directory objects. This enables you to monitor users who run a preprocessor program (which is used by the `ORACLE_LOADER` access driver) that has been added to a directory object.

See "Auditing Directory Objects" on page 9-32 for more information.

Enhancements to Transparent Data Encryption

This section contains:

- Unified Master Encryption Key
- Tablespace Master Key Rekey: Changing the Encryption Key Password
- Transparent Data Encryption Support for Oracle Exadata
- Automatic Wallet Management Across Oracle RAC Instances

Unified Master Encryption Key

In this release, the master encryption key for transparent tablespace encryption and transparent column encryption are now combined to one unified master encryption key. Combining these keys enables transparent re-key operations for both of these transparent data encryption features, regardless of whether the master encryption key is stored in the Oracle Wallet or in one of the certified Hardware Security Modules offered by RSA, SafeNet, Thales (including nCipher), and Utimaco.

For more information about transparent data encryption, see *Oracle Database Advanced Security Administrator's Guide*.

Tablespace Master Key Rekey: Changing the Encryption Key Password

In this release, Oracle Advanced Security enables you to change the master key that protects the encryption keys used to encrypt Oracle Database tablespaces. Industry initiatives, such as the Payment Card Industry Data Security Standard (PCI DSS), mandate periodic rotation of encryption keys associated with credit card data.

For more information about tablespace encryption, see *Oracle Database Advanced Security Administrator's Guide*.

Transparent Data Encryption Support for Oracle Exadata

Starting with this release, the master encryption key is copied to the intelligent storage cells, where data encrypted with transparent tablespace encryption or transparent column encryption is now decrypted before the pre-filtering of the result set takes place. This feature improves performance in databases that use transparent data encryption.

For more information about Oracle Exadata, see *Oracle Database High Availability Overview*.

Automatic Wallet Management Across Oracle RAC Instances

When you now open or close an Oracle wallet or re-key the master encryption key on one Oracle RAC instance, then the changes you make automatically are propagated to all other Oracle RAC instances.

For more information, see *Oracle Database Advanced Security Administrator's Guide*.

Enhancements to the Audit Trail Cleanup Process

Oracle Database 11*g* Release 2 (11.2) introduces several enhancements to the audit trail cleanup process. In this release, you can:

- **Timestamp audit trail records based on their archive date.** Later on, you can purge all records that were created before this archive date.

  See "Step 4: Optionally, Set an Archive Timestamp for Audit Records" on page 9-69 for more information.

- **Purge audit trail records in one operation or create a purge job.** You can purge all audit trail records in the system, or audit trail records of an individual type, such as all fine-grained audit trail records within the database audit trail. The purge operation will either remove audit trail records that were created before their timestamped archive date, or it will remove all audit trail records of the specified audit trail type. The purge job enables you to purge records based on a time interval, and also can remove records based on their timestamped archive date.

  See the following sections:

  - "Scheduling an Automatic Purge Job for the Audit Trail" on page 9-67
  - "Manually Purging the Audit Trail" on page 9-72

- **Move the database audit trail table from the SYSTEM tablespace to a different tablespace.** You can move the standard audit trail table, the fine-grained audit trail table, or both standard and fine-grained audit trail tables together. Consider moving the database audit trail from the `SYSTEM` tablespace if it is too busy.

  See "Moving the Database Audit Trail to a Different Tablespace" on page 9-60 for more information.

- **Set a batch size for the database audit trail records so that when they are purged, the purge operation deletes each batch.** In a purge operation, you remove all or some of the audit trail records. Typically, you do this after you archive the audit trail. Afterwards, the audit trail will resume collecting audit data. The batching process enables you remove the records in groups, for example, 10,000 records at a time, rather than deleting all records at a time.

See "Step 6: Optionally, Configure the Audit Trail Records to be Deleted in Batches" on page 9-71 for more information.

- **Set a maximum size and age for the operating system audit trail.** When the current audit file reaches this maximum, Oracle Database stops populating the current file and creates a new file for the subsequent audit trail records.

  See the following sections:

  - "Setting the Size of the Operating System Audit Trail" on page 9-62
  - "Setting the Age of the Operating System Audit Trail" on page 9-64

Deprecated Security-Related Features

This section contains:

- DB_EXTENDED Setting for the AUDIT_TRAIL Parameter Deprecated
- WKUSER Role and Ultra Search Schemas Deprecated
- Database Configuration Assistant No Longer Provides Default Security Settings
- ALTER USER Clause AUTHENTICATED USING PASSWORD Deprecated
- Password for the listener.ora File Deprecated

DB_EXTENDED Setting for the AUDIT_TRAIL Parameter Deprecated

The `DB_EXTENDED` setting in the `AUDIT_TRAIL` initialization parameter has been deprecated. Instead, use the `DB, EXTENDED` setting in its place.

See "Configuring Standard Auditing with the AUDIT_TRAIL Initialization Parameter" on page 9-8 for more information.

WKUSER Role and Ultra Search Schemas Deprecated

The `WKUSER` role and the `WKSYS`, `WKTEST`, `WKPROXY` schemas have been deprecated. For more information about Oracle Ultra Search, see *Oracle Ultra Search Administrator's Guide*.

Database Configuration Assistant No Longer Provides Default Security Settings

In the previous release of Oracle Database, you could use Database Configuration Assistant (DBCA) to add password security and audit options to a new database. This option is not available in this release. In this release, DBCA automatically adds audit options and password policies to new databases.

See the following sections for more information:

- "Configuring Password Settings in the Default Profile" on page 3-4
- "Using Default Auditing for Security-Relevant SQL Statements and Privileges" on page 9-35

ALTER USER Clause AUTHENTICATED USING PASSWORD Deprecated

The `AUTHENTICATED USING PASSWORD` clause of the `ALTER USER` statement has been deprecated for this release. If you use this clause, Oracle Database converts it to the `AUTHENTICATION REQUIRED` clause. If you do not specify the `AUTHENTICATION REQUIRED` clause, then Oracle Database uses either the `AUTHENTICATED USING CERTIFICATE` clause or the `AUTHENTICATED USING DISTINGUISHED NAME` clause.

See *Oracle Database SQL Language Reference* for more information about the `ALTER USER` statement options.

Password for the listener.ora File Deprecated

Setting a password for the `listener.ora` file has been deprecated for this release, because it is no longer needed. In the next release, the listener password will not be supported.

Oracle Database 11*g* Release 1 (11.1) New Security Features

This section contains:

- Automatic Secure Configuration
- New Password Protections
- SYSDBA and SYSOPER Strong Authentication
- SYSASM Privilege for Automatic Storage Management
- Encryption Enhancements
- Fine-Grained Access Control on Network Services on the Database
- Change to AUDIT BY SESSION
- Oracle XML DB Security Enhancements
- Directory Security Enhancements
- Oracle Call Interface Security Enhancements

Automatic Secure Configuration

When you create a new database, you can use Database Configuration Assistant (DBCA) to automatically create a more secure configuration than in previous releases of Oracle Database. You can enable the following secure configuration settings in one operation:

- **Password-specific settings in the default profile.** This feature enables you to enforce password expiration and other password policies. See "Configuring Password Settings in the Default Profile" on page 3-4 for more information.
- **Auditing.** This feature enables auditing for specific events such as database connections. See "Using Default Auditing for Security-Relevant SQL Statements and Privileges" on page 9-35 for more information.

To configure your database for greater security, follow the guidelines in Chapter 10, "Keeping Your Oracle Database Secure".

New Password Protections

Oracle Database now includes the following new password protections:

- **Easy ability to find default passwords.** If you have upgraded from an earlier release of Oracle Database, you may have user accounts that still have default passwords. For greater security, you should find and change these passwords. See "Finding User Accounts That Have Default Passwords" on page 3-4 for more information.
- **Password verification.** Password verification ensures that users set complex passwords when setting or resetting passwords. You can enforce password by using the default settings provided by Oracle Database, or create custom requirements to further secure the password requirements for your site.

  "Enforcing Password Complexity Verification" on page 3-11 describes built-in password verification.

- **Enforced case sensitivity.** See "Enabling or Disabling Password Case Sensitivity" on page 3-13 for more information.
- **Stronger password hashing algorithm.** This enhancement enables users to create passwords that contain mixed case or special characters. See "Ensuring Against Password Security Threats by Using the SHA-1 Hashing Algorithm" on page 3-15 for more information.

SYSDBA and SYSOPER Strong Authentication

You can now use the Secure Sockets Layer (SSL) and Kerberos strong authentication methods to authenticate users who have the `SYSDBA` and `SYSOPER` privileges.

See "Strong Authentication and Centralized Management for Database Administrators" on page 3-22 for more information.

SYSASM Privilege for Automatic Storage Management

The `SYSASM` system privilege has been added to Oracle Database 11*g* Release 2 (11.2), to be used exclusively to administer Automatic Storage Management (ASM). Use the `SYSASM` privilege instead of the `SYSDBA` privilege to connect to and administer ASM instances.

See *Oracle Automatic Storage Management Administrator's Guide* for more information about the `SYSASM` privilege.

Encryption Enhancements

This section describes the following enhancements in encryption:

- Intelligent LOB Compression, Deduplication, and Encryption with SecureFiles
- Compressed and Encrypted Dump File Sets
- Transparent Data Encryption with Hardware Security Module Integration
- Transparent Tablespace Encryption

Intelligent LOB Compression, Deduplication, and Encryption with SecureFiles

Oracle Database supports a new, faster, and scalable Large Object (LOB) storage paradigm called SecureFiles. SecureFiles, in addition to performance, supports efficient compression, deduplication (that is, coalescing duplicate data), and encryption. LOB data can now be encrypted with Oracle Database, and is available for random reads and writes.

For more information about SecureFiles, see *Oracle Database SecureFiles and Large Objects Developer's Guide*. See also *Oracle Database SQL Language Reference* for updates in the `CREATE TABLE` and `ALTER TABLE` statements to support this feature.

Compressed and Encrypted Dump File Sets

In this release, you can use Oracle Data Pump to compress and encrypt an entire dump file set. You can optionally compress and encrypt the data, metadata, or complete dump file set during an Oracle Data Pump export.

For more information, see *Oracle Database Utilities*.

Transparent Data Encryption with Hardware Security Module Integration

Transparent data encryption (TDE) stores the master key in an encrypted software wallet and uses this key to encrypt the column keys, which in turn encrypt column data. While this approach to key management is sufficient for many applications, it

may not be sufficient for environments that require stronger security. TDE has been extended to use hardware security modules (HSMs). This enhancement provides high assurance requirements of protecting the master key.

This release enables you to store the TDE master encryption key within a hardware security module (HSM) at all times, leveraging its key management capabilities. Only the table keys (for TDE column encryption) and tablespace keys (for TDE tablespace encryption) are decrypted on the HSM, before they are returned to the database; the encryption and decryption of application data remains with the database. Oracle recommends that you encrypt the traffic between HSM device and databases. This new feature provides additional security for transparent data encryption, because the master encryption key cannot leave the HSM, neither in clear text nor in encrypted format. Furthermore, it enables the sharing of the same key between multiple databases and instances in an Oracle Real Applications Clusters (Oracle RAC) or Data Guard environment.

To configure transparent data encryption with hardware security module integration, see *Oracle Database Advanced Security Administrator's Guide*.

Transparent Tablespace Encryption

Transparent tablespace encryption enables you to encrypt entire application tablespaces, encrypting all the data within these tablespaces. When a properly authorized application accesses the tablespace, Oracle Database transparently decrypts the relevant data blocks for the application.

Transparent tablespace encryption provides an alternative to TDE column encryption: It eliminates the need for granular analysis of applications to determine which columns to encrypt, especially for applications with a large number of columns containing personally identifiable information (PII), such as Social Security numbers or patient health care records. If your tables have small amounts of data to encrypt, then you can continue to use the TDE column encryption solution.

For an introduction to transparent encryption, see *Oracle Database 2 Day + Security Guide*. For detailed information about transparent tablespace encryption, see *Oracle Database Advanced Security Administrator's Guide*.

Fine-Grained Access Control on Network Services on the Database

Oracle Database provides a set of PL/SQL utility packages, such as `UTL_TCP`, `UTL_SMTP`, `UTL_MAIL`, `UTL_HTTP`, and `UTL_INADDR`, that are designed to enable database users to access network services on the database. *Oracle Database PL/SQL Packages and Types Reference* describes the PL/SQL utility packages in detail.

In a default database installation, these packages are created with `EXECUTE` privileges granted to `PUBLIC` users. This release enhances the security of these packages by providing database administrators the ability to control access to applications in the database that use these packages.

See "Managing Fine-Grained Access in PL/SQL Packages and Types" on page 4-49 for more information.

Change to AUDIT BY SESSION

The `BY SESSION` clause of the `AUDIT` statement now writes one audit record for every audited event. In previous releases, `BY SESSION` wrote one audit record for all SQL statements or operations of the same type that were executed on the same schema objects in the same user session. Now, both `BY SESSION` and `BY ACCESS` write one audit record for each audit operation. In addition, there are separate audit records for `LOGON`

and LOGOFF events. If you omit the BY ACCESS clause, then BY SESSION is used as the default.

The audit record that BY SESSION generates is different from the BY ACCESS audit record. Oracle recommends that you include the BY ACCESS clause for all AUDIT statements, which results in a more detailed audit record. In the case of LOGOFF events, the timestamp for the audit record has a greater precision than in previous releases.

Be aware that this change applies to schema object audit options, statement options, and system privileges that audit SQL statements other than data definition language (DDL) statements. Oracle Database has always audited using the BY ACCESS clause on all SQL statements and system privileges that audit a DDL statement.

See the following sections for more information:

- "How Standard Audit Records Are Generated" on page 9-21
- "Benefits of Using the BY ACCESS Clause in the AUDIT Statement" on page 9-22

Oracle XML DB Security Enhancements

This section contains:

- XML Translation Support for Oracle Database XML
- Support for Web Services

XML Translation Support for Oracle Database XML

Security objects are now stored in the Oracle XML DB repository as XMLType objects. These security objects can contain strings that need to be translated to different languages so that they can be searched or displayed in those languages. Developers can store translated strings with the XMLType and retrieve and operate on these strings depending on the language settings of the user. The advantage of this feature is that it reduces the costs associated with developing applications that are independent of the target preferred language of the user.

To configure security for XMLType objects, see *Oracle XML DB Developer's Guide*.

Support for Web Services

You can now use the Oracle XML DB HTTP server for service-oriented architecture (SOA) operations. This allows the database to be treated as simply another service provider in an SOA environment. Security administrators can control user access to Oracle Database Web services and their associated database objects by using the XDB_WEBSERVICES, XDB_WEBSERVICES_OVER_HTTP, and XDB_WEBSERVICES_WITH_PUBLIC predefined roles.

To configure Oracle Database Web services, see *Oracle XML DB Developer's Guide*.For information on this feature's predefined roles, see Table 4–3, " Oracle Database Predefined Roles" on page 4-11.

Directory Security Enhancements

In this release, administrators can now disallow anonymous access to database service information in a directory and require clients to authenticate when performing LDAP directory-based name look-ups. If you are using Microsoft Active Directory-based name lookups, then Oracle Database uses the native operating system-based authentication. If you are using Oracle Internet Directory (OID)-based name lookups, then Oracle Database performs authentication by using wallets.

To configure directory security, see *Oracle Database Net Services Reference*.

Oracle Call Interface Security Enhancements

The following security enhancements are available for Oracle Call Interface (OCI):

- Reporting bad packets that may come from malicious users or intruders
- Terminating or resuming the client or server process on receiving a bad packet
- Configuring the maximum number of authentication attempts
- Controlling the display of the Oracle database version banner, to prevent intruders from finding information about the security vulnerabilities present in the database software based on the version
- Adding banner information, such as "Unauthorized Access" and "User Actions Audited," to server connections so that clients can display this information

Database administrators can manage these security enhancements for Oracle Call Interface developers by configuring a set of new initialization parameters. See Section , "Parameters for Enhanced Security of Database Communication" for more information. See also *Oracle Call Interface Programmer's Guide* for detailed information on Oracle Call Interface.

1

Introducing Oracle Database Security

This chapter contains:

About Oracle Database Security

You can use the default Oracle Database features to configure security in the following areas for your Oracle Database installation:

- **User accounts.** When you create user accounts, you can secure them in a variety of ways. You can also create password profiles to better secure password policies for your site. Chapter 2, "Managing Security for Oracle Database Users" describes how to manage user accounts.
- **Authentication methods.** Oracle Database provides several ways to configure authentication for users and database administrators. For example, you can authenticate users on the database level, from the operating system, and on the network. Chapter 3, "Configuring Authentication" describes how authentication in Oracle Database works.
- **Privileges and roles.** You can use privileges and roles to restrict user access to data. Appendix 4, "Configuring Privilege and Role Authorization" describes how to create and manage user privileges and roles.
- **Application security.** The first step to creating a database application is to ensure that it is properly secure. Appendix 5, "Managing Security for Application Developers" discusses how to incorporate application security into your application security policies.
- **User session information using application context.** An application context is a name-value pair that holds the session information. You can retrieve session information about a user, such as the user name or terminal, and restrict database and application access for that user based on this information. Chapter 6, "Using Application Contexts to Retrieve User Information" describes how to use application context.
- **Database access on the row and column level using Virtual Private Database.** A Virtual Private Database policy dynamically imbeds a `WHERE` predicate into SQL statements the user issues. Chapter 7, "Using Oracle Virtual Private Database to Control Data Access" describes how to create and manage Virtual Private Database policies.

- **Encryption.** You can disguise data on the network to prevent unauthorized access to that data. Appendix 8, "Developing Applications Using the Data Encryption API" explains how to use the `DBMS_CRYPTO` and PL/SQL package to encrypt data.
- **Auditing database activities.** You can audit database activities in general terms, such as auditing all SQL statements, SQL privileges, schema objects, and network activity. Or, you can audit in a granular manner, such as when the IP addresses from outside the corporate network is being used. This chapter also explains how to purge the database audit trail. Appendix 9, "Verifying Security Access with Auditing" describes how to enable and configure database auditing.

In addition, Chapter 10, "Keeping Your Oracle Database Secure" provides guidelines that you should follow when you secure your Oracle Database installation.

Additional Database Security Resources

In addition to the security resources described in this guide, Oracle Database provides the following database security products:

- **Advanced security features.** See *Oracle Database Advanced Security Administrator's Guide* for information about advanced features such as transparent data encryption, wallet management, network encryption, and the RADIUS, Kerberos, Secure Sockets Layer authentication.
- **Oracle Label Security.** Oracle Label Security secures database tables at the row level, allowing you to filter user access to row data based on privileges. See *Oracle Label Security Administrator's Guide* for detailed information about Oracle Label Security.
- **Oracle Database Vault.** Oracle Database Vault provides fine-grained access control to your sensitive data, including protecting data from privileged users. *Oracle Database Vault Administrator's Guide* describes how to use Oracle Database Vault.
- **Oracle Audit Vault.** Oracle Audit Vault collects database audit data from sources such as Oracle Database audit trail tables, database operating system audit files, and database redo logs. Using Oracle Audit Vault, you can create alerts on suspicious activities, and create reports on the history of privileged user changes, schema modifications, and even data-level access. *Oracle Audit Vault Administrator's Guide* explains how to administer Oracle Audit Vault.
- **Oracle Enterprise User Security.** Oracle Enterprise User Security enables you to manage user security at the enterprise level. *Oracle Database Enterprise User Security Administrator's Guide* explains how to configure Oracle Enterprise User Security.

In addition to these products, you can find the latest information about Oracle Database security, such as new products and important information about security patches and alerts, by visiting the Security Technology Center on Oracle Technology Network at

`http://www.oracle.com/technetwork/topics/security/whatsnew/index.html`

2

Managing Security for Oracle Database Users

This chapter contains:

About User Security

Each Oracle database has a list of valid database users. To access a database, a user must run a database application, and connect to the database instance using a valid user name defined in the database. Oracle Database enables you to set up security for your users in a variety of ways. When you create user accounts, you can specify limits to the user account. You can also set limits on the amount of various system resources available to each user as part of the security domain of that user. Oracle Database provides a set of database views that you can query to find information such as resource and session information. This chapter also describes profiles. A profile is collection of attributes that apply to a user. It enables a single point of reference for any of multiple users that share those exact attributes.

Another way to manage user security is to assign users privileges and roles. Chapter 4, "Configuring Privilege and Role Authorization" provides detailed information.

Creating User Accounts

This section contains:

- Setting a Default Role for the User

For guidelines about creating and managing user accounts and passwords, see the following sections:

- "Guidelines for Securing User Accounts and Privileges" on page 10-2
- "Guidelines for Securing Passwords" on page 10-7

Creating a New User Account

You create a database user with the `CREATE USER` statement. To create a user, you must have the `CREATE USER` system privilege. Because it is a powerful privilege, a database administrator or security administrator is usually the only user who has the `CREATE USER` system privilege.

Example 2–1 creates a user and specifies the user password, default tablespace, temporary tablespace where temporary segments are created, tablespace quotas, and profile. It also grants the user the minimum privilege, `CREATE SESSION`, to log in to the database session.

Example 2–1 Creating a User Account with the CREATE SESSION Privilege

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk;
GRANT CREATE SESSION TO jward;
```

Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

A newly created user cannot connect to the database until you grant the user the `CREATE SESSION` system privileges. So, immediately after you create the user account, use the `GRANT` SQL statement to grant the user these privileges. If the user must access Oracle Enterprise Manager, you should also grant the user the `SELECT ANY DICTIONARY` privilege.

Note: As a security administrator, you should create your own roles and assign only those privileges that are needed. For example, many users formerly granted the `CONNECT` privilege did not need the additional privileges `CONNECT` used to provide. Instead, only `CREATE SESSION` was actually needed, and in fact, that is the only privilege `CONNECT` presently retains.

Creating organization-specific roles gives an organization detailed control of the privileges it assigns, and protects it in case Oracle Database changes the roles that it defines in future releases. Chapter 4, "Configuring Privilege and Role Authorization" discusses how to create and manage roles.

Specifying a User Name

Within each database, a user name must be unique with respect to other user names and roles. A user and role cannot have the same name. Furthermore, each user has an

associated schema. Within a schema, each schema object must have a unique name. In the following, the text in **bold** shows how to create the user name.

User jward is stored in the database in upper-case letters. For example:

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk
 CONTAINER = CURRENT;

SELECT USERNAME FROM ALL_USERS;

USERNAME
---------
JWARD
...
```

However, if you enclose the user name in double quotation marks, then the name is stored using the case sensitivity that you used for the name. For example:

```
CREATE USER "jward" IDENTIFIED BY password;
```

So, when you query the ALL_USERS data dictionary view, you will find that the user account is stored using the case that you used to create it.

```
SELECT USERNAME FROM ALL_USERS;

USERNAME
---------
jward
...
```

User JWARD and user jward are both stored in the database as separate user accounts. Later on, if you must modify or drop the user that you had created using double quotation marks, then you must enclose the user name in double quotation marks.

For example:

```
DROP USER "jward";
```

Assigning the User a Password

In Example 2–1 on page 2-2, the new user is to be authenticated using the database. In this case, the connecting user must supply the correct password to the database to connect successfully. To specify a password for the user, use the IDENTIFIED BY clause in the CREATE USER statement.

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk;
```

See Also:

- "Minimum Requirements for Passwords" on page 3-3 for the minimum requirements for creating passwords
- "Guidelines for Securing Passwords" on page 10-7 for additional ways to secure passwords
- Chapter 3, "Configuring Authentication" for information about authentication methods that are available for Oracle Database users

Assigning a Default Tablespace for the User

Each user should have a default tablespace. When a schema object is created in the user's schema and the DDL statement does not specify a tablespace to contain the object, Oracle Database stores the object in the default user's tablespace.

The default setting for the default tablespaces of all users is the `SYSTEM` tablespace. If a user does not create objects, and has no privileges to do so, then this default setting is fine. However, if a user is likely to create any type of object, then you should specifically assign the user a default tablespace, such as the `USERS` tablespace. Using a tablespace other than `SYSTEM` reduces contention between data dictionary objects and user objects for the same data files. In general, do not store user data in the `SYSTEM` tablespace.

You can use the `CREATE TABLESPACE` SQL statement to create a permanent default tablespace other than `SYSTEM` at the time of database creation, to be used as the database default for permanent objects. By separating the user data from the system data, you reduce the likelihood of problems with the `SYSTEM` tablespace, which can in some circumstances cause the entire database to become nonfunctional. This default permanent tablespace is not used by system users, that is, `SYS`, `SYSTEM`, and `OUTLN`, whose default permanent tablespace is `SYSTEM`. A tablespace designated as the default permanent tablespace cannot be dropped. To accomplish this goal, you must first designate another tablespace as the default permanent tablespace. You can use the `ALTER TABLESPACE` SQL statement to alter the default permanent tablespace to another tablespace. Be aware that this will affect all users or objects created after the `ALTER` DDL statement commits.

You can also set a user default tablespace during user creation, and change it later with the `ALTER USER` statement. Changing the user default tablespace affects only objects created after the setting is changed.

When you specify the default tablespace for a user, also specify a quota on that tablespace.

In the following `CREATE USER` statement, the default tablespace for user `jward` is `data_ts`, and his quota on that tablespace is `500K`:

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk;
```

Assigning a Tablespace Quota for the User

You can assign each user a tablespace quota for any tablespace (except a temporary tablespace). Assigning a quota accomplishes the following:

- Users with privileges to create certain types of objects can create those objects in the specified tablespace.
- Oracle Database limits the amount of space that can be allocated for storage of a user's objects within the specified tablespace to the amount of the quota.

By default, a user has no quota on any tablespace in the database. If the user has the privilege to create a schema object, then you must assign a quota to allow the user to create objects. At a minimum, assign users a quota for the default tablespace, and additional quotas for other tablespaces in which they can create objects.

The following `CREATE USER` statement assigns the following quotas for the `test_ts` and `data_ts` tablespaces:

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk;
```

You can assign a user either individual quotas for a specific amount of disk space in each tablespace or an unlimited amount of disk space in all tablespaces. Specific quotas prevent a user's objects from using too much space in the database. The maximum amount of space that you can assign for a tablespace is 2 TB. If you need more space, then specify `UNLIMITED` for the `QUOTA` clause.

You can assign quotas to a user tablespace when you create the user, or add or change quotas later. (You can find existing user quotas by querying the `USER_TS_QUOTAS` view.) If a new quota is less than the old one, then the following conditions remain true:

- If a user has already exceeded a new tablespace quota, then the objects of a user in the tablespace cannot be allocated more space until the combined space of these objects is less than the new quota.
- If a user has not exceeded a new tablespace quota, or if the space used by the objects of the user in the tablespace falls under a new tablespace quota, then the user's objects can be allocated space up to the new quota.

Restricting the Quota Limits for User Objects in a Tablespace

You can restrict the quota limits for user objects in a tablespace by using the `ALTER USER` SQL statement to change the current quota of the user to zero. After a quota of zero is assigned, the objects of the user in the tablespace remain, and the user can still create new objects, but the existing objects will not be allocated any new space. For example, you could not insert data into one of this user's existing tables. The operation will fail with an `ORA-1536 space quota exceeded for tables` error.

Granting Users the UNLIMITED TABLESPACE System Privilege

To permit a user to use an unlimited amount of any tablespace in the database, grant the user the `UNLIMITED TABLESPACE` system privilege. This overrides all explicit tablespace quotas for the user. If you later revoke the privilege, then you must explicitly grant quotas to individual tablespaces. You can grant this privilege only to users, not to roles.

Before granting the UNLIMITED TABLESPACE system privilege, you must consider the consequences of doing so.

Advantage:

You can grant a user unlimited access to all tablespaces of a database with one statement.

Disadvantages:

- The privilege overrides all explicit tablespace quotas for the user.
- You cannot selectively revoke tablespace access from a user with the UNLIMITED TABLESPACE privilege. You can grant selective or restricted access only after revoking the privilege.

Assigning a Temporary Tablespace for the User

You should assign each user a temporary tablespace. When a user executes a SQL statement that requires a temporary segment, Oracle Database stores the segment in the temporary tablespace of the user. These temporary segments are created by the system when performing sort or join operations. Temporary segments are owned by SYS, which has resource privileges in all tablespaces.

In the following, the temporary tablespace of jward is temp_ts, a tablespace created explicitly to contain only temporary segments.

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk;
```

To create a temporary tablespace, use the CREATE TEMPORARY TABLESPACE SQL statement.

If you do not explicitly assign the user a temporary tablespace, then Oracle Database assigns the user the default temporary tablespace that was specified at database creation, or by an ALTER DATABASE statement at a later time. If there is no default temporary tablespace explicitly assigned, then the default is the SYSTEM tablespace or another permanent default established by the system administrator. Do not store user data in the SYSTEM tablespace. Assigning a tablespace to be used specifically as a temporary tablespace eliminates file contention among temporary segments and other types of segments.

> **Note:** If your SYSTEM tablespace is locally managed, then users must be assigned a specific default (locally managed) temporary tablespace. They may not be allowed to default to using the SYSTEM tablespace because temporary objects cannot be placed in locally managed permanent tablespaces.

You can set the temporary tablespace for a user at user creation, and change it later using the ALTER USER statement. You can also establish tablespace groups instead of assigning individual temporary tablespaces.

See Also:

- "Temporary Tablespaces" in *Oracle Database Administrator's Guide*
- "Multiple Temporary Tablespaces: Using Tablespace Groups" in *Oracle Database Administrator's Guide*

Specifying a Profile for the User

You can specify a profile when you create a user. A profile is a set of limits on database resources and password access to the database. If you do not specify a profile, then Oracle Database assigns the user a default profile.

The following example demonstrates how to assign a user a profile.

```
CREATE USER jward
 IDENTIFIED BY password
 DEFAULT TABLESPACE data_ts
 QUOTA 100M ON test_ts
 QUOTA 500K ON data_ts
 TEMPORARY TABLESPACE temp_ts
 PROFILE clerk;
```

See Also: "Managing Resources with Profiles" on page 2-12

Setting a Default Role for the User

A role is a named group of related privileges that you grant as a group to users or other roles. A default role is automatically enabled for a user when the user creates a session. You can assign a user zero or more default roles.

You cannot set default roles for a user in the `CREATE USER` statement. When you first create a user, the default role setting for the user is `ALL`, which causes all roles subsequently granted to the user to be default roles. Use the `ALTER USER` statement to change the default roles for the user. For example:

```
GRANT USER jward clerk_role;

ALTER USER jward DEFAULT ROLE clerk_role;
```

Before a role can be made the default role for a user, that user must have been already granted the role.

See Also: "Managing User Roles" on page 4-6

Altering User Accounts

This section contains:

About Altering User Accounts

Users can change their own passwords. However, to change any other option of a user security domain, you must have the `ALTER USER` system privilege. Security

administrators are typically the only users that have this system privilege, as it allows a modification of *any* user security domain. This privilege includes the ability to set tablespace quotas for a user on any tablespace in the database, even if the user performing the modification does not have a quota for a specified tablespace.

Using the ALTER USER Statement to Alter a User Account

You can alter user security settings with the `ALTER USER` SQL statement. Changing user security settings affects the future user sessions, not current sessions.

Example 2–2 shows how to use the `ALTER USER` statement to alter the security settings for the user `avyrros`:

Example 2–2 Altering a User Account

```
ALTER USER avyrros
 IDENTIFIED EXTERNALLY
 DEFAULT TABLESPACE data_ts
 TEMPORARY TABLESPACE temp_ts
 QUOTA 100M ON data_ts
 QUOTA 0 ON test_ts
 PROFILE clerk;
```

The `ALTER USER` statement here changes the security settings for the user `avyrros` as follows:

- Authentication is changed to use the operating system account of the user `avyrros`.
- The default and temporary tablespaces are explicitly set for user `AVYRROS`.
- The user `avyrros` is given a 100M quota for the `DATA_TS` tablespace.
- The quota on the `test_ts` is revoked for the user `avyrros`.
- The user `avyrros` is assigned the `clerk` profile.

Changing Non-SYS User Passwords

Most users can change their own passwords with the `PASSWORD` statement, as follows:

```
PASSWORD andy
Changing password for andy
New password: password
Retype new password: password
```

No special privileges (other than those to connect to the database and create a session) are required for a user to change his or her own password. Encourage users to change their passwords frequently. "Guidelines for Securing Passwords" on page 10-7 provides advice on the best ways to secure passwords. You can find existing users for the current database instance by querying the `ALL_USERS` view.

Users can also use the `ALTER USER` SQL statement change their passwords. For example:

```
ALTER USER andy IDENTIFIED BY password
```

However, for better security, use the `PASSWORD` statement to change the account's password. The `ALTER USER` statement displays the new password on the screen, where it can be seen by any overly curious coworkers. The `PASSWORD` command does not

display the new password, so it is only known to you, not to your co-workers. In both cases, the password is encrypted on the network.

Users must have the PASSWORD and ALTER USER privilege to switch between methods of authentication. Usually, only an administrator has this privilege.

See Also:

- "Minimum Requirements for Passwords" on page 3-3 for the minimum requirements for creating passwords
- "Guidelines for Securing Passwords" on page 10-7 for additional ways to secure passwords
- Chapter 3, "Configuring Authentication" for information about authentication methods that are available for Oracle Database users

Changing the SYS User Password

If you must change the SYS user password, then you should use the ORAPWD command line utility to create a new password file that contains the password that you want to use. Do not use the ALTER USER statement or the PASSWORD command to change the SYS user password. Note the following:

- The SYS user account is used by most of the internal recursive SQL. Therefore, if you try to use the ALTER USER statement to change this password while the database is open, then there is a chance that deadlocks will result.
- If you try to use ALTER USER to change the SYS user password, and if the instance initialization parameter REMOTE_LOGIN_PASSWORDFILE has been set to SHARED, then you cannot change the SYS password. The ALTER USER statement fails with an ORA-28046: Password change for SYS disallowed error.

Example 2–3 shows how to use ORAPWD to create a password file that has a new SYS password. In this example, the new password will be stored in a password file that will be called orapworcl. (If the password file already exists, then an OPW-00005: File with same name exists - please delete or rename error warns you so that you can choose another name. If you want to overwrite the existing password file, then append the force=y argument to the ORAPWD command.)

Example 2–3 Using ORAPWD to Change the SYS User Password

```
orapwd file='orapworcl'
Enter password for SYS: new_password
```

See Also: *Oracle Database Administrator's Guide* for detailed information about the orapwd command syntax and arguments

Configuring User Resource Limits

This section contains:

- About User Resource Limits
- Types of System Resources and Limits
- Determining Values for Resource Limits of Profiles
- Managing Resources with Profiles

About User Resource Limits

You can set limits on the amount of various system resources available to each user as part of the security domain of that user. By doing so, you can prevent the uncontrolled consumption of valuable system resources such as CPU time. To set resource limits, you use Database Resource Manager, which is described in *Oracle Database Administrator's Guide*.

This resource limit feature is very useful in large, multiuser systems, where system resources are very expensive. Excessive consumption of these resources by one or more users can detrimentally affect the other users of the database. In single-user or small-scale multiuser database systems, the system resource feature is not as important, because user consumption of system resources is less likely to have a detrimental impact.

You manage user resource limits by using Database Resource Manager. You can set password management preferences using profiles, either set individually or using a default profile for many users. Each Oracle database can have an unlimited number of profiles. Oracle Database allows the security administrator to enable or disable the enforcement of profile resource limits universally.

Setting resource limits causes a slight performance degradation when users create sessions, because Oracle Database loads all resource limit data for each user upon each connection to the database.

> **See Also:** *Oracle Database Administrator's Guide* for detailed information about managing resources

Types of System Resources and Limits

Oracle Database can limit the use of several types of system resources, including CPU time and logical reads. In general, you can control each of these resources at the session level, call level, or both, as discussed in the following sections:

- Limiting the User Session Level
- Limiting Database Call Levels
- Limiting CPU Time
- Limiting Logical Reads
- Limiting Other Resources

Limiting the User Session Level

Each time a user connects to a database, a session is created. Each session uses CPU time and memory on the computer that runs Oracle Database. You can set several resource limits at the session level.

If a user exceeds a session-level resource limit, then Oracle Database terminates (rolls back) the current statement and returns a message indicating that the session limit has been reached. At this point, all previous statements in the current transaction are intact, and the only operations the user can perform are `COMMIT`, `ROLLBACK`, or disconnect (in this case, the current transaction is committed). All other operations produce an error. Even after the transaction is committed or rolled back, the user cannot accomplish any more work during the current session.

Limiting Database Call Levels

Each time a user runs a SQL statement, Oracle Database performs several steps to process the statement. During this processing, several calls are made to the database as a part of the different execution phases. To prevent any one call from using the system excessively, Oracle Database lets you set several resource limits at the call level.

If a user exceeds a call-level resource limit, then Oracle Database halts the processing of the statement, rolls back the statement, and returns an error. However, all previous statements of the current transaction remain intact, and the user session remains connected.

Limiting CPU Time

When SQL statements and other types of calls are made to Oracle Database, a certain amount of CPU time is necessary to process the call. Average calls require a small amount of CPU time. However, a SQL statement involving a large amount of data or a runaway query can potentially use a large amount of CPU time, reducing CPU time available for other processing.

To prevent uncontrolled use of CPU time, you can set fixed or dynamic limits on the CPU time for each call and the total amount of CPU time used for Oracle Database calls during a session. The limits are set and measured in CPU one-hundredth seconds (0.01 seconds) used by a call or a session.

Limiting Logical Reads

Input/output (I/O) is one of the most expensive operations in a database system. SQL statements that are I/O-intensive can monopolize memory and disk use and cause other database operations to compete for these resources.

To prevent single sources of excessive I/O, you can limit the logical data block reads for each call and for each session. Logical data block reads include data block reads from both memory and disk. The limits are set and measured in number of block reads performed by a call or during a session.

Limiting Other Resources

Oracle Database provides for limiting several other resources at the session level:

- **You can limit the number of concurrent sessions for each user.** Each user can create only up to a predefined number of concurrent sessions.
- **You can limit the idle time for a session.** If the time between calls in a session reaches the idle time limit, then the current transaction is rolled back, the session is terminated, and the resources of the session are returned to the system. The next call receives an error that indicates that the user is no longer connected to the instance. This limit is set as a number of elapsed minutes.

  Note: Shortly after a session is terminated because it has exceeded an idle time limit, the process monitor (PMON) background process cleans up after the terminated session. Until PMON completes this process, the terminated session is still counted in any session or user resource limit.

- **You can limit the elapsed connect time for each session.** If the duration of a session exceeds the elapsed time limit, then the current transaction is rolled back, the session is dropped, and the resources of the session are returned to the system. This limit is set as a number of elapsed minutes.

Note: Oracle Database does not constantly monitor the elapsed idle time or elapsed connection time. Doing so reduces system performance. Instead, it checks every few minutes. Therefore, a session can exceed this limit slightly (for example, by 5 minutes) before Oracle Database enforces the limit and terminates the session.

- **You can limit the amount of private System Global Area (SGA) space (used for private SQL areas) for a session.** This limit is only important in systems that use the shared server configuration. Otherwise, private SQL areas are located in the Program Global Area (PGA). This limit is set as a number of bytes of memory in the SGA of an instance. Use the characters **K** or **M** to specify kilobytes or megabytes.

  See Also: For instructions about enabling or disabling resource limits:

  - "Finding Information About Database Users and Profiles" on page 2-15
  - "Managing User Roles" on page 4-6
  - *Oracle Database Administrator's Guide* for detailed information about managing resources

Determining Values for Resource Limits of Profiles

Before creating profiles and setting the resource limits associated with them, you should determine appropriate values for each resource limit. You can base these values on the type of operations a typical user performs. For example, if one class of user does not usually perform a high number of logical data block reads, then use the `ALTER RESOURCE COST` SQL statement to set the `LOGICAL_READS_PER_SESSION` setting conservatively.

Usually, the best way to determine the appropriate resource limit values for a given user profile is to gather historical information about each type of resource usage. For example, the database or security administrator can use the `AUDIT SESSION` clause to gather information about the limits `CONNECT_TIME`, `LOGICAL_READS_PER_SESSION`.

You can gather statistics for other limits using the Monitor feature of Oracle Enterprise Manager (or SQL*Plus), specifically the Statistics monitor.

See Also:

- "Using Data Dictionary Views to Find Information About Users and Profiles" on page 2-15
- Chapter 9, "Verifying Security Access with Auditing"
- *Oracle Database 2 Day DBA* for more information about Database Control
- Enterprise Manager online Help for more information about the Monitor feature

Managing Resources with Profiles

A **profile** is a named set of resource limits and password parameters that restrict database usage and instance resources for a user. You can assign a profile to each user,

and a default profile to all others. Each user can have only one profile, and creating a new one supersedes an earlier version.

You need to create and manage user profiles only if resource limits are a requirement of your database security policy. To use profiles, first categorize the related types of users in a database. Just as roles are used to manage the privileges of related users, profiles are used to manage the resource limits of related users. Determine how many profiles are needed to encompass all types of users in a database and then determine appropriate resource limits for each profile.

In general, the word profile refers to a collection of attributes that apply to a user, enabling a single point of reference for any of multiple users that share those exact attributes. User profiles in Oracle Internet Directory contain attributes pertinent to directory usage and authentication for each user. Similarly, profiles in Oracle Label Security contain attributes useful in label security user administration and operations management. Profile attributes can include restrictions on system resources. You can use Database Resource Manager to set these types of resource limits.

Profile resource limits are enforced only when you enable resource limitation for the associated database. Enabling this limitation can occur either before starting up the database (using the `RESOURCE_LIMIT` initialization parameter) or while it is open (using the `ALTER SYSTEM` statement).

Though password parameters reside in profiles, they are unaffected by `RESOURCE_LIMIT` or `ALTER SYSTEM` and password management is always enabled. In Oracle Database, Database Resource Manager primarily handles resource allocations and restrictions.

See Also:

- *Oracle Database Administrator's Guide* for detailed information on managing resources
- "Finding Information About Database Users and Profiles" on page 2-15 for viewing resource information
- *Oracle Database SQL Language Reference* for information about `ALTER SYSTEM` or `RESOURCE_LIMIT`

Creating Profiles

Any authorized database user can create, assign to users, alter, and drop a profile at any time (using the `CREATE USER` or `ALTER USER` statement). Profiles can be assigned only to users and not to roles or other profiles. Profile assignments do not affect current sessions, instead, they take effect only in subsequent sessions. Be aware that when you assign a profile to an external user or a global user, the password parameters do not take effect for that user.

To find information about current profiles, query the `DBA_PROFILES` view.

See Also:

- *Oracle Database SQL Language Reference* for more information about the SQL statements that are used to manage profiles, which are `ALTER PROFILE`, `CREATE PROFILE`, and `DROP PROFILE`
- *Oracle Database Administrator's Guide* for detailed information about managing resources
- "Creating User Accounts" on page 2-1
- "Altering User Accounts" on page 2-7

Dropping Profiles

To drop a profile, you must have the DROP PROFILE system privilege. You can drop a profile (other than the default profile) using the SQL statement DROP PROFILE.To successfully drop a profile currently assigned to a user, use the CASCADE option.

The following statement drops the profile clerk, even though it is assigned to a user:

```
DROP PROFILE clerk CASCADE;
```

Any user currently assigned to a profile that is dropped is automatically assigned to the DEFAULT profile. The DEFAULT profile cannot be dropped. When a profile is dropped, the drop does not affect currently active sessions. Only sessions created after a profile is dropped use the modified pro file assignments.

Deleting User Accounts

When you drop a user account, Oracle Database removes the user account and associated schema from the data dictionary. It also immediately drops all schema objects contained in the user schema, if any.

Notes:

- If a user schema and associated objects must remain but the user must be denied access to the database, then revoke the CREATE SESSION privilege from the user.
- Do not attempt to drop the SYS or SYSTEM user. Doing so corrupts your database.

A user that is currently connected to a database cannot be dropped. To drop a connected user, you must first terminate the user sessions using the SQL statement ALTER SYSTEM with the KILL SESSION clause. You can find the session ID (SID) by querying the V$SESSION view.

Example 2–4 shows how to query V$SESSION and displays the session ID, serial number, and user name for user ANDY.

Example 2–4 Querying V$SESSION for the Session ID of a User

```
SELECT SID, SERIAL#, USERNAME FROM V$SESSION;

    SID         SERIAL#     USERNAME
------- --------------- ----------------------
    127          55234      ANDY
...
```

Example 2–5 shows how to stop the session for user andy.

Example 2–5 Killing a User Session

```
ALTER SYSTEM KILL SESSION '127, 55234';
```

You can drop a user from a database using the DROP USER statement. To drop a user and all the user schema objects (if any), you must have the DROP USER system privilege. Because the DROP USER system privilege is powerful, a security administrator is typically the only type of user that has this privilege.

If the schema of the user contains any dependent schema objects, then use the CASCADE option to drop the user and all associated objects and foreign keys that depend on the tables of the user successfully. If you do not specify CASCADE and the user schema contains dependent objects, then an error message is returned and the user is not dropped.

Before dropping a user whose schema contains objects, thoroughly investigate which objects the schema contains and the implications of dropping them. You can find the objects owned by a particular user by querying the DBA_OBJECTS view.

Example 2–6 shows how to find the objects owned by user andy.

Example 2–6 Finding Objects Owned by a User

```
SELECT OWNER, OBJECT_NAME FROM DBA_OBJECTS WHERE OWNER LIKE 'ANDY';
```

(Enter the user name in capital letters.) Pay attention to any unknown cascading effects. For example, if you intend to drop a user who owns a table, then check whether any views or procedures depend on that particular table.

Example 2–7 drops the user andy and all associated objects and foreign keys that depend on the tables owned by andy.

Example 2–7 Dropping a User Account

```
DROP USER andy CASCADE;
```

> **See Also:** *Oracle Database Administrator's Guide* for more information about terminating sessions

Finding Information About Database Users and Profiles

This section contains:

- Using Data Dictionary Views to Find Information About Users and Profiles
- Listing All Users and Associated Information
- Listing All Tablespace Quotas
- Listing All Profiles and Assigned Limits
- Viewing Memory Use for Each User Session

Using Data Dictionary Views to Find Information About Users and Profiles

Table 2–1 lists data dictionary views that contain information about database users and profiles. For detailed information about these views, see *Oracle Database Reference*.

Table 2–1 Data Dictionary Views That Display Information about Users and Profiles

View	Description
ALL_OBJECTS	Describes all objects accessible to the current user
ALL_USERS	Lists users visible to the current user, but does not describe them
DBA_PROFILES	Displays all profiles and their limits
DBA_TS_QUOTAS	Describes tablespace quotas for users
DBA_OBJECTS	Describes all objects in the database
DBA_USERS	Describes all users of the database

Table 2–1 (Cont.) Data Dictionary Views That Display Information about Users and

View	Description
DBA_USERS_WITH_DEFPWD	Lists all user accounts that have default passwords
PROXY_USERS	Describes users who can assume the identity of other users
RESOURCE_COST	Lists the cost for each resource in terms of CPUs for each session, reads for each session, connection times, and SGA
USER_PASSWORD_LIMITS	Describes the password profile parameters that are assigned to the user
USER_RESOURCE_LIMITS	Displays the resource limits for the current user
USER_TS_QUOTAS	Describes tablespace quotas for users
USER_OBJECTS	Describes all objects owned by the current user
USER_USERS	Describes only the current user
V$SESSION	Lists session information for each current session, includes user name
V$SESSTAT	Lists user session statistics
V$STATNAME	Displays decoded statistic names for the statistics shown in the V$SESSTAT view

The following sections present examples of using these views. These examples assume that the following statements have been run:

```
CREATE PROFILE clerk LIMIT
    SESSIONS_PER_USER 1
    IDLE_TIME 30
    CONNECT_TIME 600;

CREATE USER jfee
    IDENTIFIED BY password
    DEFAULT TABLESPACE users
    TEMPORARY TABLESPACE temp_ts
    QUOTA 500K ON users
    PROFILE clerk;

CREATE USER dcranney
    IDENTIFIED BY password
    DEFAULT TABLESPACE users
    TEMPORARY TABLESPACE temp_ts
    QUOTA unlimited ON users;

CREATE USER userscott
     IDENTIFIED BY password;
```

Listing All Users and Associated Information

To find all users and their associated information as defined in the database, query the DBA_USERS view. For detailed information on the DBA_USERS view, see *Oracle Database Reference*.

For example:

```
SELECT USERNAME, PROFILE, ACCOUNT_STATUS, AUTHENTICATION_TYPE FROM DBA_USERS;

USERNAME        PROFILE         ACCOUNT_STATUS   AUTHENTICATION_TYPE
--------------- --------------- ---------------  -------------------
```

```
SYS             DEFAULT         OPEN             PASSWORD
SYSTEM          DEFAULT         OPEN             PASSWORD
USERSCOTT       DEFAULT         OPEN             PASSWORD
JFEE            CLERK           OPEN             GLOBAL
DCRANNEY        DEFAULT         OPEN             EXTERNAL
```

Listing All Tablespace Quotas

Use the DBA_TS_QUOTAS view to list all tablespace quotas specifically assigned to each user. (For detailed information on this view, see *Oracle Database Reference*.) For example:

```
SELECT * FROM DBA_TS_QUOTAS;

TABLESPACE    USERNAME    BYTES     MAX_BYTES    BLOCKS    MAX_BLOCKS
----------    ---------  --------   ----------   -------   ----------
USERS         JFEE              0       512000         0          250
USERS         DCRANNEY          0           -1         0           -1
```

When specific quotas are assigned, the exact number is indicated in the MAX_BYTES column. This number is always a multiple of the database block size, so if you specify a tablespace quota that is not a multiple of the database block size, then it is rounded up accordingly. Unlimited quotas are indicated by -1.

Listing All Profiles and Assigned Limits

The DBA_PROFILE view lists all profiles in the database and associated settings for each limit in each profile. (For detailed information on this view, see *Oracle Database Reference*.) For example:

```
SELECT * FROM DBA_PROFILES ORDER BY PROFILE;

PROFILE             RESOURCE_NAME              RESOURCE_TYPE  LIMIT
-----------------   -------------------------  -------------  --------------
CLERK               COMPOSITE_LIMIT            KERNEL         DEFAULT
CLERK               FAILED_LOGIN_ATTEMPTS      PASSWORD       DEFAULT
CLERK               PASSWORD_LIFE_TIME         PASSWORD       DEFAULT
CLERK               PASSWORD_REUSE_TIME        PASSWORD       DEFAULT
CLERK               PASSWORD_REUSE_MAX         PASSWORD       DEFAULT
CLERK               PASSWORD_VERIFY_FUNCTION   PASSWORD       DEFAULT
CLERK               PASSWORD_LOCK_TIME         PASSWORD       DEFAULT
CLERK               PASSWORD_GRACE_TIME        PASSWORD       DEFAULT
CLERK               PRIVATE_SGA                KERNEL         DEFAULT
CLERK               CONNECT_TIME               KERNEL         600
CLERK               IDLE_TIME                  KERNEL         30
CLERK               LOGICAL_READS_PER_CALL     KERNEL         DEFAULT
CLERK               LOGICAL_READS_PER_SESSION  KERNEL         DEFAULT
CLERK               CPU_PER_CALL               KERNEL         DEFAULT
CLERK               CPU_PER_SESSION            KERNEL         DEFAULT
CLERK               SESSIONS_PER_USER          KERNEL         1
DEFAULT             COMPOSITE_LIMIT            KERNEL         UNLIMITED
DEFAULT             PRIVATE_SGA                KERNEL         UNLIMITED
DEFAULT             SESSIONS_PER_USER          KERNEL         UNLIMITED
DEFAULT             CPU_PER_CALL               KERNEL         UNLIMITED
DEFAULT             LOGICAL_READS_PER_CALL     KERNEL         UNLIMITED
DEFAULT             CONNECT_TIME               KERNEL         UNLIMITED
DEFAULT             IDLE_TIME                  KERNEL         UNLIMITED
DEFAULT             LOGICAL_READS_PER_SESSION  KERNEL         UNLIMITED
DEFAULT             CPU_PER_SESSION            KERNEL         UNLIMITED
```

```
DEFAULT             FAILED_LOGIN_ATTEMPTS      PASSWORD       10
DEFAULT             PASSWORD_LIFE_TIME         PASSWORD       180
DEFAULT             PASSWORD_REUSE_MAX         PASSWORD       UNLIMITED
DEFAULT             PASSWORD_LOCK_TIME         PASSWORD       1
DEFAULT             PASSWORD_GRACE_TIME        PASSWORD       7
DEFAULT             PASSWORD_VERIFY_FUNCTION   PASSWORD       UNLIMITED
DEFAULT             PASSWORD_REUSE_TIME        PASSWORD       UNLIMITED
32 rows selected.
```

To find the default profile values, run the following query:

```
SELECT * FROM DBA_PROFILES WHERE PROFILE = 'DEFAULT';

PROFILE             RESOURCE_NAME              RESOURCE_TYPE  LIMIT
-----------------   -------------------------  -------------  --------------
DEFAULT             COMPOSITE_LIMIT            KERNEL         UNLIMITED
DEFAULT             SESSIONS_PER_USER          KERNEL         UNLIMITED
DEFAULT             CPU_PER_SESSION            KERNEL         UNLIMITED
DEFAULT             CPU_PER_CALL               KERNEL         UNLIMITED
DEFAULT             LOGICAL_READS_PER_SESSION  KERNEL         UNLIMITED
DEFAULT             LOGICAL_READS_PER_CALL     KERNEL         UNLIMITED
DEFAULT             IDLE_TIME                  KERNEL         UNLIMITED
DEFAULT             CONNECT_TIME               KERNEL         UNLIMITED
DEFAULT             PRIVATE_SGA                KERNEL         UNLIMITED
DEFAULT             FAILED_LOGIN_ATTEMPTS      PASSWORD       10
DEFAULT             PASSWORD_LIFE_TIME         PASSWORD       180
DEFAULT             PASSWORD_REUSE_TIME        PASSWORD       UNLIMITED
DEFAULT             PASSWORD_REUSE_MAX         PASSWORD       UNLIMITED
DEFAULT             PASSWORD_VERIFY_FUNCTION   PASSWORD       NULL
DEFAULT             PASSWORD_LOCK_TIME         PASSWORD       1
DEFAULT             PASSWORD_GRACE_TIME        PASSWORD       7

16 rows selected.
```

Viewing Memory Use for Each User Session

To find the memory use for each user session, query the `V$SESSION` view. (For detailed information on this view, see *Oracle Database Reference*. The following query lists all current sessions, showing the Oracle Database user and current User Global Area (UGA) memory use for each session:

```
SELECT USERNAME, VALUE || 'bytes' "Current UGA memory"
   FROM V$SESSION sess, V$SESSTAT stat, V$STATNAME name
WHERE sess.SID = stat.SID
   AND stat.STATISTIC# = name.STATISTIC#
   AND name.NAME = 'session uga memory';

USERNAME                       Current UGA memory
------------------------------ ----------------------------------------------
                               18636bytes
                               17464bytes
                               19180bytes
                               18364bytes
                               39384bytes
                               35292bytes
                               17696bytes
                               15868bytes
USERSCOTT                      42244bytes
SYS                            98196bytes
SYSTEM                         30648bytes
```

```
11 rows selected.
```

To see the maximum UGA memory allocated to each session since the instance started, replace `'session uga memory'` in the preceding query with `'session uga memory max'`.

3

Configuring Authentication

This chapter contains:

About Authentication

Authentication means verifying the identity of someone (a user, device, or other entity) who wants to use data, resources, or applications. Validating that identity establishes a trust relationship for further interactions. Authentication also enables accountability by making it possible to link access and actions to specific identities. After authentication, authorization processes can allow or limit the levels of access and action permitted to that entity.

You can authenticate both database and nondatabase users for an Oracle database. For simplicity, the same authentication method is generally used for all database users, but Oracle Database allows a single database instance to use any or all methods. Oracle Database requires special authentication procedures for database administrators, because they perform special database operations. Oracle Database also encrypts passwords during transmission to ensure the security of network authentication.

After authentication, authorization processes can allow or limit the levels of access and action permitted to that entity. Authorization is described in Chapter 4, "Configuring Privilege and Role Authorization".

Configuring Password Protection

This section contains:

- What Are the Oracle Database Built-in Password Protections?
- Minimum Requirements for Passwords
- Using a Password Management Policy
- Ensuring Against Password Security Threats by Using the SHA-1 Hashing Algorithm
- Managing the Secure External Password Store for Password Credentials

See also "Guidelines for Securing Passwords" on page 10-7 for advice on securing passwords. If you want to configure Oracle XML DB to authenticate users by encrypting their passwords but you do not need to encrypt other data (for example, an Intranet email), see *Oracle XML DB Developer's Guide* for more information.

What Are the Oracle Database Built-in Password Protections?

Oracle Database provides a set of built-in password protections designed to protect your users' passwords. These password protections are as follows:

- **Password encryption.** Oracle Database automatically and transparently encrypts passwords during network (client-to-server and server-to-server) connections, using Advanced Encryption Standard (AES) before sending them across the network.
- **Password complexity checking.** In a default installation, Oracle Database provides the `verify_function_11g` password verification function to ensure that new or changed passwords are sufficiently complex to prevent intruders who try to break into the system by guessing passwords. You must manually enable password complexity checking. You can further customize the complexity of your users' passwords. See "Enforcing Password Complexity Verification" on page 3-11 for more information.
- **Preventing passwords from being broken.** If a user tries to log in to Oracle Database multiple times using an incorrect password, Oracle Database delays each login. This protection applies for attempts made from different IP addresses or multiple client connections. Afterwards, it gradually increases the time before the user can try another password, up to a maximum of about 10 seconds. If the user enters the correct password, he or she is able to log in successfully without any delay.

  This feature significantly decreases the number of passwords that an intruder would be able to try within a fixed time period when attempting to log in. The failed logon delay slows down each failed logon attempt, increasing the overall time that is required to perform a password-guessing attack, because such attacks usually require a very large number of failed logon attempts.
- **Enforced case sensitivity for passwords.** Passwords are case sensitive. For example, the password `hPP5620qr` fails if it is entered as `hpp5620QR` or `hPp5620Qr`. In previous releases, passwords were not case sensitive. See "Enabling or Disabling Password Case Sensitivity" on page 3-13 for information about how case sensitivity works, and how it affects password files and database links.
- **Passwords hashed using the Secure Hash Algorithm (SHA) cryptographic hash function SHA-1.** Oracle Database uses the SHA-1 verifier is to authenticate the user password and establish the session of the user. In addition, it enforces case sensitivity and restricts passwords to 160 bits. The advantage of using the SHA-1 verifier is that it is commonly used by Oracle Database customers and provides much better security without forcing a network upgrade. It also adheres to compliance regulations that mandate the use of strong passwords being protected

by a suitably strong password hashing algorithm. See "Ensuring Against Password Security Threats by Using the SHA-1 Hashing Algorithm" on page 3-15 for more information.

Minimum Requirements for Passwords

Passwords must not exceed 30 characters or 30 bytes. For greater security, however, follow the additional guidelines described in "Guidelines for Securing Passwords" on page 10-7.

To create passwords for users, you can use the `CREATE USER` or `ALTER USER` SQL statements. SQL statements that accept the `IDENTIFIED BY` clause also enable you to create passwords. Example 3–1 shows several SQL statements that create passwords with the `IDENTIFIED BY` clause.

Example 3–1 Password Creation SQL Statements

```
CREATE USER psmith IDENTIFIED BY password;
GRANT CREATE SESSION TO psmith IDENTIFIED BY password;
ALTER USER psmith IDENTIFIED BY password;
CREATE DATABASE LINK AUTHENTICATED BY psmith IDENTIFIED BY password;
```

See Also:

- "Enforcing Password Complexity Verification" on page 3-11 for ways that you can ensure that passwords are sufficiently complex for your site
- "Guidelines for Securing Passwords" on page 10-7 for more ways to secure passwords
- "Securing Passwords in Application Design" on page 5-3 for password protection guidelines application developers should follow
- *Oracle Database SQL Language Reference* for more information about the `CREATE USER`, `ALTER USER`, `GRANT`, and `CREATE DATABASE LINK` SQL statements

Using a Password Management Policy

This section contains:

See Also:

- "Managing Resources with Profiles" on page 2-12
- *Oracle Database SQL Language Reference* for syntax and specific information about SQL statements discussed in this section

About Managing Passwords

Database security systems that depend on passwords require that passwords be kept secret at all times. Because passwords are vulnerable to theft and misuse, Oracle Database uses a password management policy. Database administrators and security officers control this policy through user profiles, enabling greater control of database security.

Use the `CREATE PROFILE` statement to create a user profile. The profile is assigned to a user with the `CREATE USER` or `ALTER USER` statement. Details of creating and altering database users are not discussed in this section. This section describes password parameters that can be specified using the `CREATE PROFILE` (or `ALTER PROFILE`) statement.

Finding User Accounts That Have Default Passwords

When you create a database in Oracle Database 11*g* Release 2 (11.2), most of its default accounts are locked with the passwords expired. If you have upgraded from an earlier release of Oracle Database, you may have user accounts that have default passwords. These are default accounts that are created when you create a database, such as the `HR`, `OE`, and `SCOTT` accounts.

For greater security, change the passwords for these accounts. Using a default password that is commonly known can make your database vulnerable to attacks by intruders. To find both locked and unlocked accounts that use default passwords, log onto SQL*Plus using the `SYSDBA` privilege and then query the `DBA_USERS_WITH_DEFPWD` data dictionary view.

For example, to find both the names of accounts that have default passwords and the status of the account:

```
SELECT d.username, u.account_status
FROM DBA_USERS_WITH_DEFPWD d, DBA_USERS u
WHERE d.username = u.username
ORDER BY 2,1;

USERNAME  ACCOUNT_STATUS
--------- --------------------------
SCOTT     EXPIRED & LOCKED
```

Then change the passwords for any accounts that the `DBA_USERS_WITH_DEFPWD` view lists. Oracle recommends that you do **not** assign these accounts passwords that they may have had in previous releases of Oracle Database.

```
ALTER USER SCOTT ACCOUNT UNLOCK IDENTIFIED BY password;
```

Replace *`password`* with a password that is secure. "Minimum Requirements for Passwords" on page 3-3 describes the minimum requirements for passwords.

Configuring Password Settings in the Default Profile

A profile is a collection of parameters that sets limits on database resources. If you assign the profile to a user, then that user cannot exceed these limits. You can use profiles to configure database settings such as sessions per user, logging and tracing

features, and so on. Profiles can also control user passwords. To find information about the current password settings in the profile, you can query the DBA_PROFILES data dictionary view.

Table 3–1 lists the password-specific parameter settings in the default profile.

Table 3–1 Password-Specific Settings in the Default Profile

Parameter	Default Setting	Description
FAILED_LOGIN_ATTEMPTS	10	Sets the maximum times a user try to log in and to fail before locking the account. **Notes:** ▪ When you set this parameter, take into consideration users who may log in using the CONNECT THROUGH privilege. ▪ You can set limits on the number of times an unauthorized user (possibly an intruder) attempts to log in to Oracle Call Interface (OCI) applications by using the SEC_MAX_FAILED_LOGIN_ATTEMPTS initialization parameter. See "Configuring the Maximum Number of Authentication Attempts" on page 5-19 for more information about this parameter. See also "Automatically Locking a User Account After a Failed Login" on page 3-6 for more information.
PASSWORD_GRACE_TIME	7	Sets the number of days that a user has to change his or her password before it expires. See "Controlling Password Aging and Expiration" on page 3-8 for more information.
PASSWORD_LIFE_TIME	180	Sets the number of days the user can use his or her current password. See "Controlling Password Aging and Expiration" on page 3-8 for more information.
PASSWORD_LOCK_TIME	1	Sets the number of days an account will be locked after the specified number of consecutive failed login attempts. After the time passes, then the account becomes unlocked. This user's profile parameter is useful to help prevent brute force attacks on user passwords but not to increase the maintenance burden on administrators. See "Automatically Locking a User Account After a Failed Login" on page 3-6 for more information.
PASSWORD_REUSE_MAX	UNLIMITED	Sets the number of password changes required before the current password can be reused. See "Controlling User Ability to Reuse Previous Passwords" on page 3-7 for more information.

Table 3–1 (Cont.) Password-Specific Settings in the Default Profile

Parameter	Default Setting	Description
PASSWORD_REUSE_TIME	UNLIMITED	Sets the number of days before which a password cannot be reused. See "Controlling User Ability to Reuse Previous Passwords" on page 3-7 for more information.

For greater security, use the default settings described in Table 3–1, based on your needs. You can create or modify the password-specific parameters individually by using the CREATE PROFILE or ALTER PROFILE statement. For example:

```
ALTER PROFILE prof LIMIT
 FAILED_LOGIN_ATTEMPTS 9
 PASSWORD_LOCK_TIME 10;
```

See *Oracle Database SQL Language Reference* for more information about CREATE PROFILE, ALTER PROFILE, and the password-related parameters described in this section.

Disabling and Enabling the Default Password Security Settings

If your applications use the default password security settings from Oracle Database 10*g* Release 2 (10.2), then you can revert to these settings until you modify the applications to use the Release 11*g* password security settings. To do so, run the undopwd.sql script.

After you have modified your applications to conform to the Release 11*g* password security settings, you can manually update your database to use the password security configuration that suits your business needs, or you can run the secconf.sql script to apply the Release 11*g* default password settings. You can customize this script to have different security settings if you like, but remember that the settings listed in the original script are Oracle-recommended settings.

If you created your database manually, then you should run the secconf.sql script to apply the Release 11*g* default password settings to the database. Databases that have been created with Database Configuration Assistant (DBCA) will have these settings, but manually created databases do not.

The undopwd.sql and secconf.sql scripts are in the $ORACLE_HOME/rdbms/admin directory. The undopwd.sql script affects password settings only, and the secconf.sql script affects both password and audit settings. They have no effect on other security settings.

Automatically Locking a User Account After a Failed Login

Oracle Database can lock a user's account after a specified number of consecutive failed log-in attempts. You can set the PASSWORD_LOCK_TIME user's profile parameter to configure the account to unlock automatically after a specified time interval or to require database administrator intervention to be unlocked. The database administrator also can lock accounts manually, so that they must be unlocked explicitly by the database administrator.

You can specify the permissible number of failed login attempts by using the CREATE PROFILE statement. You can also specify the amount of time accounts remain locked.

Example 3–2 sets the maximum number of failed login attempts for the user johndoe to 10 (the default), and the amount of time the account locked to 30 days. The account will unlock automatically after 30 days.

Example 3–2 Locking an Account with the CREATE PROFILE Statement

```
CREATE PROFILE prof LIMIT
 FAILED_LOGIN_ATTEMPTS 10
 PASSWORD_LOCK_TIME 30;
ALTER USER johndoe PROFILE prof;
```

Each time the user unsuccessfully logs in, Oracle Database increases the delay exponentially with each login failure.

If you do not specify a time interval for unlocking the account, then PASSWORD_LOCK_TIME assumes the value specified in a default profile. (The recommended value is 1 day.) If you specify PASSWORD_LOCK_TIME as UNLIMITED, then you must explicitly unlock the account by using an ALTER USER statement. For example, assuming that PASSWORD_LOCK_TIME UNLIMITED is specified for johndoe, then you use the following statement to unlock the johndoe account:

```
ALTER USER johndoe ACCOUNT UNLOCK;
```

After a user successfully logs into an account, Oracle Database resets the unsuccessful login attempt count for the user, if it is non-zero, to zero.

The security officer can also explicitly lock user accounts. When this occurs, the account cannot be unlocked automatically, and only the security officer should unlock the account. The CREATE USER or ALTER USER statements explicitly lock or unlock user accounts. For example, the following statement locks the user account, susan:

```
ALTER USER susan ACCOUNT LOCK;
```

Controlling User Ability to Reuse Previous Passwords

You can ensure that users do not reuse their previous passwords for a specified amount of time or for a specified number of password changes. To do so, configure the rules for password reuse with CREATE PROFILE or ALTER PROFILE statements. For the complete syntax of these statements, see the *Oracle Database SQL Language Reference*.

Table 3–2 lists the CREATE PROFILE and ALTER PROFILE parameters that control ability of a user to reuse a previous password.

Table 3–2 Parameters Controlling Reuse of a Previous Password

Parameter Name	Description and Use
PASSWORD_REUSE_TIME	Requires either of the following: ▪ A number specifying how many days (or a fraction of a day) between the earlier use of a password and its next use ▪ The word UNLIMITED
PASSWORD_REUSE_MAX	Requires either of the following: ▪ An integer to specify the number of password changes required before a password can be reused ▪ The word UNLIMITED

If you do not specify a parameter, then the user can reuse passwords at any time, which is not a good security practice.

If neither parameter is UNLIMITED, then password reuse is allowed, but only after meeting both conditions. The user must have changed the password the specified number of times, and the specified number of days must have passed since the previous password was last used.

For example, suppose that the profile of user A had PASSWORD_REUSE_MAX set to 10 and PASSWORD_REUSE_TIME set to 30. User A cannot reuse a password until he or she has reset the password 10 times, and until 30 days had passed since the password was last used.

If either parameter is specified as UNLIMITED, then the user can never reuse a password.

If you set both parameters to UNLIMITED, then Oracle Database ignores both, and the user can reuse any password at any time.

Note: If you specify DEFAULT for either parameter, then Oracle Database uses the value defined in the DEFAULT profile, which sets all parameters to UNLIMITED. Oracle Database thus uses UNLIMITED for any parameter specified as DEFAULT, unless you change the setting for that parameter in the DEFAULT profile.

Controlling Password Aging and Expiration

You can specify a password lifetime, after which the password expires. This means that the next time the user logs in with the current, correct password, he or she is prompted to change the password. By default, there are no complexity or password history checks, so users can still reuse any previous or weak passwords. You can control these factors by setting the PASSWORD_REUSE_TIME, PASSWORD_REUSE_MAX, and PASSWORD_VERIFY_FUNCTION parameters. (See "Controlling User Ability to Reuse Previous Passwords" on page 3-7 and "Enforcing Password Complexity Verification" on page 3-11 for more information.)

In addition, you can set a grace period, during which each attempt to log in to the database account receives a warning message to change the password. If the user does not change it by the end of that period, then Oracle Database expires the account.

As a database administrator, you can manually set the password state to be expired, which sets the account status to EXPIRED. The user must then follow the prompts to change the password before the logon can proceed.

For example, in SQL*Plus, suppose user SCOTT tries to log in with the correct credentials, but his password has expired. User SCOTT will then see the ORA-28001: The password has expired error and be prompted to change his password, as follows:

```
Changing password for scott
New password: new_password
Retype new password: new_password
Password changed.
```

Use the CREATE PROFILE or ALTER PROFILE statement to specify a lifetime for passwords. To understand the life cycle of passwords, see "Password Change Life Cycle" on page 3-9.

Example 3–3 demonstrates how to create and assign a profile to user johndoe, and the PASSWORD_LIFE_TIME parameter specifies that johndoe can use the same password for 180 days before it expires.

Example 3–3 Setting Password Aging and Expiration with CREATE PROFILE

```
CREATE PROFILE prof LIMIT
 FAILED_LOGIN_ATTEMPTS 4
 PASSWORD_LOCK_TIME 30
 PASSWORD_LIFE_TIME 180;
ALTER USER johndoe PROFILE prof;
```

You can check the status of any account, whether it is open, in grace, or expired, by running the following query:

```
SELECT ACCOUNT_STATUS FROM DBA_USERS WHERE USERNAME = 'username';
```

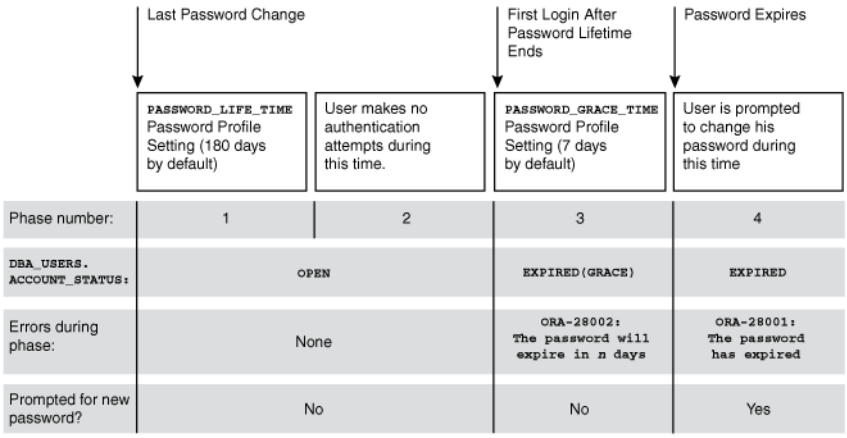
Password Change Life Cycle

Figure 3–1 shows the lifecycle of the password lifetime and grace period.

- **Phase 1:** After the user account is created, or the password of an existing account is changed, the password lifetime period begins.
- **Phase 2:** This phase represents the period of time *after* the password lifetime ends but *before* the user logs in again with the correct password. The correct credentials are needed for Oracle Database to update the account status. Otherwise, the account status will remain unchanged. Oracle Database does not have any background process to update the account status. All changes to the account status are driven by the Oracle Database server process on behalf of authenticated users.
- **Phase 3:** When the user finally does log in, the grace period begins. Oracle Database then updates the `DBA_USERS.EXPIRY_DATE` column to a new value using the current time plus the value of the `PASSWORD_GRACE_TIME` setting from the account's password profile. At this point, the user receives an `ORA-28002` warning message about the password expiring in the near future (for example, `ORA-28002 The password will expire within 7 days` if `PASSWORD_GRACE_TIME` is set to `7` days), but the user can still log in without changing the password. The `DBA_USERS.EXPIRY_DATE` column shows the time in the future when the user will be prompted to change their password.
- **Phase 4:** After the grace period (Phase 3) ends, the `ORA-28001: The password has expired` error appears, and the user is prompted to change the password after entering the current, correct password before the authentication can proceed. If the user has an Oracle Active Data Guard configuration, where there is a primary and a stand-by database, and the authentication attempt is made on the standby database (which is a read-only database), then the `ORA-28032: Your password has expired and the database is set to read-only` error appears. The user should log into the primary database and change the password there.

During any of these four phases, you can query the `DBA_USERS` data dictionary view to find the user's account status in the `DBA_USERS.ACCOUNT_STATUS` column.

Figure 3–1 Chronology of Password Lifetime and Grace Period



In the following example, the profile assigned to `johndoe` includes the specification of a grace period: `PASSWORD_GRACE_TIME = 3` (the recommended value). The first time `johndoe` tries to log in to the database after 90 days (this can be *any* day after the 90th day, that is, the 91st day, 100th day, or another day), he receives a warning message that his password will expire in 3 days. If 3 days pass, and if he does not change his password, then the password expires. After this, he receives a prompt to change his password on any attempt to log in.

```
CREATE PROFILE prof LIMIT
 FAILED_LOGIN_ATTEMPTS 4
 PASSWORD_LIFE_TIME 90
 PASSWORD_GRACE_TIME 3;

ALTER USER johndoe PROFILE prof;
```

A database administrator or a user who has the `ALTER USER` system privilege can explicitly expire a password by using the `CREATE USER` and `ALTER USER` statements. The following statement creates a user with an expired password. This setting forces the user to change the password before the user can log in to the database.

```
CREATE USER jbrown
 IDENTIFIED BY password
 ...
 PASSWORD EXPIRE;
```

There is no "password unexpire" clause for the `CREATE USER` statement, but an account can be "unexpired" by changing the password on the account.

Setting the PASSWORD_LIFE_TIME Profile Parameter to a Low Value

Be careful if you plan to set the `PASSWORD_LIFE_TIME` parameter of `CREATE PROFILE` or `ALTER PROFILE` to a low value (for example, 1 day). The `PASSWORD_LIFE_TIME` limit of a profile is measured from the last time that an account's password is changed, or the account creation time if the password has never been changed. These dates are recorded in the `PTIME` (password change time) and `CTIME` (account creation time) columns of the `SYS.USER$` system table. The `PASSWORD_LIFE_TIME` limit is not measured starting from the timestamp of the last change to the `PASSWORD_LIFE_TIME` profile parameter, as may be initially thought. Therefore, any accounts affected by the changed profile whose last password change time was more than `PASSWORD_LIFE_TIME` days ago immediately expire and enter their grace period on their next connection, issuing the `ORA-28002: The password will expire within` *n* `days` warning.

As a database administrator, you can find an account's last password change time as follows:

```
ALTER SESSION SET NLS_DATE_FORMAT='DD-MON-YYYY HH24:MI:SS';
SELECT PTIME FROM SYS.USER$ WHERE NAME = 'user_name'; -- Password change time
```

To find when the account was created and the password expiration date, issue the following query:

```
SELECT CREATED, EXPIRY_DATE FROM DBA_USERS WHERE USERNAME = 'user_name';
```

If the user who is assigned this profile is currently logged in when you set the PASSWORD_LIFE_TIME parameter and remains logged in, then Oracle Database does not change the user's account status from OPEN to EXPIRED(GRACE) when the currently listed expiration date passes. The timing begins only when the user logs into the database.

When making changes to a password profile, a database administrator must be aware that if some of the users who are subject to this profile are currently logged in to the Oracle database while their password profile is being updated by the administrator, then those users could potentially remain logged in to the system even beyond the expiration date of their password. You can find the currently logged in users by querying the USERNAME column of the V$SESSION view.

This is because the expiration date of a user's password is based on the timestamp of the last password change on their account plus the value of the PASSWORD_LIFE_TIME password profile parameter set by the administrator. It is *not* based on the timestamp of the last change to the password profile itself.

Note the following:

- If the user is not logged in when you set PASSWORD_LIFE_TIME to a low value, then the user's account status does not change until the user logs in.
- You can set the PASSWORD_LIFE_TIME parameter to UNLIMITED, but this only affects accounts that have not entered their grace period. After the grace period expires, the user must change the password.

Enforcing Password Complexity Verification

Complexity verification checks that each password is complex enough to provide reasonable protection against intruders who try to break into the system by guessing passwords. This forces users to create strong, secure passwords for database user accounts. You need to ensure that the passwords for your users are complex enough to provide reasonable protection against intruders who try to break into the system by guessing passwords.

How Oracle Database Checks the Complexity of Passwords

Oracle Database provides a sample password verification function entitled verify_function_11G in the PL/SQL script utlpwdmg.sql (located in $ORACLE_HOME/rdbms/admin) that, when enabled, checks whether users are correctly creating or modifying their passwords. The utlpwdmg.sql script provides two password verification functions: one for previous releases of Oracle Database and an updated version for Oracle Database Release 11*g*.

For better security of passwords, Oracle recommends that you associate the verify_function_11G function with the default profile. "Customizing Password Complexity Verification" on page 3-12 provides an example of how to accomplish this.

The utlpwdmg.sql script checks for the following requirements when users create or modify passwords:

- The password contains no fewer than 8 characters and does not exceed 30 characters.
- The password is not the same as the user name, nor is it the user name spelled backward or with the numbers 1–100 appended.
- The password is not the same as the server name or the server name with the numbers 1–100 appended.
- The password is not too simple, for example, welcome1, database1, account1, user1234, password1, oracle, oracle123, computer1, abcdefg1, or change_on_install.
- The password is not oracle or oracle with the numbers 1–100 appended.
- The password includes at least 1 numeric and 1 alphabetic character.
- The password differs from the previous password by at least 3 letters.

Who Can Use the Password Complexity Functions?

Before you can use the password complexity verification functions in the CREATE PROFILE or ALTER PROFILE statement, you must be granted the EXECUTE privilege on them. The password verification functions are located in the SYS schema.

Customizing Password Complexity Verification

You can create your own password complexity verification function by backing up and customizing the verify_function_11G function in the utlpwdmg.sql script. In fact, Oracle recommends that you do so to further secure your site's passwords. See also Guideline 1 in "Guidelines for Securing Passwords" on page 10-7 for general advice on creating passwords. However, be aware that the password complexity checking is not enforced for user SYS.

By default, password complexity verification is not enabled. To enable the password complexity verification:

1. Log in to SQL*Plus with administrative privileges.

   For example:

   ```
   CONNECT SYS AS SYSDBA
   Enter password: password
   ```

2. Run the utlpwdmg.sql script (or your modified version of this script) to create the password complexity functions in the SYS schema.

   ```
   @$ORACLE_HOME/RDBMS/ADMIN/utlpwdmg.sql
   ```

3. Grant any users who must use this function the EXECUTE privilege on it.

   For example:

   ```
   GRANT pmsith EXECUTE ON verify_function_11G;
   ```

4. In the default profile or the user profile, set the PASSWORD_VERIFY_FUNCTION setting to either the sample password complexity function in the utlpwdmg.sql script, or to your customized function. Use one of the following methods:

   - Log in to SQL*Plus with administrator privileges and use the CREATE PROFILE or ALTER PROFILE statement to enable the function. For example, to update the default profile to use the verify_function_11G function:

```
ALTER PROFILE default LIMIT
 PASSWORD_VERIFY_FUNCTION verify_function_11G;
```

- In Oracle Enterprise Manager, go to the Edit Profiles page and then under Complexity, select the name of the password complexity function from the Complexity function list.

After you have enabled password complexity verification, it takes effect immediately.

Note: The `ALTER USER` statement has a `REPLACE` clause. With this clause, users can change their own unexpired passwords by supplying the previous password to authenticate themselves.

If the password has expired, then the user cannot log in to SQL to issue the `ALTER USER` command. Instead, the `OCIPasswordChange()` function must be used, which also requires the previous password.

A database administrator with `ALTER ANY USER` privilege can change any user password (force a new password) without supplying the old one.

Enabling or Disabling Password Case Sensitivity

This section contains:

- About Enabling or Disabling Password Case Sensitivity
- Procedure for Enabling Password Case Sensitivity
- Finding the Password Versions of User Accounts
- How Case Sensitivity Affects Password Files
- How Case Sensitivity Affects Accounts Created for Database Link Connections

About Enabling or Disabling Password Case Sensitivity

When you create or modify user accounts, by default, passwords are case sensitive. To control the use of case sensitivity in passwords, set the `SEC_CASE_SENSITIVE_LOGON` initialization parameter. Only users who have the `ALTER SYSTEM` privilege can set the `SEC_CASE_SENSITIVE_LOGON` parameter. Set it to `TRUE` to enable case sensitivity or `FALSE` to disable case sensitivity.

For greater security, Oracle recommends that you enable case sensitivity in passwords. However, if you have compatibility issues with your applications, you can use this parameter to disable password case sensitivity. Examples of application compatibility issues are passwords for your applications being hard-coded to be case insensitive, or different application modules being inconsistent about case sensitivity when sending credentials to start a database session.

Do not set the `SEC_CASE_SENSITIVE_LOGON` parameter to `FALSE` when exclusive mode is enabled (the `SQLNET.ALLOWED_LOGON_VERSION` parameter is set to `11)`, because the more secure verifiers used in exclusive mode only support case-sensitive password checking. For compatibility reasons, Oracle Database does not prevent the use of the `FALSE` setting for `SEC_CASE_SENSITIVE_LOGON` when the `SQLNET.ALLOWED_LOGON_VERSION` parameter is set to `11`. This can result in accounts becoming inaccessible if these settings are in effect when users change their passwords or you create new user accounts.

Procedure for Enabling Password Case Sensitivity

To enable case sensitivity in passwords:

1. If you are using a password file, ensure that it was created with the IGNORECASE parameter set to N.

   The IGNORECASE parameter overrides the SEC_CASE_SENSITIVE_LOGON parameter. By default, IGNORECASE is set to Y, which means that passwords are treated as case-insensitive. For more information about password files, see *Oracle Database Administrator's Guide*.

2. Enter the following ALTER SYSTEM statement:

```
ALTER SYSTEM SET SEC_CASE_SENSITIVE_LOGON = TRUE
```

Finding the Password Versions of User Accounts

In previous releases of Oracle Database, passwords were not case sensitive. If you import user accounts from a previous release, for example, Release 10*g*, into the current database release, the case-insensitive passwords in these accounts remain case insensitive until the user changes his or her password. If the account was granted SYSDBA or SYSOPER privilege, it is imported to the password file. (See "How Case Sensitivity Affects Password Files" on page 3-14 for more information.) When a password from a user account from the previous release is changed, it then becomes case sensitive.

You can find users who have case sensitive or case insensitive passwords by querying the DBA_USERS view. The PASSWORD_VERSIONS column in this view indicates the release in which the password was created. For example:

```
SELECT USERNAME,PASSWORD_VERSIONS FROM DBA_USERS;

USERNAME                       PASSWORD_VERSIONS
------------------------------ -----------------
JONES                          10G 11G
ADAMS                          10G 11G
CLARK                          10G 11G
PRESTON                        11G
BLAKE                          10G
```

The passwords for accounts jones, adams, and clark were originally created in Release 10*g* and then reset in Release 11*g*. Their passwords, assuming case sensitivity has been enabled, are now case sensitive, as is the password for preston. However, the account for blake is still using the Release 10*g* standard, so it is case insensitive. Ask him to reset his password so that it will be case sensitive, and therefore more secure.

See *Oracle Database Reference* for more information about the DBA_USERS view.

How Case Sensitivity Affects Password Files

You can enable or disable case sensitivity for password files by using the ignorecase argument in the ORAPWD command line utility. The default value for ignorecase is n (no), which enforces case sensitivity.

Example 3–4 shows how to enable case sensitivity in password files.

Example 3–4 Enabling Password Case Sensitivity

```
orapwd file=orapw entries=100 ignorecase=n
Enter password for SYS: password
```

This creates a password file called `orapwd`. Because `ignorecase` is set to n (no), the password entered for the `password` parameter will be case sensitive. Afterwards, if you connect using this password, it succeeds—as long as you enter it using the *exact* case sensitivity in which it was created. If you enter the same password but with *different* case sensitivity, it will fail.

If you set `ignorecase` to `y`, then the passwords in the password file are case insensitive, which means that you can enter the password using any capitalization that you want.

If you imported user accounts from a previous release and these accounts were created with `SYSDBA` or `SYSOPER` privileges, then they will be included in the password file. The passwords for these accounts are case insensitive. The next time these users change their passwords, and assuming case sensitivity is enabled, the passwords become case sensitive. For greater security, have these users change their passwords.

See *Oracle Database Administrator's Guide* for more information about password files.

How Case Sensitivity Affects Accounts Created for Database Link Connections

When you create a database link connection, you must define a user name and password for the connection. When you create the database link connection, the password is case sensitive. How this user enters his or her password for connections depends on the release in which the database link was created:

- Users can connect from a pre-Release 11*g* database to a Release 11*g* database. If case sensitivity is disabled in the Release 11*g* database, then the user can enter the password using any case. If case sensitivity is enabled, however, then the user must enter the password using the case in which the password was created in the Release 11*g* database.
- If the user connecting from a Release 11*g* database to a pre-Release 11*g* database, he or she can enter his or her password using any case, because the password is still case insensitive.

You can find the user accounts for existing database links by running the `V$DBLINK` view. For example:

```
SELECT DB_LINK, OWNER_ID FROM V$DBLINK;
```

See *Oracle Database Reference* for more information about the `V$DBLINK` view.

Ensuring Against Password Security Threats by Using the SHA-1 Hashing Algorithm

The SHA-1 cryptographic hashing algorithm protects against password-based security threats by including support for mixed case characters, special characters, and multibyte characters in passwords. In addition, the SHA-1 hashing algorithm adds a **salt** to the password when it is hashed, which provides additional protection. This enables your users to create far more complex passwords, and therefore, makes it more difficult for an intruder to gain access to these passwords. Oracle recommends that you use the SHA-1 hashing algorithm.

The password versions (also known as password hash values) are considered to be extremely sensitive, because they are used as a "shared secret" between the server and person who is logging in. If an intruder learns this secret, then the protection of the authentication is immediately and severely compromised. Remember that administrative users who have account management privileges, administrative users who have the `SYSDBA` system privilege, or even users who have the `EXP_FULL_DATABASE` role can immediately access the password hash values. Therefore, this type of administrative user must be trustworthy if the integrity of the database password-based authentication is to be preserved. If you cannot trust these

administrators, then it is better to deploy a directory server (such as Oracle Database Enterprise User Security) so that the password versions remain within the Enterprise User Security directory and are never accessible to anyone except the Enterprise User Security administrator.

You optionally can configure Oracle Database to run in exclusive mode for Release 11 or later. When you enable exclusive mode, then Oracle Database uses the SHA-1 hashing algorithm exclusively. Oracle Database 11*g* exclusive mode is compatible with Oracle Database 10*g* and later products that use OCI-based drivers, including SQL*Plus, ODBC, Oracle .NET, Oracle Forms, and various third-party Oracle Database adapters. However, be aware that exclusive mode for Release 11*g* is not compatible with JDBC type-4 (thin) versions earlier than Oracle Database 11*g* or Oracle Database Client interface (OCI)-based drivers earlier than Oracle Database 10*g*. After you configure exclusive mode, Oracle recommends that you remove the previous password hash values from the data dictionary.

Follow these steps:

1. Enable exclusive mode.
   a. Create a back up copy of the `sqlnet.ora` parameter file, by default located in the `$ORACLE_HOME/network/admin` directory on UNIX operating systems and the `%ORACLE_HOME%\network\admin` directory on Microsoft Windows operating systems.
   b. Ensure that the `sqlnet.ora` file has the following line:

      ```
      SQLNET.ALLOWED_LOGON_VERSION=12
      ```

      If you have applied the October 2012 CPU or if you are using Oracle Database Release 11.2.0.3, then ensure that you set `SQLNET.ALLOWED_LOGON_VERSION` to 12, not `11`.
   c. Save and exit the `sqlnet.ora` file.
2. Verify that the passwords in test scripts or batch jobs are consistent in their use of mixed case and special characters.
3. Change all passwords to include mixed case and special characters.

   Oracle recommends that you use random passwords with a length of at least twelve characters. See Guideline 1 under "Guidelines for Securing Passwords" on page 10-7 for additional guidelines for creating passwords, and techniques for creating complex but easy to remember passwords.

   See Also: "Downloading Security Patches and Contacting Oracle Regarding Vulnerabilities" on page 10-2

Managing the Secure External Password Store for Password Credentials

This section contains:

- About the Secure External Password Store
- How Does the External Password Store Work?
- Configuring Clients to Use the External Password Store
- Managing External Password Store Credentials

About the Secure External Password Store

You can store password credentials for connecting to databases by using a client-side Oracle wallet. An Oracle wallet is a secure software container that stores authentication and signing credentials.

This wallet usage can simplify large-scale deployments that rely on password credentials for connecting to databases. When this feature is configured, application code, batch jobs, and scripts no longer need embedded user names and passwords. This reduces risk because the passwords are no longer exposed, and password management policies are more easily enforced without changing application code whenever user names or passwords change.

See Also:

- "Using Proxy Authentication with the Secure External Password Store" on page 3-40
- *Oracle Database Advanced Security Administrator's Guide* for general information about Oracle wallets

---

Note: The external password store of the wallet is separate from the area where public key infrastructure (PKI) credentials are stored. Consequently, you cannot use Oracle Wallet Manager to manage credentials in the external password store of the wallet. Instead, use the command-line utility `mkstore` to manage these credentials.

How Does the External Password Store Work?

Typically, users (and as applications, batch jobs, and scripts) connect to databases by using a standard `CONNECT` statement that specifies a database connection string. This string can include a user name and password, and an Oracle Net service name identifying the database on an Oracle Database network. If the password is omitted, the connection prompts the user for the password.

For example, the service name could be the URL that identifies that database, or a TNS alias you entered in the `tnsnames.ora` file in the database. Another possibility is a *`host:port:sid`* string.

The following examples are standard `CONNECT` statements that could be used for a client that is not configured to use the external password store:

```
CONNECT salesapp@sales_db.us.example.com
Enter password: password

CONNECT salesapp@orasales
Enter password: password

CONNECT salesapp@ourhost37:1527:DB17
Enter password: password
```

In these examples, `salesapp` is the user name, with the unique connection string for the database shown as specified in three different ways. You could use its URL `sales_db.us.example.com`, or its TNS alias `orasales` from the `tnsnames.ora` file, or its *`host:port:sid`* string.

However, when clients are configured to use the secure external password store, applications can connect to a database with the following `CONNECT` statement syntax, without specifying database login credentials:

```
CONNECT /@db_connect_string

CONNECT /@db_connect_string AS SYSDBA

CONNECT /@db_connect_string AS SYSOPER
```

In this specification, *db_connect_string* is a valid connection string to access the intended database, such as the service name, URL, or alias as shown in the earlier examples. Each user account must have its own unique connection string; you cannot create one connection string for multiple users.

In this case, the database credentials, user name and password, are securely stored in an Oracle wallet created for this purpose. The autologin feature of this wallet is turned on, so the system does not need a password to open the wallet. From the wallet, it gets the credentials to access the database for the user they represent.

> **See Also:** *Oracle Database Advanced Security Administrator's Guide* for information about autologin wallets

Configuring Clients to Use the External Password Store

If your client is already configured to use external authentication, such as Windows native authentication or Secure Sockets Layer (SSL), then Oracle Database uses that authentication method. The same credentials used for this type of authentication are typically also used to log in to the database.

For clients not using such authentication methods or wanting to override them for database authentication, you can set the `SQLNET.WALLET_OVERRIDE` parameter in `sqlnet.ora` to `TRUE`. The default value for `SQLNET.WALLET_OVERRIDE` is `FALSE`, allowing standard use of authentication credentials as before.

If you want a client to use the secure external password store feature, then perform the following configuration task:

1. Create a wallet on the client by using the following syntax at the command line:

   ```
   mkstore -wrl wallet_location -create
   ```

   For example:

   ```
   mkstore -wrl c:\oracle\product\11.2.0\db_1\wallets -create
   Enter password: password
   ```

   wallet_location is the path to the directory where you want to create and store the wallet. This command creates an Oracle wallet with the autologin feature enabled at the location you specify. The autologin feature enables the client to access the wallet contents without supplying a password. See *Oracle Database Advanced Security Administrator's Guide* for information about autologin wallets.

   The `mkstore` utility `-create` option uses password complexity verification. See "Enforcing Password Complexity Verification" on page 3-11 for more information.

2. Create database connection credentials in the wallet by using the following syntax at the command line:

   ```
   mkstore -wrl wallet_location -createCredential db_connect_string username
   Enter password: password
   ```

   For example:

   ```
   mkstore -wrl c:\oracle\product\11.2.0\db_1\wallets -createCredential orcl
   system
   ```

```
Enter password: password
```

In this specification:

- *wallet_location* is the path to the directory where you created the wallet in Step 1.
- *db_connect_string* is the TNS alias you use to specify the database in the `tnsnames.ora` file or any service name you use to identify the database on an Oracle network. By default, `tnsnames.ora` is located in the `$ORACLE_HOME/network/admin` directory on UNIX systems and in *ORACLE_HOME*`\network\admin` on Windows.
- *username* is the database login credential. When prompted, enter the password for this user.

Repeat this step for each database you want accessible using the `CONNECT /@`*db_connect_string* syntax.

Note: The *db_connect_string* used in the `CONNECT /@`*db_connect_string* statement must be identical to the *db_connect_string* specified in the `-createCredential` command.

---

3. In the client `sqlnet.ora` file, enter the `WALLET_LOCATION` parameter and set it to the directory location of the wallet you created in Step 1.

   For example, if you created the wallet in `$ORACLE_HOME/network/admin` and your Oracle home is set to `/private/ora11`, then you need to enter the following into your client `sqlnet.ora` file:

```
WALLET_LOCATION =
  (SOURCE =
    (METHOD = FILE)
    (METHOD_DATA =
  (DIRECTORY = /private/ora11/network/admin)
  )
 )
```

4. In the client `sqlnet.ora` file, enter the `SQLNET.WALLET_OVERRIDE` parameter and set it to `TRUE` as follows:

```
SQLNET.WALLET_OVERRIDE = TRUE
```

   This setting causes all `CONNECT /@`*db_connect_string* statements to use the information in the wallet at the specified location to authenticate to databases.

   When external authentication is in use, an authenticated user with such a wallet can use the `CONNECT /@`*db_connect_string* syntax to access the previously specified databases without providing a user name and password. However, if a user fails that external authentication, then these connect statements also fail.

> **Note:** If an application uses SSL for encryption, then the `sqlnet.ora` parameter, `SQLNET.AUTHENTICATION_SERVICES`, specifies SSL and an SSL wallet is created. If this application wants to use secret store credentials to authenticate to databases (instead of the SSL certificate), then those credentials must be stored in the SSL wallet. After SSL authentication, if `SQLNET.WALLET_OVERRIDE = TRUE`, then the user names and passwords from the wallet are used to authenticate to databases. If `SQLNET.WALLET_OVERRIDE = FALSE`, then the SSL certificate is used.

Example 3–5 shows a sample `sqlnet.ora` file with the `WALLET_LOCATION` and the `SQLNET.WALLET_OVERRIDE` parameters set as described in Steps 3 and 4.

Example 3–5 Sample SQLNET.ORA File with Wallet Parameters Set

```
WALLET_LOCATION =
   (SOURCE =
     (METHOD = FILE)
     (METHOD_DATA =
       (DIRECTORY = /private/ora11/network/admin)
     )
    )

SQLNET.WALLET_OVERRIDE = TRUE
SSL_CLIENT_AUTHENTICATION = FALSE
SSL_VERSION = 0
```

Managing External Password Store Credentials

This section summarizes the following tasks you can perform to manage credentials in the external password store by using the `mkstore` command-line utility:

- Listing External Password Store Contents
- Adding Credentials to an External Password Store
- Modifying Credentials in an External Password Store
- Deleting Credentials from an External Password Store

Listing External Password Store Contents Periodically, you may want to view all contents of a client wallet external password store, or you may need to check specific credentials by viewing them. Listing the external password store contents provides information you can use to decide whether to add or delete credentials from the store.

To list the contents of the external password store, enter the following command at the command line:

```
mkstore -wrl wallet_location -listCredential
```

For example:

```
mkstore -wrl c:\oracle\product\11.2.0\db_1\wallets -listCredential
```

wallet_location specifies the path to the directory where the wallet, whose external password store contents you want to view, is located. This command lists all of the credential database service names (aliases) and the corresponding user name (schema) for that database. Passwords are not listed.

Adding Credentials to an External Password Store You can store multiple credentials in one client wallet. For example, if a client batch job connects to `hr_database` and a script connects to `sales_database`, then you can store the login credentials in the same client wallet. You cannot, however, store multiple credentials (for logging in to multiple schemas) for the same database in the same wallet. If you have multiple login credentials for the same database, then they must be stored in separate wallets.

To add database login credentials to an existing client wallet, enter the following command at the command line:

```
mkstore -wrl wallet_location -createCredential db_alias username
```

For example:

```
mkstore -wrl c:\oracle\product\11.2.0\db_1\wallets -createCredential orcl system
Enter password: password
```

In this specification:

- *wallet_location* is the path to the directory where the client wallet to which you want to add credentials is stored.
- *db_alias* can be the TNS alias you use to specify the database in the `tnsnames.ora` file or any service name you use to identify the database on an Oracle network.
- *username* is the database login credential for the schema to which your application connects. When prompted, enter the password for this user.

Modifying Credentials in an External Password Store If the database connection strings change, then you can modify the database login credentials that are stored in the wallet.

To modify database login credentials in a wallet, enter the following command at the command line:

```
mkstore -wrl wallet_location -modifyCredential dbase_alias username
```

For example:

```
mkstore -wrl c:\oracle\product\11.2.0\db_1\wallets -modifyCredential sales_db
Enter password: password
```

In this specification:

- *wallet_location* is the path to the directory where the wallet is located.
- *db_alias* is a new or different alias you want to use to identify the database. It can be a TNS alias you use to specify the database in the `tnsnames.ora` file or any service name you use to identify the database on an Oracle network.
- *username* is the new or different database login credential. When prompted, enter the password for this user.

Deleting Credentials from an External Password Store If a database no longer exists or if you want to disable connections to a specific database, then you can delete all login credentials for that database from the wallet.

To delete database login credentials from a wallet, enter the following command at the command line:

```
mkstore -wrl wallet_location -deleteCredential db_alias
```

For example:

```
mkstore -wrl c:\oracle\product\11.2.0\db_1\wallets -deleteCredential orcl
```

In this specification:

- *wallet_location* is the path to the directory where the wallet is located.
- *db_alias* is the TNS alias you use to specify the database in the `tnsnames.ora` file, or any service name you use to identify the database on an Oracle Database network.

Authenticating Database Administrators

Database administrators perform special operations, such as shutting down or starting up a database, that should not be performed by non-administrative database users. Oracle Database provides the following methods to secure the authentication of database administrators who have either `SYSDBA` or `SYSOPER` privileges:

- Strong Authentication and Centralized Management for Database Administrators
- Authenticating Database Administrators by Using the Operating System
- Authenticating Database Administrators by Using Their Passwords

Strong Authentication and Centralized Management for Database Administrators

Strong authentication lets you centrally control `SYSDBA` and `SYSOPER` access to multiple databases. Consider using this type of authentication for database administration for the following situations:

- You have concerns about password file vulnerability.
- Your site has very strict security requirements.
- You want to separate the identity management from your database. By using a directory server such as Oracle Internet Directory (OID), for example, you can maintain, secure, and administer that server separately.

To enable the Oracle Internet Directory server to authorize `SYSDBA` and `SYSOPER` connections, use one of the following methods, depending on your environment:

- Configuring Directory Authentication for Administrative Users
- Configuring Kerberos Authentication for Administrative Users
- Configuring Secure Sockets Layer Authentication for Administrative Users

Configuring Directory Authentication for Administrative Users

To configure directory authentication for administrative users:

1. Configure the administrative user by using the same procedures you would use to configure a typical user.
2. In Oracle Internet Directory, grant the `SYSDBA` or `SYSOPER` privilege to the user for the database that this user will administer.

