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(2021 Revision) Chapter 4: Essential Aspects of Physical Design and Implementation of Relational Databases

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Chapter 4. Security

Data are valuable resources which must be protected from unauthorized access, either intentional or accidental. The terms of access to data are specified in the security portion of the business rules. Security business rules are supposed to define:

- Who (which users or applications) can access data in the database?
- What portion of data each entitled user can access?
- What operations each entitled user can perform on this data?

Security measures of the database and database applications must correspond to these requirements. In this chapter, we discuss the features of DBMSs that are used for implementing *database* security.

Database security measures are only a part of the complex technological security support in today's information systems (IS). In addition to technological measures, security is supported by various administrative approaches and routines. This chapter concentrates on securing the data within the database.

Database Security

The security of data is supported at several different levels, including network, application, and database (Figure 1).

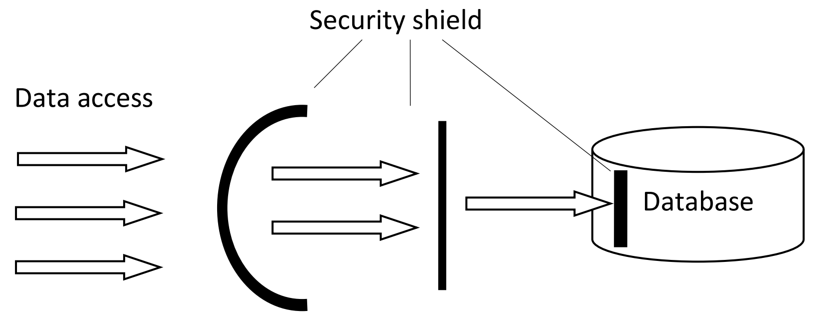


Figure 1. Multiple security shields in an IS.

This chapter focuses on security measures implemented in the database. Although security implemented outside the database plays an important role, it is crucial to understand that this outer security shield is not sufficient to protect the data and cannot substitute for the in-database security. The main shortcoming of the outer security shield is that it can be bypassed.

For example, let's say for the sake of argument that the user John is not allowed to access the database and the user Scott can access some portions of the data in the database. The application through which users work with the database implements the required security rules: (a) John cannot log into the application at all, (b) Scott can use the application, but his access to data is restricted by this application. However, there are no special security measures implemented in the database to prevent John or Scott from accessing data that they are not supposed to access. Therefore, if John or Scott decide to use another application, e.g. SQL*Plus in Oracle, they may be able to access the restricted data. As Figure 2 shows, relying on outer security measures (like security implemented in the application) and not enforcing the in-database security can lead to security breaches.

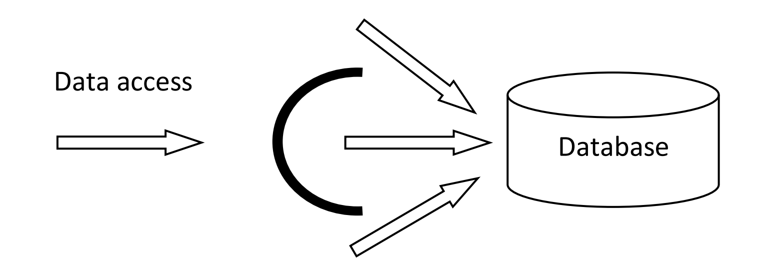


Figure 2. Bypassing security measures outside the database.

In-database security measures (Figure 3) cannot be bypassed and hence make the overall data protection more reliable.

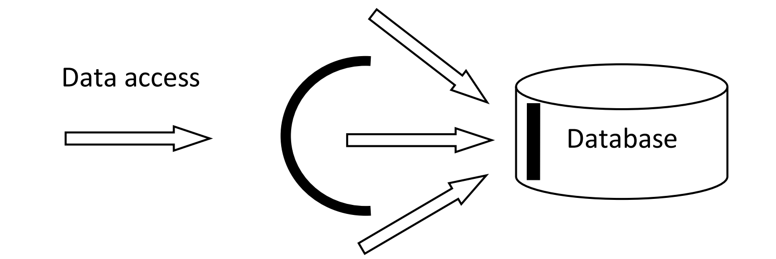


Figure 3. Reliability of database security measures.

Another advantage of implementing security in the database is that security policies are applied once, instead of being implemented repeatedly in different applications on the database.

Data security must be supported within the database.

To satisfy user requirements on data security, security measures must specify which users can perform which operations and on what data.

Database security is about ensuring that only authorized users can perform allowed operations on the data.

Security measures define certain relationships between *users, operations*, and *data***.** The required security can be ensured by checking whether the triplet of access (user, operation, data object) is valid. For example, if the user John requests data about the age of employees from the table Employee, the system checks whether *John* has the permission to *select* from the attribute *Age* of the table Employee***.***

This chapter discusses security and protection from security threats such as theft and fraud, loss of confidentiality, and loss of privacy; all of which are violations of valid relationships between a user and operations the user can perform on particular data.

In some text books the discussion of security includes such issues as integrity and availability of data. We want to emphasize the difference between the concepts of security, and integrity and availability.

The integrity of data is the correspondence of data to specific structural or action-oriented business rules. It must be supported by the appropriate implementation of integrity constraints[1], and it cannot be enforced by security measures. For example, if according to a business rule which states that the values of the attribute Age in the table Employee has to be between 18 and 65, then the CHECK constraint on the attribute Age will guarantee the integrity of this attribute. However, the CHECK constraint does not implement any security control. If the security of data requires that only the user John can modify the attribute Age, then security measures have to prevent any other user from changing values of this attribute. On the other hand, security measures are not related to integrity – even with a successful implementation of security, but without the corresponding integrity constraint, the user John can make a mistake while entering data into the Age attribute and violate the correctness of data.

Security measures shield data from unauthorized access, while integrity measures protect data from any authorized changes that can violate the correctness of the data (Figure 4). However, in some cases integrity can be additionally enforced with the help of security tools. For example, in Chapter 3 on distrbituted design we discussed integrity in the distributed database. For vertical fragmentation, inserting and deleting data has to be performed on all fragments, and it is recommended that the direct insert and delete operations on fragments should not be allowed. Instead, users should execute special procedures that implement the inserting and deleting of data into all fragments. Although these special procedures are implementing secure access, they also ensure the integrity of the data.

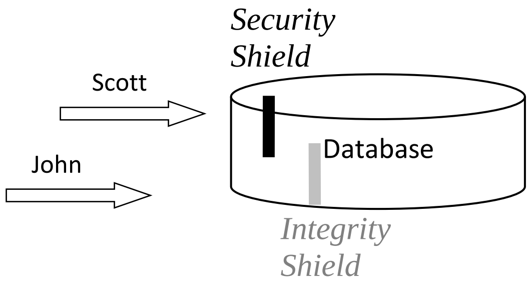


Figure 4. Security and Integrity.

The availability of data is discussed in detail in Chapter 7. The database and other components of the IS have to be reliable to provide the availability of the data. If the database is unavailable, security measures cannot change the situation and make data available to those who are authorized to use it. On the other hand, when data is available via a properly functioning IS, it is important to secure the data and ensure that unauthorized users cannot access it (Figure 5).

[1] Either by the declarative integrity constraints in a table definition, such as PRIMARY KEY, FOREIGN KEY, CHECK, or with the help of triggers.

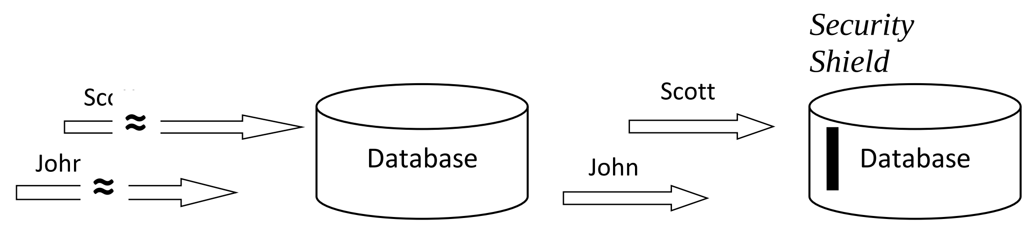


Figure 5. Security and Availability.

Security measures provided by DBMSs include:

- *Authentication of users*. Authentication measures define users who are entitled to work with a database and their credentials which the DBMS uses to authenticate users trying to get access to a database.
- *Authorization of access to data*. For users who are authenticated by the database, authorization measures define the kind of actions that these users can perform on that database.

Most DBMSs support a special method of protecting data – encryption. Encryption is the encoding of data by special procedures. Interpretation of encrypted data without the corresponding decryption key is difficult. Even if users can access the data, they will not be able to interpret and use the data.

In this chapter we will limit our discussions to the authentication and authorization tools of DBMSs.

The Basic Tools for Implementing Security

Users and Schemas

The first part in the security triplet of access is the *user*. When a user is trying to access a database resource, first the database must recognize or authenticate the user. The user name and password are the primary authentication tools. User authentication can be enhanced by additional measures, such as limiting the number of attempts to log into the database with incorrect user names/passwords, locking access to the database for a user after the submission of a certain number of incorrect passwords, or specifying an expiration date of the user's identification, and other means.

Users are objects of the database (not included in any schema). As with every other database object, a new user has to be created in the database, and then the user's identification information must be specified. This involves security issues such as who can create new database users? Can any registered database user create new users? Let us assume that there is a user, e.g. the database administrator, who can create users. Later in the chapter, we will discuss the special privileges needed for managing other users. The administrator creates the user Scott and assigns him the password 'tiger':

```
Admin>      CREATE USER Scott IDENTIFIED BY tiger;
```

After a user is created, establishing relationships between the *user,* database *objects* and *operations* has to be provided.

