

LESSON NO. : 7

ENTITY RELATIONSHIP MODEL -I**Introduction****Entity Relationship Model: Basic Concepts****Mapping Cardinalities****Entity relationship Diagram****Weak and Strong Entity sets****Aggregation****Summary****Questionnaires****7.1 Introduction:**

The Entity-Relationship Model is a high-level conceptual data model developed by Chen in 1976 to facilitate database design. The E-R Model is shown diagrammatically using E-R diagrams which represents the elements of the conceptual model that show the meanings and the relationships between those elements independent of any particular DBMS and implementation details. Cardinality of a relationship between entities is calculated by measuring how many instances of one entity are related to a single instance of another. One of the main limitations of the E-R Model is that it cannot express relationship among relationships. So to represent these relationships among relationships. We combine the entity sets and their relationship to form a higher level entity set. This process of combining entity sets and their relationships to form a high entity set so as to represent relationships among relationships is called Aggregation.

7.2 Entity Relationship Model

The entity-relationship model is based on the perception of a real world that consists of a set of basic objects called entities, and of relationships among these objects. It was developed to facilitate database design by allowing the specification of an enterprise schema which represents the overall logical structure of a database. The E-R Model is extremely useful in mapping the meanings and interactions of real-world enterprises into a conceptual schema. Entity – relationship model was originally proposed by Peter in 1976 as a way to unify the network and relational database views. Simply stated the ER model is a conceptual data model that views the real world as entities and relationships. A basic component of the model is the entity relationship diagram, which is used to visually represent data objects. For the database designer, the utility of the ER model is :

- 1) It maps well to the relational model. The constructs used in the ER model can easily be transformed into relational tables.
- 2) It is simple and easy to understand with a minimum of training. Therefore the model can be used by the database designer to communicate the design to the end user.
- 3) In addition, the model can be used as a design plan by the database developer to implement a data model in specific database management

software.

7.2.1 Basic Concepts

There are three basic notions that the E-R data model employs – entity sets, relationship sets, and attributes.

Entity : An entity is a thing or object in the real world that is distinguishable from all other objects. For example, each person in an enterprise is an entity. An entity has set of properties and the values for some set of properties may uniquely identify an entity. For example, the employee Id of a person uniquely identifies one particular person in the enterprise. Entities are principal data object about which information is to be collected. Entities are usually recognizable concepts, either concrete or abstract such as person, places, things, or events which have relevance to the database. Some specific examples of entities are EMPLOYEES, PROJECTS and INVOICES. An entity is analogous to a table in the relational model. Entities are classified as :

- 1) **Independent :** An independent entity is one that does not rely on another for identification.
- 2) **Dependent :** A dependent entity is one that relies on another for identification.

Special Entity Types : Associative entities (also known as intersection entities) are entities used to associate two or more entities in order to reconcile a many-to-many relationship. Subtypes entities are used in generalization hierarchies to represent a subset of instances of their parent entity, called the supertype, but which have attributes or relationships that apply only to the subset.

Entity set : An entity set is a set of entities of the same type that share the same properties, or attributes. The set of all persons who are customers at a given bank, for example, can be defined as the entity set customer. The individual entities that constitute the set are said to be the extension of the entity set. Thus all the customers of the given bank are the extensions of the entity set customer.

Attributes : An entity is represented by a set of attributes. Attributes are descriptive properties possessed by each member of an entity set. For example, a customer entity set of a given bank has the attributes like account number, customer name, customer address etc. For each attribute, there is a set of permitted values, called the domain or value set, of that attribute. The domain of attribute customer-name might be the set of all text strings of a certain length.

A database thus includes a collection of entity sets, each of which contains any number of entities of the same type. For example, a bank database consists of entity sets like customer, loan etc.

An attribute, as used, in the E-R Model, can be characterized by the following attribute types:

1. **Simple and composite attributes:** Simple attributes are those that cannot be divided into subparts i.e. into other attributes. For example: customer account number is a simple attribute. Composite attributes are those that can be further divided into subparts or attributes. For example: Customer_name attribute of an entity can be considered as composite attribute because it can further be divide into subparts like first name, middle name and last name.
2. **Single valued and multivalued attributes:** The attributes that have a single value for a particular entity is known as single valued attributes. For example,

employee_Id of an employee in an enterprise will be single valued for every employee. Multivalued attributes are those attributes that have multiple values for an entity. For example, employee_dependent_names for a particular employee in an enterprise can have zero, one or more names depending on the number of dependents of an employee.

3. **Null attributes:** A null value is used when an entity does not have a value for an attribute. For example, if a particular employee has no dependents, then the value of employee_dependent_names for that employee in an enterprise will be null. Null can also designate that an attribute value is unknown. An unknown value may be either missing or not known.
4. **Derived attributes:** The value of this type of attributes is derived from the values of other related attributes or entities. Some attributes may be related for a particular entity For example: the age of an employee can be derived from the date_of_birth attribute of an employee therefore they are related .

Relationship Sets: A relationship is an association among several entities. For example, we can define a relationship that associates an employee Ram Singh with Department Computer Science. This relationship specifies that Employee Ram Singh is working in the department Computer Science.

A relationship set is a set of relationships of the same type. Formally, it is a mathematical relation between $n \geq 2$ entity sets. If $E_1, E_2, E_3, \dots, E_n$ are entity sets, then relationship set R is a subset of $\{(e_1, e_2, e_3, \dots, e_n) \mid e_1 \in E_1, e_2 \in E_2, e_3 \in E_3, \dots, e_n \in E_n\}$ where $(e_1, e_2, e_3, \dots, e_n)$ is a relationship.

Consider the two entity sets *employee* and *Departments*. We define the relationship set *works for* to denote the association between employee and the department that the employees have.

The association between entity sets is referred to as participation, that is the entity sets $e_1 \in E_1, e_2 \in E_2, e_3 \in E_3, \dots, e_n \in E_n$ participate in relationship set R . A relationship instance in an E-R schema represents that an association exists between the named entities in the real world enterprise that is being modeled.

The function that an entity plays in a relationship is called that entity's role. Since entity sets participating in a relationship set are generally distinct, roles are implicit and are not usually specified. However, they are useful when the meaning of a relationship needs clarification. Such is a case when the entity sets of a relationship set are not distinct, i.e., the same entity set participates in a relationship set more than once, in different roles. In this type of relationship set, which is sometimes called a recursive relationship set, explicit role names are necessary to specify how an entity participates in a relationship instance.

A relationship can also have descriptive attributes. Consider a relationship set *depositor* with entity set *customer* and *account*. We could associate the attribute *access-date* to that relation to specify the most recent date on which a customer accessed an account. The *depositor* relationship among the entities corresponding to customer is described by access-date, which means when customer has most recently accessed the account.

The number of entity sets that participate in a relationship set is also the **degree** of the relationship set. A binary relationship set is of degree 2; a ternary relationship set is of degree 3.

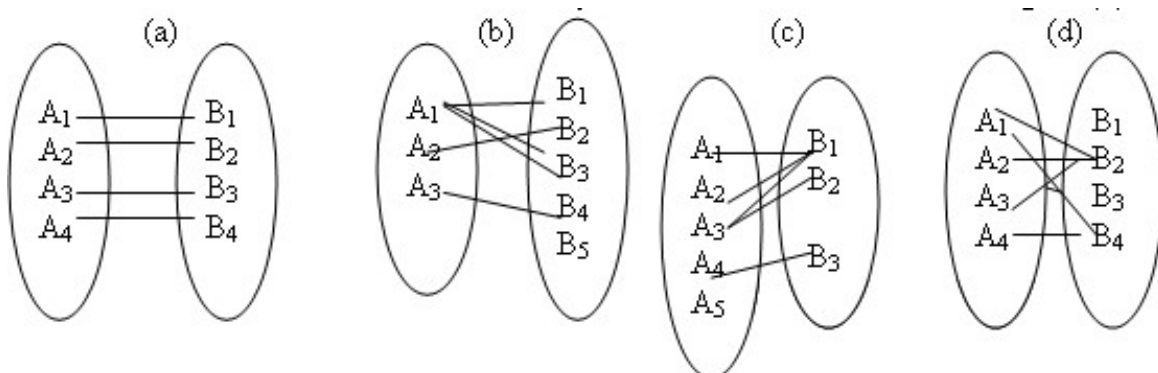
7.3 Mapping Cardinalities:

Mapping Cardinalities, or cardinality ratios, express the number of entities to which another entity can be associated via a relationship set.