   Grant `SYSDBA` or `SYSOPER` only to trusted users. See "Guidelines for Securing User Accounts and Privileges" on page 10-2 for advice on this topic.
3. Set the `LDAP_DIRECTORY_SYSAUTH` initialization parameter to `YES`:

   ```
   ALTER SYSTEM SET LDAP_DIRECTORY_SYSAUTH = YES;
   ```

When set to YES, the LDAP_DIRECTORY_SYSAUTH parameter enables SYSDBA and SYSOPER users to authenticate to the database by using a strong authentication method.

See *Oracle Database Reference* for more information about LDAP_DIRECTORY_SYSAUTH.

4. Set the LDAP_DIRECTORY_ACCESS parameter to either PASSWORD or SSL. For example:

```
ALTER SYSTEM SET LDAP_DIRECTORY_ACCESS = PASSWORD;
```

Ensure that the LDAP_DIRECTORY_ACCESS initialization parameter is not set to NONE. Setting this parameter to PASSWORD or SSL ensures that users can be authenticated using the SYSDBA or SYSOPER privileges through Oracle Internet Directory. See *Oracle Database Reference* for more information about LDAP_DIRECTORY_ACCESS.

Afterward, this user can log in by including the net service name in the CONNECT statement in SQL*Plus. For example, to log on as SYSDBA if the net service name is orcl:

```
CONNECT SOMEUSER@ORCL AS SYSDBA
Enter password: password
```

If the database is configured to use a password file for remote authentication, Oracle Database checks the password file first.

Configuring Kerberos Authentication for Administrative Users

To configure Kerberos authentication for administrative users:

1. Configure the administrative user by using the same procedures you would use to configure a typical user.

   See *Oracle Database Advanced Security Administrator's Guide* for more information.

2. Configure Oracle Internet Directory for Kerberos authentication.

   See *Oracle Database Enterprise User Security Administrator's Guide* for more information.

3. In Oracle Internet Directory, grant the SYSDBA or SYSOPER privilege to the user for the database that this user will administer.

   Grant SYSDBA or SYSOPER only to trusted users. See "Guidelines for Securing User Accounts and Privileges" on page 10-2 for advice on this topic.

4. Set the LDAP_DIRECTORY_SYSAUTH initialization parameter to YES:

```
ALTER SYSTEM SET LDAP_DIRECTORY_SYSAUTH = YES;
```

When set to YES, the LDAP_DIRECTORY_SYSAUTH parameter enables SYSDBA and SYSOPER users to authenticate to the database by using strong authentication methods. See *Oracle Database Reference* for more information about LDAP_DIRECTORY_SYSAUTH.

5. Set the LDAP_DIRECTORY_ACCESS parameter to either PASSWORD or SSL. For example:

```
ALTER SYSTEM SET LDAP_DIRECTORY_ACCESS = SSL;
```

Ensure that the LDAP_DIRECTORY_ACCESS initialization parameter is not set to NONE. Setting this parameter to PASSWORD or SSL ensures that users can be authenticated using SYSDBA or SYSOPER through Oracle Internet Directory. See *Oracle Database Reference* for more information about LDAP_DIRECTORY_ACCESS.

Afterward, this user can log in by including the net service name in the CONNECT statement in SQL*Plus. For example, to log on as SYSDBA if the net service name is orcl:

```
CONNECT /@orcl AS SYSDBA
```

Configuring Secure Sockets Layer Authentication for Administrative Users

To configure Secure Sockets Layer (SSL) authentication for administrative users:

1. Configure the client to use SSL:
   a. Configure the client wallet and user certificate. Update the wallet location in the sqlnet.ora configuration file.

      You can use Wallet Manager to configure the client wallet and user certificate. See *Oracle Database Advanced Security Administrator's Guide* for more information.

   b. Configure the Oracle net service name to include server DNs and use TCP/IP with SSL in tnsnames.ora.

   c. Configure TCP/IP with SSL in listener.ora.

   d. Set the client SSL cipher suites and the required SSL version, and then set SSL as an authentication service in sqlnet.ora.
2. Configure the server to use SSL:
   a. Enable SSL for your database listener on TCPS and provide a corresponding TNS name. You can use Net Configuration Assistant to configure the TNS name.

   b. Store the database PKI credentials in the database wallet. You can use Wallet Manager do this.

   c. Set the LDAP_DIRECTORY_ACCESS initialization parameter to SSL:

      ```
      ALTER SYSTEM SET LDAP_DIRECTORY_ACCESS = SSL;
      ```

      See *Oracle Database Reference* for more information about LDAP_DIRECTORY_ACCESS.
3. Configure Oracle Internet Directory for SSL user authentications.

   See *Oracle Database Enterprise User Security Administrator's Guide* for information on configuring enterprise user security SSL authentication.
4. In Oracle Internet Directory, grant the SYSDBA or SYSOPER privilege to the user for the database that the user will administer.
5. On the server computer, set the LDAP_DIRECTORY_SYSAUTH initialization parameter to YES.

   ```
   ALTER SYSTEM SET LDAP_DIRECTORY_SYSAUTH = YES;
   ```

   When set to YES, the LDAP_DIRECTORY_SYSAUTH parameter enables SYSDBA and SYSOPER users to authenticate to the database by using a strong authentication method. See *Oracle Database Reference* for more information about LDAP_DIRECTORY_SYSAUTH.

Afterward, this user can log in by including the net service name in the CONNECT statement in SQL*Plus. For example, to log on as SYSDBA if the net service name is orcl:

```
CONNECT /@orcl AS SYSDBA
```

Authenticating Database Administrators by Using the Operating System

Operating system authentication for a database administrator typically involves establishing a group on the operating system, granting DBA privileges to that group, and then adding the names of persons who should have those privileges to that group. (On UNIX systems, the group is the **dba** group.)

On Microsoft Windows systems, users who connect with the SYSDBA privilege can take advantage of the Windows native authentication. If these users work with Oracle Database using their domain accounts, then you must explicitly grant them local administrative privileges and ORA_DBA membership.

> **See Also:** Your Oracle Database operating system-specific documentation for information about configuring operating system authentication of database administrators

Authenticating Database Administrators by Using Their Passwords

Oracle Database uses database-specific password files to keep track of database user names that have been granted the SYSDBA and SYSOPER privileges. These privileges enable the following activities:

- The SYSOPER system privilege lets database administrators perform STARTUP, SHUTDOWN, ALTER DATABASE OPEN/MOUNT, ALTER DATABASE BACKUP, ARCHIVE LOG, and RECOVER operations. SYSOPER also includes the RESTRICTED SESSION privilege.
- The SYSDBA system privilege has all system privileges with ADMIN OPTION, including the SYSOPER system privilege, and permits CREATE DATABASE and time-based recovery.
- A password file containing users with SYSDBA or SYSOPER privileges can be shared between different databases. You can have a shared password file that contains users in addition to the SYS user. To share a password file among different databases, set the REMOTE_LOGIN_PASSWORDFILE parameter in the init.ora file to SHARED.

  If you set the REMOTE_LOGIN_PASSWORDFILE initialization parameter to EXCLUSIVE or SHARED from NONE, then ensure that the password file is in sync with the dictionary passwords. See *Oracle Database Administrator's Guide* for more information.
- Password file-based authentication is enabled by default. This means that the database is ready to use a password file for authenticating users that have SYSDBA or SYSOPER system privileges. Password file based authentication is activated as soon as you create a password file using the ORAPWD utility.

  Anyone who has EXECUTE privileges and write privileges to the $ORACLE_HOME/dbs directory can run the ORAPWD utility.

However, be aware that using password files may pose security risks. For this reason, consider using the authentication methods described in "Strong Authentication and Centralized Management for Database Administrators" on page 3-22. Examples of password security risks are as follows:

- An intruder could steal or attack the password file.
- Many users do not change the default password.
- The password could be easily guessed.
- The password is vulnerable if it can be found in a dictionary.

- Passwords that are too short, chosen perhaps for ease of typing, are vulnerable if an intruder obtains the cryptographic hash of the password.

Note: Connections requested `AS SYSDBA` or `AS SYSOPER` must use these phrases; without them, the connection fails. The Oracle Database parameter `O7_DICTIONARY_ACCESSIBILITY` is set to `FALSE` by default, to limit sensitive data dictionary access only to those authorized. The parameter also enforces the required `AS SYSDBA` or `AS SYSOPER` syntax.

See Also: *Oracle Database Administrator's Guide* for information about creating and maintaining password files

Using the Database to Authenticate Users

This section contains:

About Database Authentication

Oracle Database can authenticate users attempting to connect to a database by using information stored in that database itself. To configure Oracle Database to use database authentication, you must create each user with an associated password. User names can be multibyte, but each password must be composed of single-byte characters, even if your database uses a multibyte character set. The user must provide this user name and password when attempting to establish a connection. Oracle Database stores user passwords in the data dictionary in an encrypted format.

To identify the authentication protocols that are allowed by a client or a database, a database administrator can explicitly set the `SQLNET.ALLOWED_LOGON_VERSION` parameter in the server `sqlnet.ora` file. Each connection attempt is tested, and if the client or server does not meet the minimum version specified by its partner, authentication fails with an `ORA-28040 No matching authentication protocol` error. The parameter can take the values 11, 10, 9, or 8. The default value is 8. These values represent database server versions. Oracle recommends the value 11 for the strongest protection. However, be aware that if you set `SQLNET.ALLOWED_LOGON_VERSION` to 11, then pre-Oracle Database Release 11.1 client applications or JDBC thin clients cannot authenticate to the Oracle database using password-based authentication.

To enhance security when using database authentication, Oracle recommends that you use password management, including account locking, password aging and expiration, password history, and password complexity verification. See "Using a Password Management Policy" on page 3-3 for more information about password management.

Advantages of Database Authentication

The advantages of database authentication are as follows:

- User accounts and all authentication are controlled by the database. There is no reliance on anything outside of the database.

- Oracle Database provides strong password management features to enhance security when using database authentication.
- It is easier to administer when there are small user communities.

Creating a User Who Is Authenticated by the Database

The following SQL statement creates a user who is identified and authenticated by Oracle Database. User `sebastian` must specify the assigned password whenever he connects to Oracle Database.

```
CREATE USER sebastian IDENTIFIED BY password;
```

Using the Operating System to Authenticate Users

Some operating systems permit Oracle Database to use information they maintain to authenticate users. This has the following benefits:

- Once authenticated by the operating system, users can connect to Oracle Database more conveniently, without specifying a user name or password. For example, an operating system-authenticated user can invoke SQL*Plus and omit the user name and password prompts by entering the following command at the command line:

  ```
  SQLPLUS /
  ```

  Within SQL*Plus, you enter:

  ```
  CONNECT /
  ```

- With control over user authentication centralized in the operating system, Oracle Database need not store or manage user passwords, although it still maintains user names in the database.
- Audit trails in the database and operating system can use the same user names.
- You can authenticate both operating system and non-operating system users in the same system. For example:
  - **Authenticate users by the operating system.** You create the user account using the `IDENTIFIED EXTERNALLY` clause of the `CREATE USER` statement, and then you set the `OS_AUTHENT_PREFIX` initialization parameter to specify a prefix that Oracle Database uses to authenticate users attempting to connect to the server.
  - **Authenticate non-operating system users.** These are users who are assigned passwords and authenticated by the database.
  - **Authenticate Oracle Database Enterprise User Security users.** These user accounts where created using the `IDENTIFIED GLOBALLY` clause of the `CREATE USER` statement, and then authenticated by Oracle Internet Directory (OID) currently in the same database.

However, you should be aware of the following drawbacks to using the operating system to authenticate users:

- A user must have an operating system account on the computer that must be accessed. Not all users have operating system accounts, particularly non-administrative users.
- If a user has logged in using this method and steps away from the terminal, another user could easily log in because this user does not need any passwords or credentials. This could pose a serious security problem.

- When an operating system is used to authenticate database users, managing distributed database environments and database links requires special care. Operating system-authenticated database links can pose a security weakness. For this reason, Oracle recommends that you do not use them.

See Also:

- *Oracle Database Administrator's Guide* for more information about authentication, operating systems, distributed database concepts, and distributed data management
- Operating system-specific documentation by Oracle Database for more information about authenticating by using your operating system

Using the Network to Authenticate Users

You can authenticate users over a network by using Secure Sockets Layer with third-party services.

- Authentication Using Secure Sockets Layer
- Authentication Using Third-Party Services

Authentication Using Secure Sockets Layer

The Secure Sockets Layer (SSL) protocol is an application layer protocol. You can use it for user authentication to a database, and it is independent of global user management in Oracle Internet Directory. That is, users can use SSL to authenticate to the database without a directory server in place.

See *Oracle Database Advanced Security Administrator's Guide* for instructions about configuring SSL.

Authentication Using Third-Party Services

You need to use third-party network authentication services if you want to authenticate Oracle Database users over a network. Prominent examples include Kerberos, PKI (public key infrastructure), the RADIUS (Remote Authentication Dial-In User Service), and directory-based services, as described in the following sections.

If network authentication services are available to you, then Oracle Database can accept authentication from the network service. If you use a network authentication service, then some special considerations arise for network roles and database links.

Note: To use a network authentication service with Oracle Database, you need Oracle Database Enterprise Edition with the Oracle Database Advanced Security option.

See Also: *Oracle Database Advanced Security Administrator's Guide* for information about Oracle Enterprise Edition with the Oracle Database Advanced Security option

Authenticating Using Kerberos

Kerberos is a trusted third-party authentication system that relies on shared secrets. It presumes that the third party is secure, and provides single sign-on capabilities, centralized password storage, database link authentication, and enhanced PC security.

It does this through a Kerberos authentication server, or through Cybersafe Active Trust, a commercial Kerberos-based authentication server.

> **See Also:** *Oracle Database Advanced Security Administrator's Guide* for more information about Kerberos

Authenticating Using RADIUS

Oracle Database supports remote authentication of users through the Remote Authentication Dial-In User Service (RADIUS), a standard lightweight protocol used for user authentication, authorization, and accounting. This feature also enables users to use the RSA One-Time Password Specifications (OTPS) to authenticate to the Oracle database.

> **See Also:**
>
> - *Oracle Database Advanced Security Administrator's Guide* for information about configuring RADIUS
> - RSA documentation about OTPS

Authenticating Using Directory-Based Services

Using a central directory can make authentication and its administration efficient. Directory-based services include the following:

- **Oracle Internet Directory**, which uses the Lightweight Directory Access Protocol (LDAP), uses a central repository to store and manage information about users (called enterprise users) whose accounts were created in a distributed environment. Although database users must be created (with passwords) in each database that they need to access, enterprise user information is accessible centrally in the Oracle Internet Directory. You can also integrate this directory with Microsoft Active Directory and SunOne.

  For more information about Oracle Internet Directory, see *Oracle Internet Directory Administrator's Guide*.

- **Oracle Enterprise Security Manager** lets you store and retrieve roles from Oracle Internet Directory, which provides centralized privilege management to make administration easier and increase security levels. For more information about Oracle Enterprise Security Manager, see *Oracle Enterprise Manager Advanced Configuration*.

Authenticating Using Public Key Infrastructure

Authentication systems based on public key infrastructure (PKI) issue digital certificates to user clients, which use them to authenticate directly to servers in the enterprise without directly involving an authentication server. Oracle Database provides a PKI for using public keys and certificates, consisting of the following components:

- **Authentication and secure session key management using SSL.** See "Authentication Using Secure Sockets Layer" on page 3-28 for more information.

- **Trusted certificates.** These are used to identify third-party entities that are trusted as signers of user certificates when an identity is being validated. When the user certificate is being validated, the signer is checked by using trust points or a trusted certificate chain of certificate authorities stored in the validating system. If there are several levels of trusted certificates in this chain, then a trusted certificate at a lower level is simply trusted without needing to have all its higher-level

certificates reverified. For more information about trusted certificates, see *Oracle Database Advanced Security Administrator's Guide*.

- **OracleAS Certificate Authority.** This is a component of the Oracle Identity Management infrastructure, which provides an integrated solution for provisioning X.509 version 3 certificates for individuals, applications, and servers that require certificates for PKI-based operations such as authentication, SSL, S/MIME, and so on. For more information about OracleAS Certificate Authority, see *Oracle Application Server Certificate Authority Administrator's Guide*.
- **Oracle Wallet Manager.** An Oracle wallet is a data structure that contains the private key of a user, a user certificate, and the set of trust points of a user (trusted certificate authorities). See *Oracle Database Advanced Security Administrator's Guide* for information about managing Oracle wallets.

  You can use Oracle Wallet Manager to manage Oracle wallets. This is a standalone Java application used to manage and edit the security credentials in Oracle wallets. It performs the following operations:

  – Generates a public-private key pair and creates a certificate request for submission to a certificate authority, and creates wallets
  – Installs a certificate for the entity
  – Manages X.509 version 3 certificates on Oracle Database clients and servers
  – Configures trusted certificates for the entity
  – Opens a wallet to enable access to PKI-based services
- **X.509 version 3 certificates obtained from (and signed by) a trusted entity, a certificate authority.** Because the certificate authority is trusted, these certificates verify that the requesting entity's information is correct and that the public key on the certificate belongs to the identified entity. The certificate is loaded into an Oracle wallet to enable future authentication.

Configuring Global User Authentication and Authorization

You can use Oracle Advanced Security to centralize the management of user-related information, including authorizations, in an LDAP-based directory service. This allows users and administrators to be identified in the database as global users, meaning that they are authenticated by SSL and that the management of these users is handled outside of the database by the centralized directory service. Global roles are defined in a database and are known only to that database, but the directory service handles authorizations for global roles.

Note: You can also have users authenticated by SSL, whose authorizations are not managed in a directory, that is, they have local database roles only. See *Oracle Database Advanced Security Administrator's Guide* for details.

This centralized management enables the creation of **enterprise users** and **enterprise roles**. Enterprise users are defined and managed in the directory. They have unique identities across the enterprise and can be assigned enterprise roles that determine their access privileges across multiple databases. An enterprise role consists of one or more global roles, and might be thought of as a container for global roles.

See Also: "Strong Authentication and Centralized Management for Database Administrators" on page 3-22 if you want to centralize the management of `SYSDBA` or `SYSOPER` access

Creating a User Who Is Authorized by a Directory Service

You have the following options to specify users who are authorized by a directory service:

- Creating a Global User Who Has a Private Schema
- Creating Multiple Enterprise Users Who Share Schemas

Creating a Global User Who Has a Private Schema

The following statement shows the creation of a global user with a private schema, authenticated by SSL, and authorized by the enterprise directory service:

```
CREATE USER psmith IDENTIFIED GLOBALLY AS 'CN=psmith,OU=division1,O=oracle,C=US';
```

The string provided in the `AS` clause provides an identifier (**distinguished name,** or **DN**) meaningful to the enterprise directory.

In this case, `psmith` is a global user. But, the disadvantage here is that user `psmith` must then be created in every database that he must access, plus the directory.

Creating Multiple Enterprise Users Who Share Schemas

Multiple enterprise users can share a single schema in the database. These users are authorized by the enterprise directory service but do not own individual private schemas in the database. These users are not individually created in the database. They connect to a shared schema in the database.

To create a schema-independent user:

1. Create a shared schema in the database using the following example:

   ```
   CREATE USER appschema IDENTIFIED GLOBALLY AS '';
   ```

2. In the directory, create multiple enterprise users and a mapping object.

   The mapping object tells the database how you want to map the DNs for the users to the shared schema. You can either create a full DN mapping (one directory entry for each unique DN), or you can map, for each user, multiple DN components to one schema. For example:

   ```
   OU=division,O=Oracle,C=US
   ```

See Also: *Oracle Database Enterprise User Security Administrator's Guide* for an explanation of these mappings

Most users do not need their own schemas, and implementing schema-independent users separates users from databases. You create multiple users who share the same schema in a database, and as enterprise users, they can also access shared schemas in other databases.

Advantages of Global Authentication and Global Authorization

Some advantages of global user authentication and authorization are as follows:

- Provides strong authentication using SSL, Kerberos, or Windows native authentication.
- Enables centralized management of users and privileges across the enterprise.
- Is easy to administer: You do not have to create a schema for every user in every database in the enterprise.
- Facilitates single sign-on: Users need to sign on once to only access multiple databases and services. Further, users using passwords can have a single password to access multiple databases accepting password-authenticated enterprise users.
- Because global user authentication and authorization provide password-based access, you can migrate previously defined password-authenticated database users to the directory (using the User Migration Utility) to be centrally administered. This makes global authentication and authorization available for earlier Oracle Database release clients that are still supported.
- `CURRENT_USER` database links connect as a global user. A local user can connect as a global user in the context of a stored procedure, that is, without storing the global user password in a link definition.

See Also: The following manuals for additional information about global authentication and authorization and enterprise users and roles:

- *Oracle Database Advanced Security Administrator's Guide*
- *Oracle Database Enterprise User Security Administrator's Guide*

Configuring an External Service to Authenticate Users and Passwords

This section contains:

About External Authentication

When you use external authentication for user accounts, Oracle Database maintains the user account, but an external service performs the password administration and user authentication. This external service can be the operating system or a network service, such as Oracle Net.

With external authentication, your database relies on the underlying operating system or network authentication service to restrict access to database accounts. A database password is not used for this type of login. If your operating system or network service permits, then it can authenticate users before they can log in to the database. To enable this feature, set the initialization parameter `OS_AUTHENT_PREFIX`, and use this prefix in Oracle Database user names. The `OS_AUTHENT_PREFIX` parameter defines a prefix that Oracle Database adds to the beginning of the operating system account name of every user. Oracle Database compares the prefixed user name with the Oracle Database user names in the database when a user attempts to connect.

You should set OS_AUTHENT_PREFIX to a null string (an empty set of double quotation marks: ""). Using a null string eliminates the addition of any prefix to operating system account names, so that Oracle Database user names exactly match operating system user names.

```
OS_AUTHENT_PREFIX=" "
```

After you set OS_AUTHENT_PREFIX, it should remain the same for the life of a database. If you change the prefix, then any database user name that includes the old prefix cannot be used to establish a connection, unless you alter the user name to have it use password authentication.

The default value of this parameter is OPS$ for backward compatibility with previous versions of Oracle Database. For example, assume that you set OS_AUTHENT_PREFIX as follows:

```
OS_AUTHENT_PREFIX=OPS$
```

> **Note:** The text of the OS_AUTHENT_PREFIX initialization parameter is case-sensitive on some operating systems. See your operating system-specific Oracle Database documentation for more information about this initialization parameter.

If a user with an operating system account named tsmith is to connect to an Oracle database installation and be authenticated by the operating system, then Oracle Database checks that there is a corresponding database user OPS$tsmith and, if so, lets the user connect. All references to a user authenticated by the operating system must include the prefix, OPS$, as seen in OPS$tsmith.

Advantages of External Authentication

The advantages of external authentication are as follows:

- More choices of authentication mechanisms are available, such as smart cards, fingerprints, Kerberos, or the operating system.
- Many network authentication services, such as Kerberos support single sign-on, enabling users to have fewer passwords to remember.
- If you are already using an external mechanism for authentication, such as one of those listed earlier, then there may be less administrative overhead to use that mechanism with the database.

Creating a User Who Is Authenticated Externally

The following statement creates a user who is identified by Oracle Database and authenticated by the operating system or a network service. This example assumes that the OS_AUTHENT_PREFIX parameter has been set to a blank space (" ").

```
CREATE USER psmith IDENTIFIED EXTERNALLY;
```

Using the CREATE USER ... IDENTIFIED EXTERNALLY statement, you create database accounts that must be authenticated by the operating system or network service. Oracle Database then relies on this external login authentication when it provides that specific operating system user with access to the database resources of a specific user.

> **See Also:** *Oracle Database Advanced Security Administrator's Guide* for more information about external authentication

Authenticating User Logins Using the Operating System

By default, Oracle Database allows operating system-authenticated logins only over secure connections, which precludes using Oracle Net and a shared server configuration. This restriction prevents a remote user from impersonating another operating system user over a network connection.

Setting the `REMOTE_OS_AUTHENT` parameter to `TRUE` in the database initialization parameter file forces the database to accept the client operating system user name received over an unsecure connection and use it for account access. Because clients, in general, such as PCs, are not trusted to perform operating system authentication properly, it is very poor security practice to turn on this feature.

The default setting, `REMOTE_OS_AUTHENT = FALSE`, creates a more secure configuration that enforces proper, server-based authentication of clients connecting to an Oracle database.

Any change to this parameter takes effect the next time you start the instance and mount the database. Generally, user authentication through the host operating system offers faster and more convenient connection to Oracle Database without specifying a separate database user name or password. Also, user entries correspond in the database and operating system audit trails.

Be aware that the `REMOTE_OS_AUTHENT` parameter was deprecated in Oracle Database 11*g* Release 1 (11.1), and is retained only for backward compatibility.

Authentication User Logins Using Network Authentication

Oracle Advanced Security performs network authentication, which you can configure to use a third-party service such as Kerberos. If you are using Oracle Advanced Security as your only external authentication service, then the `REMOTE_OS_AUTHENT` parameter setting is irrelevant, because Oracle Advanced Security allows only secure connections.

Using Multitier Authentication and Authorization

In a multitier environment, Oracle Database controls the security of middle-tier applications by limiting their privileges, preserving client identities through all tiers, and auditing actions taken on behalf of clients. In applications that use a very busy middle tier, such as a transaction processing monitor, the identity of the clients connecting to the middle tier must be preserved. One advantage of using a middle tier is **connection pooling**, which allows multiple users to access a data server without each of them needing a separate connection. In such environments, you need to be able to set up and break down connections very quickly.

For these environments, you can use the Oracle Call Interface to create **lightweight sessions**, which enable database password authentication for each user. This method preserves the identity of the real user through the middle tier without the overhead of a separate database connection for each user.

You can create lightweight sessions with or without passwords. However, if a middle tier is outside of or on a firewall, then security is better when each lightweight session has its own password. For an internal application server, lightweight sessions without passwords might be appropriate.

Administration and Security in Clients, Application Servers, and Database Servers

In a multitier environment, an application server provides data for clients and serves as an interface from them to one or more database servers. The application server can validate the credentials of a client, such as a Web browser, and the database server can audit operations performed by the application server. These auditable operations include actions performed by the application server on behalf of clients, such as requests that information be displayed on the client. A request to connect to the database server is an example of an application server operation not related to a specific client.

Authentication in a multitier environment is based on trust regions. Client authentication is the domain of the application server. The application server itself is authenticated by the database server. The following operations are performed:

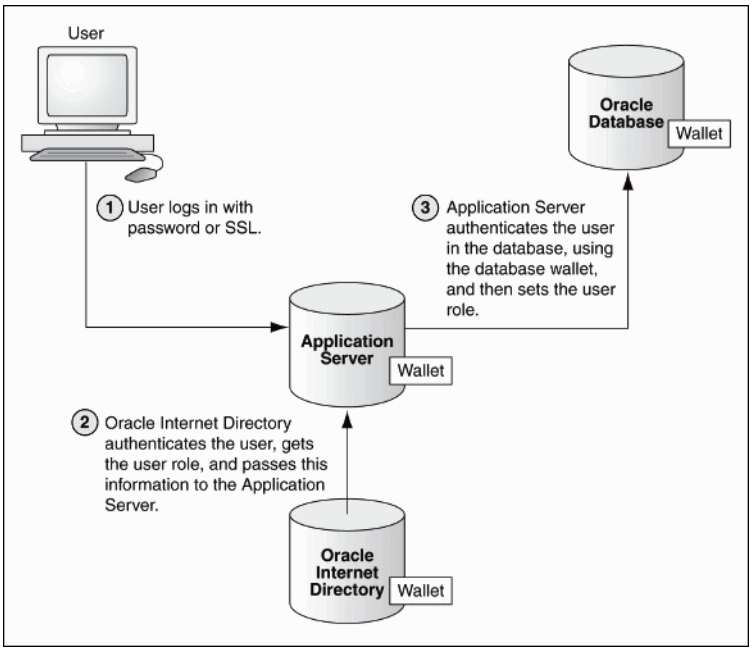
- The end user provides proof of authenticity to the application server, typically, by using a password or an X.509 certificate.
- The application server authenticates the end user and then authenticates itself to the database server.
- The database server authenticates the application server, verifies that the end user exists, and verifies that the application server has the privilege to connect for the end user.

Application servers can also enable roles for an end user on whose behalf they connect. The application server can obtain these roles from a directory, which serves as an authorization repository. The application server can only request that these roles be enabled. The database verifies the following requirements:

- That the client has these roles by checking its internal role repository
- That the application server has the privilege to connect on behalf of the user and thus to use these roles as the user could

Figure 3–2 shows an example of multitier authentication.

Figure 3–2 Multitier Authentication



The following actions take place:

1. The user logs on using a password or Secure Sockets Layer. The authentication information is passed through Oracle Application Server.
2. Oracle Internet Directory authenticates the user, gets the roles associated with that user from the wallet, and then passes this information back to Oracle Application Server.
3. Oracle Application Server checks the identity of the user in Oracle Database, which contains a wallet that stores this information, and then sets the role for that user.

Security for middle-tier applications must address the following key issues:

- **Accountability.** The database server must be able to distinguish between the actions of the application and the actions an application takes on behalf of a client. It must be possible to audit both kinds of actions.
- **Least privilege.** Users and middle tiers should be given the fewest privileges necessary to perform their actions, to reduce the danger of inadvertent or malicious unauthorized activities.

Preserving User Identity in Multitiered Environments

Many organizations want to know who the user is through all tiers of an application without sacrificing the benefits of a middle tier. Oracle Database supports the following ways to preserve user identity through the middle tier of an application:

- Using a Middle Tier Server for Proxy Authentication
- Using Client Identifiers to Identify Application Users Not Known to the Database

See Also: "Auditing SQL Statements and Privileges in a Multitier Environment" on page 9-27

Using a Middle Tier Server for Proxy Authentication

The following sections explain how to use proxy authentication:

- About Proxy Authentication
- Advantages of Proxy Authentication
- Who Can Create Proxy User Accounts?
- Creating Proxy User Accounts and Authorizing Users to Connect Through Them
- Using Proxy Authentication with the Secure External Password Store
- Passing Through the Identity of the Real User by Using Proxy Authentication
- Limiting the Privilege of the Middle Tier
- Authorizing a Middle Tier to Proxy and Authenticate a User
- Authorizing a Middle Tier to Proxy a User Authenticated by Other Means
- Reauthenticating the User Through the Middle Tier to the Database

About Proxy Authentication

Oracle Database provides proxy authentication in Oracle Call Interface (OCI), JDBC/OCI, or JDBC Thin Driver for database users or enterprise users. Enterprise

users are those who are managed in Oracle Internet Directory and who access a shared schema in the database.

You can design a middle-tier server to authenticate clients in a secure fashion by using the following three forms of proxy authentication:

- The middle-tier server authenticates itself with the database server and a client, in this case an application user or another application, authenticates itself with the middle-tier server. Client identities can be maintained all the way through to the database.
- The client, in this case a database user, is not authenticated by the middle-tier server. The clients identity and database password are passed through the middle-tier server to the database server for authentication.
- The client, in this case a global user, is authenticated by the middle-tier server, and passes one of the following through the middle tier for retrieving the client's user name.
  - Distinguished name (DN)
  - Certificate

> **Note:** The use of certificates for proxy authentication may not be supported in future Oracle Database releases.

In all cases, an administrator must authorize the middle-tier server to act on behalf of the client.

> **See Also:** *Oracle Call Interface Programmer's Guide* and *Oracle Database Advanced Application Developer's Guide* or details about designing a middle-tier server to proxy users

Advantages of Proxy Authentication

In multitier environments, proxy authentication controls the security of middle-tier applications by preserving client identities and privileges through all tiers and by auditing actions taken on behalf of clients. For example, this feature allows the identity of a user using a Web application (which acts as a proxy) to be passed through the application to the database server.

Three-tier systems provide the following benefits to organizations:

- Organizations can separate application logic from data storage, partitioning the former in application servers and the latter in databases.
- Application servers and Web servers enable users to access data stored in databases.
- Users like using a familiar, easy-to-use browser interface.
- Organizations can also lower their cost of computing by replacing many *thick clients* with numerous *thin clients* and an application server.

In addition, Oracle Database proxy authentication provides the following security benefits:

- A limited trust model, by controlling the users on whose behalf middle tiers can connect and the roles that the middle tiers can assume for the user
- Scalability, by supporting user sessions through OCI, JDBC/OCI, or JDBC Thin driver and eliminating the overhead of reauthenticating clients

- Accountability, by preserving the identity of the real user through to the database, and enabling auditing of actions taken on behalf of the real user
- Flexibility, by supporting environments in which users are known to the database, and in which users are merely application users of which the database has no awareness

> **Note:** Oracle Database supports this proxy authentication functionality in three tiers only. It does not support it across multiple middle tiers.

Who Can Create Proxy User Accounts?

To create proxy user accounts, users must have the following minimum privileges:

- The `CREATE USER` system privilege to create a database user account that will be used as a proxy user account
- The `DV_ACCTMGR` role if Oracle Database Vault is enabled, to create the proxy user account
- The ability to grant the `CREATE SESSION` system privilege to the proxy user account
- The `ALTER USER` system privilege to enable existing user accounts to connect to the database through the proxy account

Follow these guidelines when you create proxy user accounts:

- For better security and to adhere to the principle of least privilege, only grant the proxy user account the `CREATE SESSION` privilege. Do not grant this user any other privileges. The proxy user account is designed to only enable another user to connect using the proxy account. Any privileges that must be exercised during the connection should belong to the connecting user, not to the proxy account.
- As with all passwords, ensure that the password you create for the proxy user is strong and not easily guessed. Remember that multiple users will be connecting as the proxy user, so it is especially important that this password be strong. See "Guidelines for Securing Passwords" on page 10-7 for advice about creating strong passwords.
- Consider using the Advanced Security option network connection features, to prevent network eavesdropping.
- For further fine-tuning of the amount of control that the connecting user has, consider restricting the roles used by the connecting user when he or she is connected through the proxy account. The `ALTER USER` statement enables you to configure the user to connect using specified roles, any role except a specified role, or with no roles at all.

Creating Proxy User Accounts and Authorizing Users to Connect Through Them

The `CREATE USER` statement enables you to create the following types of user accounts, all of which can be used as proxy accounts:

- Database user accounts, which are authenticated by passwords
- External user accounts, which are authenticated by external sources, such as Secure Socket Layer (SSL) or Kerberos
- Global user accounts, which are authenticated by an enterprise directory service (Oracle Internet Directory).

To create a proxy user account and authorize users to connect through it:

1. Use the CREATE USER statement to create the proxy user account.

   For example:

   ```
   CREATE USER appuser IDENTIFIED BY password;
   ```

2. Use the GRANT CONNECT THROUGH clause of the ALTER USER statement to enable an existing user to connect through the proxy user account.

   For example:

   ```
   ALTER USER preston GRANT CONNECT THROUGH appuser;
   ```

   Suppose user preston has a large number of roles, but you only want her to use one role (for example, the appuser_role) when she is connected to the database through the appuser proxy account. You can use the following ALTER USER statement:

   ```
   ALTER USER preston GRANT CONNECT THROUGH appuser WITH ROLE appuser_role;
   ```

   Any other roles that user preston will not be available to her as long as she is connecting as the appuser proxy.

After you complete these steps, user preston can connect using the appuser proxy user as follows:

```
CONNECT appuser[preston]
Enter password: appuser_password
```

Note the following:

- **The proxy user can only perform activities that user preston has privileges to perform.** Remember that the proxy user itself, appuser, only has the minimum privileges (CREATE SESSION).
- **Using roles with middle-tier clients.** You can also specify roles that the middle tier is permitted to activate when connecting as the client. Operations performed on behalf of a client by a middle-tier server can be audited.
- **Finding proxy users.** To find the users who are currently authorized to connect through a middle tier, query the PROXY_USERS data dictionary view, for example:

  ```
  SELECT * FROM PROXY_USERS;
  ```

- **Removing proxy connections.** Use the REVOKE CONNECT THROUGH clause of ALTER USER to disallow a proxy connection. For example, to revoke user preston from connecting through the proxy user appuser, enter the following statement:

  ```
  ALTER USER preston REVOKE CONNECT THROUGH appuser
  ```

- **Password expiration and proxy connections.** Middle-tier use of password expiration does not apply to accounts that are authenticated through a proxy. Instead, lock the account rather than expire the password.

See Also:

- *Oracle Database SQL Language Reference* for detailed information about the `CREATE USER` statement
- *Oracle Database SQL Language Reference* for detailed information about the `ALTER USER` statement
- *Oracle Database Enterprise User Security Administrator's Guide* for information about managing proxy users in an enterprise user environment
- *Oracle Database Advanced Security Administrator's Guide* for more information about using network encryption and strong authentication
- "Auditing SQL Statements and Privileges in a Multitier Environment" on page 9-27 for details about auditing operations done on behalf of a user by a middle tier

Using Proxy Authentication with the Secure External Password Store

If you are concerned about the password used in proxy authentication being obtained by a malicious user, then you can use the secure external password store with the proxy authentication to store the password credentials in a wallet. Connecting to Oracle Database using proxy authentication and the secure external password store is ideal for situations such as running batch files. When a proxy user connects to the database and authenticates using a secure external password, the password is not exposed in the event that a malicious user tries to obtain the password.

To use proxy authentication with the secure external password store:

1. Configure the proxy authentication account, as shown in the procedure under "Creating Proxy User Accounts and Authorizing Users to Connect Through Them" on page 3-38.
2. Configure the secure external password store. See "Configuring Clients to Use the External Password Store" on page 3-18 for more information.

Afterward, the user can connect using the proxy but without having to specify a password. For example:

```
sqlplus [preston]/@db_alias
```

When you use the secure external password store, the user logging in does not need to supply the user name and password. Only the `SERVICE_NAME` value (that is, `db_alias`) from the `tnsnames.ora` file must be specified.

Passing Through the Identity of the Real User by Using Proxy Authentication

For enterprise users or database users, Oracle Call Interface, JDBC/OCI, or Thin driver enables a middle tier to set up several user sessions within a single database connection, each of which uniquely identifies a connected user (connection pooling). These sessions reduce the network overhead of creating separate network connections from the middle tier to the database.

If you want to authenticate from clients through a middle tier to the database, the full authentication sequence from the client to the middle tier to the database occurs as follows:

1. The client authenticates to the middle tier, using whatever form of authentication the middle tier will accept. For example, the client could authenticate to the

middle tier by using a user name and password or an X.509 certificate by means of SSL.

2. The middle tier authenticates itself to the database by using whatever form of authentication the database accepts. This could be a password or an authentication mechanism supported by Oracle Advanced Security, such as a **Kerberos ticket** or an X.509 certificate (SSL).
3. The middle tier then creates one or more sessions for users using OCI, JDBC/OCI, or Thin driver.
   - If the user is a database user, then the session must, as a minimum, include the database user name. If the database requires it, then the session can include a password (which the database verifies against the password store in the database). The session can also include a list of database roles for the user.
   - If the user is an enterprise user, then the session may provide different information depending on how the user is authenticated.

     Example 1: If the user authenticates to the middle tier using SSL, then the middle tier can provide the DN from the X.509 certificate of the user, or the certificate itself in the session. The database uses the DN to look up the user in Oracle Internet Directory.

     Example 2: If the user is a password-authenticated enterprise user, then the middle tier must provide, as a minimum, a globally unique name for the user. The database uses this name to look up the user in Oracle Internet Directory. If the session also provides a password for the user, then the database will verify the password against Oracle Internet Directory. User roles are automatically retrieved from Oracle Internet Directory after the session is established.
   - The middle tier may optionally provide a list of database roles for the client. These roles are enabled if the proxy is authorized to use the roles on behalf of the client.
4. The database verifies that the middle tier has the privilege to create sessions on behalf of the user.

   The `OCISessionBegin` call fails if the application server cannot perform a proxy authentication on behalf of the client by the administrator, or if the application server is not allowed to activate the specified roles.

Limiting the Privilege of the Middle Tier

Least privilege is the principle that users should have the fewest privileges necessary to perform their duties and no more. As applied to middle tier applications, this means that the middle tier should not have more privileges than it needs. Oracle Database enables you to limit the middle tier such that it can connect only on behalf of certain database users, using only specific database roles. You can limit the privilege of the middle tier to connect on behalf of an enterprise user, stored in an LDAP directory, by granting to the middle tier the privilege to connect as the mapped database user. For instance, if the enterprise user is mapped to the `APPUSER` schema, then you must at least grant to the middle tier the ability to connect on behalf of `APPUSER`. Otherwise, attempts to create a session for the enterprise user will fail.

However, you cannot limit the ability of the middle tier to connect on behalf of enterprise users. For example, suppose that user Sarah wants to connect to the database through a middle tier, `appsrv` (which is also a database user). Sarah has multiple roles, but it is desirable to restrict the middle tier to use only the `clerk` role on her behalf.

An administrator could effectively grant permission for appsrv to initiate connections on behalf of Sarah using her clerk role only, using the following syntax:

```
ALTER USER sarah GRANT CONNECT THROUGH appsrv WITH ROLE clerk;
```

By default, the middle tier cannot create connections for any client. The permission must be granted for each user.

To allow appsrv to use all of the roles granted to the client Sarah, the following statement would be used:

```
ALTER USER sarah GRANT CONNECT THROUGH appsrv;
```

Each time a middle tier initiates an OCI, JDBC/OCI, or Thin driver session for another database user, the database verifies that the middle tier is authorized to connect for that user by using the role specified.

Note: Instead of using default roles, create your own roles and assign only necessary privileges to them. Creating your own roles enables you to control the privileges granted by them and protects you if Oracle Database changes or removes default roles. For example, the CONNECT role now has only the CREATE SESSION privilege, the one most directly needed when connecting to a database.

However, CONNECT formerly provided several additional privileges, often not needed or appropriate for most users. Extra privileges can endanger the security of your database and applications. These have now been removed from CONNECT.

See Chapter 4, "Configuring Privilege and Role Authorization" for more information about roles.

Authorizing a Middle Tier to Proxy and Authenticate a User

The following statement authorizes the middle-tier server appserve to connect as user bill. It uses the WITH ROLE clause to specify that appserve activate all roles associated with bill, except payroll.

```
ALTER USER bill
    GRANT CONNECT THROUGH appserve
    WITH ROLE ALL EXCEPT payroll;
```

To revoke the middle-tier server (appserve) authorization to connect as user bill, the following statement is used:

```
ALTER USER bill REVOKE CONNECT THROUGH appserve;
```

Authorizing a Middle Tier to Proxy a User Authenticated by Other Means

Use the AUTHENTICATION REQURED clause of the ALTER USER ... GRANT CONNECT THROUGH statement to authorize a user to be proxied, but not authenticated, by a middle tier. Currently, PASSWORD is the only means supported.

The following statement illustrates this form of authentication:

```
ALTER USER mary
    GRANT CONNECT THROUGH midtier
    AUTHENTICATION REQUIRED;
```

In the preceding statement, middle-tier server midtier is authorized to connect as user mary, and midtier must also pass the user password to the database server for authorization.

Reauthenticating the User Through the Middle Tier to the Database

Administrators can specify that authentication is required by using the AUTHENTICATION REQUIRED proxy clause with the ALTER USER SQL statement. In this case, the middle tier must provide user authentication credentials.

For example, suppose that user Sarah wants to connect to the database through a middle tier, appsrv. An administrator could require that appsrv provides authentication credentials for Sarah by using the following syntax:

```
ALTER USER sarah GRANT CONNECT THROUGH appsrv AUTHENTICATION REQUIRED;
```

The AUTHENTICATION REQUIRED clause ensures that authentication credentials for the user must be presented when the user is authenticated through the specified proxy.

> **Note:** For backward compatibility, if you use the AUTHENTICATED USING PASSWORD proxy clause, then Oracle Database transforms it to AUTHENTICATION REQUIRED.

Using Password-Based Proxy Authentication When you use password-based proxy authentication, Oracle Database passes the password of the client to the middle-tier server. The middle-tier server then passes the password as an attribute to the data server for verification. The main advantage to this is that the client computer does not have to have Oracle software installed on it to perform database operations.

To pass the password of the client, the middle-tier server calls the OCIAttrSet() function as follows, passing OCI_ATTR_PASSWORD as the type of the attribute being set.

```
OCIAttrSet(
  session_handle,    /* Pointer to a handle whose attribute gets modified. */
  OCI_HTYPE_SESSION, /* Handle type: OCI user session handle. */
  password_ptr,      /* Pointer to the value of the password attribute. */
  0,                 /* The size of the password attribute value is already
                        known by the OCI library. */
  OCI_ATTR_PASSWORD, /* The attribute type. */
  error_handle);     /* An error handle used to retrieve diagnostic
                        information in the event of an error. */
```

Using Proxy Authentication with Enterprise Users If the middle tier connects to the database as a client who is an enterprise user, then either the distinguished name, or the X.509 certificate containing the distinguished name is passed over instead of the database user name. If the user is a password-authenticated enterprise user, then the middle tier must provide, as a minimum, a globally unique name for the user. The database uses this name to look up the user in Oracle Internet Directory.

To pass over the distinguished name of the client, the application server would call the Oracle Call Interface method OCIAttrSet() with OCI_ATTR_DISTINGUISHED_NAME as the attribute type, as follows:

```
OCIAttrSet(session_handle,
           OCI_HTYPE_SESSION,
           distinguished_name,
           0,
           OCI_ATTR_DISTINGUISHED_NAME,
           error_handle);
```

To pass over the entire certificate, the middle tier would call `OCIAttrSet()` with `OCI_ATTR_CERTIFICATE` as the attribute type, as follows.

```
OCIAttrSet(session_handle,
           OCI_HTYPE_SESSION,
           certificate,
           certificate_length,
           OCI_ATTR_CERTIFICATE,
           error_handle);
```

If the type is not specified, then the database uses its default certificate type of X.509.

Note:

- `OCI_ATTR_CERTIFICATE` is Distinguished Encoding Rules (DER) encoded.
- Certificate based proxy authentication using `OCI_ATTR_CERTIFICATE` will not be supported in future Oracle Database releases. Use the `OCI_ATTR_DISTINGUISHED_NAME` or `OCI_ATTR_USERNAME` attribute instead

If you are using proxy authentication for password-authenticated enterprise users, then use the same OCI attributes as for database users authenticated by password (`OCI_ATTR_USERNAME`). Oracle Database first checks the user name against the database. If it finds no user, then the database checks the user name in the directory. This user name must be globally unique.

Using Client Identifiers to Identify Application Users Not Known to the Database

The following sections explain how to use client identifiers:

- About Client Identifiers
- How Client Identifiers Work in Middle Tier Systems
- Using the CLIENT_IDENTIFIER Attribute to Preserve User Identity
- Using CLIENT_IDENTIFIER Independent of Global Application Context
- Using the DBMS_SESSION PL/SQL Package to Set and Clear the Client Identifier

About Client Identifiers

Oracle Database provides the `CLIENT_IDENTIFIER` attribute of the built-in `USERENV` application context namespace for application users. These users are known to an application but unknown to the database. The `CLIENT_IDENTIFIER` attribute can capture any value that the application uses for identification or access control, and passes it to the database. The `CLIENT_IDENTIFIER` attribute is supported in OCI, JDBC/OCI, or Thin driver.

How Client Identifiers Work in Middle Tier Systems

Many applications use session pooling to set up several sessions to be reused by multiple application users. Users authenticate themselves to a middle-tier application, which uses a single identity to log in to the database and maintains all the user connections. In this model, application users are users who are authenticated to the middle tier of an application, but who are not known to the database. You can use a

CLIENT_IDENTIFIER attribute, which acts like an application user proxy for these types of applications.

In this model, the middle tier passes a client identifier to the database upon the session establishment. The client identifier could actually be anything that represents a client connecting to the middle tier, for example, a cookie or an IP address. The client identifier, representing the application user, is available in user session information and can also be accessed with an application context (by using the USERENV naming context). In this way, applications can set up and reuse sessions, while still being able to keep track of the *application user* in the session. Applications can reset the client identifier and thus reuse the session for a different user, enabling high performance.

Using the CLIENT_IDENTIFIER Attribute to Preserve User Identity

You can use the CLIENT_IDENTIFIER predefined attribute of the built-in application context namespace, USERENV, to capture the application user name for use with global application context. You also can use the CLIENT_IDENTIFIER attribute independently. When you use the CLIENT_IDENTIFIER attribute independently from a global application context, you can set CLIENT_IDENTIFIER with the DBMS_SESSION interface. The ability to pass a CLIENT_IDENTIFIER to the database is supported in Oracle Call Interface (OCI), JDBC/OCI, or Thin driver.

When you use the CLIENT_IDENTIFIER attribute with global application context, it provides flexibility and high performance for building applications. For example, suppose a Web-based application that provides information to business partners has three types of users: gold partner, silver partner, and bronze partner, representing different levels of information available. Instead of each user having his or her own session set up with individual application contexts, the application could set up global application contexts for gold partners, silver partners, and bronze partners. Then, use the CLIENT_IDENTIFIER to point the session at the correct context to retrieve the appropriate type of data. The application need only initialize the three global contexts once and use the CLIENT_IDENTIFIER to access the correct application context to limit data access. This provides performance benefits through session reuse and through accessing global application contexts set up once, instead of having to initialize application contexts for each session individually.

See Also:

- "Using Global Application Contexts" on page 6-22 for how to implement global application contexts
- "Tutorial: Creating a Global Application Context That Uses a Client Session ID" on page 6-35

Using CLIENT_IDENTIFIER Independent of Global Application Context

Using the CLIENT_IDENTIFIER attribute is especially useful for those applications in which the users are unknown to the database. In these situations, the application typically connects as a single database user and all actions are taken as that user. Because all user sessions are created as the same user, this security model makes it difficult to achieve data separation for each user. These applications can use the CLIENT_IDENTIFIER attribute to preserve the real application user identity through to the database.

With this approach, sessions can be reused by multiple users by changing the value of the CLIENT_IDENTIFIER attribute, which captures the name of the real application user. This avoids the overhead of setting up a separate session and separate attributes for each user, and enables reuse of sessions by the application. When the CLIENT_

IDENTIFIER attribute value changes, the change is added to the next OCI, JDBC/OCI, or Thin driver call for additional performance benefits.

For example, the user Daniel connects to a Web Expense application. Daniel is not a database user; he is a typical Web Expense application user. The application accesses the built-in application context namespace and sets DANIEL as the CLIENT_IDENTIFIER attribute value. Daniel completes his Web Expense form and exits the application. Then, Ajit connects to the Web Expense application. Instead of setting up a new session for Ajit, the application reuses the session that currently exists for Daniel, by changing the CLIENT_IDENTIFIER to AJIT. This avoids the overhead of setting up a new connection to the database and the overhead of setting up a global application context. The CLIENT_IDENTIFIER attribute can be set to any value on which the application bases access control. It does not have to be the application user name.

To set the CLIENT_IDENTIFIER attribute with OCI, use the OCI_ATTR_CLIENT_IDENTIFIER attribute in the call to OCIAttrSet(). Then, on the next request to the server, the information is propagated and stored in the server sessions. For example:

```
OCIAttrSet (session,
OCI_HTYPE_SESSION,
(dvoid *) "appuser1",
(ub4)strlen("appuser1"),
OCI_ATTR_CLIENT_IDENTIFIER,
*error_handle);
```

For applications that use JDBC, be aware that JDBC does not set the client identifier. To set the client identifier in a connection pooling environment, use Dynamic Monitoring Service (DMS) metrics. If DMS is not available, then use the connection.setClientInfo method. For example:

```
connection.setClientInfo("E2E_CONTEXT.CLIENT_IDENTIFIER", "appuser");
```

See Also:

- *Oracle Call Interface Programmer's Guide* about how the OCI_ATTR_CLIENT_IDENTIFIER user session handle attribute is used in middle-tier applications
- *Oracle Database JDBC Developer's Guide* for more information about configuring client connections using JDBC

Using the DBMS_SESSION PL/SQL Package to Set and Clear the Client Identifier

To use the DBMS_SESSION package to set and clear the CLIENT_IDENTIFIER value on the middle tier, use the following interfaces:

- SET_IDENTIFIER
- CLEAR_IDENTIFIER

The middle tier uses SET_IDENTIFIER to associate the database session with a particular user or group. Then, the CLIENT_IDENTIFIER is an attribute of the session and can be viewed in session information.

If you plan to use the DBMS_SESSION.SET_IDENTIFIER procedure, be aware that the DBMS_APPLICATION_INFO.SET_CLIENT_INFO procedure can overwrite the value of the client identifier. Typically, these values should be the same, so if SET_CLIENT_INFO is set, its value can be automatically propagated to the value set by SET_IDENTIFIER if the CLIENTID_OVERWRITE event is set to ON.

To check the status of the CLIENTID_OVERWRITE event, log in to SQL*Plus and then enter the SHOW PARAMETER command. For example, assuming that CLIENTID_OVERWRITE is enabled:

```
SHOW PARAMETER EVENT

NAME                                 TYPE        VALUE
------------------------------------ ----------- ------------------
event                                string      clientid_overwrite
```

To enable the CLIENTID_OVERWRITE event system-wide, connect to SQL*Plus as SYS using the SYSDBA privilege, and then enter the following ALTER SYSTEM statement:

```
ALTER SYSTEM SET EVENTS 'CLIENTID_OVERWRITE';
```

Or, enter the following line in your init.ora file:

```
event="clientid_overwrite"
```

Then restart the database. To disable the CLIENTID_OVERWRITE event, log in to SQL*Plus as SYS with the SYSDBA privilege, and then run the following ALTER SYSTEM statement:

```
ALTER SYSTEM SET EVENTS 'CLIENTID_OVERWRITE OFF';
```

If you prefer to change the CLIENTID_OVERWRITE value for the session only, then use the ALTER SESSION statement.

Afterwards, if you set the client identifier using the DBMS_APPLICATION_INFO.SET_CLIENT_INFO procedure, you must then run DBMS_SESSION.SET_IDENTIFIER so that the client identifier settings are the same.

See Also:

- "Using Global Application Contexts" on page 6-22 for information about using client identifiers in a global application context
- *Oracle Database PL/SQL Packages and Types Reference* for more information about the DBMS_SESSION package

Finding Information About User Authentication

Table 3–3 lists data dictionary views that contain information about user authentication. For detailed information about these views, see *Oracle Database Reference*.

Table 3–3 Data Dictionary Views That Describe User Authentication

View	Description
DBA_PROFILES	Displays information about profiles, including their settings and limits.
DBA_ROLES	Displays the kind of authentication used for a database role to log in to the database, such as NONE or GLOBAL (query the AUTHENTICATION_TYPE column)

Table 3–3 (Cont.) Data Dictionary Views That Describe User Authentication

View	Description
DBA_USERS	Among other user information, displays the following: ■ The kind of authentication the user used to log in to the database, such as PASSWORD or EXTERNAL (AUTHENTICATION_TYPE column) ■ The release in which the user created his or her password (PASSWORD_VERSIONS column)
DBA_USERS_WITH_DEFPWD	Displays whether the user account password is a default password
PROXY_USERS	Displays users who are currently authorized to connect through a middle tier
V$DBLINK	Displays user accounts for existing database links (DB_LINK, OWNER_ID columns)
V$SESSION	Querying the USERNAME column displays the concurrently logged in users

4

Configuring Privilege and Role Authorization

This chapter contains:

About Privileges and Roles

Authorization includes primarily two processes:

- Permitting only certain users to access, process, or alter data.
- Applying varying limitations on user access or actions. The limitations placed on (or removed from) users can apply to objects such as schemas, tables, or rows or to resources such as time (CPU, connect, or idle times).

A user **privilege** is the right to run a particular type of SQL statement, or the right to access an object that belongs to another user, run a PL/SQL package, and so on. The types of privileges are defined by Oracle Database.

Roles are created by users (usually administrators) to group together privileges or other roles. They are a way to facilitate the granting of multiple privileges or roles to users.

This section describes the following general categories:

- **System privileges.** These privileges allow the grantee to perform standard administrator tasks in the database. Restrict them only to trusted users. "Managing System Privileges" on page 4-2 describes system privileges in detail.

- **User roles.** A **role** groups several privileges and roles, so that they can be granted to and revoked from users simultaneously. You must enable the role for a user before the user can use it. See "Managing User Roles" on page 4-6 for more information.
- **Object privileges.** Each type of object has privileges associated with it. "Managing Object Privileges" on page 4-23 describes how to manage privileges for different types of objects.

Who Should Be Granted Privileges?

You grant privileges to users so they can accomplish tasks required for their jobs. You should grant a privilege only to a user who requires that privilege to accomplish the necessary work. Excessive granting of unnecessary privileges can compromise security. For example, you never should grant `SYSDBA` or `SYSOPER` administrative privilege to users who do not perform administrative tasks.

A user can receive a privilege in two ways:

- **You can grant privileges to users explicitly.** For example, you can explicitly grant to user `psmith` the privilege to insert records into the `employees` table.
- **You can grant privileges to a role (a named group of privileges), and then grant the role to one or more users.** For example, you can grant the privileges to select, insert, update, and delete records from the `employees` table to the role named `clerk`, which in turn you can grant to users `psmith` and `robert`.

Because roles allow for easier and better management of privileges, you should usually grant privileges to roles and not to specific users.

See Also:

- "Guidelines for Securing User Accounts and Privileges" on page 10-2 for best practices to follow when granting privileges
- *Oracle Database SQL Language Reference* for the complete list of system privileges and their descriptions

Granting the SYSDBA and SYSOPER Administrative Privileges to Users

As with all powerful privileges, only grant the `SYSDBA` and `SYSOPER` administrative privileges to trusted users. However, be aware that there is a restriction for users whose names have non-ASCII characters (for example, the umlaut in the name `HÜBER`). You can grant administrative privileges to these users, but if the Oracle database instance is down, the authentication using the granted privilege is not supported if the user name has non-ASCII characters. If the database instance is up, then the authentication is supported.

Managing System Privileges

This section contains:

About System Privileges

A **system privilege** is the right to perform a particular action or to perform an action on any schema objects of a particular type. For example, the privileges to create tablespaces and to delete the rows of any table in a database are system privileges.

There are over 100 distinct system privileges. Each system privilege allows a user to perform a particular database operation or class of database operations. *Remember that system privileges are very powerful.* Only grant them when necessary to roles and trusted users of the database. You can find a complete list of system privileges and their descriptions in *Oracle Database SQL Language Reference.* To find the system privileges that have been granted to a user, you can query the DBA_SYS_PRIVS data dictionary view.

Why Is It Important to Restrict System Privileges?

Because system privileges are so powerful, by default the database is configured to prevent typical (non-administrative) users from exercising the ANY system privileges (such as UPDATE ANY TABLE) on the data dictionary. See "Guidelines for Securing User Accounts and Privileges" on page 10-2 for additional guidelines about restricting system privileges.

- Restricting System Privileges by Securing the Data Dictionary
- Allowing Access to Objects in the SYS Schema

Restricting System Privileges by Securing the Data Dictionary

To secure the data dictionary, set the O7_DICTIONARY_ACCESSIBILITY initialization parameter to FALSE, which is the default value. This feature is called the dictionary protection mechanism.

The O7_DICTIONARY_ACCESSIBILITY initialization parameter controls restrictions on system privileges when you upgrade from Oracle Database release 7 to Oracle8*i* and later releases. If the parameter is set to TRUE, then access to objects in the SYS schema is allowed (Oracle Database release 7 behavior). Because the ANY privilege applies to the data dictionary, a malicious user with ANY privilege could access or alter data dictionary tables.

To set the O7_DICTIONARY_ACCESSIBILTY initialization parameter, modify it in the init*SID*.ora file. Alternatively, you can log on to SQL*Plus as user SYS with the SYSDBA privilege and then enter an ALTER SYSTEM statement, assuming you have started the database using a server parameter file (SPFILE).

Example 4–1 shows how to set the O7_DICTIONARY_ACCESSIBILTY initialization parameter to FALSE by issuing an ALTER SYSTEM statement in SQL*Plus.

Example 4–1 Setting O7_DICTIONARY_ACCESSIBILITY to FALSE

```
ALTER SYSTEM SET O7_DICTIONARY_ACCESSIBILITY=FALSE SCOPE=SPFILE;
```

When you set O7_DICTIONARY_ACCESSIBILITY to FALSE, system privileges that enable access to objects in any schema (for example, users who have ANY privileges, such as CREATE ANY PROCEDURE) do not allow access to objects in the SYS schema. This means that access to the objects in the SYS schema (data dictionary objects) is restricted to users who connect using the SYSDBA privilege. Remember that the SYS user must log in with either the SYSDBA or SYSOPER privilege; otherwise, an ORA-28009: connection as SYS should be as SYSDBA or SYSOPER error is raised. If you set O7_DICTIONARY_ACCESSIBILITY to TRUE, then you would be able to log in to the database as user SYS without having to specify the SYSDBA or SYSOPER privilege.

System privileges that provide access to objects in other schemas do *not* give other users access to objects in the SYS schema. For example, the SELECT ANY TABLE privilege allows users to access views and tables in other schemas, but does not enable them to select dictionary objects (base tables of dynamic performance views, regular views, packages, and synonyms). You can, however, grant these users explicit object privileges to access objects in the SYS schema.

See *Oracle Database Reference* for more information about the O7_DICTIONARY_ACCESSIBILITY initialization parameter.

Allowing Access to Objects in the SYS Schema

Users with explicit object privileges or those who connect with administrative privileges (SYSDBA) can access objects in the SYS schema.

Table 4–1 lists roles that you can grant to users who need access to objects in the SYS schema.

Table 4–1 Roles to Allow Access to SYS Schema Objects

Role	Description
SELECT_CATALOG_ROLE	Grant this role to allow users SELECT privileges on data dictionary views.
EXECUTE_CATALOG_ROLE	Grant this role to allow users EXECUTE privileges for packages and procedures in the data dictionary.
DELETE_CATALOG_ROLE	Grant this role to allow users to delete records from the system audit tables SYS.AUD$ and SYS.FGA_LOG$.

Additionally, you can grant the SELECT ANY DICTIONARY system privilege to users who require access to tables created in the SYS schema. This system privilege allows query access to any object in the SYS schema, including tables created in that schema. It must be granted individually to each user requiring the privilege. It is not included in GRANT ALL PRIVILEGES, but it can be granted through a role.

> **Caution:** You should grant these roles and the SELECT ANY DICTIONARY system privilege with extreme care, because the integrity of your system can be compromised by their misuse.

Granting and Revoking System Privileges

You can grant or revoke system privileges to users and roles. If you grant system privileges to roles, then you can use the roles to exercise system privileges. For example, roles permit privileges to be made selectively available. Ensure that you follow the separation of duty guidelines described in "Guidelines for Securing Roles" on page 10-6.

Use either of the following methods to grant or revoke system privileges to or from users and roles:

- GRANT and REVOKE SQL statements
- Oracle Enterprise Manager Database Control

See Also:

- "Granting a User Privileges and Roles" on page 4-37
- "Revoking Privileges and Roles from a User" on page 4-41
- "When Do Grants and Revokes Take Effect?" on page 4-48
- "Finding Information About User Privileges and Roles" on page 4-71
- *Oracle Database 2 Day DBA* for more information about Database Control

Who Can Grant or Revoke System Privileges?

Only two types of users can grant system privileges to other users or revoke those privileges from them:

- Users who were granted a specific system privilege with the `ADMIN OPTION`
- Users with the system privilege `GRANT ANY PRIVILEGE`

For this reason, only grant these privileges to trusted users.

About ANY Privileges and the PUBLIC Role

System privileges that use the `ANY` keyword enable you to set privileges for an entire category of objects in the database. For example, the `CREATE ANY PROCEDURE` system privilege permits a user to create a procedure anywhere in the database. The behavior of an object created by users with the `ANY` privilege is not restricted to the schema in which it was created. For example, if user `JSMITH` has the `CREATE ANY PROCEDURE` privilege and creates a procedure in the schema `JONES`, then the procedure will run as `JONES`. However, `JONES` may not be aware that the procedure `JSMITH` created is running as him (`JONES`). If `JONES` has `DBA` privileges, letting `JSMITH` run a procedure as `JONES` could pose a security violation.

The `PUBLIC` role is a special role that every database user account automatically has when the account is created. By default, it has no privileges granted to it, but it does have numerous grants, mostly to Java objects. You cannot drop the `PUBLIC` role, and a manual grant or revoke of this role has no meaning, because the user account will always assume this role. Because all database user accounts assume the `PUBLIC` role, it does not appear in the `DBA_ROLES` and `SESSION_ROLES` data dictionary views.

You can grant privileges to the `PUBLIC` role, but remember that this makes the privileges available to every user in the Oracle database. For this reason, be careful about granting privileges to the `PUBLIC` role, particularly powerful privileges such as the `ANY` privileges and system privileges. For example, if `JSMITH` has the `CREATE PUBLIC SYNONYM` system privilege, he could redefine an interface that he knows everyone else uses, and then point to it with the `PUBLIC SYNONYM` that he created. Instead of accessing the correct interface, users would access the interface of `JSMITH`, which could possibly perform illegal activities such as stealing the login credentials of users.

These types of privileges are very powerful and could pose a security risk if given to the wrong person. Be careful about granting privileges using `ANY` or `PUBLIC`. As with all privileges, you should follow the principles of "least privilege" when granting these privileges to users.

To protect the data dictionary (the contents of the `SYS` schema) against users who have one or more of the powerful `ANY` system privileges, set the `O7_DICTIONARY_`

ACCESSIBILITY initialization parameter to FALSE. You can set this parameter by using an ALTER SYSTEM statement (see Example 4–1, "Setting O7_DICTIONARY_ACCESSIBILITY to FALSE" on page 4-3) or by modifying the init*SID*.ora file. See "Guidelines for Securing a Database Installation and Configuration" on page 10-12 for additional guidelines.

Managing User Roles

This section contains:

About User Roles

Managing and controlling privileges is easier when you use **roles**, which are named groups of related privileges that you grant as a group to users or other roles. Within a database, each role name must be unique, different from all user names and all other role names. Unlike schema objects, roles are not contained in any schema. Therefore, a user who creates a role can be dropped with no effect on the role.

This section contains:

The Functionality of Roles

Roles are useful for quickly and easily granting permissions to users. Although you can use Oracle Database-defined roles, you have more control and continuity if you create your own roles that contain only the privileges pertaining to your requirements. Oracle may change or remove the privileges in an Oracle Database-defined role, as it has with the CONNECT role, which now has only the CREATE SESSION privilege. Formerly, the CONNECT role had eight other privileges.

Roles have the following functionality:

- A role can be granted system or object privileges.
- Any role can be granted to any database user.

- Each role granted to a user is, at a given time, either enabled or disabled. A user's security domain includes the privileges of all roles currently enabled for the user and excludes the privileges of any roles currently disabled for the user. Oracle Database allows database applications and users to enable and disable roles to provide selective availability of privileges.
- A role can be granted to other roles. However, a role cannot be granted to itself and cannot be granted circularly. For example, role `role1` cannot be granted to role `role2` if role `role2` has previously been granted to role `role1`.
- If a role is not password authenticated or a secure application role, then you can grant the role indirectly to the user. An indirectly granted role is a role granted to the user through another role that has already been granted to this user. For example, suppose you grant user `psmith` the `role1` role. Then you grant the `role2` and `role3` roles to the `role1` role. Roles `role2` and `role3` are now under `role1`. This means `psmith` has been indirectly granted the roles `role2` and `role3`, in addition to the direct grant of `role1`. Enabling the direct `role1` for `psmith` enables the indirect roles `role2` and `role3` for this user as well.
- Optionally, you can make a directly granted role a default role. You enable or disable the default role status of a directly granted role by using the `DEFAULT ROLE` clause of the `ALTER USER` statement. Ensure that the `DEFAULT ROLE` clause refers only to roles that have been directly granted to the user. To find the directly granted roles for a user, query the `DBA_ROLE_PRIVS` data dictionary view. This view does not include the user's indirectly granted roles. To find roles that are granted to other roles, query the `ROLE_ROLE_PRIVS` view.
- If the role is password authenticated or a secure application role, then you cannot grant it indirectly to the user, nor can you make it a default role. You only can grant this type of role directly to the user. Typically, you enable password authenticated or secure application roles by using the `SET ROLE` statement.

Properties of Roles and Why They Are Advantageous

Table 4–2 describes the properties of roles that enable easier privilege management within a database.

Table 4–2 Properties of Roles and Their Description

Property	Description
Reduced privilege administration	Rather than granting the same set of privileges explicitly to several users, you can grant the privileges for a group of related users to a role, and then only the role must be granted to each member of the group.
Dynamic privilege management	If the privileges of a group must change, then only the privileges of the role need to be modified. The security domains of all users granted the group's role automatically reflect the changes made to the role.
Selective availability of privileges	You can selectively enable or disable the roles granted to a user. This allows specific control of a user's privileges in any given situation.
Application awareness	The data dictionary records which roles exist, so you can design applications to query the dictionary and automatically enable (or disable) selective roles when a user attempts to execute the application by way of a given user name.

Table 4–2 (Cont.) Properties of Roles and Their Description

Property	Description
Application-specific security	You can protect role use with a password. Applications can be created specifically to enable a role when supplied the correct password. Users cannot enable the role if they do not know the password.

Database administrators often create roles for a database application. You should grant a secure application role all privileges necessary to run the application. You then can grant the secure application role to other roles or users. An application can have several different roles, each granted a different set of privileges that allow for more or less data access while using the application.

The DBA can create a role with a password to prevent unauthorized use of the privileges granted to the role. Typically, an application is designed so that when it starts, it enables the proper role. As a result, an application user does not need to know the password for an application role.

> **See Also:** "How Roles Aid or Restrict DDL Usage" on page 4-9 for information about restrictions for procedures

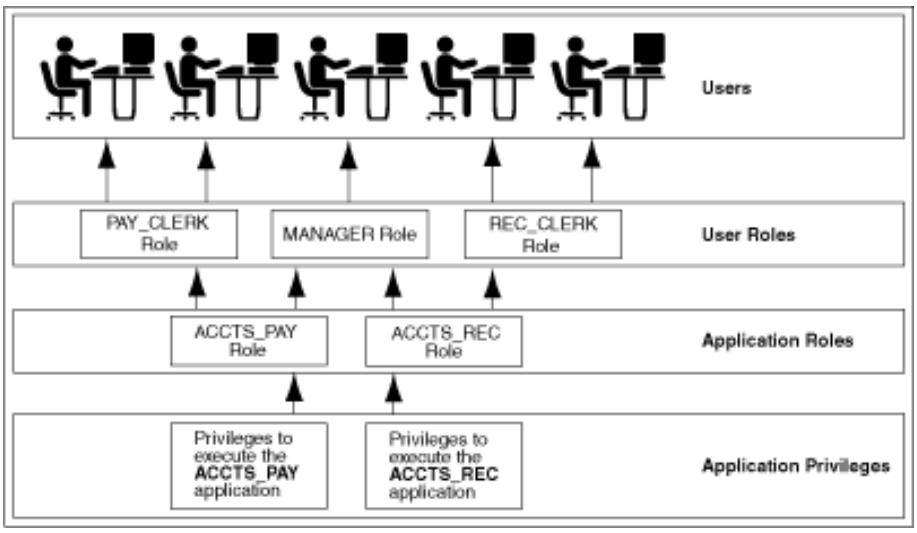
Common Uses of Roles

In general, you create a role to serve one of two purposes:

- To manage the privileges for a database application (see "Common Uses of Application Roles" on page 4-8)
- To manage the privileges for a user group (see "Common Uses of User Roles" on page 4-9)

Figure 4–1 and the sections that follow describe the two uses of roles.

Figure 4–1 Common Uses for Roles



Common Uses of Application Roles Grant an application role all privileges necessary to run a given database application. Then, grant the secure application role to other roles or to specific users. An application can have several different roles, with each role assigned a different set of privileges that allow for more or less data access while using the application.

Common Uses of User Roles Create a user role for a group of database users with common privilege requirements. You can manage user privileges by granting secure application roles and privileges to the user role and then granting the user role to appropriate users.

How Roles Affect the Scope of a User's Privileges

Each role and user has its own unique security domain. The security domain of a role includes the privileges granted to the role plus those privileges granted to any roles that are granted to the role.

The security domain of a user includes privileges on all schema objects in the corresponding schema, the privileges granted to the user, and the privileges of roles granted to the user that are **currently enabled**. (A role can be simultaneously enabled for one user and disabled for another.) This domain also includes the privileges and roles granted to the role `PUBLIC`. The `PUBLIC` role represents all users in the database.

How Roles Work in PL/SQL Blocks

The use of roles in a PL/SQL block depends on whether it is an anonymous block or a named block (stored procedure, function, or trigger), and whether it executes with definer's rights or invoker's rights.

Roles Used in Named Blocks with Definer's Rights All roles are disabled in any named PL/SQL block (stored procedure, function, or trigger) that executes with definer's rights. Roles are not used for privilege checking and you cannot set roles within a definer's rights procedure.

The `SESSION_ROLES` view shows all roles that are currently enabled. If a named PL/SQL block that executes with definer's rights queries `SESSION_ROLES`, then the query does not return any rows.

> **See Also:** *Oracle Database Reference*

Roles Used in Named Blocks with Invoker's Rights and Anonymous PL/SQL Blocks Named PL/SQL blocks that execute with invoker's rights and anonymous PL/SQL blocks are executed based on privileges granted through enabled roles. Current roles are used for privilege checking within an invoker's rights PL/SQL block. You can use dynamic SQL to set a role in the session.

> **See Also:**
>
> - *Oracle Database PL/SQL Language Reference* for an explanation of how invoker's and definer's rights can be used for name resolution and privilege checking
> - *Oracle Database PL/SQL Language Reference* for information about dynamic SQL in PL/SQL

How Roles Aid or Restrict DDL Usage

A user requires one or more privileges to successfully execute a DDL statement, depending on the statement. For example, to create a table, the user must have the `CREATE TABLE` or `CREATE ANY TABLE` system privilege. To create a view of a table that belongs to another user, the creator requires the `CREATE VIEW` or `CREATE ANY VIEW` system privilege and either the `SELECT` *`object`* privilege for the table or the `SELECT ANY TABLE` system privilege.

Oracle Database avoids the dependencies on privileges received by way of roles by restricting the use of specific privileges in certain DDL statements. The following rules describe these privilege restrictions concerning DDL statements:

- All system privileges and object privileges that permit a user to perform a DDL operation are usable when received through a role. For example:
  - **System privileges:** `CREATE TABLE`, `CREATE VIEW`, and `CREATE PROCEDURE` privileges
  - **Object privileges:** `ALTER` and `INDEX` privileges for a table

    You cannot use the `REFERENCES` object privilege for a table to define the foreign key of a table if the privilege is received through a role.
- All system privileges and object privileges that allow a user to perform a DML operation that is required to issue a DDL statement are *not* usable when received through a role. The security domain does not contain roles when a `CREATE VIEW` statement is used. For example, a user who is granted the `SELECT ANY TABLE` system privilege or the `SELECT` *`object`* privilege for a table through a role cannot use either of these privileges to create a view on a table that belongs to another user. This is because views are definer's rights objects, so when creating them you cannot use any privileges (neither system privileges or object privileges) granted to you through a role. If the privilege is granted directly to you, then you can use the privilege. However, if the privilege is revoked at a later time, then the view definition becomes invalid ("contains errors") and must recompiled before it can be used again.

The following example further clarifies the permitted and restricted uses of privileges received through roles.

Assume that a user is:

- Granted a role that has the `CREATE VIEW` system privilege
- Directly granted a role that has the `SELECT` *`object`* privilege for the `employees` table
- Directly granted the `SELECT` *`object`* privilege for the `departments` table

Given these directly and indirectly granted privileges:

- The user can issue `SELECT` statements on both the `employees` and `departments` tables.
- Although the user has both the `CREATE VIEW` and `SELECT` privilege for the `employees` table through a role, the user cannot create a view on the `employees` table, because the `SELECT` *`object`* privilege for the `employees` table was granted through a role.
- The user can create a view on the `departments` table, because the user has the `CREATE VIEW` privilege through a role and the `SELECT` privilege for the `departments` table directly.

How Operating Systems Can Aid Roles

In some environments, you can administer database security using the operating system. The operating system can be used to grant and revoke database roles and to manage their password authentication. This capability is not available on all operating systems.

See Also: Your operating system-specific Oracle Database documentation for details about managing roles through the operating system

How Roles Work in a Distributed Environment

When you use roles in a distributed database environment, ensure that all needed roles are set as the default roles for a distributed (remote) session. These roles cannot be enabled when the user connects to a remote database from within a local database session. For example, the user cannot execute a remote procedure that attempts to enable a role at the remote site.

See Also: *Oracle Database Heterogeneous Connectivity User's Guide*

Predefined Roles in an Oracle Database Installation

Oracle Database provides a set of predefined roles to help in database administration. These roles, listed in Table 4–3, are automatically defined for Oracle databases when you run the standard scripts that are part of database creation. If you install other options or products, then other predefined roles may be created.

Table 4–3 Oracle Database Predefined Roles

Predefined Role	Description
ADM_PARALLEL_EXECUTE_TASK	Provides privileges to update table data in parallel by using the DBMS_PARALLEL_EXECUTE PL/SQL package. **See Also:** *Oracle Database PL/SQL Packages and Types Reference* for more information about the DBMS_PARALLEL_EXECUTE PL/SQL package.
AQ_ADMINISTRATOR_ROLE	Provides privileges to administer Advanced Queuing. Includes ENQUEUE ANY QUEUE, DEQUEUE ANY QUEUE, and MANAGE ANY QUEUE, SELECT privileges on Advanced Queuing tables and EXECUTE privileges on Advanced Queuing packages.
AQ_USER_ROLE	Obsolete, but kept mainly for release 8.0 compatibility. Provides EXECUTE privileges on the DBMS_AQ and DBMS_AQIN packages.
AUTHENTICATEDUSER	Used by the XDB protocols to define any user who has logged in to the system.
CAPI_USER_ROLE	Provides access to packages used for implementing Information Lifecycle Management (ILM) and hierarchical storage and other applications. **See Also:** *Oracle Database SecureFiles and Large Objects Developer's Guide*
CONNECT	Provides the CREATE SESSION system privilege. This role is provided for compatibility with previous releases of Oracle Database. You can determine the privileges encompassed by this role by querying the DBA_SYS_PRIVS data dictionary view. **Note:** Oracle recommends that you design your own roles for database security rather than relying on this role. This role may not be created automatically by future releases of Oracle Database. **See Also:** *Oracle Database Reference* for a description of the DBA_SYS_PRIVS view
CSW_USR_ROLE	Provides user privileges to manage the Catalog Services for the Web (CSW) component of Oracle Spatial. **See Also:** *Oracle Spatial Developer's Guide* for more information

Table 4–3 (Cont.) Oracle Database Predefined Roles

Predefined Role	Description
CTXAPP	Provides privileges to create Oracle Text indexes and index preferences, and to use PL/SQL packages. This role should be granted to Oracle Text users. **See Also:** *Oracle Text Application Developer's Guide* for more information
CWM_USER	Provides privileges to manage Common Warehouse Metadata (CWM), which is a repository standard used by Oracle data warehousing and decision support. **See Also:** *Oracle Database Data Warehousing Guide* for more information
DATAPUMP_EXP_FULL_DATABASE	Provides privileges to export data from an Oracle database using Oracle Data Pump. **Caution:** This is a very powerful role because it provides a user access to any data in any schema in the database. Use caution when granting this role to users. **See Also:** *Oracle Database Utilities* for more information
DATAPUMP_IMP_FULL_DATABASE	Provides privileges to import data into an Oracle database using Oracle Data Pump. **Caution:** This is a very powerful role because it provides a user access to any data in any schema in the database. Use caution when granting this role to users. **See Also:** *Oracle Database Utilities* for more information
DBA	Provides all system privileges that were created with the ADMIN option. This role is provided for compatibility with previous releases of Oracle Database. You can determine the privileges encompassed by this role by querying the DBA_SYS_PRIVS data dictionary view. **Note:** Oracle recommends that you design your own roles for database security rather than relying on this role. This role may not be created automatically by future releases of Oracle Database. **See Also:** *Oracle Database Reference* for a description of the DBA_SYS_PRIVS view
DBFS_ROLE	Provides access to the DBFS (the Database Filesystem) packages and objects. **See Also:** *Oracle Database SecureFiles and Large Objects Developer's Guide*
DELETE_CATALOG_ROLE	Provides the DELETE privilege on the system audit table (AUD$).
EJBCLIENT	Provides privileges to connect to EJBs from a Java stored procedure.
EXECUTE_CATALOG_ROLE	Provides EXECUTE privileges on objects in the data dictionary.
EXP_FULL_DATABASE	Provides the privileges required to perform full and incremental database exports using the Export utility (later replaced with Oracle Data Pump). It includes these privileges: SELECT ANY TABLE, BACKUP ANY TABLE, EXECUTE ANY PROCEDURE, EXECUTE ANY TYPE, ADMINISTER RESOURCE MANAGER, and INSERT, DELETE, and UPDATE on the tables SYS.INCVID, SYS.INCFIL, and SYS.INCEXP. Also the following roles: EXECUTE_CATALOG_ROLE and SELECT_CATALOG_ROLE. This role is provided for convenience in using the export and import utilities. **Caution:** This is a very powerful role because it provides a user access to any data in any schema in the database. Use caution when granting this role to users. **See Also:** *Oracle Database Utilities* for more information

Table 4–3 (Cont.) Oracle Database Predefined Roles

Predefined Role	Description
GATHER_SYSTEM_STATISTICS	Provides privileges to update system statistics, which are collected using the DBMS_STATS.GATHER_SYSTEM_STATISTICS procedure **See Also:** *Oracle Database Performance Tuning Guide* for more information about managing optimizer statistics
GLOBAL_AQ_USER_ROLE	Provides privileges to establish a connection to an LDAP server, for use with Oracle Streams AQ. **See Also:** *Oracle Streams Advanced Queuing User's Guide* for more information
HS_ADMIN_EXECUTE_ROLE	Provides the EXECUTE privilege for users who want to use the Heterogeneous Services (HS) PL/SQL packages. **See Also:** *Oracle Database Heterogeneous Connectivity User's Guide* for more information
HS_ADMIN_ROLE	Provides privileges to both use the Heterogeneous Services (HS) PL/SQL packages and query the HS-related data dictionary views. **See Also:** *Oracle Database Heterogeneous Connectivity User's Guide* for more information
HS_ADMIN_SELECT_ROLE	Provides privileges to query the Heterogeneous Services data dictionary views. **See Also:** *Oracle Database Heterogeneous Connectivity User's Guide* for more information
IMP_FULL_DATABASE	Provides the privileges required to perform full database imports using the Import utility (later replaced with Oracle Data Pump). Includes an extensive list of system privileges (use view DBA_SYS_PRIVS to view privileges) and the following roles: EXECUTE_CATALOG_ROLE and SELECT_CATALOG_ROLE. This role is provided for convenience in using the export and import utilities. **Caution:** This is a very powerful role because it provides a user access to any data in any schema in the database. Use caution when granting this role to users.s. **See Also:** *Oracle Database Utilities* for more information
JAVADEBUGPRIV	Provides privileges to run the Oracle Database Java applications debugger. **See Also:** *Oracle Database Java Developer's Guide* for more information about managing security for Oracle Java applications
JAVAIDPRIV	Deprecated for this release.
JAVASYSPRIV	Provides major permissions to use Java2, including updating Oracle JVM-protected packages. **See Also:** *Oracle Database Java Developer's Guide* for more information about managing security for Oracle Java applications
JAVAUSERPRIV	Provides limited permissions to use Java2. **See Also:** *Oracle Database Java Developer's Guide* for more information about managing security for Oracle Java applications
JAVA_ADMIN	Provides administrative permissions to update policy tables for Oracle Database Java applications. **See Also:** *Oracle Database Java Developer's Guide* for more information about managing security for Oracle Java applications

Table 4–3 (Cont.) Oracle Database Predefined Roles

Predefined Role	Description
JAVA_DEPLOY	Provides privileges to deploy ncomp DLLs into the javavm/admin directory using the ncomp and deployns utilities. Without this role, the javavm/deploy and javavm/admin directories can be accessible. **See Also:** *Oracle Database Advanced Application Developer's Guide* for more information
JMXSERVER	Provides privileges to start and maintain a JMX agent in a database session. **See Also:** *Oracle Database Java Developer's Guide* for more information about managing Oracle Java applications
LBAC_DBA	Provides permissions to use the SA_SYSDBA PL/SQL package. **See Also:** *Oracle Label Security Administrator's Guide* for more information
LOGSTDBY_ADMINISTRATOR	Provides administrative privileges to manage the SQL Apply (logical standby database) environment. **See Also:** *Oracle Data Guard Concepts and Administration* for more information
MGMT_USER	Grants the SELECT privilege on the different views used for the SYSMAN schema.
OEM_ADVISOR	Provides privileges to create, drop, select (read), load (write), and delete a SQL tuning set through the DBMS_SQLTUNE PL/SQL package, and to access to the Advisor framework using the ADVISOR PL/SQL package. **See Also:** *Oracle Database Performance Tuning Guide* for more information
OEM_MONITOR	Provides privileges needed by the Management Agent component of Oracle Enterprise Manager to monitor and manage the database. **See Also:** *Oracle Database Performance Tuning Guide* for more information
OLAP_DBA	Provides administrative privileges to create dimensional objects in different schemas for Oracle OLAP. **See Also:** *Oracle OLAP User's Guide* for more information
OLAP_USER	Provides application developers privileges to create dimensional objects in their own schemas for Oracle OLAP. **See Also:** *Oracle OLAP User's Guide* for more information
OLAP_XS_ADMIN	Provides privileges to administer security for Oracle OLAP. **See Also:** *Oracle OLAP User's Guide* for more information
ORDADMIN	Provides privileges to administer Oracle Multimedia DICOM. **See Also:** *Oracle Multimedia DICOM Developer's Guide*
OWB$CLIENT	Provides privileges to perform standard client-related tasks for Oracle Warehouse Builder, such as creating projects, modules, tables, views, maps, and so on. Warehouse Builder automatically grants this role to all workspace owners and users. (That is, you do not need to explicitly grant it to anyone who must use Warehouse Builder.) For security reasons, the OWB$CLIENT role is not a default role for Warehouse Builder users: Oracle Warehouse Builder enables this role only when it is needed. **See Also:** *Oracle Warehouse Builder Installation and Administration Guide* for more information

Table 4–3 (Cont.) Oracle Database Predefined Roles

Predefined Role	Description
OWB_DESIGNCENTER_VIEW	Provides privileges from the database level for any registered Oracle Warehouse Builder user to query the Warehouse Builder public views, such as ALL_IV_PROJECTS. A Warehouse Builder administrator can use the ACCESS_PUBLICVIEW_BROWSER system privilege from the Warehouse Builder security level to control an Warehouse Builder user's access to those public views. **See Also:** *Oracle Warehouse Builder Installation and Administration Guide* for more information
OWB_USER	Provides privileges to create and own an Oracle Warehouse Builder workspace. When a workspace owner registers other database users to this workspace, Oracle Database grants this role to these users. Users with this role also have access to Warehouse Builder Control Center public views and other Control Center utilities. Oracle Warehouse Builder grants this role to all Warehouse Builder users. **See Also:** *Oracle Warehouse Builder Installation and Administration Guide* for more information
RECOVERY_CATALOG_OWNER	Provides privileges for owner of the recovery catalog. Includes: CREATE SESSION, ALTER SESSION, CREATE SYNONYM, CREATE VIEW, CREATE DATABASE LINK, CREATE TABLE, CREATE CLUSTER, CREATE SEQUENCE, CREATE TRIGGER, and CREATE PROCEDURE
RESOURCE	Provides the following system privileges: CREATE CLUSTER, CREATE INDEXTYPE, CREATE OPERATOR, CREATE PROCEDURE, CREATE SEQUENCE, CREATE TABLE, CREATE TRIGGER, CREATE TYPE. This role is provided for compatibility with previous releases of Oracle Database. You can determine the privileges encompassed by this role by querying the DBA_SYS_PRIVS data dictionary view. **Note:** Oracle recommends that you design your own roles for database security rather than relying on this role. This role may not be created automatically by future releases of Oracle Database. **See Also:** *Oracle Database Reference* for a description of the DBA_SYS_PRIVS view
SCHEDULER_ADMIN	Allows the grantee to execute the procedures of the DBMS_SCHEDULER package. It includes all of the job scheduler system privileges and is included in the DBA role. **See Also:** *Oracle Database Administrator's Guide* for more information about the DBMS_SCHEDULER package
SELECT_CATALOG_ROLE	Provides SELECT privilege on objects in the data dictionary.
SNMPAGENT	Used by the Enterprise Manager Management Agent.
SPATIAL_CSW_ADMIN	Provides administrative privileges to manage the Catalog Services for the Web (CSW) component of Oracle Spatial. **See Also:** *Oracle Spatial Developer's Guide* for more information
SPATIAL_WFS_ADMIN	Provides administrative privileges to manage the Web Feature Service (WFS) component of Oracle Spatial. **See Also:** *Oracle Spatial Developer's Guide* for more information
WFS_USR_ROLE	Provides user privileges for the Web Feature Service (WFS) component of Oracle Spatial. **See Also:** *Oracle Spatial Developer's Guide* for more information

Table 4–3 (Cont.) Oracle Database Predefined Roles

Predefined Role	Description
WM_ADMIN_ROLE	Provides administrative privileges for Oracle Workspace Manage. This enables users to run any DBMS_WM procedures on all version enabled tables, workspaces, and savepoints regardless of their owner. It also enables the user to modify the system parameters specific to Workspace Manager. **See Also:** *Oracle Database Workspace Manager Developer's Guide* for more information
XDBADMIN	Allows the grantee to register an XML schema globally, as opposed to registering it for use or access only by its owner. It also lets the grantee bypass access control list (ACL) checks when accessing Oracle XML DB Repository. **See Also:** *Oracle XML DB Developer's Guide* for information about XML schemas and the XML DB Repository
XDB_SET_INVOKER	Allows the grantee to define invoker's rights handlers and to create or update the resource configuration for XML repository triggers. By default, Oracle Database grants this role to the DBA role but not to the XDBADMIN role. **See Also:** *Oracle XML DB Developer's Guide* for information about Oracle Database XML repository triggers
XDB_WEBSERVICES	Allows the grantee to access Oracle Database Web services over HTTPS. However, it does not provide the user access to objects in the database that are public. To allow public access, you need to grant the user the XDB_WEBSERVICES_WITH_PUBLIC role. For a user to use these Web services, SYS must enable the Web service servlets. **See Also:** *Oracle XML DB Developer's Guide* for information about Oracle Database Web services
XDB_WEBSERVICES_OVER_HTTP	Allows the grantee to access Oracle Database Web services over HTTP. However, it does not provide the user access to objects in the database that are public. To allow public access, you need to grant the user the XDB_WEBSERVICES_WITH_PUBLIC role. **See Also:** *Oracle XML DB Developer's Guide* for information about Oracle Database Web services
XDB_WEBSERVICES_WITH_PUBLIC	Allows the grantee access to public objects through Oracle Database Web services. **See Also:** *Oracle XML DB Developer's Guide* for information about Oracle Database Web services

Note: Each installation should create its own roles and assign only those privileges that are needed, thus retaining detailed control of the privileges in use. This process also removes any need to adjust existing roles, privileges, or procedures whenever Oracle Database changes or removes roles that Oracle Database defines.

Creating a Role

You can create a role using the CREATE ROLE statement, but you must have the CREATE ROLE system privilege to do so. Typically, only security administrators have this system privilege.

After you create a role, the role has no privileges associated with it. Your next step is to grant either privileges or other roles to the new role.

You must give each role you create a unique name among existing user names and role names of the database. Roles are not contained in the schema of any user. In a database

that uses a multibyte character set, Oracle recommends that each role name contain at least one single-byte character. If a role name contains only multibyte characters, then the encrypted role name and password combination is considerably less secure. See Guideline 1 in "Guidelines for Securing Passwords" on page 10-7 for password guidelines.

Example 4–2 creates the `clerk` role.

Example 4–2 Creating a User Role Authorized by a Password

```
CREATE ROLE clerk IDENTIFIED BY password;
```

You can use the `IDENTIFIED BY` clause to authorize the role with a password. The `IDENTIFIED BY` clause of the `CREATE ROLE` statement specifies how the user must be authorized before the role can be enabled for use by a specific user to which it has been granted. If you do not specify this clause, or if you specify `NOT IDENTIFIED`, then no authorization is required when the role is enabled. Roles can be specified to be authorized by the following:

- The database using a password
- An application using a specified package
- Externally by the operating system, network, or other external source
- Globally by an enterprise directory service

These authorizations are discussed in the following sections.

As an alternative to creating password-protected roles, Oracle recommends that you use secure application roles instead. See "Securing Role Privileges by Using Secure Application Roles" on page 4-22 for more information.

You can set or change the authorization method for a role using the `ALTER ROLE` statement. Remember that you can only directly grant secure application roles or password-authenticated roles to a user.

Example 4–3 shows how to alter the `clerk` role to specify that the user must have been authorized by an external source before enabling the role.

Example 4–3 Altering a Role to be Authorized by an External Source

```
ALTER ROLE clerk IDENTIFIED EXTERNALLY;
```

To alter the authorization method for a role, you must have the `ALTER ANY ROLE` system privilege or have been granted the role with `ADMIN` option.

> **See Also:** *Oracle Database SQL Language Reference* for syntax, restrictions, and authorization information about the SQL statements used to manage roles and privileges

Specifying the Type of Role Authorization

The methods of authorizing roles are presented in this section. A role must be enabled for you to use it.

This section contains:

- Authorizing a Role by Using the Database
- Authorizing a Role by Using an Application
- Authorizing a Role by Using an External Source

See Also: "When Do Grants and Revokes Take Effect?" on page 4-48 for a discussion about enabling roles

Authorizing a Role by Using the Database

You can protect a role authorized by the database by assigning the role a password. If a user is granted a role protected by a password, then you can enable or disable the role by supplying the proper password for the role in the `SET ROLE` statement. You cannot authenticate a password-authenticated role on logon, even if you add it to the list of default roles. You must explicitly enable it with the `SET ROLE` statement using the required password.

Example 4–4 shows how to set a password-authenticated role by using the `SET ROLE` statement.

Example 4–4 Using SET ROLE for a Password-Authenticated Role

```
SET ROLE clerk IDENTIFIED BY password;
```

Example 4–2, "Creating a User Role Authorized by a Password" on page 4-17 shows a `CREATE ROLE` statement that creates a role called `clerk`. When it is enabled, the password must be supplied.

Note: In a database that uses a multibyte character set, passwords for roles must include only single-byte characters. Multibyte characters are not accepted in passwords. See Guideline 1 in "Guidelines for Securing Passwords" on page 10-7 for password guidelines.

Authorizing a Role by Using an Application

An application role (secure application role) can be enabled only by applications using an authorized PL/SQL package. Application developers do not need to secure a role by embedding passwords inside applications. Instead, they can create an application role and specify which PL/SQL package is authorized to enable the role.

To create a role enabled by an authorized PL/SQL package, use the `IDENTIFIED USING` *`package_name`* clause in the `CREATE ROLE` SQL statement.

Example 4–5 indicates that the role `admin_role` is an application role and the role can only be enabled by any module defined inside the PL/SQL package `hr.admin`.

Example 4–5 Creating a Role Authorized by a PL/SQL Package for an Application

```
CREATE ROLE admin_role IDENTIFIED USING hr.admin;
```

See the following for more information about secure application roles:

- "Securing Role Privileges by Using Secure Application Roles" on page 4-22
- "Creating Secure Application Roles to Control Access to Applications" on page 5-12
- *Oracle Database 2 Day + Security Guide*

Authorizing a Role by Using an External Source

You can define the external role locally in the database, but you cannot grant the external role to global users, to global roles, or to any other roles in the database. You can create roles that are authorized by the operating system or network clients.

Example 4–6 creates a role named accts_rec and requires that the user is authorized by an external source before it can be enabled:

Example 4–6 Creating a Role Authorized by an External Source

```
CREATE ROLE accts_rec IDENTIFIED EXTERNALLY;
```

Authorizing a Role by Using the Operating System Role authentication through the operating system is useful only when the operating system is able to dynamically link operating system privileges with applications. When a user starts an application, the operating system grants an operating system privilege to the user. The granted operating system privilege corresponds to the role associated with the application. At this point, the application can enable the application role. When the application is terminated, the previously granted operating system privilege is revoked from the operating system account of the user.

If a role is authorized by the operating system, then you must configure information for each user at the operating system level. This operation is operating system dependent.

If roles are granted by the operating system, then you do not need to have the operating system authorize them also.

> **See Also:** "Granting Roles Using the Operating System or Network" on page 4-45 for more information about roles granted by the operating system

Authorizing a Role by Using a Network Client If users connect to the database over Oracle Net, then by default, the operating system cannot authenticate their roles. This includes connections through a shared server configuration, as this connection requires Oracle Net. This restriction is the default because a remote user could impersonate another operating system user over a network connection. Oracle recommends that you set REMOTE_OS_ROLES to FALSE, which is the default.

If you are not concerned with this security risk and want to use operating system role authentication for network clients, then set the initialization parameter REMOTE_OS_ROLES in the database initialization parameter file to TRUE. The change will take effect the next time you start the instance and mount the database.

Global Role Authorization by an Enterprise Directory Service

A role can be defined as a global role, where a (global) user can only be authorized to use the role by an enterprise directory service. You define the global role locally in the database by granting privileges and roles to it, but you cannot grant the global role itself to any user or other role in the database. When a global user attempts to connect to the database, the enterprise directory is queried to obtain any global roles associated with the user.

Example 4–7 creates a global role.

Example 4–7 Creating a Global Role

```
CREATE ROLE supervisor IDENTIFIED GLOBALLY;
```

Global roles are one component of enterprise user security. A global role only applies to one database, but you can grant it to an enterprise role defined in the enterprise directory. An enterprise role is a directory structure that contains global roles on multiple databases and can be granted to enterprise users.

See "Configuring Global User Authentication and Authorization" on page 3-30 for a general discussion of global authentication and authorization of users, and its role in enterprise user management.

> **See Also:** *Oracle Database Enterprise User Security Administrator's Guide* for information about implementing enterprise user management

Granting and Revoking Roles

This section contains:

- About Granting and Revoking Roles
- Who Can Grant or Revoke Roles?

> **See Also:**
>
> - "Granting a User Privileges and Roles" on page 4-37
> - "Revoking Privileges and Roles from a User" on page 4-41
> - "When Do Grants and Revokes Take Effect?" on page 4-48
> - "Finding Information About User Privileges and Roles" on page 4-71
> - *Oracle Database 2 Day DBA* for more information about Database Control

About Granting and Revoking Roles

You can grant system or object privileges to a role, and any role can be granted to any database user or to another role (but not to itself). However, a role cannot be granted circularly, that is, role `X` cannot be granted to role `Y` if role `Y` has previously been granted to role `X`.

To provide selective availability of privileges, Oracle Database permits applications and users to enable and disable roles. Each role granted to a user is, at any given time, either enabled or disabled. The security domain of a user includes the privileges of all roles currently enabled for the user and excludes the privileges of any roles currently disabled for the user.

A role granted to a role is called an indirectly granted role. You can explicitly enable or disable it for a user. However, whenever you enable a role that contains other roles, you implicitly enable all indirectly granted roles of the directly granted role.

You grant roles to (or revoke roles from) users or other roles by using either of the following methods:

- Oracle Enterprise Manager Database Control
- The `GRANT` and `REVOKE` SQL statements

Privileges are granted to and revoked from roles using the same options.

You cannot grant a secure role (that is, an `IDENTIFIED BY` role, `IDENTIFIED USING` role, or `IDENTIFIED EXTERNALLY` role) to a non-secure role. You can use the `SET ROLE` statement to enable the secure role for the session.

Who Can Grant or Revoke Roles?

Any user with the `GRANT ANY ROLE` system privilege can grant or revoke any role except a global role to or from other users or roles of the database. (A global role is managed

in a directory, such as Oracle Internet Directory, but its privileges are contained within a single database.) By default, the SYS or SYSTEM user has this privilege. You should grant this system privilege conservatively because it is very powerful.

Any user granted a role with the ADMIN OPTION can grant or revoke that role to or from other users or roles of the database. This option allows administrative powers for roles to be granted on a selective basis.

> **See Also:** *Oracle Database Enterprise User Security Administrator's Guide* for information about global roles

Dropping Roles

In some cases, it may be appropriate to drop a role from the database. The security domains of all users and roles granted a dropped role are immediately changed to reflect the absence of the dropped role privileges. All indirectly granted roles of the dropped role are also removed from affected security domains. Dropping a role automatically removes the role from all user default role lists.

Because the existence of objects is not dependent on the privileges received through a role, tables and other objects are not dropped when a role is dropped.

You can drop a role using the SQL statement DROP ROLE. To drop a role, you must have the DROP ANY ROLE system privilege or have been granted the role with the ADMIN option.

The following statement drops the role CLERK:

```
DROP ROLE clerk;
```

Restricting SQL*Plus Users from Using Database Roles

This section describes features that you can use to restrict SQL*Plus users from using database roles and thus, prevent serious security problems.

- Potential Security Problems of Using Ad Hoc Tools
- Limiting Roles Through the PRODUCT_USER_PROFILE Table
- Using Stored Procedures to Encapsulate Business Logic

Potential Security Problems of Using Ad Hoc Tools

Prebuilt database applications explicitly control the potential actions of a user, including the enabling and disabling of user roles while using the application. By contrast, ad hoc query tools such as SQL*Plus, permit a user to submit any SQL statement (which may or may not succeed), including enabling and disabling a granted role.

Potentially, an application user can exercise the privileges attached to that application to issue destructive SQL statements against database tables by using an ad hoc tool.

For example, consider the following scenario:

- The Vacation application has a corresponding vacation role.
- The vacation role includes the privileges to issue SELECT, INSERT, UPDATE, and DELETE statements against the emp_tab table.
- The Vacation application controls the use of privileges obtained through the vacation role.

Now, consider a user who has been granted the vacation role. Suppose that, instead of using the Vacation application, the user executes SQL*Plus. At this point, the user is restricted only by the privileges granted to him explicitly or through roles, including the vacation role. Because SQL*Plus is an ad hoc query tool, the user is not restricted to a set of predefined actions, as with designed database applications. The user can query or modify data in the emp_tab table as he or she chooses.