The fact that a user is registered in the database does not mean that he can perform any operation – for every action, which is possible in the database, the user must be given explicit permission or *privilege*. Privileges for operations are *granted* to users, e.g. granting a connection to a database in Oracle is performed as:

```
Admin>      GRANT CREATE SESSION TO Scott;
```

As security involves users, actions, and data objects, a user may be granted the privilege to perform an action on all objects of a particular type, e.g. the following statement allows the user Scott to create tables:

```
Admin>      GRANT CREATE TABLE TO Scott;
```

Creation of any other object of the database: view, snapshot, index, trigger, etc. must be explicitly granted, if allowed.

Privileges, once given, can be taken away:

```
Admin>      REVOKE CREATE TABLE FROM Scott;
```

All objects created by a particular user[2], belong to this user, or, in other words, the user is the owner of these objects. These objects compose the user's schema (Figure 6). The name of the schema is the same as the name of the user. Note that not all users of the database have schemas – only those who have objects. If a user is allowed to create objects, e.g. tables, this implies that the user can perform all other legal operations on the created objects, e.g. DROP, ALTER, SELECT, INSERT, DELETE, and UPDATE on the tables.

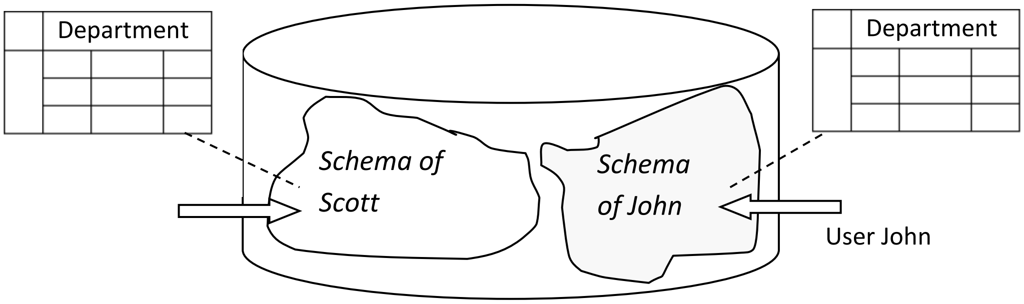


Figure 6. Users and Schemas.

A user does not need privileges to manipulate objects from his schema.

Having been given the database account, the create session and create table privileges, Scott can now get access to the database, create his tables and manipulate them. Scott does not see and cannot access any object from schemas of other users of the database, e.g. objects of John, without getting special privileges for access.

When accessing an object from another schema, the user has to specify the full object name, which is composed of the schema name and the object name. For example, if Scott wants to access the table Department in John's schema, the following request will not be successful:

```
Scott>      SELECT * FROM Department;
```

Instead of accessing John's table, Scott will see data of his own table Department because if the name of an

[2] Or on the user's behalf by a user who has such special privileges.

object is not prefixed by the schema name, the system looks for the object in the schema of the user who issues the request. Scott will be able to see data from John's table Department with the help of the following statement:

```
Scott>      SELECT * FROM John.Department;
```

Whether this request is successful depends on the privileges granted to Scott on John's table Department.

Schemas are an efficient database security tool; they restrict users' access to objects that do not belong to them.

A user must be explicitly granted privileges for a particular type of access to an object of another user. The owner of the object (or users with special privileges that are discussed later) can grant such privileges. With the following statement, John can grant Scott the privilege to select from the table Department from his schema (note that here John refers to his table and does not need to prefix the table name by the name of the schema).

```
John> GRANT SELECT ON Department TO Scott;
```

With only this privilege granted, Scott cannot modify data in John's table Department as for each new action on John's table, Scott needs a corresponding privilege.

Users need privileges for every operation on every data object owned by another user.

When being granted a particular privilege, a user may be authorized to pass this privilege to other users with the help of the `WITH GRANT` option. By the following command, John not only grants Scott the privilege to select from his table, but also gives him the right to grant this privilege to other users:

```
John> GRANT SELECT ON Department TO Scott WITH GRANT OPTION;
```

Now Scott can grant the privilege to select from the table Department from John's schema to other users:

```
Scott>      GRANT SELECT ON John.Department TO Adam;
```

The `WITH GRANT` option has to be used with caution because it can lead to uncontrollable spreading of privileges and possible violations of security requirements.

Often users need access privileges for only some columns of a table. For example, John reconsiders the privileges of Scott and wants to limit Scott to seeing only the attributes deptCode and deptName from his table Department. This can be performed by first revoking Scott's current privilege and then granting privileges on only the specific columns needed as shown below:

```
John> REVOKE SELECT ON Department FROM Scott;

John> GRANT SELECT deptCode,deptName ON Department TO
                  Scott;
```

Roles

Often numerous users of the database require similar privileges, e.g. accountants of the financial office of a company usually need similar access to data. It is difficult and time consuming to repeat the same granting actions for every user. For simplification of handling security issues, most DBMSs include a separate object *role* (or *user group*). Role is a set of privileges. After a role is created and some privileges are granted to the role, then the role (as the set of privileges) can be granted to users or other roles (Figure 7). For example, accountants of the financial office need several privileges on John's table Department. After creating the role for this group of users and granting to this role all required privileges, a new user-accountant can receive the needed privileges through one granting statement, like Scott in the example below:

```
Admin>      CREATE ROLE Accountant;
John> GRANT SELECT, INSERT ON Department TO Accountant;
Admin>      GRANT Accountant TO Scott;
```

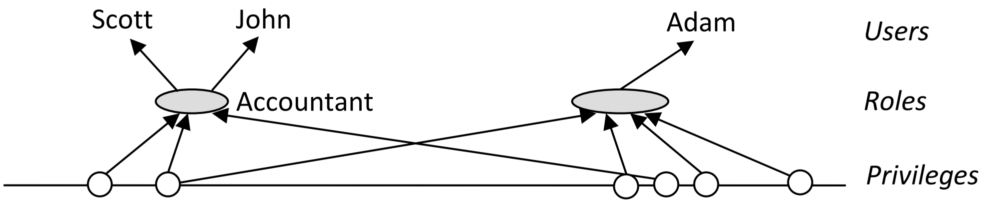


Figure 7. Users, roles and privileges.

Through the role Accountant, Scott was granted two privileges: SELECT and INSERT on John's table Department. This is equivalent to executing two direct corresponding GRANT commands.

Not only is it easier to pass privileges to numerous users through roles, but roles also make privilege management easier. If security requirements for a group of users change, these changes applied to the corresponding roles will be automatically reflected in privileges of the users who have been granted the roles. For example, if a new privilege is added to the role Accountant, then the privilege is automatically passed to user Scott and all other users through the role Accountant:

```
John> GRANT UPDATE ON Department TO Accountant;

Scott>      UPDATE John.Department SET …;
```

In other words, at any given moment, a user who has been granted a particular role has the privileges associated with that role at that moment.

Compare this to the situation when SELECT and INSERT ON Department are granted to Scott and many other users-accountants directly:

```
John>     GRANT SELECT, INSERT ON Department TO Scott;
```

If one of these two privileges needs to be revoked from this group of users, multiple revoke operations – for each user in the group – needs to take place.

Object and System Privileges

In the previous sections, a data object from the triplet (*user, action, data object*) was a particular object of a specific schema. Privileges on particular objects are called *object* privileges, e.g. the following statement grants

Scott the privilege to select from the Department table:

```
Admin>      GRANT SELECT ON Department TO Scott;
```

It is also possible to give a privilege on all data objects of a particular class in one statement, e.g. the following statement grants Scott the privilege to select from all tables:

```
Admin>      GRANT SELECT ON ANY TABLE TO Scott;
```

Such privileges are called *system* privileges. Without any additional permission, Scott will be able to select data from all tables of other users. System privileges also include such privileges as CREATE USER, CREATE ROLE, CREATE TABLE, and other privileges for special operations. System privileges have to be granted with caution.

Now we can answer the question raised at the beginning of the chapter – which users can create other users or roles? Users with the system privileges CREATE USER and CREATE ROLE can perform these operations. But who grants these users the system privileges?

The process of installation of a database usually includes the creation of a number of users with special privileges and roles, and with predefined passwords[3]. In Oracle, for example, one such user is SYS who has all privileges, including privileges to create other users and grant these users privileges. Usually, SYS creates a number of user accounts for database administrators and grants them system privileges. Then, these users can manage the other users of the database. We can think of the security system as a pyramid: from fewer users with many privileges to a larger number of users with fewer privileges – see Figure 8. Please note that on different levels we have different kinds of privileges: mostly system privileges on higher levels and mostly object privileges on lower levels.

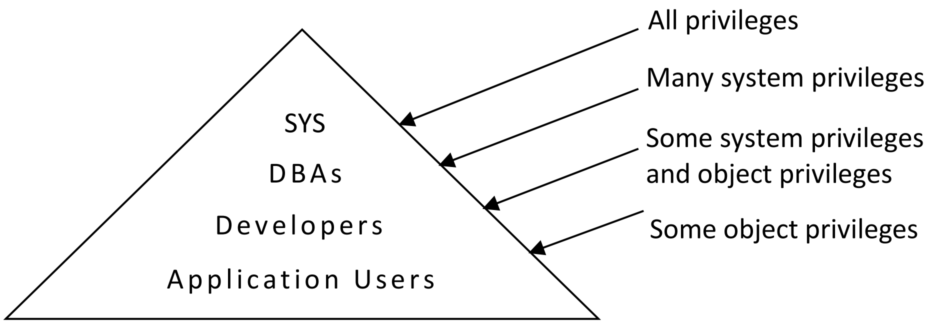


Figure 8. Security Pyramid.