Mapping cardinalities are most useful in describing binary relationship sets, although occasionally they contribute to the description of relationship sets that involve more than two entity sets.

For a binary relationship sets R between entity sets A and B, the mapping cardinality must be one of the following:

- **One to One:** An entity in A is associated with at most one entity in B, an entity in B is associated with at most one entity in A. See Figure (a)
- **One to many:** An entity in A is associated with any number of entities in B. An entity in B, however, can be associated with at most one entity in A. See Figure (b)
- **Many to one:** An entity in A is associated with at most one entity in B. An entity in B, however, can be associated with any number of entities in A. See Figure (c)
- **Many to Many:** An entity in A is associated with any number of entities in B. An entity in B, can also be associated with any number of entities in A. See Figure (d)



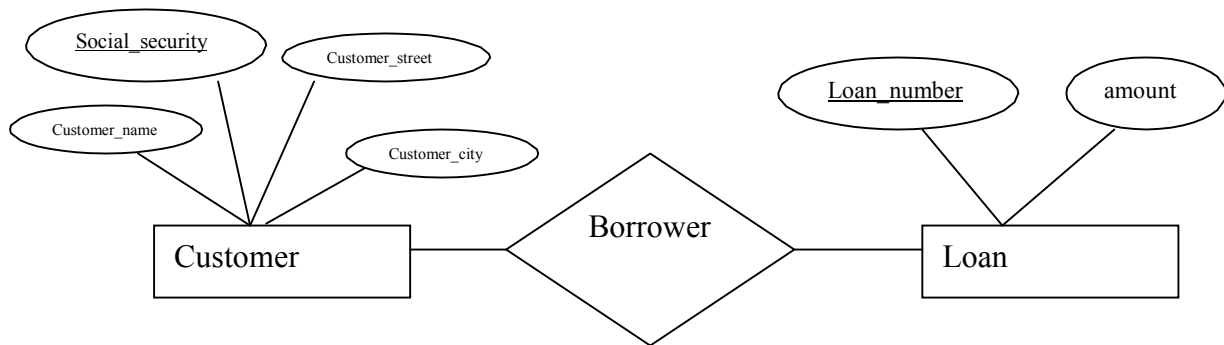
7.4 Entity Relationship Diagrams: The overall logical structure of a database can be expressed graphically by an E-R Diagram. The relative simplicity and pictorial clarity of this diagramming technique may well account in large part for the wide spread use of the E-R Model. Such a diagram consists of the following components:

- **Rectangles**, which represents entity sets.
- **Ellipses**, which represents attributes.
- **Diamonds**, which represents relationship sets.
- **Lines**, which link attributes to entity sets and entity sets to relationship sets.
- **Double ellipses**, which represents multivalued attributes.
- **Dashed ellipses**, which denote derived attributes.
- **Double Lines**, Which indicate total participation of an entity in a relationship set.

To distinguish the mapping cardinalities of relationship set, we draw either directed line (\rightarrow) or an undirected line (-) between the relationship set and the entity set.

Consider the following E-R Diagram, which consists of two entity sets, customer and loan, related through a binary relationship set borrower. The attributes associated

with customer are customer_name, social-security, customer-street, and customer-city. The attributes associated with loan are loan-number and amount. The relationship set borrower may be many to many, one to many, many to one or one to one.



In the above E-R diagram, underlined attributes are acting as primary keys of the corresponding entity sets.

Direction : The direction of a relationship indicates the originating entity of a relationship . The entity from which a relationship originates is the parent entity ; the entity where the relationship terminates is the child entity .

The type of the relation is determined by the direction of line connecting relationship component and the entity . To distinguish different types of relation , we draw either a directed line or an undirected line between the relationship set and the entity set . Directed line is used to indicate one occurrence and undirected line is used to indicate many occurrences in a relation .

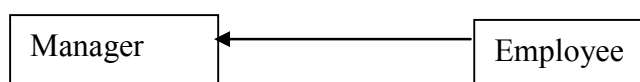
DEPARTMENT , MANAGER , EMPLOYEE , PROJECT

The relationship between a DEPARTMENT and a MANAGER is usually one-to-one ; there is only one manager per department . This relationship between entities is shown below. Each entity is represented by a rectangle and a direct line indicates the relationship between them . The relationship for MANAGER is both 1:1

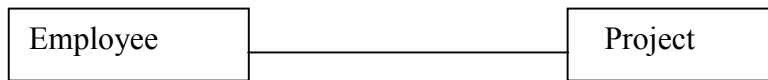


Note that a one to one relationship between two entity set does not imply that for an occurrence of an entity from one set at any time there must be an occurrence of an entity in the other set. In the case of an organisation , there could be times when a department is without a manager or when an employee who is classified as a manager may be without a department.

A one to many relationship exists from the entity MANAGER to the entity EMPLOYEE because there are several employees reporting to the manager . As we have pointed out there could be an occurrence of the entity type MANAGER having zero occurrences of the entity type EMPLOYEE reporting to him or her . A reverse relationship , from EMPLOYEE to MANAGER would be many to one since a single manager may supervise many employees.

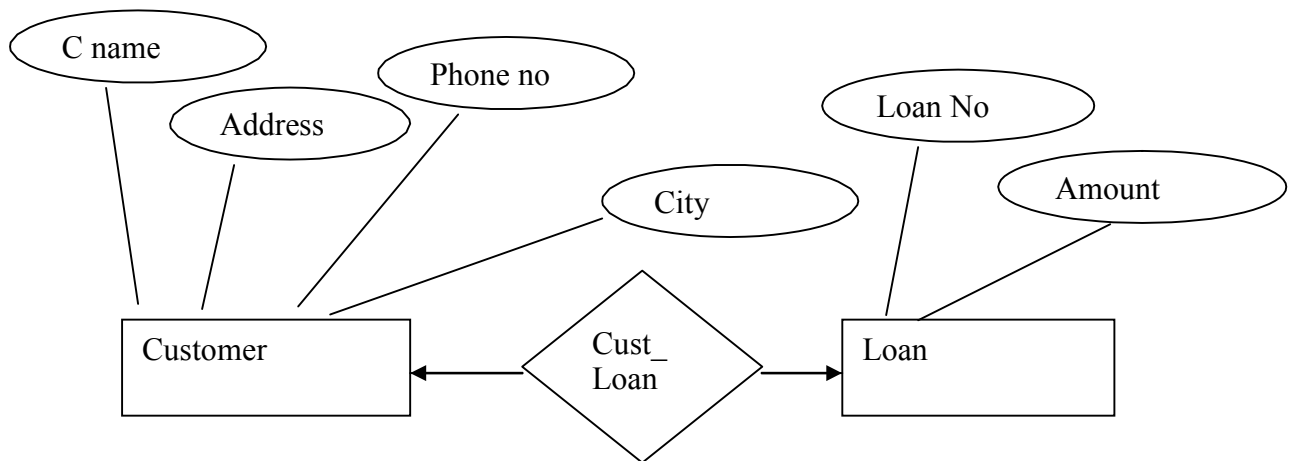


The relationship between the entity EMPLOYEE and the entity PROJECT can be derived as follows : Each employee could be involved in a number of different projects , and a number of employees could be working on a given project . This relationship between EMPLOYEE and PROJECT is many to many .It is illustrated as below .



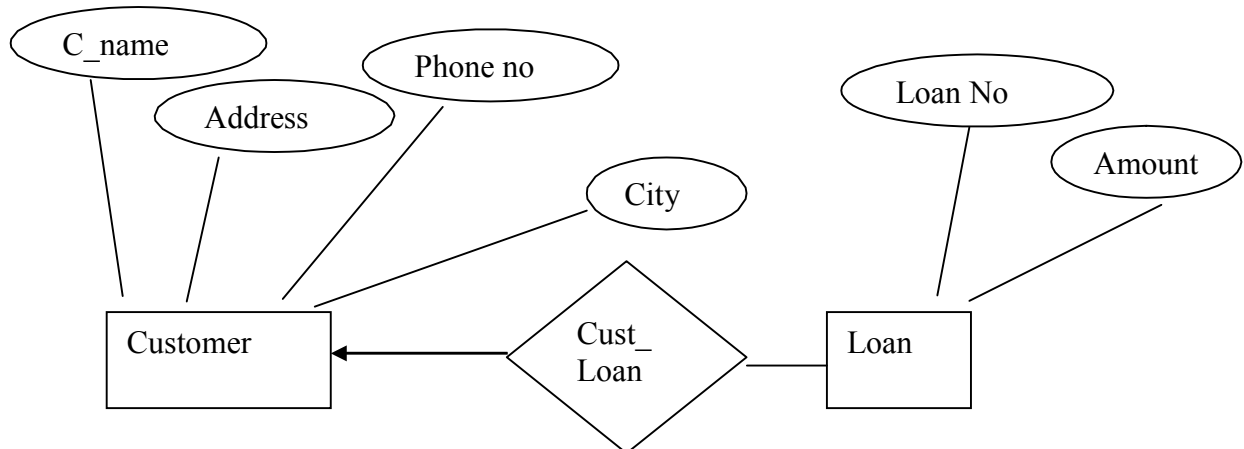
These relations can also be expressed in terms of following examples .