Limiting Roles Through the PRODUCT_USER_PROFILE Table

You can use the PRODUCT_USER_PROFILE table, which is in the SYSTEM schema, to disable certain SQL and SQL*Plus commands in the SQL*Plus environment for each user. SQL*Plus, not the Oracle Database, enforces this security. You can even restrict access to the GRANT, REVOKE, and SET ROLE commands to control user ability to change their database privileges.

The PRODUCT_USER_PROFILE table enables you to list roles that you do not want users to activate with an application. You can also explicitly disable the use of various commands, such as SET ROLE.

For example, you could create an entry in the PRODUCT_USER_PROFILE table to:

- Disallow the use of the clerk and manager roles with SQL*Plus
- Disallow the use of SET ROLE with SQL*Plus

Suppose user Marla connects to the database using SQL*Plus. Marla has the clerk, manager, and analyst roles. As a result of the preceding entry in PRODUCT_USER_PROFILE, Marla is only able to exercise her analyst role with SQL*Plus. Also, when Ginny attempts to issue a SET ROLE statement, she is explicitly prevented from doing so because of the entry in the PRODUCT_USER_PROFILE table prohibiting use of SET ROLE.

Be aware that the PRODUCT_USER_PROFILE table does not completely guarantee security, for multiple reasons. In the preceding example, while SET ROLE is disallowed with SQL*Plus, if Marla had other privileges granted to her directly, then she could exercise these using SQL*Plus.

> **See Also:** *SQL*Plus User's Guide and Reference* for more information about the PRODUCT_USER_PROFILE table

Using Stored Procedures to Encapsulate Business Logic

Stored procedures encapsulate the use of privileges with business logic so that privileges are only exercised in the context of a well-formed business transaction. For example, an application developer can create a procedure to update the employee name and address in the employees table, which enforces that the data can only be updated in normal business hours. Also, rather than grant a human resources clerk the UPDATE privilege on the employees table, a security administrator may grant the privilege on the procedure only. Then, the human resources clerk can exercise the privilege only in the context of the procedures, and cannot update the employees table directly.

Securing Role Privileges by Using Secure Application Roles

A secure application role is a role that can be enabled only by an authorized PL/SQL package (or procedure). The PL/SQL package itself reflects the security policies needed to control access to the application.

This method of role creation restricts the enabling of this type of role to the invoking application. For example, the application can perform authentication and customized authorization, such as checking whether the user has connected through a proxy.

This type of role strengthens security because passwords are not embedded in application source code or stored in a table. This way, the actions the database performs are based on the implementation of your security policies, and these definitions are stored in one place, the database, rather than in your applications. If you need to modify the policy, you do so in one place without having to modify your applications. No matter how users connect to the database, the result is always the same, because the policy is bound to the role.

To enable the secure application role, you must execute its underlying package by invoking it directly from the application when the user logs in, before the user exercises the privileges granted by the secure application role. You cannot use a logon trigger to enable a secure application role, nor can you have this type of role be a default role.

When you enable the secure application role, Oracle Database verifies that the authorized PL/SQL package is on the calling stack, that is, it verifies that the authorized PL/SQL package is issuing the command to enable the role.

You can use secure application roles to ensure the existence of a database connection. Because a secure application role is a role implemented by a package, the package can validate that users can connect to the database through a middle tier or from a specific IP address. In this way, the secure application role prevents users from accessing data outside an application. They are forced to work within the framework of the application privileges that they have been granted.

See Also:

- "Creating Secure Application Roles to Control Access to Applications" on page 5-12
- *Oracle Database 2 Day + Security Guide*

Managing Object Privileges

This section contains:

About Object Privileges

An **object privilege** is a right that you grant to a user on a database object. Some examples of object privileges include the right to:

- Use an edition
- Update a table

- Select rows from another user's table
- Execute a stored procedure of another user

> **See Also:** *Oracle Database SQL Language Reference* for a list of object privileges and the operations they authorize

Granting or Revoking Object Privileges

Each type of object has different privileges associated with it.

You can specify `ALL` [`PRIVILEGES`] to grant or revoke all available object privileges for an object. `ALL` is not a privilege; rather, it is a shortcut, or a way of granting or revoking all object privileges with one `GRANT` and `REVOKE` statement. If all object privileges are granted using the `ALL` shortcut, then individual privileges can still be revoked.

Similarly, you can revoke all individually granted privileges by specifying `ALL`. However, if you `REVOKE ALL`, and revoking causes integrity constraints to be deleted (because they depend on a `REFERENCES` privilege that you are revoking), then you must include the `CASCADE CONSTRAINTS` option in the `REVOKE` statement.

Example 4–8 revokes all privileges on the orders table in the `HR` schema using `CASCADE CONSTRAINTS`.

Example 4–8 Revoking All Object Privileges Using CASCADE CONSTRAINTS

```
REVOKE ALL
 ON orders FROM hr
 CASCADE CONSTRAINTS;
```

Managing Object Privileges

An **object privilege** grants permission to perform a particular action on a specific schema object.

Different object privileges are available for different types of schema objects. The privilege to delete rows from the `departments` table is an example of an object privilege.

Some schema objects, such as clusters, indexes, triggers, and database links, do not have associated object privileges. Their use is controlled with system privileges. For example, to alter a cluster, a user must own the cluster or have the `ALTER ANY CLUSTER` system privilege.

The following sections discuss granting and revoking such privileges:

- "Granting and Revoking Object Privileges" on page 4-25
- "Who Can Grant Object Privileges?" on page 4-25
- "Using Object Privileges with Synonyms" on page 4-25

The following sections discuss object privileges that apply to specific schema objects:

- "Managing Table Privileges" on page 4-26
- "Managing View Privileges" on page 27
- Sequences (see *Oracle Database Administrator's Guide* for information about managing sequences)
- "Managing Procedure Privileges" on page 4-29

- Functions and Packages(*Oracle Database Administrator's Guide* for information about managing object dependencies)
- "Managing Type Privileges" on page 4-33

Granting and Revoking Object Privileges

Object privileges can be granted to and revoked from users and roles. If you grant object privileges to roles, then you can make the privileges selectively available.

You can grant or revoke object privileges to or from users and roles using the following methods:

- The `GRANT` and `REVOKE` SQL statements
- Oracle Enterprise Manager Database Control

> **See Also:** *Oracle Database 2 Day DBA* for more information about Database Control

Who Can Grant Object Privileges?

A user automatically has all object privileges for schema objects contained in his or her schema. A user with the `GRANT ANY OBJECT PRIVILEGE` can grant any specified object privilege to another user with or without the `WITH GRANT OPTION` clause of the `GRANT` statement. A user with the `GRANT ANY OBJECT PRIVILEGE` can also use that privilege to revoke any object privilege that was granted either by the object owner or by some other user with the `GRANT ANY OBJECT PRIVILEGE` privilege. Otherwise, the grantee can use the privilege, but cannot grant it to other users.

> **See Also:** *Oracle Database SQL Language Reference* for information about `GRANT` and `GRANT ANY OBJECT PRIVILEGE`

Using Object Privileges with Synonyms

You can use the `CREATE SYNONYM` statement to create synonyms for tables, views, sequences, operators, procedures, stored functions, packages, materialized views, Java class schema objects, user-defined object types, or other synonyms. If you grant users the privilege to use the synonym, then the object privileges granted on the underlying objects apply whether the user references the base object by name or by using the synonym.

For example, suppose user `OE` creates the following synonym for the `CUSTOMERS` table:

```
CREATE SYNONYM customer_syn FOR CUSTOMERS;
```

Then `OE` grants the `SELECT` privilege on the `customer_syn` synonym to user `HR`.

```
GRANT SELECT ON customer_syn TO HR;
```

User `HR` then tries either of the following queries:

```
SELECT COUNT(*) FROM OE.customer_syn;

SELECT COUNT(*) FROM OE.CUSTOMERS;
```

Both queries will yield the same result:

```
  COUNT(*)
----------
       319
```

Be aware that when you grant the synonym to another user, the grant applies to the underlying object that the synonym represents, not to the synonym itself. For example, if user HR queries the ALL_TAB_PRIVS data dictionary view for his privileges, he will learn the following:

```
SELECT TABLE_SCHEMA, TABLE_NAME, PRIVILEGE
FROM ALL_TAB_PRIVS
WHERE TABLE_SCHEMA = 'OE';

TABLE_SCHEMA  TABLE_NAME  PRIVILEGE
------------  ----------  ----------
OE            CUSTOMER    SELECT
OE            ORDERS      UPDATE
```

The results show that in addition to other privileges, he has the SELECT privilege for the underlying object of the customer_syn synonym, which is the OE.CUSTOMER table.

At this point, if user OE then revokes the SELECT privilege on the customer_syn synonym from HR, here are the results if HR checks his privileges again:

```
TABLE_SCHEMA  TABLE_NAME  PRIVILEGE
------------  ----------  ---------
OE            ORDERS      UPDATE
```

User HR no longer has the SELECT privilege for the OE.CUSTOMER table. If he tries to query the OE.CUSTOMERS table, then the following error appears:

```
SELECT COUNT(*) FROM OE.CUSTOMERS;

ERROR at line 1:
ORA-00942: table or view does not exist
```

Managing Table Privileges

Object privileges for tables enable table security at the DML (data manipulation language) or DDL (data definition language) level of operation.

The following sections discuss table privileges and DML and DDL operations:

- How Table Privileges Affect Data Manipulation Language Operations
- How Table Privileges Affect Data Definition Language Operations

How Table Privileges Affect Data Manipulation Language Operations

You can grant privileges to use the DELETE, INSERT, SELECT, and UPDATE DML operations on a table or view. Grant these privileges only to users and roles that need to query or manipulate data in a table.

You can restrict INSERT and UPDATE privileges for a table to specific columns of the table. With a selective INSERT privilege, a privileged user can insert a row with values for the selected columns. All other columns receive NULL or the default value of the column. With a selective UPDATE privilege, a user can update only specific column values of a row. You can use selective INSERT and UPDATE privileges to restrict user access to sensitive data.

For example, if you do not want data entry users to alter the salary column of the employees table, then selective INSERT or UPDATE privileges can be granted that exclude the salary column. Alternatively, a view that excludes the salary column could satisfy this need for additional security.

See Also: *Oracle Database SQL Language Reference* for more information about DML operations

How Table Privileges Affect Data Definition Language Operations

The `ALTER`, `INDEX`, and `REFERENCES` privileges allow DDL operations to be performed on a table. Because these privileges allow other users to alter or create dependencies on a table, you should grant these privileges conservatively.

A user attempting to perform a DDL operation on a table may need additional system or object privileges. For example, to create a trigger on a table, the user requires both the `ALTER TABLE` object privilege for the table and the `CREATE TRIGGER` system privilege.

As with the `INSERT` and `UPDATE` privileges, you can grant the `REFERENCES` privilege on specific columns of a table. The `REFERENCES` privilege enables the grantee to use the table on which the grant is made as a parent key to any foreign keys that the grantee wishes to create in his or her own tables. This action is controlled with a special privilege because the presence of foreign keys restricts the data manipulation and table alterations that can be done to the parent key. A column-specific `REFERENCES` privilege restricts the grantee to using the named columns (which, of course, must include at least one primary or unique key of the parent table).

See Also: "Data Integrity" in *Oracle Database Concepts* for more information about primary keys, unique keys, and integrity constraints

Managing View Privileges

This section contains:

- About View Privileges
- Privileges Required to Create Views
- Increasing Table Security with Views

About View Privileges

A **view** is a presentation of data selected from one or more tables, possibly including other views. A view shows the structure of the underlying tables. Its selected data can be thought of as the result of a stored query. A view contains no actual data but rather derives what it shows from the tables and views on which it is based. You can query a view, and change the data it represents. Data in a view can be updated or deleted, and new data inserted. These operations directly alter the tables on which the view is based, and are subject to the integrity constraints and triggers of the base tables.

You can apply DML object privileges to views, similar to tables. Object privileges for a view allow various DML operations, which as noted affect the base tables from which the view is derived.

Privileges Required to Create Views

To create a view, you must meet the following requirements:

- You must have been granted one of the following system privileges, either explicitly or through a role:
  - The `CREATE VIEW` system privilege (to create a view in your schema)
  - The `CREATE ANY VIEW` system privilege (to create a view in the schema of another user)

- You must have been explicitly granted one of the following privileges:
  - The SELECT, INSERT, UPDATE, or DELETE object privileges on all base objects underlying the view
  - The SELECT ANY TABLE, INSERT ANY TABLE, UPDATE ANY TABLE, or DELETE ANY TABLE system privileges
- In addition, before you can grant other users access to you view, you must have object privileges to the base objects with the GRANT OPTION clause or appropriate system privileges with the ADMIN OPTION clause. If you do not have these privileges, then you cannot to grant other users access to your view. If you try, an ORA-01720: grant option does not exist for *object_name* error is raised, with *object_name* referring to the view's underlying object for which you do not have the sufficient privilege.

See Also: *Oracle Database SQL Language Reference*

Increasing Table Security with Views

To use a view, the user must have the appropriate privileges but only for the view itself, not its underlying objects. However, if access privileges for the underlying objects of the view are removed, then the user no longer has access. This behavior occurs because the security domain that is used when a user queries the view is that of the definer of the view. If the privileges on the underlying objects are revoked from the view's definer, then the view becomes invalid, and no one can use the view. Therefore, even if a user has been granted access to the view, the user may not be able to use the view if the definer's rights have been revoked from the view's underlying objects.

For example, suppose User A creates a view. User A has definer's rights on the underlying objects of the view. User A then grants the SELECT privilege on that view to User B so that User B can query the view. But if User A no longer has access to the underlying objects of that view, then User B no longer has access either.

Views add two more levels of security for tables, column-level security and value-based security, as follows:

- **A view can provide access to selected columns of base tables.** For example, you can define a view on the employees table to show only the employee_id, last_name, and manager_id columns:

```
CREATE VIEW employees_manager AS
    SELECT last_name, employee_id, manager_id FROM employees;
```

- **A view can provide value-based security for the information in a table.** A WHERE clause in the definition of a view displays only selected rows of base tables. Consider the following two examples:

```
CREATE VIEW lowsal AS
    SELECT * FROM employees
    WHERE salary < 10000;
```

The lowsal view allows access to all rows of the employees table that have a salary value less than 10000. Notice that all columns of the employees table are accessible in the lowsal view.

```
CREATE VIEW own_salary AS
    SELECT last_name, salary
    FROM employees
    WHERE last_name = USER;
```

In the own_salary view, only the rows with an last_name that matches the current user of the view are accessible. The own_salary view uses the user pseudo column, whose values always refer to the current user. This view combines both column-level security and value-based security.

Managing Procedure Privileges

This section contains:

Using the EXECUTE Privilege for Procedure Privileges

The EXECUTE privilege is the only **object privilege** for procedures, including standalone procedures and functions, and for those within packages. Grant this privilege only to users who need to run a procedure or to compile another procedure that calls a desired procedure.

Procedure Execution and Security Domains

A user with the EXECUTE object privilege for a specific procedure can execute the procedure or compile a program unit that references the procedure. Oracle Database performs a run-time privilege check when any PL/SQL unit is called. A user with the EXECUTE ANY PROCEDURE system privilege can execute any procedure in the database. Privileges to run procedures can be granted to a user through roles.

> **See Also:** *Oracle Database PL/SQL Language Reference* for more information about how Oracle Database checks privileges at run-time

How Procedure Privileges Affect Definer's Rights

The owner of a procedure, called the *definer*, must have all the necessary object privileges for referenced objects. If the procedure owner grants to another user the right to use that procedure, then the privileges of the procedure owner (on the objects referenced by the procedure) apply to the grantee user's exercise of the procedure. The privileges of the procedure's definer must be granted directly to the user, not granted through roles. These are termed definer's rights.

The user of a procedure who is not its owner is called the *invoker*. Additional privileges on referenced objects are required for invoker's rights procedures, but not for definer's rights procedures.

> **See Also:** "How Roles Work in PL/SQL Blocks" on page 4-9

A user of a definer's rights procedure requires only the privilege to execute the procedure and no privileges on the underlying objects that the procedure accesses. This is because a definer's rights procedure operates under the security domain of the user who owns the procedure, regardless of who is executing it. The owner of the procedure must have all the necessary object privileges for referenced objects. Fewer

privileges have to be granted to users of a definer's rights procedure. This results in stronger control of database access.

You can use definer's rights procedures to control access to private database objects and add a level of database security. By writing a definer's rights procedure and granting only `EXECUTE` privilege to a user, the user can be forced to access the referenced objects only through the procedure.

At run time, Oracle Database checks whether the privileges of the owner of a definer's rights stored procedure allow access to that procedure's referenced objects, before the procedure is executed. If a necessary privilege on a referenced object was revoked from the owner of a definer's rights procedure, then the procedure cannot be run by the owner or any other user.

Note: Trigger processing follows the same patterns as definer's rights procedures. The user runs a SQL statement, which that user is privileged to run. As a result of the SQL statement, a trigger is fired. The statements within the triggered action temporarily execute under the security domain of the user that owns the trigger. For more information, see "Overview of Triggers" in *Oracle Database Concepts*.

How Procedure Privileges Affect Invoker's Rights

An invoker's rights procedure executes with all of the invoker's privileges. Oracle Database enables the privileges that were granted to the invoker through any of the invoker's enabled roles to take effect, unless a definer's rights procedure calls the invoker's rights procedure directly or indirectly. A user of an invoker's rights procedure needs privileges (granted to the user either directly or through a role) on objects that the procedure accesses through external references that are resolved in the schema of the invoker.

The invoker needs privileges at run time to access program references embedded in DML statements or dynamic SQL statements, because they are effectively recompiled at run time.

For all other external references, such as direct PL/SQL function calls, Oracle Database checks the privileges of the owner at compile time, but does not perform a run-time check. Therefore, the user of an invoker's rights procedure does not need privileges on external references outside DML or dynamic SQL statements. Alternatively, the developer of an invoker's rights procedure must only grant privileges on the procedure itself, not on all objects directly referenced by the invoker's rights procedure.

You can create a software bundle that consists of multiple program units, some with definer's rights and others with invoker's rights, and restrict the program entry points *(controlled step-in)*. A user who has the privilege to run an entry-point procedure can also execute internal program units indirectly, but cannot directly call the internal programs. For very precise control over query processing, you can create a PL/SQL package specification with explicit cursors.

See Also:

- "Configuring an Oracle Virtual Private Database Policy" on page 7-5
- *Oracle Database PL/SQL Language Reference* for information about how Oracle Database handles name resolution and privilege checking at runtime using invoker's and definer's rights
- *Oracle Database PL/SQL Language Reference* for information about defining explicit cursors in the `CREATE PACKAGE` statement

System Privileges Required to Create or Replace a Procedure

To create or replace a procedure in your own schema, you must have the `CREATE PROCEDURE` system privilege. To create or replace a procedure in another user's schema, you must have the `CREATE ANY PROCEDURE` system privilege.

The user who owns the procedure also must have privileges for schema objects referenced in the procedure body. To create a procedure, you need to have been explicitly granted the necessary privileges (system or object) on all objects referenced by the procedure. You cannot obtain the required privileges through roles. This includes the `EXECUTE` privilege for any procedures that are called inside the procedure being created.

Note: Triggers require that privileges on referenced objects be granted directly to the owner of the trigger. Anonymous PL/SQL blocks can use any privilege, whether the privilege is granted explicitly or through a role.

System Privileges Required to Compile a Procedure

To compile a standalone procedure, run the `ALTER PROCEDURE` statement with the `COMPILE` clause. To compile a procedure that is part of a package, run the `ALTER PACKAGE` statement.

Example 4–9 shows how to compile a standalone procedure.

Example 4–9 Compiling a Procedure

```
ALTER PROCEDURE psmith.remove_emp COMPILE;
```

If the standalone or packaged procedure is in another user's schema, you must have the `ALTER ANY PROCEDURE` privilege to recompile it. You can recompile procedures in your own schema without any privileges.

How Procedure Privileges Affect Packages and Package Objects

A user with the `EXECUTE` object privilege for a package can execute any public procedure or function in the package, and can access or modify the value of any public package variable. You cannot grant specific `EXECUTE` privileges for individual constructs in a package. Therefore, you may find it useful to consider two alternatives for establishing security when developing procedures, functions, and packages for a database application. The following examples describe these alternatives.

Procedure Privileges and Packages and Package Objects: Example 1

Example 4–10 shows four procedures created in the bodies of two packages.

Example 4–10 Package Objects Affected by Procedure Privileges

```
CREATE PACKAGE BODY hire_fire AS
  PROCEDURE hire(...) IS
    BEGIN
      INSERT INTO employees . . .
    END hire;
  PROCEDURE fire(...) IS
    BEGIN
      DELETE FROM employees . . .
    END fire;
END hire_fire;

CREATE PACKAGE BODY raise_bonus AS
  PROCEDURE give_raise(...) IS
    BEGIN
      UPDATE employees SET salary = . . .
    END give_raise;
  PROCEDURE give_bonus(...) IS
    BEGIN
      UPDATE employees SET bonus = . . .
    END give_bonus;
END raise_bonus;
```

The following `GRANT EXECUTE` statements enable the `big_bosses` and `little_bosses` roles to run the appropriate procedures:

```
GRANT EXECUTE ON hire_fire TO big_bosses;
GRANT EXECUTE ON raise_bonus TO little_bosses;
```

> **Note:** Granting `EXECUTE` privilege for a package provides uniform access to all package objects.

Procedure Privileges and Packages and Package Objects: Example 2

This example shows four procedure definitions within the body of a single package. Two additional standalone procedures and a package are created specifically to provide access to the procedures defined in the main package.

```
CREATE PACKAGE BODY employee_changes AS
  PROCEDURE change_salary(...) IS BEGIN ... END;
  PROCEDURE change_bonus(...) IS BEGIN ... END;
  PROCEDURE insert_employee(...) IS BEGIN ... END;
  PROCEDURE delete_employee(...) IS BEGIN ... END;
END employee_changes;

CREATE PROCEDURE hire
  BEGIN
    employee_changes.insert_employee(...)
  END hire;

CREATE PROCEDURE fire
  BEGIN
    employee_changes.delete_employee(...)
  END fire;
```

```
PACKAGE raise_bonus IS
  PROCEDURE give_raise(...) AS
    BEGIN
      employee_changes.change_salary(...)
    END give_raise;

  PROCEDURE give_bonus(...)
    BEGIN
      employee_changes.change_bonus(...)
    END give_bonus;
```

Using this method, the procedures that actually do the work (the procedures in the `employee_changes` package) are defined in a single package and can share declared global variables, cursors, on so on. By declaring top-level procedures, `hire` and `fire`, and an additional package, `raise_bonus`, you can grant selective `EXECUTE` privileges on procedures in the main package:

```
GRANT EXECUTE ON hire, fire TO big_bosses;
GRANT EXECUTE ON raise_bonus TO little_bosses;
```

Managing Type Privileges

The following sections describe the use of privileges for types, methods, and objects:

- System Privileges for Named Types
- Object Privileges
- Method Execution Model
- Privileges Required to Create Types and Tables Using Types
- Example of Privileges for Creating Types and Tables Using Types
- Privileges on Type Access and Object Access
- Type Dependencies

System Privileges for Named Types

Table 4–4 lists system privileges for named types (object types, `VARRAY`s, and nested tables).

Table 4–4 System Privileges for Named Types

Privilege	Enables you to ...
`CREATE TYPE`	Create named types in your own schemas
`CREATE ANY TYPE`	Create a named type in any schema
`ALTER ANY TYPE`	Alter a named type in any schema
`DROP ANY TYPE`	Drop a named type in any schema
`EXECUTE ANY TYPE`	Use and reference a named type in any schema

The `RESOURCE` role includes the `CREATE TYPE` system privilege. The `DBA` role includes all of these privileges.

Object Privileges

The only object privilege that applies to named types is `EXECUTE`. If the `EXECUTE` privilege exists on a named type, then a user can use the named type to:

- Define a table
- Define a column in a relational table
- Declare a variable or parameter of the named type

The EXECUTE privilege permits a user to invoke the methods in the type, including the type constructor. This is similar to the EXECUTE privilege on a stored PL/SQL procedure.

Method Execution Model

Method execution is the same as any other stored PL/SQL procedure.

> **See Also:** "Managing Procedure Privileges" on page 4-29

Privileges Required to Create Types and Tables Using Types

To create a type, you must meet the following requirements:

- You must have the CREATE TYPE system privilege to create a type in your schema or the CREATE ANY TYPE system privilege to create a type in the schema of another user. These privileges can be acquired explicitly or through a role.
- The owner of the type must be explicitly granted the EXECUTE object privileges to access all other types referenced within the definition of the type, or have been granted the EXECUTE ANY TYPE system privilege. The owner cannot obtain the required privileges through roles.
- If the type owner intends to grant access to the type to other users, then the owner must receive the EXECUTE privileges to the referenced types with the GRANT OPTION or the EXECUTE ANY TYPE system privilege with the ADMIN OPTION. If not, then the type owner has insufficient privileges to grant access on the type to other users.

To create a table using types, you must meet the requirements for creating a table and the following additional requirements:

- The owner of the table must have been directly granted the EXECUTE object privilege to access all types referenced by the table, or has been granted the EXECUTE ANY TYPE system privilege. The owner cannot exercise the required privileges if these privileges were granted through roles.
- If the table owner intends to grant access to the table to other users, then the owner must have the EXECUTE privilege to the referenced types with the GRANT OPTION or the EXECUTE ANY TYPE system privilege with the ADMIN OPTION. If not, then the table owner has insufficient privileges to grant access on the table.

> **See Also:** "Managing Table Privileges" on page 4-26 for the requirements for creating a table

Example of Privileges for Creating Types and Tables Using Types

Assume that three users exist with the CONNECT and RESOURCE roles:

- user1
- user2
- user3

The following DDL is run in the schema of user1:

```
CREATE TYPE type1 AS OBJECT (
  attr1 NUMBER);
```

```
CREATE TYPE type2 AS OBJECT (
  attr2 NUMBER);

GRANT EXECUTE ON type1 TO user2;
GRANT EXECUTE ON type2 TO user2 WITH GRANT OPTION;
```

The following DDL is performed in the schema of `user2`:

```
CREATE TABLE tab1 OF user1.type1;
CREATE TYPE type3 AS OBJECT (
  attr3 user1.type2);
CREATE TABLE tab2 (
  col1 user1.type2);
```

The following statements succeed because `user2` has `EXECUTE` privilege on `user1.type2` with the `GRANT OPTION`:

```
GRANT EXECUTE ON type3 TO user3;
GRANT SELECT on tab2 TO user3;
```

However, the following grant fails because `user2` does not have `EXECUTE` privilege on `user1.type1` with the `GRANT OPTION`:

```
GRANT SELECT ON tab1 TO user3;
```

The following statements can be successfully run by `user3`:

```
CREATE TYPE type4 AS OBJECT (
  attr4 user2.type3);
CREATE TABLE tab3 OF type4;
```

> **Note:** Customers should discontinue using the `CONNECT` and `RESOURCE` roles. The `CONNECT` role presently retains only the `CREATE SESSION` privilege.

Privileges on Type Access and Object Access

Existing column-level and table-level privileges for DML statements apply to both column objects and row objects.

Table 4–5 lists the privileges for object tables.

Table 4–5 Privileges for Object Tables

Privilege	Enables you to...
`SELECT`	Access an object and its attributes from the table
`UPDATE`	Modify the attributes of the objects that make up the rows in the table
`INSERT`	Create new objects in the table
`DELETE`	Delete rows

Similar table privileges and column privileges apply to column objects. Retrieving instances does not in itself reveal type information. However, clients must access named type information to interpret the type instance images. When a client requests type information, Oracle Database checks for the `EXECUTE` privilege on the type.

Consider the following schema:

```
CREATE TYPE emp_type (
    eno NUMBER, ename CHAR(31), eaddr addr_t);
CREATE TABLE emp OF emp_t;
```

In addition, consider the following two queries:

```
SELECT VALUE(emp) FROM emp;
SELECT eno, ename FROM emp;
```

For either query, Oracle Database checks the `SELECT` privilege of the user for the `emp` table. For the first query, the user must obtain the `emp_type` type information to interpret the data. When the query accesses the `emp_type` type, Oracle Database checks the `EXECUTE` privilege of the user.

The second query, however, does not involve named types, so Oracle Database does not check type privileges.

In addition, by using the schema from the previous section, `user3` can perform the following queries:

```
SELECT tab1.col1.attr2 FROM user2.tab1 tab1;
SELECT attr4.attr3.attr2 FROM tab3;
```

Note that in both `SELECT` statements, `user3` does not have explicit privileges on the underlying types, but the statement succeeds because the type and table owners have the necessary privileges with the `GRANT OPTION`.

Oracle Database checks privileges on the following events, and returns an error if the client does not have the privilege for the action:

- Pinning an object in the object cache using its `REF` value causes Oracle Database to check for the `SELECT` privilege on the containing object table.
- Modifying an existing object or flushing an object from the object cache causes Oracle Database to check for the `UPDATE` privilege on the destination object table.
- Flushing a new object causes Oracle Database to check for the `INSERT` privilege on the destination object table.
- Deleting an object causes Oracle Database to check for the `DELETE` privilege on the destination table.
- Pinning an object of a named type causes Oracle Database to check `EXECUTE` privilege on the object.

Modifying the attributes of an object in a client third-generation language application causes Oracle Database to update the entire object. Therefore, the user needs the `UPDATE` privilege on the object table. Having the `UPDATE` privilege on only certain columns of the object table is not sufficient, even if the application only modifies attributes corresponding to those columns. Therefore, Oracle Database does not support column-level privileges for object tables.

Type Dependencies

As with stored objects, such as procedures and tables, types being referenced by other objects are called dependencies. There are some special issues for types on which tables depend. Because a table contains data that relies on the type definition for access, any change to the type causes all stored data to become inaccessible. Changes that can cause this are when necessary privileges required to use the type are revoked, or the type or dependent types are dropped. If these actions occur, then the table becomes invalid and cannot be accessed.

A table that is invalid because of missing privileges can automatically become valid and accessible if the required privileges are granted again. A table that is invalid because a dependent type was dropped can never be accessed again, and the only permissible action is to drop the table.

Because of the severe effects that revoking a privilege on a type or dropping a type can cause, the SQL statements `REVOKE` and `DROP TYPE`, by default, implement restricted semantics. This means that if the named type in either statement has table or type dependents, then an error is received and the statement cancels. However, if the `FORCE` clause for either statement is used, then the statement always succeeds. If there are depended-upon tables, then they are invalidated.

> **See Also:** *Oracle Database Reference* for details about using the `REVOKE`, `DROP TYPE`, and `FORCE` clauses

Granting a User Privileges and Roles

This section contains:

- Granting System Privileges and Roles
- Granting Object Privileges
- Granting Privileges on Columns

It is also possible to grant roles to a user connected through a middle tier or proxy. This is discussed in "Using a Middle Tier Server for Proxy Authentication" on page 3-36.

Granting System Privileges and Roles

You can use the `GRANT` SQL statement to grant system privileges and roles to users and roles. The following privileges are required:

- To grant a system privilege, a user must be granted the system privilege with the `ADMIN` option or must be granted the `GRANT ANY PRIVILEGE` system privilege.
- To grant a role, a user must be granted the role with the `ADMIN` option or was granted the `GRANT ANY ROLE` system privilege.

Example 4–11 grants the system privilege `CREATE SESSION` and the `accts_pay` role to the user `jward`.

Example 4–11 Granting a System Privilege and a Role to a User

```
GRANT CREATE SESSION, accts_pay TO jward;
```

Example 4–11 grants the `EXECUTE` privilege on the `exec_dir` directory object to the user `jward`.

Example 4–12 Granting the EXECUTE Privilege on a Directory Object

```
GRANT EXECUTE ON DIRECTORY exec_dir TO jward;
```

> **Note:** Object privileges cannot be granted along with system privileges and roles in the same `GRANT` statement.

Granting the ADMIN Option

If you specify the WITH ADMIN OPTION clause when you grant a privilege or role to a user or role, then the privilege grant has the following expanded capabilities:

- The grantee can grant or revoke the system privilege or role to or from any other user or role in the database. Users cannot revoke a role from themselves.
- The grantee can grant the system privilege or role with the ADMIN option.
- The grantee of a role can alter or drop the role.

Example 4–13 grants the new_dba role with the WITH ADMIN OPTION clause to user michael.

Example 4–13 Granting the ADMIN Option

```
GRANT new_dba TO michael WITH ADMIN OPTION;
```

User michael is able to not only use all of the privileges implicit in the new_dba role, but he can also grant, revoke, and drop the new_dba role as deemed necessary. Because of these powerful capabilities, use caution when granting system privileges or roles with the ADMIN option. These privileges are usually reserved for a security administrator, and are rarely granted to other administrators or users of the system.

Note: When a user creates a role, the role is automatically granted to the creator with the ADMIN option.

Creating a New User with the GRANT Statement

Oracle Database enables you to create a new user with the GRANT statement. If you specify a password using the IDENTIFIED BY clause, and the user name does not exist in the database, then a new user with that user name and password is created.

Example 4–14 creates psmith as a new user while granting psmith the CREATE SESSION system privilege.

Example 4–14 Creating a New User with the GRANT Statement

```
GRANT CREATE SESSION TO psmith IDENTIFIED BY password;
```

See Also:

- "Creating User Accounts" on page 2-1
- "Minimum Requirements for Passwords" on page 3-3

Granting Object Privileges

You can use the GRANT statement to grant object privileges to roles and users. To grant an object privilege, you must fulfill one of the following conditions:

- You own the object specified.
- You have been granted the GRANT ANY OBJECT PRIVILEGE system privilege. This privilege enables you to grant and revoke privileges on behalf of the object owner.
- The WITH GRANT OPTION clause was specified when you were granted the object privilege.

Note: System privileges and roles cannot be granted along with object privileges in the same GRANT statement.

Example 4–15 grants the SELECT, INSERT, and DELETE object privileges for all columns of the emp table to the users jfee and tsmith.

Example 4–15 Granting Object Privileges to Users

```
GRANT SELECT, INSERT, DELETE ON emp TO jfee, tsmith;
```

To grant all object privileges on the salary view to user jfee, use the ALL keyword as shown in the following example:

```
GRANT ALL ON salary TO jfee;
```

Note: A grantee cannot regrant access to objects unless the original grant included the GRANT OPTION. Thus in the example just given, jfee cannot use the GRANT statement to grant object privileges to anyone else.

Specifying the GRANT OPTION Clause

Specify the WITH GRANT OPTION clause with the GRANT statement to enable the grantee to grant the object privileges to other users. The user whose schema contains an object is automatically granted all associated object privileges with the GRANT OPTION. This special privilege allows the grantee several expanded privileges:

- The grantee can grant the object privilege to any user in the database, with or without the GRANT OPTION, and to any role in the database.
- If both of the following conditions are true, then the grantee can create views on the table, and grant the corresponding privileges on the views to any user or role in the database:
  - The grantee receives object privileges for the table with the GRANT OPTION.
  - The grantee has the CREATE VIEW or CREATE ANY VIEW system privilege.

Note: The GRANT OPTION is not valid when granting an object privilege to a role. Oracle Database prevents the propagation of object privileges through roles so that grantees of a role cannot propagate object privileges received by means of roles.

Granting Object Privileges on Behalf of the Object Owner

The GRANT ANY OBJECT PRIVILEGE system privilege enables users to grant and revoke any object privilege on behalf of the object owner. This privilege provides a convenient means for database and application administrators to grant access to objects in any schema without requiring that they connect to the schema. Login credentials do not need to be maintained for schema owners who have this privilege, which reduces the number of connections required during configuration.

This system privilege is part of the Oracle Database supplied DBA role and is thus granted (with the ADMIN option) to any user connecting AS SYSDBA (user SYS). As with other system privileges, the GRANT ANY OBJECT PRIVILEGE system privilege can only be granted by a user who possesses the ADMIN option.

The *recorded* grantor of access rights to an object is either the object owner or the person exercising the GRANT ANY OBJECT PRIVILEGE system privilege. If the grantor with GRANT ANY OBJECT PRIVILEGE does *not* have the object privilege with the GRANT OPTION, then the object owner is shown as the grantor. Otherwise, when that grantor has the object privilege with the GRANT OPTION, then that grantor is recorded as the grantor of the grant.

> **Note:** The audit record generated by the GRANT statement always shows the actual user who performed the grant.

For example, consider the following scenario. User adams possesses the GRANT ANY OBJECT PRIVILEGE system privilege. He does not possess any other grant privileges. He issues the following statement:

```
GRANT SELECT ON HR.EMPLOYEES TO blake WITH GRANT OPTION;
```

If you examine the DBA_TAB_PRIVS view, then you will see that hr is shown as the grantor of the privilege:

```
SELECT GRANTEE, GRANTOR, PRIVILEGE, GRANTABLE
  FROM DBA_TAB_PRIVS
  WHERE TABLE_NAME = 'EMPLOYEES' and OWNER = 'HR';

GRANTEE  GRANTOR PRIVILEGE    GRANTABLE
-------- ------- -----------  ----------
BLAKE    HR       SELECT      YES
```

Now assume that user blake also has the GRANT ANY OBJECT PRIVILEGE system. He issues the following statement:

```
GRANT SELECT ON HR.EMPLOYEES TO clark;
```

In this case, when you query the DBA_TAB_PRIVS view again, you see that blake is shown as being the grantor of the privilege:

```
GRANTEE  GRANTOR  PRIVILEGE  GRANTABLE
-------- -------- ---------  ----------
BLAKE    HR       SELECT     YES
CLARK    BLAKE    SELECT     NO
```

This occurs because blake already possesses the SELECT privilege on HR.EMPLOYEES with the GRANT OPTION.

> **See Also:** "Revoking Object Privileges on Behalf of the Object Owner" on page 4-42

Granting Privileges on Columns

You can grant INSERT, UPDATE, or REFERENCES privileges on individual columns in a table.

Caution: Before granting a column-specific INSERT privilege, determine if the table contains any columns on which NOT NULL constraints are defined. Granting selective insert capability without including the NOT NULL columns prevents the user from inserting any rows into the table. To avoid this situation, ensure that each NOT NULL column can either be inserted into or has a non-NULL default value. Otherwise, the grantee will not be able to insert rows into the table and will receive an error.

The following statement grants the INSERT privilege on the acct_no column of the accounts table to user psmith:

```
GRANT INSERT (acct_no) ON accounts TO psmith;
```

In the following example, object privilege for the ename and job columns of the emp table are granted to the users jfee and tsmith:

```
GRANT INSERT(ename, job) ON emp TO jfee, tsmith;
```

Row-Level Access Control

You can also provide access control at the row level, that is, within objects, using Virtual Private Database (VPD) or Oracle Label Security (OLS).

See Also:

- Chapter 7, "Using Oracle Virtual Private Database to Control Data Access"
- "Adding Policies for Column-Level Oracle Virtual Private Database" on page 7-8
- *Oracle Label Security Administrator's Guide*

Revoking Privileges and Roles from a User

This section contains:

- Revoking System Privileges and Roles
- Revoking Object Privileges
- Cascading Effects of Revoking Privileges

Revoking System Privileges and Roles

You can revoke system privileges and roles using the SQL statement REVOKE. Any user with the ADMIN option for a system privilege or role can revoke the privilege or role from any other database user or role. The revoker does not have to be the user that originally granted the privilege or role. Users with GRANT ANY ROLE can revoke *any* role.

The following statement revokes the CREATE TABLE system privilege and the accts_rec role from user psmith:

```
REVOKE CREATE TABLE, accts_rec FROM psmith;
```

Note: The ADMIN option for a system privilege or role cannot be selectively revoked. Instead, revoke the privilege or role, and then grant the privilege or role again but without the ADMIN option.

Revoking Object Privileges

To revoke an object privilege, you must fulfill one of the following conditions:

- You previously granted the object privilege to the user or role.
- You possess the GRANT ANY OBJECT PRIVILEGE system privilege that enables you to grant and revoke privileges on behalf of the object owner.

You can only revoke the privileges that you, the person who granted the privilege, directly authorized. You cannot revoke grants that were made by other users to whom you granted the GRANT OPTION. However, there is a cascading effect. If the object privileges of the user who granted the privilege are revoked, then the object privilege grants that were propagated using the GRANT OPTION are revoked as well.

Assuming you are the original grantor of the privilege, the following statement revokes the SELECT and INSERT privileges on the emp table from users jfee and psmith:

```
REVOKE SELECT, INSERT ON emp FROM jfee, psmith;
```

The following statement revokes all object privileges for the dept table that you originally granted to the human_resource role:

```
REVOKE ALL ON dept FROM human_resources;
```

Note: The GRANT OPTION for an object privilege cannot be selectively revoked. Instead, revoke the object privilege and then grant it again but without the GRANT OPTION. Users cannot revoke object privileges from themselves.

Revoking Object Privileges on Behalf of the Object Owner

The GRANT ANY OBJECT PRIVILEGE system privilege enables you to revoke any specified object privilege where the object owner is the grantor. This occurs when the object privilege is granted by the object owner, or on behalf of the owner by any user holding the GRANT ANY OBJECT PRIVILEGE system privilege.

In a situation where the object privilege was granted by both the owner of the object and the user executing the REVOKE statement (who has both the specific object privilege and the GRANT ANY OBJECT PRIVILEGE system privilege), Oracle Database only revokes the object privilege granted by the user issuing the REVOKE statement. This can be illustrated by continuing the example started in "Granting Object Privileges on Behalf of the Object Owner" on page 4-39.

At this point, user blake granted the SELECT privilege on HR.EMPLOYEES to clark. Even though blake possesses the GRANT ANY OBJECT PRIVILEGE system privilege, he also holds the specific object privilege, thus this grant is attributed to him. Assume that user HR also grants the SELECT privilege on HR.EMPLOYEES to user clark. A query of the DBA_TAB_PRIVS view shows that the following grants are in effect for the HR.EMPLOYEES table:

```
GRANTEE  GRANTOR PRIVILEGE    GRANTABLE
-------- ------- -----------  ----------
BLAKE    HR       SELECT       YES
CLARK    BLAKE    SELECT       NO
```

```
CLARK    HR       SELECT       NO
```

User blake now issues the following REVOKE statement:

```
REVOKE  SELECT ON HR.EMPLOYEES FROM clark;
```

Only the object privilege for user clark granted by user blake is removed. The grant by the object owner, HR, remains.

```
GRANTEE  GRANTOR PRIVILEGE    GRANTABLE
-------- ------- -----------  ----------
BLAKE    HR       SELECT      YES
CLARK    HR       SELECT      NO
```

If blake issues the REVOKE statement again, then this time the effect is to remove the object privilege granted by adams (on behalf of HR), using the GRANT ANY OBEJCT PRIVILEGE system privilege.

> **See Also:** "Granting Object Privileges on Behalf of the Object Owner" on page 4-39

Revoking Column-Selective Object Privileges

Although users can grant column-specific INSERT, UPDATE, and REFERENCES privileges for tables and views, they cannot selectively revoke column-specific privileges with a similar REVOKE statement. Instead, the grantor must first revoke the object privilege for all columns of a table or view, and then selectively repeat the grant of the column-specific privileges that the grantor intends to keep in effect.

For example, assume that role human_resources was granted the UPDATE privilege on the deptno and dname columns of the table dept. To revoke the UPDATE privilege on just the deptno column, issue the following two statements:

```
REVOKE UPDATE ON dept FROM human_resources;
GRANT UPDATE (dname) ON dept TO human_resources;
```

The REVOKE statement revokes the UPDATE privilege on all columns of the dept table from the role human_resources. The GRANT statement then repeats, restores, or reissues the grant of the UPDATE privilege on the dname column to the role human_resources.

Revoking the REFERENCES Object Privilege

If the grantee of the REFERENCES object privilege has used the privilege to create a foreign key constraint (that currently exists), then the grantor can revoke the privilege only by specifying the CASCADE CONSTRAINTS option in the REVOKE statement:

```
REVOKE REFERENCES ON dept FROM jward CASCADE CONSTRAINTS;
```

Any foreign key constraints currently defined that use the revoked REFERENCES privilege are dropped when the CASCADE CONSTRAINTS clause is specified.

Cascading Effects of Revoking Privileges

Depending on the type of privilege, there may be cascading effects when a privilege is revoked. This is discussed in the following sections:

- Cascading Effects When Revoking System Privileges
- Cascading Effects When Revoking Object Privileges

Cascading Effects When Revoking System Privileges

There are no cascading effects when revoking a system privilege related to DDL operations, regardless of whether the privilege was granted with or without the ADMIN option. For example, assume the following:

1. The security administrator grants the CREATE TABLE system privilege to user jfee with the ADMIN option.
2. User jfee creates a table.
3. User jfee grants the CREATE TABLE system privilege to user tsmith.
4. User tsmith creates a table.
5. The security administrator revokes the CREATE TABLE system privilege from user jfee.
6. The table created by user jfee continues to exist. User tsmith still has the table and the CREATE TABLE system privilege.

You can observe cascading effects when you revoke a system privilege related to a DML operation. If the SELECT ANY TABLE privilege is revoked from a user, then all procedures contained in the user's schema relying on this privilege can no longer be executed successfully until the privilege is reauthorized.

Cascading Effects When Revoking Object Privileges

Revoking an object privilege can have cascading effects. Remember the following:

- **Object definitions that depend on a DML object privilege can be affected if the DML object privilege is revoked.** For example, assume that the body of the test procedure includes a SQL statement that queries data from the emp table. If the SELECT privilege on the emp table is revoked from the owner of the test procedure, then the procedure can no longer be executed successfully.
- **When a REFERENCES privilege for a table is revoked from a user, any foreign key integrity constraints that are defined by the user and require the dropped REFERENCES privilege are automatically dropped.** For example, assume that user jward is granted the REFERENCES privilege for the deptno column of the dept table. This user now creates a foreign key on the deptno column in the emp table that references the deptno column of the dept table. If the REFERENCES privilege on the deptno column of the dept table is revoked, then the foreign key constraint on the deptno column of the emp table is dropped in the same operation.
- **The object privilege grants propagated using the GRANT OPTION are revoked if the object privilege of a grantor is revoked.** For example, assume that user1 is granted the SELECT object privilege on the emp table with the GRANT OPTION, and grants the SELECT privilege on emp to user2. Subsequently, the SELECT privilege is revoked from user1. This REVOKE statement is also cascaded to user2. Any objects that depend on the revoked SELECT privilege of user1 and user2 can also be affected, as described earlier.

Object definitions that require the ALTER and INDEX DDL object privileges are not affected if the ALTER or INDEX object privilege is revoked. For example, if the INDEX privilege is revoked from a user that created an index on a table that belongs to another user, then the index continues to exist after the privilege is revoked.

Granting to and Revoking from the PUBLIC Role

You can grant and revoke privileges and roles from the role PUBLIC. Because PUBLIC is accessible to every database user, all privileges and roles granted to PUBLIC are accessible to every database user.

Security administrators and database users should grant a privilege or role to PUBLIC only if every database user requires the privilege or role. This recommendation reinforces the general rule that, at any given time, each database user should have only the privileges required to accomplish the current group tasks successfully.

Revoking a privilege from PUBLIC can cause significant cascading effects. If any privilege related to a DML operation is revoked from PUBLIC (for example, SELECT ANY TABLE or UPDATE ON emp), then all procedures in the database, including functions and packages, must be *reauthorized* before they can be used again. Therefore, be careful when you grant and revoke DML-related privileges to or from PUBLIC.

See Also:

- Managing Object Dependencies in *Oracle Database Administrator's Guide* for more information about object dependencies
- "Guidelines for Securing Data" on page 10-10

Granting Roles Using the Operating System or Network

This section contains:

About Granting Roles Using the Operating System or Network

Instead of a security administrator explicitly granting and revoking database roles to and from users using GRANT and REVOKE statements, the operating system on which Oracle Database runs can grant roles to users at connect time. Roles can be administered using the operating system and passed to Oracle Database when a user creates a session. As part of this mechanism, the default roles of a user and the roles granted to a user with the ADMIN option can be identified. If the operating system is used to authorize users for roles, then all roles must be created in the database and privileges assigned to the role with GRANT statements.

Roles can also be granted through a network service.

The advantage of using the operating system to identify the database roles of a user is that privilege management for an Oracle database can be externalized. The security facilities offered by the operating system control user privileges. This option may offer advantages of centralizing security for several system activities, such as the following situation:

- MVS Oracle administrators want RACF groups to identify database user roles.

- UNIX Oracle administrators want UNIX groups to identify database user roles.
- VMS Oracle administrators want to use rights identifiers to identify database user roles.

The main disadvantage of using the operating system to identify the database roles of a user is that privilege management can only be performed at the role level. Individual privileges cannot be granted using the operating system, but they can still be granted inside the database using `GRANT` statements.

A second disadvantage of using this feature is that, by default, users cannot connect to the database through the shared server or any other network connection if the operating system is managing roles. However, you can change this default as described in "Using Network Connections with Operating System Role Management" on page 4-47.

> **Note:** The features described in this section are available only on some operating systems. See your operating system-specific Oracle Database documentation to determine if you can use these features.

Using Operating System Role Identification

To cause a database to use the operating system to identify the database roles of each user when a session is created, set the initialization parameter `OS_ROLES` to `TRUE` (and restart the instance, if it is currently running). When a user tries to create a session with the database, Oracle Database initializes the user security domain using the database roles identified by the operating system.

To identify database roles for a user, the operating system account for each Oracle Database user must have operating system identifiers (these may be called groups, rights identifiers, or other similar names) that indicate which database roles are to be available for the user. Role specification can also indicate which roles are the default roles of a user and which roles are available with the `ADMIN` option. No matter which operating system is used, the role specification at the operating system level follows the format:

`ora_`*`ID_ROLE`*`[[_d][_a][_da]]`

In this specification:

- `ID` has a definition that varies on different operating systems. For example, on VMS, `ID` is the instance identifier of the database; on VMS, it is the computer type; and on UNIX, it is the system `ID`.

  > **Note:** `ID` is case-sensitive to match your `ORACLE_SID`. `ROLE` is not case-sensitive.

- `ROLE` is the name of the database role.
- `d` is an optional character that indicates this role is to be a default role of the database user.
- `a` is an optional character that indicates this role is to be granted to the user with the `ADMIN` option. This allows the user to grant the role to other roles only. Roles cannot be granted to users if the operating system is used to manage roles.

Note: If either the d or a character is specified, then precede that character by an underscore (_).

For example, an operating system account might have the following roles identified in its profile:

```
ora_PAYROLL_ROLE1
ora_PAYROLL_ROLE2_a
ora_PAYROLL_ROLE3_d
ora_PAYROLL_ROLE4_da
```

When the corresponding user connects to the payroll instance of Oracle Database, role3 and role4 are defaults, while role2 and role4 are available with the ADMIN option.

Using Operating System Role Management

When you use operating system-managed roles, remember that database roles are being granted to an operating system user. Any database user to which the operating system user is able to connect will have the authorized database roles enabled. For this reason, you should consider defining all Oracle Database users as IDENTIFIED EXTERNALLY if you are using OS_ROLES = TRUE, so that the database accounts are tied to the operating system account that was granted privileges.

Granting and Revoking Roles When OS_ROLES Is Set to TRUE

If the OS_ROLES parameter is set to TRUE, then the operating system completely manages the granting and revoking of roles to users. Any previous granting of roles to users using GRANT statements do not apply. However, they are still listed in the data dictionary. Only the role grants to users made at the operating system level apply. Users can still grant privileges to roles and users.

Note: If the operating system grants a role to a user with the ADMIN option, then the user can grant the role only to other roles.

Enabling and Disabling Roles When OS_ROLES Is Set to TRUE

If the OS_ROLES initialization parameter is set to TRUE, then any role granted by the operating system can be dynamically enabled using the SET ROLE statement. This still applies, even if the role was defined to require a password or operating system authorization. However, any role not identified in the operating system account of a user cannot be specified in a SET ROLE statement, even if a role was granted using a GRANT statement when OS_ROLES = FALSE. (If you specify such a role, then Oracle Database ignores it.)

When OS_ROLES is set to TRUE, then the user can enable up to 148 roles. Remember that this number includes other roles that may have been granted to the role.

Using Network Connections with Operating System Role Management

If you have the operating system manage roles, then, by default, users cannot connect to the database through the shared server. This restriction is the default because a remote user could impersonate another operating system user over an unsecure connection.

If you are not concerned with this security risk and want to use operating system role management with the shared server, or any other network connection, then set the initialization parameter REMOTE_OS_ROLES to TRUE. The change takes effect the next time you start the instance and mount the database. The default setting of this parameter is FALSE.

When Do Grants and Revokes Take Effect?

Depending on what is granted or revoked, a grant or revoke takes effect at different times:

- All grants and revokes of system and object privileges to anything (users, roles, and PUBLIC) take immediate effect.
- All grants and revokes of roles to anything (users, other roles, PUBLIC) take effect only when a current user session issues a SET ROLE statement to reenable the role after the grant and revoke, or when a new user session is created after the grant or revoke.

You can see which roles are currently enabled by examining the SESSION_ROLES data dictionary view.

How the SET ROLE Statement Affects Grants and Revokes

During the user session, the user or an application can use the SET ROLE statement any number of times to change the roles currently enabled for the session. The user must already be granted the roles that are named in the SET ROLE statement.

Example 4–16 enables the role clerk, which you have already been granted, and specifies the password.

Example 4–16 Using SET ROLE to Grant a Role and Specify a Password

```
SET ROLE clerk IDENTIFIED BY password;
```

Replace *password* with a password that is secure. "Minimum Requirements for Passwords" on page 3-3 describes the minimum requirements for passwords.

Example 4–17 shows how to use SET ROLE to disable all roles.

Example 4–17 Using SET ROLE to Disable All Roles

```
SET ROLE NONE;
```

Specifying a Default Role

When a user logs on, Oracle Database enables all privileges granted explicitly to the user and all privileges in the default roles of the user.

You can set and alter a list of default roles for a user by using the ALTER USER SQL statement. The ALTER USER statement specifies roles that are to be enabled when a user connects to the database. The user must have been directly granted the roles with a GRANT statement, or the roles must have been created by the user with the CREATE ROLE privilege. For information about the restrictions of the DEFAULT ROLE clause of the ALTER USER statement, see *Oracle Database SQL Language Reference*.

Example 4–18 sets the default roles payclerk and pettycash for user jane:

Example 4–18 Using ALTER USER to Set Default Roles

```
ALTER USER jane DEFAULT ROLE payclerk, pettycash;
```

You cannot set default roles for a user in the `CREATE USER` statement. When you first create a user, the default user role setting is `ALL`, which causes all roles subsequently granted to the user to be default roles. Use the `ALTER USER` statement to limit the default user roles.

Note: When you create a role (other than a global role or an application role), it is granted implicitly to you, and your set of default roles is updated to include the new role. Be aware that only 148 roles can be enabled for a user session. When aggregate roles, such as the `DBA` role, are granted to a user, the roles granted to the role are included in the number of roles the user has. For example, if a role has 20 roles granted to it and you grant that role to the user, then the user now has 21 additional roles. Therefore, when you grant new roles to a user, use the `DEFAULT ROLE` clause of the `ALTER USER` statement to ensure that not too many roles are specified as that user's default roles.

The Maximum Number of Roles That a User Can Enable

A user can enable no more than 148 roles.You can grant a user as many roles as you want, but you should restrict the number of roles granted to a user to the minimum roles the user needs. See "Guidelines for Securing Roles" on page 10-6 for additional guidelines on granting roles to users.

Managing Fine-Grained Access in PL/SQL Packages and Types

You can configure user access control to external network services and wallets through the `UTL_TCP`, `UTL_SMTP`, `UTL_MAIL`, `UTL_HTTP`, and `UTL_INADDR` PL/SQL packages, the `DBMS_LDAP` PL/SQL package, and the `HttpUriType` type.

- **Configuring fine-grained access control for users and roles that need to access external network services from the database.** This way, specific groups of users can connect to one or more host computers, based on privileges that you grant them. Typically, you use this feature to control access to applications that run on specific host addresses.
- **Configuring fine-grained access control to Oracle wallets to make HTTP requests that require password or client-certificate authentication.** This feature enables you to grant privileges to users who are using passwords and client certificates stored in Oracle wallets to access external protected HTTP resources through the `UTL_HTTP` package. For example, you can configure applications to use the credentials stored in the wallets instead of hard-coding the credentials in the applications. For more information about how you can use wallets to store passwords and credentials, see *Oracle Database Advanced Security Administrator's Guide*.

This section contains:

About Fine-Grained Access Control to External Network Services

To configure fine-grained access control to external network services, you create an access control list (ACL), which is stored in Oracle XML DB. You can create the access control list by using Oracle XML DB itself, or by using the `DBMS_NETWORK_ACL_ADMIN` and `DBMS_NETWORK_ACL_UTILITY` PL/SQL packages. This guide explains how to use these packages to create and manage the access control list. To create an access control list by using Oracle XML DB and for general conceptual information about access control lists, see *Oracle XML DB Developer's Guide*.

This feature enhances security for network connections because it restricts the external network hosts that a database user can connect to using the PL/SQL network utility packages `UTL_TCP`, `UTL_SMTP`, `UTL_MAIL`, `UTL_HTTP`, and `UTL_INADDR`, the `DBMS_LDAP` PL/SQL package, and the `HttpUriType` type. Otherwise, an intruder who gained access to the database could maliciously attack the network, because, by default, the PL/SQL utility packages are created with the `EXECUTE` privilege granted to `PUBLIC` users. These PL/SQL network utility packages, and the `DBMS_NETWORK_ACL_ADMIN` and `DBMS_NETWORK_ACL_UTILITY` packages, support both IP Version 4 (IPv4) and IP Version 6 (IPv6) addresses. This guide explains how to manage access control to both versions. For detailed information about how the IPv4 and IPv6 notation works with Oracle Database, see *Oracle Database Net Services Administrator's Guide*.

> **See Also:** "Tutorial: Adding an Email Alert to a Fine-Grained Audit Policy" on page 9-44 for an example of configuring access control to external network services for email alerts

About Access Control to Wallets

When a user accesses Web pages that are protected by a remote Web server, the user can authenticate himself or herself by supplying the passwords and client certificates that are stored in an Oracle wallet. The Oracle wallet provides secure storage of user passwords and client certificates.

To configure access control to a wallet, you need the following components:

- **An Oracle wallet.** You can create the wallet using the Oracle Database `mkstore` utility or Oracle Wallet Manager. The HTTP request will use the external password store or the client certificate in the wallet to authenticate the user

- **An access control list to grant privileges to the user to use the wallet.** To create the access control list, you use the DBMS_NETWORK_ACL_ADMIN PL/SQL package.
- **A way to associate the wallet with the access control list.** To do so, use the DBMS_NETWORK_ACL_ADMIN PL/SQL package.

The use of wallets is beneficial because it provides secure storage of passwords and client certificates necessary to access protected Web pages.

See Also: "Configuring Access Control to a Wallet" on page 4-55

Upgrading Applications That Depend on Packages That Use External Network Services

If you have upgraded from a release before Oracle Database 11*g* Release 1 (11.1), and your applications depend on PL/SQL network utility packages UTL_TCP, UTL_SMTP, UTL_MAIL, UTL_HTTP, and UTL_INADDR, the DBMS_LDAP PL/SQL package, or the HttpUriType type, then the following error may occur when you try to run the application:

```
ORA-24247: network access denied by access control list (ACL)
```

Use the procedures in this section to reconfigure the network access for the application. See also *Oracle Database Upgrade Guide* for compatibility issues for applications that depend on the PL/SQL network utility packages. For detailed information about the network utility packages, see *Oracle Database PL/SQL Packages and Types Reference*.

Creating an Access Control List for External Network Services

When you create access control lists for network connections, you should create one access control list dedicated to a group of common users, for example, users who need access to a particular application that resides on a specific host computer. For ease of administration and for good system performance, do not create too many access control lists. Network hosts accessible to the same group of users should share the same access control list.

To create the access control list by using the DBMS_NETWORK_ACL_ADMIN package, follow these steps:

- Step 1: Create the Access Control List and Its Privilege Definitions
- Step 2: Assign the Access Control List to One or More Network Hosts

Step 1: Create the Access Control List and Its Privilege Definitions

Use the DBMS_NETWORK_ACL_ADMIN.CREATE_ACL procedure to create the content of the access control list. It contains a name of the access control list, a brief description, and privilege settings for one user or role that you want to associate with the access control list. In an access control list, privileges for each user or role are grouped together as an access control entry (ACE). An access control list must have the privilege settings for at least one user or role.

Note: You cannot import or export the access control list settings by using the Oracle Database import or export utilities such as Oracle Data Pump.

---

for example:

```
BEGIN
```

```
 DBMS_NETWORK_ACL_ADMIN.CREATE_ACL (
  acl          => 'file_name.xml',
  description  => 'file description',
  principal    => 'user_or_role',
  is_grant     => TRUE|FALSE,
  privilege    => 'connect|resolve',
  start_date   => null|timestamp_with_time_zone,
  end_date     => null|timestamp_with_time_zone);
END;
```

In this specification:

- `acl`: Enter a name for the access control list XML file. Oracle Database creates this file relative to the `/sys/acls` directory in the XML DB Repository in the database. Include the `.xml` extension. For example:

  ```
  acl => 'us-example-com-permissions.xml',
  ```

- `description`: Enter a brief description of the purpose of this file. For example:

  ```
  description => 'Network connection permission for ACCT_MGR role',
  ```

- `principal`: Enter the first user account or role being granted or denied permissions. For example:

  ```
  principal => 'ACCT_MGR',
  ```

  Enter the name of the user account or role in case sensitive characters. For example, if the database stores the role name `ACCT_MGR` in all capital letters, entering it in mixed or lower case will not work. You can find the user accounts and roles in the current database instance by querying the `DBA_USERS` and `DBA_ROLES` data dictionary views. Typically, user names and roles are stored in upper-case letters.

  If you want to enter multiple users or grant additional privileges to this user or role, use the `DBMS_NETWORK_ACL.ADD_PRIVILEGE` procedure (described next) after you have created this access control list XML file.

- `is_grant`: Enter either `TRUE` or `FALSE`, to indicate whether the privilege is to be granted or denied. For example:

  ```
  is_grant => TRUE,
  ```

- `privilege`: Enter either `connect` or `resolve`. This setting is case sensitive, so always enter it in lowercase. For example:

  ```
  privilege => 'connect',
  ```

  The `connect` privilege grants the user permission to connect to a network service at an external host. The `resolve` privilege grants the user permission to resolve a network host name or an IP address.

  A database user needs the `connect` privilege to an external network host computer if he or she is connecting using the `UTL_TCP`, `UTL_SMTP`, `UTL_MAIL`, `UTL_HTTP`, the `DBMS_LDAP` package, and the `HttpUriType` type. To resolve the host name that was given a host IP address, or the IP address that was given a host name, with the `UTL_INADDR` package, grant the database user the `resolve` privilege instead.

  You can use the data dictionary views described in "Finding Information About Access Control Lists Configured for User Access" on page 4-71 to find more information about existing privileges and network connections.

- start_date: (Optional) Enter the start date for the access control entry (ACE), in TIMESTAMP WITH TIME ZONE format (YYYY-MM-DD HH:MI:SS.FF TZR). When specified, the access control entry will be valid only on or after the specified date. The default is null. For example, to set a start date of February 28, 2008, at 6:30 a.m. in San Francisco, California, U.S., which is in the Pacific time zone:

  ```
  start_date => '2008-02-28 06:30:00.00 US/Pacific',
  ```

  The NLS_TIMESTAMP_FORMAT initialization parameter sets the default timestamp format. See *Oracle Database Reference* for more information.

- end_date: (Optional) Enter the end date for the access control entry (ACE), in TIMESTAMP WITH TIME ZONE format (YYYY-MM-DD HH:MI:SS.FF TZR). When specified, the access control entry expires after the specified date. The end_date setting must be greater than or equal to the start_date setting. The default is null.

  For example, to set an end date of December 10, 2008, at 11:59 p.m. in San Francisco, California, U.S., which is in the Pacific time zone:

  ```
  end_date => '2008-12-10 23:59:00.00 US/Pacific');
  ```

To add more users or roles to the access control list, or grant additional privileges to one user or role, use the DBMS_NETWORK_ACL.ADD_PRIVILEGE procedure. The syntax is as follows:

```
BEGIN
 DBMS_NETWORK_ACL_ADMIN.ADD_PRIVILEGE (
  acl         => 'file_name.xml',
  principal   => 'user_or_role',
  is_grant    => TRUE|FALSE,
  privilege   => 'connect|resolve',
  position    => null|value,
  start_date  => null|timestamp_with_time_zone,
  end_date    => null|timestamp_with_time_zone);
END;
```

As you can see, the parameters to add the privilege are the similar to those in the CREATE_ACL procedure, except that description is not included and the position parameter, which sets the order of precedence for multiple users or roles, was added. Because you now are adding more than one user or role, you may want to consider setting their precedence. "Setting the Precedence of Multiple Users and Roles in One Access Control List" on page 4-69 provides more information.

Other DBMS_NETWORK_ACL_ADMIN procedures that are available for this step are DELETE_PRIVILEGE and DROP_ACL.

At this stage, you have created an access control list that defines the privileges needed to connect to a network host. However, the access control list has no effect until you complete Step 2: Assign the Access Control List to One or More Network Hosts.

Step 2: Assign the Access Control List to One or More Network Hosts

After you create the access control list, then you are ready to assign it to one or more network host computers. You can use the DBMS_NETWORK_ACL_ADMIN.ASSIGN_ACL procedure to do so.

For example:

```
BEGIN
 DBMS_NETWORK_ACL_ADMIN.ASSIGN_ACL (
  acl         => 'file_name.xml',
```

```
  host        => 'network_host',
  lower_port  => null|port_number,
  upper_port  => null|port_number);
END;
```

In this specification:

- `acl`: Enter the name of the access control list XML file (from Step 1: Create the Access Control List and Its Privilege Definitions) to assign to the network host. Oracle Database creates this file relative to the `/sys/acls` directory in the XML DB Repository in the database. Include the `.xml` extension. For example:

  ```
  acl => 'us-example-com-permissions.xml',
  ```

- `host`: Enter the network host to which this access control list will be assigned. This setting can be a name or IP address of the network host. Host names are case insensitive. For example:

  ```
  host => 'us.example.com',
  ```

  If you specify `localhost`, and if the host name has not been specified with the `UTL_INADDR` and `UTL_HTTP` PL/SQL packages in situations in which the local host is assumed, then these packages will search for and use the ACL that has been assigned `localhost` for the `host` setting.

  See the following sections for more information about how network host computers in access control list assignments work:

  - "Specifying a Group of Network Host Computers" on page 4-64
  - "Checking Privilege Assignments That Affect User Access to a Network Host" on page 4-66
  - "Precedence Order for a Host Computer in Multiple Access Control List Assignments" on page 4-65
  - "Precedence Order for a Host in Access Control List Assignments with Port Ranges" on page 4-66

- `lower_port`: (Optional) For TCP connections, enter the lower boundary of the port range. Use this setting for the `connect` privilege only; omit it for the `resolve` privilege. The default is `null`, which means that there is no port restriction (that is, the ACL applies to all ports). The range of port numbers is between 1 and 65535.

  For example:

  ```
  lower_port => 80,
  ```

- `upper_port`: (Optional) For TCP connections, enter the upper boundary of the port range. Use this setting for `connect` privileges only; omit it for `resolve` privileges. The default is `null`, which means that there is no port restriction (that is, the ACL applies to all ports). The range of port numbers is between 1 and 65535

  For example:

  ```
  upper_port => 3999);
  ```

  If you enter a value for the `lower_port` and leave the `upper_port` at `null` (or just omit it), Oracle Database assumes the `upper_port` setting is the same as the `lower_port`. For example, if you set `lower_port` to `80` and omit `upper_port`, the `upper_port` setting is assumed to be `80`.

The `resolve` privilege in the access control list takes no effect when a port range is specified in the access control list assignment.

Only one access control list can be assigned to any host computer, domain, or IP subnet, and if specified, the TCP port range. When you assign a new access control list to a network target, Oracle Database unassigns the previous access control list that was assigned to the same target. However, Oracle Database does not drop the access control list. You can drop the access control list by using the `DROP_ACL` procedure. To remove an access control list assignment, use the `UNASSIGN_ACL` procedure.

Depending on how you create and maintain the access control list, the two steps may overlap. For example, you can create an access control list that has privileges for five users in it, and then apply it to two host computers. Later on, you can modify this access control list to have different or additional users and privileges, and assign it to different or additional host computers.

All access control list changes, including the assignment to network hosts, are transactional. They do not take effect until the transaction is committed.

You can find information about existing privileges and network connections by using the data dictionary views described in Table 4–6, " Data Dictionary Views That Display Information about Access Control Lists" on page 4-71.

For information about using the `DBMS_NETWORK_ACL_ADMIN` package, see *Oracle Database PL/SQL Packages and Types Reference*.

Configuring Access Control to a Wallet

This method lets you grant access to the passwords and client certificates that are stored in an Oracle wallet to users to authenticate themselves to an external Web server. This enables the user to retrieve protected Web pages from the Web server.

This section contains:

- Step 1: Create an Oracle Wallet
- Step 2: Create an Access Control List that Grants the Wallet Privileges
- Step 3: Assign the Access Control List to the Wallet
- Step 4: Make the HTTP Request with the Passwords and Client Certificates

Step 1: Create an Oracle Wallet

To create the wallet, you can use either the `mkstore` command-line utility or the Oracle Wallet Manager user interface. To store passwords in the wallet, you must use `mkstore`. You can use both standard and PKCS11 wallet types, and the wallet can be an auto-login wallet if you want. For detailed information about creating wallets, see *Oracle Database Advanced Security Administrator's Guide*.

When you create the wallet, do the following:

- Ensure that you have exported the wallet to a file.
- Make a note of the directory in which you created the wallet. You will need this directory path when you complete the procedures in this section.

See Also:

- "Example of an Access Control List for Using Passwords in a Non-Shared Wallet" on page 4-62
- "Example of an Access Control List for Wallets in a Shared Database Session" on page 4-64

Step 2: Create an Access Control List that Grants the Wallet Privileges

After you have created the wallet, you are ready to create the access control list that will assign the password or client certificate privilege the user needs to use password credentials in the wallet for HTTP authentication.

For example:

```
BEGIN
 DBMS_NETWORK_ACL_ADMIN.CREATE_ACL (
  acl         => 'file_name.xml',
  description => 'description',
  principal   => 'user_or_role',
  is_grant    => TRUE|FALSE,
  privilege   => 'privilege';
...
END;
```

In this specification:

- `acl`: Enter a name for the ACL, and make a note of this name. You will need this name in Step 3: Assign the Access Control List to the Wallet, next. Oracle Database creates this file relative to the `/sys/acls` directory in the XML DB Repository in the database. Include the `.xml` extension. For example:

  ```
  acl         => 'hr_access_wallet_acl.xml',
  ```

- `description`: Enter a brief description of the purpose of this file. For example:

  ```
  description => 'Wallet ACL for the hr_access application',
  ```

- `principal`: Enter the user account or role being granted or denied privileges. For example:

  ```
  principal   => 'HR_CLERK',
  ```

  Enter this name using case sensitive characters. For example, if the database stores the role name `HR_CLERK` in all capital letters, entering it in mixed or lower-case letters will not work. You can find the user accounts and roles in the current database instance by querying the `DBA_USERS` and `DBA_ROLES` data dictionary views. Typically, user names and roles are stored in upper-case letters.

  If you want to add multiple users, or if you want to grant this user an additional privilege, you can use the `DBMS_NETWORK_ACL.ADD_PRIVILEGE` procedure after you have created this access control list XML file.

- `is_grant`: Enter either `TRUE` or `FALSE`, to indicate whether the privilege is to be granted or denied. For example:

  ```
  is_grant    => TRUE,
  ```

- `privilege`: Enter one of the following settings using lowercase letters and hyphens. Remember that the privilege name is case-sensitive.

  – `use-passwords` to give the user permission to use passwords in the wallet

– `use-client-certificates` to authenticate the user with a client certificate in the wallet

For example:

```
privilege    => 'use-client-certificates');
```

Step 3: Assign the Access Control List to the Wallet

In this step, you assign this access control list to the wallet you created earlier. Afterward, you can check your settings by querying the `DBA_WALLET_ACLS` data dictionary view.

For example:

```
BEGIN
...
 DBMS_NETWORK_ACL_ADMIN.ASSIGN_WALLET_ACL (
  acl         => 'file_name.xml',
  wallet_path => 'file:path_to_directory_containing_wallet');
END;
```

In this specification:

- `acl`: Enter the name that you created for this wallet in Step 2: Create an Access Control List that Grants the Wallet Privileges, in the previous section. For example:

  ```
  acl         => 'hr_access_wallet_acl.xml',
  ```

- `wallet_path`: Enter the path to the directory that contains the wallet. When you specify the wallet path, you must use an absolute path and include `file:` before this directory path. Do not use environment variables, such as `$ORACLE_HOME`, nor insert a space after `file:` and before the path name. For example:

  ```
  wallet_path => 'file:/oracle/wallets/hr_access_access'
  ```

Step 4: Make the HTTP Request with the Passwords and Client Certificates

In this step, you use the `UTL_HTTP` PL/SQL package to create a request context object that is used privately with the HTTP request and its response. For detailed information about the `UTL_HTTP` package, see *Oracle Database PL/SQL Packages and Types Reference*.

For example:

```
DECLARE
 req_context UTL_HTTP.REQUEST_CONTEXT_KEY;
 req         UTL_HTTP.REQ;
BEGIN
 req_context := UTL_HTTP.CREATE_REQUEST_CONTEXT (
              wallet_path          => 'file:path_to_directory_containing_wallet',
              wallet_password      => 'wallet_password'|NULL);
 req := UTL_HTTP.BEGIN_REQUEST(
              url                  => 'URL_to_application',
              request_context      => 'request_context'|NULL);
 ...
END;
```

In this specification:

- `req_context`: Use the `UTL_HTTP.CREATE_REQUEST_CONTEXT_KEY` datatype to create the request context object. This object stores a randomly-generated numeric key that Oracle Database uses to identify the request context. The `UTL_HTTP.CREATE_REQUEST_CONTEXT` function creates the request context itself.

- req: Use the UTL_HTTP.REQ datatype to create the object that will be used to begin the HTTP request. You will refer to this object later on, when you set the user name and password from the wallet to access a password-protected Web page.
- wallet_path: Enter the path to the directory that contains the wallet. Ensure that this path is the same path you specified when you created access control list in Step 3: Assign the Access Control List to the Wallet in the previous section.You must include file: before the directory path. Do not use environment variables, such as $ORACLE_HOME.

  For example:

  ```
  wallet_path     => 'file:/oracle/wallets/hr_access_access',
  ```

- wallet_password: Enter the password used to open the wallet. The default is NULL, which is used for auto-login wallets. For example:

  ```
  wallet_password      => NULL);
  ```

- url: Enter the URL to the application that uses the wallet.

  For example:

  ```
  url                  => 'www.hr_access.example.com',
  ```

- request_context: Enter the name of the request context object that you created earlier in this section. This object prevents the wallet from being shared with other applications in the same database session.

  For example:

  ```
  request_context      => req_context);
  ```

Using a Request Context to Hold the Wallet When Sharing the Session with Other Applications

You should use a request context to hold the wallet when the database session is shared with other applications. If your application has exclusive use of the database session, you can hold the wallet in the database session by using the SET_WALLET procedure instead.

For example:

```
DECLARE
 req         UTL_HTTP.REQ;
BEGIN
 UTL_HTTP.SET_WALLET(
              path          => 'file:path_to_directory_containing_wallet',
              password      => 'wallet_password'|NULL);
 req := UTL_HTTP.BEGIN_REQUEST(
              url           => 'URL_to_application');
 ...
END;
```

If the protected URL being requested requires the user name and password to authenticate, then use the SET_AUTHENTICATION_FROM_WALLET procedure to set the user name and password from the wallet to authenticate.

Using Only a Client Certificate to Authenticate

If the protected URL being requested requires only the client certificate to authenticate, the BEGIN_REQUEST function sends the necessary client certificate from the wallet. assuming the user has been granted the use-client-certificates privilege in the

ACL assigned to the wallet. The authentication should succeed at the remote Web server and the user can proceed to retrieve the HTTP response by using the GET_RESPONSE function.

Using the Password to Authenticate

If the protected URL being requested requires the username and password to authenticate, you should use the SET_AUTHENTICATION_FROM_WALLET procedure to set the username and password from the wallet to authenticate.

For example:

```
DECLARE
 req_context UTL_HTTP.REQUEST_CONTEXT_KEY;
 req         UTL_HTTP.REQ;
BEGIN
...
 UTL_HTTP.SET_AUTHENTICATION_FROM_WALLET(
  r               => HTTP_REQUEST,
  alias           => 'alias_to_retrieve_credentials_stored_in_wallet',
  scheme          => 'AWS|Basic',
  for_proxy       => TRUE|FALSE);
END;
```

In this specification:

- r: Enter the HTTP request defined in the UTL_HTTP.BEGIN_REQUEST procedure that you created above, in the previous section. For example:

  ```
  r               => req,
  ```

- alias: Enter the alias used to identify and retrieve the user name and password credential stored in the Oracle wallet. For example, assuming the alias used to identify this user name and password credential is hr_access.

  ```
  alias           => 'hr_access',
  ```

- scheme: Enter one of the following:

  – AWS: Specifies the Amazon Simple Storage Service (S3) scheme. Use this scheme only if you are configuring access to the Amazon.com Web site. (Contact Amazon for more information about this setting.)

  – Basic: Specifies HTTP basic authentication. The default is Basic.

  For example:

  ```
  scheme          => 'Basic',
  ```

- for_proxy: Specify whether the HTTP authentication information is for access to the HTTP proxy server instead of the Web server. The default is FALSE.

  For example:

  ```
  for_proxy       => TRUE);
  ```

The use of the user name and password in the wallet requires the use-passwords privilege to be granted to the user in the ACL assigned to the wallet.

Examples of Creating Access Control Lists

The following examples demonstrate how to create access control lists.

- Example of an Access Control List for a Single Role and Network Connection

- Example of an Access Control List with Multiple Roles Assigned to Multiple Hosts
- Example of an Access Control List for Using Passwords in a Non-Shared Wallet
- Example of an Access Control List for Wallets in a Shared Database Session

> **See Also:** *Oracle Database Vault Administrator's Guide* for a tutorial that demonstrates how to use an access control list when an administrator must use the `UTL_MAIL` PL/SQL package to configure an email alert

Example of an Access Control List for a Single Role and Network Connection

Example 4–19 shows how you would create an access control list called `us-example-com-permissions.xml` to grant users who have the `ACCT_MGR` role access to network services that run on the host `us.example.com`.

Example 4–19 Creating an Access Control List for a Single Role and Network Connection

```
-- 1. Create the access control list, which includes one role:
BEGIN
 DBMS_NETWORK_ACL_ADMIN.CREATE_ACL (
  acl          => 'us-example-com-permissions.xml',
  description  => 'Network connection permission for ACCT_MGR',
  principal    => 'ACCT_MGR', -- Must be in upper case
  is_grant     => TRUE,
  privilege    => 'connect');
END;
/

-- 2. Assign the access control list a network host:
BEGIN
 DBMS_NETWORK_ACL_ADMIN.ASSIGN_ACL (
  acl         => 'us-example-com-permissions.xml',
  host        => 'www.us.example.com',
  lower_port  => 80,
  upper_port  => 80);
END;
/
```

This example creates the `us-example-com-permissions.xml` file in the `/sys/acls` directory, which is the default location. The XML file appears as follows:

```
<acl description="Network connection permission for ACCT_MGR"
  xmlns="http://xmlns.oracle.com/xdb/acl.xsd"
  xmlns:plsql="http://xmlns.oracle.com/plsql"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://xmlns.oracle.com/xdb/acl.xsd
http://xmlns.oracle.com/xdb/acl.xsd">
  <security-class>plsql:network</security-class>
  <ace>
    <grant>true</grant>
    <principal>ACCT_MGR</principal>
    <privilege><plsql:connect/></privilege>
 </ace>
</acl>
```

The `xmlns` and `xsi` elements are fixed and should not be modified, for example, in a text editor.

You can check the contents of the access control list in SQL*Plus. See *Oracle XML DB Developer's Guide* for examples.

Example of an Access Control List with Multiple Roles Assigned to Multiple Hosts

Example 4–20 shows how to create a slightly more complex version of the `us-example-com-permissions.xml` access control list. In this example, you specify multiple role privileges and their precedence position, and assigned to multiple host computers.

See"Specifying a Group of Network Host Computers" on page 4-64 and "Precedence Order for a Host Computer in Multiple Access Control List Assignments" on page 4-65 for more information about host names. See also "Setting the Precedence of Multiple Users and Roles in One Access Control List" on page 4-69 to determine the order of multiple `ACE` elements in the access control list XML file.

Example 4–20 Creating an Access Control List for Multiple Roles and Network Connections

```
-- 1. Create the access control list:
BEGIN
 DBMS_NETWORK_ACL_ADMIN.CREATE_ACL (
  acl          => 'us-example-com-permissions.xml',
  description  => 'Network connection permission for ACCT_MGR and ACCT_CLERK',
  principal    => 'ACCT_MGR', -- Must be in upper case
  is_grant     => TRUE,
  privilege    => 'resolve');
 DBMS_NETWORK_ACL_ADMIN.ADD_PRIVILEGE ( -- Creates the second role privilege
  acl          => 'us-example-com-permissions.xml',
  principal    => 'ACCT_CLERK',
  is_grant     => TRUE,
  privilege    => 'connect',
  position     => null);
END;
/

-- 2. Assign the access control list to hosts:
BEGIN
 DBMS_NETWORK_ACL_ADMIN.ASSIGN_ACL ( -- Creates the first target host
  acl          => 'us-example-com-permissions.xml',
  host         => '*.us.example.com');
 DBMS_NETWORK_ACL_ADMIN.ASSIGN_ACL ( -- Creates the second target host
  acl          => 'us-example-com-permissions.xml',
  host         => '*.uk.example.com',
  lower_port   => 80,
  upper_port   => 99);
END;
/
```

The `us-example-com-permissions.xml` appears as follows:

```
<acl description="Network connection permission for ACCT_MGR and ACCT_CLERK"
  xmlns="http://xmlns.oracle.com/xdb/acl.xsd"
  xmlns:plsql="http://xmlns.oracle.com/plsql"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://xmlns.oracle.com/xdb/acl.xsd
http://xmlns.oracle.com/xdb/acl.xsd">
  <security-class>plsql:network</security-class>
  <ace>
    <grant>true</grant>
```

```
    <principal>ACCT_MGR</principal>
    <privilege><plsql:resolve/></privilege>
  </ace>
  <ace>
    <grant>true</grant>
    <principal>ACCT_CLERK</principal>
    <privilege><plsql:connect/></privilege>
  </ace>
</acl>
```

Example 4–21 shows how the DBA_NETWORK_ACL_PRIVILEGES data dictionary view displays the privilege granted in the previous access control list.

Example 4–21 Using the DBA_NETWORK_ACL_PRIVILEGES View to Show Granted Privileges

```
ACL
ACLID               PRINCIPAL  PRIVILEGE IS_GRANT INVERT
START_DATE END_DATE
----------------------------------------
------------------------------ ---------- -------   -------- -------
---------- ----------
/sys/acls/us-example-com-permissions.xml 2EF86135D0E29B2AE040578CE4043250 ACCT_
MGR   resolve   true   false
/sys/acls/us-example-com-permissions.xml 2EF86135D0E29B2AE040578CE4043250 ACCT_
CLERK connect   true   false
```

Example 4–22 shows how the DBA_NETWORK_ACLS data dictionary view displays the host assignment of the access control list.

Example 4–22 Using the DBA_NETWORK_ACLS View to Show Host Assignments

```
HOST         LOWER_PORT UPPER_PORT
ACL
ACLID
-------------------- ---------- ----------
----------------------------------------
--------------------------------
*.us.example.com
/sys/acls/us-example-com-permissions.xml 2EF86135D0E29B2AE040578CE4043250
*.uk.example.com     80     99
/sys/acls/us-example-com-permissions.xml 2EF86135D0E29B2AE040578CE4043250
```

In these examples, the ACCT_MGR role has the resolve privilege to the first host, and the ACCT_CLERK role has the connect privilege to the first and second target hosts. The ACCT_MGR role does not have the resolve privilege to the second host because a port range is specified in the assignment to the second host.

To check the contents of the access control list in SQL*Plus, see *Oracle XML DB Developer's Guide* for examples.

Example of an Access Control List for Using Passwords in a Non-Shared Wallet

Example 4–23 configures wallet access for two Human Resources department roles, hr_clerk and hr_manager. These roles use the use-passwords privilege to access passwords stored in the wallet. In this example, the wallet will not be shared with other applications within the same database session.

Example 4–23 Configuring ACL Access Using Passwords in a Non-Shared Wallet

```
/* 1. At a command prompt, create the wallet. The following example uses the
      user name hr_access as the alias to identify the user name and password
      stored in the wallet. You must use this alias name when you call the
      SET_AUTHENTICATION_FROM_WALLET procedure later on. */
$ mkstore -wrl $ORACLE_HOME/wallets/hr_access_access -create
Enter password: password
Enter password again: password
$ mkstore -wrl $ORACLE_HOME/wallets/hr_access_access -createCredential hr_access
hr_usr
Your secret/Password is missing in the command line
Enter your secret/Password: password
Re-enter your secret/Password: password
Enter wallet password: password

/* 2. In SQL*Plus, create an access control list to grant privileges for the
      wallet. The following example grants the use-passwords privilege to the
      hr_clerk and hr_manager roles, and then it assigns this ACL to the wallet.*/
BEGIN
  DBMS_NETWORK_ACL_ADMIN.CREATE_ACL(
    acl         => 'hr_access_wallet_acl.xml',
    description => 'Wallet ACL for hr_access application',
    principal   => 'HR_CLERK', -- Must be in upper case
    is_grant    => TRUE,
    privilege   => 'use-passwords');

  DBMS_NETWORK_ACL_ADMIN.ADD_PRIVILEGE(
    acl         => 'hr_access_wallet_acl.xml',
    principal   => 'HR_MANAGER',
    is_grant    => TRUE,
    privilege   => 'use-passwords');

  DBMS_NETWORK_ACL_ADMIN.ASSIGN_WALLET_ACL(
    acl         => 'hr_access_wallet_acl.xml',
    wallet_path => 'file:/oracle/wallets/hr_access_access');
END;
/
COMMIT;

/* 3. Create a request context and request object, and then set the
      authentication for the wallet. */
DECLARE
  req_context  UTL_HTTP.REQUEST_CONTEXT_KEY;
  req          UTL_HTTP.REQ;

BEGIN
 req_context := UTL_HTTP.CREATE_REQUEST_CONTEXT(
     wallet_path          => 'file:/oracle/wallets/hr_access_access',
     wallet_password      => NULL,
     enable_cookies       => TRUE,
     max_cookies          => 300,
     max_cookies_per_site => 20);
  req := UTL_HTTP.BEGIN_REQUEST(
     url                  => 'www.hr_access.example.com',
     request_context      => req_context);
  UTL_HTTP.SET_AUTHENTICATION_FROM_WALLET(
     r                    => req,
     alias                => 'hr_access'),
     scheme               => 'Basic',
     for_proxy            => FALSE);
```

```
END;
/
```

Example of an Access Control List for Wallets in a Shared Database Session

Example 4–24 is almost the same as Example 4–23, except that it configures the wallet to be used for a shared database session; that is, all applications within the current database session will have access to this wallet.

Example 4–24 Configuring ACL Access for a Wallet in a Shared Database Session

```
/* Follow these steps:
   1. Use Oracle Wallet Manager to create the wallet and add the client
      certificate. See Oracle Database Advanced Security Administrator's Guide
      for detailed information about using Oracle Wallet Manager.

   2. In SQL*Plus, create an access control list to grant privileges for the
      wallet. The following example grants the use-client-certificates privilege
      to the hr_clerk and hr_manager roles, then it assigns this ACL to the
      wallet. */
BEGIN
  DBMS_NETWORK_ACL_ADMIN.CREATE_ACL(
    acl         => 'hr_access_wallet_acl.xml',
    description => 'Wallet ACL for hr_access application',
    principal   => 'HR_CLERK', -- Must be in upper case
    is_grant    => TRUE,
    privilege   => 'use-client-certificates');

  DBMS_NETWORK_ACL_ADMIN.ADD_PRIVILEGE(
    acl         => 'hr_access_wallet_acl.xml',
    principal   => 'HR_MANAGER',
    is_grant    => TRUE,
    privilege   => 'use-client-certificates');

  DBMS_NETWORK_ACL_ADMIN.ASSIGN_WALLET_ACL(
    acl         => 'hr_access_wallet_acl.xml',
    wallet_path => 'file:/oracle/wallets/hr_access_access');
END;
/
COMMIT;

/* 3. Create a request object to handle the HTTP authentication for the wallet.*/
DECLARE
  req  UTL_HTTP.req;
BEGIN
  UTL_HTTP.SET_WALLET(
   path            => 'file: $ORACLE_HOME/wallets/hr_access_access',
   password        => NULL);
 req := UTL_HTTP.BEGIN_REQUEST(
   url             => 'www.hr_access.example.com',
   method          => 'POST',
   http_version    => NULL,
   request_context => NULL);
END;
/
```

Specifying a Group of Network Host Computers

If you want to assign an access control list to a group of network host computers, you can use the asterisk (*) wildcard character. For example, enter `*.example.com` for host

computers that belong to a domain or `192.0.2.*` for IPv4 addresses that belong to an IP subnet. The asterisk wildcard must be at the beginning, before a period (.) in a domain, or at the end, after a period (.), in an IP subnet. For example, `*.example.com` is valid, but `*example.com` and `*.example.*` are not. Be aware that the use of wildcard characters affects the order of precedence for multiple access control lists that are assigned to the same host computer. You cannot use wildcard characters for IPv6 addresses.

The Classless Inter-Domain Routing (**CIDR**) notation defines how IPv4 and IPv6 addresses are categorized for routing IP packets on the internet. The `DBMS_NETWORK_ACL_ADMIN` package supports CIDR notation for both IPv4 and IPv6 addresses. This package considers an IPv4-mapped IPv6 address or subnet equivalent to the IPv4-native address or subnet it represents. For example, `::ffff:192.0.2.1` is equivalent to `192.0.2.1`, and `::ffff:192.0.2.1/120` is equivalent to `192.0.2.*`.

Precedence Order for a Host Computer in Multiple Access Control List Assignments

For multiple access control lists that are assigned to the host computer and its domains, the access control list that is assigned to the host computer takes precedence over those assigned to the domains. The access control list assigned to a domain has a lower precedence than those assigned to the subdomains.

For example, Oracle Database first selects the access control list assigned to the host `server.us.example.com`, ahead of other access control lists assigned to its domains. If additional access control lists were assigned to the sub domains, their order of precedence is as follows:

1. `server.us.example.com`
2. `*.us.example.com`
3. `*.example.com`
4. `*.com`
5. `*`

Similarly, for multiple access control lists that are assigned to the IP address (both IPv4 and IPv6) and the subnets it belongs to, the access control list that is assigned to the IP address takes precedence over those assigned to the subnets. The access control list assigned to a subnet has a lower precedence than those assigned to the smaller subnets it contains.

For example, Oracle Database first selects the access control list assigned to the IP address `192.0.2.3`, ahead of other access control lists assigned to the subnets it belongs to. If additional access control lists were assigned to the subnets, their order of precedence is as follows:

1. `192.0.2.3` (or `::ffff:192.0.2.3`)
2. `192.0.2.3/31` (or `::ffff:192.0.2.3/127`)
3. `192.0.2.3/30` (or `::ffff:192.0.2.3/126`)
4. `192.0.2.3/29` (or `::ffff:192.0.2.3/125`)
5. ...
6. `192.0.2.3/24` (or `::ffff:192.0.2.3/120` or `192.0.2.*`)
7. `...`
8. `192.0.2.3/16` (or `::ffff:192.0.2.3/112` or `192.0.*`)

9. ...
10. `192.0.2.3/8` (or `::ffff:192.0.2.3/104` or `192.*`)
11. ...
12. `::ffff:192.0.2.3/95`
13. `::ffff:192.0.2.3/94`
14. ...
15. `*`

Precedence Order for a Host in Access Control List Assignments with Port Ranges

When an access control list is assigned to a host computer, a domain, or an IP subnet with a port range, it takes precedence over the access control list assigned to the same host, domain, or IP subnet without a port range.

For example, for TCP connections to any port between port 80 and 99 at `server.us.example.com`, Oracle Database first selects the access control list assigned to port 80 through 99 at `server.us.example.com`, ahead of the other access control list assigned to `server.us.example.com` that is without a port range.

Checking Privilege Assignments That Affect User Access to a Network Host

Database administrators can use the `DBA_NETWORK_ACL_PRIVILEGES` data dictionary view to query network privileges that have been granted to or denied from database users and roles in the access control lists, and whether those privileges take effect during certain times only. Using the information provided by the view, you may need to combine the data to determine if a user is granted the privilege at the current time, the roles the user has, the order of the access control entries, and so on. To simplify this privilege evaluation, you can use the following `DBMS_NETWORK_ACL_ADMIN` functions to check the privilege granted to a user in an access control list:

- `CHECK_PRIVILEGE`: Checks if the specified privilege is granted to or denied from the specified user in an access control list. This procedure identifies the access control list by its path in the XML DB Repository. Use `CHECK_PRIVILEGE` if you want to evaluate a single access control list with a known path.
- `CHECK_PRIVILEGE_ACLID`: Similar to the `CHECK_PRIVILEGE` procedure, except that it enables you to specify the object ID of the access control list. Use `CHECK_PRIVILEGE_ACLID` if you need to evaluate multiple access control lists, when you query the `DBA_NETWORK_ACLS` data dictionary view. For better performance, call `CHECK_PRIVILEGE_ACLID` on multiple access control lists rather than using `CHECK_PRIVILEGE` on each one individually.

Users without database administrator privileges do not have the privilege to access the access control lists or to invoke those `DBMS_NETWORK_ACL_ADMIN` functions. However, they can query the `USER_NETWORK_ACL_PRIVILEGES` data dictionary view to check their privileges instead.

Database administrators and users can use the following `DBMS_NETWORK_ACL_UTILITY` functions to determine if two hosts, domains, or subnets are equivalent, or if a host, domain, or subnet is equal to or contained in another host, domain, or subnet:

- `EQUALS_HOST`: Returns a value to indicate if two hosts, domains, or subnets are equivalent

- CONTAINS_HOST: Returns a value to indicate if a host, domain, or subnet is equal to or contained in another host, domain, or subnet, and the relative order of precedence of the containing domain or subnet for its ACL assignments

If you do not use IPv6 addresses, database administrators and users can use the following DBMS_NETWORK_ACL_UTILITY functions to generate the list of domains or IPv4 subnet a host belongs to and to sort the access control lists by their order of precedence according to their host assignments:

- DOMAINS: Returns a list of the domains or IP subnets whose access control lists may affect permissions to a specified network host, subdomain, or IP subnet
- DOMAIN_LEVEL: Returns the domain level of a given host

The following sections explain how database administrators and users can check permissions for the user to connect to a network host or to perform domain name resolutions:

- How a DBA Can Check User Network Connection and Domain Privileges
- How Users Can Check Their Network Connection and Domain Privileges

How a DBA Can Check User Network Connection and Domain Privileges

A database administrator can query the DBA_NETWORK_ACLS view to determine which access control lists are present for a specified host computer. This view shows the access control lists that determine the access to the network connection or domain, and then determines if each access control list grants (GRANTED), denies (DENIED), or does not apply (NULL) to the access privilege of the user. Only the database administrator can query this view.

The following sections provide examples that demonstrate how the database administrator can check user privileges for network connections and domain name resolution.

- Database Administrator Checking User Connection Privileges
- Database Administrator Checking User Privileges for Domain Name Resolution

Database Administrator Checking User Connection Privileges

Example 4–25 shows how a database administrator can check the privileges for user preston to connect to www.us.example.com. Remember that the user name you enter for the user parameter in the CHECK_PRIVILEGE_ACLID procedure is case sensitive. In this example, entering the user name preston is correct, but entering Preston or preston is incorrect.

You can find the users in the current database instance by querying the DBA_USERS data dictionary view, for example:

```
SELECT USERNAME FROM DBA_USERS;
```

Example 4–25 Administrator Checking User Permissions for Network Host Connections

```
SELECT HOST, LOWER_PORT, UPPER_PORT, ACL,
       DECODE(
         DBMS_NETWORK_ACL_ADMIN.CHECK_PRIVILEGE_ACLID(ACLID, 'PRESTON',
                                                      'connect'),
         1, 'GRANTED', 0, 'DENIED', NULL) PRIVILEGE
  FROM (SELECT HOST, LOWER_PORT, UPPER_PORT, ACL, ACLID,
               DBMS_NETWORK_ACL_UTILITY.CONTAINS_HOST('www.us.example.com',
                                                      HOST) PRECEDENCE
          FROM DBA_NETWORK_ACLS)
```

```
WHERE PRECEDENCE IS NOT NULL
ORDER BY PRECEDENCE DESC,
         LOWER_PORT NULLS LAST,
         UPPER_PORT NULLS LAST;

HOST                 LOWER_PORT UPPER_PORT ACL                  PRIVILEGE
-------------------- ---------- ---------- -------------------- ---------
www.us.example.com           80         80 /sys/acls/www.xml    GRANTED
www.us.example.com         3000       3999 /sys/acls/www.xml    GRANTED
www.us.example.com                         /sys/acls/www.xml    GRANTED
*.example.com                              /sys/acls/all.xml
*                                          /sys/acls/all.xml
```

In this example, user `preston` was granted privileges for all the network host connections found for `www.us.example.com`. However, suppose `preston` had been granted access to a host connection on port 80, but then denied access to the host connections on ports 3000–3999. In this case, you need to create one access control list for the host connection on port 80, and a separate access control list for the host connection on ports 3000–3999.

Database Administrator Checking User Privileges for Domain Name Resolution

Example 4–26 shows how a database administrator can check the privileges of user `preston` to perform domain name resolution for the host `www.us.example.com`. In this example, only the access control lists assigned to hosts without a port range because the `resolve` privilege has no effect to those with a port range. (Remember that the user name you enter for the `user` parameter in `CHECK_PRIVILEGE_ACLID` is case sensitive.)

Example 4–26 Administrator Checking Permissions for Domain Name Resolution

```
SELECT HOST, ACL,
       DECODE(
         DBMS_NETWORK_ACL_ADMIN.CHECK_PRIVILEGE_ACLID(ACLID, 'PRESTON',
                                                      'resolve'),
         1, 'GRANTED', 0, 'DENIED', NULL) PRIVILEGE
  FROM (SELECT HOST, LOWER_PORT, UPPER_PORT, ACL, ACLID,
               DBMS_NETWORK_ACL_UTILITY.CONTAINS_HOST('www.us.example.com',
                                                      HOST) PRECEDENCE
         FROM DBA_NETWORK_ACLS
         WHERE LOWER_PORT IS NULL AND UPPER_PORT IS NULL)
 WHERE PRECEDENCE IS NOT NULL
 ORDER BY PRECEDENCE DESC;

 HOST                 ACL                  PRIVILEGE
 -------------------- -------------------- ---------

 www.us.example.com   /sys/acls/www.xml    GRANTED
 *.example.com        /sys/acls/all.xml
 *                    /sys/acls/all.xml
```

How Users Can Check Their Network Connection and Domain Privileges

Users can query the `USER_NETWORK_ACL_PRIVILEGES` view to check their network and domain permissions. The `USER_NETWORK_ACL_PRIVILEGES` view is `PUBLIC`, so all users can select from it.

This view hides the access control lists from the user. It evaluates the permission status for the user (`GRANTED` or `DENIED`) and filters out the `NULL` case because the user does not need to know when the access control lists do not apply to him or her. In other words, Oracle Database only shows the user on the network hosts that explicitly grant or deny

access to him or her. Therefore, the output does not display the `*.example.com` and `*` that appear in the output from the database administrator-specific `DBA_NETWORK_ACLS` view.

The following sections provide examples that demonstrate how a database administrator can check user permissions for network connections and domain name resolution.

- User Checking His or Her Network Connection Privileges
- User Checking Own Privileges for Domain Name Resolution

User Checking His or Her Network Connection Privileges

Example 4–27 shows how user `preston` can check her privileges to connect to `www.us.example.com`.