The following scenario illustrates creation of the security pyramid:

`SYS> CREATE USER DBA1 IDENTIFIED BY lion;`
`SYS> GRANT CREATE USER TO DBA1;`
…
	SYS creates a user account that will perform administrative task, e.g. creating user accounts.

[3] The passwords have to be changed upon installation.

`DBA1> CREATE USER scott IDENTIFIED BY tiger;`
`DBA1> GRANT CONNECT TO scott;`
`DBA1> GRANT CREATE TABLE TO scott;`
…
	DBA1 creates an account for a database developer who will need to create different database objects.

`DBA1> CREATE USER john IDENTIFIED BY panther;`
`DBA1> GRANT CONNECT TO john;`
	DBA1 creates an account for a database user who will be using objects created by developers.

`Scott> CREATE TABLE foo (…);`
`Scott> GRANT SELECT ON foo TO john;`
…
	Scott creates a table and grants some privileges on this table to John.

We discussed how object privileges are passed from one user to another – the owner of an object can grant privileges on operations on the object to other users with the grant option. System privileges can be passed to other users when they are granted with the `ADMIN OPTION`, e.g. the administrator grants Scott the privilege to create users and to grant this privilege to other users:

```
Admin>      GRANT CREATE USER TO Scott WITH ADMIN OPTION;
```

Now Scott can grant (revoke) the privilege to create users to (from) other users. It is not recommended to give privileges with the admin option to regular (non-administrative) users of the database.

Database Objects and Security

Usually, security requirements are more complicated than the requirements mentioned in the previous section, and the basic security tools are not sufficient to implement all the requirements. Other database objects, such as views and procedures, are often used for enhancing security.

Views

With the security measures discussed before, the finest grain of security that can be achieved is a column of a table. However, in many cases, users are required to access only particular rows of a table. For example, for the table Department in the Manufacturing Company database, users from Cleveland can access only the rows of the departments located in Cleveland.

Such security requirements can be implemented with the help of views. In Chapter 2 we showed how views are used to implement the transparency of the data in the centralized database and the transparency of the fragmentation in the distributed database. Views are also an important tool for implementing security.

In the case where a user is supposed to access only certain data in a table, the user should not be granted access to the table (or might have privileges revoked on the table in case the user was previously granted the privileges). Instead, the user can be granted access to a view defined on the table. If a view is defined on particular columns and rows of the table, the user would be able to access only these columns and rows through the view (Figure 9).

View processing includes transforming the query on the view into the query on the view definition. For example, the user John creates a view and grants reading privileges on the view to Scott (while revoking the reading privileges on the whole table):

```
John> CREATE VIEW vw_Department AS
                SELECT deptCode, DeptName
                FROM Department WHERE location = ‘Cleveland’;

John> REVOKE SELECT ON Department FROM Scott;

John> GRANT SELECT ON vw_Department TO Scott;
```

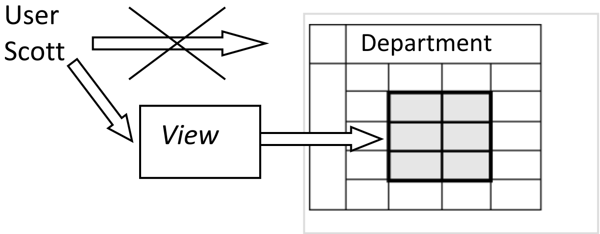


Figure 9. Views as a security tool.

Now Scott can select only from the view:

```
Scott>      SELECT * FROM John.vw_Department;
```

In Scott's request, the name of the view is substituted by the view definition and the request is transformed into the following query:

```
SELECT * FROM
(SELECT deptCode, DeptName
FROM John.Department WHERE location = ‘Cleveland’);
```

With such a security solution, Scott cannot see data beyond the view definition.

Views can be used for data modification as well. If in addition to the select privilege, Scott is granted the update privilege on the view, he can update data in the table Department through the view:

```
John> GRANT UPDATE ON vw_Department TO Scott;

Scott>      UPDATE John.vw_Department SET deptName = ‘New name’
        WHERE deptCode = ‘004’;
```

Views can prevent passing data inconsistent with the view definition into the view's table. This is accomplished with the help of `CHECK OPTION`. Let us redefine the view vw_Department:

```
John> CREATE VIEW vw_Department AS
                SELECT deptCode, DeptName
                FROM Department WHERE location = ‘Cleveland’
                WITH CHECK OPTION CONSTRAINT Department_Cleveland;
```

Now the check option constraint will control the data inserted into the table through the view corresponding to the view's conditions. For example, after Scott is granted the insert privilege on the view, his first insert into the table Department will be successful, while the second will fail because the inserted value 'Boston' for the attribute location is inconsistent with the view's constraint location = 'Cleveland':

```
John> GRANT INSERT ON vw_Department TO Scott;

Scott>      INSERT INTO John.vw_Department VALUES
                  ('999', 'Accounts Payable', 'Cleveland'); (succeeds)

Scott>      INSERT INTO John.vw_Department VALUES
                  ('888', 'Accounts Receivable', 'Boston'); (fails)
```

Definitions of views may be more complicated, e.g. can include joins or aggregates. Each DBMS has specific limitations on the possibilities of modifying data through complex views.

Stored Procedures

In Chapter 2 we discussed how stored procedures are used for implementing transparency of allocation and distribution. Stored procedures are also used for support of data security. Like views, procedures provide indirect access to specific portions of a table's data when full access to the table is not allowed.

Consider the security requirements that were supported with the help of the view in the previous section – Scott can access only data about the Cleveland departments from John's table Department. To implement these requirements using stored procedures, we create two procedures – for updates and inserts on the table:

```
John> CREATE PROCEDURE update_Cleveland
         (par_deptCode CHAR, par_deptName VARCHAR2) AS
                  BEGIN
                        UPDATE Department SET deptName = par_deptName
                WHERE deptCode = par_deptcode AND location =
                'Cleveland';
                  END;


John> CREATE PROCEDURE insert_Cleveland
         (par_deptCode CHAR, par_deptName VARCHAR2) AS
                  BEGIN
                        INSERT INTO Department
                        VALUES (par_deptCode, par_deptName,
'Cleveland');
                  END;
```

The user Scott is denied the privileges of performing direct operations on the table Department and is granted the privileges to execute these procedures. Note that the procedure for updates – update_Cleveland – ensures that the updated department is located in Cleveland (if the department is located in another city or does not exist, no rows are updated). The second procedure for inserts – insert_Cleveland – assigns Cleveland as the location for the new department.

```
John> GRANT EXECUTE update_Cleveland, insert_Cleveland
            TO Scott;

Scott>      EXEC John.insert_Cleveland ('999', 'Accounts
            Payable');
```

Parameters of this procedure call are passed to the INSERT statement of the procedure and the following insert takes place:

```
INSERT INTO John.Department
VALUES (‘999’, ‘Accounts Payable’, ‘Cleveland’);
```

Procedures enable the implementation of complicated security requirements that cannot be supported by the basic security measures or views.

Synonyms

In the previous sections we showed that the objects used for implementing transparency – views and procedures – can be effective security tools because through them, users can get access to specific portions of data of the table without getting access to the whole table. Another transparency object – synonym – is not used for implementing security because it is just an additional name for a database object and users can access the synonym only if they have the corresponding access privileges on the object itself. For example, if John creates a public synonym for his table Department, other users will need privileges on the table in order to access the synonym. Below, Scott succeeds in accessing the synonym, while Adam who does not have access privileges on the table, fails:

```
John> CREATE PUBLIC SYNONYM syn_Department FOR
                        Department;

John> GRANT SELECT ON Department TO Scott;
```

Because we used the option PUBLIC in the definition of the synonym, all users will be able to see and use it without referring to the schema of Scott (most of the other objects do not have this option).

```
Scott>      SELECT * FROM syn_Department; (succeeds)

Adam> SELECT * FROM syn_Department; (fails)
```

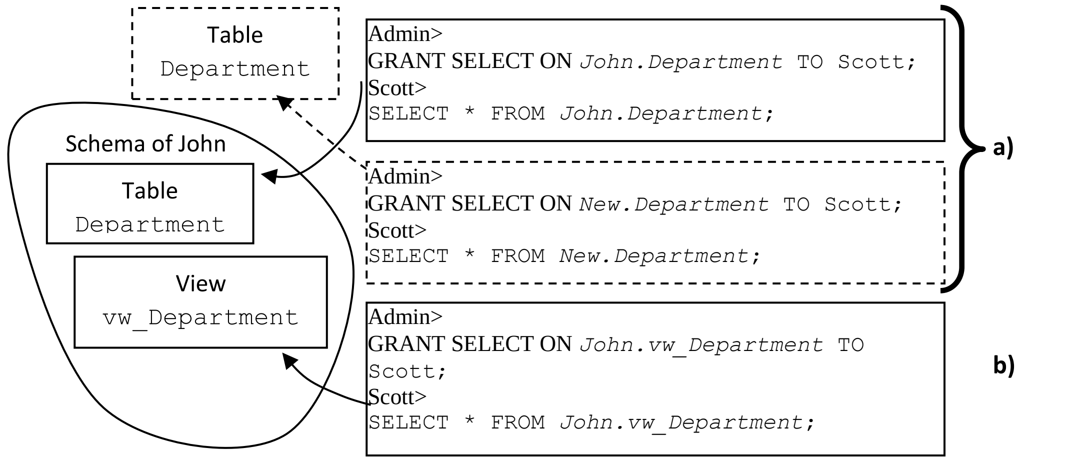
Synonyms cannot enhance security – synonyms of an object have the same security measures as the object.