Consider a Customer – Loan relationship in which the loans are given to customers. Depending on the rules of the bank, one customer can take a single loan or multiple loans and relationship may be classified as **1:1** If one customer can take only one loan .



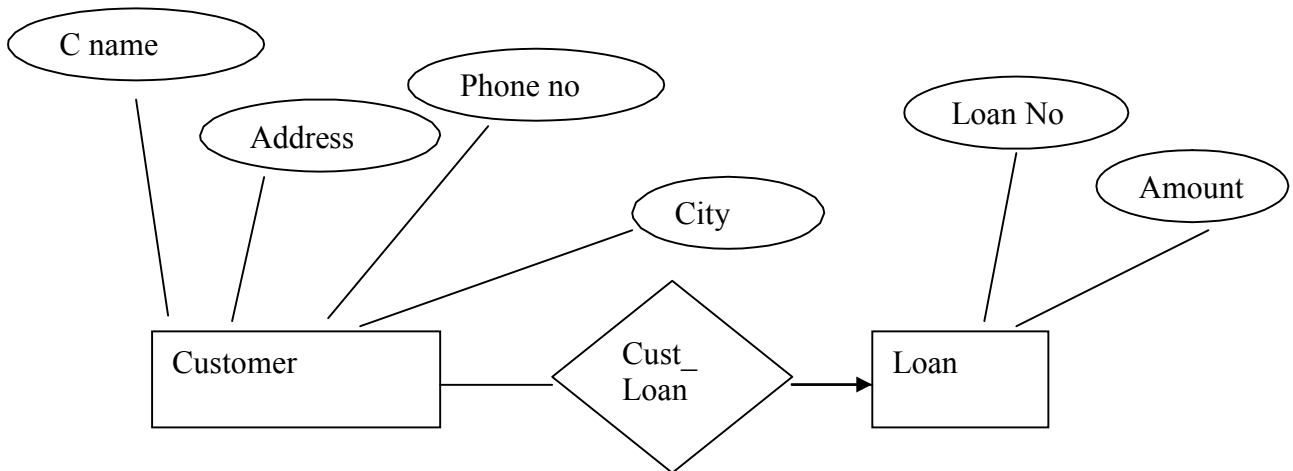
One-to-One Relationship

1:M If one customer can take multiple loans



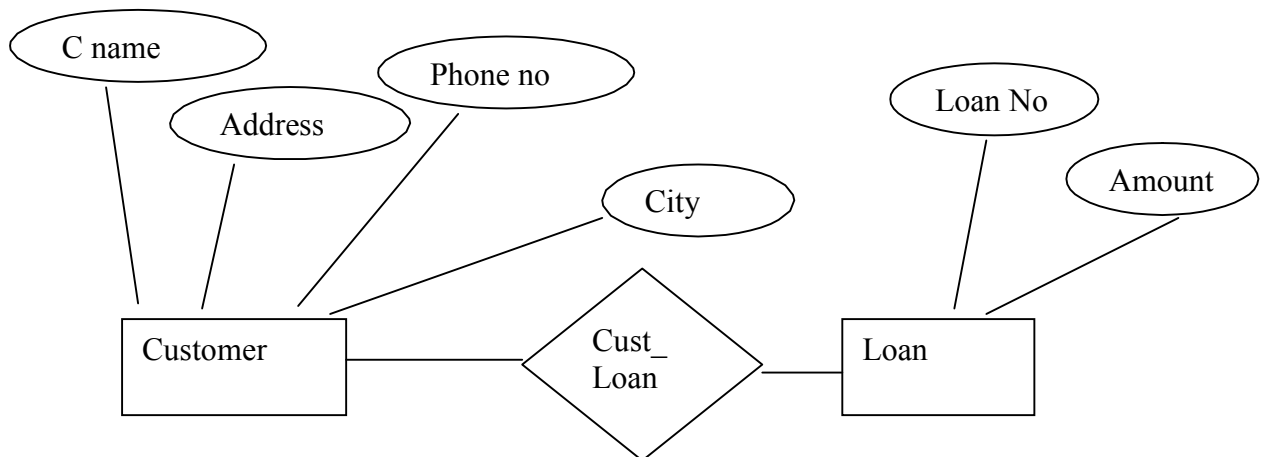
One-to-Many Relationship

M:1 If multiple customers participate for a single loan and one customer can take only one loan



Many-to-One Relationship

M:M If multiple customers participate for a single loan and one customer can take more than one loan .



Many-to-Many Relationship

7.5 Weak and Strong Entity Sets

An entity Set may not have sufficient attributes to form a primary key, such an entity set is termed as weak entity set. An entity set that has a primary key is termed as a strong entity set. For example, consider the entity payment, which has the three attributes: payment-number, payment-date, and payment-amount. Although each payment entity is distinct, payments for different loans may share the same payment number. Thus, this entity set does not have a primary key; it is a weak entity set. For a weak entity set to be meaningful, it must be part of a one-to-many relationship set. This relationship set should have no descriptive attributes, since any required attributes can be associated with the weak entity set. A member of a strong entity set is a dominant entity, whereas a member of a weak entity set is a subordinate entity.

Although a weak entity set does not have a primary key, we nevertheless need a means of distinguishing among all those entities in the entity set that depend on one particular strong

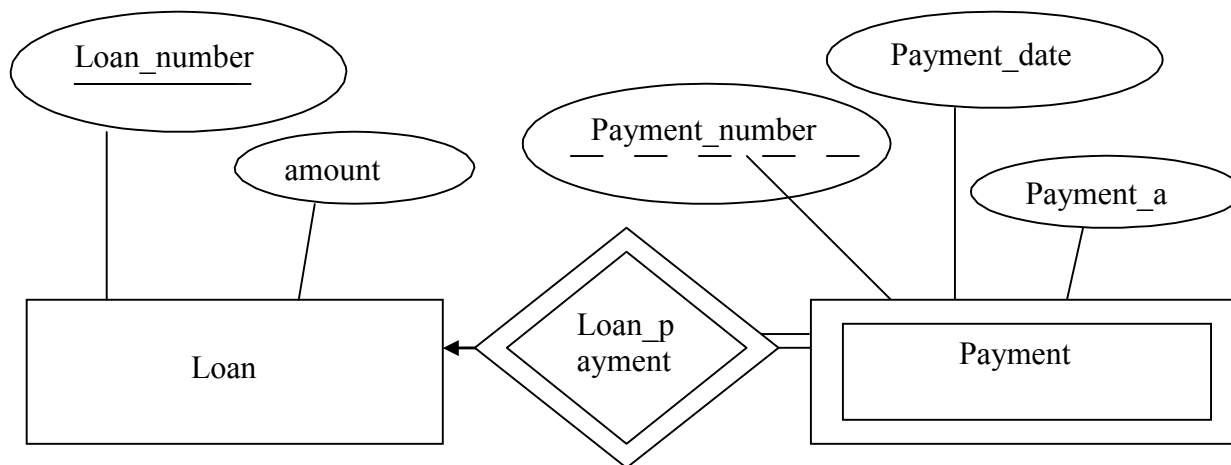
entity. The discriminator of a weak entity set is a set of attributes that allows this distinction to be made. For example, the discriminator of the weak entity set payment is the attribute payment number, since, for each loan, a payment number uniquely identifies one single payment for that loan. The discriminator of a weak entity set is also called the partial key of the entity set.

The Primary key of a weak entity set is formed from by the primary key of the strong entity set on which set is existence dependent, plus the weak entity set's discriminator. In the case of the entity set payment, its primary key is (loan-number, payment-number), where loan-number identifies the dominant entity of a payment, and payment-number distinguishes payment entities within the same loan.

The identifying dominant entity set is said to own the weak entity set that it identifies. The relationship that associates the weak entity set with an owner is the identifying relationship. In our example, loan-payment is the identifying relationship for payment.