Example 4–27 User Checking Permissions for Network Host Connections

```
SELECT HOST, LOWER_PORT, UPPER_PORT, STATUS PRIVILEGE
  FROM (SELECT HOST, LOWER_PORT, UPPER_PORT, STATUS,
               DBMS_NETWORK_ACL_UTILITY.CONTAINS_HOST('www.us.example.com',
                                                      HOST) PRECEDENCE
          FROM USER_NETWORK_ACL_PRIVILEGES
         WHERE PRIVILEGE = 'connect')
 WHERE PRECEDENCE IS NOT NULL
 ORDER BY PRECEDENCE DESC,
          LOWER_PORT NULLS LAST,
          UPPER_PORT NULLS LAST;

 HOST                 LOWER_PORT UPPER_PORT ACL                   PRIVILEGE
 -------------------- ---------- ---------- -------------------- ---------
 www.us.example.com           80         80 /sys/acls/www.xml    GRANTED
 www.us.example.com         3000       3999 /sys/acls/www.xml    GRANTED
 www.us.example.com                         /sys/acls/www.xml    GRANTED
```

User Checking Own Privileges for Domain Name Resolution

Example 4–26 shows how the user `preston` can check her privileges to perform domain name resolution for `www.us.example.com`:

Example 4–28 User Checking Privileges for Domain Name Resolution

```
SELECT HOST, STATUS PRIVILEGE
  from (SELECT HOST, STATUS,
               DBMS_NETWORK_ACL_UTILITY.CONTAINS_HOST('www.us.example.com',
                                                      HOST) PRECEDENCE
          FROM USER_NETWORK_ACL_PRIVILEGES
         WHERE PRIVILEGE = 'resolve' AND
               LOWER_PORT IS NULL AND UPPER_PORT IS NULL)
 WHERE PRECEDENCE IS NOT NULL
 ORDER BY PRECEDENCE DESC;

 HOST                 PRIVILEGE
 -------------------- ---------
 www.us.example.com   GRANTED
```

Setting the Precedence of Multiple Users and Roles in One Access Control List

By default, Oracle Database grants or denies privileges to users and roles based on their physical position in the access control list. The first user or role listed is granted

or denied privileges first, followed the second user or role, and so on. For instance, suppose the code in Example 4–20 defined one role, ACCT_MGR, and two users, sebastian and preston, and the access control list XML file ordered these three as follows:

```
<acl ...>
  ...
  <ace>
    <principal>ACCT_MGR</principal>
    <grant>true</grant>
    <privilege><plsql:connect/></privilege>
   </ace>
  <ace>
    <principal>SEBASTIAN</principal>
    <grant>false</grant>
    <privilege><plsql:connect/></privilege>
  </ace>
  <ace>
    <principal>PRESTON</principal>
    <grant>false</grant>
    <privilege><plsql:connect/></privilege>
  </ace>
</acl>
```

ACCT_MGR is granted permissions first, followed by permission denials for sebastian and then preston. However, if sebastian and preston have been granted the ACCT_MGR role, they still could log in, because the ACCT_MGR role appears first in the list.

Even though these two users were granted the acct_mgr role, their specific jobs do not require them to have access to the www.example.com host. If the positions were reversed—the acct_mgr role listed after sebastian and preston—they would be denied the privilege of connecting to the network. To set the order of precedence of the ACE elements irrespective of their physical location in the CREATE_ACL and ADD_PRIVILEGE statements, you can use the position attribute.

For example, the following statements set the ACE elements in the resultant XML file in this order:

1. The ACE element for sebastian appears first.
2. The ACE element for preston appears second.
3. The acct_mgr role appears last.

In this case, neither of these users will be able to connect, because their grant privileges, which are set to FALSE, are evaluated before the acct_mgr role.

```
BEGIN
 DBMS_NETWORK_ACL_ADMIN.CREATE_ACL (
  acl          => 'us-example-com-permissions.xml',
  description  => 'Network connection permission for ACCT_MGR and users',
  principal    => 'ACCT_MGR',
  is_grant     => TRUE,
  privilege    => 'connect');
 DBMS_NETWORK_ACL_ADMIN.ADD_PRIVILEGE (
  acl          => 'us-example-com-permissions.xml',
  principal    => 'SEBASTIAN',
  is_grant     => FALSE,
  privilege    => 'connect',
  position     => 1);
 DBMS_NETWORK_ACL_ADMIN.ADD_PRIVILEGE (
  acl          => 'us-example-com-permissions.xml',
```

```
  principal    => 'PRESTON',
  is_grant     => FALSE,
  privilege    => 'connect',
  position     => 2);
END;
/
```

Finding Information About Access Control Lists Configured for User Access

Table 4–6 lists data dictionary views that you can use to find information about existing access control lists. See *Oracle Database Reference* for more information about these views.

Table 4–6 Data Dictionary Views That Display Information about Access Control Lists

View	Description
DBA_NETWORK_ACLS	Shows the access control list assignments to the network hosts. The SELECT privilege on this view is granted to the SELECT_CATALOG_ROLE role only.
DBA_NETWORK_ACL_PRIVILEGES	Shows the network privileges defined in all access control lists that are currently assigned to network hosts. The SELECT privilege on this view is granted to the SELECT_CATALOG_ROLE role only.
DBA_WALLET_ACLS	Lists wallets that have been assigned access control lists.
USER_NETWORK_ACL_PRIVILEGES	Shows the status of the network privileges for the current user to access network hosts. The SELECT privilege on the view is granted to PUBLIC.

Finding Information About User Privileges and Roles

Table 4–7 lists data dictionary views that you can query to access information about grants of privileges and roles. See *Oracle Database Reference* for detailed information about these views.

Table 4–7 Data Dictionary Views That Display Information about Privileges and Roles

View	Description
ALL_COL_PRIVS	Describes all column object grants for which the current user or PUBLIC is the object owner, grantor, or grantee
ALL_COL_PRIVS_MADE	Lists column object grants for which the current user is object owner or grantor.
ALL_COL_PRIVS_RECD	Describes column object grants for which the current user or PUBLIC is the grantee
ALL_TAB_PRIVS	Lists the grants on objects where the user or PUBLIC is the grantee
ALL_TAB_PRIVS_MADE	Lists the all object grants made by the current user or made on the objects owned by the current user.
ALL_TAB_PRIVS_RECD	Lists object grants for which the user or PUBLIC is the grantee
DBA_COL_PRIVS	Describes all column object grants in the database
DBA_EPG_DAD_ AUTHORIZATION	Describes the database access descriptors (DAD) that are authorized to use a different user's privileges.
DBA_TAB_PRIVS	Lists all grants on all objects in the database
DBA_ROLES	Lists all roles that exist in the database, including secure application roles

Table 4–7 (Cont.) Data Dictionary Views That Display Information about Privileges and

View	Description
DBA_ROLE_PRIVS	Lists roles directly granted to users and roles. Note that it does not list the PUBLIC role.
DBA_SYS_PRIVS	Lists system privileges granted to users and roles
ROLE_ROLE_PRIVS	Lists roles granted to other roles. Information is provided only about roles to which the user has access.
ROLE_SYS_PRIVS	Lists system privileges granted to roles. Information is provided only about roles to which the user has access.
ROLE_TAB_PRIVS	Lists object privileges granted to roles. Information is provided only about roles to which the user has access.
SESSION_PRIVS	Lists the privileges that are currently enabled for the user
SESSION_ROLES	Lists all roles that are enabled for the current user. Note that it does not list the PUBLIC role.
USER_COL_PRIVS	Describes column object grants for which the current user is the object owner, grantor, or grantee
USER_COL_PRIVS_MADE	Describes column object grants for which the current user is the object owner
USER_COL_PRIVS_RECD	Describes column object grants for which the current user is the grantee
USER_EPG_DAD_ AUTHORIZATION	Describes the database access descriptors (DAD) that are authorized to use a different user's privileges.
USER_ROLE_PRIVS	Lists roles directly granted to the current user
USER_TAB_PRIVS	Lists grants on all objects where the current user is the grantee
USER_SYS_PRIVS	Lists system privileges granted to the current user
USER_TAB_PRIVS_MADE	Lists grants on all objects owned by the current user
USER_TAB_PRIVS_RECD	Lists object grants for which the current user is the grantee

This section provides some examples of using these views. For these examples, assume the following statements were issued:

```
CREATE ROLE security_admin IDENTIFIED BY password;

GRANT CREATE PROFILE, ALTER PROFILE, DROP PROFILE,
    CREATE ROLE, DROP ANY ROLE, GRANT ANY ROLE, AUDIT ANY,
    AUDIT SYSTEM, CREATE USER, BECOME USER, ALTER USER, DROP USER
    TO security_admin WITH ADMIN OPTION;

GRANT SELECT, DELETE ON SYS.AUD$ TO security_admin;

GRANT security_admin, CREATE SESSION TO swilliams;

GRANT security_admin TO system_administrator;

GRANT CREATE SESSION TO jward;

GRANT SELECT, DELETE ON emp TO jward;

GRANT INSERT (ename, job) ON emp TO swilliams, jward;
```

See Also: *Oracle Database Reference* for a detailed description of these data dictionary views

Listing All System Privilege Grants

The following query returns all system privilege grants made to roles and users:

```
SELECT * FROM DBA_SYS_PRIVS;

GRANTEE            PRIVILEGE                        ADM
-------------      -------------------------------- ---
SECURITY_ADMIN     ALTER PROFILE                    YES
SECURITY_ADMIN     ALTER USER                       YES
SECURITY_ADMIN     AUDIT ANY                        YES
SECURITY_ADMIN     AUDIT SYSTEM                     YES
SECURITY_ADMIN     BECOME USER                      YES
SECURITY_ADMIN     CREATE PROFILE                   YES
SECURITY_ADMIN     CREATE ROLE                      YES
SECURITY_ADMIN     CREATE USER                      YES
SECURITY_ADMIN     DROP ANY ROLE                    YES
SECURITY_ADMIN     DROP PROFILE                     YES
SECURITY_ADMIN     DROP USER                        YES
SECURITY_ADMIN     GRANT ANY ROLE                   YES
SWILLIAMS          CREATE SESSION                   NO
JWARD              CREATE SESSION                   NO
```

See *Oracle Database Reference* for detailed information about the `DBA_SYS_PRIVS` view.

Listing All Role Grants

The following query returns all the roles granted to users and other roles:

```
SELECT * FROM DBA_ROLE_PRIVS;

GRANTEE            GRANTED_ROLE                     ADM
------------------ -------------------------------- ---
SWILLIAMS          SECURITY_ADMIN                   NO
```

See *Oracle Database Reference* for detailed information about the `DBA_ROLE_PRIVS` view.

Listing Object Privileges Granted to a User

The following query returns all object privileges (not including column-specific privileges) granted to the specified user:

```
SELECT TABLE_NAME, PRIVILEGE, GRANTABLE FROM DBA_TAB_PRIVS
    WHERE GRANTEE = 'jward';

TABLE_NAME   PRIVILEGE    GRANTABLE
-----------  ------------ ----------
EMP          SELECT       NO
EMP          DELETE       NO
```

To list all the column-specific privileges that have been granted, use the following query:

```
SELECT GRANTEE, TABLE_NAME, COLUMN_NAME, PRIVILEGE
    FROM DBA_COL_PRIVS;

GRANTEE      TABLE_NAME     COLUMN_NAME      PRIVILEGE
```

```
-----------  ------------   -------------    --------------
SWILLIAMS    EMP            ENAME            INSERT
SWILLIAMS    EMP            JOB              INSERT
JWARD        EMP            NAME             INSERT
JWARD        EMP            JOB              INSERT
```

See *Oracle Database Reference* for detailed information about the DBA_TAB_PRIVS view.

Listing the Current Privilege Domain of Your Session

The following query lists all roles currently enabled for the issuer:

```
SELECT * FROM SESSION_ROLES;
```

If user swilliams has the security_admin role enabled and issues the previous query, then Oracle Database returns the following information:

```
ROLE
------------------------------
SECURITY_ADMIN
```

The following query lists all system privileges currently available in the security domain of the issuer, both from explicit privilege grants and from enabled roles:

```
SELECT * FROM SESSION_PRIVS;
```

If user swilliams has the security_admin role enabled and issues the previous query, then Oracle Database returns the following results:

```
PRIVILEGE
----------------------------------------
AUDIT SYSTEM
CREATE SESSION
CREATE USER
BECOME USER
ALTER USER
DROP USER
CREATE ROLE
DROP ANY ROLE
GRANT ANY ROLE
AUDIT ANY
CREATE PROFILE
ALTER PROFILE
DROP PROFILE
```

If the security_admin role is disabled for user swilliams, then the first query would return no rows, while the second query would only return a row for the CREATE SESSION privilege grant.

See *Oracle Database Reference* for detailed information about the SESSION_ROLES view.

Listing Roles of the Database

You can use the DBA_ROLES data dictionary view to list all roles of a database and the authentication used for each role. For example, the following query lists all the roles in the database:

```
SELECT * FROM DBA_ROLES;

ROLE                  PASSWORD
----------------      --------
```

```
CONNECT              NO
RESOURCE             NO
DBA                  NO
SECURITY_ADMIN       YES
```

See *Oracle Database Reference* for detailed information about the DBA_ROLES view.

Listing Information About the Privilege Domains of Roles

The ROLE_ROLE_PRIVS, ROLE_SYS_PRIVS, and ROLE_TAB_PRIVS data dictionary views contain information about the privilege domains of roles. For example, the following query lists all the roles granted to the system_admin role:

```
SELECT GRANTED_ROLE, ADMIN_OPTION
   FROM ROLE_ROLE_PRIVS
   WHERE ROLE = 'SYSTEM_ADMIN';

GRANTED_ROLE              ADM
----------------          ----
SECURITY_ADMIN            NO
```

The following query lists all the system privileges granted to the security_admin role:

```
SELECT * FROM ROLE_SYS_PRIVS WHERE ROLE = 'SECURITY_ADMIN';

ROLE                    PRIVILEGE                      ADM
----------------------- ------------------------------ ---
SECURITY_ADMIN           ALTER PROFILE                 YES
SECURITY_ADMIN           ALTER USER                    YES
SECURITY_ADMIN           AUDIT ANY                     YES
SECURITY_ADMIN           AUDIT SYSTEM                  YES
SECURITY_ADMIN           BECOME USER                   YES
SECURITY_ADMIN           CREATE PROFILE                YES
SECURITY_ADMIN           CREATE ROLE                   YES
SECURITY_ADMIN           CREATE USER                   YES
SECURITY_ADMIN           DROP ANY ROLE                 YES
SECURITY_ADMIN           DROP PROFILE                  YES
SECURITY_ADMIN           DROP USER                     YES
SECURITY_ADMIN           GRANT ANY ROLE                YES
```

The following query lists all the object privileges granted to the security_admin role:

```
SELECT TABLE_NAME, PRIVILEGE FROM ROLE_TAB_PRIVS
    WHERE ROLE = 'SECURITY_ADMIN';

TABLE_NAME                   PRIVILEGE
---------------------------  ----------------
AUD$                         DELETE
AUD$                         SELECT
```

See *Oracle Database Reference* for detailed information about the ROLE_ROLE_PRIVS, ROLE_SYS_PRIVS, and ROLE_TAB_PRIVS views.

5

Managing Security for Application Developers

This chapter contains:

About Application Security Policies

Creating an application security policy is the first step to create a secure database application. An application security policy is a list of application security requirements and rules that regulate user access to database objects.

You should draft security policies for each database application. For example, each database application should have one or more database roles that provide different levels of security when executing the application. You then can grant the database roles to other roles or directly to specific users.

Applications that can potentially allow unrestricted SQL statement processing (through tools such as SQL*Plus or SQL Developer) also need security policies that prevent malicious access to confidential or important schema objects. In particular, you must ensure that your applications handle passwords in a secure manner.

The following sections describe aspects of application security and the Oracle Database features that you can use to plan and develop secure database applications.

Considerations for Using Application-Based Security

Two main questions to consider when you formulate and implement application security are covered in the following sections:

Are Application Users Also Database Users?

Where possible, you should build applications in which application users are database users. In this way, you can leverage the intrinsic security mechanisms of the database.

For many commercial packaged applications, application users are not database users. For these applications, multiple users authenticate themselves to the application, and the application then connects to the database as a single, highly-privileged user. This is called the *One Big Application User* model.

Applications built in this way generally cannot use many of the intrinsic security features of the database, because the identity of the user is not known to the database.

Table 5–1 describes how the One Big Application User model affects various Oracle Database security features:

Table 5–1 Features Affected by the One Big Application User Model

Oracle Database Feature	Limitations of One Big Application User Model
Auditing	A basic principle of security is accountability through auditing. If One Big Application User performs all actions in the database, then database auditing cannot hold individual users accountable for their actions. The application must implement its own auditing mechanisms to capture individual user actions.
Oracle Advanced Security enhanced authentication	Strong forms of authentication supported by Oracle Advanced Security (such as client authentication over SSL, tokens, and so on) cannot be used if the client authenticating to the database is the application, rather than an individual user.
Roles	Roles are assigned to database users. Enterprise roles are assigned to enterprise users who, though not created in the database, are known to the database. If application users are not database users, then the usefulness of roles is diminished. Applications must then craft their own mechanisms to distinguish between the privileges which various application users need to access data within the application.
Enterprise user management feature of Oracle Advanced Security	The Enterprise user management feature enables an Oracle database to use the Oracle Identity Management Infrastructure by securely storing and managing user information and authorizations in an LDAP-based directory such as Oracle Internet Directory. While enterprise users do not need to be created in the database, they do need to be known to the database. The One Big Application User model cannot take advantage of Oracle Identity Management.

Is Security Better Enforced in the Application or in the Database?

Applications, whose users are also database users, can either build security into the application, or rely on intrinsic database security mechanisms such as granular privileges, virtual private databases (fine-grained access control with application context), roles, stored procedures, and auditing (including fine-grained auditing). Oracle recommends that applications use the security enforcement mechanisms of the database as much as possible.

When security is enforced in the database itself, rather than in the application, it cannot be bypassed. The main shortcoming of application-based security is that security is bypassed if the user bypasses the application to access data. For example, a user who has SQL*Plus access to the database can execute queries without going through the Human Resources application. The user, therefore, bypasses all of the security measures in the application.

Applications that use the One Big Application User model must build security enforcement into the application rather than use database security mechanisms. Because it is the application, and not the database, that recognizes users; the application itself must enforce security measures for each user.

This approach means that each application that accesses data must reimplement security. Security becomes expensive, because organizations must implement the same security policies in multiple applications, and each new application requires an expensive reimplementation.

See Also: "Potential Security Problems of Using Ad Hoc Tools" on page 4-21

Securing Passwords in Application Design

This section provides strategies for securely invoking password-protected services from a batch job, script, installation file, or application. In addition to password protection, most of these strategies can be applied to other sensitive data, such as cryptographic keys.

This section contains:

- General Guidelines for Securing Passwords in Applications
- Securing Passwords Using an External Password Store
- Securing Passwords Using the orapwd Utility
- Example of Reading Passwords in Java

See Also:

- "Minimum Requirements for Passwords" on page 3-3
- Chapter 10, "Keeping Your Oracle Database Secure" for general guidelines on securing an Oracle database

General Guidelines for Securing Passwords in Applications

These guidelines are in the following categories:

- Platform-Specific Security Threats
- Designing Applications to Handle Password Input
- Configuring Password Formats and Behavior
- Handling Passwords in SQL*Plus and SQL Scripts

Platform-Specific Security Threats

Be aware of the following potential security threats, which may not be obvious:

- **On UNIX and Linux platforms, command parameters are available for viewing by all operating system users on the same host computer.** As a result, passwords entered on the command line could be exposed to other users. However, do not assume that non-UNIX and Linux platforms are safe from this threat.
- **On some UNIX platforms, such as HP Tru64 and IBM AIX, environment variables for all processes are available for viewing by all operating system users.** However, do not assume that non-UNIX and Linux platforms are safe from this threat.

- **On Microsoft Windows, the command recall feature (the Up arrow) remembers user input across command invocations.** For example, if you use the `CONNECT SYSTEM/password` notation in SQL*Plus, exit, and then press the Up arrow to repeat the `CONNECT` command, the command recall feature reveals the connect string and displays the password. In addition, do not assume that non-Microsoft Windows platforms are safe from this threat.

Designing Applications to Handle Password Input

Follow these guidelines:

- **Design applications to interactively prompt for passwords.** For command-line utilities, do not force users to expose passwords at a command prompt.

  Check the APIs for the programming language you use to design applications for the best way to handle passwords from users. For an example of Java code that handles this functionality, see "Example of Reading Passwords in Java" on page 5-7.

- **Protect your database against SQL injection attacks.** A SQL injection attack occurs when SQL statements are appended or altered in a manner not intended by the PL/SQL application. For example, an intruder can bypass password authentication by setting a `WHERE` clause to `TRUE`.

  To address the problem of SQL injection attacks, use bind variable arguments or create validation checks. If you cannot use bind variables, then consider using the `DBMS_ASSERT` PL/SQL package to validate the properties of input values. *Oracle Database PL/SQL Packages and Types Reference* describes the `DBMS_ASSERT` package in detail. You also should review any grants to roles such as `PUBLIC`.

  See *Oracle Database PL/SQL Language Reference* for more information about preventing SQL injection.

- **If possible, design your applications to defer authentication.** For example:
  - Use certificates for logins.
  - Authenticate users by using facilities provided by the operating system. For example, applications on Microsoft Windows can use domain authentication.

- **Mask or encrypt passwords.** If you must store passwords, then mask or encrypt them. For example, you can mask passwords in log files and encrypt passwords in recovery files.

- **Authenticate each connection.** For example, if schema A exists in database 1, then do not assume that schema A in database 2 is the same user. Similarly, the local operating system user `psmith` is not necessarily the same person as remote user `psmith`.

- **Do not store clear text passwords in files or repositories.** Storing passwords in files increases the risk of an intruder accessing them.

- **Use a single master password.** For example:
  - You can grant a single database user proxy authentication to act as other database users. In this case, only a single database password is needed. See "Creating Proxy User Accounts and Authorizing Users to Connect Through Them" on page 3-38 for more information.
  - You can create a password wallet, which can be opened by the master password. The wallet then contains the other passwords. See *Oracle Database Advanced Security Administrator's Guide* for more information about Wallet Manager.

Configuring Password Formats and Behavior

Follow these guidelines:

- **Limit the lifetime for passwords.** You can set a password lifetime, after which the password expires and must be changed before the user can log in to the account. See "Controlling Password Aging and Expiration" on page 3-8 for parameters you can use to control the lifetime of a password.
- **Limit the ability of users to reuse old passwords.** See "Controlling User Ability to Reuse Previous Passwords" on page 3-7 for more information.
- **Force users to create strong, secure passwords.** See "Guidelines for Securing Passwords" on page 10-7 for advice on creating strong passwords. "Enforcing Password Complexity Verification" on page 3-11 explains how you can customize password requirements.
- **Enable case sensitivity in passwords.** See "Enabling or Disabling Password Case Sensitivity" on page 3-13 for more information.

See Also:

- "Minimum Requirements for Passwords" on page 3-3
- "Enforcing Password Complexity Verification" on page 3-11
- "Guidelines for Securing Passwords" on page 10-7

Handling Passwords in SQL*Plus and SQL Scripts

Follow these guidelines:

- **Do not invoke SQL*Plus with a password on the command line, either in programs or scripts.** If a password is required but omitted, SQL*Plus prompts the user for it and then automatically disables the echo feature so that the password is not displayed.

  The following examples are secure because passwords are not exposed on the command line. Oracle Database also automatically encrypts these passwords over the network.

  ```
  $ sqlplus system
  Enter password: password

  SQL> connect system
  Enter password: password
  ```

  The following example exposes the password to other operating system users:

  ```
  sqlplus system/password
  ```

  The next example poses two security risks. First, it exposes the password to other users who may be watching over your shoulder. Second, on some platforms, such as Microsoft Windows, it makes the password vulnerable to a command line recall attack.

  ```
  $ sqlplus /nolog
  SQL> connect system/password
  ```

- **For SQL scripts that require passwords or secret keys, for example, to create an account or to log in as an account, do not use positional parameters, such as substitution variables &1, &2, and so on.** Instead, design the script to prompt the user for the value. You should also disable the echo feature, which displays output

from a script or if you are using spool mode. To disable the echo feature, use the following setting:

```
SET ECHO OFF
```

A good practice is to ensure that the script makes the purpose of the value clear. For example, it should be clear whether or not the value will establish a new value, such as an account or a certificate, or if the value will authenticate, such as logging in to an existing account.

The following example is secure because it prevents users from invoking the script in a manner that poses security risks: It does not echo the password; it does not record the password in a spool file.

```
SET VERIFY OFF
 ACCEPT user CHAR PROMPT 'Enter user to connect to: '
 ACCEPT password CHAR PROMPT 'Enter the password for that user: ' HIDE
 CONNECT &user/&password
```

In this example:

– `SET VERIFY OFF`: Prevents the password from being displayed. (`SET VERIFY` lists each line of the script before and after substitution.) Combining the `SET VERIFY OFF` command with the `HIDE` command (in **Line 3**) is a useful technique for hiding passwords and other sensitive input data.

– `ACCEPT password`**:** Includes the `HIDE` option for the `ACCEPT password` prompt, which prevents the input password from being echoed.

The next example, which uses positional parameters, poses security risks because a user may invoke the script by passing the password on the command line. If the user does not enter a password and instead is prompted, the danger lies in that whatever the user types is echoed to the screen and to a spool file if spooling is enabled.

```
CONNECT &1/&2
```

- **Control the log in times for batch scripts.** For batch scripts that require passwords, configure the account so that the script can only log in during the time in which it is supposed to run. For example, suppose you have a batch script that runs for an hour each evening starting at 8 p.m. Set the account so that the script can only log in during this time. If an intruder manages to gain access, then he or she has less of a chance of exploiting any compromised accounts.
- **Be careful when using DML or DDL SQL statements that prompt for passwords.** In this case, sensitive information is passed in clear text over the network. You can remedy this problem by using Oracle Advanced Security. See *Oracle Database Advanced Security Administrator's Guide* for more information.

  The following example of altering a password is secure because the password is not exposed:

  ```
  password psmith
  Changing password for psmith
  New password: password
  Retype new password: password
  ```

  This example poses a security risk because the password is exposed both at the command line and on the network:

  ```
  ALTER USER psmith IDENTIFIED BY password
  ```

Securing Passwords Using an External Password Store

You can store password credentials for connecting to a database by using a client-side Oracle wallet. An Oracle wallet is a secure software container that stores the authentication and signing credentials needed for a user to log in.

See "Managing the Secure External Password Store for Password Credentials" on page 3-16 for more information about the secure external password store. See also *Oracle Database Advanced Security Administrator's Guide* for information about using Oracle Wallet Manager to configure Oracle wallets.

Securing Passwords Using the orapwd Utility

You can create a password file for users who need to connect to an application using the `SYSDBA` or `SYSOPER` privileges over a network. To create the password file, use the `ORAPWD` utility. See *Oracle Database Administrator's Guide* for more information about creating and maintaining a password file.

Example of Reading Passwords in Java

Example 5–1 demonstrates how to create a Java package that can be used to read passwords.

Example 5–1 Java Code for Reading Passwords

```
// Change the following line to a name for your version of this package
package passwords.sysman.emSDK.util.signing;

import java.io.IOException;
import java.io.PrintStream;
import java.io.PushbackInputStream;
import java.util.Arrays;

/**
 * The static readPassword method in this class issues a password prompt
 * on the console output and returns the char array password
 * entered by the user on the console input.
 */
public final class ReadPassword {
  //---------------------------------
  /**
   * Test driver for readPassword method.
   * @param args the command line args
   */
  public static void main(String[] args) {
    char[] pass = ReadPassword.readPassword("Enter password: ");
    System.out.println("The password just entered is \""
      + new String(pass) + "\"");
    System.out.println("The password length is " + pass.length);
  }
   * Issues a password prompt on the console output and returns
   * the char array password entered by the user on the console input.
   * The password is not displayed on the console (chars are not echoed).
   * As soon as the returned char array is not needed,
   * it should be erased for security reasons (Arrays.fill(charArr, ' '));
   * A password should never be stored as a java String.
   *
   * Note that Java 6 has a Console class with a readPassword method,
   * but there is no equivalent in Java 5 or Java 1.4.
   * The readPassword method here is based on Sun's suggestions at
```

```
 * http://java.sun.com/developer/technicalArticles/Security/pwordmask.
 *
 * @param prompt the password prompt to issue
 * @return new char array containing the password
 * @throws RuntimeException if some error occurs
 */
public static final char[] readPassword(String prompt)
throws RuntimeException {
  try {
    StreamMasker masker = new StreamMasker(System.out, prompt);
    Thread threadMasking = new Thread(masker);
    int firstByte = -1;
    PushbackInputStream inStream = null;
    try {
      threadMasking.start();
      inStream = new PushbackInputStream(System.in);
      firstByte = inStream.read();
    } finally {
      masker.stopMasking();
    }
    try {
      threadMasking.join();
    } catch (InterruptedException e) {
      throw new RuntimeException("Interrupt occurred when reading password");
    }
    if (firstByte == -1) {
      throw new RuntimeException("Console input ended unexpectedly");
    }
    if (System.out.checkError()) {
      throw new RuntimeException("Console password prompt output error");
    }
    inStream.unread(firstByte);
    return readLineSecure(inStream);
  }
  catch (IOException e) {
    throw new RuntimeException("I/O error occurred when reading password");
  }
}
//---------------------------------
/**
 * Reads one line from an input stream into a char array in a secure way
 * suitable for reading a password.
 * The char array will never contain a '\n' or '\r'.
 *
 * @param inStream the pushback input stream
 * @return line as a char array, not including end-of-line-chars;
 *  never null, but may be zero length array
 * @throws RuntimeException if some error occurs
 */
private static final char[] readLineSecure(PushbackInputStream inStream)
throws RuntimeException {
  if (inStream == null) {
    throw new RuntimeException("readLineSecure inStream is null");
  }
  try {
    char[] buffer = null;
    try {
      buffer = new char[128];
      int offset = 0;
      // EOL is '\n' (unix), '\r\n' (windows), '\r' (mac)
```

```
      loop:
      while (true) {
        int c = inStream.read();
        switch (c) {
        case -1:
        case '\n':
          break loop;
        case '\r':
          int c2 = inStream.read();
          if ((c2 != '\n') && (c2 != -1))
            inStream.unread(c2);
          break loop;
        default:
          buffer = checkBuffer(buffer, offset);
          buffer[offset++] = (char) c;
          break;
        }
      }
      char[] result = new char[offset];
      System.arraycopy(buffer, 0, result, 0, offset);
      return result;
    }
    finally {
      if (buffer != null)
        Arrays.fill(buffer, ' ');
    }
  }
  catch (IOException e) {
    throw new RuntimeException("I/O error occurred when reading password");
  }
}
//---------------------------------
/**
 * This is a helper method for readLineSecure.
 *
 * @param buffer the current char buffer
 * @param offset the current position in the buffer
 * @return the current buffer if it is not yet full;
 *  otherwise return a larger buffer initialized with a copy
 *  of the current buffer and then erase the current buffer
 * @throws RuntimeException if some error occurs
 */
private static final char[] checkBuffer(char[] buffer, int offset)
throws RuntimeException
{
  if (buffer == null)
    throw new RuntimeException("checkBuffer buffer is null");
  if (offset < 0)
    throw new RuntimeException("checkBuffer offset is negative");
  if (offset < buffer.length)
    return buffer;
  else {
    try {
      char[] bufferNew = new char[offset + 128];
      System.arraycopy(buffer, 0, bufferNew, 0, buffer.length);
      return bufferNew;
    } finally {
      Arrays.fill(buffer, ' ');
    }
  }
```

```
}
//---------------------------------
/**
 * This private class prints a one line prompt
 * and erases reply chars echoed to the console.
 */
private static final class StreamMasker
extends Thread {
  private static final String BLANKS = StreamMasker.repeatChars(' ', 10);
  private String m_promptOverwrite;
  private String m_setCursorToStart;
  private PrintStream m_out;
  private volatile boolean m_doMasking;
  //---------------------------------
  /**
   * Constructor.
   * @throws RuntimeException if some error occurs
   */
  public StreamMasker(PrintStream outPrint, String prompt)
  throws RuntimeException {
    if (outPrint == null)
      throw new RuntimeException("StreamMasker outPrint is null");
    if (prompt == null)
      throw new RuntimeException("StreamMasker prompt is null");
    if (prompt.indexOf('\r') != -1)
      throw new RuntimeException("StreamMasker prompt contains a CR");
    if (prompt.indexOf('\n') != -1)
      throw new RuntimeException("StreamMasker prompt contains a NL");
    m_out = outPrint;
    m_setCursorToStart = StreamMasker.repeatChars('\010',
      prompt.length() + BLANKS.length());
    m_promptOverwrite = m_setCursorToStart + prompt + BLANKS
      + m_setCursorToStart + prompt;
  }
  //---------------------------------
  /**
   * Begin masking until asked to stop.
   * @throws RuntimeException if some error occurs
   */
  public void run()
  throws RuntimeException {
    int priorityOriginal = Thread.currentThread().getPriority();
    Thread.currentThread().setPriority(Thread.MAX_PRIORITY);
    try {
      m_doMasking = true;
      while (m_doMasking) {
        m_out.print(m_promptOverwrite);
        if (m_out.checkError())
          throw new RuntimeException("Console output error writing prompt");
        try {
          Thread.currentThread().sleep(1);
        } catch (InterruptedException ie) {
          Thread.currentThread().interrupt();
          return;
        }
      }
      m_out.print(m_setCursorToStart);
    } finally {
      Thread.currentThread().setPriority(priorityOriginal);
    }
```

```
    }
    //---------------------------------
    /**
     * Instructs the thread to stop masking.
     */
    public void stopMasking() {
      m_doMasking = false;
    }
    //---------------------------------
    /**
     * Returns a repeated char string.
     *
     * @param c the char to repeat
     * @param length the number of times to repeat the char
     * @throws RuntimeException if some error occurs
     */
    private static String repeatChars(char c, int length)
    throws RuntimeException {
      if (length < 0)
        throw new RuntimeException("repeatChars length is negative");
      StringBuffer sb = new StringBuffer(length);
      for (int i = 0; i < length; i++)
        sb.append(c);
      return sb.toString();
    }
  }
}
```

Managing Application Privileges

Most database applications involve different privileges on different schema objects. Keeping track of the privileges that are required for each application can be complex. In addition, authorizing users to run an application can involve many `GRANT` operations.

To simplify application privilege management, you can create a role for each application and grant that role all the privileges a user must run the application. In fact, an application can have several roles, each granted a specific subset of privileges that allow greater or lesser capabilities while running the application.

For example, suppose every administrative assistant uses the Vacation application to record the vacation taken by members of the department. To best manage this application, you should:

1. Create a `VACATION` role.
2. Grant all privileges required by the Vacation application to the `VACATION` role.
3. Grant the `VACATION` role to all administrative assistants. Better yet, create a role that defines the privileges the administrative assistants have, and then grant the `VACATION` role to that role.

Grouping application privileges in a role aids privilege management. Consider the following administrative options:

- You can grant the role, rather than many individual privileges, to those users who run the application. Then, as employees change jobs, you need to grant or revoke only one role, rather than many privileges.

- You can change the privileges associated with an application by modifying only the privileges granted to the role, rather than the privileges held by all users of the application.
- You can determine the privileges that are necessary to run a particular application by querying the `ROLE_TAB_PRIVS` and `ROLE_SYS_PRIVS` data dictionary views.
- You can determine which users have privileges on which applications by querying the `DBA_ROLE_PRIVS` data dictionary view.

See Also:

- Chapter 4, "Configuring Privilege and Role Authorization" for a complete discussion of creating, enabling, and disabling roles, and granting and revoking privileges
- "Finding Information About User Privileges and Roles" on page 4-71 for more information about the security uses of the `ROLE_TAB_PRIVS`, `ROLE_SYS_PRIVS`, and `DBA_ROLE_PRIVS` data dictionary views

Creating Secure Application Roles to Control Access to Applications

As explained in "Securing Role Privileges by Using Secure Application Roles" on page 4-22, a secure application role is a role that is only enabled through its associated PL/SQL package or procedure. This package defines the policy needed to control access to an application.

This section contains:

- Step 1: Create the Secure Application Role
- Step 2: Create a PL/SQL Package to Define the Access Policy for the Application

See Also: *Oracle Database 2 Day + Security Guide* for a tutorial on creating a secure application role

Step 1: Create the Secure Application Role

You create a secure application role by using the SQL statement `CREATE ROLE` with the `IDENTIFIED USING` clause. You must have the `CREATE ROLE` system privilege to execute this statement.

For example, to create a secure application role called `hr_admin` that is associated with the `sec_mgr.hr_admin` package, follow these steps:

1. Create the security application role as follows:

```
CREATE ROLE hr_admin IDENTIFIED USING sec_mgr.hr_admin_role_check;
```

   This statement indicates the following:

   - The role `hr_admin` to be created is a secure application role.
   - The role can only be enabled by modules defined inside the PL/SQL procedure `sec_mgr.hr_admin_role_check`. At this stage, this procedure does not need to exist; "Step 2: Create a PL/SQL Package to Define the Access Policy for the Application" on page 5-13 explains how to create the package or procedure.

2. Grant the security application role the privileges you would normally associate with this role.

For example, to grant the hr_admin role SELECT, INSERT, UPDATE, and DELETE privileges on the HR.EMPLOYEES table, you enter the following statement:

```
GRANT SELECT, INSERT, UPDATE, DELETE ON HR.EMPLOYEES TO hr_admin;
```

Do not grant the role directly to the user. The PL/SQL procedure or package does that for you, assuming the user passes its security policies.

Step 2: Create a PL/SQL Package to Define the Access Policy for the Application

To enable or disable the secure application role, you create the security policies of the role within a PL/SQL package. You also can create an individual procedure to do this, but a package lets you group a set of procedures together. This lets you group a set of policies that, used together, present a solid security strategy to protect your applications. For users (or potential intruders) who fail the security policies, you can add auditing checks to the package to record the failure. Typically, you create this package in the schema of the security administrator.

The package or procedure must accomplish the following:

- **It must use invoker's rights to enable the role.**To create the package using invoker's rights, you must set the AUTHID property to CURRENT_USER. You cannot create the package by using definer's rights.

  For more information about invoker's rights and definer's rights, see *Oracle Database PL/SQL Language Reference*.

- **It must include one or more security checks to validate the user.** One way to validate users is to use the SYS_CONTEXT SQL function. See *Oracle Database SQL Language Reference* for more information about SYS_CONTEXT. To find session information for a user, you can use SYS_CONTEXT with an application context. See Chapter 6, "Using Application Contexts to Retrieve User Information" for details.

- **It must issue a SET ROLE SQL statement or DBMS_SESSION.SET_ROLE procedure when the user passes the security checks.** Because you create the package using invoker's rights, you must set the role by issuing the SET ROLE SQL statement or the DBMS_SESSION.SET_ROLE procedure. (However, you cannot use the SET ROLE ALL statement for this type of role enablement.) The PL/SQL embedded SQL syntax does not support the SET ROLE statement, but you can invoke SET ROLE by using dynamic SQL (for example, with EXECUTE IMMEDIATE).

  For more information about EXECUTE IMMEDIATE, see *Oracle Database PL/SQL Language Reference*.

Because of the way that you must create this package or procedure, you cannot use a logon trigger to enable or disable a secure application role. Instead, invoke the package directly from the application when the user logs in, before the user must use the privileges granted by the secure application role.

For example, suppose you wanted to restrict anyone using the hr_admin role to employees who are on site (that is, using certain terminals) and between the hours of 8 a.m. and 5 p.m. As the system or security administrator, follow these steps. (You can copy and paste this text by positioning the cursor at the start of CREATE OR REPLACE in the first line.)

1. Create the procedure as follows:

```
CREATE OR REPLACE PROCEDURE hr_admin_role_check
 AUTHID CURRENT_USER
 AS
 BEGIN
```

```
  IF (SYS_CONTEXT ('userenv','ip_address')
    BETWEEN '192.0.2.10' and '192.0.2.20'
     AND
    TO_CHAR (SYSDATE, 'HH24') BETWEEN 8 AND 17)
  THEN
    EXECUTE IMMEDIATE 'SET ROLE hr_admin';
  END IF;
 END;
/
```

In this example:

- `AUTHID CURRENT_USER` sets the `AUTHID` property to `CURRENT_USER` so that invoker's rights can be used.
- `IF (SYS_CONTEXT ('userenv','ip_address')` validates the user by using the `SYS_CONTEXT` SQL function to retrieve the user session information.
- `BETWEEN ... TO_CHAR` ceates a test to grant or deny access. The test restricts access to users who are on site (that is, using certain terminals) and working between the hours of 8:00 a.m. and 5:00 p.m. If the user passes this check, the `hr_admin` role is granted.
- `THEN... EXECUTE` grants the role to the user by issuing the `SET ROLE` statement using the `EXECUTE IMMEDIATE` command.

2. Grant `EXECUTE` permissions for the `hr_admin_role_check` procedure to any user who was assigned it.

   For example:

   ```
   GRANT EXECUTE ON hr_admin_role_check TO psmith;
   ```

To test the secure application role, log in to SQL*Plus as the user, try to enable the role, and then try to perform an action that requires the privileges the role grants.

For example:

```
CONNECT PSMITH
Enter password: password

EXECUTE sec_admin.hr_admin_role_check;

-- Actions requiring privileges granted by the role
```

Associating Privileges with User Database Roles

Ensure that users have only the privileges associated with the current database role.

This section contains:

- Why Users Should Only Have the Privileges of the Current Database Role
- Using the SET ROLE Statement to Automatically Enable or Disable Roles

Why Users Should Only Have the Privileges of the Current Database Role

A single user can use many applications and associated roles. However, you should ensure that the user has only the privileges associated with the current database role. Consider the following scenario:

- The `ORDER` role (for an application called Order) contains the `UPDATE` privilege for the `INVENTORY` table.

- The INVENTORY role (for an application called Inventory) contains the SELECT privilege for the INVENTORY table.
- Several order entry clerks were granted both the ORDER and INVENTORY roles.

In this scenario, an order entry clerk who was granted both roles can use the privileges of the ORDER role when running the INVENTORY application to update the INVENTORY table. The problem is that updating the INVENTORY table is not an authorized action for the INVENTORY application. It is an authorized action for the ORDER application. To avoid this problem, use the SET ROLE statement as explained in the following section.

Using the SET ROLE Statement to Automatically Enable or Disable Roles

Use a SET ROLE statement at the beginning of each application to automatically enable its associated role and to disable all others. This way, each application dynamically enables particular privileges for a user only when required.

The SET ROLE statement simplifies privilege management. You control what information users can access and when they can access it. The SET ROLE statement also keeps users operating in a well-defined privilege domain. If a user obtains privileges only from roles, then the user cannot combine these privileges to perform unauthorized operations.

See Also:

- "When Do Grants and Revokes Take Effect?" on page 4-48 for information about enabling and disabling roles
- "How the SET ROLE Statement Affects Grants and Revokes" on page 4-48

Protecting Database Objects by Using Schemas

A *schema* is a security domain that can contain database objects. The privileges granted to each user or role control access to these database objects.

This section contains:

- Protecting Database Objects in a Unique Schema
- Protecting Database Objects in a Shared Schema

Protecting Database Objects in a Unique Schema

You can think of most schemas as user names: the accounts that enable users to connect to a database and access the database objects. However, a *unique schema* does not allow connections to the database, but is used to contain a related set of objects. Schemas of this sort are created as typical users, and yet are not granted the CREATE SESSION system privilege (either explicitly or through a role). However, you must temporarily grant the CREATE SESSION and RESOURCE privilege to a unique schema if you want to use the CREATE SCHEMA statement to create multiple tables and views in a single transaction.

For example, a given schema might own the schema objects for a specific application. If application users have the privileges to do so, then they can connect to the database using typical database user names and use the application and the corresponding objects. However, no user can connect to the database using the schema set up for the application. This configuration prevents access to the associated objects through the schema, and provides another layer of protection for schema objects. In this case, the

application could issue an `ALTER SESSION SET CURRENT_SCHEMA` statement to connect the user to the correct application schema.

Protecting Database Objects in a Shared Schema

For many applications, users do not need their own accounts or schemas in a database. These users only need to access an application schema. For example, users John, Firuzeh, and Jane are all users of the Payroll application, and they need access to the `payroll` schema on the `finance` database. None of them need to create their own objects in the database. They need to only access the `payroll` objects. To address this issue, Oracle Advanced Security provides the enterprise users, which are schema-independent users.

Enterprise users, users managed in a directory service, do not need to be created as database users because they use a shared database schema. To reduce administration costs, you can create an enterprise user once in the directory, and point the user at a shared schema that many other enterprise users can also access.

For more information about managing enterprise users, see *Oracle Database Enterprise User Security Administrator's Guide*.

Managing Object Privileges in an Application

As part of designing your application, you need to determine the types of users who will be working with the application and the level of access that they need to accomplish their designated tasks. You must categorize these users into role groups, and then determine the privileges that must be granted to each role.

This section contains:

- What Application Developers Need to Know About Object Privileges
- SQL Statements Permitted by Object Privileges

What Application Developers Need to Know About Object Privileges

End users are typically granted object privileges. An object privilege allows a user to perform a particular action on a specific table, view, sequence, procedure, function, or package.

Table 5–2 summarizes the object privileges available for each type of object.

Table 5–2 How Privileges Relate to Schema Objects

Object Privilege	Applies to Table?	Applies to View?	Applies to Sequence?	Applies to Procedure?[1]
`ALTER`	Yes	No	Yes	No
`DELETE`	Yes	Yes	No	No
`EXECUTE`	No	No	No	Yes
`INDEX`	Yes[2]	No	No	No
`INSERT`	Yes	Yes	No	No
`REFERENCES`	Yes	No	No	No
`SELECT`	Yes	Yes[3]	Yes	No
`UPDATE`	Yes	Yes	No	No

[1] Standalone stored procedures, functions, and public package constructs

[2] Privilege that cannot be granted to a role
[3] Can also be granted for snapshots

See also "Auditing Schema Objects" on page 9-28 for detailed information about how schema objects can be audited.

SQL Statements Permitted by Object Privileges

As you implement and test your application, you should create each necessary role. Test the usage scenario for each role to ensure that the users of your application will have proper access to the database. After completing your tests, coordinate with the administrator of the application to ensure that each user is assigned the proper roles.

Table 5–3 lists the SQL statements permitted by the object privileges shown in Table 5–2.

Table 5–3 SQL Statements Permitted by Database Object Privileges

Object Privilege	SQL Statements Permitted
ALTER	ALTER object (table or sequence) CREATE TRIGGER ON object (tables only)
DELETE	DELETE FROM object (table, view, or synonym)
EXECUTE	EXECUTE object (procedure or function) References to public package variables
INDEX	CREATE INDEX ON object (table, view, or synonym)
INSERT	INSERT INTO object (table, view, or synonym)
REFERENCES	CREATE or ALTER TABLE statement defining a FOREIGN KEY integrity constraint on object (tables only)
SELECT	SELECT...FROM object (table, view, synonym, or snapshot) SQL statements using a sequence

See "About Privileges and Roles" on page 4-1 for a discussion of object privileges. See also "Auditing SQL Statements" on page 9-23 for detailed information about how SQL statements can be audited.

Parameters for Enhanced Security of Database Communication

Database administrators can manage security for their applications by following the procedures in this section.

- Reporting Bad Packets Received on the Database from Protocol Errors
- Terminating or Resuming Server Execution After Receiving a Bad Packet
- Configuring the Maximum Number of Authentication Attempts
- Controlling the Display of the Database Version Banner
- Configuring Banners for Unauthorized Access and Auditing User Actions

Reporting Bad Packets Received on the Database from Protocol Errors

Networking communication utilities such as Oracle Call Interface (OCI) or Two-Task Common (TTC) can generate a large disk file containing the stack trace and heap

dump when the server receives a bad packet, out-of-sequence packet, or a private or an unused remote procedure call. Typically, this disk file can grow quite large. An intruder can potentially cripple a system by repeatedly sending bad packets to the server, which can result in disk flooding and denial of service. An unauthenticated client can also mount this type of attack.

You can prevent these attacks by setting the `SEC_PROTOCOL_ERROR_TRACE_ACTION` initialization parameter to one of the following values:

- `None`: Configures the server to ignore the bad packets and does not generate any trace files or log messages. Use this setting if the server availability is overwhelmingly more important than knowing that bad packets are being received.

  For example:

  ```
  SEC_PROTOCOL_ERROR_TRACE_ACTION = None
  ```

- `Trace` (default setting): Creates the trace files, but it is useful for debugging purposes, for example, when a network client is sending bad packets as a result of a bug.

  For example:

  ```
  SEC_PROTOCOL_ERROR_TRACE_ACTION = Trace
  ```

- `Log`: Writes a short, one-line message to the server trace file. This choice balances some level of auditing with system availability.

  For example:

  ```
  SEC_PROTOCOL_ERROR_TRACE_ACTION = Log
  ```

- `Alert`: Sends an alert message to a database administrator or monitoring console.

  For example:

  ```
  SEC_PROTOCOL_ERROR_TRACE_ACTION = Alert
  ```

Terminating or Resuming Server Execution After Receiving a Bad Packet

After Oracle Database detects a client or server protocol error, it must continue execution. However, this could subject the server to further bad packets, which could lead to disk flooding or denial-of-service attacks.

You can control the further execution of a server process when it is receiving bad packets from a potentially malicious client by setting the `SEC_PROTOCOL_ERROR_FURTHER_ACTION` initialization parameter to one of the following values:

- `Continue` (default setting): Continues the server execution. However, be aware that the server may be subject to further attacks.

  For example:

  ```
  SEC_PROTOCOL_ERROR_FURTHER_ACTION = Continue
  ```

- `Delay,`*m*: Delays the client *m* seconds before the server can accept the next request from the same client connection. This setting prevents malicious clients from excessively using server resources while legitimate clients experience a degradation in performance but can continue to function.

  For example:

  ```
  SEC_PROTOCOL_ERROR_FURTHER_ACTION = Delay,3
  ```

- `Drop,n`: Forcefully terminates the client connection after *n* bad packets. This setting enables the server to protect itself at the expense of the client, for example, loss of a transaction. However, the client can still reconnect, and attempt the same operation again.

  For example:

  ```
  SEC_PROTOCOL_ERROR_FURTHER_ACTION = Drop,10
  ```

Configuring the Maximum Number of Authentication Attempts

With Oracle Database, a server process is first started, and then the client authenticates with this server process. An intruder could start a server process first, and then issue an unlimited number of authenticated requests with different user names and passwords in an attempt to gain access to the database.

You can limit the number of failed login attempts for application connections by setting the `SEC_MAX_FAILED_LOGIN_ATTEMPTS` initialization parameter to restrict the number of authentication attempts on a connection. After the specified number of authentication attempts fail, the database process drops the connection. By default, `SEC_MAX_FAILED_LOGIN_ATTEMPTS` is set to 10.

Remember that the `SEC_MAX_FAILED_LOGIN_ATTEMPTS` initialization parameter is designed to prevent potential intruders from attacking your applications; it does not apply to valid users. The `sqlnet.ora` `INBOUND_CONNECT_TIMEOUT` parameter and the `FAILED_LOGIN_ATTEMPTS` initialization parameter also restrict failed logins, but the difference is that these two parameters only apply to valid user accounts.

For example, to limit the maximum attempts to 5, set `SEC_MAX_FAILED_LOGIN_ATTEMPTS` as follows in the `init`*`sid`*`.ora` initialization parameter file:

```
SEC_MAX_FAILED_LOGIN_ATTEMPTS = 5
```

Controlling the Display of the Database Version Banner

Detailed product version information should not be accessible before a client connection (including an Oracle Call Interface client) is authenticated. An intruder could use the database version to find information about security vulnerabilities that may be present in the database software.

You can restrict the display of the database version banner to unauthenticated clients by setting the `SEC_RETURN_SERVER_RELEASE_BANNER` initialization parameter in the `init`*`sid`*`.ora` initialization parameter file to either `TRUE` or `FALSE`. By default, `SEC_RETURN_SERVER_RELEASE_BANNER` is set to `FALSE`.

For example, if you set it to `TRUE`, the Oracle Database displays the full correct database version:

```
Oracle Database 11g Enterprise Edition Release 11.2.0.0 - Production
```

In the future, if you install Oracle Database 11.2.0.2, for example, it will display the following banner:

```
Oracle Database 11g Enterprise Edition Release 11.2.0.2 - Production
```

However, if in that same release, you set it to `FALSE`, then Oracle Database restricts the banner to display the following fixed text starting with Release 11.2:

```
Oracle Database 11g Release 11.2.0.0.0 - Production
```

Configuring Banners for Unauthorized Access and Auditing User Actions

You should create and configure banners to warn users against unauthorized access and possible auditing of user actions. The notices are available to the client application when it logs into the database.

To configure these banners to display, set the following `sqlnet.ora` parameters on the database server side to point to a text file that contains the banner information:

- `SEC_USER_UNAUTHORIZED_ACCESS_BANNER`. For example:

  ```
  SEC_USER_UNAUTHORIZED_ACCESS_BANNER = /opt/Oracle/11g/dbs/unauthaccess.txt
  ```

- `SEC_USER_AUDIT_ACTION_BANNER`. For example:

  ```
  SEC_USER_AUDIT_ACTION_BANNER = /opt/Oracle/11g/dbs/auditactions.txt
  ```

By default, these parameters are not set. In addition, be aware that there is a 512-byte limitation for the number of characters used for the banner text.

After you set these parameters, the Oracle Call Interface application must use the appropriate OCI APIs to retrieve these banners and present them to the end user.

6

Using Application Contexts to Retrieve User Information

This chapter contains:

About Application Contexts

This section contains:

What Is an Application Context?

An application context is a set of **name-value** pairs that Oracle Database stores in memory. The application context has a label called a **namespace** (for example, `empno_ctx` for an application context that retrieves employee IDs). Inside the context are the name-value pairs (an associative array): the **name** points to a location in memory that holds the **value**. An application can use the application context to access session information about a user, such as the user ID or other user-specific information, or a client ID, and then securely pass this data to the database. You can then use this information to either permit or prevent the user from accessing data through the application. You can use application contexts to authenticate both database and nondatabase users.

Components of the Application Context

The components of the name-value pair are as follows:

- **Name.** Refers to the name of the attribute set that is associated with the value. For example, if the `empno_ctx` application context retrieves an employee ID from the `HR.EMPLOYEES` table, it could have a name such as `employee_id`.
- **Value.** Refers to a value set by the attribute. For example, for the `empno_ctx` application context, if you wanted to retrieve an employee ID from the `HR.EMPLOYEES` table, you could create a value called `emp_id` that sets the value for this ID.

Think of an application context as a global variable that holds information that is accessed during a database session. To set the values for a secure application context, you must create a PL/SQL package procedure that uses the `DBMS_SESSION.SET_CONTEXT` procedure. In fact, this is the only way that you can set application context values if the context is not marked `INITIALIZED EXTERNALLY` or `INITIALIZED GLOBALLY`. You can assign the values to the application context attributes at run time, not when you create the application context. Because the **trusted** procedure, and not the user, assigns the values, it is a called secure application context. For client-session based application contexts, another way to set the application context is to use Oracle Call Interface (OCI) calls.

Where Are the Application Context Values Stored?

Oracle Database stores the application context values in a secure data cache available in the User Global Area (UGA) or the System (sometimes called "Shared") Global Area (SGA). This way, the application context values are retrieved during the session. Because the application context stores the values in this data cache, it increases performance for your applications. You can use an application context by itself, with Oracle Virtual Private Databases policies, or with other fine-grained access control policies. See "Using Oracle Virtual Private Database with an Application Context" on page 7-3 if you are interested in using application contexts with Virtual Private Database policies.

Benefits of Using Application Contexts

Most applications contain the kind of information that can be used for application contexts. For example, in an order entry application that uses a table containing the columns `ORDER_NUMBER` and `CUSTOMER_NUMBER`, you can use the values in these columns as security attributes to restrict access by a customer to his or her own orders, based on the ID of that customer.

Application contexts are useful for the following purposes:

- Enforcing fine-grained access control (for example, in Oracle Virtual Private Database polices)
- Preserving user identity across multitier environments
- Enforcing stronger security for your applications, because the application context is controlled by a trusted procedure, not the user
- Increasing performance by serving as a secure data cache for attributes needed by an application for fine-grained auditing or for use in PL/SQL conditional statements or loops

  This cache saves the repeated overhead of querying the database each time these attributes are needed. Because the application context stores session data in cache rather than forcing your applications to retrieve this data repeatedly from a table, it greatly improves the performance of your applications.

- Serving as a holding area for name-value pairs that an application can define, modify, and access

How Editions Affects Application Context Values

Oracle Database sets the application context in all editions that are affected by the application context package. The values the application context sets are visible in all editions the application context affects.

> **See Also:** *Oracle Database Advanced Application Developer's Guide* for detailed information about editions

Types of Application Contexts

There are three general categories of application contexts:

- **Database session-based application contexts.** This type retrieves data that is stored in the database user session (that is, the UGA) cache. There are three categories of database session-based application contexts:
  - **Initialized locally.** Initializes the application context locally, to the session of the user.
  - **Initialized externally.** Initializes the application context from an Oracle Call Interface (OCI) application, a job queue process, or a connected user database link.
  - **Initialized globally.** Uses attributes and values from a centralized location, such as an LDAP directory.

  "Using Database Session-Based Application Contexts" on page 6-4 describes this type of application context.
- **Global application contexts.** This type retrieves data that is stored in the System Global Area (SGA) so that it can be used for applications that use a sessionless model, such as middle-tier applications in a three-tiered architecture. A global application context is useful if the session context must be shared across sessions, for example, through connection pool implementations.

  "Using Global Application Contexts" on page 6-22 describes this type.
- **Client session-based application contexts.** This type uses Oracle Call Interface functions on the client side to set the user session data, and then to perform the necessary security checks to restrict user access.

  "Using Client Session-Based Application Contexts" on page 6-42 describes this type.

Table 6–1 summarizes the different types of application contexts.

Table 6–1 Types of Application Contexts

Application Context Type	Stored in UGA	Stored in SGA	Supports Connected User Database Links	Supports Centralized Storage of Users' Application Context	Supports Sessionless Multitier Applications
Database session-based application context initialized locally	Yes	No	No	No	No
Database session-based application context initialized externally	Yes	No	Yes	No	No
Database session-based application context initialized globally	Yes	No	No	Yes	No
Global application context	No	Yes	No	No	Yes
Client session-based application context	Yes	No	Yes	No	Yes

Using Database Session-Based Application Contexts

This section contains:

- About Database Session-Based Application Contexts
- Creating a Database Session-Based Application Context
- Creating a PL/SQL Package to Set the Database Session-Based Application Context
- Creating a Logon Trigger to Run a Database Session Application Context Package
- Tutorial: Creating and Using a Database Session-Based Application Context
- Initializing Database Session-Based Application Contexts Externally
- Initializing Database Session-Based Application Contexts Globally
- Using Externalized Database Session-Based Application Contexts

About Database Session-Based Application Contexts

If you must retrieve session information for database users, then use a database session-based application context. This type of application context uses a PL/SQL procedure within Oracle Database to retrieve, set, and secure the data it manages.

> **Note:** If your users are application users, that is, users who are not in your database, consider using a global application context instead. See "Using Global Application Contexts" on page 6-22 for more information.

The database session-based application context is managed entirely within Oracle Database. Oracle Database sets the values, and then when the user exits the session, automatically clears the application context values stored in cache. If the user connection ends abnormally, for example, during a power failure, then the PMON background process cleans up the application context data.You do not need to explicitly clear the application context from cache.

The advantage of having Oracle Database manage the application context is that you can centralize the application context management. Any application that accesses this database will need to use this application context to permit or prevent user access to

that application. This provides benefits both in improved performance and stronger security.

You use the following components to create and use a database session-based application context:

- **The application context.** You use the `CREATE CONTEXT` SQL statement to create an application context. This statement names the application context (namespace) and associates it with a PL/SQL procedure that is designed to retrieve session data and set the application context.
- **A PL/SQL procedure to perform the data retrieval and set the context.** "About the Package That Manages the Database Session-Based Application Context" on page 6-7 describes the tasks this procedure must perform. Ideally, create this procedure within a package, so that you can include other procedures if you want (for example, to perform error checking tasks).
- **A way to set the application context when the user logs on.** Users who log on to applications that use the application context must run a PL/SQL package that sets the application context. You can achieve this with either a logon trigger that fires each time the user logs on, or you can embed this functionality in your applications.

"Tutorial: Creating and Using a Database Session-Based Application Context" on page 6-12 shows how to create and use a database session-based application context that is initialized locally.

You can also initialize session-based application contexts either externally or globally. Either method stores the context information in the user session.

- **External initialization.** This type can come from an OCI interface, a job queue process, or a connected user database link. See "Initializing Database Session-Based Application Contexts Externally" on page 6-16 for detailed information.
- **Global initialization.** This type uses attributes and values from a centralized location, such as an LDAP directory. "Initializing Database Session-Based Application Contexts Globally" on page 6-18 provides more information.

Creating a Database Session-Based Application Context

To create a database session-based application context, you use the `CREATE CONTEXT` SQL statement. Here, you create a namespace for the application context and then associate it with a PL/SQL package that manages the name-value pair that holds the session information of the user. You must have the `CREATE ANY CONTEXT` system privilege to run this statement, and the `DROP ANY CONTEXT` privilege to use the `DROP CONTEXT` statement if you drop the application context. In a database session-based application context, data is stored in the database user session (UGA) in a namespace that you create with the `CREATE CONTEXT` SQL statement.

Each application context must have a unique attribute and belong to a namespace. That is, context names must be unique within the database, not just within a schema.

The ownership of the application context is as follows: Even though a user who has been granted the `CREATE ANY CONTEXT` and `DROP ANY CONTEXT` privileges can create and drop the application context, it is owned by the `SYS` schema. Oracle Database associates the context with the schema account that created it, but if you drop this user, the context still exists in the `SYS` schema. As user `SYS`, you can drop the application context.

Example 6–1 shows how to use CREATE CONTEXT to create a database session-based application context:

Example 6–1 Creating a Database Session-Based Application Context

```
CREATE CONTEXT empno_ctx USING set_empno_ctx_pkg;
```

Here, empno_ctx is the context namespace and set_empno_ctx_pkg is the package that sets attributes for the empno_ctx namespace. When you create the application context, the PL/SQL package does not need to exist, but it must exist at run time. "Step 3: Create a Package to Retrieve Session Data and Set the Application Context" on page 6-14 shows an example of how to create a package that can be used with this application context.

Notice that when you create the context, you do not set its name-value attributes in the CREATE CONTEXT statement. Instead, you set these in the package that you associate with the application context. The reason you do this is to prevent a malicious user from changing the context attributes without proper attribute validation.

> **Note:** You cannot create a context called CLIENTCONTEXT. This word is reserved for use with client session-based application contexts. See "Using Client Session-Based Application Contexts" on page 6-42 for more information about this type of application context.

For each application, you can create an application context that has its own attributes. Suppose, for example, you have three applications: General Ledger, Order Entry, and Human Resources. You can specify different attributes for each application:

- For the order entry application context, you can specify the attribute CUSTOMER_NUMBER.
- For the general ledger application context, you can specify the attributes SET_OF_BOOKS and TITLE.
- For the human resources application context, you can specify the attributes ORGANIZATION_ID, POSITION, and COUNTRY.

The data the attributes access is stored in the tables behind the applications. For example, the order entry application uses a table called OE.CUSTOMERS, which contains the CUSTOMER_NUMBER column, which provides data for the CUSTOMER_NUMBER attribute. In each case, you can adapt the application context to your precise security needs.

Creating a PL/SQL Package to Set the Database Session-Based Application Context

This section contains:

About the Package That Manages the Database Session-Based Application Context

The PL/SQL package, usually created in the schema of the security administrator, defines procedures that manage the session data represented by the application context. It must perform the following tasks:

- **Retrieve session information.** To retrieve the user session information, you can use the `SYS_CONTEXT` SQL function. The `SYS_CONTEXT` function returns the value of the parameter associated with the context namespace. You can use this function in both SQL and PL/SQL statements. Typically, you will use the built-in `USERENV` namespace to retrieve the session information of a user. (For detailed information about the `SYS_CONTEXT` function, see *Oracle Database SQL Language Reference*.)
- **Set the name-value attributes of the application context you created with CREATE CONTEXT.** You can use the `DBMS_SESSION.SET_CONTEXT` procedure to set the name-value attributes of the application context. The name-value attributes can hold information such as the user ID, IP address, authentication mode, the name of the application, and so on. The values of the attributes you set remain either until you reset them, or until the user ends the session. Note the following:
  - If the value of the parameter in the namespace already has been set, then `SET_CONTEXT` overwrites this value.
  - Be aware that any changes in the context value are reflected immediately and subsequent calls to access the value through the `SYS_CONTEXT` function will return the most recent value.
- **Be executed by users.** After you create the package, the user will need to execute the package when he or she logs on. You can create a logon trigger to execute the package automatically when the user logs on, or you can embed this functionality in your applications. Remember that the application context session values are cleared automatically when the user ends the session, so you do not need to manually remove the session data.

It is important to remember that the procedure is a trusted procedure: It is designed to prevent the user from setting his or her own application context attribute values. The user runs the procedure, but the procedure sets the application context values, not the user.

"Tutorial: Creating and Using a Database Session-Based Application Context" on page 6-12 shows how to create a database session-based application context.

Using SYS_CONTEXT to Retrieve Session Information

The syntax for the PL/SQL function `SYS_CONTEXT` is as follows:

```
SYS_CONTEXT ('namespace','parameter'[,length])
```

In this specification:

- *`namespace`*: The name of the application context. You can specify either a string or an expression that evaluates to a string. The `SYS_CONTEXT` function returns the value of parameter associated with the context namespace at the current instant. If the value of the parameter in the namespace already has been set, then `SET_CONTEXT` overwrites this value.
- *`parameter`*: A parameter within the *`namespace`* application context. This value can be a string or an expression.
- *`length`*: Optional. The default maximum size of the return type is 256 bytes, but you can override the length by specifying a value up to 4000 bytes. Enter a value

that is a NUMBER data type, or a value that can be can be implicitly converted to NUMBER. The data type of the SYS_CONTEXT return type is a VARCHAR2.

The SYS_CONTEXT function provides a default namespace, USERENV, which describes the current session of the user logged on. You can use SYS_CONTEXT to retrieve different types of session-based information about a user, such as the user host computer ID, host IP address, operating system user name, and so on. Remember that you only use USERENV to *retrieve* session data, not *set* it. The predefined attributes are listed in the description for the PL/SQL function in the *Oracle Database SQL Language Reference*.

For example, to retrieve the name of the host computer to which a client is connected, you can use the HOST parameter of USERENV as follows:

```
SYS_CONTEXT ('userenv','host')
```

You can check the SYS_CONTEXT settings by issuing a SELECT SQL statement on the DUAL table. The DUAL table is a small table in the data dictionary that Oracle Database and user-written programs can reference to guarantee a known result. This table has one column called DUMMY and one row that contains the value X.

Example 6–2 demonstrates how to find the host computer on which you are logged, assuming that you are logged on to the SHOBEEN_PC host computer under EMP_USERS.

Example 6–2 Finding SYS_CONTEXT Values

```
SELECT SYS_CONTEXT ('USERENV', 'HOST') FROM DUAL;

SYS_CONTEXT(USERENV,HOST)
-------------------------
EMP_USERS\SHOBEEEN_PC
```

Note: The USERENV application context namespace replaces the USERENV function provided in earlier Oracle Database releases.

Using Dynamic SQL with SYS_CONTEXT

During a session in which you expect a change in policy between executions of a given query, the query must use dynamic SQL. You must use dynamic SQL because static SQL and dynamic SQL parse statements differently:

- Static SQL statements are parsed at compile time. They are not parsed again at execution time for performance reasons.
- Dynamic SQL statements are parsed every time they are executed.

Consider a situation in which Policy A is in force when you compile a SQL statement, and then you switch to Policy B and run the statement. With static SQL, Policy A remains in force. Oracle Database parses the statement at compile time, but does not parse it again upon execution. With dynamic SQL, Oracle Database parses the statement upon execution, then the switch to Policy B takes effect.

For example, consider the following policy:

```
EMPLOYEE_NAME = SYS_CONTEXT ('USERENV', 'SESSION_USER')
```

The policy EMPLOYEE_NAME matches the database user name. It is represented in the form of a SQL predicate in Oracle Virtual Private Database: the predicate is considered a policy. If the predicate changes, then the statement must be parsed again to produce the correct result.

See Also: "Using Automatic Reparsing for Fine-Grained Access Control Policy Functions" on page 7-35

Using SYS_CONTEXT in a Parallel Query

If you use SYS_CONTEXT inside a SQL function that is embedded in a parallel query, then the function includes the application context.

Consider a user-defined function within a SQL statement, which sets the user ID to 5:

```
CREATE FUNCTION set_id
 RETURN NUMBER IS
BEGIN
 IF SYS_CONTEXT ('hr', 'id') = 5
   THEN RETURN 1; ELSE RETURN 2;
 END IF;
END;
```

Now consider the following statement:

```
SELECT * FROM emp WHERE set_id( ) = 1;
```

When this statement is run as a parallel query, the user session, which contains the application context information, is propagated to the parallel execution servers (query child processes).

Using SYS_CONTEXT with Database Links

When SQL statements within a user session involve database links, then Oracle Database runs the SYS_CONTEXT SQL function at the host computer of the database link, and then captures the context information there (at the host computer).

If remote PL/SQL procedure calls are run on a database link, then Oracle Database runs any SYS_CONTEXT function inside such a procedure at the destination database of the link. In this case, only externally initialized application contexts are available at the database link destination site. For security reasons, Oracle Database propagates only the externally initialized application context information to the destination site from the initiating database link site.

Using DBMS_SESSION.SET_CONTEXT to Set Session Information

After you have used the SYS_CONTEXT function to retrieve the session data of a user, you are ready to set the application context values from the session of this user. To do so, use the DBMS_SESSION.SET_CONTEXT procedure. (Ensure that you have the EXECUTE privilege for the DBMS_SESSION PL/SQL package.)

Its syntax is as follows:

```
DBMS_SESSION.SET_CONTEXT (
   namespace VARCHAR2,
   attribute VARCHAR2,
   value     VARCHAR2,
   username  VARCHAR2,
   client_id VARCHAR2);
```

In this specification:

- namespace: The namespace of the application context to be set, limited to 30 bytes. For example, if you were using a namespace called custno_ctx, you would specify it as follows:

  ```
  namespace => 'custno_ctx',
  ```

- `attribute`: The attribute of the application context to be set, limited to 30 bytes. For example, to create the `ctx_attrib` attribute for the `custno_ctx` namespace:

  ```
  attribute => 'ctx_attrib',
  ```

- `value`: The value of the application context to be set, limited to 4000 bytes. Typically, this is the value retrieved by the `SYS_CONTEXT` function and stored in a variable. For example:

  ```
  value => ctx_value,
  ```

- `username`: Optional. The database user name attribute of the application context. The default is `NULL`, which permits any user to access the session. For database session-based application contexts, omit this setting so that it uses the `NULL` default.

  The `username` and `client_id` parameters are used for globally accessed application contexts. See "Setting the DBMS_SESSION.SET_CONTEXT username and client_id Parameters" on page 6-25 for more information.

- `client_id`: Optional. The application-specific `client_id` attribute of the application context (64-byte maximum). The default is `NULL`, which means that no client ID is specified. For database session-based application contexts, omit this setting so that it uses the `NULL` default.

See *Oracle Database PL/SQL Packages and Types Reference* for detailed information about the `DBMS_SESSION` package.

For example, remember the application context created in Example 6–1 on page 6-6:

```
CREATE CONTEXT empno_ctx USING set_empno_ctx_proc;
```

Example 6–3 shows how to create a simple procedure that creates an attribute for the `empno_ctx` application context.

Example 6–3 Simple Procedure to Create an Application Context Value

```
CREATE OR REPLACE PROCEDURE set_empno_ctx_proc(
  emp_value IN VARCHAR2)
 IS
 BEGIN
  DBMS_SESSION.SET_CONTEXT('empno_ctx', 'empno_attrib', emp_value);
 END;
/
```

In this example:

- `emp_value IN VARCHAR2` takes `emp_value` as the input parameter. This parameter specifies the value associated with the application context attribute `empno_attrib`. Its limit is 4000 bytes.
- `DBMS_SESSION.SET_CONTEXT('empno_ctx', 'empno_attrib', emp_value)` sets the value of the application context by using the `DBMS_SESSION.SET_CONTEXT` procedure:
  - `'empno_ctx'`: Refers to the application context namespace. Enclose its name in single quotation marks.
  - `'empno_attrib'`: Creates the attribute associated with the application context namespace.

– emp_value: Specifies the value for the empno_attrib attribute. Here, it refers to the emp_value parameter defined in **Line 2**.

At this stage, you can run the set_empno_ctx_proc procedure to set the application context:

```
EXECUTE set_empno_ctx_proc ('42783');
```

(In a real world scenario, you would set the application context values in the procedure itself, so that it becomes a trusted procedure. This example is only used to show how data can be set for demonstration purposes.)

To check the application context setting, run the following SELECT statement:

```
SELECT SYS_CONTEXT ('empno_ctx', 'empno_attrib') empno_attrib FROM DUAL;

EMPNO_ATTRIB
--------------
42783
```

You can also query the SESSION_CONTEXT data dictionary view to find all the application context settings in the current session of the database instance. For example:

```
SELECT * FROM SESSION_CONTEXT;

NAMESPACE                ATTRIBUTE          VALUE
-------------------------------------------------
EMPNO_CTX                EMP_ID             42783
```

See Also:

- "Tutorial: Creating and Using a Database Session-Based Application Context" on page 6-12 for how to create a package that retrieves the user session information and then sets the application context based on this information
- *Oracle Database PL/SQL Packages and Types Reference* for detailed information about the DBMS_SESSION.SET_CONTEXT procedure

Creating a Logon Trigger to Run a Database Session Application Context Package

After you create the application context and its associated package, the user must run the package procedure when he or she logs on. You can create a logon trigger that handles this automatically. You do not need to grant the user EXECUTE permissions to run the package.

Example 6–4 shows a simple logon trigger that executes a PL/SQL procedure.

Example 6–4 Creating a Simple Logon Trigger

```
CREATE OR REPLACE TRIGGER set_empno_ctx_trig AFTER LOGON ON DATABASE
 BEGIN
  sec_mgr.set_empno_ctx_proc;
 END;
```

Example 6–5 shows how to create a logon trigger that uses a WHEN OTHERS exception. Otherwise, if there is an error in the PL/SQL logic that creates an unhandled exception, then all connections to the database are blocked. This example shows a WHEN OTHERS exception that writes errors to a table in the security administrator's schema. In

a production environment, this is safer than sending the output to the user session, where it could be vulnerable to security attacks.

Example 6–5 Creating a Logon Trigger for a Production Environment

```
CREATE OR REPLACE TRIGGER set_empno_ctx_trig AFTER LOGON ON DATABASE
 BEGIN
  sec_mgr.set_empno_ctx_proc;
 EXCEPTION
  WHEN OTHERS THEN
        v_code := SQLCODE;
        v_errm := SUBSTR(SQLERRM, 1 , 64);
       -- Invoke another procedure,
       -- declared with PRAGMA AUTONOMOUS_TRANSACTION,
       -- to insert information about errors.
  INSERT INTO sec_mgr.errors VALUES (v_code, v_errm, SYSTIMESTAMP);
 END;
/
```

Example 6–6 shows how to create the same logon trigger for a development environment, in which you may want to output errors the user session for debugging purposes.

Example 6–6 Creating a Logon Trigger for a Development Environment

```
CREATE TRIGGER set_empno_ctx_trig
 AFTER LOGON ON DATABASE
 BEGIN
  sysadmin_ctx.set_empno_ctx_pkg.set_empno;
 EXCEPTION
  WHEN OTHERS THEN
   RAISE_APPLICATION_ERROR(
    -20000, 'Trigger sysadmin_ctx.set_empno_ctx_trig violation. Login denied.');
 END;
/
```

Note the following:

- **If the PL/SQL package procedure called by the logon trigger has any unhandled exceptions or raises any exceptions (because, for example, a security check failed), then the logon trigger fails.** When the logon trigger fails, the logon fails, that is, the user is denied permission to log in to the database.
- **Logon triggers may affect performance.** In addition, test the logon trigger on a sample schema user first before creating it for the database. That way, if there is an error, you can easily correct it.
- **Be aware of situations in which if you have a changing set of books, or if positions change constantly.** In these cases, the new attribute values may not be picked up right away, and you must force a cursor reparse to pick them up.

> **Note:** A logon trigger can be used because the user context (information such as `EMPNO`, `GROUP`, `MANAGER`) should be set before the user accesses any data.

Tutorial: Creating and Using a Database Session-Based Application Context

This section contains:

About This Tutorial

This tutorial shows how to create an application context that checks the employee ID of any database user who tries to log in to the database.

Step 1: Create User Accounts and Ensure the User SCOTT Is Active

1. Log on as user `SYS` and connect using the `AS SYSDBA` privilege.

   ```
   sqlplus sys as sysdba
   Enter password: password
   ```

2. Create the `sysadmin_ctx` account, who will administer the database session-based application context.

   ```
   GRANT CREATE SESSION, CREATE ANY CONTEXT, CREATE PROCEDURE, CREATE TRIGGER,
   ADMINISTER DATABASE TRIGGER TO sysadmin_ctx IDENTIFIED BY password;
   GRANT SELECT ON HR.EMPLOYEES TO sysadmin_ctx;
   GRANT EXECUTE ON DBMS_SESSION TO sysadmin_ctx;
   ```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

3. Create the following user account for Lisa Ozer, who is listed as having `lozer` for her email account in the `HR.EMPLOYEES` table.

   ```
   GRANT CREATE SESSION TO LOZER IDENTIFIED BY password;
   ```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

4. The sample user `SCOTT` will also be used in this tutorial, so query the `DBA_USERS` data dictionary view to ensure that `SCOTT` is not locked or expired.

   ```
   SELECT USERNAME, ACCOUNT_STATUS FROM DBA_USERS WHERE USERNAME = 'SCOTT';
   ```

   If the `DBA_USERS` view lists user `SCOTT` as locked and expired, then enter the following statement to unlock the `SCOTT` account and create a new password for him:

   ```
   ALTER USER SCOTT ACCOUNT UNLOCK IDENTIFIED BY password;
   ```

   Enter a password that is secure. For greater security, do **not** give the `SCOTT` account the same password from previous releases of Oracle Database. See "Minimum Requirements for Passwords" on page 3-3 for the minimum requirements for creating passwords.

Step 2: Create the Database Session-Based Application Context

1. Log on to SQL*Plus as `sysadmin_ctx`.

```
CONNECT sysadmin_ctx
Enter password: password
```

2. Create the application context using the following statement:

```
CREATE CONTEXT empno_ctx USING set_empno_ctx_pkg;
```

Remember that even though user `sysadmin_ctx` has created this application context, the `SYS` schema owns the context.

Step 3: Create a Package to Retrieve Session Data and Set the Application Context

Example 6–7 shows how to create the package you need to retrieve the session data and set the application context. Before creating the package, ensure that you are still logged on as user `sysadmin_ctx`. (You can copy and paste this text by positioning the cursor at the start of `CREATE OR REPLACE` in the first line.)

Example 6–7 Package to Retrieve Session Data and Set a Database Session Context

```
CREATE OR REPLACE PACKAGE set_empno_ctx_pkg IS
   PROCEDURE set_empno;
 END;
 /
 CREATE OR REPLACE PACKAGE BODY set_empno_ctx_pkg IS
   PROCEDURE set_empno
   IS
    emp_id HR.EMPLOYEES.EMPLOYEE_ID%TYPE;
   BEGIN
    SELECT EMPLOYEE_ID INTO emp_id FROM HR.EMPLOYEES
       WHERE email = SYS_CONTEXT('USERENV', 'SESSION_USER');
    DBMS_SESSION.SET_CONTEXT('empno_ctx', 'employee_id', emp_id);
   EXCEPTION
    WHEN NO_DATA_FOUND THEN NULL;
  END;
 END;
/
```

This package creates a procedure called `set_empno` that performs the following actions:

- `emp_id HR.EMPLOYEES.EMPLOYEE_ID%TYPE` declares a variable, `emp_id`, to store the employee ID for the user who logs on. It uses the same data type as the `EMPLOYEE_ID` column in `HR.EMPLOYEES`.
- `SELECT EMPLOYEE_ID INTO emp_id FROM HR.EMPLOYEES` performs a `SELECT` statement to copy the employee ID that is stored in the `employee_id` column data from the `HR.EMPLOYEES` table into the `emp_id` variable.
- `WHERE email = SYS_CONTEXT('USERENV', 'SESSION_USER')` uses a `WHERE` clause to find all employee IDs that match the email account for the session user. The `SYS_CONTEXT` function uses the predefined `USERENV` context to retrieve the user session ID, which is the same as the `email` column data. For example, the user ID and email address for Lisa Ozer are both the same: `lozer`.
- `DBMS_SESSION.SET_CONTEXT('empno_ctx', 'employee_id', emp_id)` uses the `DBMS_SESSION.SET_CONTEXT` procedure to set the application context:
  - `'empno_ctx'`: Calls the application context `empno_ctx`. Enclose `empno_ctx` in single quotes.

  - `'employee_id'`: Creates the attribute value of the `empno_ctx` application context name-value pair, by naming it `employee_id`. Enclose `employee_id` in single quotes.
  - `emp_id`: Sets the value for the `employee_id` attribute to the value stored in the `emp_id` variable. The `emp_id` variable was created in **Line 8** and the employee ID was retrieved in **Lines 10–11**.

  To summarize, the `set_empno_ctx_pkg.set_empno` procedure says, "Get the session ID of the user and then match it with the employee ID and email address of any user listed in the `HR.EMPLOYEES` table."

- `EXCEPTION ... WHEN_NO_DATA_FOUND` adds a `WHEN NO_DATA_FOUND` system exception to catch any no data found errors that may result from the `SELECT` statement. Without this exception, the package and logon trigger will work fine and set the application context as needed, but then any non-system administrator users other than the users listed in the `HR.EMPLOYEES` table will not be able to log in to the database. Other users should be able to log in to the database, assuming they are valid database users. Once the application context information is set, then you can use this session information as a way to control user access to a particular application.

Step 4: Create a Logon Trigger for the Package

As user `sysadmin_ctx`, create the following trigger:

```
CREATE TRIGGER set_empno_ctx_trig AFTER LOGON ON DATABASE
 BEGIN
  sysadmin_ctx.set_empno_ctx_pkg.set_empno;
 END;
/
```

Step 5: Test the Application Context

1. Log on as user `lozer`.

   ```
   CONNECT lozer
   Enter password: password
   ```

   When user `lozer` logs on, the `empno_ctx` application context collects her employee ID. You can check it as follows:

   ```
   SELECT SYS_CONTEXT('empno_ctx', 'employee_id') emp_id FROM DUAL;
   ```

   The following output should appear:

   ```
   EMP_ID
   ------------------------------------------------------------
   168
   ```

2. Log on as user `SCOTT`.

   ```
   CONNECT SCOTT
   Enter password: password
   ```

   User `SCOTT` is not listed as an employee in the `HR.EMPLOYEES` table, so the `empno_ctx` application context cannot collect an employee ID for him.

   ```
   SELECT SYS_CONTEXT('empno_ctx', 'employee_id') emp_id FROM DUAL;
   ```

   The following output should appear:

   ```
   EMP_ID
   ```

```
--------------------------------------------------
```

From here, the application can use the user session information to determine how much access the user can have in the database. You can use Oracle Virtual Private Database to accomplish this. See Chapter 7, "Using Oracle Virtual Private Database to Control Data Access" for more information.

Step 6: Remove the Components for This Tutorial

1. Log on as `SYS` and connect using `AS SYSDBA`.

   ```
   CONNECT SYS/AS SYSDBA
   Enter password: password
   ```

2. Drop the users `sysadmin_ctx` and `lozer`:

   ```
   DROP USER sysadmin_ctx CASCADE;
   DROP USER lozer;
   ```

3. Drop the application context.

   ```
   DROP CONTEXT empno_ctx;
   ```

   Remember that even though `sysadmin_ctx` created the application context, it is owned by the `SYS` schema.

4. If you want, lock and expire `SCOTT`, unless other users want to use this account:

   ```
   ALTER USER SCOTT PASSWORD EXPIRE ACCOUNT LOCK;
   ```

Initializing Database Session-Based Application Contexts Externally

When you initialize a database session-based application context externally, you specify a special type of namespace that accepts the initialization of attribute values from external resources and then stores them in the local user session. Initializing an application context externally enhances performance because it is stored in the UGA and enables the automatic propagation of attributes from one session to another. Connected user database links are supported only by application contexts initialized from OCI-based external sources.

This section contains:

- Obtaining Default Values from Users
- Obtaining Values from Other External Resources
- Initializing Application Context Values from a Middle-Tier Server

Obtaining Default Values from Users

Sometimes you need the default values from users. Initially, these default values may be hints or preferences, and then after validation, they become trusted contexts. Similarly, it may be more convenient for clients to initialize some default values, and then rely on a login event trigger or applications to validate the values.

For job queues, the job submission routine records the context being set at the time the job is submitted, and restores it when executing the batched job. To maintain the integrity of the context, job queues cannot bypass the designated PL/SQL package to set the context. Rather, the externally initialized application context accepts initialization of context values from the job queue process.

Automatic propagation of context to a remote session may create security problems. Developers or administrators can effectively handle the context that takes default

values from resources other than the designated PL/SQL procedure by using logon triggers to reset the context when users log in.

Obtaining Values from Other External Resources

You can create an application context that accepts the initialization of attributes and values through external resources. Examples include an OCI interface, a job queue process, or a database link.

Externally initialized application contexts provide the following features:

- For remote sessions, automatic propagation of context values that are in the externally initialized application context namespace
- For job queues, restoration of context values that are in the externally initialized application context namespace
- For OCI interfaces, a mechanism to initialize context values that are in the externally initialized application context namespace

Although any client program that is using Oracle Call Interface can initialize this type of namespace, you can use login event triggers to verify the values. It is up to the application to interpret and trust the values of the attributes.

Example 6–8 shows how to create a database session-based application context that obtains values from an external source.

Example 6–8 Creating an Externalized Database Session-based Application Context

```
CREATE CONTEXT ext_ctx USING ext_ctx_pkg INITIALIZED EXTERNALLY;
```

Initializing Application Context Values from a Middle-Tier Server

Middle-tier servers can initialize application context values on behalf of database users. Context attributes are propagated for the remote session at initialization time, and the remote database accepts the values if the namespace is externally initialized.

For example, a three-tier application creating lightweight user sessions through OCI or JDBC/OCI can access the `PROXY_USER` attribute in `USERENV`. This attribute enables you to determine if the user session was created by a middle-tier application. You could allow a user to access data only for connections where the user is proxied. If users connect directly to the database, then they would not be able to access any data.

You can use the `PROXY_USER` attribute from the `USERENV` namespace within Oracle Virtual Private Database to ensure that users only access data through a particular middle-tier application. For a different approach, you can develop a secure application role to enforce your policy that users access the database only through a specific proxy.

See Also:

- "Preserving User Identity in Multitiered Environments" on page 3-36 for information about proxy authentication and about using the `USERENV` attribute `CLIENT_IDENTIFIER` to preserve user identity across multiple tiers
- "Using a Middle Tier Server for Proxy Authentication" on page 3-36 for information about using a secure application role to enforce a policy through a specific proxy
- *Oracle Database JDBC Developer's Guide*
- *Oracle Call Interface Programmer's Guide*

Initializing Database Session-Based Application Contexts Globally

This section contains:

About Initializing Database Session-Based Application Contexts Globally

You can use a centralized location to store the database session-based application context of the user. This enables applications to set up a user context during initialization based upon user identity. In particular, this feature supports Oracle Label Security labels and privileges. Initializing an application context globally makes it easier to manage contexts for large numbers of users and databases.

For example, many organizations want to manage user information centrally, in an LDAP-based directory. Enterprise User Security, a feature of Oracle Advanced Security, supports centralized user and authorization management in Oracle Internet Directory. However, there may be additional attributes an application must retrieve from Lightweight Directory Access Protocol (LDAP) to use for Oracle Virtual Private Database enforcement, such as the user title, organization, or physical location. Initializing an application context globally enables you to retrieve these types of attributes.

Using Database Session-Based Application Contexts with LDAP

An application context that is initialized globally uses LDAP, a standard, extensible, and efficient directory access protocol. The LDAP directory stores a list of users to which this application is assigned. Oracle Database uses a directory service, typically Oracle Internet Directory, to authenticate and authorize enterprise users.

Note:

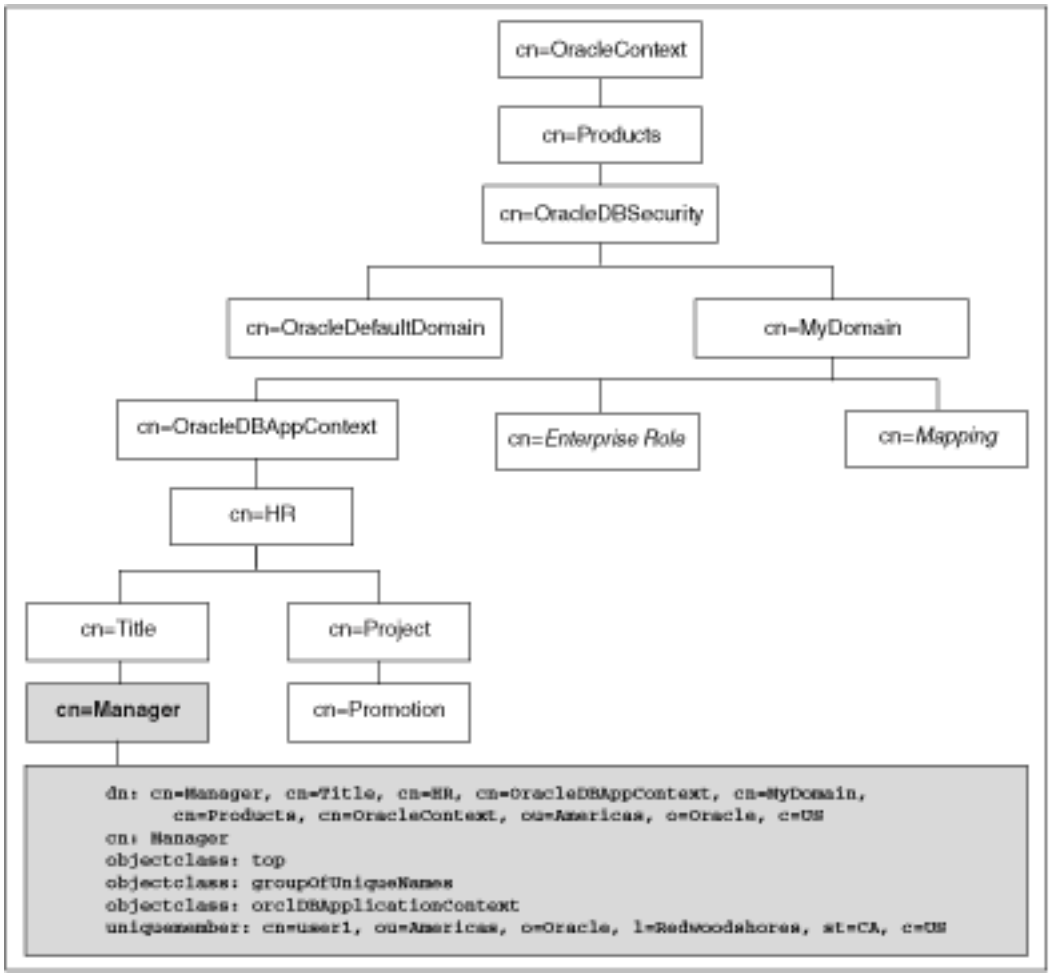
- Enterprise User Security requires Oracle Advanced Security.
- You can use third-party directories such as Microsoft Active Directory and Sun Microsystems SunONE as the directory service.

The `orclDBApplicationContext` LDAP object (a subclass of `groupOfUniqueNames`) stores the application context values in the directory. The location of the application context object is described in Figure 6–1, which is based on the Human Resources example.

The LDAP object `inetOrgPerson` enables multiple entries to exist for some attributes. However, be aware that when these entries are loaded into the database and accessed with the `SYS_LDAP_USER_DEFAULT` context namespace, only the first of these entries is returned. For example, the `inetOrgPerson` object for a user allows multiple entries for `telephoneNumber` (thus allowing a user to have multiple telephone numbers stored). When you use the `SYS_LDAP_USER_DEFAULT` context namespace, only the first telephone number is retrieved.

On the LDAP side, an internal C function is required to retrieve the `orclDBApplicationContext` value, which returns a list of application context values to the database. In this example, `HR` is the namespace; Title and Project are the attributes; and Manager and Promotion are the values.

Figure 6–1 Location of Application Context in LDAP Directory Information Tree



How Globally Initialized Database Session-Based Application Contexts Work

To use a globally initialized secure application, you need to first configure Enterprise User Security, a feature of Oracle Advanced Security. Then, you set up the application context values for the user in the database and the directory.

When a global user (enterprise user) connects to the database, Enterprise User Security verifies the identity of the user connecting to the database. After authentication, the global user roles and application context are retrieved from the directory. When the user logs on to the database, the global roles and initial application context are already set.

> **See Also:** *Oracle Database Enterprise User Security Administrator's Guide* for information about configuring Enterprise User Security

Example of Initializing a Database Session-Based Application Context Globally

You can configure and store the initial application context for a user, such as the department name and title, in the LDAP directory. The values are retrieved during user login so that the context is set properly. In addition, any information related to the user is retrieved and stored in the `SYS_USER_DEFAULTS` application context namespace. The following procedure shows how this is accomplished:

1. Create the application context in the database.

```
CREATE CONTEXT hr USING hrapps.hr_manage_pkg INITIALIZED GLOBALLY;
```

2. Create and add new entries in the LDAP directory.

   An example of the entries added to the LDAP directory follows. These entries create an attribute named `Title` with the attribute value `Manager` for the application (namespace) `HR`, and assign user names `user1` and `user2`. In the following, `cn=example` refers to the name of the domain.

```
dn:
cn=OracleDBAppContext,cn=example,cn=OracleDBSecurity,cn=Products,cn=OracleConte
xt,ou=Americas,o=oracle,c=US
changetype: add
cn: OracleDBAppContext
objectclass: top
objectclass: orclContainer

dn:
cn=hr,cn=OracleDBAppContext,cn=example,cn=OracleDBSecurity,cn=Products,cn=Oracl
eContext,ou=Americas,o=oracle,c=US
changetype: add
cn: hr
objectclass: top
objectclass: orclContainer

dn: cn=Title,cn=hr,
cn=OracleDBAppContext,cn=example,cn=OracleDBSecurity,cn=Products,cn=OracleConte
xt,ou=Americas,o=oracle,c=US
changetype: add
cn: Title
objectclass: top
objectclass: orclContainer

dn: cn=Manager,cn=Title,cn=hr,
cn=OracleDBAppContext,cn=example,cn=OracleDBSecurity,cn=Products,cn=OracleConte
xt,ou=Americas,o=oracle,c=US
cn: Manager
objectclass: top
objectclass: groupofuniquenames
objectclass: orclDBApplicationContext
uniquemember: CN=user1,OU=Americas,O=Oracle,L=Redwoodshores,ST=CA,C=US
uniquemember: CN=user2,OU=Americas,O=Oracle,L=Redwoodshores,ST=CA,C=US
```

3. If an LDAP `inetOrgPerson` object entry exists for the user, then the connection retrieves the attributes from `inetOrgPerson`, and assigns them to the namespace `SYS_LDAP_USER_DEFAULT`. The following is an example of an `inetOrgPerson` entry:

```
dn: cn=user1,ou=Americas,O=oracle,L=redwoodshores,ST=CA,C=US
changetype: add
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
cn: user1
sn: One
givenName: User
initials: UO
title: manager, product development
uid: uone
mail: uone@us.example.com
```

```
telephoneNumber: +1 650 555 0105
employeeNumber: 00001
employeeType: full time
```

4. Connect to the database.

   When `user1` connects to a database that belongs to the `example` domain, `user1` will have his `Title` set to `Manager`. Any information related to `user1` will be retrieved from the LDAP directory. The value can be obtained using the following syntax:

   ```
   SYS_CONTEXT('namespace','attribute name')
   ```

   For example:

   ```
   DECLARE
    tmpstr1 VARCHAR2(30);
    tmpstr2 VARCHAR2(30);
   BEGIN
    tmpstr1 = SYS_CONTEXT('HR','TITLE);
    tmpstr2 = SYS_CONTEXT('SYS_LDAP_USER_DEFAULT','telephoneNumber');
    DBMS_OUTPUT.PUT_LINE('Title is ' || tmpstr1);
    DBMS_OUTPUT.PUT_LINE('Telephone Number is ' || tmpstr2);
   END;
   ```

   The output of this example is:

   ```
   Title is Manager
   Telephone Number is +1 650 555 0105
   ```

Using Externalized Database Session-Based Application Contexts

Many applications store attributes used for fine-grained access control within a database metadata table. For example, an `employees` table could include cost center, title, signing authority, and other information useful for fine-grained access control. Organizations also centralize user information for user management and access control in LDAP-based directories, such as Oracle Internet Directory. Application context attributes can be stored in Oracle Internet Directory, and assigned to one or more enterprise users. They can also be retrieved automatically upon login for an enterprise user, and then used to initialize an application context.

Note: Enterprise User Security is a feature of Oracle Advanced Security.

See Also:

- "Initializing Database Session-Based Application Contexts Externally" on page 6-16 for information about initializing local application context through external resources such as an OCI interface, a job queue process, or a database link
- "Initializing Database Session-Based Application Contexts Globally" on page 6-18 for information about initializing local application context through a centralized resource, such as Oracle Internet Directory
- *Oracle Database Enterprise User Security Administrator's Guide* for information about enterprise users

Using Global Application Contexts

This section contains:

About Global Application Contexts

A global application context enables application context values to be accessible across database sessions, including Oracle RAC instances.Oracle Database stores the global application context information in the System (sometimes called "Shared") Global Area (SGA) so that it can be used for applications that use a sessionless model, such as middle-tier applications in a three-tiered architecture. These applications cannot use a session-based application context because users authenticate to the application, and then it typically connects to the database as a single identity. Oracle Database initializes the global application context once, rather than for each user session. This improves performance, because connections are reused from a connection pool.

There are three general uses for global application contexts:

- **You must share application values globally for all database users.** For example, you may need to disable access to an application based on a specific situation. In this case, the values the application context sets are not user-specific, nor are they based on the private data of a user. The application context defines a situation, for example, to indicate the version of application module that is running.
- **You have database users who must move from one application to another.** In this case, the second application the user is moving to has different access requirements from the first application.
- **You must authenticate nondatabase users, that is, users who are not known to the database.** This type of user, who does not have a database account, typically connects through a Web application by using a connection pool. These types of applications connect users to the database as single user, using the One Big Application User authentication model. To authenticate this type of user, you use the client session ID of the user.

A global application context has the following components:

- **The global application context.** You use the `CREATE CONTEXT` SQL statement to create the global application context, and include the `ACCESSED GLOBALLY` clause in the statement. This statement names the application context and associates it with a PL/SQL procedure that is designed to set the application data context data. The global application context is created and stored in the database schema of the security administrator who creates it.
- **A PL/SQL package to set the attributes.** The package must contain a procedure that uses the `DBMS_SESSION.SET_CONTEXT` procedure to set the global application context. The `SET_CONTEXT` procedure provides parameters that enable you to create

a global application context that fits any of the three user situations described in this section. You create, store, and run the PL/SQL package on the database server. Typically, it belongs in the schema of the security administrator who created it.

- **A middle-tier application to get and set the client session ID.** For nondatabase users, which require a client session ID to be authenticated, you can use the Oracle Call Interface (OCI) calls in the middle-tier application to retrieve and set their session data. You can also use the `DBMS_SESSION.SET_IDENTIFIER` procedure to set the client session ID. An advantage of creating a client session ID to store the nondatabase user's name is that you can query the `CLIENT_ID` column of `DBA_AUDIT_TRAIL`, `DBA_FGA_AUDIT_TRAIL`, and `DBA_COMMON_AUDIT_TRAIL` data dictionary views to audit this user's activity.

Note: Be aware that the `DBMS_APPLICATION_INFO.SET_CLIENT_INFO` setting can overwrite the value. See "Using the DBMS_SESSION PL/SQL Package to Set and Clear the Client Identifier" on page 3-46 for more information.

Using Global Application Contexts in an Oracle Real Application Clusters Environment

In an Oracle RAC environment, whenever a global application context is loaded or changed, it is visible only to the existing active instances. Be aware that setting a global application context value in an Oracle RAC environment has performance overhead of propagating the context value consistently to all Oracle RAC instances.

If you flush the global application context (using the `ALTER SYSTEM FLUSH GLOBAL_CONTEXT` SQL statement) in one Oracle RAC instance, then all the global application context is flushed in all other Oracle RAC instances as well.

Creating a Global Application Context

To create a global application context, use the `CREATE CONTEXT` SQL statement to create the application context and include the `ACCESSED GLOBALLY` clause in the statement. You must have the `CREATE ANY CONTEXT` system privilege before you can use the `CREATE CONTEXT` statement, and the `DROP ANY CONTEXT` privilege before you can drop the context with the `DROP CONTEXT` statement. As with local application contexts, the global application context is created and stored in the database schema of a security administrator.

The ownership of the global application context is as follows: Even though a user who has been granted the `CREATE ANY CONTEXT` and `DROP ANY CONTEXT` privileges can create and drop the global application context, it is owned by the `SYS` schema. Oracle Database associates the context with the schema account that created it, but if you drop this user, the context still exists in the `SYS` schema. As user `SYS`, you can drop the application context.

Example 6–9 shows how to create the global application context `global_hr_ctx`, which is set by the `hr_ctx_pkg` package.

Example 6–9 Creating a Global Application Context

```
CREATE OR REPLACE CONTEXT global_hr_ctx USING hr_ctx_pkg ACCESSED GLOBALLY;
```

Creating a PL/SQL Package to Manage a Global Application Context

This section contains:

- About the Package That Manages the Global Application Context
- How Editions Affects the Results of a Global Application Context PL/SQL Package
- Setting the DBMS_SESSION.SET_CONTEXT username and client_id Parameters
- Sharing Global Application Context Values for All Database Users
- Setting a Global Context for Database Users Who Move Between Applications
- Setting a Global Application Context for Nondatabase Users
- Clearing Session Data When the Session Closes

For detailed information about the `DBMS_SESSION` package, see *Oracle Database PL/SQL Packages and Types Reference*.

About the Package That Manages the Global Application Context

The task of the PL/SQL package that you associate with a global application context is to use the `DBMS_SESSION` package to set and clear the global application context values. You must have the `EXECUTE` privilege for the `DBMS_SESSION` package before you use its procedures. Typically, you create and store this package in the database schema of a security administrator. The `SYS` schema owns the `DBMS_SESSION` package.