Security and Transparency

Views and procedures – objects that are used for implementing security of the database – are also used for the support of data transparency. Though technically transparency and security are different features of the database, there is a logical connection between them. If users are not allowed to access a particular database resource, this resource has to be transparent to them. By sustaining security we can achieve transparency, and we can use transparency for implementing security. However, while transparency is a highly desirable feature of the database, security is a required one.

Let us again discuss views and see how they can not only enforce security, but can also make security measures less dependent on database changes. If we define security measures on views, and not on tables, we enforce the transparency of the data for these security measures. For example, the table Department is in John’s schema, and Scott is running an application that accesses this table. If for some reason the table is moved to another schema or is renamed, then the application has to be changed, as well as the security measures – see Figure 10a).

If there is a tier of views (see discussion of transparency in Chapter 2), and security measures are defined on those views, then changes to the table will only cause a redefinition of the views and can be transparent to the security measures and applications see Figure 10b).



```
Admin>
GRANT SELECT ON John.Department TO Scott;
Scott>
SELECT * FROM John.Department;
```

```
Admin>
GRANT SELECT ON New.Department TO Scott;
Scott>
SELECT * FROM New.Department;
```

```
Admin>
GRANT SELECT ON John.vw_Department TO
Scott;
Scott>
SELECT * FROM John.vw_Department;
```

Figure 10. Security measures on tables and views.

Additional Security Measures

In many DBMSs security is enhanced by additional measures:

- *Limiting resources:* Often administrators establish limits on users' resources consumption, such as CPU time, memory, storage and other resources, to prevent the excessive use of resources.
- *User accounts management:* It is recommended to manage users' accounts by setting expiration dates and requiring regular modifications of passwords, control of passwords' complexity, etc.
- *Auditing:* Often various database activities are audited – information about users' actions is recorded in the database. Audit information can help in discovering security breaches.

Security in the Distributed Database

In a distributed database, each component database should have the required security measures for access of local users. If the database is accessed remotely (from another database), the database has to authenticate the access and check whether it is authorized. Therefore, when users need to access data from several databases, in addition to the local authentication of users and authorization of local access, developers have to implement distributed security, which includes remote user authentication and distributed authorization of access throughout all component databases.

Remote User Authentication

We will call the site from which a user is working, the local site, and the site which the user tries to access, the remote site. If a user who is working on the local site is accessing data in the remote database, the local database sends identification information to the remote database. Here, the local database is perceived by the remote database as a user requesting access. The local site can identify itself in several different ways:

1. *As a specific user of the remote database.* For example, the Boston database is always authenticated in the New York database as the user John. Any user of the Boston database who tries to access the New York database is authenticated there as John. This approach requires the user John to be created in the New York database (Figure 11).

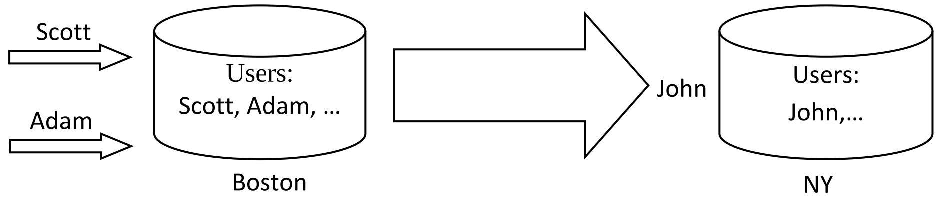


Figure 11. Authentication as a specific local user.

2. *As a local user who is requesting remote access.* For example, for Scott's request, the Boston database is authenticated by the New York database as Scott, and for John's – as John. In this case, local users who need remote access must be replicated in the New York database (Figure 12).

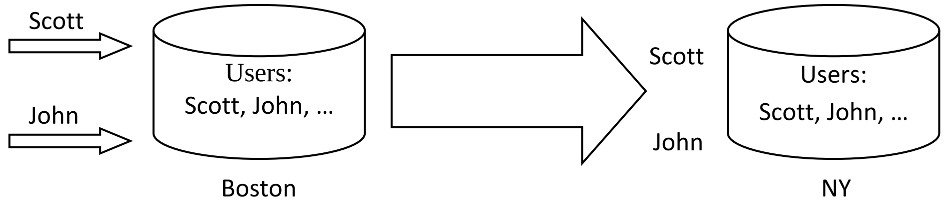


Figure 12. Authentication as a requesting user.

3. *As one or more of the local users.* Identification information depends on the local user requesting remote access and the type of access. For example, in some situations, Scott's request to the New York database results in authentication of the Boston database as Scott and in others – as John. Depending on how Scott is accessing the remote database, users Scott or John must be replicated in the New York database (Figure 13).

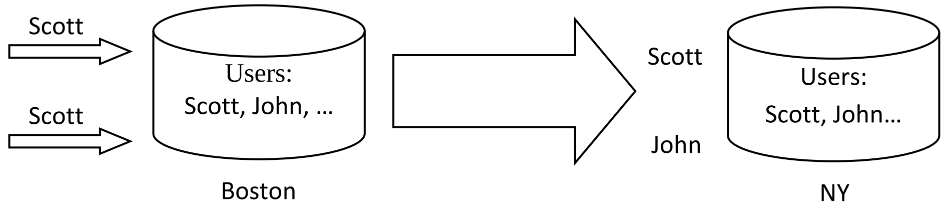


Figure 13. Authentication as one or more of the local users.

Distributed Authorization of Access

If a user is authenticated by a remote database, the user's access to the remote data will be defined by authorization rules.

Authorization for remote access cannot be established from the local database – each database manages authorization autonomously. Combining authentication methods and replication of users with authorization rules on the remote site can produce multiple security scenarios.

Consider the situation when the local database identifies itself as a local user and requests a remote resource as in Figure 4-12. The local user Scott who is replicated in the remote database requests data from his table Employee in the New York database:

```
Scott>      SELECT * FROM Employee@ny;
```

The New York database receives this as a request from Scott and authenticates it. After that, Scott is allowed to access the remote table Employee from his schema.

The scenario is different for the situation when the local database identifies itself as a specific local user as in Figure 11. The request that originates from Scott reaches the New York database as a request from John. Because the table name in the request is not prefixed by a schema name, the remote database will look into John's schema and hence the request will be unsuccessful.

For the request to be successful, the following two considerations have to be made:

- Scott has to rewrite the request as:

  ```
  Scott>     SELECT * FROM Scott.Employee@ny;
  ```

- The user John has to be granted a corresponding privilege on Scott's table Employee in the remote database (by Scott or another authorized user):

  ```
  GRANT SELECT ON Scott.Employee TO John;
  ```

Authorization of access in the remote database depends on how the local database authenticates itself. On the other hand, the way the remote database permits access for local users determines the solution for authentication of the local database. Analysis of several different distributed security solutions in Oracle are discussed later in this chapter.

Distribution and Security

The support of security for distributed and centralized database solutions is different. Recall how we discussed restricting Scott's access to particular rows of the table Department with the help of a view or procedure in the centralized database. If we consider the distributed solution from Chapter 3 (when each site has a fragment of the table Department with local departments), then security measures will be different. We will not need views or procedures to limit access to specific rows; instead, Scott will be a local user of the Cleveland database and will have privileges to access the Cleveland fragment of the table Department. We should also ensure that Scott does not have access to the New York and Boston databases.

Security Measures in Oracle

Basic Features

Basic security in Oracle is supported by users, schemas, and granting (revoking) privileges. The following example demonstrates some basic security features.

Admin:	CREATE USER Scott IDENTIFIED BY tiger;
	GRANT CREATE SESSION TO Scott;
		Administrator creates the user Scott and grants him the privilege to log into the database.

Scott:	CREATE TABLE Emp
	(ID NUMBER,
	name VARCHAR2(30));
	Insufficient privileges
		Scott successfully logs into the database. After that, he tries to create a table and fails because he does not have the corresponding privilege.

Admin:	GRANT CREATE TABLE TO Scott;	Administrator grants Scott the privilege to create tables.

Scott:	CREATE TABLE Employee
	(ID NUMBER PRIMARY KEY,
	name VARCHAR2(30));
		Scott creates a table.

Admin:	CREATE USER Adam IDENTIFIED BY lion;
	GRANT CREATE SESSION TO Adam;
		Administrator creates the user Adam and grants him the privilege to log into the database.

Adam:	SELECT * FROM Scott.Emp; *Table or view does not exist*	Adam tries to select from the table Employee in Scott's schema, but without the required privilege he does not see the table.
Scott:	GRANT SELECT ON Employee TO Adam;	Scott grants Adam the privilege to select from his table.
Adam:	SELECT * FROM Scott.Employee; *0 rows selected*	Adam successfully accesses the table (the table is empty).
Scott:	SELECT * FROM Employee; *0 rows selected*	Scott selects from his table with the same result as Adam.
Scott:	REVOKE SELECT ON Employee FROM Adam;	Scott revokes from Adam the privilege to select from the table.
Adam:	CREATE TABLE Proj (pno NUMBER PRIMARY KEY, ID NUMBER REFERENCES Scott.Employee) *Insufficient privileges*	Adam wants to create a table and fails because he does not have sufficient privileges.
Scott:	GRANT CREATE TABLE TO Adam; *Insufficient privileges*	Scott wants to grant Adam the privilege to create tables and fails because he does not have the privileges to grant the create table privilege to other users (he was granted the create table privilege without admin option).
Admin:	GRANT CREATE TABLE TO Adam;	Administrator grants the privilege for creating tables to Adam.

Adam:	CREATE TABLE Proj (pno NUMBER PRIMARY KEY, ID NUMBER REFERENCES Scott.Employee); *Table or view does not exist*	Adam's second attempt to create a table fails because he references the table from another schema without having the required privileges.
Scott:	GRANT REFERENCES ON Scott.Employee TO Adam;	Scott allows Adam to reference his table Employee.
Adam:	SELECT * FROM Scott.Employee; *Table or view does not exist*	Adam tries to select from Scott's table and fails because this privilege has been revoked.