A weak entity set in E-R Diagram is represented by a doubly outlined box, and the corresponding identifying relationship by a doubly outlined diamond.

The relationship between weak entity and strong entity set can be expressed with following example. In the following example loan-payment is the identifying relationship for payment entity. A weak entity set is represented by doubly outlined box corresponding identifying relation by a doubly outlined diamond. Here double line indicate total participation of weak entity in strong entity set it; means that every payment must be related via loan-payment to some account. The arrow from loan payment to loan indicates that each payment is for single loan. The discriminator of a weak entity set is underlined with dashed lines rather than solid line.



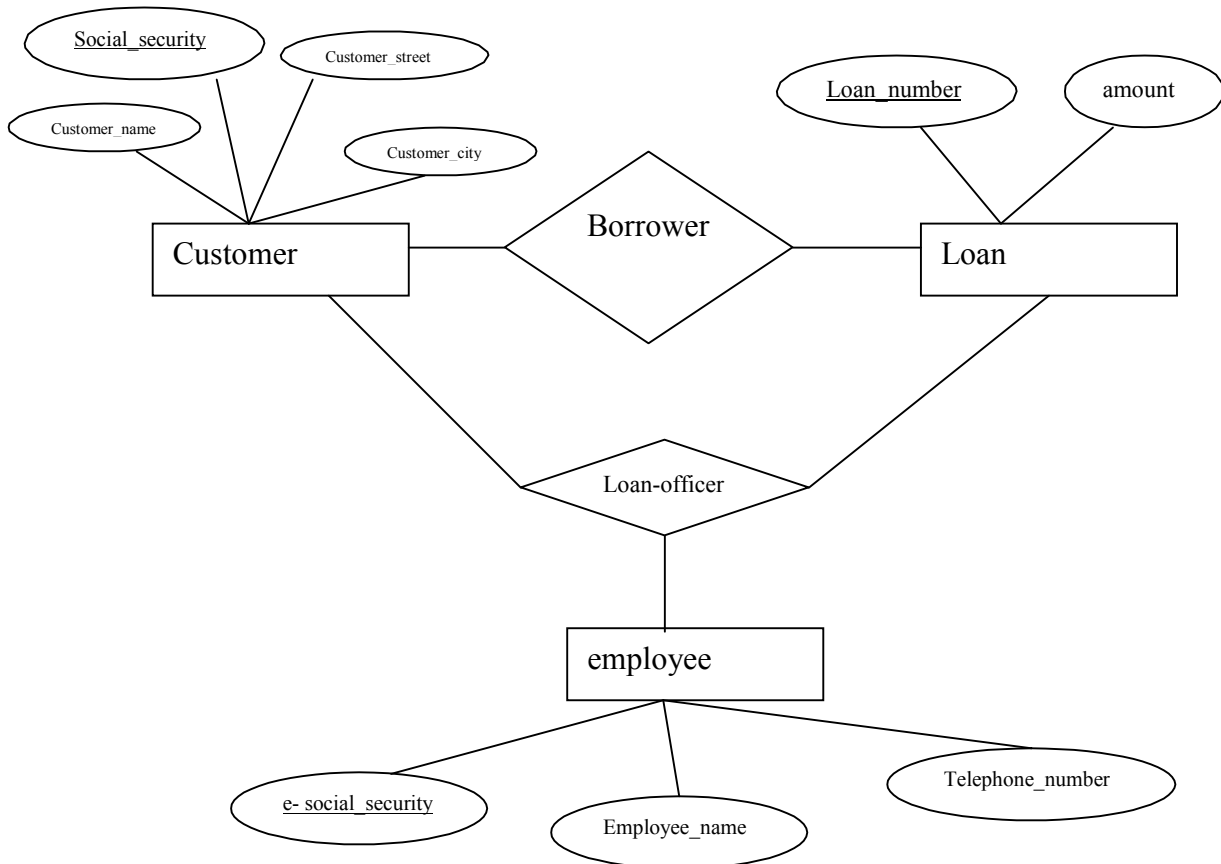
Relation between strong and weak entity set

7.6 Aggregation

One limitation of the E-R Model is that it is not possible to express relationships among relationships. To illustrate the need for such a construct, we consider a database describing information about customers and their loans. Suppose that each customer-loan pair may have a bank employee who is the loan officer for that particular pair. Using our basic E-R Diagram constructs, we obtain E-R diagram drawn in following figure (a) . It

appears that the relationship sets borrower and loan-officer can be combined into one single relationship set. Nevertheless, we should not combine them, because doing so would obscure the logical structure of this schema. For example, if we consider the borrower and loan-officer relationship sets, then this combination specifies that a loan officer must be assigned to every customer-loan pair, which is not true. The separation into two different relationship sets solves this problem.

There is redundant information in the resultant figure, however, since every customer-loan pair in loan-officer is also in borrower. If the loan officer were a value rather than an employee entity, we could instead make loan-officer a multivalued attribute of the relationship borrower. But doing so makes it more difficult to find, for example, customer-loan pairs for which an employee is responsible. Since the loan officer is an employee entity, this alternative is ruled out in any case. The best way is to model a situation such as the one just described is to use aggregation. **Aggregation** is an abstraction through which relationships are treated as higher-level entities. Thus, for our example, we regard the relationship set borrower and the entity sets customer and loan as a higher-level entity set called borrower. Such an entity set is treated in the same manner as is any other entity set. A common situation for aggregation is shown in figure (b).