Unlike PL/SQL packages used to set a local application context, you do not include a `SYS_CONTEXT` function to get the user session data. You do not need to include this function because the owner of the session, recorded in the `USERENV` context, is the same for every user who is connecting.

You can run the procedures within the PL/SQL package for a global application context at any time. You do not need to create logon and logoff triggers to execute the package procedures associated with the global application context. A common practice is to run the package procedures from within the database application. Additionally, for nondatabase users, you use middle-tier applications to get and set client session IDs.

How Editions Affects the Results of a Global Application Context PL/SQL Package

You can control the behavior of a global application context package—and for packages used for Oracle Virtual Private Database and fine-grained audit policies, as well—across multiple editions, as follows:

- **Have the PL/SQL package results be the same across all editions.** To do so, create the package in the schema of a user who has not been editions enabled. To find users who are not editions enabled, you can query the `DBA_USERS` and `USER_USERS` data dictionary views. Remember that `SYS`, `SYSTEM`, and other default Oracle Database administrative accounts that are listed in the `DBA_REGISTRY` data dictionary view are not and cannot be editions enabled.
- **Have the PL/SQL package results depend on the current state of the edition in which the package is run.** Here, the results may be different across all editions to which the package applies. In this case, create the package in the schema of a user who has been editions enabled. If the schema is editions enabled, then it is likely that there will be different actual copies of the package in different editions, where each copy has different behavior. This is useful for the following types of scenarios:
  - The package must use a new application context.
  - The package must encode input values using a different scheme.

– The package must apply different validation rules for users logging in to the database.

For PL/SQL packages that set a global application context, use a single getter function to wrap the primitive `SYS_CONTEXT` calls that will read the key-value application context pairs. You can put this getter function in the same package as the application context setter procedure. This approach lets you tag the value for the application context key to reflect a relevant concept. For example, the tag can be the edition in which the setter function is actual. Or, it can be the current edition of the session that set the context, which you can find by using `SYS_CONTEXT('USERENV', 'CURRENT_EDITION_NAME')`. This tag can be any specific notion to which the setter function applies.

> **See Also:** *Oracle Database Advanced Application Developer's Guide* for detailed information about editions

Setting the DBMS_SESSION.SET_CONTEXT username and client_id Parameters

In addition to the `namespace`, `attribute`, and `value` parameters, the `DBMS_SESSION.SYS_CONTEXT` procedure provides the `client_id` and `username` parameters. Use these settings for global application contexts. Table 6–2 explains how the combination of these settings controls the type of global application context you can create.

Table 6–2 Setting the DBMS_SESSION.SET_CONTEXT username and client_id Parameters

Combination Settings	Result
`username` set to `NULL` `client_id` set to `NULL`	This combination enables all users to access the application context. See "Sharing Global Application Context Values for All Database Users" on page 6-26 for more information. These settings are also used for database session-based application contexts. See "Using Database Session-Based Application Contexts" on page 6-4 for more information.
`username` set to a value `client_id` set to `NULL`	This combination enables an application context to be accessed by multiple sessions, as long as the `username` setting is the same throughout. Ensure that the user name specified is a valid database user. See "Setting a Global Context for Database Users Who Move Between Applications" on page 6-27 for more information.
`username` set to `NULL` `client_id` set to a value	This combination enables an application to be accessed by multiple user sessions, as long as the `client_id` parameter is set to the same value throughout. This enables sessions of all users to see the application context values.
`username` set to a value `client_id` set to a value	This combination enables the following two scenarios: ■ **Lightweight users.** If the user does not have a database account, the username specified is a connection pool owner. The `client_id` setting is then associated with the nondatabase user who is logging in. ■ **Database users.** If the user is a database user, this combination can be used for stateless Web sessions. Setting the `username` parameter in the `SET_CONTEXT` procedure to `USER` calls the Oracle Database-supplied `USER` function. The `USER` function specifies the session owner from the application context retrieval process and ensures that only the user who set the application context can access the context. See *Oracle Database SQL Language Reference* for more information about the `USER` function. See "Setting a Global Application Context for Nondatabase Users" on page 6-28 for more information.

Sharing Global Application Context Values for All Database Users

To share global application values for all database users, set the `namespace`, `attribute`, and `value` parameters in the `SET_CONTEXT` procedure. In this scenario, *all* users who have database accounts will potentially have access to data in the database.

Example 6–10 shows how to create a package that sets and clears this type of global application context.

Example 6–10 Package to Manage Global Application Values for All Database Users

```
CREATE OR REPLACE PACKAGE hr_ctx_pkg
   AS
    PROCEDURE set_hr_ctx(sec_level IN VARCHAR2);
    PROCEDURE clear_hr_context;
   END;
  /
  CREATE OR REPLACE PACKAGE BODY hr_ctx_pkg
   AS
    PROCEDURE set_hr_ctx(sec_level IN VARCHAR2)
    AS
    BEGIN
     DBMS_SESSION.SET_CONTEXT(
      namespace  => 'global_hr_ctx',
      attribute  => 'job_role',
      value      => sec_level);
     END set_hr_ctx;

  PROCEDURE clear_hr_context
    AS
    BEGIN
     DBMS_SESSION.CLEAR_CONTEXT('global_hr_ctx', 'job_role');
    END clear_context;
  END;
 /
```

In this example:

- `DBMS_SESSION.SET_CONTEXT ... END set_hr_ctx` uses the `DBMS_SESSION.SET_CONTEXT` procedure to set values for the namespace, attribute, and value parameters. The `sec_level` value is specified when the database application runs the `hr_ctx_pkg.set_hr_ctx` procedure.

  The `username` and `client_id` values are not set, hence, they are `NULL`. This enables all users (database users) to have access to the values, which is appropriate for server-wide settings.
- `namespace => 'global_hr_ctx'` sets the `namespace` to `global_hr_ctx`.
- `attribute => 'job_role'` creates the `job_role` attribute.
- `value => sec_level` sets the value for the `job_role` attribute to `sec_level`.
- `PROCEDURE clear_hr_context` creates the `clear_hr_context` procedure to clear the context values. See "Clearing Session Data When the Session Closes" on page 6-32 for more information.

Typically, you execute this procedure within a database application. For example, if all users logging in are clerks, and you want to use "clerk" as a security level, you would embed a call within a database application similar to the following:

```
BEGIN
 hr_ctx_pkg.set_hr_ctx('clerk');
```

```
END;
/
```

If the procedure successfully completes, you can check the application context setting as follows:

```
SELECT SYS_CONTEXT('global_hr_ctx', 'job_role') job_role FROM DUAL;

JOB_ROLE
-----------
clerk
```

To clear this application context, enter the following:

```
BEGIN
 hr_ctx_pkg.clear_hr_context;
END;
/
```

To check that it is really cleared, the following `SELECT` statement should return no values:

```
SELECT SYS_CONTEXT('global_hr_ctx', 'job_role') job_role FROM DUAL;

JOB_ROLE
-----------
```

> **Note:** If Oracle Database returns error messages saying that you have insufficient privileges, ensure that you have correctly created the global application context. You should also query the `DBA_CONTEXT` database view to ensure that your settings are correct, for example, that you are calling the procedure from the schema in which you created it.
>
> If `NULL` is returned, then you may have inadvertently set a client identifier. To clear the client identifier, run the following procedure:
>
> ```
> EXEC DBMS_SESSION.CLEAR_IDENTIFIER;
> ```

Setting a Global Context for Database Users Who Move Between Applications

To set a global application context for database users who move from one application to another, particularly when the applications have different access requirements, include the `username` parameter in the `SET_CONTEXT` procedure. This parameter specifies that the same schema be used for all sessions.

Use the following `SET_CONTEXT` parameters:

- `namespace`
- `attribute`
- `value`
- `username`

Oracle Database matches the `username` value so that the other application can recognize the application context. This enables the user to move between applications.

By omitting the `client_id` setting, its value is `NULL`, the default. This means that values can be seen by multiple sessions if the `username` setting is the same for a database user who maintains the same context in different applications. For example, you can have a

suite of applications that control user access with Oracle Virtual Private Database policies, with each user restricted to a job role.

Example 6–11 demonstrates how to set the username parameter so that a specific user can move between applications. This example is similar to the package that was created in Example 6–10 on page 6-26. The use of the username parameter is indicated in **bold** typeface.

Example 6–11 Package to Manage Global Application Context Values for a User Moving Between Applications

```
CREATE OR REPLACE PACKAGE hr_ctx_pkg
  AS
    PROCEDURE set_hr_ctx(sec_level IN VARCHAR2, user_name IN VARCHAR2);
    PROCEDURE clear_hr_context;
   END;
  /
  CREATE OR REPLACE PACKAGE BODY hr_ctx_pkg
   AS
    PROCEDURE set_hr_ctx(sec_level IN VARCHAR2, user_name IN VARCHAR2)
    AS
     BEGIN
      DBMS_SESSION.SET_CONTEXT(
       namespace  => 'global_hr_ctx',
       attribute  => 'job_role',
       value      => sec_level,
       username   => user_name);
      END set_hr_ctx;

   PROCEDURE clear_hr_context
    AS
     BEGIN
      DBMS_SESSION.CLEAR_CONTEXT('global_hr_ctx');
     END clear_context;
  END;
 /
```

Typically, you execute this procedure within a database application by embedding a call similar to the following example. Ensure that the value for the user_name parameter (scott in this case) is a valid database user name.

```
BEGIN
 hr_ctx_pkg.set_hr_ctx('clerk', 'scott');
END;
```

A secure way to manage this type of global application context is within your applications, embed code to grant a secure application role to the user. This code should include EXECUTE permissions on the trusted PL/SQL package that sets the application context. In other words, the application, not the user, will set the context for the user.

Setting a Global Application Context for Nondatabase Users

When a nondatabase user, that is, a user who is not known to the database (such as a Web application user), starts a client session, the application server generates a client session ID. Once this ID is set on the application server, it must be passed to the database server side. You do this by using the DBMS_SESSION.SET_IDENTIFIER procedure to set the client session ID. To set the context, you set the client_id parameter in the DBMS_SESSION.SET_CONTEXT procedure, in a PL/SQL procedure on

the server side. This enables you to manage the application context globally, yet each client sees only his or her assigned application context.

The `client_id` value is the key here to getting and setting the correct attributes for the global application context. Remember that the client identifier is controlled by the middle-tier application, and once set, it remains open until it is cleared.

A typical way to manage this type of application context is to place the `session_id` value (`client_identifier`) in a cookie, and send it to the end user's HTML page so that is returned on the next request. A lookup table in the application should also keep client identifiers so that they are prevented from being reused for other users and to implement an end-user session time out.

For nondatabase users, configure the following `SET_CONTEXT` parameters:

- `namespace`
- `attribute`
- `value`
- `username`
- `client_id`

Example 6–12 shows how to create a package that manages this type of global application context.

Example 6–12 Package to Manage Global Application Context Values for Nondatabase Users

```
CREATE OR REPLACE PACKAGE hr_ctx_pkg
  AS
   PROCEDURE set_session_id(session_id_p IN NUMBER);
   PROCEDURE set_hr_ctx(sec_level_attr IN VARCHAR2,
      sec_level_val IN VARCHAR2);
   PROCEDURE clear_hr_session(session_id_p IN NUMBER);
   PROCEDURE clear_hr_context;
  END;
/
  CREATE OR REPLACE PACKAGE BODY hr_ctx_pkg
   AS
    session_id_global NUMBER;
  PROCEDURE set_session_id(session_id_p IN NUMBER)
   AS
   BEGIN
    session_id_global := session_id_p;
    DBMS_SESSION.SET_IDENTIFIER(session_id_p);
  END set_session_id;

  PROCEDURE set_hr_ctx(sec_level_attr IN VARCHAR2,
     sec_level_val IN VARCHAR2)
   AS
   BEGIN
    DBMS_SESSION.SET_CONTEXT(
     namespace  => 'global_hr_ctx',
     attribute  => sec_level_attr,
     value      => sec_level_val,
     username   => USER,
     client_id  => session_id_global);
   END set_hr_ctx;

  PROCEDURE clear_hr_session(session_id_p IN NUMBER)
   AS
   BEGIN
      DBMS_SESSION.SET_IDENTIFIER(session_id_p);
      DBMS_SESSION.CLEAR_IDENTIFIER;
   END clear_hr_session;

  PROCEDURE clear_hr_context
  AS
  BEGIN
   DBMS_SESSION.CLEAR_CONTEXT('global_hr_ctx', session_id_global);
  END clear_hr_context;
 END;
 /
```

In this example:

- `session_id_global NUMBER` creates the `session_id_global` variable, which will hold the client session ID. The `session_id_global` variable is referenced throughout the package definition, including the procedure that creates the global application context attributes and assigns them values. This means that the global application context values will always be associated with this particular session ID.

- `PROCEDURE set_session_id ... END set_session_id` creates the `set_session_id` procedure, which writes the client session ID to the `session_id_global` variable.
- `PROCEDURE set_hr_ctx ... END set_hr_ctx` creates the `set_hr_ctx` procedure, which creates global application context attributes and enables you to assign values to these attributes. Within this procedure:
  - `username => USER` specifies the `username` value. This example sets it by calling the Oracle Database-supplied `USER` function, which adds the session owner from the context retrieval process. The `USER` function ensures that only the user who set the application context can access the context. See *Oracle Database SQL Language Reference* for more information about the `USER` function.

    If you had specified `NULL` (the default for the `username` parameter), then any user can access the context.

    Setting both the `username` and `client_id` values enables two scenarios. For lightweight users, set the `username` parameter to a connection pool owner (for example, `APPS_USER`), and then set `client_id` to the client session ID. If you want to use a stateless Web session, set the `user_name` parameter to the same database user who has logged in, and ensure that this user keeps the same client session ID. See "Setting the DBMS_SESSION.SET_CONTEXT username and client_id Parameters" on page 6-25 for an explanation of how different `username` and `client_id` settings work.
  - `client_id => session_id_global` specifies `client_id` value. This example sets it to the `session_id_global` variable. This associates the context settings defined here with a specific client session ID, that is, the one that is set when you run the `set_session_id` procedure. If you specify the `client_id` parameter default, `NULL`, then the global application context settings could be used by any session.
- `PROCEDURE clear_hr_session ... END clear_hr_session` creates the `clear_hr_session` procedure to clear the client session identifier. **Line 33** sets it to ensure that you are clearing the correct session ID, that is, the one stored in variable session_id_p defined in **Line 10**.
- `PROCEDURE clear_hr_context ... END clear_hr_context` creates the `clear_hr_context` procedure, so that you can clear the context settings for the current user session, which were defined by the `global_hr_ctx` variable. See "Clearing Session Data When the Session Closes" on page 6-32 for more information.

See Also:

- "Tutorial: Creating a Global Application Context That Uses a Client Session ID" on page 6-35 for a tutorial that demonstrates how a global application context used for client session IDs works
- "Setting the Client Session ID Using a Middle-Tier Application" on page 6-33
- "Using Client Identifiers to Identify Application Users Not Known to the Database" on page 3-44 for information about how client identifiers work on middle-tier systems

Clearing Session Data When the Session Closes

The application context exists entirely within memory. When the user exits a session, you need to clear the context for the `client_identifier` value. This releases memory and prevents other users from accidentally using any left over values.

To clear session data when a user exits a session, use either of the following methods in the server-side PL/SQL package:

- **Clearing the client identifier when a user exits a session.** Use the `DBMS_SESSION.CLEAR_IDENTIFIER` procedure. For example:

  ```
  DBMS_SESSION.CLEAR_IDENTIFIER;
  ```

- **Continuing the session but still clearing the context.** If you want the session to continue, but you still need to clear the context, use the `DBMS_SESSION.CLEAR_CONTEXT` or the `DBMS_SESSION.CLEAR_ALL_CONTEXT` procedure. For example:

  ```
  DBMS_SESSION.CLEAR_CONTEXT('my_ctx', 'my_attribute');
  ```

  The `CLEAR_CONTEXT` procedure clears the context for the current user. To clear the context values for all users, for example, when you need to shut down the application server, use the `CLEAR_ALL_CONTEXT` procedure.

  Global application context values are available until they are cleared, so you should use `CLEAR_CONTEXT` or `CLEAR_ALL_CONTEXT` to ensure that other sessions do not have access to these values. Be aware that any changes in the context value are reflected immediately and subsequent calls to access the value through the `SYS_CONTEXT` function will return the most recent value.

Embedding Calls in Middle-Tier Applications to Manage the Client Session ID

This section contains:

About Managing Client Session IDs Using a Middle-Tier Application

The application server generates the client session ID. From a middle-tier application, you can get, set, and clear the client session IDs. To do so, embed either Oracle Call Interface (OCI) calls or `DBMS_SESSION` PL/SQL package procedures into the middle-tier application code.

The application authenticates the user, sets the client identifier, and sets it in the current session. The PL/SQL package `SET_CONTEXT` sets the `client_identifier` value in the application context. See "Setting a Global Application Context for Nondatabase Users" on page 6-28 for more information.

Retrieving the Client Session ID Using a Middle-Tier Application

When a user starts a client session, the application server generates a client session ID. To retrieve this client ID, you can use the `OCIStmtExecute` call with any of the following statements:

```
SELECT SYS_CONTEXT('userenv', 'client_identifier') FROM dual;

SELECT CLIENT_IDENTIFIER from V$SESSION;
```

```
SELECT value FROM session_context WHERE attribute='CLIENT_IDENTIFIER';
```

Example 6–13 shows how to use the OCIStmtExecute call to retrieve a client session ID value.

Example 6–13 Using OCIStmtExecute to Retrieve a Client Session ID Value

```
oratext    clientid[31];
 OCIDefine  *defnp1 = (OCIDefine *) 0;
 OCIStmt    *statementhndle;
 oratext    *selcid = (oratext *)"SELECT SYS_CONTEXT('userenv',
             'client_identifier') FROM  DUAL";

 OCIStmtPrepare(statementhndle, errhp, selcid,
  (ub4) strlen((char *) selcid), (ub4) OCI_NTV_SYNTAX, (ub4) OCI_DEFAULT);

OCIDefineByPos(statementhndle, &defnp1, errhp, 1, (dvoid *)clientid, 31,
  SQLT_STR, (dvoid *) 0, (ub2 *) 0, (ub2 *) 0, OCI_DEFAULT);

OCIStmtExecute(servhndle, statementhndle, errhp, (ub4) 1, (ub4) 0,
  (CONST OCISnapshot *) NULL, (OCISnapshot *) NULL, OCI_DEFAULT);

printf("CLIENT_IDENTIFIER = %s \n", clientid);
```

In this example:

- oratext, OCIDefine, OCIStmt, and oratext create variables to store the client session ID, reference call for OCIDefine, the statement handle, and the SELECT statement to use.
- OCIStmtPrepar prepares the statement selcid for execution.
- OCIDefineByPos defines the output variable clientid for client session ID.
- OCIStmtExecute executes the statement in the selcid variable.
- printf prints the formatted output for the retrieved client session ID.

Setting the Client Session ID Using a Middle-Tier Application

After you use the OCIStmtExecute call to retrieve the client session ID, you are ready to set this ID. The DBMS_SESSION.SET_CONTEXT procedure in the server-side PL/SQL package then sets this session ID and optionally, overwrites the application context values.

Ensure that the middle-tier application code checks that the client session ID value (for example, the value written to user_id in the previous examples) matches the client_id setting defined in the server-side DBMS_SESSION.SET_CONTEXT procedure. The sequence of calls on the application server side should be as follows:

1. **Get the current client session ID.** The session should already have this ID, but it is safer to ensure that it truly has the correct value.
2. **Clear the current client session ID.** This prepares the application to service a request from a different end user.
3. **Set the new client session ID or the client session ID that has been assigned to the end user.** This ensures that the session is using a different set of global application context values.

You can use the following methods to set the client session ID on the application server side:

- **Oracle Call Interface.** Set the OCI_ATTR_CLIENT_IDENTIFIER attribute in an OCIAttrSet OCI call. This attribute sets the client identifier in the session handle to track the end user identity.

  The following example shows how to use OCIAttrSet with the ATTR_CLIENT_IDENTIFIER parameter. The user_id setting refers to a variable that stores the ID of the user who is logging on.

  ```
  OCIAttrSet((void *)session_handle, (ub4) OCI_HTYPE_SESSION,
             (void *) user_id, (ub4)strlen(user_id),
             OCI_ATTR_CLIENT_IDENTIFIER, error_handle);
  ```

- **DBMS_SESSION package.** Use the DBMS_SESSION.SET_IDENTIFIER procedure to set the client identifier for the global application context. For example, assuming you are storing the ID of the user logging on in a variable called user_id, you would enter the following line into the middle-tier application code:

  ```
  DBMS_SESSION.SET_IDENTIFIER(user_id);
  ```

  Note: When the application generates a session ID for use as a CLIENT_IDENTIFIER, then the session ID must be suitably random and protected over the network by encryption. If the session ID is not random, then a malicious user could guess the session ID and access the data of another user. If the session ID is not encrypted over the network, then a malicious user could retrieve the session ID and access the connection.

  You can encrypt the session ID by using Oracle Advanced Security. See *Oracle Database Advanced Security Administrator's Guide* for more information. To learn more about encrypting data over a network, see *Oracle Database 2 Day + Security Guide*.

For both OCIAttrSet and DBMS_SESSION.SET_IDENTIFIER, you can check the value of this identifier as follows:

```
SELECT SYS_CONTEXT('userenv', 'client_identifier') FROM dual;
```

Another way to check this value is to query the V$SESSION view:

```
SELECT CLIENT_IDENTIFIER from V$SESSION;
```

Clearing Session Data Using a Middle-Tier Application

The application context exists entirely within memory. When the user exits a session, you need to clear the context for the client_identifier value. This releases memory and prevents other users from accidentally using any left over values

To clear session data when a user exits a session, use either of the following methods in the middle-tier application code:

- **Clearing the client identifier when a user exits a session.** Use the DBMS_SESSION.CLEAR_IDENTIFIER procedure. For example:

  ```
  DBMS_SESSION.CLEAR_IDENTIFIER;
  ```

- **Continuing the session but still clearing the context.** If you want the session to continue, but you still need to clear the context, use the DBMS_SESSION.CLEAR_CONTEXT or the DBMS_SESSION.CLEAR_ALL_CONTEXT procedure. For example:

  ```
  DBMS_SESSION.CLEAR_CONTEXT(namespace, client_identifier, attribute);
  ```

  The CLEAR_CONTEXT procedure clears the context for the current user. To clear the context values for all users, for example, when you need to shut down the application server, use the CLEAR_ALL_CONTEXT procedure.

  Global application context values are available until they are cleared, so you should use CLEAR_CONTEXT or CLEAR_ALL_CONTEXT to ensure that other sessions do not have access to these values.

Tutorial: Creating a Global Application Context That Uses a Client Session ID

This section contains:

About This Tutorial

This tutorial shows how to create a global application context that uses a client session ID for a lightweight user application. It demonstrates how to control nondatabase user access by using a connection pool.

Step 1: Create User Accounts

You must create two users for this example: a security administrator who will manage the application context and its package, and a user account that owns the connection pool.

In this tutorial:

1. Log on to SQL*Plus as SYS and connect using AS SYSDBA.

   ```
   sqlplus sys as sysdba
   Enter password: password
   ```

2. Create the sysadmin_ctx account, who will administer the global application context.

   ```
   GRANT CREATE SESSION, CREATE ANY CONTEXT, CREATE PROCEDURE TO sysadmin_ctx
   IDENTIFIED BY password;

   GRANT EXECUTE ON DBMS_SESSION TO sysadmin_ctx;
   ```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

3. Create the database account apps_user, who will own the connection pool.

   ```
   GRANT CREATE SESSION TO apps_user IDENTIFIED BY password;
   ```

Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

Step 2: Create the Global Application Context

1. Log on as the security administrator sysadmin_ctx.

```
CONNECT sysadmin_ctx
Enter password: password
```

2. Create the cust_ctx global application context.

```
CREATE CONTEXT global_cust_ctx USING cust_ctx_pkg ACCESSED GLOBALLY;
```

The cust_ctx context is created and associated with the schema of the security administrator sysadmin_ctx. However, the SYS schema owns the application context.

Step 3: Create a Package for the Global Application Context

1. As sysadmin_ctx, create the following PL/SQL package:

```
CREATE OR REPLACE PACKAGE cust_ctx_pkg
  AS
   PROCEDURE set_session_id(session_id_p IN NUMBER);
   PROCEDURE set_cust_ctx(sec_level_attr IN VARCHAR2,
     sec_level_val IN VARCHAR2);
   PROCEDURE clear_hr_session(session_id_p IN NUMBER);
   PROCEDURE clear_hr_context;
  END;
 /
CREATE OR REPLACE PACKAGE BODY cust_ctx_pkg
  AS
  session_id_global NUMBER;

 PROCEDURE set_session_id(session_id_p IN NUMBER)
  AS
  BEGIN
   session_id_global := session_id_p;
   DBMS_SESSION.SET_IDENTIFIER(session_id_p);
 END set_session_id;

 PROCEDURE set_cust_ctx(sec_level_attr IN VARCHAR2, sec_level_val IN VARCHAR2)
  AS
  BEGIN
   DBMS_SESSION.SET_CONTEXT(
    namespace  => 'global_cust_ctx',
    attribute  => sec_level_attr,
    value      => sec_level_val,
    username   => USER, -- Retrieves the session user, in this case, apps_user
    client_id  => session_id_global);
  END set_cust_ctx;

  PROCEDURE clear_hr_session(session_id_p IN NUMBER)
   AS
   BEGIN
     DBMS_SESSION.SET_IDENTIFIER(session_id_p);
     DBMS_SESSION.CLEAR_IDENTIFIER;
   END clear_hr_session;

 PROCEDURE clear_hr_context
```

```
  AS
  BEGIN
   DBMS_SESSION.CLEAR_CONTEXT('global_cust_ctx', session_id_global);
  END clear_hr_context;
 END;
/
```

For a detailed explanation of how this type of package works, see Example 6–12 on page 6-30.

2. Grant `EXECUTE` privileges on the `cust_ctx_pkg` package to the connection pool owner, `apps_user`.

```
GRANT EXECUTE ON cust_ctx_pkg TO apps_user;
```

Step 4: Test the Global Application Context

At this stage, you are ready to explore how this global application context and session ID settings work.

1. Log on to SQL*Plus as the connection pool owner, user `apps_user`.

```
CONNECT apps_user
Enter password: password
```

2. When the connection pool user logs on, the application sets the client session identifier as follows:

```
BEGIN
 sysadmin_ctx.cust_ctx_pkg.set_session_id(34256);
END;
/
```

You can test and check the value of the client session identifier as follows:

   a. Connect to SQL*Plus as the connection pool user `apps_user`.

   b. Set the session ID:

```
EXEC sysadmin_ctx.cust_ctx_pkg.set_session_id(34256);
```

   c. Check the session ID:

```
SELECT SYS_CONTEXT('userenv', 'client_identifier') FROM dual;
```

The following output should appear:

```
SYS_CONTEXT('USERENV','CLIENT_IDENTIFIER')
--------------------------------------------------
34256
```

3. As user `apps_user`, set the global application context as follows:

```
EXEC sysadmin_ctx.cust_ctx_pkg.set_cust_ctx('Category', 'Gold Partner');
EXEC sysadmin_ctx.cust_ctx_pkg.set_cust_ctx('Benefit Level', 'Highest');
```

(In a real-world scenario, the middle-tier application would set the global application context values, similar to how the client session identifier was set in Step 2.)

4. Enter the following `SELECT SYS_CONTEXT` statement to check that the settings were successful:

```
col category format a13
col benefit_level format a14
```

```
SELECT SYS_CONTEXT('global_cust_ctx', 'Category') category, SYS_
CONTEXT('global_cust_ctx', 'Benefit Level') benefit_level FROM dual;
```

The following output should appear:

```
CATEGORY       BENEFIT_LEVEL
-------------  --------------
Gold Partner   Highest
```

What `apps_user` has done here, within the client session 34256, is set a global application context on behalf of a nondatabase user. This context sets the `Category` and `Benefit Level` `DBMS_SESSION.SET_CONTEXT attributes` to be `Gold Partner` and `Highest`, respectively. The context exists only for user `apps_user` with client ID 34256. When a nondatabase user logs in, behind the scenes, he or she is really logging on as the connection pool user `apps_user`. Hence, the `Gold Partner` and `Highest` context values are available to the nondatabase user.

Suppose the user had been a database user and could log in without using the intended application. (For example, the user logs in using SQL*Plus.) Because the user has not logged in through the connection pool user `apps_user`, the global application context appears empty to our errant user. This is because the context was created and set under the `apps_user` session. If the user runs the `SELECT SYS_CONTEXT` statement, the following output appears:

```
CATEGORY       BENEFIT_LEVEL
-------------  --------------
```

Next, try the following test:

1. As user `apps_user`, clear the session ID.

   ```
   EXEC sysadmin_ctx.cust_ctx_pkg.clear_hr_session(34256);
   ```

2. Check the global application context settings again.

   ```
   SELECT SYS_CONTEXT('global_cust_ctx', 'Category') category, SYS_
   CONTEXT('global_cust_ctx', 'Benefit Level') benefit_level FROM dual;

   CATEGORY       BENEFIT_LEVEL
   -------------  --------------
   ```

   Because `apps_user` has cleared the session ID, the global application context settings are no longer available.

3. Restore the session ID to 34256, and then check the context values.

   ```
   EXEC sysadmin_ctx.cust_ctx_pkg.set_session_id(34256);

   SELECT SYS_CONTEXT('global_cust_ctx', 'Category') category, SYS_
   CONTEXT('global_cust_ctx', 'Benefit Level') benefit_level FROM dual;
   ```

   The following output should appear:

   ```
   CATEGORY       BENEFIT_LEVEL
   -------------  --------------
   Gold Partner   Highest
   ```

   As you can see, resetting the session ID to 34256 brings the application context values back again. To summarize, the global application context must be set only *once* for this user, but the client session ID must be set *each time* the user logs on.

4. Now try clearing and then checking the global application context values.

```
EXEC sysadmin_ctx.cust_ctx_pkg.clear_hr_context;

SELECT SYS_CONTEXT('global_cust_ctx', 'Category') category, SYS_
CONTEXT('global_cust_ctx', 'Benefit Level') benefit_level FROM dual;
```

The following output should appear:

```
CATEGORY       BENEFIT_LEVEL
-------------  --------------
```

At this stage, the client session ID, 34256 is still in place, but the application context settings no longer exist. This enables you to continue the session for this user but without using the previously set application context values.

Step 5: Remove the Components for This Tutorial

1. Log on as `SYS` and connect using `AS SYSDBA`.

   ```
   CONNECT sys/as sysdba
   Enter password: password
   ```

2. Drop the global application context.

   ```
   DROP CONTEXT global_cust_ctx;
   ```

   Remember that even though `sysadmin_ctx` created the global application context, it is owned by the `SYS` schema.

3. Drop the two sample users.

   ```
   DROP USER sysadmin_ctx CASCADE;
   DROP USER apps_user;
   ```

Global Application Context Processes

This section contains:

- Simple Global Application Context Process
- Global Application Context Process for Lightweight Users

Simple Global Application Context Process

Consider the application server, `AppSvr`, that has assigned the client identifier `12345` to client `SCOTT`. The `AppSvr` application uses the `SCOTT` user to create a session (that is, it is not a connection pool.) The value assigned to the context attribute can come from anywhere, for example, from running a `SELECT` statement on a table that holds the responsibility codes for users. When the application context is populated, it is stored in memory. As a result, any action that needs the responsibility code can access it quickly with `SYS_CONTEXT` call, without the overhead of accessing a table. The only advantage of a global context over a local context in this case is if `SCOTT` were changing applications frequently and used the same context in each application.

The following steps show how the global application context process sets the client identifier for `SCOTT`:

1. The administrator creates a global context namespace by using the following statement:

   ```
   CREATE OR REPLACE CONTEXT hr_ctx USING hr.init ACCESSED GLOBALLY;
   ```

2. The administrator creates a PL/SQL package for the hr_ctx application context to indicate that, for this client identifier, there is an application context called responsibility with a value of 13 in the HR namespace.:

```
CREATE OR REPLACE PROCEDURE hr.init
 AS
 BEGIN
  DBMS_SESSION.SET_CONTEXT(
    namespace => 'hr_ctx',
    attribute => 'responsibility',
    value     => '13',
    username  => 'SCOTT',
    client_id => '12345' );
 END;
/
```

   This PL/SQL procedure is stored in the HR database schema, but typically it is stored in the schema of the security administrator.

3. The AppSvr application issues the following command to indicate the connecting client identity each time scott uses AppSvr to connect to the database:

```
EXEC DBMS_SESSION.SET_IDENTIFIER('12345');
```

4. When there is a SYS_CONTEXT('hr_ctx','responsibility') call within the database session, the database matches the client identifier, 12345, to the global context, and then returns the value 13.

5. When exiting this database session, AppSvr clears the client identifier by issuing the following procedure:

```
EXEC DBMS_SESSION.CLEAR_IDENTIFIER( );
```

6. To release the memory used by the application context, AppSvr issues the following procedure:

```
DBMS_SESSION.CLEAR_CONTEXT('hr_ctx', '12345');
```

   CLEAR_CONTEXT is needed when the user session is no longer active, either on an explicit logout, timeout, or other conditions determined by the AppSvr application.

> **Note:** After a client identifier in a session is cleared, it becomes a NULL value. This implies that subsequent SYS_CONTEXT calls only retrieve application contexts with NULL client identifiers, until the client identifier is set again using the SET_IDENTIFIER interface.

Global Application Context Process for Lightweight Users

The following steps show the global application context process for a lightweight user application. The lightweight user, robert, is not known to the database through the application.

1. The administrator creates the global context namespace by using the following statement:

```
CREATE CONTEXT hr_ctx USING hr.init ACCESSED GLOBALLY;
```

2. The HR application server, AppSvr, starts and then establishes multiple connections to the HR database as the appsmgr user.

3. User robert logs in to the HR application server.

4. AppSvr authenticates robert to the application.
5. AppSvr assigns a temporary session ID (or uses the application user ID), 12345, for this connection.
6. The session ID is returned to the Web browser used by robert as part of a cookie or is maintained by AppSvr.
7. AppSvr initializes the application context for this client by calling the hr.init package, which issues the following statements:

```
DBMS_SESSION.SET_CONTEXT( 'hr_ctx', 'id', 'robert', 'APPSMGR', 12345 );
DBMS_SESSION.SET_CONTEXT( 'hr_ctx', 'dept', 'sales', 'APPSMGR', 12345 );
```

8. AppSvr assigns a database connection to this session and initializes the session by issuing the following statement:

```
DBMS_SESSION.SET_IDENTIFIER( 12345 );
```

9. All SYS_CONTEXT calls within this database session return application context values that belong only to the client session.

   For example, SYS_CONTEXT('hr','id') returns the value robert.

10. When finished with the session, AppSvr issues the following statement to clean up the client identity:

```
DBMS_SESSION.CLEAR_IDENTIFIER ( );
```

Even if another user logged in to the database, this user cannot access the global context set by AppSvr, because AppSvr specified that only the application with user APPSMGR logged in can see it. If AppSvr used the following, then any user session with client ID set to 12345 can see the global context:

```
DBMS_SESSION.SET_CONTEXT( 'hr_ctx', 'id', 'robert', NULL , 12345 );
DBMS_SESSION.SET_CONTEXT( 'hr_ctx', 'dept', 'sales', NULL , 12345 );
```

Setting USERNAME to NULL enables different users to share the same context.

> **Note:** Be aware of the security implication of different settings of the global context. NULL in the user name means that any user can access the global context. A NULL client ID in the global context means that a session with an uninitialized client ID can access the global context. To ensure that only the user who has logged on can access the session, specify USER instead of NULL.

You can query the client identifier set in the session as follows:

```
SELECT SYS_CONTEXT('USERENV','CLIENT_IDENTIFIER') FROM dual;
```

The following output should appear:

```
SYS_CONTEXT('USERENV','CLIENT_IDENTIFIER')
------------------------------------------------
12345
```

A security administrator can see which sessions have the client identifier set by querying the V$SESSION view for the CLIENT_IDENTIFIER and USERNAME, for example:

```
COL client_identifier format a18
SELECT CLIENT_IDENTIFIER, USERNAME from V$SESSION;
```

The following output should appear:

```
CLIENT_IDENTIFIER   USERNAME
------------------  --------
12345               APPSMGR
```

To check the amount of global context area (in bytes) being used, use the following query:

```
SELECT SYS_CONTEXT('USERENV','GLOBAL_CONTEXT_MEMORY') FROM dual;
```

The following output should appear:

```
SYS_CONTEXT('USERENV','GLOBAL_CONTEXT_MEMORY')
----------------------------------------------
584
```

See Also: For more information about using the `CLIENT_IDENTIFIER` predefined attribute of the `USERENV` application context:

- "Using the CLIENT_IDENTIFIER Attribute to Preserve User Identity" on page 3-45
- *Oracle Database SQL Language Reference*
- *Oracle Call Interface Programmer's Guide*

Using Client Session-Based Application Contexts

This section contains:

About Client Session-Based Application Contexts

In a client session-based application context, you use Oracle Call Interface (OCI) functions to set and clear user session information, which is then stored in the User Global Area (UGA).

The advantage of this type of application context is that an individual application can check for specific nondatabase user session data, rather than having the database perform this task. Another advantage is that the calls to set the application context value are included in the next call to the server, which improves performance.

However, be aware that application context security is compromised with a client session-based application context: any application user can set the client application context, and no check is performed in the database.

You configure the client session-based application context for the client application only. You do not configure any settings on the database server to which the client connects. Any application context settings in the database server do not affect the client session-based application context.

To configure a client session-based application context, use the `OCIAppCtxSet` OCI function. A client session-based application context uses the `CLIENTCONTEXT`

namespace, updatable by any OCI client or by the existing DBMS_SESSION package for application context. Oracle Database performs no privilege or package security checks for this type.

The CLIENTCONTEXT namespace enables a single application transaction to both change the user context information and use the same user session handle to service the new user request. You can set or clear individual values for attributes in the CLIENTCONTEXT namespace, or clear all their values.

- An OCI client uses the OCIAppCtx function to set variable length data for the namespace, called OCISessionHandle. The OCI network single, round-trip transport sends all the information to the server in one round-trip. On the server side, you can query the application context information by using the SYS_CONTEXT SQL function on the namespace. For example:
- A JDBC client uses the oracle.jdbc.internal.OracleConnection function to achieve the same purposes.

Any user can set, clear, or collect the information in the CLIENTCONTEXT namespace, because it is not protected by package-based security.

> **See Also:** *Oracle Call Interface Programmer's Guide* for more information about client application contexts

Setting a Value in the CLIENTCONTEXT Namespace

For Oracle Call Interface, to set a value in the CLIENTCONTEXT namespace, use a command in the following syntax:

```
err = OCIAppCtxSet((void *) session_handle,(dvoid *)"CLIENTCONTEXT",(ub4) 13,
                   (dvoid *)attribute_name, length_of_attribute_name
                   (dvoid *)attribute_value, length_of_attribute_value, errhp,
                   OCI_DEFAULT);
```

In this specification:

- *session_handle*: Represents the OCISessionHandle namespace.
- *attribute_name*: Name of attribute. For example, responsibility, with a length of 14.
- *attribute_value*: Value of attribute. For example, manager, with a length of 7.

> **See Also:** "Managing Scalable Platforms" in *Oracle Call Interface Programmer's Guide* for details about the OCIAppCtx function

Retrieving the CLIENTCONTEXT Namespace

To retrieve the CLIENTCONTEXT namespace, you can use the Oracle Call Interface OCIStmtExecute call with either of the following statements:

```
SELECT SYS_CONTEXT('CLIENTCONTEXT', 'Attribute-1') FROM dual;

SELECT VALUE FROM SESSION_CONTEXT
WHERE NAMESPACE='CLIENTCONTEXT' AND ATTRIBUTE='attribute-1';
```

The *Attribute-1* value can be any attribute value that has already been set in the CLIENTCONTEXT namespace. Oracle Database only retrieves the set attribute; otherwise, it returns NULL. Typically, you set the attribute by using the OCIAppCtxSet call. In addition, you can embed a DBMS_SESSION.SET_CONTEXT call in the OCI code to set the attribute value.

Example 6–13 shows how to use the OCIStmtExecute call to retrieve a client session ID value.

Example 6–14 Retrieving a Client Session ID Value for Client Session-Based Contexts

```
oratext    clientid[31];
OCIDefine  *defnp1 = (OCIDefine *) 0;
OCIStmt    *statementhndle;
oratext    *selcid = (oratext *)"SELECT SYS_CONTEXT('CLIENTCONTEXT',
            attribute) FROM  DUAL";

OCIStmtPrepare(statementhndle, errhp, selcid, (ub4) strlen((char *) selcid),
  (ub4) OCI_NTV_SYNTAX, (ub4) OCI_DEFAULT);

OCIDefineByPos(statementhndle, &defnp1, errhp, 1, (dvoid *)clientid, 31,
  SQLT_STR, (dvoid *) 0, (ub2 *) 0, (ub2 *) 0, OCI_DEFAULT);

OCIStmtExecute(servhndle, statementhndle, errhp, (ub4) 1, (ub4) 0,
  (CONST OCISnapshot *) NULL, (OCISnapshot *) NULL, OCI_DEFAULT);

printf("CLIENT_IDENTIFIER = %s \n", clientid);
```

In this example:

- oratext, OCIDefine, OCIStmt, and oratext create variables to store the client session ID, reference call for OCIDefine, the statement handle, and the SELECT statement to use.
- OCIStmtPrepare prepares the statement selcid for execution.
- OCIDefineByPos defines the output variable clientid for client session ID.
- OCIStmtExecute executes the statement in the selcid variable.
- printf prints the formatted output for the retrieved client session ID.

Clearing a Setting in the CLIENTCONTEXT Namespace

For Oracle Call Interface, to clear a setting in CLIENTCONTEXT, set the value to NULL or to an empty string by using one of the following commands:

```
(void) OCIAppCtxSet((void *) session_handle, (dvoid *)"CLIENTCONTEXT", 13,
                    (dvoid *)attribute_name, length_of_attribute_name,
                    (dvoid *)0, 0,errhp
                    OCI_DEFAULT);
```

or

```
(void) OCIAppCtxSet((void *) session_handle, (dvoid *)"CLIENTCONTEXT", 13
                    (dvoid *)attribute_name, length_of_attribute_name,
                    (dvoid *)"", 0,errhp,
                    OCI_DEFAULT);
```

Clearing All Settings in the CLIENTCONTEXT Namespace

For Oracle Call Interface (OCI), use a command of the following form:

```
err = OCIAppCtxClearAll((void *) session_handle,
                        (dvoid *)"CLIENTCONTEXT", 13,
                         errhp,
                         OCI_DEFAULT);
```

Finding Information About Application Contexts

Table 6–3 lists data dictionary views that you can query to find information about application contexts. For detailed information about these views, see *Oracle Database Reference.*

Table 6–3 Data Dictionary Views That Display Information about Application Contexts

View	Description
ALL_CONTEXT	Describes all context namespaces in the current session for which attributes and values were specified using the DBMS_SESSION.SET_CONTEXT procedure. It lists the namespace and its associated schema and PL/SQL package.
ALL_POLICY_CONTEXTS	Describes the driving contexts defined for the synonyms, tables, and views accessible to the current user. (A driving context is a context used in a Virtual Private Database policy.)
DBA_CONTEXT	Provides all context namespace information in the database. Its columns are the same as those in the ALL_CONTEXT view, except that it includes the TYPE column. The TYPE column describes how the application context is accessed or initialized.
DBA_POLICY_CONTEXTS	Describes all driving contexts in the database that were added by the DBMS_RLS.ADD_POLICY_CONTEXT procedure. Its columns are the same as those in ALL_POLICY_CONTEXTS.
SESSION_CONTEXT	Describes the context attributes and their values set for the current session.
USER_POLICY_CONTEXTS	Describes the driving contexts defined for the synonyms, tables, and views owned by the current user. Its columns (except for OBJECT_OWNER) are the same as those in ALL_POLICY_CONTEXTS.
V$CONTEXT	Lists set attributes in the current session. Users do not have access to this view unless you grant the user the SELECT privilege on it.
V$SESSION	Lists detailed information about each current session. Users do not have access to this view unless you grant the user the SELECT privilege on it.

Tip: In addition to these views, check the database trace file if you find errors when running applications that use application contexts. See *Oracle Database Performance Tuning Guide* for more information about trace files. The USER_DUMP_DEST initialization parameter sets the directory location of the trace files. You can find the value of this parameter by issuing SHOW PARAMETER USER_DUMP_DEST in SQL*Plus.

7

Using Oracle Virtual Private Database to Control Data Access

This chapter contains:

About Oracle Virtual Private Database

This section contains:

What Is Oracle Virtual Private Database?

Oracle Virtual Private Database (VPD) enables you to create security policies to control database access at the row and column level. Essentially, Oracle Virtual Private Database adds a dynamic `WHERE` clause to a SQL statement that is issued against the table, view, or synonym to which an Oracle Virtual Private Database security policy was applied.

Oracle Virtual Private Database enforces security, to a fine level of granularity, directly on database tables, views, or synonyms. Because you attach security policies directly to these database objects, and the policies are automatically applied whenever a user accesses data, there is no way to bypass security.

When a user directly or indirectly accesses a table, view, or synonym that is protected with an Oracle Virtual Private Database policy, Oracle Database dynamically modifies the SQL statement of the user. This modification creates a `WHERE` condition (called a predicate) returned by a function implementing the security policy. Oracle Database modifies the statement dynamically, transparently to the user, using any condition that

can be expressed in or returned by a function. You can apply Oracle Virtual Private Database policies to SELECT, INSERT, UPDATE, INDEX, and DELETE statements.

For example, suppose a user performs the following query:

```
SELECT * FROM OE.ORDERS;
```

The Oracle Virtual Private Database policy dynamically appends the statement with a WHERE clause. For example:

```
SELECT * FROM OE.ORDERS
 WHERE SALES_REP_ID = 159;
```

In this example, the user can only view orders by Sales Representative 159.

If you want to filter the user based on the session information of that user, such as the ID of the user, then you can create the WHERE clause to use an application context. For example:

```
SELECT * FROM OE.ORDERS
 WHERE SALES_REP_ID = SYS_CONTEXT('USERENV','SESSION_USER');
```

Note: Oracle Virtual Private Database does not support filtering for DDLs, such as TRUNCATE or ALTER TABLE statements.

Benefits of Using Oracle Virtual Private Database Policies

Oracle Virtual Private Database policies provide the following benefits:

- Basing Security Policies on Database Objects Rather Than Applications
- Controlling How Oracle Database Evaluates Policy Functions

Basing Security Policies on Database Objects Rather Than Applications

Attaching Oracle Virtual Private Database security policies to database tables, views, or synonyms, rather than implementing access controls in all your applications, provides the following benefits:

- **Security.** Associating a policy with a database table, view, or synonym can solve a potentially serious application security problem. Suppose a user is authorized to use an application, and then drawing on the privileges associated with that application, wrongfully modifies the database by using an ad hoc query tool, such as SQL*Plus. By attaching security policies directly to tables, views, or synonyms, fine-grained access control ensures that the same security is in force, no matter how a user accesses the data.
- **Simplicity.** You add the security policy to a table, view, or synonym only once, rather than repeatedly adding it to each of your table-based, view-based, or synonym-based applications.
- **Flexibility.** You can have one security policy for SELECT statements, another for INSERT statements, and still others for UPDATE and DELETE statements. For example, you might want to enable Human Resources clerks to have SELECT privileges for all employee records in their division, but to update only salaries for those employees in their division whose last names begin with A through F. Furthermore, you can create multiple policies for each table, view, or synonym.

Controlling How Oracle Database Evaluates Policy Functions

Running policy functions multiple times can affect performance. You can control the performance of policy functions by configuring how Oracle Database caches the Oracle Virtual Private Database predicates. The following options are available:

- Evaluate the policy once for each query (static policies).
- Evaluate the policy only when an application context within the policy function changes (context-sensitive policies).
- Evaluate the policy each time it is run (dynamic policies).

See "Optimizing Performance by Using Oracle Virtual Private Database Policy Types" on page 7-14 for information configuring these policy types.

Which Privileges Are Used to Run Oracle Virtual Private Database Policy Functions?

For greater security, the Oracle Virtual Private Database policy function runs as if it had been declared with definer's rights. Do not declare it as invoker's rights because this can confuse yourself and other users who maintain the code.

> **See Also:** *Oracle Database PL/SQL Language Reference* for detailed information about definer's rights

Using Oracle Virtual Private Database with an Application Context

You can use application contexts with Oracle Virtual Private Database policies. When you create an application context, it securely caches user information. Only the designated application package can set the cached environment. It cannot be changed by the user or outside the package. In addition, because the data is cached, performance is increased. Chapter 6, "Using Application Contexts to Retrieve User Information" describes application contexts in detail.

For example, suppose you want to base access to the `ORDERS_TAB` table on the customer ID number. Rather than querying the customer ID number for a logged-in user each time you need it, you could store the number in the application context. Then, the customer number is available in the session when you need it.

Application contexts are especially helpful if your security policy is based on multiple security attributes. For example, if a policy function bases a `WHERE` predicate on four attributes (such as employee number, cost center, position, spending limit), then multiple subqueries must execute to retrieve this information. Instead, if this data is available through an application context, then performance is much faster.

You can use an application context to return the correct security policy, enforced through a predicate. For example, consider an order entry application that enforces the following rules: customers only see their own orders, and clerks see all orders for all customers. These are two different policies. You could define an application context with a `position` attribute, and this attribute could be accessed within the policy function to return the correct predicate, depending on the value of the attribute. Thus, you can enable a user in the `clerk` position to retrieve all orders, but a user in the `customer` position can see only those records associated with that particular user.

To design a fine-grained access control policy that returns a specific predicate for an attribute, you need to access the application context within the function that implements the policy. For example, suppose you want to limit customers to seeing only their own records. The user performs the following query:

```
SELECT * FROM orders_tab
```

Fine-grained access control dynamically modifies this query to include the following WHERE predicate:

```
SELECT * FROM orders_tab
  WHERE custno = SYS_CONTEXT ('order_entry', 'cust_num');
```

Continuing with the preceding example, suppose you have 50,000 customers, and you do not want to have a different predicate returned for each customer. Customers all share the same WHERE predicate, which prescribes that they can only see their own orders. It is merely their customer numbers that are different.

Using application context, you can return one WHERE predicate within a policy function that applies to 50,000 customers. As a result, there is one shared cursor that executes differently for each customer, because the customer number is evaluated at execution time. This value is different for every customer. Use of application context in this case provides optimum performance, and at row-level security.

The SYS_CONTEXT function works much like a bind variable; only the SYS_CONTEXT arguments are constants.

Components of an Oracle Virtual Private Database Policy

To implement Oracle Virtual Private Database, you must create a function to generate the dynamic WHERE clause, and a policy to attach this function to the objects that you want to protect.

- Creating a Function to Generate the Dynamic WHERE Clause
- Creating a Policy to Attach the Function to the Objects You Want to Protect

See Also:

- "Which Privileges Are Used to Run Oracle Virtual Private Database Policy Functions?" on page 7-3
- "Tutorials: Creating Oracle Virtual Private Database Policies" on page 7-19

Creating a Function to Generate the Dynamic WHERE Clause

To generate the dynamic WHERE clause (predicate), you must create a function (not a procedure) that defines the restrictions that you want to enforce. Usually, the security administrator creates this function in his or her own schema. For more complex behavior, such as including calls to other functions or adding checks to track failed logon attempts, create these functions within a package.

The function must have the following behavior:

- **It must take as arguments a schema name and an object (table, view, or synonym) name as inputs.** Define input parameters to hold this information, but do not specify the schema and object name themselves within the function. The policy that you create with the DBMS_RLS package (described in "Creating a Policy to Attach the Function to the Objects You Want to Protect" on page 7-5) provides the names of the schema, and object to which the policy will apply. You must create the parameter for the schema first, followed by the parameter for the object.
- **It must provide a return value for the WHERE clause predicate that will be generated.** The return value for the WHERE clause is always a VARCHAR2 data type.

- **It must generate a valid WHERE clause.** This code can be as basic as the example in "Tutorial: Creating a Simple Oracle Virtual Private Database Policy" on page 7-19, in that its `WHERE` clause is the same for all users who log on.

  But in most cases, you may want to design the `WHERE` clause to be different for each user, each group of users, or each application that accesses the objects you want to protect. For example, if a manager logs in, the `WHERE` clause can be specific to the rights of that particular manager. You can do this by incorporating an application context, which accesses user session information, into the `WHERE` clause generation code. "Tutorial: Implementing a Policy with a Database Session-Based Application Context" on page 7-22 demonstrates how to create an Oracle Virtual Private Database policy that uses an application context.

  You can create Oracle Virtual Private Database functions that do not use an application context, but an application context creates a much stronger Oracle Virtual Private Database policy, by securely basing user access on the session attributes of that user, such as the user ID. Chapter 6, "Using Application Contexts to Retrieve User Information" discusses different types of application contexts in detail.

  In addition, you can embed C or Java calls to access operating system information or to return `WHERE` clauses from an operating system file or other source.

- **It must not select from a table within the associated policy function.** Although you can define a policy against a table, you cannot select that table from within the policy that was defined against the table.

Note: If you plan to run the function across different editions, you can control the results of the function: whether the results are uniform across all editions, or specific to the edition in which the function is run. See "How Editions Affects the Results of a Global Application Context PL/SQL Package" on page 6-24 for more information.

Creating a Policy to Attach the Function to the Objects You Want to Protect

After you create the function, you need to create an Oracle Virtual Private Database policy that associates the function with a table, view, or synonym. You create the policy by using the `DBMS_RLS` package. If you are not `SYS`, then you must be granted `EXECUTE` privileges to use the `DBMS_RLS` package. This package contains procedures that enable you to manage the policy and set fine-grained access control. For example, to attach the policy to a table, you use the `DBMS_RLS.ADD_POLICY` procedure. Within this setting, you set fine-grained access control, such as setting the policy to go into effect when a user issues a `SELECT` or `UPDATE` statement on the table or view.

The combination of creating the function and then applying it to a table or view is referred to as creating the Oracle Virtual Private Database policy.

"Tutorials: Creating Oracle Virtual Private Database Policies" on page 7-19 provides examples of how to create Virtual Private Database policies. See "Configuring an Oracle Virtual Private Database Policy" on page 7-5 for detailed information.

Configuring an Oracle Virtual Private Database Policy

This section contains:

- About Oracle Virtual Private Database Policies
- Attaching a Policy to a Database Table, View, or Synonym

- Enforcing Policies on Specific SQL Statement Types
- Controlling the Display of Column Data with Policies
- Working with Oracle Virtual Private Database Policy Groups
- Optimizing Performance by Using Oracle Virtual Private Database Policy Types

About Oracle Virtual Private Database Policies

After you create a function that defines the actions of the Oracle Virtual Private Database `WHERE` clause, you need to associate this function with the database table to which the VPD action applies. You can do this by configuring an Oracle Virtual Private Database policy. The policy itself is a mechanism for managing the Virtual Private Database function. The policy also enables you to add fine-grained access control, such as specifying the types of SQL statements or particular table columns the policy affects. When a user tries to access the data in this database object, the policy goes into effect automatically.

This section describes commonly used ways of attaching policies to tables, views, and synonyms. To manage an Oracle Virtual Private Database policy, you use the `DBMS_RLS` package, which is described in detail in *Oracle Database PL/SQL Packages and Types Reference*.

Table 7–1 lists the procedures in the `DBMS_RLS` package.

Table 7–1 DBMS_RLS Procedures

Procedure	Description
For Handling Individual Policies	
`DBMS_RLS.ADD_POLICY`	Adds a policy to a table, view, or synonym
`DBMS_RLS.ENABLE_POLICY`	Enables (or disables) a policy you previously added to a table, view, or synonym
`DBMS_RLS.REFRESH_POLICY`	Invalidates cursors associated with nonstatic policies
`DBMS_RLS.DROP_POLICY`	To drop a policy from a table, view, or synonym
For Handling Grouped Policies	
`DBMS_RLS.CREATE_POLICY_GROUP`	Creates a policy group
`DBMS_RLS.DELETE_POLICY_GROUP`	Drops a policy group
`DBMS_RLS.ADD_GROUPED_POLICY`	Adds a policy to the specified policy group
`DBMS_RLS.ENABLE_GROUPED_POLICY`	Enables a policy within a group
`DBMS_RLS.REFRESH_GROUPED_POLICY`	Parses again the SQL statements associated with a refreshed policy
`DBMS_RLS.DISABLE_GROUPED_POLICY`	Disables a policy within a group
`DBMS_RLS.DROP_GROUPED_POLICY`	Drops a policy that is a member of the specified group
For Handling Application Contexts	
`DBMS_RLS.ADD_POLICY_CONTEXT`	Adds the context for the active application
`DBMS_RLS.DROP_POLICY_CONTEXT`	Drops the context for the application

See Also:

- "Components of an Oracle Virtual Private Database Policy" on page 7-4 for a description of the type of function that you need to create to control user access to a database table, view, or synonym
- Chapter 6, "Using Application Contexts to Retrieve User Information" if you plan to use application contexts in the Oracle Virtual Private Database policy (which in most cases, you would)
- "Tutorials: Creating Oracle Virtual Private Database Policies" on page 7-19 for examples of using application contexts in sample Oracle Virtual Private Database functions

Attaching a Policy to a Database Table, View, or Synonym

To attach a policy to a table, view, or synonym, you use the `DBMS_RLS.ADD_POLICY` procedure. You need to specify the table, view, or synonym to which you are adding a policy, and a name for the policy. You can also specify other information, such as the types of statements the policy controls (`SELECT`, `INSERT`, `UPDATE`, `DELETE`, `CREATE INDEX`, or `ALTER INDEX`).

Example 7–1 shows how to use `DBMS_RLS.ADD_POLICY` to attach an Oracle Virtual Private Database policy called `secure_update` to the `HR.EMPLOYEES` table. The function attached to the policy is `check_updates`.

Example 7–1 Attaching a Simple Oracle Virtual Private Database Policy to a Table

```
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'check_updates',
...
```

If the function was created inside a package, include the package name. For example:

```
 policy_function => 'pkg.check_updates',
...
```

Note: Although you can define a policy against a table, you cannot select that table from within the policy that was defined against the table.

Enforcing Policies on Specific SQL Statement Types

You can enforce Oracle Virtual Private Database policies for `SELECT`, `INSERT`, `UPDATE`, `INDEX`, and `DELETE` statements. If you do not specify a statement type, by default, Oracle Database specifies `SELECT`, `INSERT`, `UPDATE`, and `DELETE`, but not `INDEX`. Enter any combination of these statement types by using the `statement_types` parameter in the `DBMS_RLS.ADD_POLICY` procedure. Enclose the list in a pair of single quotation marks.

Example 7–2 shows an how to use the `statement_types` parameter to specify the `SELECT` and `INDEX` statements for a policy.

Example 7–2 Specifying SQL Statement Types with DBMS_RLS.ADD_POLICY

```
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'check_updates',
  statement_types => 'SELECT,INDEX');
END;
/
```

When you specify the `statement_types` parameter, be aware of the following functionality:

- **The application code affected by the Virtual Private Database policy can include the MERGE INTO statement.** However, in the Virtual Private Database policy, you must ensure that the `statement_types` parameter includes all three of the `INSERT`, `UPDATE`, and `DELETE` statements for the policy to succeed. Alternatively, you can omit the `statement_types` parameter. (This functionality is available with Oracle Database 11*g* Release 2 (11.2.0.2).)
- **Be aware that a user who has privileges to maintain an index can see all the row data, even if the user does not have full table access under a regular query such as SELECT.** For example, a user can create a function-based index that contains a user-defined function with column values as its arguments. During index creation, Oracle Database passes column values of every row into the user function, making the row data available to the user who creates the index. You can enforce Oracle Virtual Private Database policies on index maintenance operations by specifying `INDEX` with the `statement_types` parameter.

Controlling the Display of Column Data with Policies

You can create policies that enforce row-level security when a security-relevant column is referenced in a query.

- Adding Policies for Column-Level Oracle Virtual Private Database
- Displaying Only the Column Rows Relevant to the Query
- Using Column Masking to Display Sensitive Columns as NULL Values

Adding Policies for Column-Level Oracle Virtual Private Database

Column-level policies enforce row-level security when a query references a security-relevant column. You can apply a column-level Oracle Virtual Private Database policy to tables and views, but not to synonyms.

To apply the policy to a column, specify the security-relevant column by using the `SEC_RELEVANT_COLS` parameter of the `DBMS_RLS.ADD_POLICY` procedure. This parameter applies the security policy whenever the column is referenced, explicitly or implicitly, in a query.

For example, users who are not in a Human Resources department typically are allowed to view only their own Social Security numbers. A sales clerk initiates the following query:

```
SELECT fname, lname, ssn FROM emp;
```

The function implementing the security policy returns the predicate `ssn='my_ssn'`. Oracle Database rewrites the query and executes the following:

```
SELECT fname, lname, ssn FROM emp
 WHERE ssn = 'my_ssn';
```

Example 7–3 shows a Oracle Virtual Private Database policy in which sales department users cannot see the salaries of people outside the department (department number 30) of the sales department users. The relevant columns for this policy are `sal` and `comm`. First, the Oracle Virtual Private Database policy function is created, and then it is added by using the `DBMS_RLS` PL/SQL package.

Example 7–3 Creating a Column-Level Oracle Virtual Private Database Policy

```
CREATE OR REPLACE FUNCTION hide_sal_comm (
 v_schema IN VARCHAR2,
 v_objname IN VARCHAR2)

RETURN VARCHAR2 AS
con VARCHAR2 (200);

BEGIN
 con := 'deptno=30';
 RETURN (con);
END hide_sal_comm;
```

Then you configure the policy with the `DBMS_RLS.ADD_POLICY` procedure as follows:

```
BEGIN
 DBMS_RLS.ADD_POLICY (
  object_schema     => 'scott',
  object_name       => 'emp',
  policy_name       => 'hide_sal_policy',
  policy_function   => 'hide_sal_comm',
  sec_relevant_cols => 'sal,comm');
END;
```

Displaying Only the Column Rows Relevant to the Query

The default behavior for column-level Oracle Virtual Private Database is to restrict the number of rows returned for a query that references columns containing sensitive information. You specify these security-relevant columns by using the `SEC_RELEVANT_COLUMNS` parameter of the `DBMS_RLS.ADD_POLICY` procedure, as shown in Example 7–3 on page 7-9.

For example, consider sales department users with the `SELECT` privilege on the `emp` table, which is protected with the column-level Oracle Virtual Private Database policy created in Example 7–3. The user (for example, user `SCOTT`) runs the following query:

```
SELECT ENAME, d.dname, JOB, SAL, COMM
 FROM emp e, dept d
 WHERE d.deptno = e.deptno;
```

The database returns the following rows:

```
ENAME      DNAME          JOB              SAL       COMM
---------- -------------- --------- ---------- ----------
ALLEN      SALES          SALESMAN        1600        300
WARD       SALES          SALESMAN        1250        500
MARTIN     SALES          SALESMAN        1250       1400
BLAKE      SALES          MANAGER         2850
TURNER     SALES          SALESMAN        1500          0
JAMES      SALES          CLERK            950
```

```
6 rows selected.
```

The only rows that are displayed are those that the user has privileges to access all columns in the row.

Using Column Masking to Display Sensitive Columns as NULL Values

If a query references a sensitive column, then the default action of column-level Oracle Virtual Private Database restricts the number of rows returned. With column-masking behavior, all rows display, even those that reference sensitive columns. However, the sensitive columns display as NULL values. To enable column-masking, set the SEC_RELEVANT_COLS_opt parameter of the DBMS_RLS.ADD_POLICY procedure.

For example, consider the results of the sales clerk query, described in the previous example. If column-masking is used, then instead of seeing only the row containing the details and Social Security number of the sales clerk, the clerk would see all rows from the emp table, but the ssn column values would be returned as NULL. Note that this behavior is fundamentally different from all other types of Oracle Virtual Private Database policies, which return only a subset of rows.

In contrast to the default action of column-level Oracle Virtual Private Database, column-masking displays all rows, but returns sensitive column values as NULL. To include column-masking in your policy, set the SEC_RELEVANT_COLS_OPT parameter of the DBMS_RLS.ADD_POLICY procedure to DBMS_RLS.ALL_ROWS.

Example 7–4 shows column-level Oracle Virtual Private Database column-masking. It uses the same VPD policy as Example 7–3 on page 7-9, but with sec_relevant_cols_opt specified as DBMS_RLS.ALL_ROWS.

Example 7–4 Adding a Column Masking to an Oracle Virtual Private Database Policy

```
BEGIN
 DBMS_RLS.ADD_POLICY(
   object_schema         => 'scott',
   object_name           => 'emp',
   policy_name           => 'hide_sal_policy',
   policy_function       => 'hide_sal_comm',
   sec_relevant_cols     =>' sal,comm',
   sec_relevant_cols_opt => dbms_rls.ALL_ROWS);
END;
```

Assume that a sales department user with SELECT privilege on the emp table (such as user SCOTT) runs the following query:

```
SELECT ENAME, d.dname, job, sal, comm
 FROM emp e, dept d
 WHERE d.deptno = e.deptno;
```

The database returns all rows specified in the query, but with certain values masked because of the Oracle Virtual Private Database policy:

```
ENAME      DNAME          JOB              SAL       COMM
---------- -------------- --------- ---------- ----------
CLARK      ACCOUNTING     MANAGER
KING       ACCOUNTING     PRESIDENT
MILLER     ACCOUNTING     CLERK
JONES      RESEARCH       MANAGER
FORD       RESEARCH       ANALYST
ADAMS      RESEARCH       CLERK
SMITH      RESEARCH       CLERK
SCOTT      RESEARCH       ANALYST
```

```
WARD       SALES          SALESMAN        1250        500
TURNER     SALES          SALESMAN        1500          0
ALLEN      SALES          SALESMAN        1600        300
JAMES      SALES          CLERK            950
BLAKE      SALES          MANAGER         2850
MARTIN     SALES          SALESMAN        1250       1400

14 rows selected.
```

The column-masking returned all rows requested by the sales user query, but made the `sal` and `comm` columns `NULL` for employees outside the sales department.

The following considerations apply to column-masking:

- Column-masking applies only to `SELECT` statements.
- Column-masking conditions generated by the policy function must be simple Boolean expressions, unlike regular Oracle Virtual Private Database predicates.
- For applications that perform calculations, or do not expect `NULL` values, use standard column-level Oracle Virtual Private Database, specifying `SEC_RELEVANT_COLS` rather than the `SEC_RELEVANT_COLS_OPT` column-masking option.
- Do not include columns of the object data type (including the `XMLtype`) in the `sec_relevant_cols` setting. This column type is not supported for the `sec_relevant_cols` setting.
- Column-masking used with `UPDATE AS SELECT` updates only the columns that users are allowed to see.
- For some queries, column-masking may prevent some rows from displaying. For example:

  ```
  SELECT * FROM emp
   WHERE sal = 10;
  ```

  Because the column-masking option was set, this query may not return rows if the `salary` column returns a `NULL` value.

Working with Oracle Virtual Private Database Policy Groups

This section contains:

- About Oracle Virtual Private Database Policy Groups
- Creating a New Oracle Virtual Private Database Policy Group
- Designating a Default Policy Group with the SYS_DEFAULT Policy Group
- Establishing Multiple Policies for Each Table, View, or Synonym
- Validating the Application Used to Connect to the Database

> **See Also:** "Tutorial: Implementing an Oracle Virtual Private Database Policy Group" on page 7-28

About Oracle Virtual Private Database Policy Groups

You can group multiple security policies together, and apply them to an application. A policy group is a set of security policies that belong to an application. You can designate an application context (known as a *driving context* or *policy context*) to indicate the policy group in effect. Then, when a user accesses the table, view, or synonym column, Oracle Database looks up the driving context to determine the

policy group in effect. It enforces all the associated policies that belong to the policy group.

Policy groups are useful for situations where multiple applications with multiple security policies share the same table, view, or synonym. This enables you to identify those policies that should be in effect when the table, view, or synonym is accessed.

For example, in a hosting environment, Company A can host the BENEFIT table for Company B and Company C. The table is accessed by two different applications, Human Resources and Finance, with two different security policies. The Human Resources application authorizes users based on ranking in the company, and the Finance application authorizes users based on department. Integrating these two policies into the BENEFIT table requires joint development of policies between the two companies, which is not a feasible option. By defining an application context to drive the enforcement of a particular set of policies to the base objects, each application can implement a private set of security policies.

To do this, you organize security policies into groups. By referring to the application context, Oracle Database determines which group of policies should be in effect at run time. The server enforces all the policies that belong to that policy group.

Creating a New Oracle Virtual Private Database Policy Group

To add a policy to a table, view, or synonym, use the DBMS_RLS.ADD_GROUPED_POLICY procedure to specify the group to which the policy belongs. To specify which policies will be effective, you can add a driving context using the DBMS_RLS.ADD_POLICY_CONTEXT procedure. If the driving context returns an unknown policy group, then an error is returned.

If the driving context is not defined, then Oracle Database runs all policies. Likewise, if the driving context is NULL, then policies from all policy groups are enforced. An application accessing the data cannot bypass the security setup module (which sets up application context) to avoid any applicable policies.

You can apply multiple driving contexts to the same table, view, or synonym, and each of them will be processed individually. This enables you to configure multiple active sets of policies to be enforced.

Consider, for example, a hosting company that hosts Benefits and Financial applications, which share some database objects. Both applications are striped for hosting using a SUBSCRIBER policy in the SYS_DEFAULT policy group. Data access is partitioned first by subscriber ID, then by whether the user is accessing the Benefits or Financial applications (determined by a driving context). Suppose that Company A, which uses the hosting services, wants to apply a custom policy that relates only to its own data access. You could add an additional driving context (such as COMPANY A SPECIAL) to ensure that the additional, special policy group is applied for data access for Company A only. You would not apply this under the SUBSCRIBER policy, because the policy relates only to Company A, and it is more efficient to segregate the basic hosting policy from other policies.

Designating a Default Policy Group with the SYS_DEFAULT Policy Group

Within a group of security policies, you can designate one security policy to be the default security policy. This is useful in situations where you partition security policies by application, so that they will be always be in effect. Default security policies allow developers to base security enforcement under all conditions, while partitioning security policies by application (using security groups) enables layering of additional, application-specific security on top of default security policies. To implement default security policies, you add the policy to the SYS_DEFAULT policy group.

Policies defined in this group for a particular table, view, or synonym are run with with the policy group specified by the driving context. As described earlier, a driving context is an application context that indicates the policy group in effect. The SYS_DEFAULT policy group may or may not contain policies. You cannot to drop the SYS_DEFAULT policy group. If you do, then Oracle Database displays an error.

If, to the SYS_DEFAULT policy group, you add policies associated with two or more objects, then each object will have a separate SYS_DEFAULT policy group associated with it. For example, the emp table in the scott schema has one SYS_DEFAULT policy group, and the dept table in the scott schema has a different SYS_DEFAULT policy group associated with it. Think of them as being organized in the tree structure as follows:

```
SYS_DEFAULT
  - policy1 (scott/emp)
  - policy3 (scott/emp)
SYS_DEFAULT
  - policy2 (scott/dept)
```

You can create policy groups with identical names. When you select a particular policy group, its associated schema and object name are displayed in the property sheet on the right side of the screen.

Establishing Multiple Policies for Each Table, View, or Synonym

You can establish several policies for the same table, view, or synonym. Suppose, for example, you have a base application for Order Entry, and each division of your company has its own rules for data access. You can add a division-specific policy function to a table without having to rewrite the policy function of the base application.

All policies applied to a table are enforced with AND syntax. If you have three policies applied to the CUSTOMERS table, then each policy is applied to the table. You can use policy groups and an application context to partition fine-grained access control enforcement so that different policies apply, depending upon which application is accessing data. This eliminates the requirement for development groups to collaborate on policies, and simplifies application development. You can also have a default policy group that is always applicable (for example, to enforce data separated by subscriber in a hosting environment).

Validating the Application Used to Connect to the Database

The package implementing the driving context must correctly validate the application that is being used to connect to the database. Although Oracle Database checks the call stack to ensure that the package implementing the driving context sets context attributes, inadequate validation can still occur within the package.

For example, in applications where database users or enterprise users are known to the database, the user needs the EXECUTE privilege on the package that sets the driving context. Consider a user who knows that:

- The BENEFITS application enables more liberal access than the HR application.
- The setctx procedure (which sets the correct policy group within the driving context) does not perform any validation to determine which application is actually connecting. That is, the procedure does not check either the IP address of the incoming connection (for a three-tier system) or the proxy_user attribute of the user session.

This user could pass to the driving context package an argument setting the context to the more liberal BENEFITS policy group, and then access the HR application instead. Because the setctx does no further validation of the application, this user bypasses the more restrictive HR security policy.

By contrast, if you implement proxy authentication with Oracle Virtual Private Database, then you can determine the identity of the middle tier (and the application) that is connecting to the database on behalf of a user. The correct policy will be applied for each application to mediate data access.

For example, a developer using the proxy authentication feature could determine that the application (the middle tier) connecting to the database is HRAPPSERVER. The package that implements the driving context can thus verify whether the proxy_user in the user session is HRAPPSERVER. If so, then it can set the driving context to use the HR policy group. If proxy_user is not HRAPPSERVER, then it can deny access.

In this case, the following query is executed:

```
SELECT * FROM apps.benefit;
```

Oracle Database picks up policies from the default policy group (SYS_DEFAULT) and active namespace HR. The query is internally rewritten as follows:

```
SELECT * FROM apps.benefit
 WHERE company = SYS_CONTEXT('ID','MY_COMPANY')
 and SYS_CONTEXT('ID','TITLE') = 'MANAGER';
```

Optimizing Performance by Using Oracle Virtual Private Database Policy Types

This section contains:

- About Oracle Virtual Private Database Policy Types
- Using the Dynamic Policy Type to Automatically Rerun Policy Functions
- Using a Static Policy to Prevent Policy Functions from Rerunning for Each Query
- Using a Shared Static Policy to Share a Policy with Multiple Objects
- When to Use Static and Shared Static Policies
- Using a Context-Sensitive Policy for Predicates That Do Not Change After Parsing
- Using a Shared Context Sensitive Policy to Share a Policy with Multiple Objects
- When to Use Context-Sensitive and Shared Context-Sensitive Policies
- Summary of the Five Oracle Virtual Private Database Policy Types

About Oracle Virtual Private Database Policy Types

You can optimize performance each time a policy runs by specifying a policy type for your policies. Policy types control how Oracle Database caches Oracle Virtual Private Database policy predicates. Consider setting a policy type for your policies, because the execution of policy functions can use a significant amount of system resources. Minimizing the number of times that a policy function can run optimizes database performance.

You can choose from five policy types: DYNAMIC, STATIC, SHARED_STATIC, CONTEXT_SENSITIVE, and SHARED_CONTEXT_SENSITIVE. These enable you to precisely specify how often a policy predicate should change. To specify the policy type, set the policy_type parameter of the DBMS_RLS.ADD POLICY procedure.

Using the Dynamic Policy Type to Automatically Rerun Policy Functions

The DYNAMIC policy type runs the policy function each time a user accesses the Virtual Private Database-protected database objects. If you do not specify a policy type in the DBMS_RLS.ADD_POLICY procedure, then, by default, your policy will be dynamic. You can specifically configure a policy to be dynamic by setting the policy_type parameter of the DBMS_RLS.ADD_POLICY procedure to DYNAMIC.

This policy type does not optimize database performance as the static and context sensitive policy types do. However, Oracle recommends that before you set policies as either static or context-sensitive, you should first test them as DYNAMIC policy types, which run every time. Testing policy functions as DYNAMIC policies first enables you to observe how the policy function affects each query, because nothing is cached. This ensures that the functions work properly before you enable them as static or context-sensitive policy types to optimize performance.

You can use the DBMS_UTILITY.GET_TIME function to measure the start and end times for a statement to execute. For example:

```
-- 1. Get the start time:
SELECT DBMS_UTILITY.GET_TIME FROM DUAL;

  GET_TIME
----------
   2312721

-- 2. Run the statement:
SELECT COUNT(*) FROM HR.EMPLOYEES;

  COUNT(*)
----------
       107

-- 3. Get the end time:
SELECT DBMS_UTILITY.GET_TIME FROM DUAL;

  GET_TIME
----------
   2314319
```

Example 7–5 shows how to create the DYNAMIC policy type.

Example 7–5 Creating a DYNAMIC Policy with DBMS_RLS.ADD_POLICY

```
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.DYNAMIC);
END;
/
```

> **See Also:** "About Auditing Functions, Procedures, Packages, and Triggers" on page 9-32 for information about how Oracle Database audits the underlying policy function for dynamic policies

Using a Static Policy to Prevent Policy Functions from Rerunning for Each Query

The static policy type enforces the same predicate for all users in the instance. Oracle Database stores static policy predicates in SGA, so policy functions do not rerun for each query. This results in faster performance.

You can enable static policies by setting the `policy_type` parameter of the `DBMS_RLS.ADD_POLICY` procedure to either `STATIC` or `SHARED_STATIC`, depending on whether or not you want the policy to be shared across multiple objects.

Example 7–6 shows how to create the `STATIC` policy type.

Example 7–6 Creating a STATIC Policy with DBMS_RLS.ADD_POLICY

```
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.STATIC);
END;
/
```

Each execution of the same cursor could produce a different row set for the same predicate, because the predicate may filter the data differently based on attributes such as `SYS_CONTEXT` or `SYSDATE`.

For example, suppose you enable a policy as either a `STATIC` or `SHARED_STATIC` policy type, which appends the following predicate to all queries made against policy protected database objects:

```
WHERE dept = SYS_CONTEXT ('hr_app','deptno')
```

Although the predicate does not change for each query, it applies to the query based on session attributes of the `SYS_CONTEXT`. In the case of the preceding example, the predicate returns only those rows where the department number matches the `deptno` attribute of the `SYS_CONTEXT`, which is the department number of the user who is querying the policy-protected database object.

Note: When using shared static policies, ensure that the policy predicate does not contain attributes that are specific to a particular database object, such as a column name.

See Also: "About Auditing Functions, Procedures, Packages, and Triggers" on page 9-32 for information about how Oracle Database audits the underlying policy function for static policies

Using a Shared Static Policy to Share a Policy with Multiple Objects

If, for example, you wanted to apply the policy in Example 7–6 to a second table in the `HR` schema that may contain financial data that you want to side, you would use the `SHARED_STATIC` setting for both tables.

Example 7–7 shows how to set the `SHARED_STATIC` policy type for two tables that share the same policy.

Example 7–7 Creating a SHARED_STATIC Policy with DBMS_RLS.ADD_POLICY

```
-- 1. Create a policy for the first table, employees:
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.SHARED_STATIC);
END;
/
-- 2. Create a policy for the second table, fin_data:
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'fin_data',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.SHARED_STATIC);
END;
/
```

When to Use Static and Shared Static Policies

Static policies are ideal for environments where every query requires the same predicate and fast performance is essential, such as hosting environments. For these situations when the policy function appends the same predicate to every query, rerunning the policy function each time adds unnecessary overhead to the system. For example, consider a data warehouse that contains market research data for customer organizations that are competitors. The warehouse must enforce the policy that each organization can see only their own market research, which is expressed by the following predicate:

```
WHERE subscriber_id = SYS_CONTEXT('customer', 'cust_num')
```

Using `SYS_CONTEXT` for the application context enables the database to dynamically change the rows that are returned. You do not need to rerun the function, so the predicate can be cached in the SGA, thus conserving system resources and improving performance.

Using a Context-Sensitive Policy for Predicates That Do Not Change After Parsing

In contrast to static policies, context-sensitive policies do not always cache the predicate. With context-sensitive policies, the database assumes that the predicate will change after statement parse time. But if there is no change in local application context, Oracle Database does not rerun the policy function within the user session. If there was a change in context, then the database reruns the policy function to ensure that it captures any changes to the predicate since the initial parsing.

You can enable context-sensitive policies by setting the `policy_type` parameter of the `DBMS_RLS.ADD_POLICY` procedure to either `CONTEXT_SENSITIVE` or `SHARED_CONTEXT_SENSITIVE`.

Example 7–8 shows how to create the `CONTEXT_SENSITIVE` policy type.

Example 7–8 Creating a CONTEXT_SENSITIVE Policy with DBMS_RLS.ADD_POLICY

```
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
```

```
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.CONTEXT_SENSITIVE);
END;
/
```

Context-sensitive policies are useful when different predicates should apply depending on which user is executing the query. For example, consider the case where managers should have the predicate `WHERE group` set to `managers`, and employees should have the predicate `WHERE empno` set to `emp_id`.

Shared context-sensitive policies operate in the same way as regular context-sensitive policies, except they can be shared across multiple database objects. For this policy type, all objects can share the policy function from the UGA, where the predicate is cached until the local session context changes.

Note: When using shared context-sensitive policies, ensure that the policy predicate does not contain attributes that are specific to a particular database object, such as a column name.

See Also: "About Auditing Functions, Procedures, Packages, and Triggers" on page 9-32 for information about how Oracle Database audits the underlying policy function for dynamic policies

Using a Shared Context Sensitive Policy to Share a Policy with Multiple Objects

Example 7–9 Ishows how to create two shared context sensitive policies that share a policy with multiple tables.

Example 7–9 Creating a SHARED_CONTEXT_SENSITIVE Policy with DBMS_RLS.ADD_POLICY

```
-- 1. Create a policy for the first table, employees:
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'employees',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.SHARED_CONTEXT_SENSITIVE);
END;
/
--2. Create a policy for the second table, fin_data:
BEGIN
 DBMS_RLS.ADD_POLICY(
  object_schema   => 'hr',
  object_name     => 'fin_data',
  policy_name     => 'secure_update',
  policy_function => 'hide_fin',
  policy_type     => dbms_rls.SHARED_CONTEXT_SENSITIVE);
END;
/
```

When to Use Context-Sensitive and Shared Context-Sensitive Policies

Context-sensitive policies are useful when a predicate does not need to change for a user session, but the policy must enforce two or more different predicates for different

users or groups. For example, consider a `sales_history` table with a single policy. This policy states that analysts can see only their own products and regional employees can see only their own region. In this case, the database must rerun the policy function each time the type of user changes. The performance gain is realized when a user can log in and issue several DML statements against the protected object without causing the server to rerun the policy function.

> **Note:** For session pooling where multiple clients share a database session, the middle tier must reset the context during client switches.

Summary of the Five Oracle Virtual Private Database Policy Types

Table 7–2 summarizes the types of policy types available.

Table 7–2 DBMS_RLS.ADD_POLICY Policy Types

Policy Types	When the Policy Function Executes	Usage Example	Shared Across Multiple Objects?
`DYNAMIC`	Policy function re-executes every time a policy-protected database object is accessed.	Applications where policy predicates must be generated for each query, such as time-dependent policies where users are denied access to database objects at certain times during the day	No
`STATIC`	Once, then the predicate is cached in the SGA[1]	View replacement	No
`SHARED_ STATIC`	Same as `STATIC`	Hosting environments, such as data warehouses where the same predicate must be applied to multiple database objects	Yes
`CONTEXT_ SENSITIVE`	▪ At statement parse time ▪ At statement execution time when the local application context changed since the last use of the cursor	Three-tier, session pooling applications where policies enforce two or more predicates for different users or groups	No
`SHARED_ CONTEXT_ SENSITIVE`	First time the object is reference in a database session. Predicates are cached in the private session memory UGA so policy functions can be shared among objects.	Same as `CONTEXT_SENSITIVE`, but multiple objects can share the policy function from the session UGA	Yes

[1] Each execution of the same cursor could produce a different row set for the same predicate because the predicate may filter the data differently based on attributes such as `SYS_CONTEXT` or `SYSDATE`.

Tutorials: Creating Oracle Virtual Private Database Policies

This section contains:

- Tutorial: Creating a Simple Oracle Virtual Private Database Policy
- Tutorial: Implementing a Policy with a Database Session-Based Application Context
- Tutorial: Implementing an Oracle Virtual Private Database Policy Group

Tutorial: Creating a Simple Oracle Virtual Private Database Policy

This section contains:

- About This Tutorial

About This Tutorial

Suppose you wanted to create a simple Oracle Virtual Private Database policy that limits access to all orders in the `OE.ORDERS` table that were created by Sales Representative 159. In essence, the policy translates the following statement:

```
SELECT * FROM OE.ORDERS;
```

To the following statement:

```
SELECT * FROM OE.ORDERS
 WHERE SALES_REP_ID = 159;
```

Step 1: Ensure That the OE User Account Is Active

1. Log on to SQL*Plus as user `SYSTEM` with the `SYSDBA` privilege.

   ```
   sqlplus sys as sysdba
   Enter password: password
   ```

2. Run the following `SELECT` statement on the `DBA_USERS` data dictionary view:

   ```
   SELECT USERNAME, ACCOUNT_STATUS FROM DBA_USERS WHERE USERNAME = 'OE';
   ```

   If the `DBA_USERS` view lists user `OE` as locked and expired, then enter the following statement to unlock the `OE` account and create a new password:

   ```
   ALTER USER OE ACCOUNT UNLOCK IDENTIFIED BY password;
   ```

   Replace *password* with a password that is secure. For greater security, do not reuse the same password that was used in previous releases of Oracle Database. See "Minimum Requirements for Passwords" on page 3-3 for more information.

Step 2: Create a Policy Function

Create the following function, which will append the `WHERE SALES_REP_ID = 159` clause to any `SELECT` statement on the `OE.ORDERS` table. (You can copy and paste this text by positioning the cursor at the start of `CREATE OR REPLACE` in the first line.)

```
CREATE OR REPLACE FUNCTION auth_orders(
  schema_var IN VARCHAR2,
  table_var  IN VARCHAR2
 )
 RETURN VARCHAR2
 IS
  return_val VARCHAR2 (400);
 BEGIN
  return_val := 'SALES_REP_ID = 159';
  RETURN return_val;
 END auth_orders;
/
```

In this example:

- schema_var and table_var create input parameters to specify to store the schema name, OE, and table name, ORDERS. First, define the parameter for the schema, and then define the parameter for the object, in this case, a table. Always create them in this order. The Virtual Private Database policy you create will need these parameters to specify the OE.ORDERS table.
- RETURN VARCHAR2 returns the string that will be used for the WHERE predicate clause. Remember that return value is always a VARCHAR2 data type.
- IS ... RETURN return_val encompasses the creation of the WHERE SALES_REP_ID = 159 predicate.

Step 3: Create the Oracle Virtual Private Database Policy

Next, create the following policy by using the ADD_POLICY procedure in the DBMS_RLS package. (You can copy and paste this text by positioning the cursor at the start of BEGIN in the first line.)

```
BEGIN
  DBMS_RLS.ADD_POLICY (
    object_schema    => 'oe',
    object_name      => 'orders',
    policy_name      => 'orders_policy',
    function_schema  => 'sys',
    policy_function  => 'auth_orders',
    statement_types  => 'select, insert, update, delete'
   );
 END;
/
```

In this example:

- object_schema => 'oe' specifies the schema that you want to protect, that is, OE.
- object_name => 'orders' specifies the object within the schema to protect, that is, the ORDERS table.
- policy_name => 'orders_policy' names this policy orders_policy.
- function_schema => 'sys' specifies the schema in which the auth_orders function was created. In this example, auth_orders was created in the SYS schema. But typically, it should be created in the schema of a security administrator.
- policy_function => 'auth_orders' specifies a function to enforce the policy. Here, you specify the auth_orders function that you created in Step 2: Create a Policy Function.
- statement_types => 'select' specifies the operations to which the policy applies. In this example, the policy applies to all SELECT, INSERT, UPDATE, and DELETE statements the user may perform.

Step 4: Test the Policy

After you create the Oracle Virtual Private Database policy, it goes into effect immediately. The next time a user, including the owner of the schema, performs a SELECT on OE.ORDERS, only the orders by Sales Representative 159 will be accessed.

1. Log on as user OE.

```
CONNECT oe
Enter password: password
```

2. Enter the following SELECT statement:

```
SELECT COUNT(*) FROM ORDERS;
```

The following output should appear:

```
 COUNT(*)
---------
         7
```

The policy is in effect for user OE: As you can see, only 7 of the 105 rows in the orders table are returned.

But users with administrative privileges still have access to all the rows in the table.

3. Log back on as user SYS.

```
CONNECT sys/as sysdba
Enter password: password
```

4. Enter the following SELECT statement:

```
SELECT COUNT(*) FROM OE.ORDERS;
```

The following output should appear:

```
 COUNT(*)
---------
       105
```

Step 5: Remove the Components for This Tutorial

1. As user SYS, remove the function and policy as follows:

```
DROP FUNCTION auth_orders;
EXEC DBMS_RLS.DROP_POLICY('OE','ORDERS','ORDERS_POLICY');
```

2. If you need to lock and expire the OE account, then enter the following statement:

```
ALTER USER OE ACCOUNT LOCK PASSWORD EXPIRE;
```

Tutorial: Implementing a Policy with a Database Session-Based Application Context

This section contains:

About This Tutorial

This tutorial shows how you can use a database session-based application context to implement a policy in which customers can see only their own orders. You create the following layers of security:

1. When a user logs on, a database session-based application context checks whether the user is a customer. If a user is not a customer, the user still can log on, but this user cannot access the orders entry table you will create for this example.
2. If the user is a customer, he or she can log on. After the customer has logged on, an Oracle Virtual Private Database policy restricts this user to see only his or her orders.
3. As a further restriction, the Oracle Virtual Private Database policy prevents users from adding, modifying, or removing orders.

Step 1: Create User Accounts and Sample Tables

1. Start SQL*Plus and log on as a user who has administrative privileges.

   ```
   sqlplus sys as sysdba
   Enter password: password
   ```

2. Create the following administrative user, who will administer the Oracle Virtual Private Database policy.

   The following SQL statements create this user and then grant the user the necessary privileges for completing this tutorial.

   ```
   GRANT CREATE SESSION, CREATE ANY CONTEXT, CREATE PROCEDURE, CREATE TRIGGER,
   ADMINISTER DATABASE TRIGGER TO sysadmin_vpd IDENTIFIED BY password;
   GRANT EXECUTE ON DBMS_SESSION TO sysadmin_vpd;
   GRANT EXECUTE ON DBMS_RLS TO sysadmin_vpd;
   ```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

3. Create the following user accounts:

   ```
   GRANT CREATE SESSION TO tbrooke IDENTIFIED BY password;
   GRANT CREATE SESSION TO owoods IDENTIFIED BY password;
   ```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

4. Check the status of the sample user `SCOTT`, who you will use for this tutorial:

   ```
   SELECT USERNAME, ACCOUNT_STATUS FROM DBA_USERS WHERE USERNAME = 'SCOTT';
   ```

   If the `DBA_USERS` view lists user `SCOTT` as locked and expired, then enter the following statement to unlock the `SCOTT` account and create a new password for him:

   ```
   ALTER USER SCOTT ACCOUNT UNLOCK IDENTIFIED BY password;
   ```

   Replace *password* with a password that is secure. For greater security, do not reuse the same password that was used in previous releases of Oracle Database. See "Minimum Requirements for Passwords" on page 3-3 for more information.

5. Connect as user `SCOTT`, and then create and populate the `customers` table.

   ```
   CONNECT scott
   Enter password: password
   ```

```
CREATE TABLE customers (
 cust_no    NUMBER(4),
 cust_email VARCHAR2(20),
 cust_name  VARCHAR2(20));

INSERT INTO customers VALUES (1234, 'TBROOKE', 'Thadeus Brooke');
INSERT INTO customers VALUES (5678, 'OWOODS', 'Oberon Woods');
```

When you enter the user email addresses, enter them in upper-case letters. Later on, when you create the application context PL/SQL package, the `SESSION_USER` parameter of the `SYS_CONTEXT` function expects the user names to be in upper case. Otherwise, you will be unable to set the application context for the user.

6. User `sysadmin_vpd` will need `SELECT` privileges for the customers table, so as user `SCOTT`, grant him this privilege.

```
GRANT SELECT ON customers TO sysadmin_vpd;
```

7. Create and populate the `orders_tab` table.

```
CREATE TABLE orders_tab (
  cust_no  NUMBER(4),
  order_no NUMBER(4));

INSERT INTO orders_tab VALUES (1234, 9876);
INSERT INTO orders_tab VALUES (5678, 5432);
INSERT INTO orders_tab VALUES (5678, 4592);
```

8. Users `tbrooke` and `owoods` need to query the `orders_tab` table, so grant them the `SELECT` privilege.

```
GRANT SELECT ON orders_tab TO tbrooke;
GRANT SELECT ON orders_tab TO owoods;
```

At this stage, the two sample customers, `tbrooke` and `owoods`, have a record of purchases in the `orders_tab` order entry table, and if they tried right now, they can see all the orders in this table.

Step 2: Create a Database Session-Based Application Context

1. Connect as user `sysadmin_vpd`.

```
CONNECT sysadmin_vpd
Enter password: password
```

2. Enter the following statement:

```
CREATE OR REPLACE CONTEXT orders_ctx USING orders_ctx_pkg;
```

This statement creates the `orders_ctx` application context. Remember that even though user `sysadmin_vpd` has created this context and it is associated with the `sysadmin_vpd` schema, the `SYS` schema owns the application context.

Step 3: Create a PL/SQL Package to Set the Application Context

As user `sysadmin_vpd`, create the following PL/SQL package, which will set the database session-based application context when the customers `tbrooke` and `owoods` log onto their accounts. (You can copy and paste this text by positioning the cursor at the start of `CREATE OR REPLACE` in the first line.)

```
CREATE OR REPLACE PACKAGE orders_ctx_pkg IS
```

```
  PROCEDURE set_custnum;
 END;
/
CREATE OR REPLACE PACKAGE BODY orders_ctx_pkg IS
  PROCEDURE set_custnum
  AS
    custnum NUMBER;
  BEGIN
     SELECT cust_no INTO custnum FROM SCOTT.CUSTOMERS
        WHERE cust_email = SYS_CONTEXT('USERENV', 'SESSION_USER');
     DBMS_SESSION.SET_CONTEXT('orders_ctx', 'cust_no', custnum);
  EXCEPTION
   WHEN NO_DATA_FOUND THEN NULL;
  END set_custnum;
END;
/
```

In this example:

- `custnum NUMBER` creates the `custnum` variable, which will hold the customer ID.
- `SELECT cust_no INTO custnum` performs a `SELECT` statement to copy the customer ID that is stored in the `cust_no` column data from the `scott.customers` table into the `custnum` variable.
- `WHERE cust_email = SYS_CONTEXT('USERENV', 'SESSION_USER')` uses a `WHERE` clause to find all the customer IDs that match the user name of the user who is logging on.
- `DBMS_SESSION.SET_CONTEXT('orders_ctx', 'cust_no', custnum)` sets the `orders_ctx` application context values by creating the `cust_no` attribute and then setting it to the value stored in the `custnum` variable.
- `EXCEPTION ... WHEN` adds a `WHEN NO_DATA_FOUND` system exception to catch any `no data found` errors that may result from the `SELECT` statement in **Lines 10–11**.

To summarize, the `sysadmin_vpd.set_cust_num` procedure identifies whether or not the session user is a registered customer by attempting to select the user's customer ID into the `custnum` variable. If the user is a registered customer, then Oracle Database sets an application context value for this user. As you will see in Step 5: Create a PL/SQL Policy Function to Limit User Access to Their Orders, the policy function uses the context value to control the access a user has to data in the `orders_tab` table.

Step 4: Create a Logon Trigger to Run the Application Context PL/SQL Package

The logon trigger runs the procedure in the PL/SQL package that you created in Step 3: Create a PL/SQL Package to Set the Application Context the next time a user logs on, so that the application context can be set.

As user `sysadmin_vpd`, create the following trigger:

```
CREATE TRIGGER set_custno_ctx_trig AFTER LOGON ON DATABASE
 BEGIN
  sysadmin_vpd.orders_ctx_pkg.set_custnum;
 END;
/
```

> **See Also:** "Creating a Logon Trigger to Run a Database Session Application Context Package" on page 6-11

At this stage, if you log on as either tbrooke or owoods, the logon trigger should set the application context for the user when it fires the sysadmin_vpd.orders_ctx_pkg.set_custnum procedure. You can test it as follows:

```
CONNECT tbrooke
Enter password: password

SELECT SYS_CONTEXT('orders_ctx', 'cust_no') custnum FROM DUAL;
```

The following output should appear:

```
EMP_ID
------------------------------------------------------------------
1234
```

Step 5: Create a PL/SQL Policy Function to Limit User Access to Their Orders

The next step is to create a PL/SQL function that, when the user who has logged in performs a SELECT * FROM scott.orders_tab query, displays only the orders of that user.

As user sysadmin_vpd, create the following function:

```
CREATE OR REPLACE FUNCTION get_user_orders(
  schema_p   IN VARCHAR2,
  table_p    IN VARCHAR2)
 RETURN VARCHAR2
 AS
  orders_pred VARCHAR2 (400);
 BEGIN
  orders_pred := 'cust_no = SYS_CONTEXT(''orders_ctx'', ''cust_no'')';
 RETURN orders_pred;
END;
/
```

This function creates and returns a WHERE predicate that translates to "where the orders displayed belong to the user who has logged in." It then appends this WHERE predicate to any queries this user may run against the scott.orders_tab table. Next, you are ready to create an Oracle Virtual Private Database policy that applies this function to the orders_tab table.

Step 6: Create the New Security Policy

As user sysadmin_vpd, create the policy as follows:

```
BEGIN
 DBMS_RLS.ADD_POLICY (
  object_schema    => 'scott',
  object_name      => 'orders_tab',
  policy_name      => 'orders_policy',
  function_schema  => 'sysadmin_vpd',
  policy_function  => 'get_user_orders',
  statement_types  => 'select');
END;
/
```

This statement creates a policy named orders_policy and applies it to the orders_tab table, which customers will query for their orders, in the SCOTT schema. The get_user_orders function implements the policy, which is stored in the sysadmin_vpd schema. The policy further restricts users to issuing SELECT statements only.

Step 7: Test the New Policy

1. Log on as user tbrooke.

```
CONNECT tbrooke
Enter password: password
```

   User tbrooke can log on because he has passed the requirements you defined in the application context.

2. As user tbrooke, access your purchases.

```
SELECT * FROM scott.orders_tab;
```

   The following output should appear:

```
   CUST_NO    ORDER_NO
----------  ----------
      1234        9876
```

   User tbrooke has passed the second test. He can access his own orders in the scott.orders_tab table.

3. Log on as user owoods, and then access your purchases.

```
CONNECT owoods
Enter password: passwords

SELECT * FROM scott.orders_tab
```

   The following output should appear:

```
   CUST_NO    ORDER_NO
----------  ----------
      5678        5432
      5678        4592
```

   As with user tbrooke, user owoods can log on and see a listing of his own orders.

Note the following:

- You can create several predicates based on the position of a user. For example, a sales representative would be able to see records only for his customers, and an order entry clerk would be able to see any customer order. You could expand the custnum_sec function to return different predicates based on the user position context value.
- The use of an application context in a fine-grained access control package effectively gives you a bind variable in a parsed statement. For example:

```
SELECT * FROM scott.orders_tab
   WHERE cust_no = SYS_CONTEXT('order_entry', 'cust_num');
```

  This is fully parsed and optimized, but the evaluation of the cust_num attribute value of the user for the order_entry context takes place at run-time. This means that you get the benefit of an optimized statement that executes differently for each user who issues the statement.

> **Note:** You can improve the performance of the function in this tutorial by indexing cust_no.

- You can set context attributes based on data from a database table or tables, or from a directory server using Lightweight Directory Access Protocol (LDAP).

  See Also: *Oracle Database PL/SQL Language Reference* for more information about triggers

Compare and contrast this tutorial, which uses an application context within the dynamically generated predicate, with "About Oracle Virtual Private Database Policies" on page 7-6, which uses a subquery in the predicate.

Step 8: Remove the Components for This Tutorial

1. Connect as user `OE` and remove the `orders_tab` and `customers` tables.

```
CONNNECT SCOTT
Enter password: password

DROP TABLE orders_tab;
DROP TABLE customers;
```

2. Connect as user `SYS`, connecting with `AS SYSDBA`.

```
CONNECT sys/as sysdba
Enter password: password
```

3. Run the following statements to drop the components for this tutorial:

```
DROP CONTEXT orders_ctx;
DROP USER sysadmin_vpd CASCADE;
DROP USER tbrooke;
DROP USER owoods;
```

Tutorial: Implementing an Oracle Virtual Private Database Policy Group

This section contains:

About This Tutorial

"Working with Oracle Virtual Private Database Policy Groups" on page 7-11 describes how you can group a set of policies for use in an application. When a nondatabase user logs onto the application, Oracle Database grants the user access based on the policies defined within the appropriate policy group.

For column-level access control, every column or set of hidden columns is controlled by one policy. In this tutorial, you must hide two sets of columns. So, you need to create two policies, one for each set of columns that you want to hide. You only want one policy for each user; the driving application context separates the policies for you.

Step 1: Create User Accounts and Other Components for This Tutorial

1. Log on as user SYS with the SYSDBA privilege.

```
sqlplus sys as sysdba
Enter password: password
```

2. Create the following users:

```
GRANT CREATE SESSION TO apps_user IDENTIFIED BY password;
GRANT CREATE SESSION, CREATE PROCEDURE, CREATE ANY CONTEXT TO sysadmin_pg
IDENTIFIED BY password;
```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

3. Grant the following additional privilege to user sysadmin_pg:

```
GRANT EXECUTE ON DBMS_RLS TO sysadmin_pg;
```

4. Log on as user OE.

```
CONNECT OE
Enter password: password
```

   If the OE account is locked and expired, then reconnect as user SYS with the SYSDBA privilege and enter the following statement to unlock the account and give it s new password:

```
ALTER USER OE ACCOUNT UNLOCK IDENTIFIED BY password;
```

   Replace *password* with a password that is secure. For greater security, do not reuse the same password that was used in previous releases of Oracle Database. See "Minimum Requirements for Passwords" on page 3-3 for more information.