Adam:	CREATE TABLE proj
	(pno NUMBER PRIMARY KEY,
	ID NUMBER REFERENCES
	Scott.Employee);
		Adam succeeds in creating a table with the reference to the table of Scott.

Previous demonstrations of using views and procedures for implementing security were provided in Oracle.

Roles and PUBLIC Pseudo-User

In addition to the basic functionality, roles in Oracle have some special properties:

- Roles granted to a particular user can be dynamically enabled or disabled, which enables control of the user's privileges depending on the situation. For example, if the user Scott opens a session and starts an application, all roles granted to him may be disabled by the statement SET ROLE NONE. All previously granted roles can be enabled by SET ROLE ALL. A particular role can be enabled by SET ROLE *role*.
- Roles can be protected by passwords. When enabling a role, a user must specify the password assigned to the role:

```
CREATE ROLE Accountant IDENTIFIED BY tiger;
```

- Special secure application roles can be enabled only by authorized PL/SQL packages. This mechanism restricts the enabling of such roles to the invoking application.

Oracle has three predefined roles with different sets of system privileges: CONNECT, RESOURCE, and DBA. These roles can be granted to users, e.g. the following statement grants the user Adam the role CONNECT and with it such privileges as ALTER SESSION, CREATE CLUSTER, CREATE DATABASE LINK, CREATE SEQUENCE, CREATE SESSION, CREATE SYNONYM, CREATE TABLE, CREATE VIEW:

```
GRANT CONNECT TO Adam;
```

In Oracle, there is a pseudo-user named PUBLIC who is not a regular user as it cannot have a schema. A privilege or role granted to PUBLIC will be given to every user – past, present, and future. Therefore, privileges should be granted to PUBLIC with caution.

Authentication

The database authenticates a user by *name* and *password*:

```
CREATE USER Scott IDENTIFIED BY tiger;
```

Additionally, users can be authenticated by the *operating system*. Oracle relies on the operating system authentication and does not require the user to authenticate himself if they are created as:

```
CREATE USER John IDENTIFIED EXTERNALLY;
```

Another way to authenticate a user is the *proxy* authentication. A proxy user is a user who is allowed to connect to the database on behalf of another user. If a user needs a proxy connection, this user is given few privileges such as the privilege to connect to the database. After the user connects to the database, the database opens a second--a proxy--session on this user's behalf. In the commands below we create the user Adam and grant him the privilege to connect to the database. After that we make the user Scott a proxy user for Adam. Now, if Adam connects to the database, the database will create a session as the user Scott on behalf of Adam. This Scott session that was created on behalf of Adam is subject to all of the rules and privileges of the user Scott – it can only do what Scott is allowed to do.

```
CREATE USER Adam IDENTIFIED BY lion;

GRANT CREATE SESSION TO Adam;

ALTER USER Scott GRANT CONNECT THROUGH Adam;
```

The proxy user authentication introduced in Oracle 10g provides help in resolving the security problems that exist in some enterprise multi-tier applications. Often a user logs into a client application and then relies on the application to login on his behalf in the database. Applications often use pre-spawned Oracle connections that are created by a single Oracle user ID with the generic name, e.g. the user Sap for the SAP application rather than using thousands of different user ids. Unfortunately, when the end-users connect anonymously through a proxy application, there is no end-user level auditing and security through traditional security tools like granting privileges or using roles.

With Oracle proxy users, though the application connects to the database using the generic user name, the end-user's authentication information is also carried to the database with the help of the enhanced SQL command that allows proxy:

```
 CONNECT Sap[Scott]/tiger
```

The application generic database user is created as before. However, we do not grant this user any privileges except the privilege to connect to the database. For example, for the SAP application:

```
CREATE USER Sap IDENTIFIED BY lion;

GRANT CREATE SESSION TO Sap;
```

Additionally, we create end-user database accounts with all required privileges and define these accounts as proxy accounts for the application account:

```
ALTER USER Scott_ny GRANT CONNECT THROUGH Sap;
```

When the user Scott connects to the application, the application logs into the database (as Sap in our example) and then the database connects Scott into the database. This way the database preserves control over all actions of Scott and can provide an audit trail on Scott's actions. This is schematically shown in Figure 14.

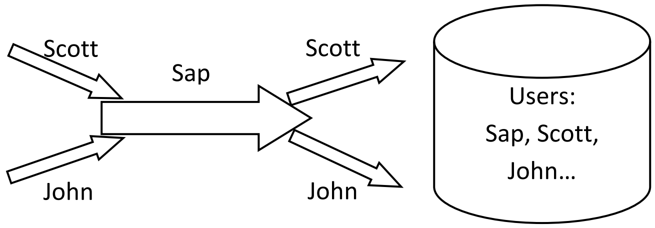


Figure 14. Proxy connections.

INSTEAD OF Triggers

Earlier, when discussing views, we mentioned that not all views allow for modifications thus limiting their usage for implementing security and transparency. For example, the views that contain set operators, `DISTINCT` operator, aggregate or analytic functions, `GROUP BY`, `ORDER BY`, most joins, and some other constructs cannot be modified directly.

To overcome this limitation, Oracle introduced `INSTEAD OF` trigger.

For example, to limit access to data about employees of Boston we have the view that is based on the join of two tables:

```
CREATE OR REPLACE VIEW vw_Empl_Boston AS
SELECT e.emplID, e.emplName, d.deptCode, d.deptName
FROM Employee e INNER JOIN Department d
     ON e.deptCode = e.deptCode
WHERE location = 'Boston';
```

Because we want to be able to update data about employees through this view, we need to create the INSTEAD OF trigger as shown below (the example illustrates updates of the employees' names; for updates of other attributes the trigger needs to be expanded):

```
CREATE OR REPLACE TRIGGER trig_vw_Empl_Boston
INSTEAD OF UPDATE ON vw_Empl_Boston
FOR EACH ROW
BEGIN
     UPDATE employee
     SET emplName = :NEW.emplName
     WHERE emplID = OLD:emplID;
END;
```

With this trigger, when a user tries to update the view

```
UPDATE vw_Empl_Boston SET emplName = 'John' WHERE emplID = 123;
```

the system starts the trigger that will perform

```
UPDATE employee SET emplName = 'John' WHERE emplID = 123;
```

Fine-Grained Access Control

In many cases, the discussed security tools are not enough to implement the required security support. Imagine a bank application through which users, who are bank customers, access their bank accounts. Obviously, none of them can get access to the whole table (or tables) with data about accounts. If we try to apply the views solution and create a view for each user, the database will contain thousands of views, if not more, and maintenance of such a database will be extremely expensive.

We may think of using procedures, e.g. a procedure for depositing or withdrawing money on an account. Assume that there is the table Account (accountNumb, balance) with data about balances on customers' accounts. Here is a simple example of such a procedure:

```
DBA> CREATE PROCEDURE test
            (par_account NUMBER, par_sum NUMBER) AS

      BEGIN
            UPDATE Account
            SET balance = balance + par_sum
            WHERE accountNumb = par_account;
      END;
```

The procedure has two parameters: the first defines the account number of the customer, the second – the amount of the deposit. The bank application passes the account number and the amount of deposit to the procedure which then executes the UPDATE statement.

For example, if a customer with account 12345 wants to deposit $100, the application will perform the following procedure call:

```
EXEC dba.test(12345, 100);
```

This call will pass the parameters into the procedure and the following UPDATE statement will be executed:

```
UPDATE dba.Account SET balance = balance + 100
WHERE accountNumb = 12345;
```

With the help of this procedure we can limit customers to accessing the data of their accounts only. Each customer will be granted the privilege to execute the procedure (either individually as below or through a role):

```
GRANT EXEC ON test TO Scott;
```

Though the solution looks elegant, there is a problem caused by the fact that a user's authentication is not performed in the database, but in the application. The application defines the account of a user and passes this information to the procedure. Suppose that the account 12345 belongs to Scott. Now imagine the situation when user John with the account number 67890 (who also can execute the procedure) connects to the database through another application, e.g. SQL*PLUS, and then issues the following two statements, the first of which, resulting in withdrawing $1000 from Scott's account, violates security requirements:

```
John> EXEC dba.test(12345, -1000);

      EXEC dba.test(67890, 1000);
```

This is a good demonstration of what we warned about in the beginning of the chapter – security implemented in the application can be bypassed.

Oracle has special tools for implementing fine-grained access control when using views is impractical and procedures do not guarantee the needed protection. Security requirements are implemented through special functions called security policies. Security policies are attached to tables or views and every time a user issues a DML statement on the secured table or view, Oracle attaches the policy to the statement. Attachment of the policy is performed transparently to the user. Fine-grained access control allows for context-dependent and row-based security control (see Figure 15).

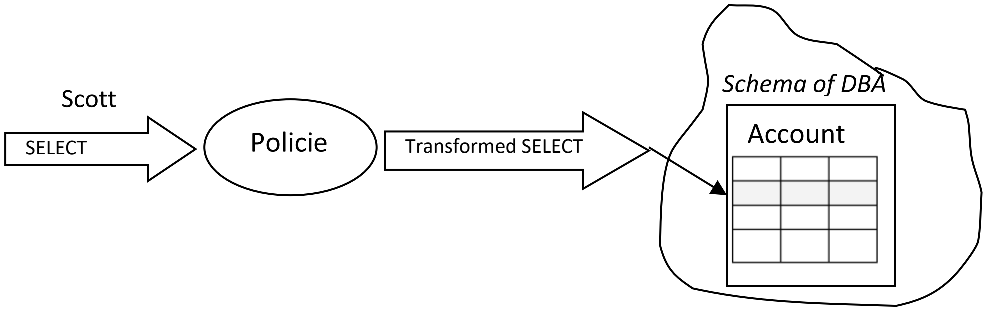


Figure 15. Fine-grained secure access with the help of policies.