Figure(a): E-R diagram with redundant relationships

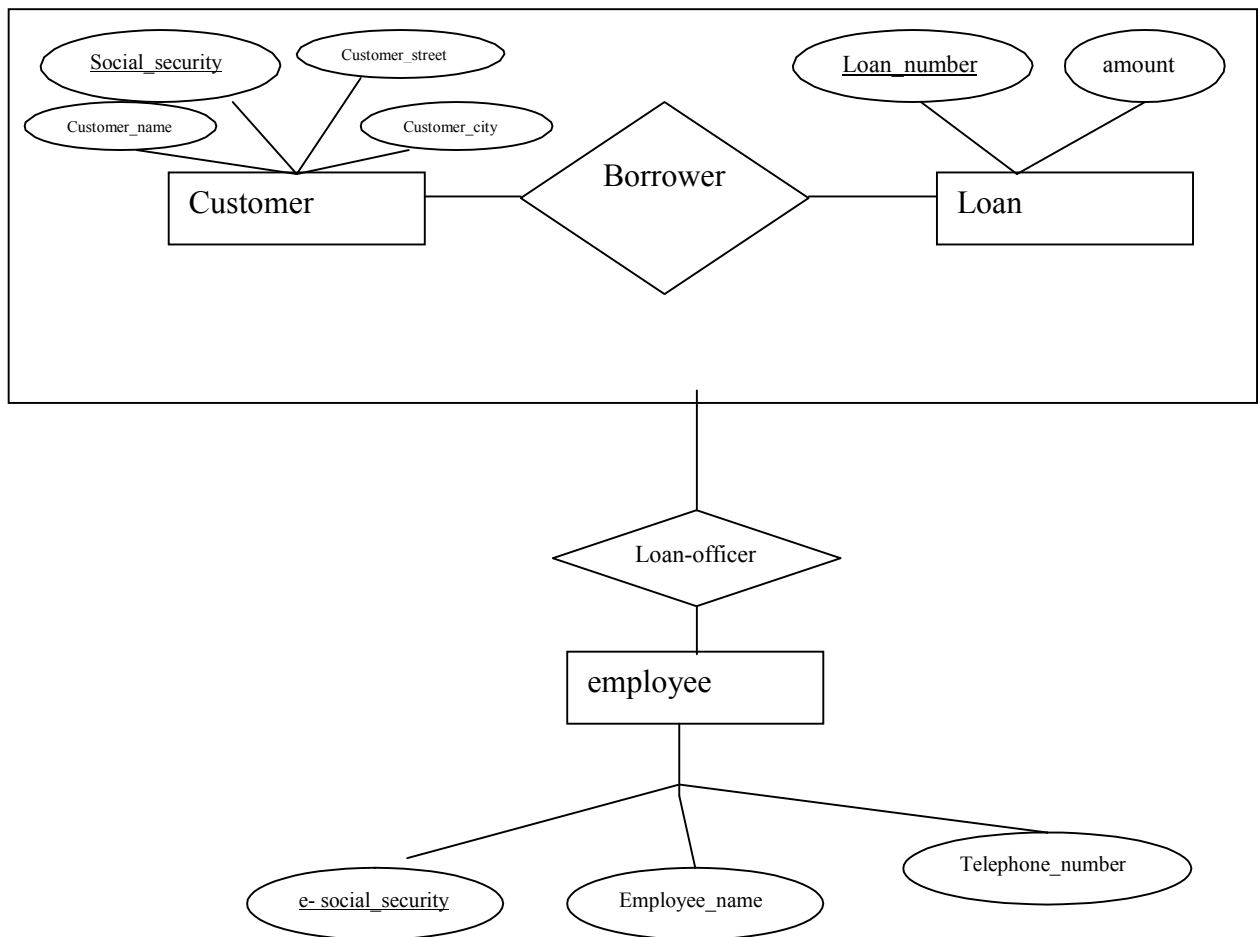
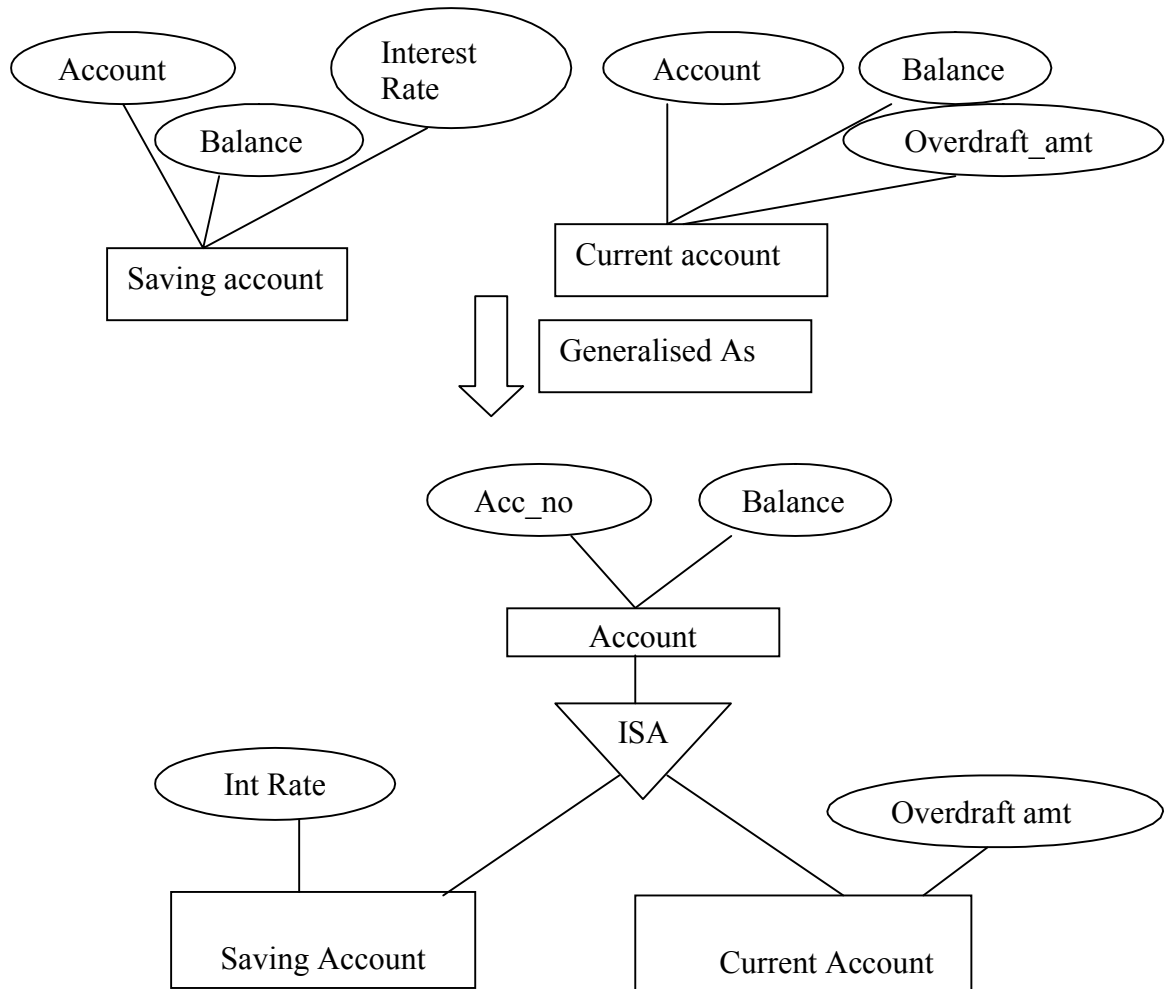


Figure (b) : E-R Diagram with aggregation

Generalization

A generalization hierarchy is a form of abstraction that specifies that two or more entities that share common attributes can be generalized into a higher level entity type called a supertype or generic entity . The lower level of entities become the subtype or categories to the supertype . Subtypes are dependent entities .

Generalization is used to emphasize the similarities among lower-level entity sets and to hide differences . It makes ER diagram simpler because shared attributes are not repeated . Generalisation is denoted through a triangle component labeled ' IS A ' , as shown below

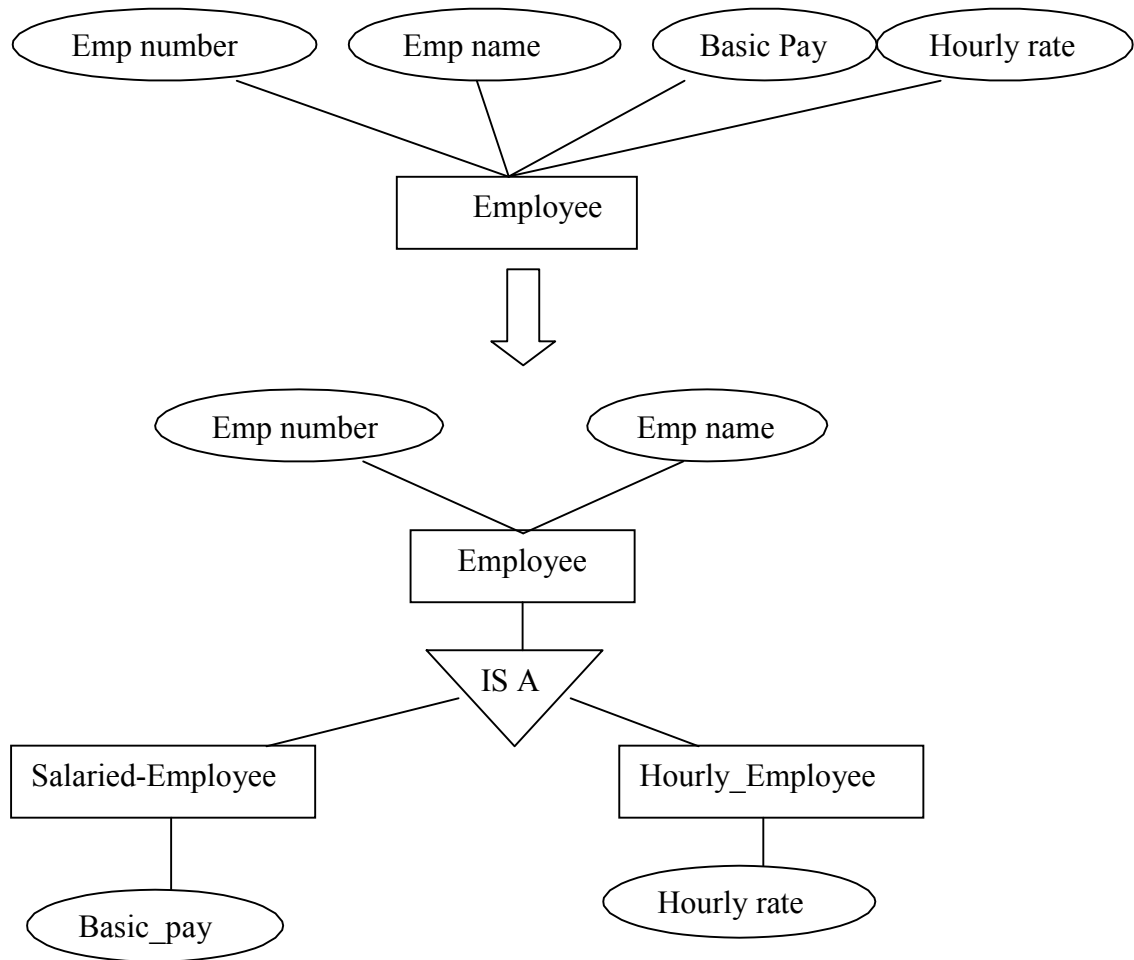


Account is the higher level entity set and Saving account and Current account are lower level entity sets .