5. Create the product_code_names table:

```
CREATE TABLE product_code_names(
group_a     varchar2(32),
year_a      varchar2(32),
group_b     varchar2(32),
year_b      varchar2(32));
```

6. Insert some values into the product_code_names table:

```
INSERT INTO product_code_names values('Biffo','2008','Beffo','2004');
INSERT INTO product_code_names values('Hortensia','2008','Bunko','2008');
INSERT INTO product_code_names values('Boppo','2006','Hortensia','2003');

COMMIT;
```

7. Grant the apps_user user SELECT privileges on the product_code_names table.

```
GRANT SELECT ON product_code_names TO apps_user;
```

Step 2: Create the Two Policy Groups

Next, you must create a policy group for each of the two nondatabase users, provider_a and provider_b.

1. Connect as user sysadmin_pg.

```
CONNECT sysadmin_pg
Enter password: password
```

2. Create the provider_a_group policy group, to be used by user provider_a:

```
BEGIN
 DBMS_RLS.CREATE_POLICY_GROUP(
 object_schema   => 'oe',
 object_name     => 'product_code_names',
 policy_group    => 'provider_a_group');
END;
/
```

3. Create the provider_b_group policy group, to be used by user provider_b:

```
BEGIN
 DBMS_RLS.CREATE_POLICY_GROUP(
 object_schema   => 'oe',
 object_name     => 'product_code_names',
 policy_group    => 'provider_b_group');
END;
/
```

Step 3: Create PL/SQL Functions to Control the Policy Groups

Each of the policy groups that you created in Step 2: Create the Two Policy Groups must have a function that defines how the application can control data access for users provider_a and provider_b.

1. Create the vpd_function_provider_a function, which restricts the data accessed by user provider_a.

```
CREATE OR REPLACE FUNCTION vpd_function_provider_a
 (schema in varchar2, tab in varchar2) return varchar2 as
  predicate  varchar2(8) default NULL;
  BEGIN
   IF LOWER(SYS_CONTEXT('USERENV','CLIENT_IDENTIFIER')) = 'provider_a'
    THEN predicate := '1=2';
   ELSE NULL;
  END IF;
  RETURN predicate;
END;
/
```

   This function checks that the user logging in is really user provider_a. If this is true, then only the data in the product_code_names table columns group_a and year_a will be visible to provider_a. Data in columns group_b and year_b will not appear for provider_a. This works as follows: Setting predicate := '1=2' hides the relevant columns. In Step 4: Add the PL/SQL Functions to the Policy Groups, you specify these columns in the SEC_RELEVANT_COLS parameter.

   See "Creating a Function to Generate the Dynamic WHERE Clause" on page 7-4 for detailed information on the components of this type of function.

2. Create the vpd_function_provider_b, function, which restricts the data accessed by user provider_a.

```
CREATE OR REPLACE FUNCTION vpd_function_provider_b
 (schema in varchar2, tab in varchar2) return varchar2 as
  predicate  varchar2(8) default NULL;
  BEGIN
   IF LOWER(SYS_CONTEXT('USERENV','CLIENT_IDENTIFIER')) = 'provider_b'
    THEN predicate := '1=2';
   ELSE NULL;
  END IF;
```

```
  RETURN predicate;
END;
/
```

Similar to the vpd_function_provider_a function, this function checks that the user logging in is really user provider_b. If this is true, then only the data in the columns group_b and year_b will be visible to provider_b, with data in the group_a and year_a not appearing for provider_b. Similar to the vpd_function_provider_a function, predicate := '1=2' hides the relevant columns specified Step 4: Add the PL/SQL Functions to the Policy Groups in the SEC_RELEVANT_COLS parameter.

Step 4: Add the PL/SQL Functions to the Policy Groups

Now that you have created the necessary functions, you are ready to associate them with their appropriate policy groups.

1. Add the vpd_function_provider_a function to the provider_a_group policy group.

```
BEGIN
 DBMS_RLS.ADD_GROUPED_POLICY(
 object_schema         => 'oe',
 object_name           => 'product_code_names',
 policy_group          => 'provider_a_group',
 policy_name           => 'filter_provider_a',
 function_schema       => 'sysadmin_pg',
 policy_function       => 'vpd_function_provider_a',
 statement_types       => 'select',
 policy_type           => DBMS_RLS.CONTEXT_SENSITIVE,
 sec_relevant_cols     => 'group_b,year_b',
 sec_relevant_cols_opt => DBMS_RLS.ALL_ROWS);
END;
/
```

The group_b and year_b columns specified in the sec_relevant_cols parameter are hidden from user provider_a.

2. Add the vpd_function_provider_b function to the provider_b_group policy group.

```
BEGIN
 DBMS_RLS.ADD_GROUPED_POLICY(
 object_schema         => 'oe',
 object_name           => 'product_code_names',
 policy_group          => 'provider_b_group',
 policy_name           => 'filter_provider_b',
 function_schema       => 'sysadmin_pg',
 policy_function       => 'vpd_function_provider_b',
 statement_types       => 'select',
 policy_type           => DBMS_RLS.CONTEXT_SENSITIVE,
 sec_relevant_cols     => 'group_a,year_a',
 sec_relevant_cols_opt => DBMS_RLS.ALL_ROWS);
END;
/
```

The group_a and year_a columns specified in the sec_relevant_cols parameter are hidden from user provider_b.

Step 5: Create the Driving Application Context

The application context determines which policy the nondatabase user who is the logging on should use.

1. As user `sysadmin_pg`, create the driving application context as follows:

```
CREATE OR REPLACE CONTEXT provider_ctx USING provider_package;
```

2. Create the PL/SQL `provider_package` package for the application context.

```
CREATE OR REPLACE PACKAGE provider_package IS
 PROCEDURE set_provider_context (policy_group varchar2 default NULL);
END;
/
CREATE OR REPLACE PACKAGE BODY provider_package AS
 PROCEDURE set_provider_context (policy_group varchar2 default NULL) IS
 BEGIN
  CASE LOWER(SYS_CONTEXT('USERENV', 'CLIENT_IDENTIFIER'))
   WHEN 'provider_a' THEN
    DBMS_SESSION.SET_CONTEXT('provider_ctx','policy_group','PROVIDER_A_GROUP');
   WHEN 'provider_b' THEN
    DBMS_SESSION.SET_CONTEXT('provider_ctx','policy_group','PROVIDER_B_GROUP');
  END CASE;
 END set_provider_context;
END;
/
```

3. Associate the `provider_ctx` application context with the `product_code_names` table, and then provide a name.

```
BEGIN
 DBMS_RLS.ADD_POLICY_CONTEXT(
 object_schema  =>'oe',
 object_name    =>'product_code_names',
 namespace      =>'provider_ctx',
 attribute      =>'policy_group');
END;
/
```

4. Grant the `apps_user` account the `EXECUTE` privilege for the `provider_package` package.

```
GRANT EXECUTE ON provider_package TO apps_user;
```

Step 6: Test the Policy Groups

Now you are ready to test the two policy groups.

1. Connect as user `apps_user` and then enter the following statements to ensure that the output you will create later on is nicely formatted.

```
CONNECT apps_user
Enter password: password

col group_a format a16
col group_b format a16;
col year_a format a16;
col year_b format a16;
```

2. Set the session identifier to `provider_a`.

```
EXEC DBMS_SESSION.SET_IDENTIFIER('provider_a');
```

Here, the application sets the identifier. Setting the identifier to `provider_a` sets the `apps_user` user to a user who should only see the products available to products in the `provider_a_group` policy group.

3. Run the `provider_package` to set the policy group based on the context.

```
EXEC sysadmin_pg.provider_package.set_provider_context;
```

At this stage, you can check the application context was set, as follows:

```
SELECT SYS_CONTEXT('USERENV', 'CLIENT_IDENTIFIER') AS END_USER FROM DUAL;
```

The following output should appear:

```
END_USER
-----------------
provider_a
```

4. Enter the following `SELECT` statement:

```
SELECT * FROM oe.product_code_names;
```

The following output should appear:

```
GROUP_A          YEAR_A           GROUP_B          YEAR_B
---------------- ---------------- ---------------- ----------------
Biffo            2008
Hortensia        2008
Boppo            2006
```

5. Set the client identifier to `provider_b` and then enter the following statements:

```
EXEC DBMS_SESSION.SET_IDENTIFIER('provider_b');
EXEC sysadmin_pg.provider_package.set_provider_context;
SELECT * FROM oe.product_code_names;
```

The following output should appear:

```
GROUP_A          YEAR_A           GROUP_B          YEAR_B
---------------- ---------------- ---------------- ----------------
                                  Beffo            2004
                                  Bunko            2008
                                  Hortensia        2003
```

Step 7: Remove the Components for This Tutorial

1. Connect as user `OE` and drop the `product_code_names` table.

```
CONNECT OE
Enter password: password

DROP TABLE product_code_names;
```

2. Connect as user `SYS` and drop the application context and users for this tutorial.

```
CONNECT SYS/AS SYSDBA
Enter password: password

DROP CONTEXT provider_ctx;
DROP USER sysadmin_pg cascade;
DROP USER apps_user;
```

How Oracle Virtual Private Database Works with Other Oracle Features

This section contains:

Using Oracle Virtual Private Database Policies with Editions

If you are preparing an application for edition-based redefinition, and you cover each table that the application uses with an editioning view, then you must move the Virtual Private Database polices that protect these tables to the editioning view.

When an editioned object has a Virtual Private Database t policy, then it applies in all editions in which the object is visible. When an editioned object is actualized, any VPD policies that are attached to it are newly attached to the new actual occurrence. When you newly apply a VPD policy to an inherited editioned object, this action will actualize it.

> **See Also:** *Oracle Database Advanced Application Developer's Guide* for detailed information about editions

Using SELECT FOR UPDATE in User Queries on VPD-Protected Tables

As a general rule, users should not include the `FOR UPDATE` clause when querying Virtual Private Database-protected tables. The Virtual Private Database technology depends on rewriting the user's query against an inline view that includes the VPD predicate generated by the VPD policy function. Because of this, the same limitations on views also apply to VPD-protected tables. If a user's query against a VPD-protected table includes the `FOR UPDATE` clause in a `SELECT` statement, in most cases, the query may not work. However, the user's query may work in some situations if the inline view generated by VPD is sufficiently simple.

> **See Also:** *Oracle Database SQL Language Reference* for more information about the restrictions of the `FOR UPDATE` clause in the `SELECT` statement

How Oracle Virtual Private Database Policies Affect Outer or ANSI Join Operations

Oracle Virtual Private Database rewrites SQL by using dynamic views. For SQL that contains outer join or ANSI operations, some views may not merge and some indexes may not be used. This problem is a known optimization limitation. To remedy this problem, rewrite the SQL to not use outer joins or ANSI operations.

How Oracle Virtual Private Database Security Policies Work with Applications

An Oracle Virtual Private Database security policy is applied within the database itself, rather than within an application. Hence, a user trying to access data by using a different application cannot bypass the Oracle Virtual Private Database security policy. Another advantage of creating the security policy in the database is that you maintain it in one central place, rather than maintaining individual security policies in multiple applications. Oracle Virtual Private Database provides stronger security than application-based security, at a lower cost of ownership.

You may want to enforce different security policies depending on the application that is accessing data. Consider a situation in which two applications, Order Entry and Inventory, both access the `orders` table. You may want to have the Inventory application use a policy that limits access based on type of product. At the same time, you may want to have the Order Entry application use a policy that limits access based on customer number.

In this case, you must partition the use of fine-grained access by application. Otherwise, both policies would be automatically concatenated together, which may not be the result that you want. You can specify two or more policy groups, and a driving application context that determines which policy group is in effect for a given transaction. You can also designate default policies that always apply to data access. In a hosted application, for example, data access should be limited by subscriber ID. See "Tutorial: Implementing an Oracle Virtual Private Database Policy Group" on page 7-28 for an example of how you can create policy groups that use an application context to determine which group should be used.

Using Automatic Reparsing for Fine-Grained Access Control Policy Functions

By default, queries against objects enabled with fine-grained access control run the policy function to ensure that the most current predicate is used for each policy. For example, in the case of a time-based policy function, in which queries are only allowed between 8:00 a.m. and 5:00 p.m., a cursor execution parsed at noon runs the policy function at that time, ensuring that the policy is consulted again for the query. Even if the curser was parsed at 9 a.m., when it runs later on (for example, at noon), then the Virtual Private Database policy function runs again to ensure that the execution of the cursor is still permitted at the current time (noon). This ensures that the security check it must perform is the most recent.

Automatic re-execution of the Virtual Private Database policy function does not occur when you set the `DBMS_RLS.ADD_POLICY` setting `STATIC_POLICY` to `TRUE` while adding the policy. This setting causes the policy function to return the same predicate.

Using Oracle Virtual Private Database Policies and Flashback Query

By default, operations on the database use the most recently committed data available. The flashback query feature enables you to query the database at some point in the past. To write an application that uses flashback query, you can use the `AS OF` clause in SQL queries to specify either a time or a system change number (SCN), and then query against the committed data from the specified time. You can also use the `DBMS_FLASHBACK` PL/SQL package, which requires more code, but enables you to perform multiple operations, all of which refer to the same point in time.

However, if you use flashback query against a database object that is protected with Oracle Virtual Private Database policies, then the current policies are applied to the old data. Applying the current Oracle Virtual Private Database policies to flashback query data is more secure because it reflects the most current business policy.

See Also:

- *Oracle Database Advanced Application Developer's Guide* for more information about the flashback query feature and how to write applications that use it
- *Oracle Database PL/SQL Packages and Types Reference* for more information about the DBMS_FLASHBACK PL/SQL package

Using Oracle Virtual Private Database and Oracle Label Security

This section contains:

- Using Oracle Virtual Private Database to Enforce Oracle Label Security Policies
- Oracle Virtual Private Database and Oracle Label Security Exceptions

See Also: *Oracle Label Security Administrator's Guide*

Using Oracle Virtual Private Database to Enforce Oracle Label Security Policies

You can use Oracle Virtual Private Database policies to provide column or row-level access control based on Oracle Label Security user authorizations. In general, you need to perform the following steps:

1. When you create the Oracle Label Security policy, do not apply the policy to the table that you want to protect. (The Virtual Private Database policy that you create handles this for you.) In the SA_SYSDBA.CREATE_POLICY procedure, set the default_options parameter to NO_CONTROL.
2. Create the Oracle Label Security label components and authorize users as you normally would.
3. When you create the Oracle Virtual Private Database policy, do the following:
   - In the PL/SQL function that you create for the policy, use the Oracle Label Security DOMINATES function to compare the authorization of the user with the label that you created in Step 2. (See *Oracle Label Security Administrator's Guide* for more information about the dominance functions.) The DOMINATES function determines if the user authorization is equal to, or if it is more sensitive than, the label used in the comparison. If the user authorization passes, then the user is granted access to the column. Otherwise, the user is denied access.
   - In the Virtual Private Database policy definition, apply this function to the table that you want to protect. In the DBMS_RLS.ADD_POLICY procedure, use the sensitive column (SEC_RELEVANT_COLS parameter) and column masking (SEC_RELEVANT_COLS_OPT parameter) functionality to show or hide columns based on Oracle Label Security user authorizations.

For an example of how to accomplish this, visit the following Oracle Technology Network site:

http://www.oracle.com/technetwork/database/focus-areas/security/ols-cs1-099558.html

Oracle Virtual Private Database and Oracle Label Security Exceptions

Be aware of the following exceptions when you use Oracle Virtual Private Database and Oracle Label Security:

- **When you are exporting data, Oracle Virtual Private Database and Oracle Label Security policies are not enforced during a direct path export operation.** In a

direct path export operation, Oracle Database reads data from disk into the buffer cache and transfers rows directly to the Export client. See *Oracle Database Utilities* for more information about direct path export operations.

- **You cannot apply Oracle Virtual Private Database policies and Oracle Label Security policies to objects in the SYS schema.** The SYS user and users making a DBA-privileged connection to the database (for example, CONNECT/AS SYSDBA) do not have Oracle Virtual Private Database or Oracle Label Security policies applied to their actions. The database user SYS is thus always exempt from Oracle Virtual Private Database or Oracle Label Security enforcement, regardless of the export mode, application, or utility used to extract data from the database.

  However, you can audit SYSDBA actions by enabling auditing upon installation and specifying that this audit trail be stored in a secure location in the operating system. See "Auditing SYS Administrative Users" on page 9-53 for more information. You can also closely monitor the SYS user by using Oracle Database Vault.

- **Database users who were granted the EXEMPT ACCESS POLICY privilege, either directly or through a database role, are exempt from Oracle Virtual Private Database enforcements.** The system privilege EXEMPT ACCESS POLICY allows a user to be exempted from all fine-grained access control policies on any SELECT or DML operation (INSERT, UPDATE, and DELETE). This provides ease of use for administrative activities, such as installation and import and export of the database, through a non-SYS schema.

  However, the following policy enforcement options remain in effect even when EXEMPT ACCESS POLICY is granted:

  – INSERT_CONTROL, UPDATE_CONTROL, DELETE_CONTROL, WRITE_CONTROL, LABEL_UPDATE, and LABEL_DEFAULT

  – If the Oracle Label Security policy specifies the ALL_CONTROL option, then all enforcement controls are applied except READ_CONTROL and CHECK_CONTROL.

  Because EXEMPT ACCESS POLICY negates the effect of fine-grained access control, you should only grant this privilege to users who have legitimate reasons for bypassing fine-grained access control enforcement. Do not grant this privilege using the WITH ADMIN OPTION. If you do, users could pass the EXEMPT ACCESS POLICY privilege to other users, and thus propagate the ability to bypass fine-grained access control.

Note:

- The EXEMPT ACCESS POLICY privilege does not affect the enforcement of object privileges such as SELECT, INSERT, UPDATE, and DELETE. These privileges are enforced even if a user was granted the EXEMPT ACCESS POLICY privilege.
- The SYS_CONTEXT values that Oracle Virtual Private Database uses are not propagated to secondary databases for failover.

Exporting Data Using the EXPDP Utility access_method Parameter

If you try to use the Oracle Data Pump Export (EXPDP) utility with the access_method parameter set to direct_path to export data from a schema which contains an object that has a Virtual Private Database policy defined on it, then the following error message may appear and the export operation will fail:

```
ORA-31696: unable to export/import TABLE_DATA:"schema.table" using client
specified DIRECT_PATH method
```

This problem only occurs when you perform a schema-level export as a user who has not been granted the EXP_FULL_DATABASE role. It does not occur during a full database export, which requires the EXP_FULL_DATABASE role. The EXP_FULL_DATABASE role includes the EXEMPT ACCESS POLICY system privilege, which bypasses Virtual Private Database policies.

To find the underlying problem, try the EXPDP invocation again, but do not set the access_method parameter to direct_path. Instead, use either automatic or external_table. The underlying problem could be a permissions problem, for example:

```
ORA-39181: Only partial table data may be exported due to fine grain access
control on "schema_name"."object_name"
```

> **See Also:** *Oracle Database Utilities* for more information about using Data Pump Export.

User Models and Oracle Virtual Private Database

You can use Oracle Virtual Private Database in the following types of user models:

- **Application users who are also database users.** Oracle Database enables applications to enforce fine-grained access control for each user, regardless of whether that user is a database user or an application user unknown to the database. When application users are also database users, Oracle Virtual Private Database enforcement works as follows: users connect to the database, and then the application sets up application contexts for each session. (You can use the default USERENV application context namespace, which provides many parameters for retrieve different types of user session data.) As each session is initiated under a different user name, it can enforce different fine-grained access control conditions for each user.
- **Proxy authentication using OCI or JDBC/OCI.** Proxy authentication permits different fine-grained access control for each user, because each session (OCI or JDBC/OCI) is a distinct database session with its own application context.
- **Proxy authentication integrated with Enterprise User Security.** If you have integrated proxy authentication by using Enterprise User Security, you can retrieve user roles and other attributes from Oracle Internet Directory to enforce Oracle Virtual Private Database policies. (In addition, globally initialized application context can also be retrieved from the directory.)
- **Users connecting as One Big Application User.** Applications connecting to the database as a single user on behalf of all users can have fine-grained access control for each user. The user for that single session is often called *One Big Application User*. Within the context of that session, however, an application developer can create a global application context attribute to represent the individual application user (for example, REALUSER). Although all database sessions and audit records are created for One Big Application User, the attributes for each session can vary, depending on who the end user is. This model works best for applications with a limited number of users and no reuse of sessions. The scope of roles and database auditing is diminished because each session is created as the same database user. For more information about global application contexts, see "Using Global Application Contexts" on page 6-22.
- **Web-based applications.** Web-based applications typically have hundreds of users. Even when there are persistent connections to the database, supporting data

retrieval for many user requests, these connections are not specific to particular Web-based users. Instead, Web-based applications typically set up and reuse connections, to provide scalability, rather than having different sessions for each user. For example, when Web users Jane and Ajit connect to a middle tier application, it may establish a single database session that it uses on behalf of both users. Typically, neither Jane nor Ajit is known to the database. The application is responsible for switching the user name on the connection, so that, at any given time, it is either Jane or Ajit using the session.

Oracle Virtual Private Database helps with connection pooling by allowing multiple connections to access more than one global application context. This ability makes it unnecessary to establish a separate application context for each distinct user session.

Table 7–3 summarizes how Oracle Virtual Private Database applies to user models.

Table 7–3 Oracle Virtual Private Database in Different User Models

User Model Scenario	Individual Database Connection	Separate Application Context per User	Single Database Connection	Application Must Switch User Name
Application users are also database users	Yes	Yes	No	No
Proxy authentication using OCI or JDBC/OCI	Yes	Yes	No	No
Proxy authentication integrated with Enterprise User Security[1]	No	No	Yes	Yes
One Big Application User	No	No[2]	No	Yes[2]
Web-based applications	No	No	Yes	Yes

[1] User roles and other attributes, including globally initialized application context, can be retrieved from Oracle Internet Directory to enforce Oracle Virtual Private Database.

[2] Application developers can create a global application context attribute representing individual application users (for example, `REALUSER`), which can then be used for controlling each session attributes, or for auditing.

Finding Information About Oracle Virtual Private Database Policies

Table 7–4 lists data dictionary views that you can use to find information about Oracle Virtual Private Database policies. See *Oracle Database Reference* for more information about these views.

Table 7–4 Data Dictionary Views That Display Information about VPD Policies

View	Description
`ALL_POLICIES`	Describes all Oracle Virtual Private Database security policies for objects accessible to the current user.
`ALL_POLICY_CONTEXTS`	Describes the driving contexts defined for the synonyms, tables, and views accessible to the current user. A driving context is an application context used in an Oracle Virtual Private Database policy.
`ALL_POLICY_GROUPS`	Describes the Oracle Virtual Private Database policy groups defined for the synonyms, tables, and views accessible to the current user
`ALL_SEC_RELEVANT_COLS`	Describes the security relevant columns of the security policies for the tables and views accessible to the current user
`DBA_POLICIES`	Describes all Oracle Virtual Private Database security policies in the database.

Table 7–4 (Cont.) Data Dictionary Views That Display Information about VPD Policies

View	Description
DBA_POLICY_GROUPS	Describes all policy groups in the database.
DBA_POLICY_CONTEXTS	Describes all driving contexts in the database. Its columns are the same as those in ALL_POLICY_CONTEXTS.
DBA_SEC_RELEVANT_COLS	Describes the security relevant columns of all security policies in the database
USER_POLICIES	Describes all Oracle Virtual Private Database security policies associated with objects owned by the current user. This view does not display the OBJECT_OWNER column.
USER_POLICY_CONTEXTS	Describes the driving contexts defined for the synonyms, tables, and views owned by the current user. Its columns (except for OBJECT_OWNER) are the same as those in ALL_POLICY_CONTEXTS.
USER_SEC_RELEVANT_COLS	Describes the security relevant columns of the security policies for the tables and views owned by the current user. Its columns (except for OBJECT_OWNER) are the same as those in ALL_SEC_RELEVANT_COLS.
USER_POLICY_GROUPS	Describes the policy groups defined for the synonyms, tables, and views owned by the current user. This view does not display the OBJECT_OWNER column.
V$VPD_POLICY	Displays all the fine-grained security policies and predicates associated with the cursors currently in the library cache. This view is useful for finding the policies that were applied to a SQL statement.

Tip: In addition to these views, check the database trace file if you find errors in application that use Virtual Private Database policies. See *Oracle Database Performance Tuning Guide* for more information about trace files. The USER_DUMP_DEST initialization parameter specifies the current location of the trace files. You can find the value of this parameter by issuing SHOW PARAMETER USER_DUMP_DEST in SQL*Plus.

8

Developing Applications Using the Data Encryption API

This chapter contains:

See Also:

- *Oracle Database 2 Day + Security Guide* for an introduction to network encryption
- *Oracle Database Advanced Security Administrator's Guide* for information about using transparent data encryption and tablespace encryption

Security Problems That Encryption Does Not Solve

While there are many good reasons to encrypt data, there are many reasons not to encrypt data. Encryption does not solve all security problems, and may make some problems worse. The following sections describe some misconceptions about encryption of stored data:

Principle 1: Encryption Does Not Solve Access Control Problems

Most organizations need to limit data access to users who need to see this data. For example, a human resources system may limit employees to viewing only their own employment records, while allowing managers of employees to see the employment records of subordinates. Human resource specialists may also need to see employee records for multiple employees.

Typically, you can use access control mechanisms to address security policies that limit data access to those with a need to see it. Oracle Database has provided strong,

independently evaluated access control mechanisms for many years. It enables access control enforcement to a fine level of granularity through Virtual Private Database.

Because human resource records are considered sensitive information, it is tempting to think that all information should be encrypted for better security. However, encryption cannot enforce granular access control, and it may hinder data access. For example, an employee, his manager, and a human resources clerk may all need to access an employee record. If all employee data is encrypted, then all three must be able to access the data in unencrypted form. Therefore, the employee, the manager and the human resources clerk would have to share the same encryption key to decrypt the data. Encryption would, therefore, not provide any additional security in the sense of better access control, and the encryption might hinder the proper or efficient functioning of the application. An additional issue is that it is difficult to securely transmit and share encryption keys among multiple users of a system.

A basic principle behind encrypting stored data is that it must not interfere with access control. For example, a user who has the `SELECT` privilege on `emp` should not be limited by the encryption mechanism from seeing all the data he is otherwise allowed to see. Similarly, there is little benefit to encrypting part of a table with one key and part of a table with another key if users need to see all encrypted data in the table. In this case, encryption adds to the overhead of decrypting the data before users can read it. If access controls are implemented well, then encryption adds little additional security within the database itself. A user who has privileges to access data within the database has no more nor any less privileges as a result of encryption. Therefore, you should never use encryption to solve access control problems.

Principle 2: Encryption Does Not Protect Against a Malicious Database Administrator

Some organizations, concerned that a malicious user might gain elevated (database administrator) privileges by guessing a password, like the idea of encrypting stored data to protect against this threat. However, the correct solution to this problem is to protect the database administrator account, and to change default passwords for other privileged accounts. The easiest way to break into a database is by using a default password for a privileged account that an administrator allowed to remain unchanged. One example is `SYS/CHANGE_ON_INSTALL`.

While there are many destructive things a malicious user can do to a database after gaining the `DBA` privilege, encryption will not protect against many of them. Examples include corrupting or deleting data, exporting user data to the file system to email the data back to himself to run a password cracker on it, and so on.

Some organizations are concerned that database administrators, typically having all privileges, are able to see all data in the database. These organizations feel that the database administrators should administer the database, but should not be able to see the data that the database contains. Some organizations are also concerned about concentrating so much privilege in one person, and would prefer to partition the DBA function, or enforce two-person access rules.

It is tempting to think that encrypting all data (or significant amounts of data) will solve these problems, but there are better ways to protect against these threats. For example, Oracle Database supports limited partitioning of `DBA` privileges. Oracle Database provides native support for `SYSDBA` and `SYSOPER` users. `SYSDBA` has all privileges, but `SYSOPER` has a limited privilege set (such as startup and shutdown of the database).

Furthermore, you can create smaller roles encompassing several system privileges. A `jr_dba` role might not include all system privileges, but only those appropriate to a junior database administrator (such as `CREATE TABLE`, `CREATE USER`, and so on).

Oracle Database also enables auditing the actions taken by SYS (or SYS-privileged users) and storing that audit trail in a secure operating system location. Using this model, a separate auditor who has root privileges on the operating system can audit all actions by SYS, enabling the auditor to hold all database administrators accountable for their actions.

See "Auditing SYS Administrative Users" on page 9-53 for information about ways to audit database administrators.

You can also fine-tune the access and control that database administrators have by using Oracle Database Vault. See *Oracle Database Vault Administrator's Guide* for more information.

The database administrator function is a trusted position. Even organizations with the most sensitive data, such as intelligence agencies, do not typically partition the database administrator function. Instead, they manage their database administrators strongly, because it is a position of trust. Periodic auditing can help to uncover inappropriate activities.

Encryption of stored data must not interfere with the administration of the database, because otherwise, larger security issues can result. For example, if by encrypting data you corrupt the data, then you create a security problem, the data itself cannot be interpreted, and it may not be recoverable.

You can use encryption to limit the ability of a database administrator or other privileged user to see data in the database. However, it is not a substitute for managing the database administrator privileges properly, or for controlling the use of powerful system privileges. If untrustworthy users have significant privileges, then they can pose multiple threats to an organization, some of them far more significant than viewing unencrypted credit card numbers.

Principle 3: Encrypting Everything Does Not Make Data Secure

A common error is to think that if encrypting some data strengthens security, then encrypting everything makes all data secure.

As the discussion of the previous two principles illustrates, encryption does not address access control issues well, and it is important that encryption not interfere with normal access controls. Furthermore, encrypting an entire production database means that all data must be decrypted to be read, updated, or deleted. Encryption is inherently a performance-intensive operation; encrypting all data will significantly affect performance.

Availability is a key aspect of security. If encrypting data makes data unavailable, or adversely affects availability by reducing performance, then encrypting everything will create a new security problem. Availability is also adversely affected by the database being inaccessible when encryption keys are changed, as good security practices require on a regular basis. When the keys are to be changed, the database is inaccessible while data is decrypted and reencrypted with a new key or keys.

There may be advantages to encrypting data stored off-line. For example, an organization may store backups for a period of 6 months to a year off-line, in a remote location. Of course, the first line of protection is to secure the facility storing the data, by establishing physical access controls. Encrypting this data before it is stored may provide additional benefits. Because it is not being accessed on-line, performance need not be a consideration. While an Oracle database does not provide this capability, there are vendors who provide encryption services. Before embarking on large-scale encryption of backup data, organizations considering this approach should thoroughly

test the process. It is essential to verify that data encrypted before off-line storage can be decrypted and re-imported successfully.

Data Encryption Challenges

In cases where encryption can provide additional security, there are some associated technical challenges, as described in the following sections:

- Encrypting Indexed Data
- Generating Encryption Keys
- Transmitting Encryption Keys
- Storing Encryption Keys
- Changing Encryption Keys
- Encrypting Binary Large Objects

Encrypting Indexed Data

Special difficulties arise when encrypted data is indexed. For example, suppose a company uses a national identity number, such as the U.S. Social Security number (SSN), as the employee number for its employees. The company considers employee numbers to be sensitive data, and, therefore, wants to encrypt data in the `employee_number` column of the `employees` table. Because `employee_number` contains unique values, the database designers want to have an index on it for better performance.

However, if `DBMS_CRYPTO` or the `DBMS_OBFUSCATION_TOOLKIT` (or another mechanism) is used to encrypt data in a column, then an index on that column will also contain encrypted values. Although an index can be used for equality checking (for example, `SELECT * FROM emp WHERE employee_number = '987654321'`), if the index on that column contains encrypted values, then the index is essentially unusable for any other purpose. You should not encrypt indexed data.

Oracle recommends that you do not use national identity numbers as unique IDs. Instead, use the `CREATE SEQUENCE` statement to generate unique identity numbers. Reasons to avoid using national identity numbers are as follows:

- There are privacy issues associated with overuse of national identity numbers (for example, identity theft).
- Sometimes national identity numbers can have duplicates, as with U.S. Social Security numbers.

Generating Encryption Keys

Encrypted data is only as secure as the key used for encrypting it. An encryption key must be securely generated using secure cryptographic key generation. Oracle Database provides support for secure random number generation, with the `RANDOMBYTES` function of `DBMS_CRYPTO`. (This function replaces the capabilities provided by the `GetKey` procedure of the earlier `DBMS_OBFUSCATION_TOOLKIT`.) `DBMS_CRYPTO` calls the secure random number generator (RNG) previously certified by RSA Security.

Note: Do not use the DBMS_RANDOM package. The DBMS_RANDOM package generates pseudo-random numbers, which, as Randomness Recommendations for Security (RFC-1750) states that using pseudo-random processes to generate secret quantities can result in pseudo-security.

Be sure to provide the correct number of bytes when you encrypt a key value. For example, you must provide a 16-byte key for the ENCRYPT_AES128 encryption algorithm.

Transmitting Encryption Keys

If the encryption key is to be passed by the application to the database, then you must encrypt it. Otherwise, an intruder could get access to the key as it is being transmitted. Network encryption, such as that provided by Oracle Advanced Security, protects all data in transit from modification or interception, including cryptographic keys.

Storing Encryption Keys

Storing encryption keys is one of the most important, yet difficult, aspects of encryption. To recover data encrypted with a symmetric key, the key must be accessible to an authorized application or user seeking to decrypt the data. At the same time, the key must be inaccessible to someone who is maliciously trying to access encrypted data that he is not supposed to see.

The options available to a developer are:

- Storing the Encryption Keys in the Database
- Storing the Encryption Keys in the Operating System
- Users Managing Their Own Encryption Keys
- Using Transparent Database Encryption and Tablespace Encryption

Storing the Encryption Keys in the Database

Storing the keys in the database cannot always provide infallible security if you are trying to protect against the database administrator accessing encrypted data. An all-privileged database administrator could still access tables containing encryption keys. However, it can often provide good security against the casual curious user or against someone compromising the database file on the operating system.

As a trivial example, suppose you create a table (EMP) that contains employee data. You want to encrypt the employee Social Security number (SSN) stored in one of the columns. You could encrypt employee SSN using a key that is stored in a separate column. However, anyone with SELECT access on the entire table could retrieve the encryption key and decrypt the matching SSN.

While this encryption scheme seems easily defeated, with a little more effort you can create a solution that is much harder to break. For example, you could encrypt the SSN using a technique that performs some additional data transformation on the employee_number before using it to encrypt the SSN. This technique might be as simple as using an XOR operation on the employee_number and the birth date of the employee to determine the validity of the values.

As additional protection, PL/SQL source code performing encryption can be wrapped, (using the WRAP utility) which obfuscates (scrambles) the code. The WRAP utility

processes an input SQL file and obfuscates the PL/SQL units in it. For example, the following command uses the `keymanage.sql` file as the input:

```
wrap iname=/mydir/keymanage.sql
```

A developer can subsequently have a function in the package call the `DBMS_OBFUSCATION_TOOLKIT` with the key contained in the wrapped package.

Oracle Database enables you to obfuscate dynamically generated PL/SQL code. The `DBMS_DDL` package contains two subprograms that allow you to obfuscate dynamically generated PL/SQL program units. For example, the following block uses the `DBMS_DDL.CREATE_WRAPPED` procedure to wrap dynamically generated PL/SQL code.

```
BEGIN
......
SYS.DBMS_DDL.CREATE_WRAPPED(function_returning_PLSQL_code());
......
END;
```

While wrapping is not unbreakable, it makes it harder for an intruder to get access to the encryption key. Even in cases where a different key is supplied for each encrypted data value, you should not embed the key value within a package. Instead, wrap the package that performs the key management (that is, data transformation or padding).

> **See Also:** *Oracle Database PL/SQL Language Reference* for additional information about the `WRAP` command line utility and the `DBMS_DDL` subprograms for dynamic wrapping

An alternative to wrapping the data is to have a separate table in which to store the encryption key and to envelope the call to the keys table with a procedure. The key table can be joined to the data table using a primary key to foreign key relationship. For example, `employee_number` is the primary key in the `employees` table that stores employee information and the encrypted SSN. The `employee_number` column is a foreign key to the `ssn_keys` table that stores the encryption keys for the employee SSN. The key stored in the `ssn_keys` table can also be transformed before use (by using an `XOR` operation), so the key itself is not stored unencrypted. If you wrap the procedure, then that can hide the way in which the keys are transformed before use.

The strengths of this approach are:

- Users who have direct table access cannot see the sensitive data unencrypted, nor can they retrieve the keys to decrypt the data.
- Access to decrypted data can be controlled through a procedure that selects the encrypted data, retrieves the decryption key from the key table, and transforms it before it can be used to decrypt the data.
- The data transformation algorithm is hidden from casual snooping by wrapping the procedure, which obfuscates the procedure code.
- `SELECT` access to both the data table and the keys table does not guarantee that the user with this access can decrypt the data, because the key is transformed before use.

The weakness to this approach is that a user who has `SELECT` access to both the key table and the data table, and who can derive the key transformation algorithm, can break the encryption scheme.

The preceding approach is not infallible, but it is adequate to protect against easy retrieval of sensitive information stored in clear text.

Storing the Encryption Keys in the Operating System

Storing keys in a flat file in the operating system is another option. Oracle Database enables you to make callouts from PL/SQL, which you could use to retrieve encryption keys. However, if you store keys in the operating system and make callouts to it, then your data is only as secure as the protection on the operating system. If your primary security concern is that the database can be broken into from the operating system, then storing the keys in the operating system makes it easier for an intruder to retrieve encrypted data than storing the keys in the database itself.

Users Managing Their Own Encryption Keys

Having the user supply the key assumes the user will be responsible with the key. Considering that 40 percent of help desk calls are from users who have forgotten their passwords, you can see the risks of having users manage encryption keys. In all likelihood, users will either forget an encryption key, or write the key down, which then creates a security weakness. If a user forgets an encryption key or leaves the company, then your data is not recoverable.

If you do decide to have user-supplied or user-managed keys, then you need to ensure you are using network encryption so that the key is not passed from the client to the server in the clear. You also must develop key archive mechanisms, which is also a difficult security problem. Key archives and backdoors create the security weaknesses that encryption is attempting to solve.

Using Transparent Database Encryption and Tablespace Encryption

Transparent database encryption and tablespace encryption provide secure encryption with automatic key management for the encrypted tables and tablespaces. If the application requires protection of sensitive column data stored on the media, then these two types of encryption are a simple and fast way of achieving this.

> **See Also:** *Oracle Database Advanced Security Administrator's Guide* for more information about transparent data encryption

Changing Encryption Keys

Prudent security practice dictates that you periodically change encryption keys. For stored data, this requires periodically unencrypting the data, and reencrypting it with another well-chosen key. You would most likely change the encryption key while the data is not being accessed, which creates another challenge. This is especially true for a Web-based application encrypting credit card numbers, because you do not want to shut down the entire application while you switch encryption keys.

Encrypting Binary Large Objects

Certain data types require more work to encrypt. For example, Oracle Database supports storage of binary large objects (BLOBs), which stores very large objects (for example, multiple gigabytes) in the database. A BLOB can be either stored internally as a column, or stored in an external file.

For an example of using `DBMS_CRYPTO` on BLOB data, see "Example of Encryption and Decryption Procedures for BLOB Data" on page 8-12.

Storing Data Encryption by Using the DBMS_CRYPTO Package

The DBMS_CRYPTO package provides several ways to address the security issues that were discussed. (For backward compatibility, DBMS_OBFUSCATION_TOOLKIT is also provided.)

While encryption is not the ideal solution for addressing several security threats, it is clear that selectively encrypting sensitive data before storage in the database does improve security. Examples of such data could include:

- Credit card numbers
- National identity numbers

Oracle Database provides the PL/SQL package DBMS_CRYPTO to encrypt and decrypt stored data. This package supports several industry-standard encryption and hashing algorithms, including the Advanced Encryption Standard (AES) encryption algorithm. AES was approved by the National Institute of Standards and Technology (NIST) to replace the Data Encryption Standard (DES).

The DBMS_CRYPTO package enables encryption and decryption for common Oracle Database data types, including RAW and large objects (LOBs), such as images and sound. Specifically, it supports BLOBs and CLOBs. In addition, it provides Globalization Support for encrypting data across different database character sets.

The following cryptographic algorithms are supported:

- Data Encryption Standard (DES), Triple DES (3DES, 2-key)
- Advanced Encryption Standard (AES)
- SHA-1 Cryptographic Hash
- SHA-1 Message Authentication Code (MAC)

Block cipher modifiers are also provided with DBMS_CRYPTO. You can choose from several padding options, including Public Key Cryptographic Standard (PKCS) #5, and from four block cipher chaining modes, including Cipher Block Chaining (CBC). Padding must be done in multiples of eight bytes.

Note:

- DES is no longer recommended by the National Institute of Standards and Technology (NIST).
- Usage of SHA-1 is more secure than MD5.
- Keyed MD5 is not vulnerable.

Table 8–1 compares the DBMS_CRYPTO package features to the other PL/SQL encryption package, the DBMS_OBFUSCATION_TOOLKIT.

Table 8–1 DBMS_CRYPTO and DBMS_OBFUSCATION_TOOLKIT Feature Comparison

Package Feature	DBMS_CRYPTO	DBMS_OBFUSCATION_TOOLKIT
Cryptographic algorithms	DES, 3DES, AES, RC4, 3DES_2KEY	DES, 3DES
Padding forms	PKCS5, zeroes	None supported
Block cipher chaining modes	CBC, CFB, ECB, OFB	CBC
Cryptographic hash algorithms	SHA-1, MD4, MD5	MD5

Table 8–1 (Cont.) DBMS_CRYPTO and DBMS_OBFUSCATION_TOOLKIT Feature Comparison

Package Feature	DBMS_CRYPTO	DBMS_OBFUSCATION_TOOLKIT
Keyed hash (MAC) algorithms	HMAC_MD5, HMAC_SH1	None supported
Cryptographic pseudo-random number generator	RAW, NUMBER, BINARY_INTEGER	RAW, VARCHAR2
Database types	RAW, CLOB, BLOB	RAW, VARCHAR2

DBMS_CRYPTO is intended to replace the OBFUSCATION_TOOLKIT package, because it is easier to use and supports a range of algorithms that accommodate both new and existing systems. Although 3DES_2KEY and MD4 are provided for backward compatibility, you achieve better security using 3DES, AES, or SHA-1. Therefore, 3DES_2KEY is not recommended.

The DBMS_CRYPTO package includes cryptographic checksum capabilities (MD5), which are useful for comparisons, and the ability to generate a secure random number (the RANDOMBYTES function). Secure random number generation is an important part of cryptography; predictable keys are easily guessed keys; and easily guessed keys may lead to easy decryption of data. Most cryptanalysis is done by finding weak keys or poorly stored keys, rather than through brute force analysis (cycling through all possible keys).

Note: Do not use DBMS_RANDOM, because it is unsuitable for cryptographic key generation.

Key management is programmatic. That is, the application (or caller of the function) must supply the encryption key. This means that the application developer must find a way of storing and retrieving keys securely. The relative strengths and weaknesses of various key management techniques are discussed in the sections that follow. The DBMS_OBFUSCATION_TOOLKIT package, which can handle both string and raw data, requires the submission of a 64-bit key. The DES algorithm itself has an effective key length of 56-bits.

Note: The DBMS_OBFUSCATION_TOOLKIT is granted to PUBLIC by default. Oracle recommends that you revoke this grant.

While the DBMS_OBFUSCATION_TOOLKIT package can take either VARCHAR2 or RAW data types, it is preferable to use the RAW data type for keys and encrypted data. Storing encrypted data as VARCHAR2 can cause problems if it passes through Globalization Support routines. For example, when transferring a database to another database that uses another character set.

To convert between VARCHAR2 and RAW data types, use the CAST_TO_RAW and CAST_TO_VARCHAR2 functions of the UTL_RAW package.

See Also:

- *Oracle Database PL/SQL Packages and Types Reference* for detailed information about the DBMS_CRYPTO package
- *Oracle Database PL/SQL Packages and Types Reference* for detailed information about the OBFUSCATION_TOOLKIT package
- *Oracle Database PL/SQL Packages and Types Reference* for detailed information about the UTL_RAW package

Examples of Using the Data Encryption API

This section contains:

- Example of a Data Encryption Procedure
- Example of AES 256-Bit Data Encryption and Decryption Procedures
- Example of Encryption and Decryption Procedures for BLOB Data

Example of a Data Encryption Procedure

The following sample PL/SQL program (dbms_crypto.sql) shows how to encrypt data. This example code performs the following actions:

- Encrypts a string (VARCHAR2 type) using DES after first converting it into the RAW data type.

  This step is necessary because encrypt and decrypt functions and procedures in DBMS_CRYPTO package work on the RAW data type only, unlike functions and packages in the DBMS_OBFUSCATION_TOOLKIT package.
- Shows how to create a 160-bit hash using SHA-1 algorithm.
- Demonstrates how MAC, a key-dependent one-way hash, can be computed using the MD5 algorithm.

The dbms_crypto.sql procedure follows:

```
DECLARE
    input_string     VARCHAR2(16) := 'tigertigertigert';
    raw_input        RAW(128) :=
UTL_RAW.CAST_TO_RAW(CONVERT(input_string,'AL32UTF8','US7ASCII'));
    key_string       VARCHAR2(8)  := 'scottsco';
    raw_key          RAW(128) :=
UTL_RAW.CAST_TO_RAW(CONVERT(key_string,'AL32UTF8','US7ASCII'));
    encrypted_raw    RAW(2048);
    encrypted_string VARCHAR2(2048);
    decrypted_raw    RAW(2048);
    decrypted_string VARCHAR2(2048);
-- Begin testing Encryption:
BEGIN
    dbms_output.put_line('> Input String                    : ' ||
    CONVERT(UTL_RAW.CAST_TO_VARCHAR2(raw_input),'US7ASCII','AL32UTF8'));
    dbms_output.put_line('> ========= BEGIN TEST Encrypt =========');
    encrypted_raw := dbms_crypto.Encrypt(
        src => raw_input,
        typ => DBMS_CRYPTO.DES_CBC_PKCS5,
        key => raw_key);
        dbms_output.put_line('> Encrypted hex value             : ' ||
        rawtohex(UTL_RAW.CAST_TO_RAW(encrypted_raw)));
decrypted_raw := dbms_crypto.Decrypt(
```

```
        src => encrypted_raw,
        typ => DBMS_CRYPTO.DES_CBC_PKCS5,
        key => raw_key);
    decrypted_string :=
    CONVERT(UTL_RAW.CAST_TO_VARCHAR2(decrypted_raw),'US7ASCII','AL32UTF8');
dbms_output.put_line('> Decrypted string output          : ' ||
        decrypted_string);
if input_string = decrypted_string THEN
    dbms_output.put_line('> String DES Encyption and Decryption successful');
END if;
dbms_output.put_line('');
dbms_output.put_line('> ========= BEGIN TEST Hash =========');
    encrypted_raw := dbms_crypto.Hash(
        src => raw_input,
        typ => DBMS_CRYPTO.HASH_SH1);
dbms_output.put_line('> Hash value of input string       : ' ||
        rawtohex(UTL_RAW.CAST_TO_RAW(encrypted_raw)));
dbms_output.put_line('> ========= BEGIN TEST Mac =========');
    encrypted_raw := dbms_crypto.Mac(
        src => raw_input,
        typ => DBMS_CRYPTO.HMAC_MD5,
        key => raw_key);
dbms_output.put_line('> Message Authentication Code      : ' ||
        rawtohex(UTL_RAW.CAST_TO_RAW(encrypted_raw)));
dbms_output.put_line('');
dbms_output.put_line('> End of DBMS_CRYPTO tests  ');
END;
/
```

Example of AES 256-Bit Data Encryption and Decryption Procedures

The following PL/SQL block shows how to encrypt and decrypt a predefined variable named `input_string` using the AES 256-bit algorithm with Cipher Block Chaining and PKCS #5 padding.

```
declare
   input_string       VARCHAR2 (200) := 'Secret Message';
   output_string      VARCHAR2 (200);
   encrypted_raw      RAW (2000);             -- stores encrypted binary text
   decrypted_raw      RAW (2000);             -- stores decrypted binary text
   num_key_bytes      NUMBER := 256/8;        -- key length 256 bits (32 bytes)
   key_bytes_raw      RAW (32);               -- stores 256-bit encryption key
   encryption_type    PLS_INTEGER :=          -- total encryption type
                         DBMS_CRYPTO.ENCRYPT_AES256
                       + DBMS_CRYPTO.CHAIN_CBC
                       + DBMS_CRYPTO.PAD_PKCS5;
begin
   DBMS_OUTPUT.PUT_LINE ('Original string: ' || input_string);
   key_bytes_raw := DBMS_CRYPTO.RANDOMBYTES (num_key_bytes);
   encrypted_raw := DBMS_CRYPTO.ENCRYPT
      (
         src => UTL_I18N.STRING_TO_RAW (input_string, 'AL32UTF8'),
         typ => encryption_type,
         key => key_bytes_raw
      );
    -- The encrypted value in the encrypted_raw variable can be used here:
   decrypted_raw := DBMS_CRYPTO.DECRYPT
      (
         src => encrypted_raw,
         typ => encryption_type,
```

```
        key => key_bytes_raw
      );
   output_string := UTL_I18N.RAW_TO_CHAR (decrypted_raw, 'AL32UTF8');
   DBMS_OUTPUT.PUT_LINE ('Decrypted string: ' || output_string);
end;
```

Example of Encryption and Decryption Procedures for BLOB Data

The following sample PL/SQL program (`blob_test.sql`) shows how to encrypt and decrypt BLOB data. This example code does the following, and prints out its progress (or problems) at each step:

- Creates a table for the BLOB column
- Inserts the raw values into that table
- Encrypts the raw data
- Decrypts the encrypted data

The `blob_test.sql` procedure follows:

```
-- 1. Create a table for BLOB column:
create table table_lob (id number, loc blob);

-- 2. Insert 3 empty lobs for src/enc/dec:
insert into table_lob values (1, EMPTY_BLOB());
insert into table_lob values (2, EMPTY_BLOB());
insert into table_lob values (3, EMPTY_BLOB());

set echo on
set serveroutput on

declare
    srcdata    RAW(1000);
    srcblob    BLOB;
    encrypblob BLOB;
    encrypraw  RAW(1000);
    encrawlen  BINARY_INTEGER;
    decrypblob BLOB;
    decrypraw  RAW(1000);
    decrawlen  BINARY_INTEGER;

    leng       INTEGER;

begin

    -- RAW input data 16 bytes
    srcdata := hextoraw('6D6D6D6D6D6D6D6D6D6D6D6D6D6D6D6D');

    dbms_output.put_line('---');
    dbms_output.put_line('input is ' || srcdata);
    dbms_output.put_line('---');

    -- select empty lob locators for src/enc/dec
    select loc into srcblob from table_lob where id = 1;
    select loc into encrypblob from table_lob where id = 2;
    select loc into decrypblob from table_lob where id = 3;

    dbms_output.put_line('Created Empty LOBS');
    dbms_output.put_line('---');
```

```
    leng := DBMS_LOB.GETLENGTH(srcblob);
    IF leng IS NULL THEN
        dbms_output.put_line('Source BLOB Len NULL ');
    ELSE
        dbms_output.put_line('Source BLOB Len ' || leng);
    END IF;

    leng := DBMS_LOB.GETLENGTH(encrypblob);
    IF leng IS NULL THEN
        dbms_output.put_line('Encrypt BLOB Len NULL ');
    ELSE
        dbms_output.put_line('Encrypt BLOB Len ' || leng);
    END IF;

    leng := DBMS_LOB.GETLENGTH(decrypblob);
    IF leng IS NULL THEN
        dbms_output.put_line('Decrypt  BLOB Len NULL ');
    ELSE
        dbms_output.put_line('Decrypt BLOB Len ' || leng);
    END IF;

    -- 3. Write source raw data into blob:
    DBMS_LOB.OPEN (srcblob, DBMS_LOB.lob_readwrite);
    DBMS_LOB.WRITEAPPEND (srcblob, 16, srcdata);
    DBMS_LOB.CLOSE (srcblob);

    dbms_output.put_line('Source raw data written to source blob');
    dbms_output.put_line('---');

    leng := DBMS_LOB.GETLENGTH(srcblob);
    IF leng IS NULL THEN
        dbms_output.put_line('source BLOB Len NULL ');
    ELSE
        dbms_output.put_line('Source BLOB Len ' || leng);
    END IF;

    /*
    * Procedure Encrypt
    * Arguments: srcblob -> Source BLOB
    *            encrypblob -> Output BLOB for encrypted data
    *            DBMS_CRYPTO.AES_CBC_PKCS5 -> Algo : AES
    *                                         Chaining : CBC
    *                                         Padding : PKCS5
    *            256 bit key for AES passed as RAW
    *                ->
    hextoraw('000102030405060708090A0B0C0D0E0F101112131415161718191A1B1C1D1E1F')
    *            IV (Initialization Vector) for AES algo passed as RAW
    *                -> hextoraw('00000000000000000000000000000000')
    */

    DBMS_CRYPTO.Encrypt(encrypblob,
                srcblob,
                DBMS_CRYPTO.AES_CBC_PKCS5,
                hextoraw
('000102030405060708090A0B0C0D0E0F101112131415161718191A1B1C1D1E1F'),
                hextoraw('00000000000000000000000000000000'));


    dbms_output.put_line('Encryption Done');
    dbms_output.put_line('---');
```

```
leng := DBMS_LOB.GETLENGTH(encrypblob);
IF leng IS NULL THEN
    dbms_output.put_line('Encrypt BLOB Len NULL');
ELSE
    dbms_output.put_line('Encrypt BLOB Len ' || leng);
END IF;

-- 4. Read encrypblob to a raw:
encrawlen := 999;

DBMS_LOB.OPEN (encrypblob, DBMS_LOB.lob_readwrite);
DBMS_LOB.READ (encrypblob, encrawlen, 1, encrypraw);
DBMS_LOB.CLOSE (encrypblob);

dbms_output.put_line('Read encrypt blob to a raw');
dbms_output.put_line('---');

dbms_output.put_line('Encrypted data is (256 bit key) ' || encrypraw);
dbms_output.put_line('---');

/*
* Procedure Decrypt
* Arguments: encrypblob -> Encrypted BLOB to decrypt
*            decrypblob -> Output BLOB for decrypted data in RAW
*            DBMS_CRYPTO.AES_CBC_PKCS5 -> Algo : AES
*                                         Chaining : CBC
*                                         Padding : PKCS5
*            256 bit key for AES passed as RAW (same as used during Encrypt)
*                ->
hextoraw('000102030405060708090A0B0C0D0E0F101112131415161718191A1B1C1D1E1F')
*            IV (Initialization Vector) for AES algo passed as RAW (same as
*            used during Encrypt)
*                -> hextoraw('00000000000000000000000000000000')
*/

DBMS_CRYPTO.Decrypt(decrypblob,
            encrypblob,
            DBMS_CRYPTO.AES_CBC_PKCS5,
            hextoraw
       ('000102030405060708090A0B0C0D0E0F101112131415161718191A1B1C1D1E1F'),
            hextoraw('00000000000000000000000000000000'));

leng := DBMS_LOB.GETLENGTH(decrypblob);
IF leng IS NULL THEN
    dbms_output.put_line('Decrypt BLOB Len NULL');
ELSE
    dbms_output.put_line('Decrypt BLOB Len ' || leng);
END IF;

-- Read decrypblob to a raw
decrawlen := 999;

DBMS_LOB.OPEN (decrypblob, DBMS_LOB.lob_readwrite);
DBMS_LOB.READ (decrypblob, decrawlen, 1, decrypraw);
DBMS_LOB.CLOSE (decrypblob);

dbms_output.put_line('Decrypted data is (256 bit key) ' || decrypraw);
dbms_output.put_line('---');
```

```
    DBMS_LOB.OPEN (srcblob, DBMS_LOB.lob_readwrite);
    DBMS_LOB.TRIM (srcblob, 0);
    DBMS_LOB.CLOSE (srcblob);

    DBMS_LOB.OPEN (encrypblob, DBMS_LOB.lob_readwrite);
    DBMS_LOB.TRIM (encrypblob, 0);
    DBMS_LOB.CLOSE (encrypblob);

    DBMS_LOB.OPEN (decrypblob, DBMS_LOB.lob_readwrite);
    DBMS_LOB.TRIM (decrypblob, 0);
    DBMS_LOB.CLOSE (decrypblob);

end;
/

truncate table table_lob;
drop table table_lob;
```

Finding Information About Encrypted Data

Table 8–2 lists data dictionary views that you can query to access information about encrypted data. See *Oracle Database Reference* for detailed information about these views.

Table 8–2 Data Dictionary Views That Display Information about Encrypted Data

View	Description
ALL_ENCRYPTED_COLUMNS	Describes encryption algorithm information for all encrypted columns in all tables accessible to the user
DBA_ENCRYPTED_COLUMNS	Describes encryption algorithm information for all encrypted columns in the database
USER_ENCRYPTED_COLUMNS	Describes encryption algorithm information for all encrypted columns in all tables in the schema of the user
V$ENCRYPTED_TABLESPACES	Displays information about the tablespaces that are encrypted
V$ENCRYPTION_WALLET	Displays information on the status of the wallet and the wallet location for transparent data encryption
V$RMAN_ENCRYPTION_ALGORITHMS	Displays supported encryption algorithms.

9

Verifying Security Access with Auditing

This chapter contains:

> **See Also:** "Guidelines for Auditing" on page 10-18 for general guidelines to follow for auditing your system

About Auditing

This section contains:

> **See Also:** *Oracle Audit Vault and Database Firewall Administrator's Guide* for more information about Oracle Audit Vault and Database Firewall, which provides advanced auditing features

What Is Auditing?

Auditing is the monitoring and recording of selected user database actions, from both database users and nondatabase users[1]. You can base auditing on individual actions, such as the type of SQL statement executed, or on combinations of data that can include the user name, application, time, and so on. You can audit both successful and failed activities. To use auditing, you enable it, and then configure what must be audited. The actions that you audit are recorded in either data dictionary tables or in operating system files.

Oracle recommends that you enable and configure auditing. Auditing is an effective method of enforcing strong internal controls so that your site can meet its regulatory compliance requirements, as defined in the Sarbanes-Oxley Act. This enables you to monitor business operations, and find any activities that may deviate from company policy. Doing so translates into tightly controlled access to your database and the application software, ensuring that patches are applied on schedule and preventing ad hoc changes. By enabling auditing by default, you can generate an audit record for audit and compliance personnel. Be selective with auditing and ensure that it meets your business compliance needs.

Why Is Auditing Used?

You typically use auditing to perform the following activities:

- **Enable accountability for actions.** These include actions taken in a particular schema, table, or row, or affecting specific content.
- **Deter users (or others, such as intruders) from inappropriate actions based on their accountability.**
- **Investigate suspicious activity.** For example, if a user is deleting data from tables, then a security administrator might decide to audit all connections to the database and all successful and unsuccessful deletions of rows from all tables in the database.
- **Notify an auditor of the actions of an unauthorized user.** For example, an unauthorized user could be changing or deleting data, or the user has more privileges than expected, which can lead to reassessing user authorizations.
- **Monitor and gather data about specific database activities.** For example, the database administrator can gather statistics about which tables are being updated, how many logical I/Os are performed, or how many concurrent users connect at peak times.
- **Detect problems with an authorization or access control implementation.** For example, you can create audit policies that you expect will never generate an audit record because the data is protected in other ways. However, if these policies generate audit records, then you will know the other security controls are not properly implemented.
- **Address auditing requirements for compliance.** Regulations such as the following have common auditing-related requirements:
  - Sarbanes-Oxley Act
  - Health Insurance Portability and Accountability Act (HIPAA)

[1] "Nondatabase users" refers to application users who are recognized in the database using the `CLIENT_IDENTIFIER` attribute. To audit this type of user, you can use a fine-grained audit policy. See "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36 for more information.

- International Convergence of Capital Measurement and Capital Standards: a Revised Framework (Basel II)
- Japan Privacy Law
- European Union Directive on Privacy and Electronic Communications

Protecting the Database Audit Trail

When auditing for suspicious database activity, you should protect the integrity of the audit trail records to guarantee the accuracy and completeness of the auditing information.

Oracle Database writes the database audit trail to the `SYS.AUD$` and `SYS.FGA_LOG$` tables. Audit records generated as a result of object audit options set for the `SYS.AUD$` and `SYS.FGA_LOG$` tables can only be deleted from the audit trail by someone who has connected with administrator privileges. Remember that administrators are also audited for unauthorized use. See "Auditing SYS Administrative Users" on page 9-53 for more information.

Other ways to protect the database audit trail are as follows:

- **Set the O7_DICTIONARY_ACCESSIBILITY initialization parameter to FALSE (the default).** This way, only users who have the `SYSDBA` privilege can perform DML actions on the audit data in the `SYS.AUD$` and `SYS.FGA_LOG$` tables. In a default installation, `O7_DICTIONARY_ACCESSIBILITY` is set to `FALSE`.
- **If you have Oracle Database Vault installed, create a realm around the SYSTEM.AUD$ table.** By default, the `AUD$` table is in the `SYSTEM` schema. (The synonym `SYS.AUD$` refers to the `SYSTEM.AUD$` table.) See *Oracle Database Vault Administrator's Guide* for more information about realms in Oracle Database Vault.

See Also:

- "Auditing General Activities with Standard Auditing" on page 9-6
- "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36

Activities That Are Always Written to the Standard and Fine-Grained Audit Records

When standard auditing is enabled (that is, you set `AUDIT_TRAIL` to `DB` or `DB, EXTENDED`), Oracle Database audits all data manipulation language (DML) operations, such as `INSERT`, `UPDATE`, `MERGE`, and `DELETE` on the `SYS.AUD$` and `SYS.FGA_LOG$` tables by non-`SYS` users. (It performs this audit even if you have not set audit options for the `AUD$` and `FGA_LOGS$` tables.) Typically, non-`SYS` users do not have access to these tables, except if they have been explicitly granted access. If a non-`SYS` user tampers with the data in the `SYS.FGA_LOG$` and `SYS.AUD$` tables, then Oracle Database writes an audit record for each action.

Oracle Database audits `SYS` user's `DELETE`, `INSERT`, `UPDATE`, and `MERGE` operations on the `SYS.FGA_LOG$` and `SYS.AUD$` tables if you have set the `AUDIT_SYS_OPERATIONS` initialization parameter to `TRUE`. In this case the audit records of all `SYS` operations are written to whatever directory the `AUDIT_FILE_DEST` initialization parameter points to. If `AUDIT_FILE_DEST` is not set, then it writes the records to an operating system-dependent location.

See Also:

- "Auditing General Activities with Standard Auditing" on page 9-6
- "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36

Activities That Are Always Audited for All Platforms

Oracle Database always audits certain database-related operations and writes them to the operating system audit files. It includes the actions of any user who is logged in with the SYSDBA or SYSOPER privilege. This is called **mandatory auditing**. Even if you have enabled the database audit trail (that is, setting the AUDIT_TRAIL parameter to DB), Oracle Database still writes mandatory records to operating system files.

By default, the operating system files are in the $ORACLE_BASE/admin/$ORACLE_SID/adump directory for both UNIX and Windows systems. On Windows systems, Oracle Database also writes this information to the Windows Event Viewer. You can change the location of this directory by setting the AUDIT_FILE_DEST initialization parameter, which is described in "Specifying a Directory for the Operating System Audit Trail" on page 9-17.

Mandatory auditing includes the following operations:

- **Database startup.** An audit record is generated that lists the operating system user starting the instance, the user terminal identifier, and the date and time stamp. This data is stored in the operating system audit trail because the database audit trail is not available until after the startup has successfully completed.
- **SYSDBA and SYSOPER logins.** Oracle Database records all SYSDBA and SYSOPER connections.
- **Database shutdown.** An audit record is generated that lists the operating system user shutting down the instance, the user terminal identifier, and the date and time stamp.

Note: If you set the AUDIT_SYSLOG_LEVEL initialization parameter, mandatory actions are written the to the UNIX syslog. See "Using the Syslog Audit Trail on UNIX Systems" on page 9-18 for more information about the syslog audit trail. See also your operating system-specific Oracle Database documentation for more information about the operating system and syslog audit trail.

Auditing in a Distributed Database

Auditing is site autonomous. An instance audits only the statements issued by directly connected users. A local Oracle Database node cannot audit actions that take place in a remote database.

Best Practices for Auditing

Follow these best practices guidelines:

- As a general rule, design your auditing strategy to collect the amount of information that you need to meet compliance requirements, but being sure to focus on activities that cause the greatest security concerns. For example, auditing every table in the database is not practical, but auditing table columns that contain sensitive data, such as salaries, is. With both standard and fine-grained auditing,

there are mechanisms you can use to design audit policies that focus on specific activities to audit.

- Periodically archive and purge the audit trail data. See "Purging Audit Trail Records" on page 9-65 for more information.

  See Also: "Guidelines for Auditing" on page 10-18 for general guidelines to follow for auditing your system

Selecting an Auditing Type

You must perform a specific set of steps depending on the type of auditing that you want to perform: general activities (such as SQL statement actions), commonly used auditing activities, or fine-grained auditing.

In addition to these types of auditing, remember that Oracle Database mandatorily audits some activities. See Activities That Are Mandatorily Audited for more information.

Auditing SQL Statements, Privileges, and Other General Activities

Oracle Database provides a set of default audit settings that you can enable for commonly used security-relevant SQL statements and privileges.

Location of audit records: Oracle Database writes these audit records to the location based on the `AUDIT_TRAIL` initialization parameter. See also "About Audit Records" on page 9-57.

General steps:

1. Follow the instructions in "Using Default Auditing for Security-Relevant SQL Statements and Privileges" on page 9-35 to enable default auditing.

   To understand more about the database audit trail, see "Managing Audit Trail Records" on page 9-57.

2. To monitor audit activities, periodically query the database audit trail data dictionary views. See "Finding Information About Audited Activities" on page 9-80.

3. Perform maintenance on the database audit trail. See "Managing the Database Audit Trail" on page 9-58.

4. Periodically archive and purge the contents of the audit trail. See "Purging Audit Trail Records" on page 9-65.

Auditing Commonly Used Security-Relevant Activities

You can audit at the most granular level, data access, and actions based on content, using Boolean measures, such as `value > 7800` or the IP address from which an action occurred.

Location of audit records: You can write the audit records to either the database audit trail or an operating system audit trail in XML format. See also "About Audit Records" on page 9-57.

General steps:

1. See "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36 to understand more about auditing specific activities.

2. Decide whether you want to write audit records to the database audit trail or to an operating system file. See "Managing the Database Audit Trail" on page 9-58.
3. Use the `DBMS_FGA` PL/SQL package to configure fine-grained auditing policies. The `DBMS_FGA.ADD_POLICY` procedure provides the `audit_trail` parameter, which you use to select the audit trail type. You can choose between a database audit trail or an operating system audit trail using XML files. See the following sections:

   "Creating an Audit Trail for Fine-Grained Audit Records" on page 9-39

   "Using the DBMS_FGA Package to Manage Fine-Grained Audit Policies" on page 9-39
4. To monitor audit activities, periodically check the operating system records you configured, or query the audit trail data dictionary views. See "Finding Information About Audited Activities" on page 9-80.
5. Perform maintenance on the audit trail. See "Managing Audit Trail Records" on page 9-57.
6. Periodically archive and purge the contents of the audit trail. See "Purging Audit Trail Records" on page 9-65.

Auditing Specific, Fine-Grained Activities

You can audit the top-level SQL statements issued by users who have connected using the `SYSDBA` or `SYSOPER` privilege. (Top-level refers to statements directly issued by a user. Statements run from a PL/SQL procedure or function are not considered top-level.)

Location of audit records: Oracle Database writes these audit records to an operating system audit trail only. On Windows, Oracle Database writes the `SYS` audit records to the Windows Event log by default. For UNIX systems, you can write records to a syslog file. See also "About Audit Records" on page 9-57.

General steps:

1. See "Auditing SYS Administrative Users" on page 9-53 to configure administrative auditing.
2. To understand more about the operating system audit trail, see Managing the Operating System Audit Trail on page 9-62.
3. To monitor audit activities, periodically check the operating system or syslog records you configured. If you are writing to an XML file, you can query the `V$XML_AUDIT_TRAIL` and `DBA_COMMON_AUDIT_TRAIL` views. See "Finding Information About Audited Activities" on page 9-80.
4. Perform maintenance on the audit trail. See "Managing Audit Trail Records" on page 9-57
5. Periodically archive and purge the contents of the audit trail. See "Purging Audit Trail Records" on page 9-65.

Auditing General Activities with Standard Auditing

This section contains:

- About Standard Auditing
- Configuring Standard Auditing with the AUDIT_TRAIL Initialization Parameter
- What Do the Operating System and Database Audit Trails Have in Common?

- Using the Operating System Audit Trail
- Using the Syslog Audit Trail on UNIX Systems
- How the AUDIT and NOAUDIT SQL Statements Work
- Auditing SQL Statements
- Auditing Privileges
- Auditing SQL Statements and Privileges in a Multitier Environment
- Auditing Schema Objects
- Auditing Directory Objects
- Auditing Functions, Procedures, Packages, and Triggers
- Auditing Network Activity

See Also:

- "Auditing SYS Administrative Users" on page 9-53 to learn how to use standard auditing to audit `SYS` users
- *Oracle Database 2 Day + Security Guide* for a tutorial on creating a standard audit trail

About Standard Auditing

This section contains:

- What Is Standard Auditing?
- Who Can Perform Standard Auditing?
- When Are Standard Audit Records Created?

What Is Standard Auditing?

In standard auditing, you audit SQL statements, privileges, schema objects, and network activity. You configure standard auditing by using the `AUDIT` SQL statement and `NOAUDIT` to remove this configuration. You can write the audit records to either the database audit trail or to operating system audit files.

Who Can Perform Standard Auditing?

Any user can configure auditing for the objects in his or her own schema, by using the `AUDIT` statement. To undo the audit configuration for this object, the user can use the `NOAUDIT` statement. No additional privileges are needed to perform this task. Users can run `AUDIT` statements to set auditing options regardless of the `AUDIT_TRAIL` parameter setting. If auditing has been disabled, the next time it is enabled, Oracle Database will record the auditing activities set by the `AUDIT` statements. "Enabling or Disabling the Standard Audit Trail" on page 9-8 explains how to enable standard auditing.

Note the following:

- To audit objects in another schema, the user must have the `AUDIT ANY` system privilege.
- To audit system privileges, the user must have the `AUDIT SYSTEM` privilege.
- If the `O7_DICTIONARY_ACCESSIBILITY` initialization parameter has been set to `FALSE` (the default), then only users who have the `SYSDBA` privilege can perform DML actions on the audit data in the `SYS.AUD$` and `SYS.FGA_LOG$` tables. For

greater security, set the O7_DICTIONARY_ACCESSIBILITY parameter to FALSE so that non-SYSDBA users cannot audit SYS objects.

See Also:

- GRANT in *Oracle Database SQL Language Reference* for a listing of available system and object privileges
- AUDIT in *Oracle Database SQL Language Reference* for a full listing of audit options

When Are Standard Audit Records Created?

You, as the security administrator, enable or disable standard auditing for the entire database. If it is disabled, then no audit records are created. Configuring audit options is described in the previous section, "Who Can Perform Standard Auditing?"

When auditing is enabled in the database and an action configured to be audited occurs, Oracle Database generates an audit record during or after the execution phase of the SQL statement. Oracle Database individually audits SQL statements inside PL/SQL program units, as necessary, when the program unit is run.

The generation and insertion of an audit trail record is independent of a user transaction being committed. That is, even if a user transaction is rolled back, the audit trail record remains committed.

Statement and privilege audit options in effect at the time a database user connects to the database remain in effect for the duration of the session. When the session is already active, setting or changing statement or privilege audit options does not take effect in that session. The modified statement or privilege audit options take effect only when the current session ends and a new session is created.

In contrast, changes to schema object audit options become immediately effective for current sessions.

See Also: *Oracle Database Concepts* for information about the different phases of SQL statement processing and shared SQL

Configuring Standard Auditing with the AUDIT_TRAIL Initialization Parameter

This section contains:

- Enabling or Disabling the Standard Audit Trail
- Settings for the AUDIT_TRAIL Initialization Parameter

Enabling or Disabling the Standard Audit Trail

You enable the standard audit trail by setting the AUDIT_TRAIL initialization parameter. This setting determines whether to create the audit trail in the database audit trail, write the audit activities to an operating system file, or to disable auditing.

To enable or disable the standard audit trail, log in to SQL*Plus with administrative privileges, and use the ALTER SYSTEM statement. Afterwards, you need to restart the database instance.

To check the current value of the AUDIT_TRAIL parameter, use the SHOW PARAMETER command in SQL*Plus.

Example 9–1 shows how to check the AUDIT_TRAIL parameter setting.

Example 9–1 Checking the Current Value of the AUDIT_TRAIL Initialization Parameter

```
SHOW PARAMETER AUDIT_TRAIL

NAME                                 TYPE        VALUE
------------------------------------ ----------- -------
audit_trail                          string      DB
```

Example 9–2 shows how to log onto SQL*Plus, enable the standard audit trail, and then restart the database instance.

Example 9–2 Enabling the Standard Audit Trail

```
CONNECT SYSTEM
Enter password: password

ALTER SYSTEM SET AUDIT_TRAIL=DB SCOPE=SPFILE;
System altered.

CONNECT SYS/AS SYSOPER
Enter password: password

SHUTDOWN
Database closed.
Database dismounted.
ORACLE instance shut down.

STARTUP
ORACLE instance started.
```

This example uses the `SCOPE` clause because the database instance had been started using a server parameter file (`SPFILE`). Starting the database with a server parameter file is the preferred way of starting a database instance. See *Oracle Database Administrator's Guide* for information about creating configuring server parameter files.

Settings for the AUDIT_TRAIL Initialization Parameter

Table 9–1 lists the settings you can use for the `AUDIT_TRAIL` initialization parameter.

Table 9–1 AUDIT_TRAIL Initialization Parameter Settings

AUDIT_TRAIL Value	Description
DB	Directs audit records to the database audit trail (the SYS.AUD$ table), except for mandatory and SYS audit records, which are always written to the operating system audit trail. ("Selecting an Auditing Type" on page 9-5 describes the location of the audit records for each type of auditing.) Use this setting for a general database for manageability. DB is the default setting for the AUDIT_TRAIL parameter. If the database was started in read-only mode with AUDIT_TRAIL set to DB, then Oracle Database internally sets AUDIT_TRAIL to OS. Check the alert log for details. See also "Managing the Database Audit Trail" on page 9-58.

DB,EXTENDED	Behaves the same as AUDIT_TRAIL=DB, but also populates the SQL bind and SQL text CLOB-type columns of the SYS.AUD$ table, when available.
	
	DB,EXTENDED enables you to capture the SQL statement used in the action that was audited. You can capture both the SQL statement that caused the audit, and any associated bind variables. However, be aware that you only can capture data from the following column datatypes: CHAR, NCHAR, VARCHAR, VARCHAR2, NVARCHAR2, NUMBER, FLOAT, BINARY_FLOAT, BINARY_DOUBLE, LONG, ROWID, DATE, TIMESTAMP, and TIMESTAMP WITH TIMEZONE. Also be aware that DB, EXTENDED can capture sensitive data, such as credit card information. See also "Auditing Sensitive Information" on page 10-18.
	
	If the database was started in read-only mode with AUDIT_TRAIL set to DB, EXTENDED, then Oracle Database internally sets AUDIT_TRAIL to OS. Check the alert log for details.
	
	You can specify DB,EXTENDED in any of the following ways:
	
	`ALTER SYSTEM SET AUDIT_TRAIL=DB,EXTENDED SCOPE=SPFILE;`
	`ALTER SYSTEM SET AUDIT_TRAIL=DB, EXTENDED SCOPE=SPFILE;`
	`ALTER SYSTEM SET AUDIT_TRAIL='DB','EXTENDED' SCOPE=SPFILE;`
	`ALTER SYSTEM SET AUDIT_TRAIL=EXTENDED,DB SCOPE=SPFILE;`
	`ALTER SYSTEM SET AUDIT_TRAIL=EXTENDED, DB SCOPE=SPFILE;`
	
	However, do not enclose DB, EXTENDED in quotes, for example:
	
	`ALTER SYSTEM SET AUDIT_TRAIL='DB, EXTENDED' SCOPE=SPFILE;`
	
	In previous releases, the setting was DB_EXTENDED. This setting has been retained for backward compatibility but may not be available in future releases.

OS	Directs all audit records to an operating system file. Oracle recommends that you use the OS setting, particularly if you are using an ultra-secure database configuration. See "Advantages of the Operating System Audit Trail" on page 9-16 for more information. See also Example 9–3, "Text File Operating System Audit Trail" on page 9-13. If you set AUDIT_TRAIL to OS, then set the following additional initialization parameters: ■ AUDIT_FILE_DEST, which specifies the location of the operating system audit record file. On UNIX systems, the default location is $ORACLE_BASE/admin/$ORACLE_SID/adump. For better performance on UNIX systems, set the AUDIT_FILE_DEST parameter to a directory on a disk that is locally attached to the host running the Oracle Database instance. On Windows, the OS setting writes the audit trail to the Application area of the Windows Event Viewer. ■ AUDIT_SYS_OPERATIONS, if you want to audit the top-level SQL statements directly issued by users who have connected with the SYSDBA or SYSOPER privilege. To enable this auditing, set AUDIT_SYS_OPERATIONS to TRUE. If you set AUDIT_SYS_OPERATIONS to TRUE and AUDIT_TRAIL to XML or XML,EXTENDED, then Oracle Database writes SYS audit records operating system files in XML format. ■ AUDIT_SYSLOG_LEVEL, which writes SYS and standard OS audit records to the system audit log using the SYSLOG utility. This option only applies to UNIX environments. See "Configuring Syslog Auditing" on page 9-19 for more information. See also "Managing the Operating System Audit Trail" on page 9-62.

Table 9–1 (Cont.) AUDIT_TRAIL Initialization Parameter Settings

AUDIT_TRAIL Value	Description
XML	Writes to the operating system audit record file in XML format. Records all elements of the AuditRecord node given by the XML schema in http://xmlns.oracle.com/oracleas/schema/dbserver_audittrail-11_2.xsd except Sql_Text and Sql_Bind to operating system XML audit files. (This .xsd file represents the schema definition of the XML audit file. An XML schema is a document written in the XML Schema language.) See also "Advantages of the Operating System Audit Trail" on page 9-16 and Example 9–4, "XML File Operating System Audit Trail" on page 9-15. If you set the XML value, then also set the AUDIT_FILE_DEST parameter. For all platforms, including Windows, the default location for XML audit trail records is $ORACLE_BASE/admin/$ORACLE_SID/adump. The XML AUDIT_TRAIL value does not affect syslog audit file. In other words, if you have set the AUDIT_TRAIL parameter to XML, then the syslog audit records will still be in text format, not XML file format. You can control the output for SYS and mandatory audit records as follows: ■ **To write SYS and mandatory audit files to operating system files in XML format:** Set AUDIT_TRAIL to XML or XML,EXTENDED, set AUDIT_SYS_OPERATIONS to TRUE, but do not set the AUDIT_SYSLOG_LEVEL parameter. ■ **To write SYS and mandatory audit records to syslog audit files and standard audit records to XML audit files:** Set AUDIT_TRAIL to XML or XML,EXTENDED, set AUDIT_SYS_OPERATIONS to TRUE, and set the AUDIT_SYSLOG_LEVEL parameter.

XML, EXTENDED	Behaves the same as AUDIT_TRAIL=XML, but also includes SQL text and SQL bind information in the operating system XML audit files.
	
	You can specify XML,EXTENDED in either of the following ways:
	`ALTER SYSTEM SET AUDIT_TRAIL=XML, EXTENDED SCOPE=SPFILE;`
	`ALTER SYSTEM SET AUDIT_TRAIL='XML','EXTENDED' SCOPE=SPFILE;`
	
	However, do not enclose XML, EXTENDED in quotes, for example:
	`ALTER SYSTEM SET AUDIT_TRAIL='XML, EXTENDED' SCOPE=SPFILE;`
	
	See also the following sections:
	■ "Advantages of the Operating System Audit Trail" on page 9-16
	■ "Auditing Sensitive Information" on page 10-18

NONE	Disables standard auditing.

Note the following:

- **You do not need to restart the database after you run the AUDIT or NOAUDIT statements.** You only need to restart the database if you made a universal change, such as changing the AUDIT_TRAIL initialization parameter.
- **You do not need to set AUDIT_TRAIL to enable either fine-grained auditing or SYS auditing.** For fine-grained auditing, you add and remove fine-grained audit policies as necessary, applying them to the specific operations or objects you want to monitor. To enable SYS auditing, set the AUDIT_SYS_OPERATIONS parameter to TRUE.

What Do the Operating System and Database Audit Trails Have in Common?

The operating system and database audit trails both capture many of the same types of actions. Table 9–2 lists the operating system audit trail records. Most map to equivalent columns in the DBA_AUDIT_TRAIL view. For a description of these columns, see *Oracle Database Reference*.

Table 9–2 Common Audited Actions in the Operating System and Database Audit Trails

Operating System Audit Record	Equivalent DBA_AUDIT_TRAIL View Column
SESSIONID	SESSIONID
ENTRYID	ENTRYID
STATEMENT	STATEMENTID
USERID	USERNAME
USERHOST	USERHOST
TERMINAL	TERMINAL
ACTION	ACTION
SYS$OPTIONS	Indicates what audit option was set with AUDIT or NOAUDIT, or what privilege was granted or revoked.[1]
RETURNCODE	RETURNCODE
OBJ$CREATOR	OWNER
OBJ$NAME	OBJ_NAME
OBJ$PRIVILEGES	OBJ_PRIVILEGE
AUTH$GRANTEE	GRANTEE
NEW$OWNER	NEW_OWNER
NEW$NAME	NEW_NAME
SES$ACTIONS	SES_ACTIONS
LOGOFF$PREAD	LOGOFF_PREAD
LOGOFF$LWRITE	LOGOFF_LWRITE
COMMENT$TEXT	COMMENT_TEXT
OS$USERID	OS_USERNAME
PRIV$USED	PRIV_USED
SES$LABEL	CLIENT_ID
SES$TID	Does not have an equivalent in the DBA_AUDIT_TRAIL view, but it does appear in the SYS.AUD$ table
SPARE2	Does not have an equivalent in the DBA_AUDIT_TRAIL view, but it does appear in the SYS.AUD$ table

[1] For example, if the ACTION value is 104 (for AUDIT) or 105 (for NOAUDIT), then the SYS$OPTIONS number represents an audit option listed in the STMT_AUDIT_OPTION_MAP table. If the ACTION value is 108 (for GRANT) or 109 (for REVOKE), then the number represents a privilege listed in the SYSTEM_PRIVILEGE_MAP table.

Using the Operating System Audit Trail

This section contains:

- About the Operating System Trail
- What Do Operating System Audit Trail Records Look Like?
- Advantages of the Operating System Audit Trail
- How the Operating System Audit Trail Works
- Specifying a Directory for the Operating System Audit Trail

About the Operating System Trail

As an alternative to creating standard audit records in the DBA_AUDIT_TRAIL (SYS.AUD$ table), you can create standard audit records in operating system files. The operating system file that contains the audit trail can include any of the following data:

- Database audit trail records
- Mandatory audit records (that is, database actions that are always audited)
- Audit records for administrative users (SYS)

You can write the operating system audit records to either a text file or an XML file.

What Do Operating System Audit Trail Records Look Like?

The operating system audit trail files are in either text or XML file format. Be aware that the contents of the text and XML operating system files have some differences, and that the formats may change across different releases. With each release of Oracle Database, new enhancements, such as the audit type, have been made to the XML file, but not the text file. The text operating system file has a different presentation for the timestamp, for example:

```
Wed May  6 00:57:36 2009 -07:00
```

However, this timestamp does not appear in the event log or syslog, which have their own format for timestamps. The timestamp string only appears in the text operating system audit files.

Example 9–3 shows a typical text operating system audit trail for a logon operation on an Oracle database that is installed on Microsoft Windows. (The text in the actual record wraps around, but for this manual, each item is separated onto its own line for easier readability.)

Example 9–3 Text File Operating System Audit Trail

```
Audit trail:
LENGTH: "349"
SESSIONID:[5] "43464"
ENTRYID:[1] "1"
STATEMENT:[1] "1"
USERID:[6] "DBSNMP"
USERHOST:[7] "SHOBEEN"
TERMINAL:[3] "MAU"
ACTION:[3] "100"
RETURNCODE:[1] "0"
COMMENT$TEXT:[97] "Authenticated by: DATABASE; Client address:
(ADDRESS=(PROTOCOL=tcp)(HOST=192.0.2.4)(PORT=2955))"
OS$USERID:[19] "NT AUTHORITY\SYSTEM"
DBID:[10] "1212547373"
PRIV$USED:[1] "5"
```

In this example:

- LENGTH refers to the total number of bytes used in this audit record. This number includes the trailing newline bytes (\n), if any, at the end of the audit record.
- [] brackets indicate the length of each value for each audit entry. For example, the USERID entry, DBSNMP, is 6 bytes long.
- SESSIONID indicates the audit session ID number. You can also find the session ID by querying the AUDSID column in the V$SESSION data dictionary view.

- ENTRYID indicates the current audit entry number, assigned to each audit trail record. The audit ENTRYID sequence number is shared between fine-grained audit records and regular audit records.
- STATEMENT is a numeric ID assigned to the statement the user runs. It appears for each statement issued during the user session, because a statement can result in multiple audit records.
- ACTION is a numeric value representing the action the user performed. The corresponding name of the action type is in the AUDIT_ACTIONS table. For example, action 100 refers to LOGON.
- RETURNCODE indicates if the audited action was successful. 0 indicates success. If the action fails, the return code lists the Oracle Database error number. For example, if you try to drop a non-existent table, the error number is ORA-00903 invalid table name, which in turn translates to 903 in the RETURNCODE setting.
- COMMENT$TEXT indicates additional comments about the audit record. For example, for LOGON audit records, it can indicate the authentication method.It corresponds to the COMENT_TEXT column of the DBA_COMMON_AUDIT_TRAIL data dictionary view.
- DBID is a database identifier calculated when the database is created. It corresponds to the DBID column of the V$DATABASE data dictionary view.
- ECONTEXT_ID indicates the application execution context identifier.
- PRIVS$USED refers to the privilege that was used to perform an action. To find the privilege, query the SYSTEM_PRIVILEGE_MAP table. For example, privilege 5 refers to -5 in this table, which means CREATE SESSION. PRIVS$USED corresponds to the PRIV_USED column in the DBA_COMMON_AUDIT_TRAIL, which lists the privilege by name.

Other possible values are as follows:

- SCN (for example, SCN:8934328925) indicates the System Change Number (SCN). Use this value if you want to perform a flashback query to find the value of a setting (for example, a column) at a time in the past. For example, to find the value of the ORDER_TOTAL column of the OE.ORDERS table based on the SCN number, use the following SELECT statement:

```
SELECT ORDER_TOTAL
FROM OE.ORDERS
AS OF SCN = 8934328925
WHERE ORDER_TOTAL = 86;
```

- SES_ACTIONS indicates the actions that took place during the session. This field is present only if the event was audited with the BY SESSION clause. Because this field does not explain in detail the actions that occurred during the session, you should configure the audit event with the BY ACCESS clause.

  The SES_ACTIONS field contains 16 characters. Positions 14, 15, and 16 are reserved for future use. In the first 12 characters, each position indicates the result of an action. They are: ALTER, AUDIT, COMMENT, DELETE, GRANT, INDEX, INSERT, LOCK, RENAME, SELECT, UPDATE, and FLASHBACK. For example, if the user had successfully run the ALTER statement, the SES_ACTIONS setting is as follows:

  ```
  S---------------
  ```

  The S, in the first position (for ALTER), indicates success. Had the ALTER statement failed, the letter F would have appeared in its place. If the action resulted in both a success and failure, then the letter is B.

- SES$TID indicates the ID of the object affected by the audited action.
- SPARE2 indicates whether the user modified SYS.AUD$ table. 0 means the user modified SYS.AUD$; otherwise, the value is NULL.

Similarly, Example 9–4 shows how an XML audit trail record appears. The text wraps around in the actual record, but for this manual, each element appears on its own line for easier readability. To find all the tags that appear in the XML audit file, you can view its schema in a Web browser at

http://www.oracle.com/technology/oracleas/schema/dbserver_audittrail-11_2.xsd

Example 9–4 XML File Operating System Audit Trail

```
<?xml version="1.0" encoding="UTF-8"?>
  <Audit xmlns="http://xmlns.oracle.com/oracleas/schema/dbserver_audittrail-11_
2.xsd"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://xmlns.oracle.com/oracleas/schema/dbserver_
audittrail-11_2.xsd">
   <Version>11.2</Version>
   <AuditRecord>
     <Audit_Type>1</Audit_Type>
       <Session_Id>43535</Session_Id>
       <StatementId>1</StatementId>
       <EntryId>1</EntryId>
       <Extended_Timestamp>2009-04-29T18:32:26.062000Z</Extended_Timestamp>
       <DB_User>SYSMAN</DB_User>
       <OS_User>SYSTEM</OS_User>
       <Userhost>shobeen</Userhost>
       <OS_Process>3164:3648</OS_Process>
       <Terminal>mau</Terminal>
       <Instance_Number>0</Instance_Number>
       <Action>100</Action>
       <TransactionId>0000000000000000</TransactionId>
       <Returncode>0</Returncode>
       <Comment_Text>Authenticated by: DATABASE; Client address:
(ADDRESS=(PROTOCOL=tcp)(HOST=192.0.2.4)(PORT=3536))</Comment_Text>
       <Priv_Used>5</Priv_Used>
</AuditRecord>
</Audit>
```

In this example:

- AuditRecord element contains the entire audit record. (See Example 9–3 for more information about the elements within the Audit_Record element.)
- Audit_Type indicates the type of audit trail. Possible values are as follows:
  - 1: Standard audit record
  - 2: Fine-grained audit record
  - 4: SYS audit record
  - 8: Mandatory audit record

  This field only appears in the XML audit files, not the OS text audit files.
- Extended_Timestamp indicates the time of the audited operation (timestamp of user login for entries created by AUDIT SESSION), in Coordinated Universal Time

(UTC) or Greenwich Mean Time (GMT). This field only appears in the XML audit files, not the OS text audit files.

- `Instance_Number` indicates the instance number to which the user is connected, for an Oracle Real Application Clusters environment. In this example, the number is `0`, which is used for single-instance database installations. The `INSTANCE_NUMBER` initialization parameter specifies this number.

The following values can appear if you set the `AUDIT_TRAIL` parameter to `XML, EXTENDED`. Both are listed in the `DBA_COMMON_AUDIT_TRAIL` data dictionary view.

- `Sql_Bind` (for example, `<Sql_Bind>#1(5):89</Sql_Bind>`) shows the value of the bind variable. The syntax is as follows:

  VariablePosition`(`*LengthOfVariableValue*`):`*ValueofBindVariable*

  The example `#1(5):89` indicates that there is 1 bind variable; its value is 5 characters long; and the value of the bind variable is `89`.

- `Sql_Text` (for example, `<Sql_Text>begin procedure_one(:num); end; </Sql_Text>`) appears if you have set the `AUDIT_TRAIL` parameter to `XML, EXTENDED`. It shows the SQL text that the user entered.

Advantages of the Operating System Audit Trail

Using the operating system audit trail offers these advantages:

- It reduces the likelihood of a denial-of-service (DoS) attack.
- It makes it easier to secure the audit trail. If the auditor is distinct from the database administrator, then you *must* use the `OS`, `XML`, or `XML, EXTENDED` setting. Otherwise, a database administrator can view and modify any auditing information that is stored in the database.
- Because you are writing the audit trail to a specific location that you can restrict to specific users, the operating system audit trail enforces separation of duty concepts.
- Writing the audit trail to an operating system file results in the least amount of overhead on the database. For this reason, it is excellent for very large databases.
- Audit records stored in operating system files can be more secure than database-stored audit records because access can require file permissions that database administrators do not have. Greater availability is another advantage to operating system storage for audit records, because they remain available even if the database is temporarily inaccessible.
- If the `AUDIT_TRAIL` initialization parameter is set to `XML` (or `XML, EXTENDED`), then Oracle Database writes audit records to the operating system as XML files. You can use the `V$XML_AUDIT_TRAIL` view to make XML audit records available to database administrators through a SQL query, providing enhanced usability.
- The `DBA_COMMON_AUDIT_TRAIL` view includes the standard and fine grained audit trails written to database tables, XML-format audit trail records, and the contents of the `V$XML_AUDIT_TRAIL` dynamic view (standard, fine grained, `SYS` and mandatory).
- Using your operating system audit trail can enable you to consolidate audit records from multiple sources, including Oracle Database and other applications. Examining system activity can be more efficient with all audit records in one place. If you use XML audit records, then you can use of any standard XML editing tool to review or extract information from those records.

How the Operating System Audit Trail Works

The operating system audit trail writes the audit data to an operating system file. You can enable this feature by setting the AUDIT_TRAIL initialization parameter to one of the following values:

- OS: Writes the audit trail records to a text operating system file on UNIX systems and to the applications Event Viewer on Microsoft Windows.
- XML: Writes the audit trail records to an XML file.
- XML, EXTENDED: Writes the audit trail records to an XML file and includes SQL text and SQL bind information in the operating system XML audit files.

The AUDIT_FILE_DEST initialization parameter sets the location of the operating system audit file. If you want to audit top-level statements issued by users who log in to the database with the SYSDBA or SYSOPER privilege, then set the AUDIT_SYS_OPERATIONS parameter to TRUE. See Table 9–1, " AUDIT_TRAIL Initialization Parameter Settings" on page 9-10 for more information about these settings.

The records that are written to an operating system file are not recorded to the SYS.AUD$ and SYS.FGA_LOG$ tables. You can still view the contents of the XML operating system audit files by querying the DBA_COMMON_AUDIT_TRAIL data dictionary views. Querying this view parses all XML files (all files with an .xml extension) in the AUDIT_FILE_DEST directory, and then presents them in relational table format. Because XML is a standard document format, many utilities are available to parse and analyze XML data. Consult the operating system-specific Oracle Database documentation to find if this feature has been implemented on your operating system.

Specifying a Directory for the Operating System Audit Trail

Use the AUDIT_FILE_DEST initialization parameter to specify an operating system directory into which the audit trail is written, when the AUDIT_TRAIL initialization parameter is set to OS, XML, or XML, EXTENDED. You must set AUDIT_FILE_DEST to a valid directory with permissions restricted to the owner of the Oracle software and the DBA group. Mandatory auditing information also goes into that directory, as do audit records for user SYS if the AUDIT_SYS_OPERATIONS initialization parameter is specified. You can change the AUDIT_FILE_DEST parameter by using the following ALTER SYSTEM statement, which enables the new destination to be effective for all subsequent sessions.

```
ALTER SYSTEM SET AUDIT_FILE_DEST = directory_path DEFERRED;
```

To find the current setting of the AUDIT_FILE_DEST parameter, issue the following command:

```
SHOW PARAMETER AUDIT_FILE_DEST
```

The location of the operating system files depends on the following:

- If the database is not running and you have not set the AUDIT_FILE_DEST parameter, then the operating system files are placed in the first default location $ORACLE_BASE/admin/$ORACLE_SID/adump directory.
- If the database is not running and the first default location, the $ORACLE_BASE/admin/$ORACLE_SID/adump directory, is inaccessible or cannot be written to, or the Oracle process cannot identify the environment variables, then the second default location, $ORACLE_HOME/rdbms/audit is used.
- When the database is open and Oracle Database reads the initialization file (init*SID*.ora) for the database instance, the value of AUDIT_FILE_DEST parameter is used as the operating system audit file directory.

- For UNIX and Solaris systems, all operating system files are written to a directory in the operating system. For Windows, the operating system text records are available from the Windows Event Viewer, but operating system XML files are available from an operating system directory, as explained in the preceding bulleted items.

Notes: For platforms other than UNIX, Solaris, and Windows, check the platform documentation to learn the correct target directory for operating system files.

Using the Syslog Audit Trail on UNIX Systems

On UNIX systems, you can audit the activities of users, including privileged users, and record these activities in a syslog file by creating a syslog audit trail.

This section contains:

About the Syslog Audit Trail

You can use a syslog audit trail to configure centralized audit facility provided by the operating system Syslog facility. Syslog is a standard protocol on UNIX-based systems for logging information from different components of a network. Applications call the `syslog()` function to log information to the syslog daemon, which then determines where to log the information. Be aware that when you configure the use of syslog files, the messages are sent to the syslog daemon process. The syslog daemon process does not return an acknowledgement to Oracle Database indicating a committed write to the syslog files.

Because applications, such as an Oracle process, use the `syslog()` function to log information to the syslog daemon, a privileged user would not have permissions to the file system where syslog messages are logged. For this reason, audit records stored using a syslog audit trail can be more secure than audit records stored using an operating system audit trail. In addition to restricting permissions to a file system for a privileged user, for a syslog audit trail to be secure, neither privileged users nor the Oracle process should have `root` access to the system where the audit records are written.

Caution: You should have a strong understanding of how to work with `syslog` before enabling `syslog` auditing. See the following references for more information about syslog:

- *Oracle Database Reference* for information about the `AUDIT_SYSLOG_LEVEL` initialization parameter
- The UNIX man page for the `syslogd` utility for more information about the *`facility.priority`* settings and their directory paths

Format of the Information Stored in the Syslog Audit Trail

Similar to the operating system audit trail records, Oracle Database encodes the syslog records to ensure greater security. If you have Oracle Audit Vault installed, you can use its Syslog Collector to extract and transfer syslog audit records to centralized Oracle Audit Vault server.

What Does the Syslog Audit Trail Look Like?

Example 9–5 shows how the syslog audit trail can appear. (For this example, the text has been reformatted for easier readability. In reality, the text is all on one line.) As with other Oracle Database audit trails, the brackets indicate the length of the value that was audited. For syslog audit trails, the text from (and including) `LENGTH:` is Oracle Database audit record. The prepended text (the date and `Oracle Audit [10085]` line) is added by the syslog utility.

Example 9–5 Syslog Audit Trail for SYS User

```
May 14 23:40:15 shobeen
Oracle Audit[10085]:
LENGTH : '171'
ACTION :[18] 'select * from aud$'
DATABASE USER:[1] '/'
PRIVILEGE :[6] 'SYSDBA'
CLIENT USER:[7] 'laurelh'
CLIENT TERMINAL:[6] 'pts/12'
STATUS:[1] '0'
DBID:[9] '562317007'
```

Configuring Syslog Auditing

To enable syslog auditing, follow these steps:

1. Assign the value of `OS` to the `AUDIT_TRAIL` initialization parameter, as described in "Enabling or Disabling the Standard Audit Trail" on page 9-8.

   For example:

   ```
   ALTER SYSTEM SET AUDIT_TRAIL=OS SCOPE=SPFILE;
   ```

2. Manually set the `AUDIT_SYSLOG_LEVEL` parameter to the initialization parameter file, `init`*`sid`*`.ora`.

   Set the `AUDIT_SYSLOG_LEVEL` parameter to specify a facility and priority in the format `AUDIT_SYSLOG_LEVEL=`*`facility.priority`*.

   - *`facility`*: Describes the part of the operating system that is logging the message. Accepted values are `user`, `local0`–`local7`, `syslog`, `daemon`, `kern`, `mail`, `auth`, `lpr`, `news`, `uucp`, and `cron`.

     The `local0`–`local7` values are predefined tags that enable you to sort the syslog message into categories. These categories can be log files or other destinations that the syslog utility can access. To find more information about these types of tags, refer to the `syslog` utility `MAN` page.

   - *`priority`*: Defines the severity of the message. Accepted values are `notice`, `info`, `debug`, `warning`, `err`, `crit`, `alert`, and `emerg`.

   The syslog daemon compares the value assigned to the facility argument of the `AUDIT_SYSLOG_LEVEL` parameter with the `syslog.conf` file to determine where to log information.

For example, the following statement identifies the facility as `local1` with a priority level of `warning`:

```
AUDIT_SYSLOG_LEVEL=local1.warning
```

See *Oracle Database Reference* for more information about `AUDIT_SYSLOG_LEVEL`.

3. Log in to the computer that contains the syslog configuration file, `/etc/syslog.conf`, with the superuser (root) privilege.
4. Add the audit file destination to the `syslog` configuration file `syslog.conf`.

   For example, assuming you had set the `AUDIT_SYSLOG_LEVEL` to `local1.warning`, enter the following:

   ```
   local1.warning /var/log/audit.log
   ```

   This setting logs all warning messages to the `/var/log/audit.log` file.
5. Restart the syslog logger:

   ```
   $/etc/rc.d/init.d/syslog restart
   ```

   Now, all audit records will be captured in the file `/var/log/audit.log` through the syslog daemon.
6. Restart the database instance:

   ```
   CONNECT SYS / AS SYSOPER
   Enter password: password

   SHUTDOWN IMMEDIATE
   STARTUP
   ```

How the AUDIT and NOAUDIT SQL Statements Work

This section contains:

- Enabling Standard Auditing with the AUDIT SQL Statement
- Auditing Statement Executions: Successful, Unsuccessful, or Both
- How Standard Audit Records Are Generated
- How Do Cursors Affect Standard Auditing?
- Benefits of Using the BY ACCESS Clause in the AUDIT Statement
- Auditing Actions Performed by Specific Users
- Removing the Audit Option with the NOAUDIT SQL Statement

> **See Also:** *Oracle Database SQL Language Reference* for a description of the `AUDIT` statement syntax

Enabling Standard Auditing with the AUDIT SQL Statement

To configure the standard auditing option, use the `AUDIT` SQL statement.