Fine-grained access is implemented with the help of the supplied package `DBMS_RLS.` Packages are objects of the database, which are composed of procedures, functions, and definitions of types and variables. Oracle has a number of supplied packages, which support additional functionality of the database. Procedures of the DBMS_RLS package allow specifying the table or the view to which the policy is added, the name of the policy, the function which implements the policy, the type of statement to which the policy applies (SELECT, INSERT, UPDATE, or DELETE), and some additional information.

The following example explains how Oracle security policies work for the example of the bank application. Assume that in addition to the table Account there is the table Customer(name, accountNumb, …)with information about customers.

1. Define what predicate has to be added to each statement. In our case, we need a predicate that ensures that a customer accesses data from his account only. If a customer has logged into the database using his name, then the following predicate will return the customer's account number, which can later be used to restrict access to data (the system variable USER contains the name of the current user):

```
accountNumb = (SELECT accountNumb
                  FROM Customer
                  WHERE name = USER);
```

2. Create a function that returns this predicate. With the help of the package DBMD_RLS we attach the function to the table Account as a security policy for any DML statement, so that this function adds the predicate to every DML statement on the table Account (for details see Oracle documentation).
3. Because of the attached security policy, for every statement on the table Account, Oracle calls the function that implements the policy and modifies the statement by attaching the predicate to it. For example, a simple select by Scott on the table Account will be transformed in the following way:

```
SELECT * FROM Account
 WHERE accountNumb =
       (SELECT accountNumb FROM Customer WHERE name = SCOTT);
```

4. Oracle executes the dynamically modified statement, and because of the added predicate, the user can access only the account associated with his name.

Fine-grained access control is based on database authentication of users and is more reliable than the procedural solutions discussed before. This tool supports what is called a Virtual Private Database in which each user sees his own private portion of the database.

Label Security

The Oracle Label Security feature is built upon the fine-grained control features; it is useful in situations similar to the following. Imagine a table with a company's documents of different security levels – from documents that can be accessed by all users to documents which have strongly restricted access. For example, the table Document below contains two types of rows: rows that can be accessed by all users and rows that can be accessed by employees of the company only.

docID	docName	docLabel
1	Company profile	Public
2	Company payroll	Internal
3	Company partners	Public
…		

We use labels in the following way:

- Define how to label the rows according to their security type, e.g. 'Public' and 'Internal', and keep the labels in a new column docLabel.
- Define security levels for all labels by assigning numbers; higher numbers mean more restrictions. In our case, the value 'Internal' implies more restrictions than the value 'Public', and we assign 10000 to 'Public' and 20000 to 'Internal'.
- Define security policies on the column docLabel and its values, and attach them to the table Document.
- Associate security labels with users.

A user's request to data is transformed by adding the respective security predicate defined on the labels of the column docLabel. For example:

- User Scott is associated with the label 'Public'.
- His request to the table Document is transformed by adding a conditional clause that allows him to access rows that have security levels lower than or equal to level 10000 of the 'Public' value. He can access only the records labeled 'Public'.

- User John is associated with the label 'Internal', and he is able to access rows with the security levels lower than or equal to 20000 or, in our case, all rows of the table.

Figure 16 shows associations between users, labels, and security levels.

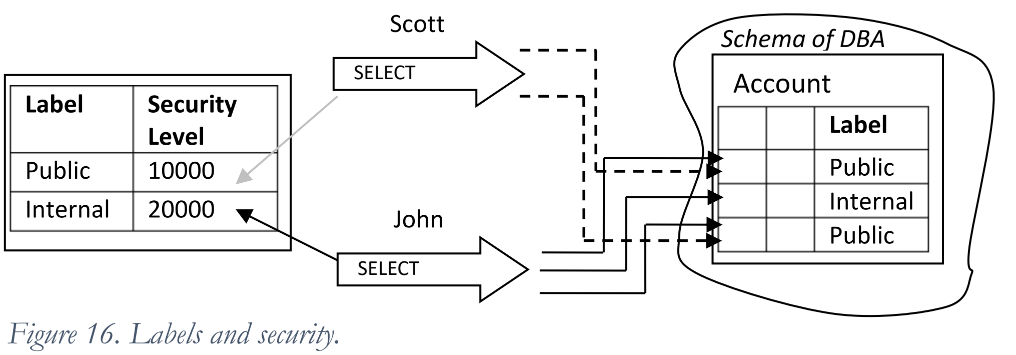


Figure 16. Labels and security.

Note that if there are only few security levels, then we can apply the views solution – create a view for each security level using the column docLabel and grant users the privileges on corresponding views.

Additional Measures

Profiles and Limiting Resources

The management of security measures in Oracle can be enhanced by user profiles. A profile defines additional password constraints and computer resources limitations. In the following profile, the password constraints the maximum number of attempts to log in as 3, the account lock time after 3 unsuccessful attempts as 1 day, and the number of days the same password can be used for authentication as 30 days. The resources part of the profile defines that a user can have an unlimited number of concurrent sessions, not more than 30 seconds on each CPU call, and be connected to a database for not longer than 45 minutes:

```
CREATE PROFILE clerk LIMIT
      FAILED_LOGIN_ATTEMPTS        3
      PASSWORD_LOCK_TIME           1
      PASSWORD_LIFE_TIME           30
      SESSIONS_PER_USER            UNLIMITED
      CPU_PER_CALL                 3000
      CONNECT_TIME                 45;
```

The administrator can create different profiles for different groups of users. After a profile is assigned to a user, the user's password will be managed according to the password parameters of the profile, and while working with the database the user will be subject to the profile resources limitations:

```
ALTER USER Scott PROFILE clerk;
```

Auditing

Auditing activities on the database can help to recognize unauthorized access. In addition to customized auditing usually implemented in triggers, Oracle supports standard auditing with the help of the SQL command AUDIT. In the first of the following examples, auditing is assigned for select operations on any table, and in the second – for any select and update operation performed by users Scott and John:

```
      AUDIT SELECT TABLE;

      AUDIT SELECT TABLE, UPDATE TABLE BY Scott, John;
```

Audit records include such information as the operation that was audited, the user performing the operation, and the date and time of the operation. For further analysis, audit records are stored in the data dictionary table called DBA_AUDIT_TRAIL, or in operating system files.

To audit occurrences of a SQL statement, you must have AUDIT SYSTEM system privilege. To audit operations on a schema object, the object you choose for auditing must be in your own schema or you must have AUDIT ANY system privilege.

Privileges and the Data Dictionary

The data dictionary contains information about security measures implemented in the database, such as the users and the objects they have privileges to access, the allowed type of access, the owners of these objects, who granted the privileges, and other similar information. For example the user Scott can see his object privilege to select from Adam's table Test that was granted to Scott by user SYS without the grant option from the dictionary view USER_TAB_PRIVS:

```
      Scott>      SELECT * FROM user_tab_privs;

GRANTEE   OWNER   TABLE_NAME   GRANTOR   PRIVILEGE   GRANTABLE
-------   -----   ----------   -------   ---------   ---------
SCOTT     ADAM    TEST         SYS       SELECT      NO
```

The view USER_ROLE_PRIVS shows information about a user's roles. The following example shows that Scott was granted two system roles CONNECT and RESOURCE, both without the admin option:

```
      Scott>      SELECT * FROM user_role_privs;

USERNAME     GRANTED_ROLE     ADMIN_OPTION     DEFAULT   OS_
--------     ------------     ------------     -------   ----
SCOTT        CONNECT          NO               YES       NO
SCOTT        RESOURCE         NO               YES       NO
```

Administrators can see users' object privileges in the view DBA_TAB_PRIVS, system privileges in the view DBA_SYS_PRIVS, and roles in the view DBA_ROLE_PRIVS.

Oracle Database Vault

Oracle Database Vault enhances the database security features by offering the ability to restrict the access of users with system privileges. Additionally, it permits controlling actions depending on the context of access, such as the time, the computer where the request originates, etc. The features of the Vault are described in the Appendix 4.

Security in the Distributed Oracle Database

In the distributed Oracle database separate databases can “see” other databases through database links. Oracle provides several types of links. The type of a database link in the distributed database depends on security requirements.

Information about the links available to a user is contained in the view ALL_DB_LINKS.

Types of Database Links

The database link defines the logical connection or the communication path from one database to another. When a user tries to access a remote database via the link, Oracle opens a database session in the remote database on behalf of the request of the local user. There are two types of database links: private and public. The type of a link defines which local users can get to the remote database with the help of the link (Figure 17).

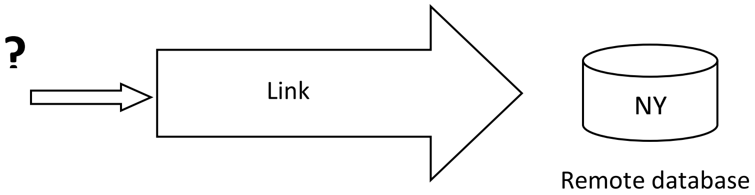


Figure 17. User on the initiating end of a link.

Private Links

Private database links can be created in a particular schema. Only the owner of the private link can use it to connect to the remote database directly (Figure 18).