Specialization

Specialization is the process of taking subsets of a higher level entity set to form lower level entity sets . It is a process of defining a set of subclasses of an entity type, which is called as superclass of the specialization . The process of defining subclass is based on the basis of some distinct characteristics of the entities in the superclass .

For example specialization of the Employee entity type may yield the set of subclasses namely Salaried_Employee and Hourly_Employee on the method of pay as shown below.



7.7 Summary

The entity-relationship model is based on the perception of a real world that consists of a set of basic objects called entities, and of relationships among these objects. There are three basic notions that the E-R data model employs – entity sets, relationship sets, and attributes. An entity is a thing or object in the real world that is distinguishable from all other objects. An entity set is a set of entities of the same type that share the same properties, or attributes. An entity is represented by a set of attributes. Attributes are descriptive properties possessed by each member of an entity set. A relationship is an association among several entities.

A relationship set is a set of relationships of the same type. Mapping Cardinalities, or cardinality ratios, express the number of entities to which another entity can be associated via a relationship set.

Mapping cardinalities are most useful in describing binary relationship sets, although occasionally they contribute to the description of relationship sets that involve more than two entity sets. The overall logical structure of a database can be expressed graphically by an E-R Diagram. The relative simplicity and pictorial clarity of this diagramming technique may well account in large part for the wide spread use of the E-R Model. An entity Set may not have sufficient attributes to form a primary key, such an entity set is termed as weak entity set. An entity set that has a primary key is termed as a

strong entity set. One limitation of the E-R Model is that it is not possible to express relationships among relationships. This limitation can be removed through aggregation. Aggregation is an abstraction through which relationships are treated as higher-level entities.

7.8 Questionnaires:

1. Define entity, entity set, attribute, relationship and relationship set.
2. What do you mean by an attribute? Explain various types of attributes.
3. What is an E-R Diagram? Explain various constructs for drawing E-R Diagram.
4. Explain E-R Model.
5. Define Weak and strong entity sets with suitable examples.
6. Define aggregation with suitable example. Why it is needed?
7. Differentiate between weak and strong entity sets.
8. What do you mean by mapping cardinality? Explain various mapping cardinalities with suitable examples.

ENTITY RELATIONSHIP MODEL -II

Introduction
Generalization
Converting ER Diagrams to tables
Summary
Questionnaires

8.1 Introduction:

The refinement from an initial entity set into successive levels of entity subgroups represents a top-down design process in which, distinctions are made explicit. The design process may also be processed in a bottom-up manner, in which multiple entity sets are synthesized into a higher-level entity set based on common features. Generalization is a simple inversion of Specialization. A database that conforms to an E-R database schema can be represented by a collection of tables. For each entity set and for each relationship set in the database, there is a unique table that is assigned the name of the corresponding entity set or relationship set. Each table has multiple columns, each of which has a unique name.

8.2 Generalization

The refinement from an initial entity set into successive levels of entity subgroups represents a top-down design process in which, distinctions are made explicit. The design process may also be processed in a bottom-up manner, in which multiple entity sets are synthesized into a higher-level entity set based on common features. The database designer may have first identified a checking-account entity set with the attributes account-number, balance, and overdraft-amount, and a savings-account entity set with the attributes account-number, balance, and interest-rate.

There are similarities between the checking-account entity set and the savings-account entity set in the sense that they have several attributes in common. This commonality can be expressed by generalization, which is a containment relationship that exists between a higher-level entity set and one or more lower-level entity sets. Higher- and lower-level entity sets also may be designated by the terms superclass and subclass respectively. The account entity set is the superclass of the savings-account and checking-account subclasses.

For all practical purposes, generalization is a simple inversion of specialization. We will apply both processes, in combination, in the course of designing the E-R Schema for an enterprise. In terms of the E-R diagram itself, we do not distinguish between specialization and generalization. New levels of entity representation will be distinguished (specialization) or synthesized (generalization) as the design schema comes to express fully the database application and the user requirements of the database. Differences in the two approaches may be characterized by their starting point and overall goal.

Specialization stems from a single entity set, it emphasizes differences among entities within the set by creating distinct lower-level entity sets. These lower-level entity sets may have attributes, or may participate in relationships, that do not apply to all the

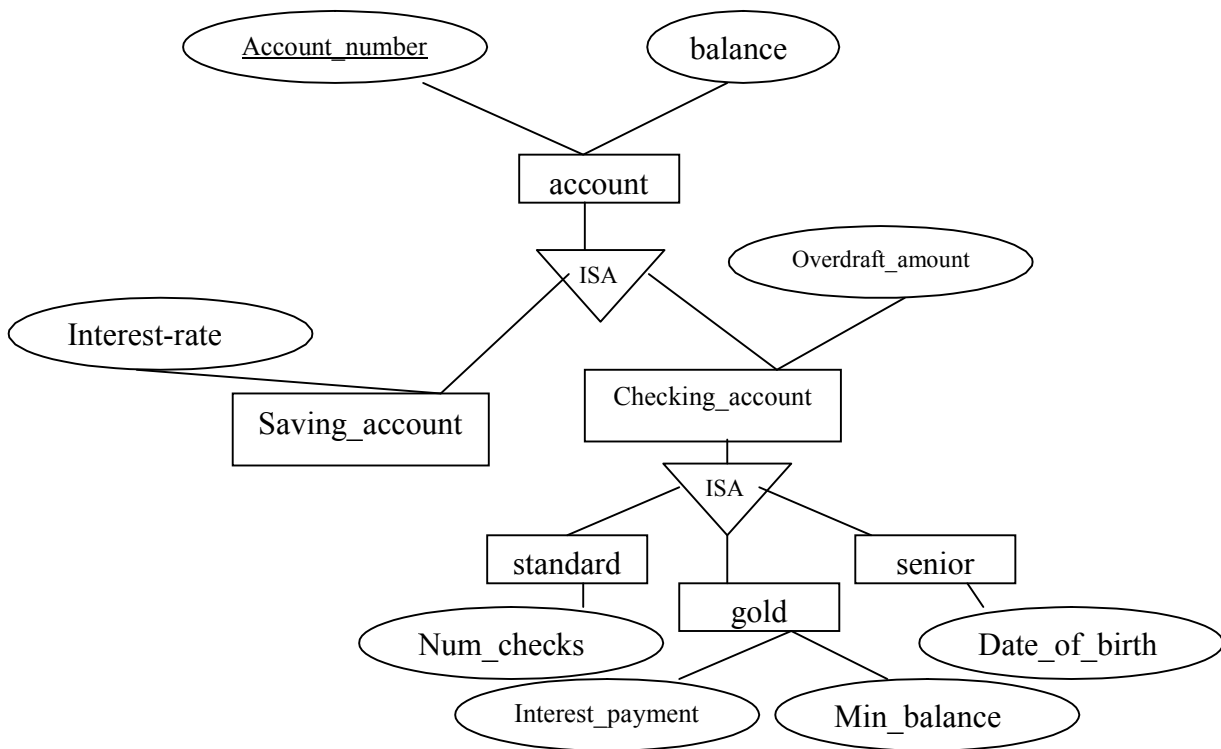
entities in the higher-level entity set. Indeed, the reason a designer applies specialization is to represent such distinct features. If savings-account and checking-account did not each have unique attributes, there would be no need to specialize the account entity set.

Generalization proceeds from the recognition that a number of entity sets share some common features. Based on their commonalities, generalization synthesizes these entity sets into a simple, higher-level entity set. Generalization is used to emphasize the similarities among lower-level entity sets and to hide the differences; it also permits an economy of representation in that shared attributes are not repeated.

A crucial property of the higher-level and lower-level entities created by specialization and generalization is attribute inheritance. The attributes of the higher-level entity sets are said to be inherited by the lower-level entity sets. For example: savings-account and checking-account inherit the attributes of account. Thus saving-account is described by its account-number, balance and Interest rate and Checking account is described by its account-number, balance, and overdraft-amount attributes. A lower-level entity set also inherits participation in the relationship sets in which its higher-level participates. Both the savings-account and checking-account entity sets participate in the depositor relationship set. Attributes inheritance applies through all tiers of the lower-level entity sets. The standard, gold, and senior lower-level entity sets inherit the attributes and relationship participation of both checking-account and account.