Table 9–3 lists the categories in which you can use the `AUDIT` statement.

Table 9–3 Standard Auditing Levels and Their Effects

Level	Effect
Statement	Audits specific SQL statements or groups of statements that affect a particular type of database object. For example, `AUDIT TABLE` audits the `CREATE TABLE`, `TRUNCATE TABLE`, `COMMENT ON TABLE`, and `DELETE [FROM] TABLE` statements.
Privilege	Audits SQL statements that are authorized by the specified system privilege. For example, `AUDIT CREATE ANY TRIGGER` audits statements issued using the `CREATE ANY TRIGGER` system privilege.
Object	Audits specific statements on specific objects, such as `ALTER TABLE` on the `HR.EMPLOYEES` table.
Network	Audits unexpected errors in network protocol or internal errors in the network layer.

Auditing Statement Executions: Successful, Unsuccessful, or Both

For statement, privilege, and schema object auditing, Oracle Database permits the selective auditing of successful executions of statements, unsuccessful attempts to execute statements, or both. This enables you to monitor actions even if the audited statements do not complete successfully. Monitoring unsuccessful SQL statement can expose users who are snooping or acting maliciously, though most unsuccessful SQL statements are neither.

This method of auditing is also useful in that it reduces the audit trail, helping you to focus on specific actions. This can aid in maintaining good database performance.

The options are as follows:

- **WHENEVER SUCCESSFUL clause:** This clause audits only successful executions of the audited statement.
- **WHENEVER NOT SUCCESSFUL clause:** This clause audits only unsuccessful executions of the audited statement.

  Auditing an unsuccessful statement execution generates an audit report only if a valid SQL statement is issued but fails, because it lacks proper authorization or references a nonexistent schema object. Statements that fail to execute because they were not valid cannot be audited.

  For example, an enabled privilege auditing option set to audit unsuccessful statement executions audits statements that use the target system privilege but failed for other reasons. One example is when a `CREATE TABLE` auditing condition is set, but some `CREATE TABLE` statements fail due to insufficient quota for the specified tablespace.
- **Omitting WHENEVER SUCCESSFUL or WHENEVER NOT SUCCESSFUL:** If you omit these clauses, then Oracle Database audits both successful and unsuccessful executions of the audited statement.

For example:

```
AUDIT CREATE TABLE BY ACCESS WHENEVER NOT SUCCESSFUL;
```

How Standard Audit Records Are Generated

Oracle Database generates an audit record for each execution of an audited statement or operation, as follows:

- Each time the SQL statement for which auditing was configured is executed. This also includes the execution of the statements within PL/SQL procedures.
- Each time the privilege for which auditing was configured is used
- Each time the object for which auditing was configured is operated upon

How Do Cursors Affect Standard Auditing?

For each execution of an auditable operation within a cursor, Oracle Database inserts one audit record into the audit trail. Events that cause cursors to be reused include the following:

- An application, such as Oracle Forms, holding a cursor open for reuse
- Subsequent execution of a cursor using new bind variables
- Statements executed within PL/SQL loops where the PL/SQL engine optimizes the statements to reuse a single cursor

Auditing is *not* affected by whether or not a cursor is shared. Each user creates her or his own audit trail records on first execution of the cursor.

Benefits of Using the BY ACCESS Clause in the AUDIT Statement

By default, Oracle Database writes a new audit record for every audited event, using the `BY ACCESS` clause functionality. To use this functionality, either include `BY ACCESS` in the `AUDIT` statement, or if you want, you can omit it because it is the default. (As of Oracle Database 11*g* Release 2 (11.2.0.2), the `BY ACCESS` clause is the default setting.)

Oracle recommends that you audit `BY ACCESS` and not `BY SESSION` in your `AUDIT` statements. The benefits of using the `BY ACCESS` clause in the `AUDIT` statement are as follows:

- The audit records generated through the `BY ACCESS` audit option have more information, such as execution status (return code), date and time of execution, the privileges used, the objects accessed, the SQL text itself and its bind values. In addition, the `BY ACCESS` audit option captures the SCN for each execution and this can help flashback queries.
- Oracle Database records separately each execution of a SQL statement, the use of a privilege, and access to the audited object. Given that the values for the return code, timestamp, SQL text recorded are accurate for each execution, this can help you find how many times the action was performed.
- The `BY ACCESS` audit records have separate `LOGON` and `LOGOFF` entries, each with fine-grained timestamps.

For example:

```
AUDIT SELECT TABLE BY ACCESS;
```

In this scenario:

- The user `jward` connects to the database and issues five `SELECT` statements against the table named `departments` and then disconnects from the database.
- The user `swilliams` connects to the database and issues three `SELECT` statements against the `departments` table and then disconnects from the database.

The audit trail contains eight records, one recorded for each `SELECT` statement.

Auditing Actions Performed by Specific Users

Statement and privilege audit options can audit statements issued by any user or statements issued by a specific list of users. By focusing on specific users, you can minimize the number of audit records generated.

Example 9–6 shows how to audit statements by users `scott` and `blake` when they query or update a table or view.

Example 9–6 Using AUDIT to Audit User Actions

```
AUDIT SELECT TABLE, UPDATE TABLE BY scott, blake BY ACCESS;
```

See *Oracle Database SQL Language Reference* for additional information about auditing by user.

Removing the Audit Option with the NOAUDIT SQL Statement

The `NOAUDIT` statement removes the audit option. Use it to reset statement and privilege audit options, and object audit options. A `NOAUDIT` statement that sets statement and privilege audit options can include the `BY` *`user`* clause to specify a list of users to limit the scope of the statement and privilege audit options.

You can use the `NOAUDIT` statement to disable an audit option selectively using the `WHENEVER` clause. If the clause is not specified, then the auditing option is disabled entirely, for both successful and unsuccessful cases.

The `NOAUDIT` statement does not support the `BY ACCESS` clause. You can remove audit options, no matter how they were turned on, by using an appropriate `NOAUDIT` statement.

> **See Also:** *Oracle Database SQL Language Reference* for a description of the `NOAUDIT` statement syntax

Auditing SQL Statements

This section contains:

- About SQL Statement Auditing
- Types of SQL Statements That Are Audited
- Configuring SQL Statement Auditing
- Removing SQL Statement Auditing

About SQL Statement Auditing

SQL statement auditing is the selective auditing of related groups of SQL statements regarding a particular type of database structure or schema object, but not a specifically named structure or schema object.

Types of SQL Statements That Are Audited

The statements that you can audit are in the following categories:

- **DDL statements.** For example, `AUDIT TABLE` audits all `CREATE` and `DROP TABLE` statements
- **DML statements.** For example, `AUDIT SELECT TABLE` audits all `SELECT ... FROM TABLE/VIEW` statements, regardless of the table or view

Statement auditing can be broad or focused, for example, by auditing the activities of all database users or of only a select list of activities.

Configuring SQL Statement Auditing

Use the AUDIT statement to configure SQL statement auditing. You must have the AUDIT SYSTEM system privilege before you can enable auditing. Typically, only the security administrator is granted this system privilege.

Example 9–7 shows how to audit the SELECT TABLE SQL statement.

Example 9–7 Using AUDIT to Enable SQL Statement Auditing

```
AUDIT SELECT TABLE BY ACCESS;
```

Example 9–8 shows how to audit all unsuccessful SELECT, INSERT, and DELETE statements on all tables by all database users, and by individual audited statement.

Example 9–8 Auditing Unsuccessful Statements

```
AUDIT SELECT TABLE, INSERT TABLE, DELETE TABLE
      BY ACCESS
      WHENEVER NOT SUCCESSFUL;
```

If you plan to audit all SQL statements, individual user connections, or references to non-existent objects, follow these guidelines:

- **Auditing all SQL statements for individual users.** You can use the ALL STATEMENTS clause to audit *only* the top-level SQL statements. The behavior of this audit option is different from other statement audit options. If the SQL statement is issued from inside a PL/SQL procedure, then the ALL STATEMENTS audit option does not audit it. This audit option does not affect any other AUDIT options that you may have already set.

  For example, to audit all successful statements issued by users jward and jsmith, enter the following:

  ```
  AUDIT ALL STATEMENTS BY jward, jsmith BY ACCESS WHENEVER SUCCESSFUL;
  ```

- **Auditing all the SQL statement shortcut activities performed by individual users.** You can use the ALL clause to audit all the SQL statement shortcuts listed in Table 13-1 and Table 13-2 in *Oracle Database SQL Language Reference*.

  For example:

  ```
  AUDIT ALL BY jward BY ACCESS;
  ```

- **Auditing all SQL statements for the current session, regardless of user.** You can use the IN SESSION CURRENT clause for ALL STATEMENTS audit option to audit top-level SQL statements in the lifetime of the user session. You cannot use the IN SESSION CURRENT clause for a specific user. You cannot use the NOAUDIT statement to cancel it, but the auditing lasts only as long as the user session lasts. When the user ends the session, the auditing ends.

  For example, to audit all unsuccessful statements in any current user session:

  ```
  AUDIT ALL STATEMENTS IN SESSION CURRENT BY ACCESS WHENEVER NOT SUCCESSFUL;
  ```

  You can use the AUDIT ALL STATEMENTS audit option with the IN SESSION CURRENT clause in a database logon trigger. The database logon trigger can use SYS_CONTEXT function to configure this auditing only under certain conditions,

such as the time a user logs in between 6:30 p.m. to 9:00 a.m. This would enable you to capture SQL statements performed by users who log in to the database during non-work hours.

This type of auditing is useful to increase the collection of audit activity when you suspect this connection may not be secure or could pose an internal threat. For example, by using a database logon trigger, you can query contents of the connection context using the SYS_CONTEXT function.

The logon trigger functionality can establish that this connection should be audited more fully. Issue the following SQL command:

```
AUDIT ALL STATEMENTS IN SESSION CURRENT;
```

This type of auditing remains in effect until this session is terminated.

- **Auditing login and logoff connections and disconnections.** The AUDIT SESSION statement generates an independent audit record for every login and logoff event. This enables you to audit all successful and unsuccessful connections to and disconnections from the database, regardless of user.

  For example:

  ```
  AUDIT SESSION BY ACCESS;
  ```

  You can set this option selectively for individual users also, as in the following example:

  ```
  AUDIT SESSION BY jward, jsmith BY ACCESS;
  ```

- **Auditing statements that fail because an object does not exist.** The NOT EXISTS option of the AUDIT statement specifies auditing of all SQL statements that fail because the target object does not exist.

  For example:

  ```
  AUDIT NOT EXISTS;
  ```

See *Oracle Database SQL Language Reference* for detailed information about the AUDIT SQL statement.

Removing SQL Statement Auditing

To remove SQL statement auditing, use the use the NOAUDIT SQL statement. (Privilege auditing will still be enabled.) You must have the AUDIT SYSTEM system privilege before you can remove SQL statement auditing. If you have configured the AUDIT ALL STATEMENTS option, then issuing the NOAUDIT AUDIT STATEMENTS statement does not affect other audit options you may have set. If you included the IN SESSION CURRENT clause in the AUDIT statement, you cannot remove this AUDIT statement using the NOAUDIT statement. (The audit setting discontinues when the user's session ends.)

Example 9–9 shows examples of using the NOAUDIT statement to remove auditing.

Example 9–9 Using NOAUDIT to Remove Session and SQL Statement Auditing

```
NOAUDIT session;
NOAUDIT session BY preston, sebastian;
NOAUDIT SELECT TABLE, INSERT TABLE, DELETE TABLE, EXECUTE PROCEDURE;
```

Example 9–10 shows how to remove all statement auditing by using the NOAUDIT statement.

Example 9–10 Using NOAUDIT to Remove ALL STATEMENTS Auditing

```
NOAUDIT ALL STATEMENTS;
```

See *Oracle Database SQL Language Reference* for detailed information about the NOAUDIT statement.

Auditing Privileges

This section contains:

- About Privilege Auditing
- Types of Privileges That Can Be Audited
- Configuring Privilege Auditing
- Removing Privilege Auditing

About Privilege Auditing

Privilege auditing audits statements that use a system privilege, such as SELECT ANY TABLE. In this kind of auditing, SQL statements that require the audited privilege to succeed are recorded.

Types of Privileges That Can Be Audited

You can audit the use of any system privilege. Similar to statement auditing, privilege auditing audits the activities of all database users or only a specified list.

If you set similar audit options for both statement and privilege auditing, then only a single audit record is generated. For example, if the statement clause TABLE and the system privilege CREATE TABLE are both audited, then only a single audit record is generated each time a table is created.

Privilege auditing does not occur if the action is already permitted by the existing owner and object privileges. Privilege auditing is triggered only if the privileges are insufficient, that is, only if what makes the action possible is a system privilege. For example, suppose that user SCOTT has been granted the SELECT ANY TABLE privilege and the SELECT ANY TABLE is being audited. If SCOTT selects his own table (for example, SCOTT.EMP), then the SELECT ANY TABLE privilege is not used. Because he performed the SELECT statement within his own schema, no audit record is generated. On the other hand, if SCOTT selects from another schema (for example, the HR.EMPLOYEES table), then an audit record *is* generated. Because SCOTT selected a table outside his own schema, he needed to use the SELECT ANY TABLE privilege.

Privilege auditing is more focused than statement auditing, because each privilege auditing option audits only specific types of statements, not a related list of statements. For example, the statement auditing clause, TABLE, audits CREATE TABLE, ALTER TABLE, and DROP TABLE statements. However, the privilege auditing option, CREATE TABLE, audits only CREATE TABLE statements, because only the CREATE TABLE statement requires the CREATE TABLE privilege.

See the listing of system privileges in the GRANT SQL statement section of *Oracle Database SQL Language Reference*.

Configuring Privilege Auditing

Privilege audit options are the same as their corresponding system privileges. For example, the option to audit use of the DELETE ANY TABLE privilege is DELETE ANY TABLE.

Example 9–11 shows how to audit the DELETE ANY TABLE privilege.

Example 9–11 Using AUDIT to Configure Privilege Auditing

```
AUDIT DELETE ANY TABLE BY ACCESS;
```

To audit all successful and unsuccessful uses of the DELETE ANY TABLE system privilege, enter the following statement:

```
AUDIT DELETE ANY TABLE BY ACCESS;
```

Removing Privilege Auditing

The following statement removes all privilege audit options:

```
NOAUDIT ALL PRIVILEGES;
```

This example disables the audit settings from Example 9–11:

```
NOAUDIT DELETE ANY TABLE;
```

To disable privilege auditing options, you must have the AUDIT SYSTEM system privilege. Usually, only the security administrator is granted this system privilege.

Auditing SQL Statements and Privileges in a Multitier Environment

You can use the AUDIT statement to audit the activities of a client in a multitier environment. In a multitier environment, Oracle Database preserves the identity of a client through all tiers. Thus, you can audit actions taken on behalf of the client by a middle-tier application, by using the BY *user* clause in your AUDIT statement. The audit applies to all user sessions, including proxy sessions.

The middle tier can also set the user client identity in a database session, enabling the auditing of end-user actions through the middle-tier application. The end-user client identity then shows up in the audit trail.

Example 9–12 shows how to audit SELECT TABLE statements issued by the user jackson.

Example 9–12 Using AUDIT to Audit a SQL Statement for a User

```
AUDIT SELECT TABLE BY jackson;
```

You can audit user activity in a multitier environment. Once audited, you can verify these activities by querying the DBA_AUDIT_TRAIL data dictionary view.

Figure 9–1 illustrates how you can audit proxy users by querying the COMMENT_TEXT, PROXY_SESSIONID, ACTION_NAME, and SESSION_ID columns of the DBA_AUDIT_TRAIL view. In this scenario, both the database user and proxy user accounts are known to the database. Session pooling can be used.

Figure 9–1 Auditing Proxy Users

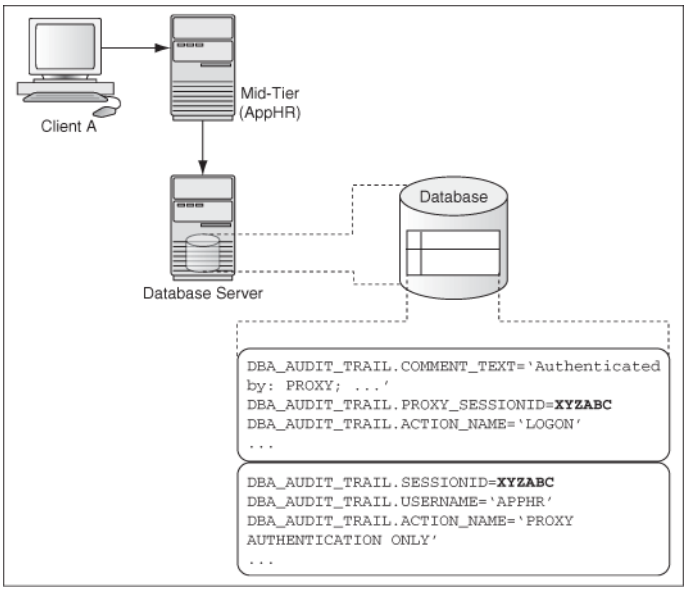
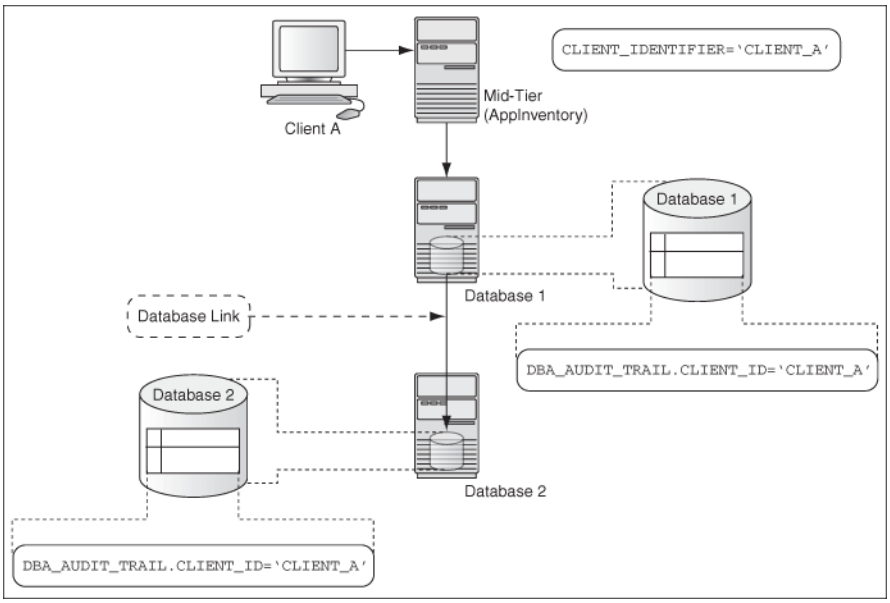


Figure 9–2 illustrates how you can audit client identifier information across multiple database sessions by querying the `CLIENT_ID` column of the `DBA_AUDIT_TRAIL` data dictionary view. In this scenario, the client identifier has been set to `CLIENT_A`. As with the proxy user-database user scenario described in Figure 9–1, session pooling can be used.

Figure 9–2 Auditing Client Identifier Information Across Sessions



See Also: "Preserving User Identity in Multitiered Environments" on page 3-36 for more information about user authentication in a multitiered environment

Auditing Schema Objects

This section contains:

About Schema Object Auditing

Schema object auditing monitors actions performed on the audited schema objects, such as tables or views. Object auditing applies to all users but is limited to the audited object only. Users can use the `AUDIT` and `NOAUDIT` statements on objects in their own schemas.

Types of Schema Objects That Can Be Audited

You can audit statements that refer to tables, views, sequences, standalone stored procedures or functions, and packages, but not individual procedures within packages. (See "Auditing Functions, Procedures, Packages, and Triggers" on page 9-32 for more information about auditing these types of objects.)

You cannot directly audit statements that reference clusters, database links, indexes, or synonyms. However, you can indirectly audit access to these schema objects, by auditing the operations that affect the base table.

When you audit a schema object, the auditing applies to all users of the database. You cannot set these options for a specific list of users. You can set default schema object audit options for all auditable schema objects.

> **See Also:** *Oracle Database SQL Language Reference* for information about auditable schema objects

Using Standard Auditing with Editioned Objects

When an editioned object has an audit policy, then it applies in all editions in which the object is visible. When an editioned object is actualized, any audit policies that are attached to it are newly attached to the new actual occurrence. When you newly apply an audit policy to an inherited editioned object, this action will actualize it.

You can find the editions in which audited objects appear by querying the `OBJECT_NAME` and `OBJ_EDITION_NAME` columns in the `DBA_COMMON_AUDIT_TRAIL` and `V$XML_AUDIT_TRAIL` data dictionary views.

> **See Also:** *Oracle Database Advanced Application Developer's Guide* for detailed information about editions

Schema Object Audit Options for Views, Procedures, and Other Elements

The definitions for views and procedures (including stored functions, packages, and triggers) reference underlying schema objects. Because of this dependency, some unique characteristics apply to auditing views and procedures, such as the likelihood of generating multiple audit records.

Views and procedures are subject to the enabled audit options on the base schema objects, including the default audit options. These options also apply to the resulting SQL statements.

Consider the following series of SQL statements:

```
AUDIT SELECT ON HR.EMPLOYEES BY ACCESS;

CREATE VIEW employees_departments AS
  SELECT employee_id, last_name, department_id
    FROM employees, departments
    WHERE employees.department_id = departments.department_id;

AUDIT SELECT ON employees_departments BY ACCESS;

SELECT * FROM employees_departments;
```

As a result of the query on the `employees_departments` view, two audit records are generated: one for the query on the `employees_departments` view and one for the query on the base table `employees` (indirectly through the `employees_departments` view). The query on the base table `departments` does not generate an audit record because the `SELECT` audit option for this table is not enabled. All audit records pertain to the user that queried the `employees_departments` view.

In the given example, if the `AUDIT SELECT ON HR.EMPLOYEES;` statement is omitted, then using the `employees_departments` view does not generate an audit record for the `EMPLOYEES` table.

Configuring Schema Object Auditing

You can use the `AUDIT` statement to configure object auditing in the current edition. *Oracle Database SQL Language Reference* lists valid object audit options for `AUDIT` and the schema object types for which each option is available.

A user can set any object audit option for the objects contained in his or her schema. The `AUDIT ANY` system privilege is required to set an object audit option for an object contained in another user schema or to set the default object auditing option. Usually, only the security administrator is granted the `AUDIT ANY` privilege.

Figure 9–13 shows how to audit all successful and unsuccessful `DELETE` statements on the `laurel.emp` table.

Example 9–13 Configuring Auditing for a Schema Table

```
AUDIT DELETE ON laurel.emp BY ACCESS;
```

Example 9–14 shows how to audit all successful `SELECT`, `INSERT`, and `DELETE` statements on the `dept` table owned by user `jward`.

Example 9–14 Auditing Successful Statements on a Schema Table

```
AUDIT SELECT, INSERT, DELETE
     ON jward.dept
     BY ACCESS
     WHENEVER SUCCESSFUL;
```

Example 9–15 shows how you can use the `ON DEFAULT` clause to apply to any new objects (tables, views, and sequences) that are created after you set the `AUDIT` statement. In this example, new objects that are created in the future will be audited for all unsuccessful `SELECT` statements:

Example 9–15 Configuring Auditing for Any New Objects Using the DEFAULT Clause

```
AUDIT SELECT
     ON DEFAULT
```

```
    BY ACCESS
    WHENEVER NOT SUCCESSFUL;
```

Example 9–16 shows how to audit the execution of PL/SQL procedure or function.

Example 9–16 Auditing the Execution of a Procedure or Function

```
AUDIT EXECUTE ON sec_mgr.auth_orders BY ACCESS;
```

Removing Object Auditing

Use the NOAUDIT statement to remove object auditing. The following statements turn off the corresponding auditing options:

```
NOAUDIT DELETE
   ON emp;
NOAUDIT SELECT, INSERT, DELETE
   ON jward.dept;
```

To remove all object audit options on the emp table, enter the following statement:

```
NOAUDIT ALL ON emp;
```

To remove all default object audit options, enter the following statement:

```
NOAUDIT ALL ON DEFAULT;
```

All schema objects that are created before this NOAUDIT statement is issued continue to use the default object audit options in effect at the time of their creation, unless overridden by an explicit NOAUDIT statement after their creation.

To remove object audit options for a specific object, you must be the owner of the schema object. To remove the object audit options of an object in the schema of another user or to remove default object audit options, you must have the AUDIT ANY system privilege. A user with privileges to remove object audit options of an object can override the options set by any user.

Setting Audit Options for Objects That May Be Created in the Future

You can create audit settings for objects that do not exist yet, such as the insertion and deletion of tables to be created. There are two approaches that you can take. One approach is to use the statement audit options in the AUDIT statement. For example, to audit all inserts on future tables, enter the following SQL statement:

```
AUDIT INSERT TABLE BY ACCESS;
```

The second approach is to invoke the AUDIT statement using the ON DEFAULT clause. For example:

```
AUDIT ALL ON DEFAULT BY ACCESS;
```

This statement audits by default all subsequent object creation statements. The ON keyword specifies object auditing. The ON DEFAULT clause configures auditing for subsequently created objects that are affected by the following statements:

Statements A-D	Statements E-I	Statements I-R	Statements S-Y
ALTER	EXECUTE	INSERT	SELECT
AUDIT	GRANT	LOCK	UPDATE
COMMENT	FLASHBACK	READ	-

Statements A-D	Statements E-I	Statements I-R	Statements S-Y
DELETE	INDEX	RENAME	-

To restrict ON DEFAULT to a specific action, enter a statement similar to the following:

```
AUDIT ALTER, DELETE ON DEFAULT BY ACCESS;
```

For more information about the audit options and the ON DEFAULT clause of the AUDIT SQL statement, see *Oracle Database SQL Language Reference*. To find objects audited by default, query the ALL_DEF_AUDIT_OPTS data dictionary view.

Auditing Directory Objects

This section contains:

- About Directory Object Auditing
- Configuring Directory Object Auditing
- Removing Directory Object Auditing

About Directory Object Auditing

You can audit directory objects. For example, suppose you create a directory object that contains a preprocessor program that the ORACLE_LOADER access driver will use. You can audit anyone who runs this program within this directory object.

Configuring Directory Object Auditing

Use the AUDIT statement to enable object auditing. Example 9–17 shows how to audit the EXECUTE privilege on the directory object my_exec.

Example 9–17 Auditing a Directory Object

```
AUDIT EXECUTE ON DIRECTORY my_exec BY ACCESS;
```

Removing Directory Object Auditing

Use the NOAUDIT statement to disable directory object auditing. For example:

```
NOAUDIT EXECUTE ON DIRECTORY my_exec;
```

Auditing Functions, Procedures, Packages, and Triggers

This section contains:

- About Auditing Functions, Procedures, Packages, and Triggers
- Configuring the Auditing of Functions, Procedures, Packages, and Triggers
- Removing the Auditing of Functions, Procedures, Packages, and Triggers

About Auditing Functions, Procedures, Packages, and Triggers

You can audit functions, procedures, PL/SQL packages, and triggers. The areas that you can audit are as follows:

- You can individually audit standalone functions, standalone procedures, and PL/SQL packages.
- If you audit a PL/SQL package, Oracle Database audits all functions and procedures within the package.

- If you enable auditing for all executions, Oracle Database audits all triggers in the database, as well as all the functions and procedures within PL/SQL packages.
- You cannot audit individual functions or procedures within a PL/SQL package.

If you want to audit functions that are associated with Oracle Virtual Private database policies, note the following:

- **Dynamic policies:** Oracle Database evaluates the policy function twice, once during SQL statement parsing and again during execution. As a result, two audit records are generated for each evaluation.
- **Static policies:** Oracle Database evaluates the policy function once and then caches it in the SGA. As a result, only one audit record is generated.
- **Context-sensitive policies:** Oracle Database executes the policy function once, during statement parsing. As a result, only one audit record is generated.

Configuring the Auditing of Functions, Procedures, Packages, and Triggers

Example 9–18 shows how to audit the execution of any function, procedure, package, or trigger, by any user in the database.

Example 9–18 Auditing All Functions, Procedures, Packages, and Triggers

```
AUDIT EXECUTE PROCEDURE BY ACCESS;
```

Example 9–19 shows how to audit user `psmith`'s successful and unsuccessful executions of functions, procedures, packages, and triggers.

Example 9–19 Auditing a User's Execution of Functions, Procedures, Packages, and Triggers

```
AUDIT EXECUTE PROCEDURE BY psmith BY ACCESS;
```

Example 9–20 shows how to audit a standalone procedure entitled `check_work` that is in the `sales_data` schema. This idea applies to standalone functions as well.

Example 9–20 Auditing the Execution of a Procedure or Function within a Schema

```
AUDIT EXECUTE ON sales_data.check_work BY ACCESS WHENEVER SUCCESSFUL;
```

Removing the Auditing of Functions, Procedures, Packages, and Triggers

Use the `NOAUDIT` statement to remove the auditing of functions, procedures, and triggers. For example:

```
NOAUDIT EXECUTE PROCEDURE;

NOAUDIT EXECUTE PROCEDURE BY psmith;

NOAUDIT EXECUTE ON sales_data.checkwork;
```

Auditing Network Activity

This section contains:

- About Network Auditing
- Configuring Network Auditing
- Removing Network Auditing

About Network Auditing

You can use the AUDIT statement to audit unexpected errors in network protocol or internal errors in the network layer. Network auditing captures errors that occur during communication with the client on the network. These are errors thrown by the SQL*Net driver. There can be several causes of network errors. For example, an internal event set by a database engineer for testing purposes can cause a network error. Other causes include conflicting configuration settings for encryption, such as the network not finding the information required to create or process expected encryption. The errors that network auditing uncovers (such as ACTION 122 Network Error) are not connection failures: network auditing is only concerned with data as it travels across the network.

The audit record for network auditing lists the authentication type and SQL*Net address of the client (if available) in the COMMENT_TEXT field of the audit record, using the following format:

```
Authenticated by: authentication_type; Client Address: SQLNetAddress_of_client
```

The `Client Address: SQLNetAddress_of_client` portion only appears if this information is available.

Table 9–4 shows how to remedy four common error conditions.

Table 9–4 Auditable Network Error Conditions

Error	Cause	Action
TNS-02507 Encryption algorithm not installed	After picking an algorithm, the server was unable to find an index for it in its table of algorithms. This should be impossible because the algorithm was chosen (indirectly) from that list.	Turn on tracing for further details, and then rerun the operation. (Note that this error is not normally visible to the user.) If the error persists, then contact Oracle Support Services.
TNS-12648 Encryption or data integrity algorithm list empty	An Oracle Advanced Security list-of-algorithms parameter was empty.	Change the list to contain the name of at least one installed algorithm, or remove the list entirely if every installed algorithm is not acceptable.
TNS-12649 Unknown encryption or data integrity algorithm	An Oracle Advanced Security list-of-algorithms parameter included an algorithm name that was not recognized.	Remove that algorithm name, correct it if it was misspelled, or install the driver for the missing algorithm.
TNS-12650 No common encryption or data integrity algorithm	The client and server have no algorithm in common for either encryption or data integrity or both.	Choose sets of algorithms that overlap. In other words, add one of the client algorithm choices to the server list, or add one of the server list choices to the client algorithm.

Configuring Network Auditing

To configure network auditing, use the AUDIT statement. For example:

```
AUDIT NETWORK BY ACCESS;
```

Removing Network Auditing

To remove network auditing:

```
NOAUDIT NETWORK;
```

Using Default Auditing for Security-Relevant SQL Statements and Privileges

This section contains:

- About the Default Auditing Settings
- Privileges That Oracle Database Audits by Default
- Disabling and Enabling Default Audit Settings

About the Default Auditing Settings

When you use Database Configuration Assistant (DBCA) to create a new database, Oracle Database configures the database to audit the most commonly used security-relevant SQL statements and privileges. It also sets the `AUDIT_TRAIL` initialization parameter to `DB`. If you decide to use a different audit trail type (for example, `OS` if you want to write the audit trail records to operating system files), then you can do that: Oracle Database continues to audit the privileges that are audited by default. If you disable auditing by setting the `AUDIT_TRAIL` parameter to `NONE`, then no auditing takes place.

If you manually create a database, then you should run the `secconf.sql` script to apply the default audit settings to your database. See "Disabling and Enabling Default Audit Settings" on page 9-36 for more information.

To individually control the auditing of SQL statements and privileges, use the `AUDIT` and `NOAUDIT` statements. For more information, see "Auditing SQL Statements" on page 9-23 and "Auditing Privileges" on page 9-26.

Privileges That Oracle Database Audits by Default

Oracle Database audits the following privileges by default:

Privileges A-C	Privileges C-D	Privileges D-G
ALTER ANY PROCEDURE	CREATE ANY LIBRARY	DROP ANY TABLE
ALTER ANY TABLE	CREATE ANY PROCEDURE	DROP PROFILE
ALTER DATABASE	CREATE ANY TABLE	DROP USER
ALTER PROFILE	CREATE EXTERNAL JOB	EXEMPT ACCESS POLICY
ALTER SYSTEM	CREATE PUBLIC DATABASE LINK	GRANT ANY OBJECT PRIVILEGE
ALTER USER	CREATE SESSION	GRANT ANY PRIVILEGE
AUDIT SYSTEM	CREATE USER	GRANT ANY ROLE
CREATE ANY JOB	DROP ANY PROCEDURE	-

Oracle Database audits the following SQL shortcuts by default:

Shortcuts D-P	Shortcuts P-R	Shortcuts S
DATABASE LINK	PUBLIC SYNONYM	SYSTEM AUDIT
PROFILE	ROLE	SYSTEM GRANT

See Also:

- *Oracle Database SQL Language Reference* for detailed information about the SQL statements described in this section

  sql_statement_shortcut in *Oracle Database SQL Language Reference* for a list of accepted SQL shortcuts you can use with the `AUDIT` statement

Disabling and Enabling Default Audit Settings

If your applications use the default audit settings from Oracle Database 10*g* Release 2 (10.2), then you can revert to these audit settings until you modify the applications to use the Release 11*g* audit settings. To do so, run the `undoaud.sql` script.

After you have modified your applications to conform to the Release 11*g* audit settings, then you can manually update your database to use the audit configuration that suits your business needs, or you can run the `secconf.sql` script to apply the Release 11*g* default audit settings. You can customize this script to have different security settings if you like, but remember that the settings listed in the original script are Oracle-recommended settings.

If you created your database manually, then you should run the `secconf.sql` script to apply the Release 11*g* default audit settings to the database. Databases that have been created with Database Configuration Assistant will have these settings, but manually created databases do not.

The `undoaud.sql` and `secconf.sql` scripts are in the `$ORACLE_HOME/rdbms/admin` directory. The `undoaud.sql` script affects audit settings only, and the `secconf.sql` script affects both audit and password settings. They have no effect on other security settings.

Auditing Specific Activities with Fine-Grained Auditing

This section contains:

About Fine-Grained Auditing

Fine-grained auditing enables you to create policies that define specific conditions that must take place for the audit to occur. This enables you to monitor data access based on content. It provides granular auditing of queries, and INSERT, UPDATE, and DELETE operations. For example, a central tax authority must track access to tax returns to guard against employee snooping, with enough detail to determine what data was accessed. It is not enough to know that SELECT privilege was used by a specific user on a particular table. Fine-grained auditing provides this deeper functionality.

In general, fine-grained audit policies are based on simple, user-defined SQL predicates on table objects as conditions for selective auditing. During fetching, whenever policy conditions are met for a row, the query is audited.

You can use fine-grained auditing to audit the following types of actions:

- Accessing a table between 9 p.m. and 6 a.m. or on Saturday and Sunday
- Using an IP address from outside the corporate network
- Selecting or updating a table column
- Modifying a value in a table column

Note:

- Fine-grained auditing is supported only with cost-based optimization. For queries using rule-based optimization, fine-grained auditing checks before applying row filtering, which could result in an unnecessary audit event trigger.
- Policies currently in force on an object involved in a flashback query are applied to the data returned from the specified flashback snapshot (based on time or system change number (SCN).
- If you want to use fine-grained auditing to audit data that is being directly loaded (for example, using Oracle Warehouse Builder to execute DML statements), then Oracle Database transparently makes all direct loads that are performed in the database instance into conventional loads. If you want to preserve the direct loading of data, consider using standard auditing instead.

Where Are Fine-Grained Audit Records Stored?

Fine-grained audit records are stored in the SYS.FGA_LOG$ table. To find the records have been generated for the audit policies that are in effect, you can query the DBA_FGA_AUDIT_TRAIL data dictionary view. The DBA_COMMON_AUDIT_TRAIL data dictionary view combines both standard and fine-grained audit log records. In addition, you can query the V$XML_AUDIT_TRAIL view to find fine-grained audit records that were written in XML formatted files. For detailed information about these views, see *Oracle Database Reference*.

Oracle Database always audits DELETE, INSERT, UPDATE, and MERGE operations on the SYS.FGA_LOG$ (and SYS.AUD$) tables to the SYS.AUD$ table. It does not allow the audit records to be deleted, unless user SYS performs these operations. If you have set the AUDIT_SYS_OPERATIONS initialization parameter to TRUE, then user SYS's operations are audited. In this case the audit records of all SYS operations are written to whatever

directory the AUDIT_FILE_DEST initialization parameter points to. If AUDIT_FILE_DEST is not set, then it writes the records to an operating system-dependent location.

Advantages of Fine-Grained Auditing

Fine-grained auditing creates a more meaningful audit trail, one that includes only very specific actions that you want to audit. It excludes unnecessary information that occurs if each table access was recorded. Fine-grained auditing has the following advantages over standard auditing:

- **It performs a Boolean condition check.** If the Boolean condition you specify is met, for example, a table being accessed on a Saturday, then the audit takes place.
- **It captures the SQL that triggered the audit.** You can capture both the SQL statement that caused the audit, and any associated bind variables. Be aware that you can only capture data from scalar column types. You cannot capture data from object columns, LOBs, or user-defined column types. For example, suppose you have the following query:

  ```
  SELECT NAME FROM EMPLOYEE WHERE SSN = :1
  ```

  If :1 is of integer type and the value for SSN is 987654321, then the audit trail can capture this information. However, the audit trail cannot capture this information if :1 is a BLOB, CLOB, object, or user-defined type.

  This feature is available if you create the fine grained audit policy with the audit_trail parameter of the DBMS_FGA.ADD_POLICY PL/SQL procedure to DB+EXTENDED or XML+EXTENDED.
- **It adds extra protection to sensitive columns.** You can audit specific relevant columns that may hold sensitive information, such as salaries or Social Security numbers.
- **It provides an event handler feature.** For example, you can write a function that sends an email alert to a security administrator when an audited column that should not be changed at midnight is updated.
- **You do not need to set initialization parameters to enable fine-grained auditing.** Instead of setting initialization parameters such as AUDIT_TRAIL, you use the DBMS_FGA PL/SQL package to add and remove fine-grained auditing policies as necessary applying them to the specific operations or objects you want to monitor.

What Permissions Are Needed to Create a Fine-Grained Audit Policy?

To create a fine-grained audit policy, you must have EXECUTE privileges on the DBMS_FGA PL/SQL package. The package is owned by the SYS user.

Activities That Are Always Audited in Fine-Grained Auditing

The SYS.AUD$ table records all data manipulation language (DML) statements, such as INSERT, UPDATE, MERGE, and DELETE, that are performed on the SYS.FGA_LOG$ table by non-SYS users. Oracle Database performs the audit even if auditing has not been configured for the SYS.FGA_LOG$ table, which is the table in which these activities occur. You can check these activities by querying the DBA_FGA_AUDIT_TRAIL and DBA_COMMON_AUDIT_TRAIL views. See also "Activities That Are Always Written to the Standard and Fine-Grained Audit Records" on page 9-3.

Using Fine-Grained Audit Policies with Editions

If you are preparing an application for edition-based redefinition, and you cover each table that the application uses with an editioning view, then you must move the fine-grained audit polices that protect these tables to the editioning view.

Creating an Audit Trail for Fine-Grained Audit Records

You designate the audit trail format for fine-grained auditing by setting the audit_trail parameter for the `DBMS_FGA.ADD_POLICY` policy (not to be confused with the `AUDIT_TRAIL` initialization parameter) when you create the audit policy. Setting this parameter to `XML` or `XML+EXTENDED` writes the records to the operating system files in XML format. If you prefer to write the fine-grained audit records to the `SYS.FGA_LOG$` table, then set the `audit_trail` parameter for the `DBMS_FGA.ADD_POLICY` parameter to `DB` or `DB+EXTENDED`. For a list of reasons why writing audit records to operating system files is beneficial, see "Advantages of the Operating System Audit Trail" on page 9-16.

You can use the `V$XML_AUDIT_TRAIL` data dictionary view to make audit records from XML files available to DBAs through a SQL query, providing enhanced usability. Querying this view causes all XML files (all files with an `.xml` extension) in the `AUDIT_FILE_DEST` directory to be parsed and presented in relational table format.

The `DBA_COMMON_AUDIT_TRAIL` view includes the contents of the `V$XML_AUDIT_TRAIL` dynamic view for standard and fine-grained audit records.

Because the audit XML files are stored in files with the `.xml` extension on all platforms, the dynamic view presents audit information similarly on all platforms. See *Oracle Database Reference* for detailed information about the `V$XML_AUDIT_TRAIL` view contents.

Note: If you audit tables that have sensitive data, remember that `DB+EXTENDED` and `XML+EXTENDED` settings for the `DBMS_FGA.ADD_POLICY` `audit_trail` parameter will capture this data. See "Auditing Sensitive Information" on page 10-18 for ways to handle this scenario.

How the Fine-Grained Audit Trail Generates Records

The fine-grained audit trail captures an audit record for each reference of a table or a view within a SQL statement. For example, if you run a `UNION` statement that references the `HR.EMPLOYEES` table twice, then an audit policy for statement generates two audit records, one for each access of the `HR.EMPLOYEES` table.

Using the DBMS_FGA Package to Manage Fine-Grained Audit Policies

This section contains:

About the DBMS_FGA PL/SQL Package

To manage a fine-grained audit policy, you use the `DBMS_FGA` PL/SQL package. This package enables you to add all combinations of `SELECT`, `INSERT`, `UPDATE`, and `DELETE` statements to one policy. You also can audit `MERGE` statements, by auditing the

underlying actions of INSERT and UPDATE. To audit MERGE statements, configure fine-grained access on the INSERT and UPDATE statements. Only one record is generated for each policy for successful MERGE operations. To administer fine-grained audit policies, you must have the EXECUTE privilege on the DBMS_FGA package.

The audit policy is bound to the table for which you created it. This simplifies the management of audit policies because the policy only must be changed once in the database, not in each application. In addition, no matter how a user connects to the database—from an application, a Web interface, or through SQL*Plus or Oracle SQL Developer—Oracle Database records any actions that affect the policy.

If any rows returned from a query match the audit condition that you define, then Oracle Database inserts an audit entry into the fine-grained audit trail. This entry excludes all the information that is reported in the regular audit trail. In other words, only one row of audit information is inserted into the audit trail for every fine-grained audit policy that evaluates to true.

For detailed information about the syntax of the DBMS_FGA package, see *Oracle Database PL/SQL Packages and Types Reference*. See also *Oracle Database Advanced Application Developer's Guide*.

Note: If you plan to use the DBMS_FGA package policy across different editions, then you can control the results of the policy: whether the results are uniform across all editions, or specific to the edition in which the policy is used. See "How Editions Affects the Results of a Global Application Context PL/SQL Package" on page 6-24 for more information.

Creating a Fine-Grained Audit Policy

To create a fine-grained audit policy, use the DBMS_FGA.ADD_POLICY procedure. This procedure creates an audit policy using the supplied predicate as the audit condition. Oracle Database executes the policy predicate with the privileges of the user who created the policy. The maximum number of fine-grained policies on any table or view object is 256. Oracle Database stores the policy in the data dictionary table, but you can create the policy on any table or view that is not in the SYS schema.

After you create the fine-grained audit policy, it does not reside in any specific schema, although the definition for the policy is stored in the SYS.FGA$ data dictionary table.

You cannot modify a fine-grained audit policy after you have created it. If you need to modify the policy, drop it and then recreate it.

Be aware that if a table column has a fine-grained audit policy, you cannot encrypt or decrypt this column (by using the UPDATE statement). To do so raises an ORA-28133: full table access is restricted by fine-grained security error. If you want to update the column, first temporarily disable the fine-grained audit policy and then encrypt or decrypt the column. Afterwards, re-enable the fine-grained audit policy. See "Disabling and Enabling a Fine-Grained Audit Policy" on page 9-43 for more information.

The syntax for the ADD_POLICY procedure is:

```
DBMS_FGA.ADD_POLICY(
   object_schema      VARCHAR2,
   object_name        VARCHAR2,
   policy_name        VARCHAR2,
   audit_condition    VARCHAR2,
```

```
audit_column       VARCHAR2,
handler_schema     VARCHAR2,
handler_module     VARCHAR2,
enable             BOOLEAN,
statement_types    VARCHAR2,
audit_trail        BINARY_INTEGER IN DEFAULT,
audit_column_opts  BINARY_INTEGER IN DEFAULT);
```

In this specification:

- `object_schema`: Specifies the schema of the object to be audited. (If NULL, the current log-on user schema is assumed.)
- `object_name`: Specifies the name of the object to be audited.
- `policy_name`: Specifies the name of the policy to be created. Ensure that this name is unique.
- `audit_condition`: Specifies a Boolean condition in a row. `NULL` is allowed and acts as `TRUE`. See "Auditing Specific Columns and Rows" on page 9-43 for more information. If you specify `NULL` or no audit condition, then any action on a table with that policy creates an audit record, whether or not rows are returned.

  Follow these guidelines:

  – Do not include functions, which execute the auditable statement on the same base table, in the `audit_condition` setting. For example, suppose you create a function that executes an `INSERT` statement on the `HR.EMPLOYEES` table. The policy's `audit_condition` contains this function and it is for `INSERT` statements (as set by `statement_types`). When the policy is used, the function executes recursively until the system has run out of memory. This can raise the error `ORA-1000: maximum open cursors exceeded` or `ORA-00036: maximum number of recursive SQL levels (50) exceeded`.

  – Do not issue the `DBMS_FGA.ENABLE_POLICY` or `DBMS_FGA.DISABLE_POLICY` statement from a function in a policy's condition.

- `audit_column`: Specifies one or more columns to audit, including hidden columns. If set to `NULL` or omitted, all columns are audited. These can include Oracle Label Security hidden columns or object type columns. The default, NULL, causes audit if any column is accessed or affected.
- `handler_schema`: If an alert is used to trigger a response when the policy is violated, specifies the name of the schema that contains the event handler. The default, `NULL`, uses the current schema. See also "Tutorial: Adding an Email Alert to a Fine-Grained Audit Policy" on page 9-44.
- `handler_module`: Specifies the name of the event handler. Include the package the event handler is in. This function is invoked only after the first row that matches the audit condition in the query is processed.

  Follow these guidelines:

  – Do not create recursive fine-grained audit handlers. For example, suppose you create a handler that executes an `INSERT` statement on the `HR.EMPLOYEES` table. The policy that is associated with this handler is for `INSERT` statements (as set by the `statement_types` parameter). When the policy is used, the handler executes recursively until the system has run out of memory. This can raise the error `ORA-1000: maximum open cursors exceeded` or `ORA-00036: maximum number of recursive SQL levels (50) exceeded`.

  - Do not issue the DBMS_FGA.ENABLE_POLICY or DBMS_FGA.DISABLE_POLICY statement from a policy handler. Doing so can raise the ORA-28144: Failed to execute fine-grained audit handler error.

- enable: Enables or disables the policy using true or false. If omitted, the policy is enabled. The default is TRUE.
- statement_types: Specifies the SQL statements to be audited: INSERT, UPDATE, DELETE, or SELECT only. The default is SELECT.
- audit_trail: Specifies the destination (DB or XML) of fine-grained audit records. Also specifies whether to populate LSQLTEXT and LSQLBIND in FGA_LOG$. However, be aware that sensitive data, such as credit card information, can be recorded in clear text. See "Auditing Sensitive Information" on page 10-18 for how you can handle this scenario.

  If you set the audit_trail parameter to XML, then the XML files are written to the directory specified by the AUDIT_FILE_DEST initialization parameter.

  For read-only databases, Oracle Database writes the fine-grained audit trail to XML files, regardless of the audit_trail setting.
- audit_column_opts: If you specify more than one column in the audit_column parameter, then this parameter determines whether to audit all or specific columns. See "Auditing Specific Columns and Rows" on page 9-43 for more information.

See *Oracle Database PL/SQL Packages and Types Reference* for additional details about the ADD_POLICY syntax.

Example 9–21 shows how to audit statements INSERT, UPDATE, DELETE, and SELECT on table HR.EMPLOYEES. Note that this example omits the audit_column_opts parameter, because it is not a mandatory parameter.

Example 9–21 Using DBMS_FGA.ADD_POLICY to Create a Fine-Grained Audit Policy

```
BEGIN
  DBMS_FGA.ADD_POLICY(
   object_schema      => 'HR',
   object_name        => 'EMPLOYEES',
   policy_name        => 'chk_hr_employees',
   enable             =>  TRUE,
   statement_types    => 'INSERT, UPDATE, SELECT, DELETE',
   audit_trail        =>  DBMS_FGA.DB);
END;
/
```

At this point, if you query the DBA_AUDIT_POLICIES view, you will find the new policy listed:

```
SELECT POLICY_NAME FROM DBA_AUDIT_POLICIES;

POLICY_NAME
------------------------------
CHK_HR_EMPLOYEES
```

Afterwards, any of the following SQL statements log an audit event record.

```
SELECT COUNT(*) FROM HR.EMPLOYEES WHERE COMMISSION_PCT = 20 AND SALARY > 4500;

SELECT SALARY FROM HR.EMPLOYEES WHERE DEPARTMENT_ID = 50;
```

```
DELETE FROM HR.EMPLOYEES WHERE SALARY > 1000000;
```

Auditing Specific Columns and Rows

You can fine-tune the audit behavior by targeting a specific column, referred to as a *relevant column*, to be audited if a condition is met. To accomplish this, you use the `audit_column` parameter to specify one or more sensitive columns. In addition, you can audit data in specific rows by using the `audit_condition` parameter to define a Boolean condition.

Example 9–21 on page 9-42 performs an audit if anyone in Department 50 tries to access the `salary` and `commission_pct` columns.

```
audit_condition    => 'DEPARTMENT_ID = 50',
audit_column       => 'SALARY,COMMISSION_PCT,'
```

As you can see, this feature is enormously beneficial. It not only enables you to pinpoint particularly important types of data to audit, but it provides increased protection for columns that contain sensitive data, such as Social Security numbers, salaries, patient diagnoses, and so on.

If the `audit_column` lists more than one column, you can use the `audit_column_opts` parameter to specify whether a statement is audited when the query references *any* column specified in the `audit_column` parameter or only when *all* columns are referenced. For example:

```
audit_column_opts   => DBMS_FGA.ANY_COLUMNS,

audit_column_opts   => DBMS_FGA.ALL_COLUMNS,
```

If you do not specify a relevant column, then auditing applies to all columns.

For more information about the `audit_condition`, `audit_column`, and `audit_column_opts` parameters in the `DBMS_FGA.ADD_POLICY` procedure, see *Oracle Database PL/SQL Packages and Types Reference*. See also the usage notes for the `ADD_POLICY` procedure in that section.

Disabling and Enabling a Fine-Grained Audit Policy

You can disable a fine-grained audit policy by using the `DBMS_FGA.DISABLE_POLICY` procedure. The syntax for `DISABLE_POLICY` is:

```
DBMS_FGA.DISABLE_POLICY(
   object_schema  VARCHAR2,
   object_name    VARCHAR2,
   policy_name    VARCHAR2 );
```

Example 9–22 shows how to disable the fine-grained audit policy created in Example 9–21 on page 9-42.

Example 9–22 Disabling a Fine-Grained Audit Policy

```
DBMS_FGA.DISABLE_POLICY(
  object_schema        => 'HR',
  object_name          => 'EMPLOYEES',
  policy_name          => 'chk_hr_employees');
/
```

For detailed information about the `DISABLE_POLICY` syntax, see *Oracle Database PL/SQL Packages and Types Reference*.

Example 9–23 show how to reenable the chk_hr_emp policy by using the DBMS_FGA.ENABLE_POLICY procedure:

Example 9–23 Enabling a Fine-Grained Audit Policy

```
DBMS_FGA.ENABLE_POLICY(
  object_schema        => 'HR',
  object_name          => 'EMPLOYEES',
  policy_name          => 'chk_hr_employees',
  enable               => TRUE);
/
```

For detailed information about the ENABLE_POLICY syntax, see *Oracle Database PL/SQL Packages and Types Reference*.

Dropping a Fine-Grained Audit Policy

Oracle Database automatically drops the audit policy if you remove the object specified in the object_name parameter of the DBMS_FGA.ADD_POLICY procedure, or if you drop the user who created the audit policy.

Example 9–24 shows how to drop a fine-grained audit policy manually by using the DBMS_FGA.DROP_POLICY procedure.

Example 9–24 Dropping a Fine-Grained Audit Policy

```
DBMS_FGA.DROP_POLICY(
  object_schema      => 'HR',
  object_name        => 'EMPLOYEES',
  policy_name        => 'chk_hr_employees');
```

See *Oracle Database PL/SQL Packages and Types Reference* for detailed information about the DROP_POLICY syntax.

Tutorial: Adding an Email Alert to a Fine-Grained Audit Policy

This section contains:

About This Tutorial

You can add an email alert to a fine-grained audit policy that goes into effect when a user (or an intruder) violates the policy. To accomplish this, you first must create a procedure that generates the alert, and then use the following DBMS_FGA.ADD_POLICY parameters to call this function when someone violates this policy:

- handler_schema: The schema in which the handler event is stored

- handler_module: The name of the event handler

The alert can come in any form that best suits your environment: an email or pager notification, updates to a particular file or table, and so on. Creating alerts also helps to meet certain compliance regulations, such as California Senate Bill 1386. In this tutorial, you will create an email alert.

In this tutorial, you create an email alert that notifies a security administrator that a Human Resources representative is trying to select or modify salary information in the HR.EMPLOYEES table. The representative is permitted to make changes to this table, but to meet compliance regulations, we want to create a record of all salary selections and modifications to the table.

Step 1: Install and Configure the UTL_MAIL PL/SQL Package

1. Log on as user SYS with the SYSDBA privilege.

```
sqlplus sys as sysdba
Enter password: password
```

2. Install the UTL_MAIL package.

```
@$ORACLE_HOME/rdbms/admin/utlmail.sql
@$ORACLE_HOME/rdbms/admin/prvtmail.plb
```

   The UTL_MAIL package enables you to manage email. See *Oracle Database PL/SQL Packages and Types Reference* for more information about UTL_MAIL.

   Be aware that currently, the UTL_MAIL PL/SQL package does not support SSL servers.

3. Check the current value of the SMTP_OUT_SERVER initialization parameter, and make a note of this value so that you can restore it when you complete this tutorial.

   For example:

```
SHOW PARAMETER SMTP_OUT_SERVER
```

   If the SMTP_OUT_SERVER parameter has already been set, then output similar to the following appears:

```
NAME                    TYPE              VALUE
----------------------- ----------------- ----------------------------------
SMTP_OUT_SERVER         string            some_imap_server.example.com
```

4. Issue the following ALTER SYSTEM statement:

```
ALTER SYSTEM SET SMTP_OUT_SERVER="imap_mail_server.example.com";
```

   Replace *imap_mail_server* with the name of your SMTP server, which you can find in the account settings in your email tool. Enclose these settings in quotation marks. For example:

```
ALTER SYSTEM SET SMTP_OUT_SERVER="my_imap_server.example.com"
```

5. Connect as SYS using the SYSOPER privilege and then restart the database.

```
CONNECT SYS/AS SYSOPER
Enter password: password

SHUTDOWN IMMEDIATE
STARTUP
```

6. Ensure that the SMTP_OUT_SERVER parameter setting is correct.

```
CONNECT SYS/AS SYSDBA
Enter password: password

SHOW PARAMETER SMTP_OUT_SERVER
```

Output similar to the following appears:

```
NAME                 TYPE             VALUE
-------------------- ---------------- --------------------------------
SMTP_OUT_SERVER      string           my_imap_server.example.com
```

Step 2: Create User Accounts

1. Ensure that you are connected as SYS using the SYSDBA privilege, and then create the sysadmin_fga account, who will create the fine-grained audit policy.

For example:

```
CONNECT SYS/AS SYSDBA
Enter password: password

GRANT CREATE SESSION, DBA TO sysadmin_fga IDENTIFIED BY password;
GRANT EXECUTE ON DBMS_FGA TO sysadmin_fga;
GRANT CREATE PROCEDURE, DROP ANY PROCEDURE TO sysadmin_fga;
GRANT EXECUTE ON UTL_TCP TO sysadmin_fga;
GRANT EXECUTE ON UTL_SMTP TO sysadmin_fga;
GRANT EXECUTE ON UTL_MAIL TO sysadmin_fga;
GRANT EXECUTE ON DBMS_NETWORK_ACL_ADMIN TO sysadmin_fga;
```

Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

The UTL_TCP, UTL_SMTP, UTL_MAIL, and DBMS_NETWORK_ACL_ADMIN PL/SQL packages are used by the email security alert that you create.

2. Connect as user SYSTEM.

```
CONNECT SYSTEM
Enter password: password
```

3. Ensure that the HR schema account is unlocked and has a password. If necessary, unlock HR and grant this user a password.

```
SELECT USERNAME, ACCOUNT_STATUS FROM DBA_USERS WHERE USERNAME = 'HR';
```

If the DBA_USERS view lists user HR as locked and expired, then enter the following statement to unlock the HR account and create a new password:

```
ALTER USER HR ACCOUNT UNLOCK IDENTIFIED BY password;
```

Enter a password that is secure. For greater security, do **not** give the HR account the same password from previous releases of Oracle Database. "Minimum Requirements for Passwords" on page 3-3 for the minimum requirements for creating passwords.

4. Create a user account for Susan Mavris, who is an HR representative, and then grant this user access to the HR.EMPLOYEES table.

```
GRANT CREATE SESSION TO smavris IDENTIFIED BY password;
GRANT SELECT, INSERT, UPDATE, DELETE ON HR.EMPLOYEES TO SMAVRIS;
```

Step 3: Configure an Access Control List File for Network Services

Before you can use PL/SQL network utility packages such as UTL_MAIL, you must configure an access control list (ACL) file that enables fine-grained access to external network services. For detailed information about this topic, see "Managing Fine-Grained Access in PL/SQL Packages and Types" on page 4-49.

To configure an access control list for the email alert:

1. Connect to SQL*Plus as user sysadmin_fga.

```
CONNECT sysadmin_fga
Enter password: password
```

2. Create the following access control list and its privilege definitions.

```
BEGIN
 DBMS_NETWORK_ACL_ADMIN.CREATE_ACL (
  acl          => 'email_server_permissions.xml',
  description  => 'Enables network permissions for the email server',
  principal    => 'SYSADMIN_FGA',
  is_grant     => TRUE,
  privilege    => 'connect');
END;
/
```

   Ensure that you enter your exact user name for the principal setting, in upper-case letters. For this tutorial, enter SYSADMIN_FGA for the name of the principal.

3. Assign the access control list to the outgoing SMTP network host for your email server.

```
BEGIN
 DBMS_NETWORK_ACL_ADMIN.ASSIGN_ACL (
  acl         => 'email_server_permissions.xml',
  host        => 'SMTP_OUT_SERVER_setting',
  lower_port  => port);
END;
/
```

   In this example:

   - *SMTP_OUT_SERVER_setting*: Enter the SMTP_OUT_SERVER setting that you set for the SMTP_OUT_SERVER parameter in "Step 1: Install and Configure the UTL_MAIL PL/SQL Package" on page 9-45. This setting should match exactly the setting that your email tool specifies for its outgoing server.
   - *port*: Enter the port number that your email tool specifies for its outgoing server. Typically, this setting is 25. Enter this value for the lower_port setting. (Currently, the UTL_MAIL package does not support SSL. If your email server is an SSL server, then enter 25 for the port number, even if the email server uses a different port number.)

Step 4: Create the Email Security Alert PL/SQL Procedure

As user sysadmin_fga, create the following procedure. (You can copy and paste this text by positioning the cursor at the start of CREATE OR REPLACE in the first line.)

```
CREATE OR REPLACE PROCEDURE email_alert (sch varchar2, tab varchar2, pol varchar2)
AS
msg varchar2(20000) := 'HR.EMPLOYEES table violation. The time is: ';
BEGIN
  msg := msg||TO_CHAR(SYSDATE, 'Day DD MON, YYYY HH24:MI:SS');
```

```
UTL_MAIL.SEND (
    sender      => 'youremail@example.com',
    recipients  => 'recipientemail@example.com',
    subject     => 'Table modification on HR.EMPLOYEES',
    message     => msg);
END email_alert;
/
```

In this example:

- `CREATE OR REPLACE PROCEDURE ...AS`: You must include a signature that describes the schema name (sch), table name (tab), and the name of the audit procedure (pol) that you will define in audit policy in the next step.
- `sender and recipients`: Replace *youremail@example.com* with your email address, and *recipientemail@example.com* with the email address of the person you want to receive the notification.

Step 5: Create and Test the Fine-Grained Audit Policy Settings

1. As user `sysadmin_fga`, create the `chk_hr_emp` policy fine-grained audit policy as follows.

```
BEGIN
 DBMS_FGA.ADD_POLICY (
  object_schema      =>  'HR',
  object_name        =>  'EMPLOYEES',
  policy_name        =>  'CHK_HR_EMP',
  audit_column       =>  'SALARY',
  handler_schema     =>  'SYSADMIN_FGA',
  handler_module     =>  'EMAIL_ALERT',
  enable             =>   TRUE,
  statement_types    =>  'SELECT, UPDATE',
  audit_trail        =>   DBMS_FGA.DB + DBMS_FGA.EXTENDED);
END;
/
```

2. Commit the changes you have made to the database.

```
COMMIT;
```

3. Test the settings that you have created so far.

```
EXEC email_alert ('hr', 'employees', 'chk_hr_emp');
```

   SQL*Plus should display a `PL/SQL procedure successfully completed` message, and in a moment, depending on the speed of your email server, you should receive the email alert.

   If you receive an `ORA-24247: network access denied by access control list (ACL)` error followed by `ORA-06512: at` *string*`line` *string* errors, then check the settings in the access control list file.

Step 6: Test the Alert

1. Connect to SQL*Plus as user `smavris`, check your salary, and give yourself a nice raise.

```
CONNECT smavris
Enter password: password

SELECT SALARY FROM HR.EMPLOYEES WHERE LAST_NAME = 'Mavris';
```

```
SALARY
-----------
6500

UPDATE HR.EMPLOYEES SET SALARY = 13000 WHERE LAST_NAME = 'Mavris';
```

2. Now select from a column other than `SALARY` in the `HR.EMPLOYEES` table.

```
SELECT FIRST_NAME, LAST_NAME FROM HR.EMPLOYEES WHERE LAST_NAME = 'Raphaely';
```

The following output should appear:

```
FIRST_NAME           LAST_NAME
-------------------- --------------------
Den                  Raphaely
```

By now, depending on the speed of you email server, you (or your recipient) should have received an email with the subject header `Table modification on HR.EMPLOYEES` notifying you of the tampering of the `HR.EMPLOYEES` table.

3. As user `sysadmin_fga`, query the `DBA_FGA_AUDIT_TRAIL` data dictionary view, which contains the Susan Mavris's audited activities.

```
CONNECT sysadmin_fga
Enter password: password

col dbuid format a10
col lsqltext format a66
col ntimestamp# format a15

SELECT DBUID, LSQLTEXT, NTIMESTAMP# FROM SYS.FGA_LOG$ WHERE POLICYNAME='CHK_HR_
EMP';
```

Output similar to the following appears:

```
DBUID      LSQLTEXT
---------- ------------------------------------------------------------------
NTIMESTAMP#
------------------------------------------------------------------------------
SMAVRIS    SELECT SALARY FROM HR.EMPLOYEES WHERE LAST_NAME = 'Mavris'
23-JUN-09 03.48.59.111000 PM

SMAVRIS    UPDATE HR.EMPLOYEES SET SALARY = 13000 WHERE LAST_NAME = 'Mavris'
23-JUN-09 03.49.07.330000 PM
```

The audit trail captures the two SQL statements that Susan Mavris ran that affected the `SALARY` column in the `HR.EMPLOYEES` table. The third statement she ran, in which she asked about Den Raphaely, was not recorded because it was not affected by the audit policy. This is because Oracle Database executes the audit function as an autonomous transaction, committing only the actions of the `handler_module` setting and not any user transaction. The function has no effect on any user SQL transaction.

Step 7: Remove the Components for This Tutorial

1. Connect to SQL*Plus as user `SYSTEM` privilege, and then drop users `sysadmin_fga` (including the objects in the `sysadmin_fga` schema) and `smavris`.

```
CONNECT SYSTEM
Enter password: password

DROP USER sysadmin_fga CASCADE;
```

```
DROP USER smavris;
```

2. Connect as user HR and remove the loftiness of Susan Mavris's salary.

```
CONNECT HR
Enter password: password

UPDATE HR.EMPLOYEES SET SALARY = 6500 WHERE LAST_NAME = 'Mavris';
```

3. If you want, lock and expire HR, unless other users want to use this account:

```
ALTER USER HR PASSWORD EXPIRE ACCOUNT LOCK;
```

4. Connect as user SYS with the SYSDBA privilege, and drop the email_server_permissions.xml access control list.

```
BEGIN
   DBMS_NETWORK_ACL_ADMIN.DROP_ACL(
     acl => 'email_server_permissions.xml');
END;
/
```

Access control lists reside in the SYS schema, not the schema of the user who created them.

5. Issue the following ALTER SYSTEM statement to restore the SMTP_OUT_SERVER parameter to the previous value, from Step 4 under "Step 1: Install and Configure the UTL_MAIL PL/SQL Package" on page 9-45:

```
ALTER SYSTEM SET SMTP_OUT_SERVER="previous_value";
```

Enclose this setting in quotation marks. For example:

```
ALTER SYSTEM SET SMTP_OUT_SERVER="some_imap_server.example.com"
```

6. Restart the database instance.

```
SHUTDOWN

STARTUP
```

Tutorial: Auditing Nondatabase Users

This section contains:

About This Tutorial

This tutorial shows how to create a fine-grained audit policy that audits a nondatabase user's actions, based on the identity set in the client identifier.

Step 1: Create the User Account and Ensure the User HR Is Active

1. Log on as user SYS with the SYSDBA privilege.

```
sqlplus SYS AS SYSDBA
Enter password: password
```

2. Create the sysadmin_fga account, who will create the fine-grained audit policy.

```
GRANT CREATE SESSION, DBA TO sysadmin_fga IDENTIFIED BY password;
GRANT SELECT ON OE.ORDERS TO sysadmin_fga;
GRANT EXECUTE ON DBMS_FGA TO sysadmin_fga;
GRANT SELECT ON SYS.FGA_LOG$ TO sysadmin_fga;
```

   Replace *password* with a password that is secure. See "Minimum Requirements for Passwords" on page 3-3 for more information.

3. The sample user OE will also be used in this tutorial, so query the DBA_USERS data dictionary view to ensure that OE is not locked or expired.

```
SELECT USERNAME, ACCOUNT_STATUS FROM DBA_USERS WHERE USERNAME = 'OE';
```

   If the DBA_USERS view lists user OE as locked and expired, log in as user SYSTEM and then enter the following statement to unlock the OE account and create a new password:

```
ALTER USER OE ACCOUNT UNLOCK IDENTIFIED BY password;
```

   Enter a password that is secure. For greater security, do **not** give the OE account the same password from previous releases of Oracle Database. "Minimum Requirements for Passwords" on page 3-3 for the minimum requirements for creating passwords.

Step 2: Create the Fine-Grained Audit Policy

1. Connect to SQL*Plus as user sysadmin_fga.

```
CONNECT sysadmin_fga
Enter password: password
```

2. Create the following policy:

```
BEGIN
 DBMS_FGA.ADD_POLICY(OBJECT_SCHEMA => 'OE',
   OBJECT_NAME                     => 'ORDERS',
   POLICY_NAME                     => 'ORDERS_FGA_POL',
   AUDIT_CONDITION                 => 'SYS_CONTEXT(''USERENV'', ''CLIENT_
IDENTIFIER'') = ''Robert''',
   HANDLER_SCHEMA                  => NULL,
   HANDLER_MODULE                  => NULL,
   ENABLE                          => True,
   STATEMENT_TYPES                 => 'INSERT,UPDATE,DELETE,SELECT',
   AUDIT_TRAIL                     => DBMS_FGA.DB + DBMS_FGA.EXTENDED,
   AUDIT_COLUMN_OPTS               => DBMS_FGA.ANY_COLUMNS);
END;
/
```

   In this example, the AUDIT_CONDITION parameter assumes the nondatabase user is named Robert. The policy will monitor any INSERT, UPDATE, DELETE, and SELECT statements Robert will attempt.

Step 3: Test the Policy

1. Connect as user OE and select from the OE.ORDERS table.

```
CONNECT OE
Enter password: password
```

```
SELECT COUNT(*) FROM ORDERS;
```

The following output appears:

```
  COUNT(*)
----------
       105
```

2. Connect as user `sysadmin_fga` and then check if any audit records were generated.

```
CONNECT sysadmin_fga
Enter password: password

SELECT DBUID, LSQLTEXT FROM SYS.FGA_LOG$ WHERE POLICYNAME='ORDERS_FGA_POL';
```

The following output appears:

```
no rows selected
```

Because no nondatabase users were logged in to query the `OE.ORDERS` table, the audit trail is empty.

3. Reconnect as user `OE`, set the client identifier to `Robert`, and then reselect from the `OE.ORDERS` table.

```
CONNECT OE
Enter password: password

EXEC DBMS_SESSION.SET_IDENTIFIER('Robert');

SELECT COUNT(*) FROM ORDERS;
```

The following output should appear:

```
  COUNT(*)
----------
       105
```

4. Reconnect as user `sysadmin_fga` and then check the audit trail again.

```
CONNECT sysadmin_fga
Enter password: password

SELECT DBUID, LSQLTEXT FROM SYS.FGA_LOG$ WHERE POLICYNAME='ORDERS_FGA_POL';
```

This time, because `Robert` has made his appearance and queried the `OE.ORDERS` table, the audit trail captures his actions:

```
DBUID            LSQLTEXT
---------------- ----------------------------
OE               SELECT COUNT(*) FROM ORDERS;
```

Step 4: Remove the Components for This Tutorial

1. Connect to SQL*Plus as user `SYSTEM`, and then drop user `sysadmin_fga` (including the objects in the `sysadmin_fga` schema).

```
CONNECT SYSTEM
Enter password: password

DROP USER sysadmin_fga CASCADE;
```

2. If you want, lock and expire OE, unless other users want to use this account:

```
ALTER USER OE PASSWORD EXPIRE ACCOUNT LOCK;
```

Auditing SYS Administrative Users

This section contains:

- Auditing User SYSTEM
- Auditing User SYS and Users Who Connect as SYSDBA and SYSOPER

Auditing User SYSTEM

You can audit the SYSTEM user by using all the standard and fine-grained audit features. Insofar as auditing is concerned, user SYSTEM is a typical database user (such as HR or OE) and requires no special configuration to be audited.

Example 9–25 shows how to audit any table insert operations issued by user SYSTEM.

Example 9–25 Auditing Table Insert Operations by User SYSTEM

```
AUDIT INSERT ANY TABLE BY SYSTEM BY ACCESS;
```

Auditing User SYS and Users Who Connect as SYSDBA and SYSOPER

You can fully audit sessions for users who connect as SYS, including all users connecting using the SYSDBA or SYSOPER privileges. This enables you to write the actions of administrative users to an operating system file, even if the AUDIT_TRAIL parameter is set to NONE, DB, or DB, EXTENDED. Writing the actions of administrator users to an operating system audit file is safer than writing to the SYS.AUD$ table, because administrative users can remove rows from this table that indicate their bad behavior.

To configure audit settings for SYSDBA and SYSOPER users:

1. Set the AUDIT_SYS_OPERATIONS initialization parameter to TRUE.

   ```
   ALTER SYSTEM SET AUDIT_SYS_OPERATIONS=TRUE SCOPE=SPFILE;
   ```

   This setting records the top-level operations directly issued by users who have connected to the database using the SYSDBA or SYSOPER privilege. It writes the audit records to the operation system audit trail. The SQL text of every statement is written to the ACTION field in the operating system audit trail record.

2. If you want to write system administrator activities to XML files, then set the AUDIT_TRAIL initialization parameter to either XML or XML, EXTENDED.

   For example:

   ```
   ALTER SYSTEM SET AUDIT_TRAIL=XML, EXTENDED SCOPE=SPFILE;
   ```

   In all operating systems, if you set AUDIT_TRAIL to either XML or XML,EXTENDED, then audit records are written as XML files in the directory specified by the AUDIT_FILE_DEST initialization parameter. By default, Oracle Database writes the audit records to operating system files.

   See Table 9–1, " AUDIT_TRAIL Initialization Parameter Settings" on page 9-10 for more information about these settings. See also "Enabling or Disabling the Standard Audit Trail" on page 9-8.

3. Restart the database.

After you restart the database, Oracle Database audits all successful actions performed by SYSDBA and SYSOPER users, and writes these audit records to the operating system audit trail, and not to the SYS.AUD$ table.

In Windows, if you have set the AUDIT_TRAIL initialization parameter OS, then Oracle Database writes audit records as events to the Event Viewer log file.

Note: The $ORACLE_BASE/admin/$ORACLE_SID/adump directory is the first default location used if the AUDIT_FILE_DEST initialization parameter is not set or does not point to a valid directory. If writing to that first default location fails or the database is closed, then Oracle Database uses the *$ORACLE_HOME/rdbms/audit* directory as the backup default location. If that attempt fails, then the audited operation fails and a message is written to the alert log.

When AUDIT_TRAIL is set to OS, audit file names continue to be in the following form:

$ORACLE_SID_short_form_process_name_processid_sequence_number.aud

The sequence number starts from number 1.

For example, the short process name ora is used for dedicated server processes, and the names s001, s002, and so on are used for shared server processes.

When AUDIT_TRAIL is set to XML or XML, EXTENDED, the same audit file names have the extension xml instead of aud.

If you do not specify the AUDIT_FILE_DEST initialization parameter, then the default location is $ORACLE_BASE/admin/$ORACLE_SID/adump in Linux and Solaris, and %ORACLE_BASE%\admin\%ORACLE_SID%\adump for Microsoft Windows. For other operating systems, refer to their audit trail documentation.

Oracle Database audits all SYS-issued SQL statements indiscriminately and regardless of the setting of the AUDIT_TRAIL initialization parameter.

Consider the following SYS session:

```
CONNECT SYS AS SYSDBA;
Enter password: password

ALTER SYSTEM FLUSH SHARED_POOL;
UPDATE salary SET base=1000 WHERE name='laurel';
```

When SYS auditing is enabled, both the ALTER SYSTEM and UPDATE statements are displayed in the operating system audit file, similar to the following output. (Be aware that this format may change in different Oracle Database releases.)

```
Tue May  5 04:53:37 2009 -07:00
LENGTH : '159'
ACTION :[7] 'CONNECT'
DATABASE USER:[1] '/'
PRIVILEGE :[6] 'SYSDBA'
CLIENT USER:[7] 'laurelh'
CLIENT TERMINAL:[5] 'pts/0'
STATUS:[1] '0'
DBID:[9] '561542328'

Tue May  5 04:53:40 2009 -07:00
```

```
LENGTH : '183'
ACTION :[30] 'ALTER SYSTEM FLUSH SHARED_POOL'
DATABASE USER:[1] '/'
PRIVILEGE :[6] 'SYSDBA'
CLIENT USER:[7] 'laurelh'
CLIENT TERMINAL:[5] 'pts/0'
STATUS:[1] '0'
DBID:[9] '561542328'

Tue May  5 04:53:49 2009 -07:00
LENGTH : '200'
ACTION :[47] 'UPDATE salary SET base=1000 WHERE name='laurel''
DATABASE USER:[1] '/'
PRIVILEGE :[6] 'SYSDBA'
CLIENT USER:[7] 'laurelh'
CLIENT TERMINAL:[5] 'pts/0'
STATUS:[1] '0'
DBID:[9] '561542328'
```

The brackets indicate the length of the value. For example, `PRIVILEGE` is set to `SYSDBA`, which uses 6 characters. In addition, the values are in single quotes for `SYS` and mandatory audit records.

Because of the superuser privileges available to users who connect as `SYSDBA`, Oracle recommends that database administrators rarely use this connection and only when necessary. Database administrators can usually perform normal day-to-day maintenance activity. These database administrators are typical database users with the `DBA` role, or have been granted privileges that are the equivalent of a `DBA` role (for example, `mydba` or `jr_dba`) that your organization customizes.

Using Triggers to Write Audit Data to a Separate Table

You can use triggers to supplement the built-in auditing features of Oracle Database. The trigger that you create records user actions to a separate database table. When an activity fires the trigger, the trigger records the action in this table. Triggers are useful when you want to record customized information such as before-and-after changes to a table. For detailed information about creating triggers, see *Oracle Database PL/SQL Language Reference*.

You do not need to have auditing enabled for the trigger to work, nor does it matter what type of auditing you do have enabled. The trigger works outside of the database audit functionality.

Follow these guidelines if you want to create audit triggers:

- **Never write the trigger so that it writes data to the SYS.AUD$ table.** In fact, you should never modify the `SYS.AUD$` table contents. If you try to write values to `SYS.AUD$` and the trigger does not work as expected, then it could adversely affect standard auditing. The `SYS.AUD$` table is an Oracle Database-owned table, and only Oracle Database should write to it.
- **If possible, create the trigger as an AFTER trigger.** The triggering statement is subjected to any applicable constraints. If no records are found, then the `AFTER` trigger does not fire, and audit processing is not carried out unnecessarily.
- **Create the trigger as either an AFTER row or AFTER statement trigger**. Choosing between `AFTER` row and `AFTER` statement triggers depends on the information being audited. For example, row triggers provide value-based auditing for each table row. Triggers can also require you to supply a reason code for issuing the

audited SQL statement, which can be useful in both row and statement-level auditing situations.

Table 9–5 provides a comparison of trigger-based auditing and the built-in database auditing features.

Table 9–5 Comparison of Built-in Auditing and Trigger-Based Auditing

Audit Feature	Description
DML and DDL auditing	Standard auditing options permit auditing of DML and DDL statements regarding all types of schema objects and structures. Comparatively, triggers permit auditing of DML statements entered against tables, and DDL auditing at `SCHEMA` or `DATABASE` level.
Centralized audit trail	All database audit information is recorded centrally and automatically using the auditing features of the database.
Declarative method	Auditing features enabled using the standard database features are easier to declare and maintain, and less prone to errors, when compared to auditing functions defined by triggers.
Auditing options can be audited	Any changes to existing auditing options can also be audited to guard against malicious database activity.
Session and execution time auditing	Using the database auditing features, records are generated once every time an audited statement is entered. With triggers, an audit record is generated each time a trigger-audited table is referenced.
Auditing of unsuccessful data access	Database auditing can be set to audit when unsuccessful data access occurs. However, unless autonomous transactions are used, any audit information generated by a trigger is rolled back if the triggering statement is rolled back. For more information about autonomous transactions, see *Oracle Database Concepts*.
Sessions can be audited	Connections, disconnections, and session activity (physical I/Os, logical I/Os, deadlocks, and so on) can be recorded using standard database auditing.

In Example 9–26, a trigger audits modifications to the `emp_tab` table for specific rows. The trigger writes the old and new values to the `emp_audit_tab` table, including the user who performed the update and the time the update took place.

Example 9–26 Audit Trigger to Record Before and After Changes to a Table

```
/* 1. Create the following table: */
CREATE TABLE emp_tab (
   empno               NUMBER(4),
   ename               VARCHAR2(10),
   job                 VARCHAR2(9),
   mgr                 NUMBER(4),
   hiredate            DATE,
   sal                 NUMBER(8,2),
   deptno              NUMBER(2));

/* 2. Create a table to capture the audit data. */
CREATE TABLE emp_audit_tab (
   oldname             VARCHAR2(10),
   oldjob              VARCHAR2(9),
   oldsal              NUMBER (8,2),
   newname             VARCHAR2(10),
   newjob              VARCHAR2(9),
   newsal              NUMBER(8,2),
   user1               varchar2(10),
```

```
   systemdate          TIMESTAMP);

/* 3. Create a trigger to record the old and new values, the author of the change,
      and when the change took place. */
CREATE OR REPLACE TRIGGER emp_audit_trig
  AFTER INSERT OR DELETE OR UPDATE ON emp_tab
  FOR EACH ROW
BEGIN
   INSERT INTO emp_audit_tab (
   oldname, oldjob, oldsal,
   newname, newjob, newsal,
   user1, systemdate
  )
  VALUES (
    :OLD.ename, :OLD.job, :OLD.sal,
    :NEW.ename, :NEW.job, :NEW.sal,
    user, sysdate
  );
END;
/
```

To test this trigger, add a row to the `emp_tab` table, and then change the value the `ename`, `job`, or `sal` column in the `emp_tab` table. Then query the `emp_audit_tab` table to find the audit data.

Managing Audit Trail Records

This section contains:

- About Audit Records
- Managing the Database Audit Trail
- Managing the Operating System Audit Trail

About Audit Records

Audit records include information about the operation that was audited, the user who performed the operation[2], and the date and time of the operation. Depending on the type of auditing you choose, you can write audit records to data dictionary tables, called the **database audit trail**, or in operating system files, called the **operating system audit trail**.

If you choose to write audit records to the database audit trail, Oracle Database writes the audit records to the `SYS.AUD$` table for default and standard auditing, and to the `SYS.FGA_LOG$` table for fine-grained auditing. Both of these tables reside in the `SYSTEM` tablespace and are owned by the `SYS` schema. You can check the contents of these tables by querying the following data dictionary views:

- `DBA_AUDIT_TRAIL` for the `SYS.AUD$` contents
- `DBA_FGA_AUDIT_TRAIL` for the `SYS.FGA_LOG$` contents
- `DBA_COMMON_AUDIT_TRAIL` for both `SYS.AUD$` and `SYS.FGA_LOG$` contents

[2] Oracle Database records the actions of both database and nondatabase users in the `SYS.AUD$` and `SYS.FGA_LOG$` tables. The `CLIENTID` column in these tables records the name of the nondatabase user. The `USERID` column in the `SYS.AUD$` table and the `DBUID` column of the `SYS.FGA_LOG$` store the database user account. For nondatabase users, the `USERID` and `DBUID` columns store the database user account that was created to enable the nondatabase user access to the database. The `DBA_AUDIT_TRAIL`, `DBA_FGA_AUDIT_TRAIL`, and `DBA_COMMON_AUDIT_TRAIL` views store this information in the `CLIENT_ID`, `USERNAME`, and `DB_USER` columns.

"Finding Information About Audited Activities" on page 9-80 describes more data dictionary views that you can use to view to contents of the SYS.AUD$ and SYS.FGA_LOG$ tables.

If you choose to write audit records to an operating system file, you can write them to either a text file or to an XML file. You can check the contents of the audit XML files by querying the V$XML_AUDIT_TRAIL data dictionary view.

Managing the Database Audit Trail

This section contains:

- Database Audit Trail Contents
- Controlling the Size of the Database Audit Trail
- Moving the Database Audit Trail to a Different Tablespace
- Protecting the Database Audit Trail
- Auditing the Database Audit Trail
- Archiving the Database Audit Trail

See Also: "Purging Audit Trail Records" on page 9-65

Database Audit Trail Contents

The database audit trail is a pair of tables, AUD$ (for standard auditing) and FGA_LOG$ (for fine-grained auditing), in the SYS schema of each Oracle Database data dictionary. It records both standard and fine-grained audit activities. Several data dictionary views can help you use the information in this table. "Finding Information About Audited Activities" on page 9-80 lists all the auditing-related views.

The database audit trail record contains different types of information, depending on the events audited and the auditing options set. For example, if you have set the AUDIT_TRAIL initialization parameter to DB, EXTENDED or XML, EXTENDED, then the SQL_BIND and SQL_TEXT columns show any SQL bind variables used for a SQL statement and SQL text that triggered the audit, respectively. For full details about the contents of these views, refer to *Oracle Database Reference*. However, be aware that the format and columns of the DBA_AUDIT_TRAIL view may change across Oracle Database releases.

Note: If the AUDIT_TRAIL initialization parameter is set to XML or XML, EXTENDED, then Oracle Database sends standard audit records to operating system files in XML format. Because XML is a standard document format, many utilities are available to parse and analyze XML data.

If the database destination for audit records becomes full or unavailable, and, therefore, unable to accept new records, then an audited action cannot complete. Instead, Oracle Database generates an error message and does not audit the action. You can control the size of the audit trail to make it more manageable. (In fact, Oracle strongly recommends that you do so.) See "Controlling the Size of the Database Audit Trail" on page 9-59 for more information. See also "Keeping Audited Information Manageable" on page 10-18.

The audit trail does not store information about any data values that might be involved in the audited statement. For example, old and new data values of updated

rows are not stored when an UPDATE statement is audited. However, you can perform this specialized type of auditing by using fine-grained auditing methods.

You can use the Flashback Query feature to show the old and new values of the updated rows, subject to any auditing policy presently in force. The current policies are enforced even if the flashback is to an old query that was originally subject to a different policy. Current business access rules always apply.

See Also:

- "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36 for more information about methods of fine-grained auditing
- *Oracle Database Administrator's Guide* for information about auditing table changes by using Flashback Transaction Query
- Flashback entries in the table of system privileges listed in the GRANT SQL statement section of *Oracle Database SQL Language Reference*

Note: You can find information about the log history by querying the V$LOGMNR_CONTENTS data dictionary view. The CLIENT_ID column of this view records changes to the session client identifier. To query this view, you must have the SELECT ANY TRANSACTION system privilege.

Controlling the Size of the Database Audit Trail

If the database audit trail is full and no more audit records can be inserted, then underlying statement cannot complete successfully until you purge the audit trail. Oracle Database issues errors to all users who issue statements that cause the audit. Therefore, you must control the growth and size of the audit trail.

When auditing is enabled and audit records are being generated, the audit trail increases according to two factors:

- The number of audit options turned on
- The frequency of execution of audited statements

To control the growth of the audit trail, you can use the following methods:

- **Enable and disable database auditing.** If it is enabled, then audit records are generated and stored in the audit trail. If it is disabled, then audit records are not generated. (Remember that some activities are always audited.)
- **Be selective about the audit options that are turned on.** If more selective auditing is performed, then useless or unnecessary audit information is not generated and stored in the audit trail. You can use fine-grained auditing to selectively audit only certain conditions.
- **Tightly control the ability to perform object auditing.** You can accomplish this in the following ways:
  - A security administrator owns all objects and never grants the AUDIT ANY system privilege to any other user. Alternatively, all schema objects can belong to a schema for which the corresponding user does not have CREATE SESSION privilege.
  - All objects are contained in schemas that do not correspond to real database users (that is, the CREATE SESSION privilege is not granted to the

corresponding user). The security administrator is the only user granted the AUDIT ANY system privilege.

In both scenarios, a security administrator controls entirely object auditing.

The maximum size of the database audit trail tables (AUD$ and FGA_LOG$) is determined by the default storage parameters of the SYSTEM tablespace, in which it is stored by default. If you are concerned that a too-large database audit trail will affect the SYSTEM table performance, then consider moving the database audit trail tables to a different tablespace.

> **See Also:** Operating system-specific Oracle Database documentation for more information about managing the operating system audit trail when directing audit records to that location

Moving the Database Audit Trail to a Different Tablespace

By default, the SYSTEM tablespace stores the database audit trail SYS.AUD$ and SYS.FGA_LOG$ tables. You can change this default location to another tablespace, such as the SYSAUX tablespace or a user-created tablespace. You may want to move the database audit trail tables to a different tablespace if the SYSTEM tablespace is too busy. Another reason for moving these audit trail tables to a different tablespace is if you plan to purge them by using the DBMS_AUDIT_MGMT PL/SQL package procedures.

Be aware that moving the database audit trail tables to a different tablespace can take a long time, depending on the amount of audit data in the audit tables, so you may want to do this during a time when database activity is slow.

To move the database audit trail from SYSTEM to a different tablespace:

1. Log in to SQL*Plus as an administrator who has the EXECUTE privilege on the DBMS_AUDIT_MGMT PL/SQL package.

   For more information about the DBMS_AUDIT_MGMT PL/SQL package, see *Oracle Database PL/SQL Packages and Types Reference*.

2. Check the tablespace to which you want to move the database audit trail tables.

   You may need to optimize and allocate more space to this tablespace, including the SYSAUX auxiliary tablespace. For more information, see *Oracle Database Performance Tuning Guide*.

3. Run the DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_LOCATION PL/SQL procedure to specify the name of the destination tablespace.

   For example:

```
BEGIN
 DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_LOCATION(
  AUDIT_TRAIL_TYPE            => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
  AUDIT_TRAIL_LOCATION_VALUE  => 'AUD_AUX');
END;
```

   In this example:

   - AUDIT_TRAIL_TYPE: Refers to the database audit trail type. Enter one of the following values:
     - DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD: Standard audit trail table, AUD$.
     - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD: Fine-grained audit trail table, FGA_LOG$.

  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD: Both standard and fine-grained audit trail tables.

- AUDIT_TRAIL_LOCATION_VALUE: Specifies the destination tablespace. This example specifies a tablespace named AUD_AUX.

Auditing the Database Audit Trail

At times an application must give the SYS.AUD$ system table access to regular users (non-SYSDBA users). For example, an audit report generator needs access to AUD$ table to generate daily reports on possible violations. Also, many installations have a distinct auditor role to achieve separation of duty.

In this case, be aware that DML statements such as INSERT, UPDATE, MERGE, and DELETE are always audited and recorded in the SYS.AUD$ table. You can check these activities by querying the DBA_AUDIT_TRAIL and DBA_COMMON_AUDIT_TRAIL views.

If a user has SELECT, UPDATE, INSERT, and DELETE privileges on SYS.AUD$ and executes a SELECT operation, then the audit trail will have a record of that operation. That is, SYS.AUD$ will have a row identifying the SELECT action on itself, as for example row 1.

If a user later tries to delete this row from SYS.AUD$, then the DELETE operation succeeds, because the user has the privilege to perform this action. However, this DELETE action on SYS.AUD$ is also recorded in the audit trail. Setting up this type of auditing acts as a safety feature, potentially revealing unusual or unauthorized actions.

Note: DELETE, INSERT, UPDATE, and MERGE operations on the SYS.AUD$ and SYS.FGA_LOG$ tables are always audited. These audit records are not allowed to be deleted.

See Also: "Auditing Sensitive Information" on page 10-18

Archiving the Database Audit Trail

You should periodically archive and then purge the audit trail to prevent it from growing too large. Archiving and purging both frees audit trail space and facilitates the purging of the database audit trail. See "Purging Audit Trail Records" on page 9-65 for different ways of purging the audit trail records.

You can create an archive of the database audit trail by using one of the following methods:

- **Oracle Audit Vault.** You install Oracle Audit Vault separately from Oracle Database. For more information, see *Oracle Audit Vault Administrator's Guide*.
- **Oracle Data Warehouse.** Oracle Data Warehouse is automatically installed with Oracle Database. For more information, see *Oracle Warehouse Builder Installation and Administration Guide*.

After you complete the archive, you can purge the database audit trail contents. See "Purging Audit Trail Records" on page 9-65 for more information.

To archive standard and fine-grained audit records, you can copy the relevant records to a normal database table. For example:

```
INSERT INTO table SELECT ... FROM SYS.AUD$ ...;
INSERT INTO table SELECT ... FROM SYS.FGA_LOG$ ...;
```

See Also: The following sections for information about different ways of purging the database audit trail

- "Scheduling an Automatic Purge Job for the Audit Trail" on page 9-67
- "Manually Purging the Audit Trail" on page 9-72
- "Purging a Subset of Records from the Database Audit Trail" on page 9-74

Managing the Operating System Audit Trail

This section contains:

- If the Operating System Audit Trail Becomes Full
- Setting the Size of the Operating System Audit Trail
- Setting the Age of the Operating System Audit Trail
- Archiving the Operating System Audit Trail

See Also:

- "Purging Audit Trail Records" on page 9-65
- "Using the Syslog Audit Trail on UNIX Systems" on page 9-18
- "Activities That Are Always Audited for All Platforms"

If the Operating System Audit Trail Becomes Full

Be aware that an operating system audit trail or file system, including the Windows Event Log, can become full, and therefore, unable to accept new records, including audit records from Oracle Database. In this case, Oracle Database cancels and rolls back the operation being performed, including operations that normally are always audited. (See "Activities That Are Always Audited for All Platforms" on page 9-4.) If the operating system audit trail becomes full, then set the `AUDIT_TRAIL` parameter to use database audit trail (such as `DB` or `DB, EXTENDED`). This prevents the audited actions from completing if their audit records cannot be stored. You should periodically archive and purge the operating system audit file to prevent these types of failures.

If you plan to use operating system auditing, then ensure that the operating system audit trail or the file system does not fill completely. Most operating systems provide administrators with sufficient information and warning to ensure this does not occur. If you configure auditing to use the database audit trail, you can prevent this potential loss of audit information. Oracle Database prevents audited events from occurring if the audit trail is unable to accept the database audit record for the statement.

Periodically archive and then purge the operating system audit trail. See "Archiving the Operating System Audit Trail" on page 9-65 and "Purging Audit Trail Records" on page 9-65for more information.

Setting the Size of the Operating System Audit Trail

To control the size of the operating system audit trail, set the `DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE` property by using the `DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY` PL/SQL procedure. Remember that you must have the `EXECUTE` privilege for the `DBMS_AUDIT_MGMT` PL/SQL package before you can use it. When the operating system file meets the size limitation you set, Oracle Database stops adding records to the current

file and then creates a new operating system file for the subsequent records. For more information about the DBMS_AUDIT_MGMT PL/SQL package, see *Oracle Database PL/SQL Packages and Types Reference*.

If you set both the DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE and the DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE (described in "Setting the Age of the Operating System Audit Trail" on page 9-64) properties, then Oracle Database performs the action based the property value limit that is met first.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY(
   AUDIT_TRAIL_TYPE            =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS,
   AUDIT_TRAIL_PROPERTY        =>  DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE,
   AUDIT_TRAIL_PROPERTY_VALUE  =>  10240);
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Specifies the operating system audit trail. Enter one of the following values:
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS: Operating system audit trail files with the .aud extension. (This setting does not apply to Windows Event Log entries. Nor does it apply to syslog audit records, when the AUDIT_SYSLOG_LEVEL initialization parameter is set.)
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML: XML audit trail files.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FILES: Both operating system and XML audit trail files.
- AUDIT_TRAIL_PROPERTY: Specifies the DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE property, which sets the maximum size. To find the status of the current property settings, query the PARAMETER_NAME and PARAMETER_VALUE columns of the DBA_AUDIT_MGMT_CONFIG_PARAMS data dictionary view.
- AUDIT_TRAIL_PROPERTY_VALUE: Sets the maximum size to 10240 kilobytes, that is, 10 megabytes. The default setting is 10,000 kilobytes (approximately 10 megabytes). Do not exceed 2 gigabytes.

Clearing the DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE Setting

To clear the maximum file size setting, use the DBMS_AUDIT_MGMT.CLEAR_AUDIT_TRAIL_PROPERTY procedure.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.CLEAR_AUDIT_TRAIL_PROPERTY(
   AUDIT_TRAIL_TYPE         =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS,
   AUDIT_TRAIL_PROPERTY     =>  DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE,
   USE_DEFAULT_VALUES       =>  TRUE );
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Specifies the operating system audit trail. Enter one of the AUDIT_TRAIL_TYPE values described in "Setting the Size of the Operating System Audit Trail" on page 9-62.

- AUDIT_TRAIL_PROPERTY: Specifies the DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE property. You can query the DBA_AUDIT_MGMT_CONFIG_PARAMS data dictionary view to find the current status of this property.
- USE_DEFAULT_VALUES: Enter one of the following values:
  - TRUE: Clears the current value and uses the default value, 10,000 kilobytes, instead.
  - FALSE: Oracle Database does not use a default maximum size for the operating system or XML file growth. The files will continue to grow without limitation unless you configure the DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE property. The default setting is FALSE.

Setting the Age of the Operating System Audit Trail

To control the age of the operating system audit trail, use the DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY PL/SQL procedure. Remember that you must have the EXECUTE privilege for the DBMS_AUDIT_MGMT PL/SQL package before you can use it. When the operating system file meets the age limitation you set, Oracle Database stops adding records to the current file and then creates a new operating system file for the subsequent records. For more information about the DBMS_AUDIT_MGMT PL/SQL package, see *Oracle Database PL/SQL Packages and Types Reference*.

If you set both the DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE and the DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE (described in "Setting the Size of the Operating System Audit Trail" on page 9-62) properties, then Oracle Database controls the growth of the Audit file based on the property value limit that is met first.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY(
   AUDIT_TRAIL_TYPE            =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS,
   AUDIT_TRAIL_PROPERTY        =>  DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE,
   AUDIT_TRAIL_PROPERTY_VALUE  =>  10 );
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Specifies the operating system audit trail. Enter one of the following values:
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS: Operating system audit trail files with the .aud extension. (This setting does not apply to Windows Event Log entries. Nor does it apply to syslog audit records, when the AUDIT_SYSLOG_LEVEL initialization parameter is set.)
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML: XML audit trail files.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FILES: Both operating system and XML audit trail files.
- AUDIT_TRAIL_PROPERTY: Specifies the DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE property to set the maximum age. To find the status of the current property setting, query the DBA_AUDIT_MGMT_CONFIG_PARAMS data dictionary view.
- AUDIT_TRAIL_PROPERTY_VALUE: Sets the maximum age to 10 days. Enter a value between 1 and 495. The default age is 5 days.