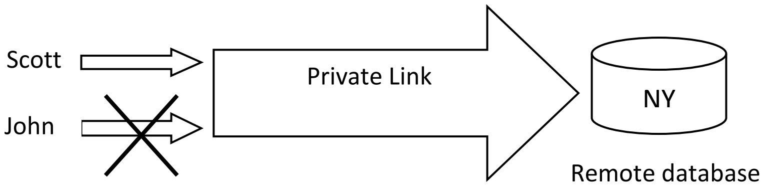


Figure 18. Using private links directly.

In the following example, Scott creates a private link to the New York database and tries to delete a row from the remote table Employee. Note that because the name of the table is not prefixed with the name of the schema, it means that Scott is trying to delete records from his table Employee in the New York database through his private link[4]. Scott can use his private link to access objects from other schemas in the New York database if he has corresponding privileges. User John cannot use the private link of Scott.

[4] Scott must be replicated in the New York database.

Scott:	CREATE DATABASE LINK ny USING
	ny.ourcompany.us.com;
		Scott creates a private database link.

Scott:	DELETE FROM Employee@ny
	WHERE ID = 12345;
	1 rows processed
		Scott uses the link to access his table in the remote database.

Scott:	SELECT * FROM
	Adam.Employee@ny;
	Table or view doesn't exist
		Scott uses the link to access data from the Employee table in Adam's schema in the remote database and fails because he does not have the required privilege.

John:	DELETE FROM Employee@ny
	WHERE ID = 67890;
	Not enough privileges to use the link
		John tries to use the private link of Scott and fails.

Only the owner of the private link can use the link directly in remote requests.

The advantage of the private link is its security. Only the user who is the owner of the link can get to the remote database through this link directly. Later in this chapter we will show how under certain conditions a private link can enable other users of the local database to get connected to the remote database.

Public Links

Public database links make a remote database visible to any user of the local database.

In the next example, John, using the public link created by Scott, succeeds in reaching the remote database where he is authenticated as John. His first request fails because he does not have the table Employee in his schema. His second request to Scott's table Employee succeeds. Note that for this example Scott and John must be replicated in the New York database, and John must be granted the privilege to select from Scott's table Employee.

Scott:	CREATE PUBLIC DATABASE LINK ny USING
	ny.ourcompany.us.com;
		Scott creates a public database link.

John:	DELETE FROM Employee@ny
	WHERE ID = 12345;
	Table or view doesn't exist
		John uses the link to access the remote table Employee and fails because he does not have such table in his schema.

John:	DELETE FROM Scott.Employee@ny
	WHERE ID = 12345;
	1 rows processed
		John succeeds in using the link to access the remote table Employee in Scott's schema.

Any local user can use the public link for remote requests.

Public links are less secure than the private links, but with the help of one public link the administrator can enable all local users to access the remote database. Note that the required security still can be managed by appropriate authorizations in the remote database.

Security Options for Database Links

The type of the link – private or public – defines who in the local database can use the link and get access to the remote database. Another property of the link – the security option – specifies how the local database identifies itself to the remote database, or, in other words, who is the user associated with at the destination end of the link (Figure 19).

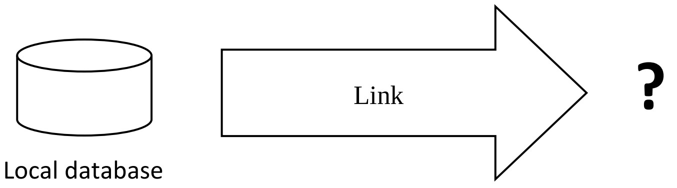


Figure 19. Users on the destination end of a link.

Fixed User Database Links

The fixed user database link specifies the credentials of a user who will be connected to the remote database. If the fixed user database link is used:

- Users of the local database connect to the remote site as the fixed user.
- They establish a connection to the fixed user's schema in the remote database (Figure 20).

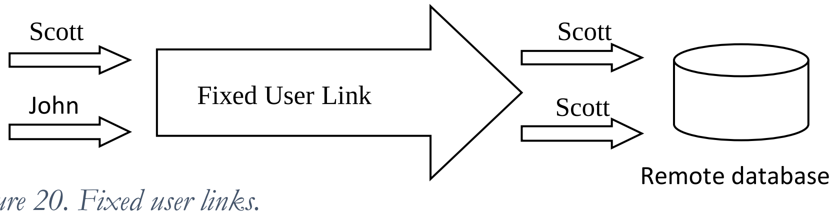


Figure 20. Fixed user links.

Users of the fixed user link should not be replicated in the remote database.

In the following example, every user of the local database who tries to connect to the remote database is authenticated in the remote database as Scott/tiger. Note that Adam accesses

Scott's table Employee in the remote database without specifying Scott's schema because he is authenticated by the remote database as Scott.

John:	`CREATE PUBLIC DATABASE LINK ny USING`
	`ny.ourcompany.us.com CONNECT TO Scott`
	`IDENTIFIED BY tiger;`
		John creates a public database link with the fixed user security option.

Adam:	`DELETE FROM Employee@ny`
	`WHERE ID = 12345;`
	`0 rows processed`
		Adam uses the public link and accesses Scott's table Employee in the remote database as Scott.

The disadvantages of the fixed links are: 1) all users of the local database can access the remote objects for which the fixed user has authorizations, and 2) the local user is authenticated as the fixed user on the remote site, and the fixed user's privileges rather than the actual user's privileges on the remote site are in effect. This can compromise the security of the distributed database.

Connected User Database Links

The connected user database link does not include any user credentials in the definition of the link. The remote database uses the local credentials of the connected user. For example, if Scott connects to the remote database, he is always authenticated there as Scott (Figure 21).

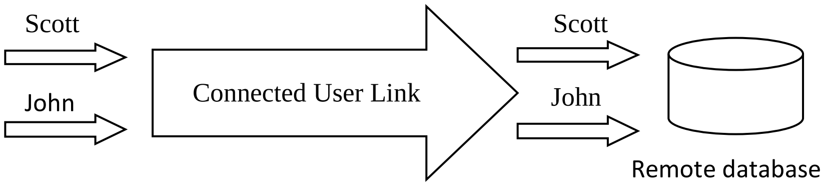


Figure 21. Connected user links.

Users of the connected user link – their names and passwords – must be replicated in the remote database.

To create a connected user database link, you simply omit the CONNECT TO clause. The following example creates a connected user database link:

```
CREATE PUBLIC DATABASE LINK ny USING ny.ourcompany.us.com;
```

Among other considerations, the connected user link is used when users need to perform specific operations in both databases, e.g., create tables.

Current User Database Links

Oracle supports an interesting security option – current user – that connects to the remote database as one of local users, but not necessarily as the user who requests remote access. The current user database link is specified by the CURRENT_USER option:

```
CREATE DATABASE LINK ny USING ny.ourcompany.us.com;

CONNECT TO CURRENT_USER;
```

When a local user is requesting a remote resource directly, the current user link acts like the connected user link. That means the local database sends the credentials of the local user to the remote database. The local user in this case has to be replicated in the remote database. If, on the other hand, a local user tries to access the remote resource indirectly – through a local procedure that contains the remote request – then the local database presents itself to the remote database as the owner of the procedure. For example, in the local database Scott has the stored procedure test which contains a remote request, and he has granted the privilege to execute this procedure to John. When John executes the procedure, the link within the procedure sees Scott (not John) as the current user of the database. Figure 22 shows how users from the local site are authenticated on the remote site through the current user link.

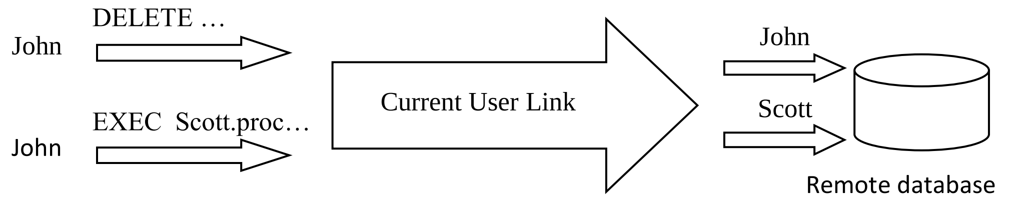


Figure 22. Current user links.

The current user security option can make private links available to users who execute procedures belonging to the same schema as the private link. In the following example, user John fails to use the private link of Scott directly, but succeeds in using it indirectly through Scott's procedure. John does not have to be replicated on the remote site because the remote database authenticates the owner of the procedure – the user Scott.

`Scott:`	`CREATE DATABASE LINK ny USING`
	`ny.ourcompany.us.com`
	
	`CONNECT TO CURRENT_USER;`
		Scott creates a private link with the current user security option.

`Scott:`	`CREATE PROCEDURE test (par_ID NUMBER)`
	`AS`
	`BEGIN`
	`   DELETE FROM Employee@ny`
	`   WHERE ID = par_ID;`
	`END;`
	
	`GRANT EXECUTE ON test TO John;`
		Scott creates a stored procedure and grants the privilege to execute it to John.

`John:`	`DELETE FROM scott.Employee@ny`
	`WHERE ID = 12345;`
	`(Access is denied)`
		John tries to use the private link directly and fails because the link is private.

`John:`	`EXEC Scott.test (12345);`
	`Procedure successfully completed`
		John uses the private link indirectly through the procedure of Scott and succeeds.

Note that with the *connected user* security option in the procedure of Scott, John will be authenticated in the remote database as John.

It is important to remember that the type of the link or its security option by themselves do not address security requirements; we always need to consider a combination of the link, and authentication and authorization of access in the remote database.