Whether a given portion of an E-R model was arrived at by specialization or generalization, the outcome is basically the same:

- A higher-level entity set with attributes and relationships that apply to all of its lower-level entity sets.
- Lower-level entity sets with distinctive features that apply only within a particular lower-level entity set.



8.3 Converting E-R diagrams into tables

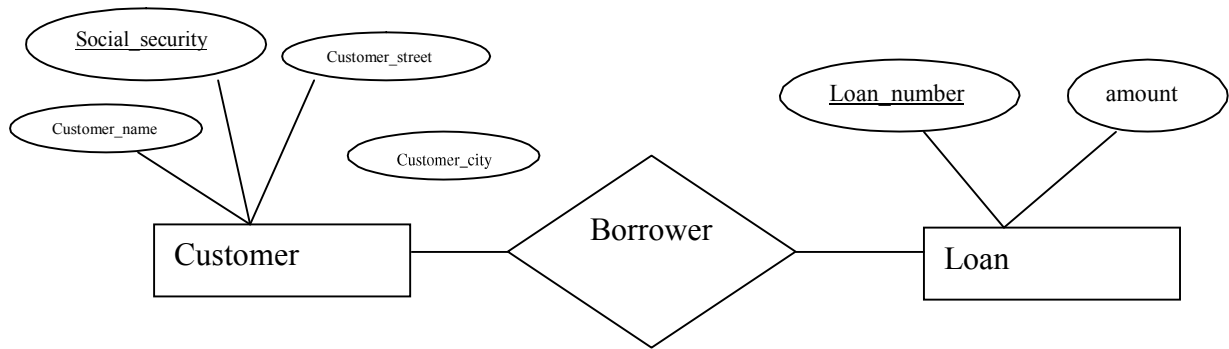
A database that conforms to an E-R database schema can be represented by a collection of tables. For each entity set and for each relationship set in the database, there is a unique table that is assigned the name of the corresponding entity set or relationship set. Each table has multiple columns, each of which has a unique name.

Both the E-R model and the relational database are abstract, logical representations of real world enterprises. Because the two models employ similar design principles, we can convert an E-R design into a relational design. Consequently a database representation from an E-R diagram to a table format is the basis for deriving a relational database design from an E-R diagram. In the following section, we will explain how to convert the E-R diagram or schema into tables.

8.3.1 Tabular representation of Strong Entity Sets

Let E be a strong entity set with descriptive attributes $a_1, a_2, a_3, \dots, a_n$. We represent this entity by a table called E with n distinct columns, each of which corresponds to one of the attributes of E. Each row in this table corresponds to one entity of the entity set E.

Consider the entity set loan of the E-R diagram shown below:



This entity set has two attributes: loan_number and amount. We represent this entity set by table loan, with two columns, as shown in following figure. The row (L-17,1000) in the loan table means that loan number L-17 has a amount of Rs. 1000. We can add a new entity to the database by inserting a row into a table. We can also delete or modify rows.

Table : loan	
Loan_number	amount
L-17	1000

Let D_1 denote the set of all loan numbers and let D_2 denote the set of all balances. Any row of the loan table must consist of a 2-tuple (v_1, v_2) where v_1 is a loan, v_1 belongs to D_1 and v_2 is an amount where v_2 belongs to D_2 . In general, the loan table will contain only a subset of the set of all possible rows. We refer to the set of all possible rows of loan as the Cartesian product of D_1 and D_2 denoted by $D_1 \times D_2$.

In general, if we have a table of n columns, we denote the Cartesian product of $D_1, D_2, D_3, \dots, D_n$ by $D_1 \times D_2 \times D_3 \dots \times D_n$.

Similarly, another example, consider the entity set customer of the E-R Diagram shown above. This entity set has the attributes customer_name, social_security, customer_street, customer_city. The table corresponding to customer has four columns as shown in Figure below:

Table : Customer			
Customer_name	Social_security	Customer_street	Customer_city
Suresh	123-4-567	Phase I	Patiala

8.3.2 Tabular Representation of Weak entity Sets

Let A be a weak entity set with attributes $a_1, a_2, a_3, \dots, a_n$. Let B be the strong entity set on which A is dependent. Let the primary key of B consists of attributes $b_1, b_2, b_3, \dots, b_n$. We represent the entity set A by a table called A with one column for each attribute of the set:

$$\{ a_1, a_2, a_3, \dots, a_n \} \cup \{ b_1, b_2, b_3, \dots, b_n \}$$

As an illustration, consider the entity set payment consisting of attributes payment_number, payment_date, payment_amount. The primary key of the loan entity set, on which payment is dependent, is loan_number. Thus , payment is represented by a table with four columns labeled loan_number, payment_number, payment_date, payment_amount as shown in following figure:

Table: payment			
Loan_number	Payment_number	Payment_date	Payment_amount
L-17	67	10-11-2006	1000

8.3.3 Tabular Representation of Relationship sets

Let R be a relationship set, let $a_1, a_2, a_3, \dots, a_n$ be the set of attributes formed by the union of the primary keys of each of the entity sets participating in R, and let descriptive attributes (if any) of r be $b_1, b_2, b_3, \dots, b_n$. We represent this relationship set by a table called R with one column for each attribute of the set:

$$\{ a_1, a_2, a_3, \dots, a_n \} \cup \{ b_1, b_2, b_3, \dots, b_n \}$$

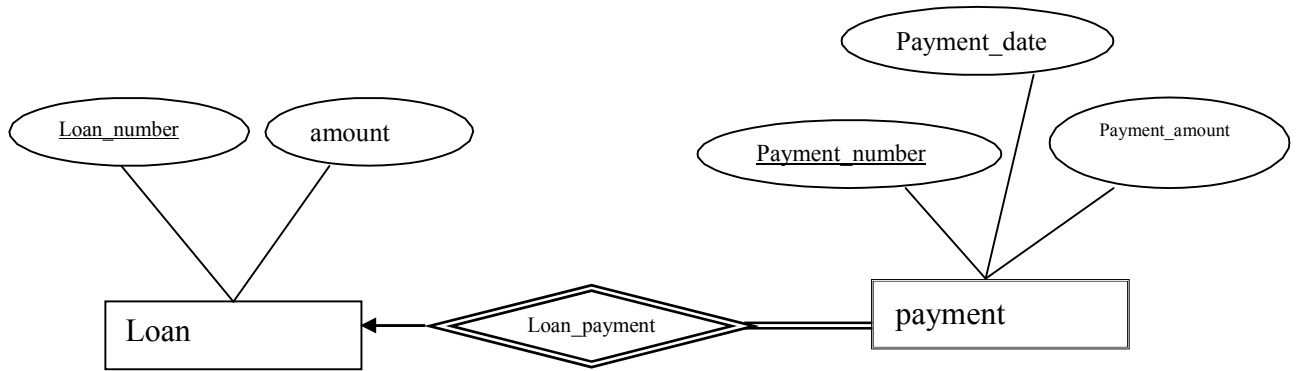
As an illustration, consider the relationship set borrower in the E-R Diagram shown above. This relationship set involves the following two entity sets:

- Customer, with the primary key social security
- Loan, with the primary key loan_number

Since the relationship set has no attributes, the borrower table has two columns labeled social_security and loan_number as shown in figure below:

Table : borrower	
Social_security	Loan_number
123-4-567	67

The case of a relationship set linking a weak entity set to the corresponding strong entity set is special. As we noted earlier, these relationships are many-to-one and have no descriptive attributes. Furthermore, the primary key of a weak entity set includes the primary key of the strong entity sets. In the E-R diagram shown below, the weak entity set payment is dependent on the strong entity set loan via the relationship set loan-payment. The primary key of payment is {loan_number, payment_number} and the primary key of loan is {loan_number}. Since loan_payment has no descriptive attributes, the table for loan_payment would have two columns, loan_number and payment_number. The table for the entity set payment has four columns, loan_number, payment_number, payment_date, payment_amount. Thus, the loan-payment table is redundant. In general, the table for the relationship set linking a weak entity set with its corresponding strong entity set is redundant and does not need to be present in a tabular representation of E-R diagram.



Multivalued Attributes

We have seen that attributes in an E-R diagram generally map directly into columns for the appropriate tables. Multivalued attributes, however, are an exception; new tables are created for these attributes.

For a multivalued attribute *M*, we create a table *T* with a column *C* that corresponds to *M* and columns corresponding to primary key of the entity set or relationship set of which *M* is an attribute. For example, consider the E-R diagram that includes the multivalued attribute *dependent_name*. For this multivalued attribute, we create a table *dependent_name*, with columns *dname*, referring to the *dependent_name* attribute of employee, and *e_social_security*, representing the primary key of the entity set employee. Each dependent of an employee is represented as a unique row in the table.