Clearing the DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE Setting

To clear the maximum file age setting, use the `DBMS_AUDIT_MGMT.CLEAR_AUDIT_TRAIL_PROPERTY` procedure.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.CLEAR_AUDIT_TRAIL_PROPERTY(
   AUDIT_TRAIL_TYPE         =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS,
   AUDIT_TRAIL_PROPERTY     =>  DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE,
   USE_DEFAULT_VALUES       =>  TRUE );
END;
/
```

In this example:

- `AUDIT_TRAIL_TYPE`: Specifies operating system audit trail. Enter one of the `AUDIT_TRAIL_TYPE` values listed in "Setting the Age of the Operating System Audit Trail" on page 9-64.
- `AUDIT_TRAIL_PROPERTY`: Specifies the `DBMS_AUDIT_MGMT.OS_FILE_MAX_AGE` property. Query the `PARAMETER_NAME` and `PARAMETER_VALUE` columns of the `DBA_AUDIT_MGMT_CONFIG_PARAMS` data dictionary view to find the current status of this property.
- `USE_DEFAULT_VALUES`: Specify one of the following values:
  - `TRUE`: Clears the current value and uses the default value, 5 days, instead.
  - `FALSE`: Oracle Database does not use a default maximum age for the operating system or XML file growth. In this case, the files will continue to age without limitation unless you configure the `DBMS_AUDIT_MGMT.OS_FILE_MAX_SIZE` property. The default setting is `FALSE`.

Archiving the Operating System Audit Trail

You should periodically archive the operating system audit trail. Use your platform-specific operating system tools to create an archive of the operating system audit files.

Use the following methods to archive the operating system audit files:

- **Use Oracle Audit Vault.** You install Oracle Audit Vault separately from Oracle Database. For more information, see *Oracle Audit Vault Administrator's Guide*.
- **Create tape or disc backups.** You can create a compressed file of the audit files, and then store it on tapes or discs. Consult your operating system documentation for more information.

Afterwards, you should purge (delete) the operating system audit records both to free audit trail space and to facilitate audit trail management. See "Purging Audit Trail Records" on page 9-65 for different ways that you can use to purge the operating system audit trail records.

Purging Audit Trail Records

This section contains:

About Purging Audit Trail Records

You should periodically archive and then delete (purge) audit trail records, because the audit trail cannot accept new records if it grows too large. This section describes a variety of ways that you can use to purge both the database and operating system audit trail records. You can purge a subset of database audit trail records. For both database and operating system audit trail types, you can manually purge the records or create a purge job that performs at a specified time interval. In that case, the purge operation either purges the audit trail records that were created before the archive timestamp, or it purges all audit trail records.

To perform the audit trail purge tasks, in most cases, you use the `DBMS_AUDIT_MGMT` PL/SQL package. You must have the `EXECUTE` privilege for `DBMS_AUDIT_MGMT` before you can use it.

If you have Oracle Audit Vault installed, the audit trail purge process differs from the procedures described in this manual. For example, Oracle Audit Vault archives the audit trail for you. See *Oracle Audit Vault Administrator's Guide*.

Note: Oracle Database audits all deletions from the audit trail, without exception. See "Auditing the Database Audit Trail" on page 9-61 and "Auditing SYS Administrative Users" on page 9-53.

See Also:

- *Oracle Database PL/SQL Packages and Types Reference* for more information about the `DBMS_AUDIT_MGMT` PL/SQL package
- *Oracle Database Reference* for detailed information about the `DBA_AUDIT_MGMT`-related views

Selecting an Audit Trail Purge Method

Table 9–6 provides a roadmap for selecting an audit trail purge method.

Table 9–6 Selecting an Audit Trail Purge Method

What Do You Want to Purge?	About This Type of Purge Method
All audit records, or audit records created before a specified timestamp, on a regularly scheduled basis	You can schedule a purge operation to occur an specific times. For example, you can schedule it for every Saturday at 2 a.m. **General steps:** 1. If necessary, tune online and archive redo log sizes to accommodate the additional records generated during the audit table purge process. 2. Plan a timestamp and archive strategy. 3. Initialize the audit trail cleanup operation. 4. Set an archive timestamp for the audit records. 5. Create and schedule the purge job. 6. Optionally, configure the audit trail to be deleted in batches. See "Scheduling an Automatic Purge Job for the Audit Trail" on page 9-67 for more information.
All audit records, or records that were created before a specified timestamp, when you want	You can manually purge the audit records right away in a one-time operation, rather than creating a purge schedule. **General steps:** 1. If necessary, tune online and archive redo log sizes to accommodate the additional records generated during the audit table purge process. 2. Plan a timestamp and archive strategy. 3. Initialize the audit trail cleanup operation. 4. Set an archive timestamp for the audit records. 5. Optionally, configure the audit trail to be deleted in batches. 6. Run the purge operation. See "Manually Purging the Audit Trail" on page 9-72 for more information.
Just a subset of the audit records from the database audit trail	You can manually purge just a subset of the audit records. For example, you can delete all audit records that were created between May 14, 2010 and June 14, 2010. **General steps:** 1. If necessary, tune online and archive redo log sizes to accommodate the additional records generated during the audit table purge process. 2. Archive the audit records you want to purge. 3. As a user with administrative privileges, delete from the `SYS.AUD$` table. See "Purging a Subset of Records from the Database Audit Trail" on page 9-74 for more information.

Scheduling an Automatic Purge Job for the Audit Trail

You can purge the entire audit trail, or only a portion of the audit trail that was created before a timestamp. For the database audit trail, the individual audit records created before the timestamp can be purged. For the operating system audit trail, you purge audit files that were created before the timestamp.

Be aware that purging the audit trail, particularly a large one, can take a while to complete. Consider scheduling the purge job so that it runs during a time when the database is not busy.

You can create multiple purge jobs for different audit trail types, so long as they do not conflict. For example, you can create a purge job for the standard audit trail table and then the fine-grained audit trail table. However, you cannot then create a purge job for

both or all types, that is, by using the DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD or DBMS_AUDIT_MGMT.AUDIT_TRAIL_ALL property.

To create and schedule an automatic purge job:

- Step 1: If Necessary, Tune Online and Archive Redo Log Sizes
- Step 2: Plan a Timestamp and Archive Strategy
- Step 3: Initialize the Audit Trail Cleanup Operation
- Step 4: Optionally, Set an Archive Timestamp for Audit Records
- Step 5: Create and Schedule the Purge Job
- Step 6: Optionally, Configure the Audit Trail Records to be Deleted in Batches

Step 1: If Necessary, Tune Online and Archive Redo Log Sizes

The purge process may generate additional redo logs. Before you run this process, you may need to tune online and archive redo log sizes to accommodate the additional records generated during the audit table purge process. For more information about tuning log files, see *Oracle Database Performance Tuning Guide* and *Oracle Database Administrator's Guide*.

Step 2: Plan a Timestamp and Archive Strategy

You must record the timestamp of the database and operating system audit records before you can archive them. You can check the timestamp date by querying the DBA_AUDIT_MGMT_LAST_ARCH_TS data dictionary view. Later on, when the purge takes place, Oracle Database purges only the audit trail records that were created before the date of this timestamp. See "Step 4: Optionally, Set an Archive Timestamp for Audit Records" on page 9-69 for more information.

After you have timestamped the records, you are ready to archive them. See the following sections for more information:

- "Archiving the Database Audit Trail" on page 9-61
- "Archiving the Operating System Audit Trail" on page 9-65

Step 3: Initialize the Audit Trail Cleanup Operation

Before you can purge the audit trail by using the DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL PL/SQL procedure, you must initialize the audit trail for the cleanup operation. For the database audit trail, if you have not moved the database audit trail tables (SYS.AUD$ and SYS.FGA_LOG$) from the SYSTEM tablespace to another tablespace, this process moves these tables to the SYSAUX tablespace or to the tablespace that you specified in "Moving the Database Audit Trail to a Different Tablespace" on page 9-60. Be aware that moving these tables takes a while, so you may want to schedule the initialization process during time when the database is not busy.

To initialize the audit trail cleanup operation:

1. Log in to SQL*Plus as an administrative user who has the EXECUTE privilege on the DBMS_AUDIT_MGMT PL/SQL package.
2. If you have not done so already, initialize the audit trail cleanup operation by running the DBMS_AUDIT_MGMT.INIT_CLEANUP procedure. (You only need to perform this step once.

   You can check if the audit trail has been initialized for cleanup by running the DBMS_AUDIT_MGMT.IS_CLEANUP_INITIALIZED function. See "Verifying That the Audit Trail Is Initialized for Cleanup" on page 9-75.)

For example:

```
BEGIN
 DBMS_AUDIT_MGMT.INIT_CLEANUP(
  AUDIT_TRAIL_TYPE            => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
  DEFAULT_CLEANUP_INTERVAL    => 12 );
END;
/
```

In this specification:

- AUDIT_TRAIL_TYPE: Enter one of the following values:
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD: Standard audit trail table, AUD$.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD: Fine-grained audit trail table, FGA_LOG$.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD: Both standard and fine-grained audit trail tables.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS: Operating system audit trail files with the .aud extension. (This setting does not apply to Windows Event Log entries.)
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML: XML Operating system audit trail files.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FILES: Both operating system and XML audit trail files.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_ALL: All audit trail records, that is, both database audit trail and operating system audit trail types.
- DEFAULT_CLEANUP_INTERVAL: Specify the desired default hourly purge interval (for example, 12 for every 12 hours). The DBMS_AUDIT_MGMT procedures use this value to determine how to purge audit records. The timing begins when you run the DBMS_AUDIT_MGMT.INIT_CLEANUP procedure. To update this value later, set the DBMS_AUDIT_MGMT.CLEAN_UP_INTERVAL property of the DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY procedure.

  The DEFAULT_CLEANUP_INTERVAL setting must indicate the frequency in which DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL is called. If you are uncertain about the frequency, set it to an approximate value. You can change this value later on by using the DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY procedure.

Step 4: Optionally, Set an Archive Timestamp for Audit Records

If you want to delete all of the audit trail, you can bypass this step.

You can set a timestamp when the last audit record was archived. Setting an archive timestamp provides a hint to the cleanup infrastructure that the cleanup operation will be invoked every 6 hours.

For the database audit trail, you must set the timestamp after you have initialized the audit trail cleanup operation. To find the last archive timestamps for the audit trail, you can query the DBA_AUDIT_MGMT_LAST_ARCH_TS data dictionary view. After you set the timestamp, all audit records in the audit trail that indicate a time earlier than that timestamp are purged when you run the DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL PL/SQL procedure. If you want to clear the archive timestamp setting, see "Clearing the Archive Timestamp Setting" on page 9-78.

For the operating system audit trail, remember that you cannot delete individual audit records in the operating system (including XML) audit files. Instead, Oracle Database removes the entire file that contains the timestamped records.

If you are using Oracle Real Application Clusters (Oracle RAC), then use Network Time Protocol (NTP) to synchronize the time on each computer where you have installed an Oracle Database instance. For example, suppose you set the time for one Oracle RAC instance node at 11:00:00 a.m. and then set the next Oracle RAC instance node at 11:00:05. As a result, the two nodes have inconsistent times. You can use Network Time Protocol (NTP) to synchronize the times for these Oracle RAC instance nodes.

To set the timestamp, use the `DBMS_AUDIT_MGMT.SET_LAST_ARCHIVE_TIMESTAMP` PL/SQL procedure.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.SET_LAST_ARCHIVE_TIMESTAMP(
   AUDIT_TRAIL_TYPE     =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   LAST_ARCHIVE_TIME    =>  '2009-05-28 06:30:00.00'
   RAC_INSTANCE_NUMBER  =>  0 );
END;
/
```

In this example:

- `AUDIT_TRAIL_TYPE`: Enter one of the following settings:
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD`: Specified the standard audit trail table, `AUD$`.
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD`: Specifies the fine-grained audit trail table, `FGA_LOG$`.
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS`: Operating system audit trail files with the `.aud` extension. (This setting does not apply to Windows Event Log entries.)
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML`: Specifies XML audit trail files.
- `LAST_ARCHIVE_TIME`: Enter the timestamp in `YYYY-MM-DD HH:MI:SS.FF` UTC (Coordinated Universal Time) format for `AUDIT_TRAIL_DB_AUD` and `AUDIT_TRAIL_FGA_STD` (standard and fine-grained audit trails), and in the Local Time Zone for `AUDIT_TRAIL_OS` and `AUDIT_TRAIL_XML` (operating system and XML audit trails).
- `RAC_INSTANCE_NUMBER`: Specifies the instance number for an Oracle RAC installation. If you specified the `DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD` or `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD` audit trail types, you can omit the `RAC_INSTANCE_NUMBER` argument. This is because there is only one `AUD$` and `FGA_LOG$` table, even for an Oracle RAC installation. The default is `0`, which is used for single-instance database installations.

Typically, after you set the timestamp, you can use the `DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL` PL/SQL procedure to remove the audit records that were created before the timestamp date.

Step 5: Create and Schedule the Purge Job

Create and schedule the purge job by running the `DBMS_AUDIT_MGMT.CREATE_PURGE_JOB` PL/SQL procedure.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.CREATE_PURGE_JOB (
   AUDIT_TRAIL_TYPE            => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   AUDIT_TRAIL_PURGE_INTERVAL  => 12,
   AUDIT_TRAIL_PURGE_NAME      => 'Standard_Audit_Trail_PJ',
   USE_LAST_ARCH_TIMESTAMP     => TRUE );
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Enter one of the following values:
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD: Standard audit trail table, AUD$
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD: Fine-grained audit trail table, FGA_LOG$
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD: Both standard and fine-grained audit trail tables
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS: Operating system audit trail files with the .aud extension. (This setting does not apply to Windows Event Log entries.)
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML: XML audit trail files
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FILES: Both operating system and XML audit trail files
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_ALL: All audit trail records, that is, both database audit trail and operating system audit trail types
- AUDIT_TRAIL_PURGE_INTERVAL: Specify the hourly interval for this purge job to run. The timing begins when you run the DBMS_AUDIT_MGMT.CREATE_PURGE_JOB procedure, in this case, 12 hours after you run this procedure. Later on, if you want to update this value, run the DBMS_AUDIT_MGMT.SET_PURGE_JOB_INTERVAL procedure.
- USE_LAST_ARCH_TIMESTAMP: Enter either of the following settings:
  - TRUE: Deletes audit records created before the last archive timestamp. To check the last recorded timestamp, query the LAST_ARCHIVE_TS column of the DBA_AUDIT_MGMT_LAST_ARCH_TS data dictionary view. The default value is TRUE. Oracle recommends that you set USE_LAST_ARCH_TIMESTAMP to TRUE.
  - FALSE: Deletes all audit records without considering last archive timestamp. Be careful about using this setting, in case you inadvertently delete audit records that should not have been deleted.

Step 6: Optionally, Configure the Audit Trail Records to be Deleted in Batches

By default, the DBMS_AUDIT_MGMT package procedures delete the database and operating system audit trail records in batches of 10000 database audit records, or 1000 operating system audit files. You can set this batch size to a different value if you want. Later on, when Oracle Database runs the purge job, it deletes each batch, rather than all records together. If the audit trail is very large (and they can grow quite large), deleting the records in batches facilitates the purge operation.

To find the current batch setting, you can query the PARAMETER_NAME and PARAMETER_VALUE columns of the DBA_AUDIT_MGMT_CONFIG_PARAMS data dictionary view. To set the batch size, use the DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY procedure. If you later want to clear this setting, see "Clearing the Database Audit Trail Batch Size" on page 9-78.

For example:

```
BEGIN
 DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY(
  AUDIT_TRAIL_TYPE            => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
  AUDIT_TRAIL_PROPERTY        => DBMS_AUDIT_MGMT.DB_DELETE_BATCH_SIZE,
  AUDIT_TRAIL_PROPERTY_VALUE  => 100000);
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Specifies the audit trail type, which in this case is the database system audit trail. Enter one of the following values:
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD: Standard audit trail table, AUD$.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD: Fine-grained audit trail table, FGA_LOG$.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS: Operating system audit files.
  - DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML: XML audit files.
- AUDIT_TRAIL_PROPERTY: Uses the DBMS_AUDIT_MGMT.DB_DELETE_BATCH_SIZE property to indicate the database audit trail batch size setting. If you want to batch the operating system audit trail, then use the FILE_DELETE_BATCH_SIZE property.
- AUDIT_TRAIL_PROPERTY_VALUE: Sets the number of audit record files to be 100,000 for each batch. Enter a value between 100 and 1000000. To determine this number, consider the total number of records being purged, and the time interval in which the purge operation is performed. The default is 10000 for the database audit trail and 1000 for the operating system audit trail records.

Manually Purging the Audit Trail

You can manually purge the audit trail right away, without scheduling a purge job. Similar to a purge job, you can purge audit trail records that were created before an archive timestamp date or all the records in the audit trail.

Note the following about the DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL PL/SQL procedure:

- Only the current audit directory is cleaned up when you run this procedure.
- On Microsoft Windows, because the DBMS_AUDIT_MGMT package does not support cleanup of Windows Event Viewer, setting the AUDIT_TRAIL_TYPE property to DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS has no effect. This is because operating system audit records on Windows are written to Windows Event Viewer. The DBMS_AUDIT_MGMT package does not support this type of cleanup operation.
- On UNIX platforms, if you set the AUDIT_SYSLOG_LEVEL initialization parameter to a valid value as listed in *Oracle Database Reference*, then Oracle Database writes the operating system log files to syslog files. If you set the AUDIT_TRAIL_TYPE property to DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS, then the procedure only removes .aud files under audit directory (This directory is specified by the AUDIT_FILE_DEST initialization parameter).
- When the AUDIT_TRAIL_TYPE parameter is set to DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML, this procedure only cleans up XML audit files (.xml) in the current audit directory. Oracle Database maintains an index file, called adx_*$ORACLE_SID*.txt,

which lists the XML files that were generated by the XML auditing. The cleanup procedure does not remove this file.

For database audit trails, you must initialize the cleanup infrastructure by running the `DBMS_AUDIT_MGMT.INIT_CLEANUP` procedure, and then purging the database audit trail by using the method described in "Purging a Subset of Records from the Database Audit Trail" on page 9-74.

To manually purge the audit trail:

1. Follow these steps under "Scheduling an Automatic Purge Job for the Audit Trail" on page 9-67:
   - Step 1: If Necessary, Tune Online and Archive Redo Log Sizes
   - Step 2: Plan a Timestamp and Archive Strategy
   - Step 3: Initialize the Audit Trail Cleanup Operation
   - Step 4: Optionally, Set an Archive Timestamp for Audit Records
   - Step 5: Create and Schedule the Purge Job
   - Step 6: Optionally, Configure the Audit Trail Records to be Deleted in Batches
2. Purge the audit trail records by running the `DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL` PL/SQL procedure.

   For example:

```
BEGIN
  DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL(
   AUDIT_TRAIL_TYPE           =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   USE_LAST_ARCH_TIMESTAMP    =>  TRUE );
END;
/
```

   In this example:

   - `AUDIT_TRAIL_TYPE`: Enter one of the following values:
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD`: Standard audit trail table, `AUD$`
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD`: Fine-grained audit trail table, `FGA_LOG$`
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD`: Both standard and fine-grained audit trail tables
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS`: Operating system audit trail files with the `.aud` extension. (This setting does not apply to Windows Event Log entries.)
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML`: XML audit trail files
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FILES`: Both operating system and XML audit trail files
     - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_ALL`: All audit trail records, that is, both database audit trail and operating system audit trail types
   - `USE_LAST_ARCH_TIMESTAMP`: Enter either of the following settings:
     - `TRUE`: Deletes audit records created before the last archive timestamp. To set the archive timestamp, see "Step 4: Optionally, Set an Archive Timestamp for Audit Records" on page 9-69. The default (and

recommended) value is TRUE. Oracle recommends that you set USE_LAST_ARCH_TIMESTAMP to TRUE.

– FALSE: Deletes all audit records without considering last archive timestamp. Be careful about using this setting, in case you inadvertently delete audit records that should have been deleted.

Purging a Subset of Records from the Database Audit Trail

You can manually remove records from the database audit trail tables. This method can be useful if you want to remove a specific subset of records. You can use this method if the database audit trail table is in any tablespace, including the SYSTEM tablespace.

For example, to delete audit records that were created later than the evening of February 28, 2009 but before March 28, 2009, enter the following statement:

```
DELETE FROM SYS.AUD$
   WHERE NTIMESTAMP# > TO_TIMESTAMP ('28-FEB-09 09.07.59.907000 PM') AND
   NTIMESTAMP# < TO_TIMESTAMP ('28-MAR-09 09.07.59.907000 PM');
```

Alternatively, to delete *all* audit records from the audit trail, enter the following statement:

```
DELETE FROM SYS.AUD$;
```

Only the user SYS or a user to whom SYS granted the DELETE privilege on SYS.AUD$ can delete records from the database audit trail.

Note: If the audit trail is full and connections are being audited (that is, if the AUDIT SESSION statement is set), then typical users cannot connect to the database because the associated audit record for the connection cannot be inserted into the audit trail. In this case, connect as SYS with the SYSDBA privilege, and make space available in the audit trail. Remember that operations by SYS are not recorded in the standard audit trail, but they are audited if you set the AUDIT_SYS_OPERATIONS parameter to TRUE.

After you delete the rows from the database audit trail table, the freed space is available for reuse by that table. (The SYS.AUD$ table is allocated only as many extents as are necessary to maintain current audit trail records.) You do not need to do anything to make this space available to the table for reuse. If you want to use this space for another table, then follow these steps:

1. Move the AUD$ table to an auto segment space managed tablespace.

   For example:

   ```
   BEGIN
     DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_LOCATION
      (audit_trail_type => DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD,
      audit_trail_location_value => 'USERS');
   END;
   /
   ```

2. Run the following statements:

   ```
   ALTER TABLE SYSTEM.AUD$ ENABLE ROW MOVEMENT;
   ALTER TABLE SYSTEM.AUD$ SHRINK SPACE CASCADE;
   ```

3. If you must move the AUD$ table back to the SYSTEM tablespace, then run the following statement:

```
BEGIN
 DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_LOCATION
  (audit_trail_type => DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD,
  audit_trail_location_value => 'SYSTEM');
END;
/
```

If you want to both delete all the rows from the database audit trail table and free the used space for other tablespace objects, use the TRUNCATE TABLE statement. For example:

```
TRUNCATE TABLE SYS.AUD$;
```

> **Note:** SYS.AUD$ and SYS.FGA_LOG$ are the only SYS objects that can ever be directly modified.

Other Audit Trail Purge Operations

This section contains:

- Verifying That the Audit Trail Is Initialized for Cleanup
- Setting the Default Audit Trail Purge Interval for Any Audit Trail Type
- Cancelling the Initialization Cleanup Settings
- Enabling or Disabling an Audit Trail Purge Job
- Setting the Default Audit Trail Purge Job Interval for a Specified Purge Job
- Deleting an Audit Trail Purge Job
- Clearing the Archive Timestamp Setting
- Clearing the Database Audit Trail Batch Size

Verifying That the Audit Trail Is Initialized for Cleanup

You can check if the audit trail has been initialized for cleanup by running the DBMS_AUDIT_MGMT.IS_CLEANUP_INITIALIZED function. If the audit trail has been initialized, then this function returns TRUE. If it is not, it returns FALSE.

For example:

```
SET SERVEROUTPUT ON
BEGIN
 IF
   DBMS_AUDIT_MGMT.IS_CLEANUP_INITIALIZED(DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD)
 THEN
   DBMS_OUTPUT.PUT_LINE('AUD$ is initialized for cleanup');
 ELSE
   DBMS_OUTPUT.PUT_LINE('AUD$ is not initialized for cleanup.');
 END IF;
END;
/
```

This example verifies that the database standard audit trail has been initialized and returns a message indicating its status. To select a setting for a different audit trail, choose from the AUDIT_TRAIL_TYPE settings described in "Step 3: Initialize the Audit

Trail Cleanup Operation" on page 9-68.

Setting the Default Audit Trail Purge Interval for Any Audit Trail Type

You can set a default purge operation interval, in hours, that must pass before the next purge operation takes place for a specified audit trail type.

For example:

```
BEGIN
 DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY(
  AUDIT_TRAIL_TYPE            => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
  AUDIT_TRAIL_PROPERTY        => DBMS_AUDIT_MGMT.CLEAN_UP_INTERVAL,
  AUDIT_TRAIL_PROPERTY_VALUE  => 24 );
END;
/
```

In this example:

- `AUDIT_TRAIL_TYPE`: Specifies the audit trail type, which in this case is the database standard audit trail. Choose from the following settings:
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD`: Standard audit trail table, `AUD$`
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD`: Fine-grained audit trail table, `FGA_LOG$`
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD`: Both standard and fine-grained audit trail tables
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS`: Operating system audit trail files with the `.aud` extension. (This setting does not apply to Windows Event Log entries.)
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML`: XML Operating system audit trail files
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FILES`: Both operating system and XML audit trail files
  - `DBMS_AUDIT_MGMT.AUDIT_TRAIL_ALL`: All audit trail records, that is, both database audit trail and operating system audit trail types

  You can set a default interval for multiple audit trail types, so long as they do not conflict. For example, you can set individual intervals for the `DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD` and `DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD` properties, but not for the `DBMS_AUDIT_MGMT.AUDIT_TRAIL_DB_STD` property.
- `AUDIT_TRAIL_PROPERTY`: Sets the `DBMS_AUDIT_MGMT.CLEAN_UP_INTERVAL` property to indicate the purge operation interval setting. To find the current property settings, query the `PARAMETER_NAME` and `PARAMETER_VALUE` columns of the `DBA_AUDIT_MGMT_CONFIG_PARAMS` data dictionary view. The timing begins when you set the `DBMS_AUDIT_MGMT.CLEAN_UP_INTERVAL` property.
- `AUDIT_TRAIL_PROPERTY_VALUE`: Updates the default hourly interval set by the `DBMS_AUDIT_MGMT.INIT_CLEANUP` procedure. Enter a value between 1 and 999.

Cancelling the Initialization Cleanup Settings

You can cancel the `DBMS_AUDIT_MGMT.INIT_CLEANUP` settings, that is, the default cleanup interval, by invoking the `DBMS_AUDIT_MGMT.DEINIT_CLEANUP` procedure.

For example, to cancel all purge settings for the standard audit trail:

```
BEGIN
 DBMS_AUDIT_MGMT.DEINIT_CLEANUP(
  AUDIT_TRAIL_TYPE  => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD);
```

```
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Enter one of the AUDIT_TRAIL_TYPE settings listed in "Step 3: Initialize the Audit Trail Cleanup Operation" on page 9-68.

Enabling or Disabling an Audit Trail Purge Job

To enable or disable an audit trail purge job, use the DBMS_AUDIT_MGMT.SET_PURGE_JOB_STATUS PL/SQL procedure.

For example:

```
BEGIN
 DBMS_AUDIT_MGMT.SET_PURGE_JOB_STATUS(
  AUDIT_TRAIL_PURGE_NAME      => 'OS_Audit_Trail_PJ',
  AUDIT_TRAIL_STATUS_VALUE    => DBMS_AUDIT_MGMT.PURGE_JOB_ENABLE);
END;
/
```

In this example:

- AUDIT_TRAIL_PURGE_NAME: Specifies a purge job called OS_Audit_Trail_PJ. To find existing purge jobs, query the JOB_NAME and JOB_STATUS columns of the DBA_AUDIT_MGMT_CLEANUP_JOBS data dictionary view.
- AUDIT_TRAIL_STATUS_VALUE: Enter one of the following properties:
  - DBMS_AUDIT_MGMT.PURGE_JOB_ENABLE: Enables the specified purge job.
  - DBMS_AUDIT_MGMT.PURGE_JOB_DISABLE: Disables the specified purge job.

Setting the Default Audit Trail Purge Job Interval for a Specified Purge Job

You can set a default purge operation interval, in hours, that must pass before the next purge job operation takes place. The interval setting that is used in the DBMS_AUDIT_MGMT.CREATE_PURGE_JOB procedure takes precedence over this setting.

For example:

```
BEGIN
 DBMS_AUDIT_MGMT.SET_PURGE_JOB_INTERVAL(
  AUDIT_TRAIL_PURGE_NAME       => 'OS_Audit_Trail_PJ',
  AUDIT_TRAIL_INTERVAL_VALUE   => 24 );
END;
/
```

In this example:

- AUDIT_TRAIL_PURGE_NAME: Specifies the name of the audit trail purge job. To find a list of existing purge jobs, query the JOB_NAME and JOB_STATUS columns of the DBA_AUDIT_MGMT_CLEANUP_JOBS data dictionary view.
- AUDIT_TRAIL_INTERVAL_VALUE: Updates the default hourly interval set by the DBMS_AUDIT_MGMT.CREATE_PURGE_JOB procedure. Enter a value between 1 and 999. The timing begins when you run the purge job.

Deleting an Audit Trail Purge Job

To delete an audit trail purge job, use the DBMS_AUDIT_MGMT.DROP_PURGE_JOB PL/SQL procedure. To find existing purge jobs, query the JOB_NAME and JOB_STATUS columns of the DBA_AUDIT_MGMT_CLEANUP_JOBS data dictionary view.

For example:

```
BEGIN
 DBMS_AUDIT_MGMT.DROP_PURGE_JOB(
  AUDIT_TRAIL_PURGE_NAME  => 'FGA_Audit_Trail_PJ');
END;
/
```

In this example:

- AUDIT_TRAIL_PURGE_NAME: Specifies a purge job called FGA_Audit_Trail_PJ.

Clearing the Archive Timestamp Setting

To clear the archive timestamp setting, use the DBMS_AUDIT_MGMT.CLEAR_LAST_ARCHIVE_TIMESTAMP PL/SQL procedure.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.CLEAR_LAST_ARCHIVE_TIMESTAMP(
   AUDIT_TRAIL_TYPE     =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML',
   RAC_INSTANCE_NUMBER  =>  1 );
END;
/
```

In this example:

- RAC_INSTANCE_NUMBER: If the AUDIT_TRAIL_TYPE property is set to DBMS_AUDIT_MGMT.AUDIT_TRAIL_OS or DBMS_AUDIT_MGMT.AUDIT_TRAIL_XML, then you cannot set RAC_INSTANCE_NUMBER to 0. You can omit this setting or specify 1 to indicate an instance number.

  You can omit the RAC_INSTANCE_NUMBER setting when AUDIT_TRAIL_TYPE is DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD or DBMS_AUDIT_MGMT.AUDIT_TRAIL_FGA_STD, or if the database is not an Oracle RAC database. Otherwise, specify the correct instance number. You can find the instance number by issuing the SHOW PARAMETER INSTANCE_NUMBER command in SQL*Plus.

Clearing the Database Audit Trail Batch Size

To clear the batch size setting, use the DBMS_AUDIT_MGMT.CLEAR_AUDIT_TRAIL_PROPERTY procedure.

For example:

```
BEGIN
  DBMS_AUDIT_MGMT.CLEAR_AUDIT_TRAIL_PROPERTY(
   AUDIT_TRAIL_TYPE        =>  DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   AUDIT_TRAIL_PROPERTY    =>  DBMS_AUDIT_MGMT.DB_DELETE_BATCH_SIZE,
   USE_DEFAULT_VALUES      =>  TRUE );
END;
/
```

In this example:

- AUDIT_TRAIL_TYPE: Specifies the audit trail type, which in this case is the database system audit trail. Enter one of the AUDIT_TRAIL_TYPE values listed in "Step 6:

Optionally, Configure the Audit Trail Records to be Deleted in Batches" on page 9-71.

- AUDIT_TRAIL_PROPERTY: Specifies the DB_DELETE_BATCH_SIZE property. Query the DBA_AUDIT_MGMT_CONFIG_PARAMS data dictionary view to find the current status of this property.
- USE_DEFAULT_VALUES: Is set to TRUE, which clears the current audit record batch size and uses the default value, 10000, instead.

Example: Directly Calling a Database Audit Trail Purge Operation

The pseudo code in Example 9–27 creates a database audit trail purge operation that the user calls by invoking the DBMS_ADUIT.CLEAN_AUDIT_TRAIL procedure. The purge operation deletes records that were created before the last archived timestamp by using a loop. The loop archives the audit records, calculates which audit records were archived and uses the SetCleanUpAuditTrail call to set the last archive timestamp, and then calls the CLEAN_AUDIT_TRAIL procedure. It deletes the database audit trail records in batches of 100,000 records each. In this example, major steps are in **bold** typeface.

Example 9–27 Directly Calling a Database Audit Trail Purge Operation

```
-- 1. Initialize the AUD$ table for cleanup:
PROCEDURE CleanUpAuditTrailMain()
BEGIN
  -- Connect to the database using appropriate login.
  CALL ConnectToDatabase();
  -- The login used must have privileges to modify Audit settings.
  -- Currently, the DBA will be the authorized user

  DBMS_AUDIT_MGMT.INIT_CLEANUP(
   AUDIT_TRAIL_TYPE           => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   DEFAULT_CLEANUP_INTERVAL   => 12 );
END; /*PROCEDURE */
/
-- 2. Optionally, set the batch size:
BEGIN
  DBMS_AUDIT_MGMT.SET_AUDIT_TRAIL_PROPERTY(
   AUDIT_TRAIL_TYPE           => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   AUDIT_TRAIL_PROPERTY       => DBMS_AUDIT_MGMT.DB_DELETE_BATCH_SIZE,
   AUDIT_TRAIL_PROPERTY_VALUE => 100000 /* delete batch size */);
END; /*PROCEDURE */
/
-- 3. Set the last archive timestamp:
PROCEDURE SetCleanUpAuditTrail()
BEGIN
  CALL FindLastArchivedTimestamp(AUD$);
  DBMS_AUDIT_MGMT.SET_LAST_ARCHIVE_TIMESTAMP(
   AUDIT_TRAIL_TYPE          => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
   LAST_ARCHIVE_TIME         => '20-AUG-2009 00:00:00');
END /* PROCEDURE */
/
-- 4. Run a customized archive procedure to purge the audit trail records:
BEGIN
  CALL MakeAuditSettings();
  LOOP (/* How long to loop*/)
    -- Invoke function for audit record archival
    CALL DoAuditRecordArchival(AUD$);
```

```
    CALL SetCleanUpAuditTrail();
    IF(/* Clean up is needed immediately */)
      DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL(
       AUDIT_TRAIL_TYPE        => DBMS_AUDIT_MGMT.AUDIT_TRAIL_AUD_STD,
       USE_LAST_ARCH_TIMESTAMP => TRUE);
    END IF
  END LOOP /*LOOP*/
END; /* PROCEDURE */
/
```

Finding Information About Audited Activities

This section contains:

- Using Data Dictionary Views to Find Information About the Audit Trail
- Using Audit Trail Views to Investigate Suspicious Activities
- Deleting the Audit Trail Views

> **Tip:** To find error information about audit policies, check the trace files. The `USER_DUMP_DEST` initialization parameter sets the location of the trace files.

Using Data Dictionary Views to Find Information About the Audit Trail

Table 9–7 lists data dictionary views that provide auditing information. For detailed information about these views, see *Oracle Database Reference*.

Table 9–7 Data Dictionary Views That Display Information about the Database Audit Trail

View	Description
`ALL_AUDIT_POLICIES`	Describes the fine-grained auditing policies on the tables and views accessible to the current user
`ALL_AUDIT_POLICY_COLUMNS`	Describes the fine-grained auditing policy columns on the tables and views accessible to the current user.
`ALL_DEF_AUDIT_OPTS`	Lists default object-auditing options that are to be applied when objects are created
`AUDIT_ACTIONS`	Describes audit trail action type codes
`DBA_AUDIT_EXISTS`	Lists audit trail entries produced `BY AUDIT NOT EXISTS`
`DBA_AUDIT_MGMT_CLEAN_EVENTS`	Displays the history of purge events. Periodically, as user `SYS` connected with the `SYSDBA` privilege, you should delete the contents of this view so that it does not grow too large. For example: `DELETE FROM DBA_AUDIT_MGMT_CLEAN_EVENTS;`
`DBA_AUDIT_MGMT_CLEANUP_JOBS`	Displays the currently configured audit trail purge jobs
`DBA_AUDIT_MGMT_CONFIG_PARAMS`	Displays the currently configured audit trail properties that are used by the `DBMS_AUDIT_MGMT` PL/SQL package
`DBA_AUDIT_MGMT_LAST_ARCH_TS`	Displays the last archive timestamps that have set for audit trail purges.
`DBA_AUDIT_OBJECT`	Lists audit trail records for all objects in the system
`DBA_AUDIT_POLICIES`	Lists all the fine-grained auditing policies on the system
`DBA_AUDIT_SESSION`	Lists all audit trail records concerning `CONNECT` and `DISCONNECT`
`DBA_AUDIT_POLICY_COLUMNS`	Describes the fine-grained auditing policy columns on the tables and views throughout the database.

Table 9–7 (Cont.) Data Dictionary Views That Display Information about the Database Audit Trail

View	Description
DBA_AUDIT_STATEMENT	Lists audit trail records concerning GRANT, REVOKE, AUDIT, NOAUDIT, and ALTER SYSTEM statements throughout the database
DBA_AUDIT_TRAIL	Lists all standard audit trail entries in the AUD$ table
DBA_COMMON_AUDIT_TRAIL	Combines standard and fine-grained audit log records, and includes SYS and mandatory audit records written in XML format
DBA_FGA_AUDIT_TRAIL	Lists audit trail records for fine-grained auditing.
DBA_OBJ_AUDIT_OPTS	Displays the objects on which auditing options have been enabled
DBA_PRIV_AUDIT_OPTS	Describes current system privileges being audited across the system and by user
DBA_STMT_AUDIT_OPTS	Describes current statement auditing options across the system and by user
USER_AUDIT_OBJECT	Lists audit trail records for statements concerning objects that are accessible to the current user
USER_AUDIT_POLICIES	Describes the fine-grained auditing policy columns on the tables and views accessible to the current user.
USER_AUDIT_SESSION	Lists all audit trail records concerning connections and disconnections for the current user
USER_AUDIT_STATEMENT	Lists audit trail records concerning GRANT, REVOKE, AUDIT, NOAUDIT, and ALTER SYSTEM statements issued by the user
USER_AUDIT_TRAIL	Lists all standard audit trail entries in the AUD$ table relating to the current user
USER_OBJ_AUDIT_OPTS	Describes auditing options on all objects owned by the current user
V$LOGMNR_CONTENTS	Contains log history information. To query this view, you must have the SELECT ANY TRANSACTION privilege.
V$XML_AUDIT_TRAIL	Shows standard, fine-grained, SYS, and mandatory audit records written in XML format files.

Using Audit Trail Views to Investigate Suspicious Activities

This section provides examples that demonstrate how to examine and interpret the information in the audit trail. Suppose you want to audit the database for the following suspicious activities:

- Passwords, tablespace settings, and quotas for some database users are altered without authorization.
- A high number of deadlocks occur, most likely because of users acquiring exclusive table locks.
- Rows are arbitrarily deleted from the emp table in laurel's schema.

You suspect the users jward and swilliams of several of these detrimental actions.

To investigate, you issue the following statements (in the order specified):

```
AUDIT ALTER, INDEX, RENAME ON DEFAULT;
CREATE VIEW laurel.employee AS SELECT * FROM laurel.emp;
AUDIT SESSION BY jward, swilliams;
AUDIT ALTER USER;
AUDIT LOCK TABLE
    BY ACCESS
    WHENEVER SUCCESSFUL;
```

```
AUDIT DELETE ON laurel.emp
    BY ACCESS
    WHENEVER SUCCESSFUL;
```

The following statements are subsequently issued by the user `jward`:

```
ALTER USER tsmith QUOTA 0 ON users;
DROP USER djones;
```

The following statements are subsequently issued by the user `swilliams`:

```
LOCK TABLE laurel.emp IN EXCLUSIVE MODE;
DELETE FROM laurel.emp WHERE mgr = 7698;
ALTER TABLE laurel.emp ALLOCATE EXTENT (SIZE 100K);
CREATE INDEX laurel.ename_index ON laurel.emp (ename);
CREATE PROCEDURE laurel.fire_employee (empid NUMBER) AS
  BEGIN
    DELETE FROM laurel.emp WHERE empno = empid;
  END;
/

EXECUTE laurel.fire_employee(7902);
```

The following sections display the information relevant to your investigation that can be viewed using the audit trail views in the data dictionary:

- Listing Active Statement Audit Options
- Listing Active Privilege Audit Options
- Listing Active Object Audit Options for Specific Objects
- Listing Default Object Audit Options
- Listing Audit Records
- Listing Audit Records for the AUDIT SESSION Option

Listing Active Statement Audit Options

The following query returns all the statement audit options that are set:

```
SELECT * FROM DBA_STMT_AUDIT_OPTS;
```

Output similar to the following appears:

```
USER_NAME            AUDIT_OPTION         SUCCESS         FAILURE
-------------------- -------------------- ----------      ---------
JWARD                DROP ANY CLUSTER     BY ACCESS       BY ACCESS
SWILLIAMS            DEBUG PROCEDURE      BY ACCESS       BY ACCESS
MSEDLAK              ALTER RESOURCE COST  BY ACCESS       BY ACCESS
```

Listing Active Privilege Audit Options

The following query returns all the privilege audit options that are set:

```
SELECT * FROM DBA_PRIV_AUDIT_OPTS;
```

Output similar to the following appears:

```
USER_NAME           PRIVILEGE            SUCCESS      FAILURE
------------------- -------------------- ---------    ----------
PSMITH              BY ACCESS            BY ACCESS
```

Listing Active Object Audit Options for Specific Objects

The following query returns all audit options set for any objects with names that start with the characters `emp` and that are contained in the schema of `laurel`:

```
SELECT * FROM DBA_OBJ_AUDIT_OPTS
    WHERE OWNER = 'LAUREL' AND OBJECT_NAME LIKE 'EMP%';
```

Output similar to the following appears:

```
OWNER   OBJECT_NAME OBJECT_TY ALT AUD COM DEL GRA IND INS LOC ...
-----   ----------- --------- --- --- --- --- --- --- --- --- ...
LAUREL EMP         TABLE     S/S -/- -/- A/- -/- S/S -/- -/- ...
LAUREL EMPLOYEE    VIEW      -/- -/- -/- A/- -/- S/S -/- -/- ...
```

The view returns information about all the audit options for the specified object. The information in the view is interpreted as follows:

- A dash (`-`) indicates that the audit option is not set.
- The `S` character indicates that the audit option is set `BY SESSION`.
- The `A` character indicates that the audit option is set `BY ACCESS`.
- Each audit option has two possible settings, `WHENEVER SUCCESSFUL` and `WHENEVER NOT SUCCESSFUL`, separated by a slash (`/`). For example, the `DELETE` audit option for `laurel.emp` is set `BY ACCESS` for successful `DELETE` statements and not set at all for unsuccessful `DELETE` statements.

Listing Default Object Audit Options

The following query returns all default object audit options:

```
SELECT * FROM ALL_DEF_AUDIT_OPTS;
```

Output similar to the following appears:

```
ALT AUD COM DEL GRA IND INS LOC REN SEL UPD REF EXE FBK REA
--- --- --- --- --- --- --- --- --- --- --- --- --- --- ---
S/S -/- -/- -/- -/- S/S -/- -/- S/S -/- -/- -/- -/- /-  -/-
```

Notice that the view returns information similar to the `USER_OBJ_AUDIT_OPTS` and `DBA_OBJ_AUDIT_OPTS` views (refer to previous example).

Listing Audit Records

The following query lists audit records generated for all objects in the database:

```
SELECT * FROM DBA_AUDIT_OBJECT;
```

Listing Audit Records for the AUDIT SESSION Option

The following query lists audit information corresponding to the `AUDIT SESSION` statement audit option:

```
SELECT USERNAME, LOGOFF_TIME, LOGOFF_LREAD, LOGOFF_PREAD,
    LOGOFF_LWRITE, LOGOFF_DLOCK
    FROM DBA_AUDIT_SESSION;
```

Output similar to the following appears:

```
USERNAME   LOGOFF_TI LOGOFF_LRE LOGOFF_PRE LOGOFF_LWR LOGOFF_DLO
---------- --------- ---------- ---------- ---------- ----------
JWARD      02-AUG-91         53          2         24          0
SWILLIAMS  02-AUG-91       3337        256        630          0
```

Deleting the Audit Trail Views

If you disable auditing and no longer need the audit trail views, then delete them by connecting to the database as `SYS` and run the script file `CATNOAUD.SQL`. The location of the `CATNOAUD.SQL` script is operating system-dependent.

10

Keeping Your Oracle Database Secure

This chapter contains:

About the Security Guidelines in This Chapter

This chapter provides a set of guidelines to keep your Oracle database secure. Information security, and privacy and protection of corporate assets and data are critical in any business. Oracle Database comprehensively addresses the need for information security by providing cutting-edge security features such as deep data protection, auditing, scalable security, secure hosting, and data exchange.

Oracle Database leads the industry in security. To maximize the security features offered by Oracle Database in any business environment, it is imperative that the database itself be well protected.

Security guidelines provide advice about how to configure Oracle Database to be secure by adhering to and recommending industry-standard and advisable security practices for operational database deployments. Many of the guidelines described in this section address common regulatory requirements such as those described in the Sarbanes-Oxley Act. For more information about how Oracle Database addresses regulatory compliance, protection of personally identifiable information, and internal threats, visit:

`http://www.oracle.com/technetwork/topics/security/whatsnew/index.html`

Downloading Security Patches and Contacting Oracle Regarding Vulnerabilities

This section contains:

- Applying Security Patches and Workaround Solutions
- Contacting Oracle Security Regarding Vulnerabilities in Oracle Database

Applying Security Patches and Workaround Solutions

Always apply all relevant security patches for both the operating system on which Oracle Database resides and Oracle Database itself, and for all installed Oracle Database options and components.

Periodically check the security site on Oracle Technology Network for details about security alerts released by Oracle at

`http://www.oracle.com/technetwork/topics/security/alerts-086861.html`

Also check the Oracle Worldwide Support Service site, My Oracle Support, for details about available and upcoming security-related patches at

`https://support.oracle.com`

Contacting Oracle Security Regarding Vulnerabilities in Oracle Database

If you are an Oracle customer or an Oracle partner, use My Oracle Support to submit a Service Request on any potential Oracle product security vulnerability. Otherwise, send an email to `secalert_us@oracle.com` with a complete description of the problem, including product version and platform, together with any scripts and examples. Oracle encourages those who want to contact Oracle Security to employ email encryption, using our encryption key.

Guidelines for Securing User Accounts and Privileges

Follow these guidelines to secure user accounts and privileges:

1. **Practice the principle of least privilege.**

   Oracle recommends the following guidelines:

   a. **Grant necessary privileges only.**

      Do not provide database users or roles more privileges than are necessary. (If possible, grant privileges to roles, not users.) In other words, the *principle of least privilege* is that users be given only those privileges that are actually required to efficiently perform their jobs.

      To implement this principle, restrict the following as much as possible:

      – The number of `SYSTEM` and `OBJECT` privileges granted to database users.

      – The number of people who are allowed to make `SYS`-privileged connections to the database.

      – The number of users who are granted the `ANY` privileges, such as the `DROP ANY TABLE` privilege. For example, there is generally no need to grant `CREATE ANY TABLE` privileges to a non-DBA-privileged user.

- The number of users who are allowed to perform actions that create, modify, or drop database objects, such as the `TRUNCATE TABLE`, `DELETE TABLE`, `DROP TABLE` statements, and so on.

b. Limit granting the CREATE ANY EDITION and DROP ANY EDITION privileges.

To maintain additional versions of objects, editions can increase resource and disk space consumption in the database. Only grant the `CREATE ANY EDITION` and `DROP ANY EDITION` privileges to trusted users who are responsible for performing upgrades.

c. Restrict the CREATE ANY JOB, BECOME USER, EXP_FULL_DATABASE, and IMP_FULL_DATABASE privileges.

These are powerful security-related privileges. Only grant these privileges to users who need them.

d. Restrict library-related privileges to trusted users only.

The `CREATE LIBRARY`, `CREATE ANY LIBRARY`, `ALTER ANY LIBRARY`, and `EXECUTE ANY LIBRARY` privileges, and grants of `EXECUTE ON` *`library_name`* convey a great deal of power to users. If you plan to create PL/SQL interfaces to libraries, only grant the `EXECUTE` privilege to the PL/SQL interface. Do not grant `EXECUTE` on the underlying library. You must have the `EXECUTE` privilege on a library to create the PL/SQL interface to it. However, users have this privilege implicitly on libraries that they create in their own schemas. Explicit grants of `EXECUTE ON` *`library_name`* are rarely required. Only make an explicit grant of these privileges to trusted users, and never to the `PUBLIC` role.

e. Restrict synonym-related privileges to trusted users only.

The `CREATE PUBLIC SYNONYM` and `DROP PUBLIC SYNONYM` system privileges convey a great deal of power to these users. Do not grant these privileges to users, unless they are trusted.

f. Do not allow non-administrative users access to objects owned by the SYS schema.

Do not allow users to alter table rows or schema objects in the `SYS` schema, because doing so can compromise data integrity. Limit the use of statements such as `DROP TABLE`, `TRUNCATE TABLE`, `DELETE`, `INSERT`, or similar object-modification statements on `SYS` objects only to highly privileged administrative users.

The `SYS` schema owns the data dictionary. You can protect the data dictionary by setting the `O7_DICTIONARY_ACCESSIBILITY` parameter to `FALSE`. See Guideline 1 under "Guidelines for Securing Data" on page 10-10 for more information.

g. Only grant the EXECUTE privilege on the DBMS_RANDOM PL/SQL package to trusted users.

The `EXECUTE` privilege on the `DBMS_RANDOM` package could permit users who normally should have only minimal access to execute the functions associated with this package.

h. Restrict permissions on run-time facilities.

Many Oracle Database products use run-time facilities, such as Oracle Java Virtual Machine (OJVM). Do not assign all permissions to a database run-time facility. Instead, grant specific permissions to the explicit document root file paths for facilities that might run files and packages outside the database.

Here is an example of a vulnerable run-time call, which individual files are specified:

```
call dbms_java.grant_permission('wsmith',
'SYS:java.io.FilePermission','<<ALL FILES>>','read');
```

Here is an example of a better (more secure) run-time call, which specifies a directory path instead:

```
call dbms_java.grant_permission('wsmith',
'SYS:java.io.FilePermission','<<actual directory path>>','read');
```

2. **Lock and expire default (predefined) user accounts.**

   Oracle Database installs with several default database user accounts. Upon successful installation of the database, the Database Configuration Assistant automatically locks and expires most default database user accounts.

   If you perform a manual (without using Database Configuration Assistant) installation of Oracle Database, then no default database users are locked upon successful installation of the database server. Or, if you have upgraded from a previous release of Oracle Database, you may have default accounts from earlier releases. Left open in their default states, these user accounts can be exploited, to gain unauthorized access to data or disrupt database operations.

   You should *lock* and *expire* all default database user accounts. Oracle Database provides SQL statements to perform these operations. For example:

   ```
   ALTER USER ANONYMOUS PASSWORD EXPIRE ACCOUNT LOCK;
   ```

   See *Oracle Database SQL Language Reference* for more information about the `ALTER USER` statement.

   Installing additional products and components after the initial installation also results in creating more default database accounts. Database Configuration Assistant automatically locks and expires all additionally created database user accounts. Unlock only those accounts that need to be accessed on a regular basis and assign a strong, meaningful password to each of these unlocked accounts. Oracle provides SQL and password management to perform these operations.

   If any default database user account other than the ones left open is required for any reason, then a database administrator (DBA) must unlock and activate that account with a new, secure password.

   See *Oracle Database 2 Day + Security Guide* for a description of the predefined user accounts that are created when you install Oracle Database.

   If a default database user account, other than the ones left open, is required for any reason, then a database administrator (DBA) can unlock and activate that account with a new, secure password.

   Oracle Enterprise Manager Accounts

   If you install Oracle Enterprise Manager, the `SYSMAN` and `DBSNMP` accounts are open, unless you configure Oracle Enterprise Manager for central administration. In this case, the `SYSMAN` account (if present) will be locked.

   If you do not install Oracle Enterprise Manager, then only the `SYS` and `SYSTEM` accounts are open. Database Configuration Assistant locks and expires all other accounts (including `SYSMAN` and `DBSNMP`).

3. **Use the following data dictionary views to find information about user access to the database.**

- DBA_*
- DBA_ROLES
- DBA_SYS_PRIVS
- DBA_ROLE_PRIVS
- DBA_TAB_PRIVS
- DBA_AUDIT_TRAIL (if standard auditing is enabled)
- DBA_FGA_AUDIT_TRAIL (if fine-grained auditing is enabled)

4. **Monitor the granting of the following privileges only to users and roles who need these privileges.**

   By default, Oracle Database audits the following privileges:

   - ALTER SYSTEM
   - AUDIT SYSTEM
   - CREATE EXTERNAL JOB

   Oracle recommends that you also audit the following privileges:

   - ALL PRIVILEGES (which includes privileges such as BECOME USER, CREATE LIBRARY, and CREATE PROCEDURE)
   - DBMS_BACKUP_RESTORE package
   - EXECUTE to DBMS_SYS_SQL
   - SELECT ANY TABLE
   - SELECT on PERFSTAT.STATS$SQLTEXT
   - SELECT on PERFSTAT.STATS$SQL_SUMMARY
   - SELECT on SYS.SOURCE$
   - Privileges that have the WITH ADMIN clause
   - Privileges that have the WITH GRANT clause
   - Privileges that have the CREATE keyword

5. **Revoke access to the following:**
   - The SYS.USER_HISTORY$ table from all users except SYS and DBA accounts
   - The RESOURCE role from typical application accounts
   - The CONNECT role from typical application accounts
   - The DBA role from users who do not need this role

6. **Grant privileges only to roles.**

   Granting privileges to roles and not individual users makes the management and tracking of privileges much easier.

7. **Limit the proxy account (for proxy authorization) privileges to CREATE SESSION only.**

8. **Use secure application roles to protect roles that are enabled by application code.**

Secure application roles allow you to define a set of conditions, within a PL/SQL package, that determine whether or not a user can log on to an application. Users do not need to use a password with secure application roles.

Another approach to protecting roles from being enabled or disabled in an application is the use of role passwords. This approach prevents a user from directly accessing the database in SQL (rather than the application) to enable the privileges associated with the role. However, Oracle recommends that you use secure application roles instead, to avoid having to manage another set of passwords.

9. **Discourage users from using the NOLOGGING clause in SQL statements.**

   In some SQL statements, the user has the option of specifying the `NOLOGGING` clause, which indicates that the database operation is not logged in the online redo log file. Even though the user specifies the clause, a redo record is still written to the online redo log file. However, there is no data associated with this record. Because of this, using `NOLOGGING` has the potential for malicious code to be entered can be accomplished without an audit trail.

Guidelines for Securing Roles

Follow these guidelines when managing roles:

1. **Grant a role to users only if they need all privileges of the role.**

   Roles (groups of privileges) are useful for quickly and easily granting permissions to users. Although you can use Oracle-defined roles, you have more control and continuity if you create your own roles containing only the privileges pertaining to your requirements. Oracle may change or remove the privileges in an Oracle Database-defined role, as it has with the `CONNECT` role, which now has only the `CREATE SESSION` privilege. Formerly, this role had eight other privileges.

   Ensure that the roles you define contain only the privileges that reflect job responsibility. If your application users do not need all the privileges encompassed by an existing role, then apply a different set of roles that supply just the correct privileges. Alternatively, create and assign a more restricted role.

   For example, it is imperative to strictly limit the privileges of user `SCOTT`, because this is a well known account that may be vulnerable to intruders. Because the `CREATE DBLINK` privilege allows access from one database to another, drop its privilege for `SCOTT`. Then, drop the entire role for the user, because privileges acquired by means of a role cannot be dropped individually. Re-create your own role with only the privileges needed, and grant that new role to that user. Similarly, for better security, drop the `CREATE DBLINK` privilege from all users who do not require it.

2. **Do not grant user roles to application developers.**

   Roles are not meant to be used by application developers, because the privileges to access schema objects within stored programmatic constructs need to be granted directly. Remember that roles are not enabled within stored procedures except for invoker's right procedures. See "How Roles Work in PL/SQL Blocks" on page 4-9 for information about this topic.

3. **Create and assign roles specific to each Oracle Database installation.**

   This principle enables the organization to retain detailed control of its roles and privileges. This also avoids the necessity to adjust if Oracle Database changes or

removes Oracle Database-defined roles, as it has with `CONNECT`, which now has only the `CREATE SESSION` privilege. Formerly, it also had eight other privileges.

4. **For enterprise users, create global roles.**

   Global roles are managed by an enterprise directory service, such as Oracle Internet Directory. See the following sections for more information about global roles:

   - "Configuring Global User Authentication and Authorization" on page 3-30
   - "Global Role Authorization by an Enterprise Directory Service" on page 4-19
   - *Oracle Database Enterprise User Security Administrator's Guide*

Guidelines for Securing Passwords

When you create a user account, Oracle Database assigns a default password policy for that user. The password policy defines rules for how the password should be created, such as a minimum number of characters, when it expires, and so on. You can strengthen passwords by using password policies. See also "Configuring Password Protection" on page 3-1 for additional ways to protect passwords.

Follow these guidelines to further strengthen passwords:

1. **Choose passwords carefully.**

   "Minimum Requirements for Passwords" on page 3-3 describes the minimum requirements for passwords. Follow these additional guidelines when you create or change passwords:

   - Make the password between 12 and 30 characters and numbers.
   - Have the password contain at least one digit, one upper-case character, and one lower-case character.
   - Use mixed case letters and special characters in the password. (See "Ensuring Against Password Security Threats by Using the SHA-1 Hashing Algorithm" on page 3-15 for more information.)
   - You can include multibyte characters in the password.
   - Use the database character set for the password's characters, which can include the underscore (_), dollar ($), and number sign (#) characters.
   - You must enclose the following passwords in double-quotation marks:
     - Passwords containing multibyte characters.
     - Passwords starting with numbers or special characters and containing alphabetical characters. For example:

       ```
       "123abc"

       "#abc"

       "123dc$"
       ```

     - Passwords containing any character other than alphabetical characters, numbers, and special characters. For example:

       ```
       "abc>"

       "abc@",

       " "
       ```

- You do not need to specify the following passwords in double-quotation marks.
  - Passwords starting with an alphabet character (a–z, A–Z) and containing numbers(0–9) or special characters ($, #, _). For example:

    ```
    abc123

    ab23a

    ab$#_
    ```

  - Passwords containing only numbers.
  - Passwords containing only alphabetical characters.
- Do not use an actual word for the entire password.

2. **To create a longer, more complex password from a shorter, easier to remember password, follow these techniques:**
   - Create passwords from the first letters of the words of an easy-to-remember sentence. For example, "I usually work until 6 almost every day of the week" can be `Iuwu6aedotw`.
   - Combine two weaker passwords, such as `welcome1` and `binky` into `WelBinkyCome1`.
   - Repeat a character at the beginning or end of the password.
   - Add a string, another password, or part the same password to the beginning or end of the password that you want to create. For example, ways that you can modify the password `fussy2all` are as follows:
     - `fussy2all34hj2`
     - `WelBinkyCome1fussy2all`
     - `fusfussy2all`
   - Double some or all of the letters. For example, `welcome13` can become `wwellCcooMmee13`.
3. **Ensure that the password is sufficiently complex.**

   Oracle Database provides a password verification routine, the PL/SQL script `UTLPWDMG.SQL`, that you can run to check whether or not passwords are sufficiently complex. Ideally, edit the `UTLPWDMG.SQL` script to provide stronger password protections. See also "Enforcing Password Complexity Verification" on page 3-11 for a sample routine that you can use to check passwords.
4. **Associate a password function with the user profile or the default profile.**

   The `PASSWORD_VERIFY_FUNCTION` clause of the `CREATE PROFILE` and `ALTER PROFILE` statements associates a password function with a user profile or the default profile. Password functions ensure that users create strong passwords using guidelines that are specific to your site. Having a password function also requires a user changing his or her own password (without the `ALTER USER` system privilege) to provide both the old and new passwords. You can create your own password functions or use the password functions that Oracle Database provides.

   See "Customizing Password Complexity Verification" on page 3-12 for more information.
5. **Change default user passwords.**

Oracle Database installs with a set of predefined, default user accounts. Security is most easily broken when a default database user account still has a default password *even after installation*. This is particularly true for the user account SCOTT, which is a well known account that may be vulnerable to intruders. In Oracle Database 11*g* Release 2 (11.2), default accounts are installed locked with the passwords expired, but if you have upgraded from a previous release, you may still have accounts that use default passwords.

To find user accounts that have default passwords, query the DBA_USERS_WITH_DEFPWD data dictionary view. See "Finding User Accounts That Have Default Passwords" on page 3-4 for more information.

6. **Change default passwords of administrative users.**

   You can use the same or different passwords for the SYS, SYSTEM, SYSMAN, and DBSNMP administrative accounts. Oracle recommends that you use different passwords for each. In any Oracle environment (production or test), assign strong, secure, and distinct passwords to these administrative accounts. If you use Database Configuration Assistant to create a new database, then it requires you to enter passwords for the SYS and SYSTEM accounts, disallowing the default passwords CHANGE_ON_INSTALL and MANAGER.

   Similarly, for production environments, do not use default passwords for administrative accounts, including SYSMAN and DBSNMP.

   See *Oracle Database 2 Day + Security Guide* for information about changing a default password.

7. **Enforce password management.**

   Apply basic password management rules (such as password length, history, , and so forth) to all user passwords. Oracle Database has password policies enabled for the default profile. Guideline 1 in this section lists these password policies. *Oracle Database 2 Day + Security Guide* lists initialization parameters that you can use to further secure user passwords.

   You can find information about user accounts by querying the DBA_USERS view. The PASSWORD column of the DBA_USERS view indicates whether the password is global, external, or null. The DBA_USERS view provides useful information such as the user account status, whether the account is locked, and password versions.

   Oracle also recommends, if possible, using Oracle Advanced Security (an option to Oracle Database Enterprise Edition) with network authentication services (such as Kerberos), token cards, smart cards, or X.509 certificates. These services provide strong authentication of users, and provide protection against unauthorized access to Oracle Database.

8. **Do not store user passwords in clear text in Oracle tables.**

   For better security, do not store passwords in clear text (that is, human readable) in Oracle tables. You can correct this problem by using a secure external password store to encrypt the table column that contains the password. See "Managing the Secure External Password Store for Password Credentials" on page 3-16 for information.

   When you create or modify a password for a user account, Oracle Database automatically creates a cryptographic hash or digest of the password. If you query the DBA_USERS view to find information about a user account, the data in the PASSWORD column indicates if the user password is global, external, or null.

Guidelines for Securing Data

Follow these guidelines to secure data on your system:

1. **Enable data dictionary protection.**

   Oracle recommends that you protect the data dictionary to prevent users that have the ANY system privilege from using those privileges on the data dictionary. Altering or manipulating the data in data dictionary tables can permanently and detrimentally affect the operation of a database.

   To enable data dictionary protection, set the following initialization parameter to FALSE (which is the default) in the init*sid*.ora control file:

   ```
   O7_DICTIONARY_ACCESSIBILITY = FALSE
   ```

   You can set the O7_DICTIONARY_ACCESSIBILITY parameter in a server parameter file. For more information about server parameter files, see *Oracle Database Administrator's Guide*.

   After you set O7_DICTIONARY_ACCESSIBILTY to FALSE, only users who have the SELECT ANY DICTIONARY privilege and those authorized users making DBA-privileged (for example CONNECT / AS SYSDBA) connections can use the ANY system privilege on the data dictionary. If O7_DICTIONARY_ACCESSIBILITY parameter is not set to FALSE, then any user with the DROP ANY TABLE (for example) system privilege will be able to drop parts of the data dictionary. However, if a user *needs* view access to the data dictionary, then you can grant that user the SELECT ANY DICTIONARY system privilege.

   Note:

   - In a default installation, the O7_DICTIONARY_ACCESSIBILITY parameter is set to FALSE. However, in Oracle8*i*, this parameter is set to TRUE by default, and must be changed to FALSE to enable this security feature.
   - The SELECT ANY DICTIONARY privilege is not included in the GRANT ALL PRIVILEGES statement, but you can grant it through a role. Chapter 4, "Configuring Privilege and Role Authorization" describes roles in detail.

2. **Restrict operating system access.**

   Follow these guidelines:

   - Limit the number of operating system users.
   - Limit the privileges of the operating system accounts (administrative, root-privileged, or DBA) on the Oracle Database host computer to the least privileges required for a user to perform necessary tasks.
   - Restrict the ability to modify the default file and directory permissions for the Oracle Database home (installation) directory or its contents. Even privileged operating system users and the Oracle owner should not modify these permissions, unless instructed otherwise by Oracle.
   - Restrict symbolic links. Ensure that when you provide a path or file to the database, neither the file nor any part of the path is modifiable by an untrusted user. The file and all components of the path should be owned by the database administrator or trusted account, such as *root*.

This recommendation applies to all types of files: data files, log files, trace files, external tables, BFILE data types, and so on.

3. **Encrypt sensitive data and all backup media that contains database files.**

   According to common regulatory compliance requirements, you must encrypt sensitive data such as credit card numbers and passwords. When you delete sensitive data from the database, encrypted data does not linger in data blocks, operating system files, or sectors on disk.

   In most cases, you may want to use transparent data encryption to encrypt your sensitive data. See *Oracle Database Advanced Security Administrator's Guide* for more information. See also "Security Problems That Encryption Does Not Solve" on page 8-1 for when you should not encrypt data.

4. **For Oracle Automatic Storage Management (Oracle ASM) environments on Linux and UNIX systems, use Oracle ASM File Access Control to restrict access to the Oracle ASM disk groups.**

   If you use different operating system users and groups for Oracle Database installations, then you can configure Oracle ASM File Access Control to restrict the access to files in Oracle ASM disk groups to only authorized users. For example, a database administrator would only be able to access the data files for the databases that he or she manages. This administrator would not be able to see or overwrite the data files belonging (or used by) other databases.

   For more information about managing Oracle ASM File Access Control for disk groups, see *Oracle Automatic Storage Management Administrator's Guide*. For information about the various privileges required for multiple software owners on Linux systems, see also *Oracle Automatic Storage Management Administrator's Guide*.

Guidelines for Securing the ORACLE_LOADER Access Driver

Follow these guidelines to secure the `ORACLE_LOADER` access driver:

1. **Create a separate operating system directory to store the access driver preprocessors.** You (or the operating system manager) may need to create multiple directories if different Oracle Database users will run different preprocessors. If you want to prevent one set of users from using one preprocessor while allowing those users access to another preprocessor, then place the preprocessors in separate directories. If all the users need equal access, then you can place the preprocessors together in one directory. After you create these operating system directories, in SQL*Plus, you can create a directory object for each directory.

2. **Grant the operating system user ORACLE the correct operating system privileges to run the access driver preprocessor.** In addition, protect the preprocessor program from `WRITE` access by operating system users other than the user responsible for managing the preprocessor program.

3. **Grant the EXECUTE privilege to each user who will run the preprocessor program in the directory object.** Do not grant this user the `WRITE` privilege on the directory object. Never grant users both the `EXECUTE` and `WRITE` privilege for directory objects.

4. **Grant the WRITE privilege sparingly to anyone who will manage directory objects that contain preprocessors.** This prevents database users from accidentally or maliciously overwriting the preprocessor program.

5. **Create a separate operating system directory and directory object for any data files that are required for external tables.** Ensure that these are separate from the directory and directory object used by the access directory preprocessor.

   Work with the operating system manager to ensure that only the appropriate operating system users have access to this directory. Grant the `ORACLE` operating system user `READ` access to any directory that has a directory object with `READ` privileges granted to database users. Similarly, grant the `ORACLE` operating system user `WRITE` access to any directory that has the `WRITE` privilege granted to database users.

6. **Create a separate operating system directory and directory object for any files that the access driver generates.** This includes log files, bad files, and discarded files. You and the operating system manager must ensure that this directory and directory object have the proper protections, similar to those described in Guideline 5. The database user may need to access these files when resolving problems in data files, so you and the operating system manager must determine a way for this user to read those files.

7. **Grant the CREATE ANY DIRECTORY and DROP ANY DIRECTORY privileges sparingly.** Users who have these privileges and users who have been granted the `DBA` role have full access to all directory objects.

8. **Consider auditing the DROP ANY DIRECTORY privilege.** See "Auditing Privileges" on page 9-26 for more information about auditing privileges.

9. **Consider auditing the directory object.** See "Auditing Directory Objects" on page 9-32 for more information.

See Also: Oracle Database Utilities for more information about the `ORACLE_DATAPUMP` access driver

Guidelines for Securing a Database Installation and Configuration

For this release, changes were made to the default configuration of Oracle Database to make it more secure. The recommendations in this section augment the new, secure default configuration.

Follow these guidelines to secure the database installation and configuration:

1. **Before you begin an Oracle Database installation on UNIX systems, ensure that the umask value is 022 for the Oracle owner account.**

   See *Oracle Database Administrator's Reference for Linux and UNIX-Based Operating Systems* for more information about managing Oracle Database on Linux and UNIX systems.

2. **Install only what is required.**

   Options and Products: The Oracle Database CD pack contains products and options in addition to the database. Install additional products and options only as necessary. Use the Custom Installation feature to avoid installing unnecessary products, or perform a typical installation, and then deinstall options and products that are not required. There is no need to maintain additional products and options if they are not being used. They can always be properly installed, as required.

   Sample Schemas: Oracle Database provides sample schemas to provide a common platform for examples. If your database will be used in a production environment, then do not install the sample schema. If you have installed the sample schema on a test database, then before going to production, remove or

relock the sample schema accounts. See *Oracle Database Sample Schemas* for more information about the sample schemas.

3. **During installation, when you are prompted for a password, create a secure password.**

   Follow Guidelines 1, 5, and 6 in "Guidelines for Securing Passwords" on page 10-7.

4. **Immediately after installation, lock and expire default user accounts.**

   See Guideline 2 in "Guidelines for Securing User Accounts and Privileges" on page 10-2.

Guidelines for Securing the Network

Security for network communications is improved by using client, listener, and network guidelines to ensure thorough protection. Using SSL is an essential element in these lists, enabling top security for authentication and communications.

These guidelines are as follows:

- Securing the Client Connection
- Securing the Network Connection
- Securing a Secure Sockets Layer Connection

Securing the Client Connection

Because authenticating client computers is problematic, typically, user authentication is performed instead. This approach avoids client system issues that include falsified IP addresses, hacked operating systems or applications, and falsified or stolen client system identities. Nevertheless, the following guidelines improve the security of client connections:

1. **Enforce access controls effectively and authenticate clients stringently.**

   By default, Oracle allows operating system-authenticated logins only over secure connections, which precludes using Oracle Net and a shared server configuration. This default restriction prevents a remote user from impersonating another operating system user over a network connection.

   Setting the initialization parameter `REMOTE_OS_AUTHENT` to `TRUE` forces the database to accept the client operating system user name received over an unsecure connection and use it for account access. Because clients, such as PCs, are not trusted to perform operating system authentication properly, it is poor security practice to use this feature.

   The default setting, `REMOTE_OS_AUTHENT = FALSE`, creates a more secure configuration that enforces proper, server-based authentication of clients connecting to an Oracle database. Be aware that the `REMOTE_OS_AUTHENT` was deprecated in Oracle Database Release 11*g* (11.1) and is retained only for backward compatibility.

   You should not alter the default setting of the `REMOTE_OS_AUTHENT` initialization parameter, which is `FALSE`.

   Setting this parameter to `FALSE` does not mean that users cannot connect remotely. It means that the database will not trust that the client has already authenticated, and will therefore apply its standard authentication processes.

Be aware that the REMOTE_OS_AUTHENT parameter was deprecated in Oracle Database 11*g* Release 1 (11.1), and is retained only for backward compatibility.

2. **Configure the connection to use encryption.**

   Oracle network encryption makes eavesdropping difficult. To learn how to configure encryption, see *Oracle Database Advanced Security Administrator's Guide*.

3. **Set up strong authentication.**

   See *Oracle Database Advanced Security Administrator's Guide* for more information about using Kerberos and public key infrastructure (PKI).

Securing the Network Connection

Protecting the network and its traffic from inappropriate access or modification is the essence of network security. You should consider all paths the data travels, and assess the threats on each path and node. Then, take steps to lessen or eliminate those threats and the consequences of a security breach. In addition, monitor and audit to detect either increased threat levels or penetration attempts.

To manage network connections, you can use Oracle Net Manager. For an introduction to using Oracle Net Manager, see *Oracle Database 2 Day DBA*. See also *Oracle Database Net Services Administrator's Guide*.

The following practices improve network security:

1. **Use Secure Sockets Layer (SSL) when administering the listener.**

   See "Securing a Secure Sockets Layer Connection" on page 10-16 for more information.

2. **Monitor listener activity.**

   You can monitor listener activity by using Enterprise Manager Database Control. In the Database Control home page, under General, click the link for your listener. The Listener page appears. This page provides detailed information, such as the category of alert generated, alert messages, when the alert was triggered, and so on. This page provides other information as well, such as performance statistics for the listener.

3. **Prevent online administration by requiring the administrator to have the write privilege on the listener password and on the listener.ora file on the server.**

   a. Add or alter this line in the listener.ora file:

   ```
   ADMIN_RESTRICTIONS_LISTENER=ON
   ```

   b. Use RELOAD to reload the configuration.

   c. Use SSL when administering the listener by making the TCPS protocol the first entry in the address list, as follows:

   ```
   LISTENER=
     (DESCRIPTION=
       (ADDRESS_LIST=
         (ADDRESS=
           (PROTOCOL=tcps)
           (HOST = sales.us.example.com)
           (PORT = 8281)))
   ```

   To administer the listener remotely, you define the listener in the listener.ora file on the client computer. For example, to access listener USER281 remotely, use the following configuration:

```
user281 =
  (DESCRIPTION =
    (ADDRESS =
      (PROTOCOL = tcps)
      (HOST = sales.us.example.com)
      (PORT = 8281))
    )
  )
```

For more information about the parameters in `listener.ora`, see *Oracle Database Net Services Reference*.

4. **Do not set the listener password.**

   Ensure that the password has not been set in the `listener.ora` file. The local operating system authentication will secure the listener administration. The remote listener administration is disabled when the password has not been set. This prevents brute force attacks of the listener password.

   The listener password has been deprecated in this release. It will not be supported in the next release of Oracle Database.

5. **When a host computer has multiple IP addresses associated with multiple network interface controller (NIC) cards, configure the listener to the specific IP address.**

   This allows the listener to listen on all the IP addresses. You can restrict the listener to listen on a specific IP address. Oracle recommends that you specify the specific IP addresses on these types of computers, rather than allowing the listener to listen on all IP addresses. Restricting the listener to specific IP addresses helps to prevent an intruder from stealing a TCP end point from under the listener process.

6. **Restrict the privileges of the listener, so that it cannot read or write files in the database or the Oracle server address space.**

   This restriction prevents external procedure agents spawned by the listener (or procedures executed by an agent) from inheriting the ability to perform read or write operations. The owner of this separate listener process should not be the owner that installed Oracle Database or executes the Oracle Database instance (such as `ORACLE`, the default owner).

   For more information about configuring external procedures in the listener, see *Oracle Database Net Services Administrator's Guide*.

7. **Use encryption to secure the data in flight.**

   See *Oracle Database 2 Day + Security Guide* and *Oracle Database Advanced Security Administrator's Guide* for more information about network data encryption.

8. **Use a firewall.**

   Appropriately placed and configured firewalls can prevent outside access to your databases.

   - Keep the database server behind a firewall. Oracle Database network infrastructure, Oracle Net (formerly known as Net8 and SQL*Net), provides support for a variety of firewalls from various vendors. Supported proxy-enabled firewalls include Gauntlet from Network Associates and Raptor from Axent. Supported packet-filtering firewalls include PIX Firewall from Cisco, and supported stateful inspection firewalls (more sophisticated packet-filtered firewalls) include Firewall-1 from CheckPoint.
   - Ensure that the firewall is placed outside the network to be protected.

- Configure the firewall to accept only those protocols, applications, or client/server sources that you know are safe.
- Use a product such as Oracle Connection Manager to manage multiplex multiple client network sessions through a single network connection to the database. It can filter on source, destination, and host name. This product enables you to ensure that connections are accepted only from physically secure terminals or from application Web servers with known IP addresses. (Filtering on IP address alone is not enough for authentication, because it can be falsified.)

9. **Prevent unauthorized administration of the Oracle listener.**

   For more information about the listener, see *Oracle Database Net Services Administrator's Guide*.

10. **Check network IP addresses.**

    Use the Oracle Net *valid node checking* security feature to allow or deny access to Oracle server processes from network clients with specified IP addresses. To use this feature, set the following `sqlnet.ora` configuration file parameters:

    ```
    tcp.validnode_checking = YES

    tcp.excluded_nodes = {list of IP addresses}

    tcp.invited_nodes = {list of IP addresses}
    ```

    The `tcp.validnode_checking` parameter enables the feature. The `tcp.excluded_nodes` and `tcp.invited_nodes` parameters deny and enable specific client IP addresses from making connections to the Oracle listener. This helps to prevent potential Denial of Service attacks.

    You can use Oracle Net Manager to configure these parameters. See *Oracle Database Net Services Administrator's Guide* for more information.

11. **Encrypt network traffic.**

    If possible, use Oracle Advanced Security to encrypt network traffic among clients, databases, and application servers. *Oracle Database 2 Day + Security Guide* provides an introduction to network encryption. For detailed information about network encryption, see *Oracle Database Advanced Security Administrator's Guide*.

12. **Secure the host operating system (the system on which Oracle Database is installed).**

    Secure the host operating system by disabling all unnecessary operating system services. Both UNIX and Windows provide a variety of operating system services, most of which are not necessary for typical deployments. These services include FTP, TFTP, TELNET, and so forth. Be sure to close both the UDP and TCP ports for each service that is being disabled. Disabling one type of port and not the other does not make the operating system more secure.

Securing a Secure Sockets Layer Connection

Secure Sockets Layer (SSL) is the Internet standard protocol for secure communication, providing mechanisms for data integrity and data encryption. These mechanisms can protect the messages sent and received by you or by applications and servers, supporting secure authentication, authorization, and messaging through certificates and, if necessary, encryption. Good security practices maximize protection and minimize gaps or disclosures that threaten security. The following guidelines show the

cautious attention to detail necessary for the successful use of SSL. For detailed information about Oracle SSL configuration, see *Oracle Database Advanced Security Administrator's Guide*.

1. **Ensure that configuration files (for example, for clients and listeners) use the correct port for SSL, which is the port configured upon installation.**

   You can run HTTPS on any port, but the standards specify port 443, where any HTTPS-compliant browser looks by default. The port can also be specified in the URL, for example:

   ```
   https://secure.example.com:4445/
   ```

   If a firewall is in use, then it too must use the same ports for secure (SSL) communication.

2. **Ensure that TCPS is specified as the PROTOCOL in the ADDRESS parameter in the tnsnames.ora file (typically on the client or in the LDAP directory).**

   An identical specification must appear in the `listener.ora` file (typically in the `$ORACLE_HOME/network/admin` directory).

3. **Ensure that the SSL mode is consistent for both ends of every communication. For example, the database (on one side) and the user or application (on the other) must have the same SSL mode.**

   The mode can specify either client or server authentication (one-way), both client and server authentication (two-way), or no authentication.

4. **Ensure that the server supports the client cipher suites and the certificate key algorithm in use.**

5. **Enable DN matching for both the server and client, to prevent the server from falsifying its identity to the client during connections.**

   This setting ensures that the server identity is correct by matching its global database name against the DN from the server certificate.

   You can enable DN matching in the `tnsnames.ora` file. For example:

   ```
   set:SSL_SERVER_CERT_DN="cn=finance,cn=OracleContext,c=us,o=example"
   ```

   Otherwise, a client application would not check the server certificate, which could allow the server to falsify its identity.

6. **Do not remove the encryption from your RSA private key inside your server.key file, which requires that you enter your pass phrase to read and parse this file.**

   Note: A server without SSL does not require a pass phrase.

   If you decide your server is secure enough, you could remove the encryption from the RSA private key while preserving the original file. This enables system boot scripts to start the database server, because no pass phrase is needed. Ideally, restrict permissions to the root user only, and have the Web server start as `root`, but then log on as another user. Otherwise, anyone who gets this key can impersonate you on the Internet, or decrypt the data that was sent to the server.

See Also:

- *Oracle Database Advanced Security Administrator's Guide* for general SSL information, including configuration
- *Oracle Database Net Services Reference* for TCP-related parameters in `sqlnet.ora`

Guidelines for Auditing

This section contains:

Auditing Sensitive Information

Be aware that sensitive data, such as credit card numbers, appear in the fine-grained audit trail if you collect SQL text. For standard auditing, setting the `AUDIT_TRAIL` initialization parameter to `DB, EXTENDED` or `XML, EXTENDED` enables the collection of SQL text. For fine-grained auditing, you would set the `audit_trail` parameter of the `DBMS_FGA` PL/SQL package to `DBMS_FGA.DB + DBMS_FGA.EXTENDED` or `DBMS_FGA.XML + DBMS_FGA.EXTENDED`.

If you have sensitive data that is being audited, consider using either of the following solutions:

- **Move the audit trail out of the SYSTEM tablespace and into SYSAUX or another tablespace.** See "Moving the Database Audit Trail to a Different Tablespace" on page 9-60. Afterwards, encrypt this tablespace. For more information about tablespace encryption, see *Oracle Database Advanced Security Administrator's Guide*.
- **Do not enable the collection of SQL text in the audit trail.** Use the following settings instead:
  - **Standard auditing:** Set the `AUDIT_TRAIL` initialization parameter to `DB`, `OS`, or `XML`. See "Configuring Standard Auditing with the AUDIT_TRAIL Initialization Parameter" on page 9-8.
  - **Fine-grained auditing:** Set the `DBMS_FGA.ADD_POLICY audit_trail` parameter to `DBMS_FGA.DB` or `DBMS_FGA.XML`. See "Creating a Fine-Grained Audit Policy" on page 9-40.

Keeping Audited Information Manageable

Although auditing is relatively inexpensive, limit the number of audited events as much as possible. This minimizes the performance impact on the execution of audited statements and the size of the audit trail, making it easier to analyze and understand.

Follow these guidelines when devising an auditing strategy:

1. **Evaluate your reason for auditing.**

   After you have a clear understanding of the reasons for auditing, you can devise an appropriate auditing strategy and avoid unnecessary auditing.

For example, suppose you are auditing to investigate suspicious database activity. This information by itself is not specific enough. What types of suspicious database activity do you suspect or have you noticed? A more focused auditing strategy might be to audit unauthorized deletions from arbitrary tables in the database. This purpose narrows the type of action being audited and the type of object being affected by the suspicious activity.

2. **Audit knowledgeably.**

   Audit the minimum number of statements, users, or objects required to get the targeted information. This prevents unnecessary audit information from cluttering the meaningful information and using valuable space in the `SYSTEM` tablespace. Balance your need to gather sufficient security information with your ability to store and process it.

   For example, if you are auditing to gather information about database activity, then determine exactly what types of activities you want to track, audit only the activities of interest, and audit only for the amount of time necessary to gather the information that you want. As another example, do not audit *objects* if you are only interested in logical I/O information for each session.

3. **Before you implement an auditing strategy, consult your legal department.**

   You should have the legal department of your organization review your audit strategy. Because your auditing will monitor other users in your organization, you must ensure that you are correctly following the compliance and corporate policy of your site.

Auditing Typical Database Activity

When your purpose for auditing is to gather historical information about particular database activities, use the following guidelines:

1. **Audit only pertinent actions.**

   At a minimum, audit user access, the use of system privileges, and changes to the database schema structure. To avoid cluttering meaningful information with useless audit records and reduce the amount of audit trail administration, only audit the targeted database activities. Remember also that auditing too much can affect database performance.

   For example, auditing changes to all tables in a database produces far too many audit trail records and can slow down database performance. However, auditing changes to critical tables, such as salaries in a Human Resources table, is useful.

   You can audit specific actions by using fine-grained auditing, which is described in "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36.

2. **Archive audit records and purge the audit trail.**

   After you collect the required information, archive the audit records of interest and then purge the audit trail of this information. See the following sections:

   - "Archiving the Database Audit Trail" on page 9-61
   - "Archiving the Operating System Audit Trail" on page 9-65
   - "Purging Audit Trail Records" on page 9-65
   - "Controlling the Size of the Database Audit Trail" on page 9-59
   - "Setting the Size of the Operating System Audit Trail" on page 9-62

3. **Remember your company's privacy considerations.**

Privacy regulations often lead to additional business privacy policies. Most privacy laws require businesses to monitor access to personally identifiable information (PII), and monitoring is implemented by auditing. A business-level privacy policy should address all relevant aspects of data access and user accountability, including technical, legal, and company policy concerns.

4. **Check the Oracle Database log files for additional audit information**

   The log files generated by Oracle Database contain useful information that you can use when auditing a database. For example, an Oracle database creates an alert file to record `STARTUP` and `SHUTDOWN` operations, and structural changes such as adding data files to the database.

   For example, if you want to audit committed or rolled back transactions, you can use the redo log files.

Auditing Suspicious Database Activity

When you audit to monitor suspicious database activity, use the following guidelines:

1. **First audit generally, and then specifically.**

   When you start to audit for suspicious database activity, often not much information is available to target specific users or schema objects. Therefore, set audit options more generally at first, that is, by using the standard audit options described in Chapter 9, "Verifying Security Access with Auditing" explains how you can use the standard audit options to audit SQL statements, schema objects, privileges, and so on.

   After you have recorded and analyzed the preliminary audit information, disable general auditing, and then audit specific actions. You can use fine-grained auditing, which is described in "Auditing Specific Activities with Fine-Grained Auditing" on page 9-36, to audit specific actions. Continue this process until you have gathered enough evidence to draw conclusions about the origin of the suspicious database activity.

2. **Audit common suspicious activities.**

   Common suspicious activities are as follows:

   - Users who access the database during unusual hours
   - Multiple failed user login attempts
   - Login attempts by non-existent users

   In addition, monitor users who share accounts or multiple users who are logging in from the same IP address. You can query the `DBA_AUDIT_SESSION` data dictionary view to find this kind of activity. For a very granular approach, create fine-grained audit policies.

3. **Protect the audit trail.**

   When auditing for suspicious database activity, protect the audit trail so that audit information cannot be added, changed, or deleted without being audited. You can audit the standard audit trail by using the `AUDIT` SQL statement.

   For example:

   ```
   AUDIT SELECT ON SYS.AUD$ BY ACCESS;
   ```

   See also "Auditing the Database Audit Trail" on page 9-61.

To audit the fine-grained audit trail, as user SYS, you would enter the following statement:

```
AUDIT SELECT ON SYS.FGA$ BY ACCESS;
```

If you have Oracle Database Vault enabled, you can further protect the SYS.AUDIT$, SYSTEM.AUD$, SYS.FGA$, and SYS.FGA_LOG$ tables by enclosing them in a realm. (In an Oracle Database Vault environment, the AUD$ table is moved to the SYSTEM schema when Oracle Label Security is enabled. SYS.AUD$ becomes a synonym for the SYSTEM.AUD$ table.) See *Oracle Database Vault Administrator's Guide* for more information.

Recommended Audit Settings

Database schema or structure changes. Use the following AUDIT statement settings:

- AUDIT ALTER ANY PROCEDURE BY ACCESS;
- AUDIT ALTER ANY TABLE BY ACCESS;
- AUDIT ALTER DATABASE BY ACCESS;
- AUDIT ALTER SYSTEM BY ACCESS;
- AUDIT CREATE ANY EDITION;
- AUDIT CREATE ANY JOB BY ACCESS;
- AUDIT CREATE ANY LIBRARY BY ACCESS;
- AUDIT CREATE ANY PROCEDURE BY ACCESS;
- AUDIT CREATE ANY TABLE BY ACCESS;
- AUDIT CREATE EXTERNAL JOB BY ACCESS;
- AUDIT DROP ANY EDITION;
- AUDIT DROP ANY PROCEDURE BY ACCESS;
- AUDIT DROP ANY TABLE BY ACCESS;

Database access and privileges. Use these AUDIT statement settings:

- AUDIT ALTER PROFILE BY ACCESS;
- AUDIT ALTER USER BY ACCESS;
- AUDIT AUDIT SYSTEM BY ACCESS;
- AUDIT CREATE PUBLIC DATABASE LINK BY ACCESS;
- AUDIT CREATE SESSION BY ACCESS;
- AUDIT CREATE USER BY ACCESS;
- AUDIT DROP PROFILE BY ACCESS;
- AUDIT DROP USER BY ACCESS;
- AUDIT EXEMPT ACCESS POLICY BY ACCESS;
- AUDIT GRANT ANY OBJECT PRIVILEGE BY ACCESS;
- AUDIT GRANT ANY PRIVILEGE BY ACCESS;
- AUDIT GRANT ANY ROLE BY ACCESS;
- AUDIT ROLE BY ACCESS;

Addressing the CONNECT Role Change

The CONNECT role was introduced with Oracle Database version 7, which added new and robust support for database roles. The CONNECT role is used in sample code, applications, documentation, and technical papers. In Oracle Database 10*g* Release 2 (10.2), the CONNECT role was changed. If you are upgrading from a release earlier than Oracle Database 10.2 to the current release, then read this section.

This section contains:

Why Was the CONNECT Role Changed?

The CONNECT role was originally established with the following privileges:

Privileges A-C	Privileges C
ALTER SESSION	CREATE SESSION
CREATE CLUSTER	CREATE SYNONYM
CREATE DATABASE LINK	CREATE TABLE
CREATE SEQUENCE	CREATE VIEW

Beginning in Oracle Database 10*g* Release 2, the CONNECT role has only the CREATE SESSION privilege, all other privileges are removed.

Although the CONNECT role was frequently used to provision new accounts in Oracle Database, connecting to the database does not require all those privileges. Making this change enables you to enforce good security practices more easily.

Each user should have only the privileges needed to perform his or her tasks, an idea called the principle of least privilege. Least privilege mitigates risk by limiting privileges, so that it remains easy to do what is needed while concurrently reducing the ability to do inappropriate things, either inadvertently or maliciously.

How the CONNNECT Role Change Affects Applications

The effects of the changes to the CONNECT role can be seen in database upgrades, account provisioning, and installation of applications using new databases.

How the CONNECT Role Change Affects Database Upgrades

Upgrading your existing Oracle database to Oracle Database 10*g* Release 2 (10.2) automatically changes the CONNECT role to have only the CREATE SESSION privilege. Most applications are not affected because the applications objects already exist: no new tables, views, sequences, synonyms, clusters, or database links need to be created.

Applications that create tables, views, sequences, synonyms, clusters, or database links, or that use the ALTER SESSION command dynamically, may fail due to insufficient privileges.

How the CONNECT Role Change Affects Account Provisioning

If your application or DBA grants the CONNECT role as part of the account provisioning process, then only CREATE SESSION privileges are included. Any additional privileges must be granted either directly or through another role.

This issue can be addressed by creating a new customized database role.

See Also: Approaches to Addressing the CONNECT Role Change on page 10-24

How the CONNECT Role Change Affects Applications Using New Databases

New databases created using the Oracle Database 10*g* Release 2 (10.2) Utility (DBCA), or using database creation templates generated from DBCA, define the CONNECT role with only the CREATE SESSION privilege. Installing an application to use a new database may fail if the database schema used for the application is granted privileges solely through the CONNECT role.

How the CONNECT Role Change Affects Users

The change to the CONNECT role affects three classes of users differently: general users, application developers, and client/server applications.

How the CONNECT Role Change Affects General Users

The new CONNECT role supplies only the CREATE SESSION privilege. Users who connect to the database to use an application are not affected, because the CONNECT role still has the CREATE SESSION privilege.

However, appropriate privileges will not be present for a certain set of users if they are provisioned solely with the CONNECT role. These are users who create tables, views, sequences, synonyms, clusters, or database links, or use the ALTER SESSION command. The privileges they need are no longer provided with the CONNECT role. To authorize the additional privileges needed, the database administrator must create and apply additional roles for the appropriate privileges, or grant them directly to the users who need them.

Note that the ALTER SESSION privilege is required for setting events. Few database users should require the ALTER SESSION privilege.

```
ALTER SESSION SET EVENTS ........
```

The alter session privilege is *not* required for other alter session commands.

```
ALTER SESSION SET NLS_TERRITORY = FRANCE;
```

How the CONNECT Role Change Affects Application Developers

Application developers provisioned solely with the CONNECT role do not have appropriate privileges to create tables, views, sequences, synonyms, clusters, or database links, nor to use the ALTER SESSION statement. The database administrator must either create and apply additional roles for the appropriate privileges, or grant them directly to the application developers who need them.

How the CONNECT Role Change Affects Client Server Applications

Most client/server applications that use dedicated user accounts will not be affected by this change. However, applications that create private synonyms or temporary tables using dynamic SQL in the user schema during account provisioning or run-time

operations will be affected. They will require additional roles or grants to acquire the system privileges appropriate to their activities.

Approaches to Addressing the CONNECT Role Change

Oracle recommends the following three approaches to address the impact of this change.

Approach 1: Create a New Database Role

The privileges removed from the CONNECT role can be managed by creating a new database role.

First, connect to the upgraded Oracle database and create a new database role. The following example uses a role called my_app_developer.

```
CREATE ROLE my_app_developer;
GRANT CREATE TABLE, CREATE VIEW, CREATE SEQUENCE, CREATE SYNONYM, CREATE CLUSTER,
CREATE DATABASE LINK, ALTER SESSION TO my_app_developer;
```

Second, determine which users or database roles have the CONNECT role, and grant the new role to these users or roles.

```
SELECT USER$.NAME, ADMIN_OPTION, DEFAULT_ROLE
 FROM USER$, SYSAUTH$, DBA_ROLE_PRIVS
 WHERE PRIVILEGE# =
 (SELECT USER# FROM USER$ WHERE NAME = 'CONNECT')
 AND USER$.USER# = GRANTEE#
 AND GRANTEE = USER$.NAME
 AND GRANTED_ROLE = 'CONNECT';

NAME                           ADMIN_OPTI DEF
------------------------------ ---------- ---
R1                             YES        YES
R2                             NO         YES

GRANT my_app_developer TO R1 WITH ADMIN OPTION;
GRANT my_app_developer TO R2;
```

You can determine the privileges that users require by using Oracle Auditing. The audit information can then be analyzed and used to create additional database roles with finer granularity.

Privileges not used can then be revoked for specific users. Note that before auditing, the database initialization parameter AUDIT_TRAIL must be initialized and the database restarted.

```
AUDIT CREATE TABLE, CREATE SEQUENCE, CREATE SYNONYM, CREATE DATABASE LINK, CREATE
CLUSTER, CREATE VIEW, ALTER SESSION;
```

Database privilege usage can now be monitored periodically.

```
SELECT USERID, NAME FROM AUD$, SYSTEM_PRIVILEGE_MAP
WHERE - PRIV$USED = PRIVILEGE;

USERID                         NAME
------------------------------ ----------------
ACME                           CREATE TABLE
ACME                           CREATE SEQUENCE
ACME                           CREATE TABLE
ACME                           ALTER SESSION
```

```
APPS                           CREATE TABLE
APPS                           CREATE TABLE
APPS                           CREATE TABLE
APPS                           CREATE TABLE

8 rows selected.
```

Approach 2: Restore CONNECT Privileges

Starting with Oracle Database 10*g* Release 2 (10.2), Oracle provided a script called `rstrconn.sql` in the `$ORACLE_HOME/rdbms/admin` directory. After a database upgrade or new database creation, this script can be used to grant the privileges that were removed from the `CONNECT` role in Oracle Database 10*g* Release 2 (10.2).

If this approach is used, then privileges that are not used should be revoked from users who do not need them. To identify such privileges and users, the database must be restarted with the database initialization parameter `AUDIT_TRAIL` initialized, for example, `AUDIT_TRAIL=DB`. Oracle Database auditing should then be turned on to monitor what privileges are used, as follows:

```
AUDIT CREATE TABLE, CREATE SEQUENCE, CREATE SYNONYM, CREATE DATABASE LINK, CREATE
CLUSTER, CREATE VIEW, ALTER SESSION;
```

Database privilege usage can also be monitored periodically.

```
SELECT USERID, NAME FROM AUD$, SYSTEM_PRIVILEGE_MAP
WHERE - PRIV$USED = PRIVILEGE;

USERID                         NAME
------------------------------ ----------------
ACME                           CREATE TABLE
ACME                           CREATE SEQUENCE
ACME                           CREATE TABLE
ACME                           ALTER SESSION
APPS                           CREATE TABLE
APPS                           CREATE TABLE
APPS                           CREATE TABLE
APPS                           CREATE TABLE
8 rows selected.
```

New View Showing CONNECT Grantees A new view enables administrators who continue using the old `CONNECT` role to see quickly which users have that role.

Table 10–1 shows the columns in the new `DBA_CONNECT_ROLE_GRANTEES` view.

Table 10–1 Columns and Contents for DBA_CONNECT_ROLE_GRANTEES

Column Name	Contents
Grantee	User granted the `CONNECT` role
Path_of_connect_role_grant	Role (or nested roles) by which the user is granted `CONNECT`
Admin_opt	`VARCHAR2(3)`, `YES` if user has the `ADMIN` option on `CONNECT`; otherwise, `NO`

Approach 3: Conduct Least Privilege Analysis

Oracle partners and application providers should use this approach to deliver more secure products to the Oracle customer base. The principle of least privilege mitigates risk by limiting privileges to the minimum set required to perform a given function.

For each class of users that the analysis shows need the same set of privileges, create a role with only those privileges. Remove all other privileges from those users, and assign that role to those users. As needs change, you can grant additional privileges, either directly or through these new roles, or create new roles to meet new needs. This approach helps to ensure that inappropriate privileges have been limited, thereby reducing the risk of inadvertent or malicious harm.

Glossary

application context

A name-value pair that enables an application to access session information about a user, such as the user ID or other user-specific information, and then securely pass this data to the database.

See also **global application context**.

application role

A database role that is granted to application users and that is secured by embedding passwords inside the application.

See also **secure application role**.

certificate

An ITU x.509 v3 standard data structure that securely binds an identify to a public key.

A certificate is created when an entity's public key is signed by a trusted identity, a certificate authority. The certificate ensures that the entity's information is correct, and that the public key belongs to that entity.

A certificate contains the entity's name, identifying information, and public key. It is also likely to contain a serial number, expiration date, and information about the rights, uses, and privileges associated with the certificate. Finally, it contains information about the certificate authority that issued it.

certificate revocation list (CRL)

See **CRL**.

Classless Inter-Domain Routing

See **CIDR**.

cleartext

Unencrypted plain text.

CIDR

The standard notation used for IP addresses. In CIDR notation, an IPv6 subnet is denoted by the subnet prefix and the size in bits of the prefix (in decimal), separated by the slash (/) character. For example, `fe80:0000:0217:f2ff::/64` denotes a subnet with addresses `fe80:0000:0217:f2ff:0000:0000:0000:0000` through `fe80:0000:0217:f2ff:ffff:ffff:ffff:ffff`. The CIDR notation includes support for IPv4 addresses. For example, `192.0.2.1/24` denotes the subnet with addresses `192.0.2.1` through `192.0.2.255`.

CRL

A set of signed data structures that contain a list of revoked **certificates**. The authenticity and integrity of the CRL is provided by a digital signature appended to it. Usually, the CRL signer is the same entity that signed the issued certificate.

definer's rights procedure

A procedure (or program unit) that executes with the privileges of its owner, not its current user. Definer's rights subprograms are bound to the schema in which they are located.

For example, assume that user `blake` and user `scott` each have a table called `dept` in their respective user schemas. If user `blake` calls a definer's rights procedure, which is owned by user `scott`, to update the `dept` table, then this procedure will update the `dept` table in the `scott` schema. This is because the procedure executes with the privileges of the user who owns (defined) the procedure (that is, `scott`).

See also **invoker's rights procedure**.

decryption

Decoding an encyrpted message so that it is readable.

denial-of-service (DoS) attack

An attack that renders a Web site inaccessible or unusable. The denial-of-service attack can occur in many different ways but frequently includes attacks that cause the site to crash, reject connections, or perform too slowly to be usable. DoS attacks come in two forms:

- Basic denial-of-service attacks, which require only one or a few computers
- Distributed denial-of-service (DDoS) attacks, which require many computers to execute

directly granted role

A **role** that has been granted directly to the user, as opposed to an **indirectly granted role**.

encryption

Disguising a message, rendering it unreadable to all but the intended recipient.

forced cleanup

The ability to forcibly cleanup (that is, remove) all audit records from the database. To accomplish this, you set the `USE_LAST_ARCH_TIMESTAMP` argument of the `DBMS_AUDIT_MGMT.CLEAN_AUDIT_TRAIL` procedure to `FALSE`.

See also **purge job**.

Forwardable Ticket Granting Ticket

A special Kerberos ticket that can be forwarded to proxies, permitting the proxy to obtain additional Kerberos tickets on behalf of the client for proxy authentication.

See also **Kerberos ticket**.

global application context

A name-value pair that enables application context values to be accessible across database sessions.

See also **application context**.

indirectly granted role

A **role** granted to a user through another role that has already been granted to this user. Then you grant the `role2` and `role3` roles to the `role1` role. Roles `role2` and `role3` are now under `role1`. This means `psmith` has been indirectly granted the roles `role2` and `role3`, in addition to the direct grant of `role1`. Enabling the direct role1 for psmith enables the indirect roles role2 and role3 for this user as well.

integrity

A guarantee that the contents of a message received were not altered from the contents of the original message sent.

invoker's rights procedure

A procedure (or program unit) that executes with the privileges of the current user, that is, the user who invokes the procedure. These procedures are not bound to a particular schema. They can be run by a variety of users and allow multiple users to manage their own data by using centralized application logic. Invoker's rights procedures are created with the `AUTHID` clause in the declaration section of the procedure code.

For example, assume that user `blake` and user `scott` each have a table called `dept` in their respective user schemas. If user `blake` calls an invoker's rights procedure, which is owned by user `scott`, to update the `dept` table, then this procedure will update the `dept` table in the `blake` schema. This is because the procedure executes with the privileges of the user who invoked the procedure (that is, `blake`.).

See also **definer's rights procedure**.

KDC

A computer that issues Kerberos tickets.

See also **Kerberos ticket**.

Kerberos ticket

A temporary set of electronic credentials that verify the identity of a client for a particular service. Also referred to as a service ticket.

Key Distribution Center (KDC)

See **KDC**.

last archive timestamp

A timestamp that indicates the timestamp of the last archived audit record. For the database audit trail, this timestamp indicates the last audit record archived. For operating system audit files, it indicates the highest last modified timestamp property of the audit file that was archived. To set this timestamp, you use the `DBMS_AUDIT_MGMT.SET_LAST_ARCHIVE_TIMESTAMP` PL/SQL procedure.

See also **purge job**.

lightweight user session

A user session that contains only information pertinent to the application that the user is logging onto. The lightweight user session does not hold its own database resources, such as transactions and cursors; hence it is considered "lightweight." Lightweight user sessions consume far less system resources than traditional database session. Because lightweight user sessions consume much fewer server resources, a lightweight user session can be dedicated to each end user and can persist for as long as the application deems necessary.

mandatory auditing

Activities that are audited by default, regardless of whether or not auditing was enabled. These activities include connections to the instance with administrator privileges, database startups, and database shutdowns. Oracle Database writes these activities to the operating system audit trail.

namespace

In Oracle Database security, the name of an application context. You create this name in a `CREATE CONTEXT` statement.

Oracle Virtual Private Database

A set of features that enables you to create security policies to control database access at the row and column level. Essentially, Oracle Virtual Private Database adds a dynamic `WHERE` clause to a SQL statement that is issued against the table, view, or synonym to which an Oracle Virtual Private Database security policy was applied.

PUBLIC role

A special role that every database account automatically has. By default, it has no privileges assigned to it, but it does have grants to many Java objects. You cannot drop the `PUBLIC` role, and a manual grant or revoke of this role has no meaning, because the user account will always assume this role. Because all database user accounts assume the `PUBLIC` role, it does not appear in the `DBA_ROLES` and `SESSION_ROLES` data dictionary views.

purge job

A database job created by the `DBMS_AUDIT_MGMT.CREATE_PURGE_JOB` procedure, which manages the deletion of the audit trail. A database administrator schedules, enables, and disables the purge job. When the purge job becomes active, it deletes audit records from the database audit tables, or it deletes Oracle Database operating system audit files.

See also **forced cleanup**, **last archive timestamp**.

role

A named group of related privileges that you grant as a group to users or other roles.

See also **indirectly granted role**.

salt

In cryptography, a way to strengthen the security of encrypted data. Salt is a random string that is added to the data before it is encrypted, making it more difficult for attackers to steal the data by matching patterns of ciphertext to known ciphertext samples. Salt is often also added to passwords, before the passwords are encrypted, to avoid dictionary attacks, a method that unethical hackers (attackers) use to steal passwords. The encrypted salted values make it difficult for attackers to match the hash value of encrypted passwords (sometimes called verifiers) with their dictionary lists of common password hash values.

secure application role

A database role that is granted to application users, but secured by using an invoker's right stored procedure to retrieve the role password from a database table. A secure application role password is not embedded in the application.

See also **application role**.

separation of duty

Restricting activities only to those users who must perform them. For example, you should not grant the `SYSDBA` privilege to any user. Only grant this privilege to administrative users. Separation of duty is required by many compliance policies. See "Guidelines for Securing User Accounts and Privileges" on page 10-2 for guidelines on granting privileges to the correct users.

service ticket

See **Kerberos ticket**.

wallet

A data structure used to store and manage security credentials for an individual entity.

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