Examples: Implementing Security Measures in the Centralized and Distributed Databases

The Centralized Database

Consider the following security measures for the centralized implementation of the database for the Manufacturing Company case:

1. Prepare roles for users who work with local data (departments and employees) of the three cities.
2. Create a role for users who work with all data.
3. Create views to enable secure access to portions of the local data (in the example below we create views on the table Department only).
4. Create views for users of all the data. Remember that views support not only security, but also transparency of data. These views are not required by security requirements, but they definitely enhance the transparency of the database and the applications’ independence from possible database changes.
5. Grant the required privileges to the roles.
6. Create the users of local data.
7. Create the users of all the data.
8. Grant roles to the users.

1.	`CREATE ROLE Clerk_Boston;`
	`CREATE ROLE Clerk_NewYork;`
	`CREATE ROLE Clerk_Cleveland;`

2.	`CREATE ROLE Manager;`

3.	`CREATE VIEW vw_Department_Boston AS`
	`SELECT * FROM Department WHERE location = ‘Boston’;`
	
	`CREATE VIEW vw_Department_NewYork AS`
	`SELECT * FROM Department WHERE location = ‘New York’;`
	
	`CREATE VIEW vw_Department_Cleveland AS`
	`SELECT * FROM Department WHERE location = ‘Cleveland’;`

4.	`CREATE VIEW vw_allDepartments AS`
	`SELECT * FROM Department;`

5.	`GRANT SELECT, INSERT, UPDATE, DELETE ON vw_Department_Boston TO`
	`Clerk_Boston;`
	
	`GRANT SELECT, INSERT, UPDATE, DELETE ON vw_Department_NewYork TO`
	`Clerk_NewYork;`
	
	`GRANT SELECT, INSERT, UPDATE, DELETE ON vw_Department_Cleveland TO`
	`Clerk_Cleveland;`
	
	`GRANT SELECT, INSERT, UPDATE, DELETE ON vw_allDepartments TO`
	`Manager;`

6.	`CREATE USER John IDENTIFIED BY abc;`

	CREATE USER Smith IDENTIFIED BY def;
	CREATE USER Scott IDENTIFIED BY uvw;

7.	CREATE USER Adam IDENTIFIED BY xyz;

8.	GRANT Clerk_Boston TO John;
	GRANT Clerk_NewYork TO Smith;
	GRANT Clerk_Cleveland TO Scott;
	GRANT Manager TO Adam;

The Distributed Database

For the distributed solution of Chapter 3 we need to implement the local security measures in each database and the distributed security measures for users of the application that accesses all the data and is executed from the New York database. In the example below, we will discuss the security measures of the Boston and New York databases (the security measures in the Cleveland and Boston databases are similar):

1. Consider the necessary database links. In our case, some users of the New York database access the Boston database, while users of the Boston database access only local data. We need the database link from the New York database to the Boston database. Assuming that there are a few users of the New York database who work with Boston data, we will create a connected user link.
2. Create a role for users who work with local data in each database.
3. Create a role for users who access all data in the New York database.
4. Create local views in each database.
5. Create views that implement transparency of distribution in the New York database (because only New York users need access to all the data).
6. Grant required privileges to the roles.
7. Create users of local data in each database.
8. Create users of all the data in the New York database.
9. Grant corresponding roles to the users in each database.

	Boston	New York
1.		CREATE PUBLIC DATABASE LINK boston USING Boston.ourcompany.us.com;
2.	CREATE ROLE Clerk;	CREATE ROLE Clerk;
3.		CREATE ROLE Manager;

4.	CREATE VIEW vw_Department AS
	SELECT * FROM Department;
		CREATE VIEW vw_Department AS
		SELECT * FROM Department;

5.		CREATE VIEW vw_allDepartments[5] AS
		SELECT * FROM Department UNION
		SELECT * FROM Department@boston;

6.	GRANT SELECT, INSERT, UPDATE, DELETE ON vw_Department TO Clerk;	GRANT SELECT, INSERT, UPDATE, DELETE ON vw_Department TO Clerk; GRANT SELECT, INSERT, UPDATE, DELETE ON

[5] Remember, in this demonstration we are considering only two databases, that is why the view is based on the union of two fragments. In the actual situation the view will be based on the union of all three fragments.

		vw_allDepartments TO Manager;
7.	CREATE USER John IDENTIFIED BY abc;	CREATE USER Smith IDENTIFIED BY def;
8.		CREATE USER Adam IDENTIFIED BY xyz;

9.	GRANT Clerk TO John;	GRANT Clerk TO Smith;
		GRANT Manager TO Adam;

Summary

Securing data or preventing unauthorized access to data is a crucial feature of any database and database application. Though a database application usually features protection for data access, the most reliable way of securing of data is to provide for it in the database itself, where security measures are integrated with data and cannot be bypassed. DBMSs offer tools for implementing various security requirements.

Securing data means ensuring that only authorized users perform allowed operations on the data. Databases enforce security measures by authentication and authorizations control. Authentication is performed with the help of user names and passwords. An entitled user receives the database user name and is assigned the authentication information associated with it, such as a password and profile.

Database users have to be authorized to perform database operations. Authorization is performed through granting permissions or privileges for specific operations on particular data. Authorization can also be performed through the granting of groups of privileges, called roles.

A user who is granted privileges to create database objects is considered the owner of the objects he creates or, in other words, these objects belong to the owner's schema. The owner does not need to be granted privileges to perform legal operations on the objects, e.g. a user who created a table can alter or drop it, as well as manipulate data in it. Other users, however, cannot access an object without the owner's permission – a granted object privilege. Each type of access to an object requires a corresponding privilege, for example, if a user is granted the privilege to select from a table, this does not enable him to manipulate data in the table.

In addition to object privileges there are system privileges that enable users to perform a particular operation on all objects of a specified class. For example, a user can be given the privilege to select from any database table. In this case, to access data from a particular table the user does not need the permission of the table's owner. Other examples are the privileges to create database objects, e.g. tables, views, users, etc.

Often, it is necessary to limit a users' access to specific portions of data in a table. This is accomplished with the help of views and procedures. Users are not authorized to access the table directly; instead, they are granted privileges to access a view or use a procedure. These views and procedures are implemented in such a way that they restrict the users' access to a portion of data from the table.

Special DBMS tools support fine-grained access to data. Such tools allow for implementing security control that is context-dependent and row-based.

In the distributed database, security measures include local authentication of users and local authorization of access combined with authentication of separate databases that are communicating with each other.

A traditional sequence of steps for implementing security measures is the following:

- *Analyzing security requirements and implementation of the database*. Research the requirements on access to data in the database and how the database is implemented. Security measures depend on the implementation of the database, e.g. whether it is centralized or distributed.
- *Implementing connection of databases*. If the database is distributed, define databases that need to access other databases and implement connections. Utilize the properties of database connections of the particular DBMS to enhance security solutions depending on the needs for remote access. For example, in Oracle, use the different types and security options for links to maintain distributed security in the easiest way depending on how many local users need remote access and what their remote access needs are.
- *Creating roles*. Create roles for groups of users depending on their different needs in data.
- *Creating views and procedures*. Create views and procedures that implement transparency and maintain data security depending on the data access needs.
- *Granting privileges to roles*. Grant privileges for various types of access on the views and procedures of the previous step to the roles.
- *Creating users*. For users of the database, create user accounts with authentication information.
- *Granting roles to users*. Grant required roles to users.
- *Implementing fine-grain security*. If necessary, implement fine-grain security measures using special features of the DBMS.

Data can be additionally protected by DBMS encryption tools.

Database security measures are only a part of the complex technical security support in the IS. Technical security measures must be enhanced by various non-technical security procedures and rules.

Review Questions

- How is the database for your course project protected from access by other students?
- How can a professor get access to the data of all his or her students?
- Why is it important to implement security support in the database?
- What are basic security measures? Describe how they work and the situations in which it is reasonable to apply each of them.
- What is user authentication?
- How do roles help in managing the database security?
- What are schemas? Explain how schemas secure access to data.
- What is authorization of access?
- What are object and system privileges?
- What are the approaches to implementing fine-grain security measures?
- What are the main security problems in the distributed database?
- How does Oracle provides connections to remote databases?
- How can local data be protected from remote access?
- What is the difference between public and private links?
- How do the security options of links in Oracle implement security of access to remote data?

Practical Assignments

1. Describe the possible scenarios for using private and public links with different security options.

2. For one of your tables:
    a. Define how to protect the table from access by other users.
    b. Provide the possibility for another user to access data from the table.
    c. Provide the possibility for another user to access definite rows of the table.

d. Provide the possibility for another user to create a table with reference to your table.

3. Specify the creation of a user with some administrative responsibilities, e.g. creating database users.

4. Consider the security requirements for students who take database courses and need to implement database projects; and professors who teach these courses and need to check the students' database projects. Suggest security measures for the students and professors.

5. Describe security measures for different scenarios of access to a table in a centralized database:
   a. All users access the same part of the table.
   b. Several different groups of users need to access different parts of the table.
   c. Numerous users have to access different parts of the table.

6. For each of the following situations describe different scenarios of security implementation and explain the benefits and disadvantages of each approach (use different types of links, replication of users, and various authorization schemes):
   a. You have table A in one database, and table B in another database. User X must have access to table A and must be prevented from access to table B.
   b. You have a table in the remote database. Local users should be able to access this table on the remote site, and should be prevented from accessing other remote objects in your or other schemas on the remote database.
   c. In the remote database, you have the table A and user X has the table B. Local users should be able to access Table A and Table B on the remote site, but should be prevented from accessing any other remote object.
   d. You must have access to any remote object of user X.
   e. Several local users need access to multiple different objects of the remote database.
   f. Most local users need access to several objects of the remote database.
   g. All local users need access to different objects of the remote database.

7. Implement the required security for one of the case assignments of Appendix 1:
   a. For a centralized solution, consider creating views, procedures, and roles.
   b. For a distributed solution, build local security measures for each database, define appropriate database links, and enable the necessary remote access.