8.3.5 Tabular Representation of Generalization

There are two different methods for transforming to a tabular form an E-R diagram that includes generalization.

1. Create a table for the higher-level entity set. For each lower-level entity set, create a table that includes a column for each of the attributes of that entity set plus a column for each attribute of the primary key of the higher-level entity set. Thus, for the E-R diagram in section 8.2, we have three tables:
 - Account, with attribute *account_number* and *balance*
 - Savings_account, with attributes *account_number* and *interest_rate*
 - Checking_account, with attributes *account_number* and *overdraft_amount*
2. If the generalization is disjoint and complete – that is if no entity is a member of two lower-level entity sets directly below a higher-level entity set, and if every entity in the higher-level entity set is also a member of one of the lower-level entity sets – then an alternative representation is possible. Here, create no table for the higher level entity set. Instead, for each lower-level entity set, create a table that includes a column for each of the attributes of that entity set plus a column for each attribute of the higher level entity set. Then, for the E-R diagram in section 8.2 we have two tables:

- saving_account, with attributes account_number, balance, and interest_rate.
- Checking_account, with attributes accounts_number, balance, and overdraft_amount

The saving_account and checking_account relations corresponding to these tables both have account-numbers as the primary key.

If the second method were used for an overlapping generalization, some values such as balance would be stored twice unnecessarily. Similarly, If the generalization were not complete—that is , if accounts were neither savings nor checking accounts—then such accounts could not be represented with the second option.

8.4 Summary

Specialization stems from a single entity set, it emphasizes differences among entities within the set by creating distinct lower-level entity sets. Generalization proceeds from the recognition that a number of entity sets share some common features. Based on their commonalities, generalization synthesizes these entity sets into a simple, higher-level entity set. Generalization is used to emphasize the similarities among lower-level entity sets and to hide the differences; it also permits an economy of representation in that shared attributes are not repeated. Generalization is a simple inversion of Specialization. Both the E-R model and the relational database are abstract, logical representations of real world enterprises. Because the two models employ similar design principles, we can convert an E-R design into a relational design. Consequently a database representation from an E-R diagram to a table format is the basis for deriving a relational database design from an E-R diagram.

8.5 Questionnaires

1. Explain the concept of generalization with suitable example.
2. Explain the steps for converting E-R Diagrams into tables.

OVERVIEW OF NETWORK AND HIERARCHIAL DATA MODEL**Introduction****Overview the Network Data Model****Overview the Hierarchical Data Model****Summary****Questionnaires****9.1 Introduction:**

The network data model represents entities by records and expresses relationships between entities by means of sets implemented by the use of pointers or links. The model allows the representation of an arbitrary relationship. The DBTG proposal places a number of restrictions on the use of the links. A set is a means of representing a one-to-many relationship between record types. A set type can have an arbitrary number of occurrences.

Like the network data model, the hierarchical data model uses the records and pointers or links to represent entities and relationships among them. However, unlike the network data model, the data structure used is a rooted tree with a strict parent-to-child ordering. IBM's IMS DBMS includes the features of Hierarchical Model

9.2 The Network Data Model

The network data model was formalized in the late 1960s by the Database Task Group of the Conference on Data System Language (DBTG / CODASYL). Their first report which has been revised a number of times, contained detailed specifications for the network data model. The specifications contained in the report and its subsequent revisions have been built on commercial DBMS using DBTG model.

The Network data Model (NDM) represents data for any entity set by a logical record type. The data for an instance of an entity set is represented by a record occurrence of the record type.

DBTG Model:

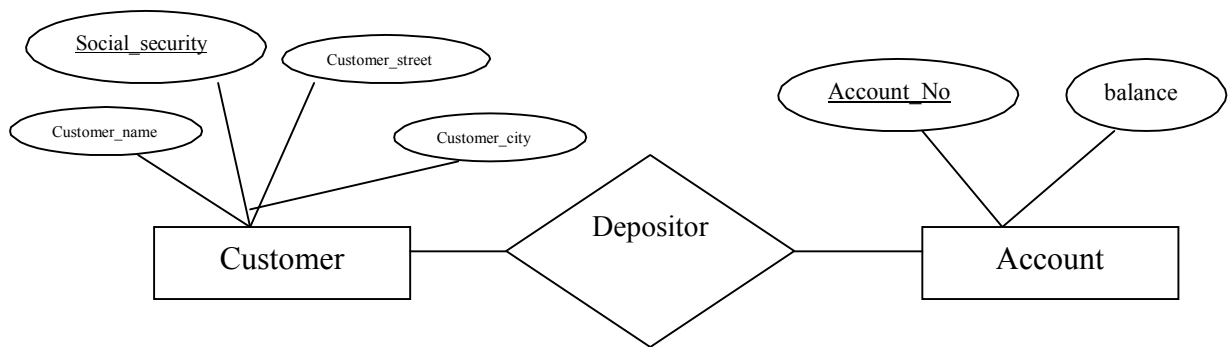
The DBTG model uses two different structures to represent the database entities and relationships between the entities, namely record type and set type.

A *record type* is used to represent an entity type. It is made up of a number of data items that represent the attributes of the entity.

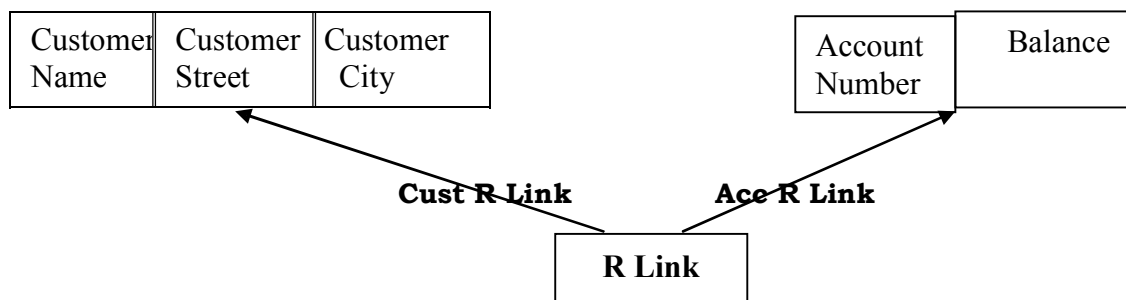
A *set type* is used to represent a directed relationship between two record types, the so called owner record type, and the member record type. The set type, like the record type, is named and specifies that there is one-to-many relationship (1: M) between the owner and member record types. The set type can have more than one record type as its member, but only one record type is allowed to be the *owner in a given set type*. A database could have one or more occurrences of each of its record and set types. An *occurrence of a set type* consists of an occurrence of the owner record type and any number of occurrences of each of its member record types. A record type cannot be a member of two distinct occurrences of the same set type.

In this model, only many-to-one links can be used. One-to-one links are represented as many-to-one links. Many-to-many links are disallowed to simplify the implementation.

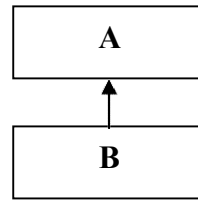
For example:



In the above E-R Diagram, depositor relationship is many-to-many and to transfer the relationship into DBTG model, we have to convert this many-to-many relationship into many-to-one relationships as only many-to-one relationships are allowed in the DBTG model. Thus, we must create a new dummy record type, R link that may either have no fields or have a single field containing an externally defined unique identifier, and two many-to-one links – cust R Link and Acc R Link as follows:



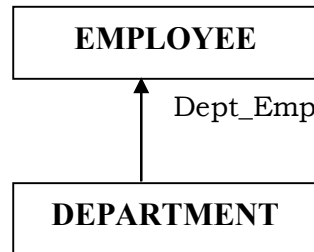
In the DBTG model, a data structure diagram consists of two record types and are linked to each other through many-to-one relationships. The general form of this structure is



This structure is referred to as DBTG set.

DBTG Set:

Bachman introduced a graphical means called a data structure diagram to denote the logical relationship implied by a set. Here a labeled rectangle represents the corresponding entity or record type. An arrow that connects two labeled rectangles represents the corresponding entity or record type. The arrow direction is from the owner record type to the member record type. Figure shows two record types (DEPARTMENT and EMPLOYEE) and the set type DEPT_EMP, with DEPARTMENT as the owner record type and EMPLOYEE as the member record type.



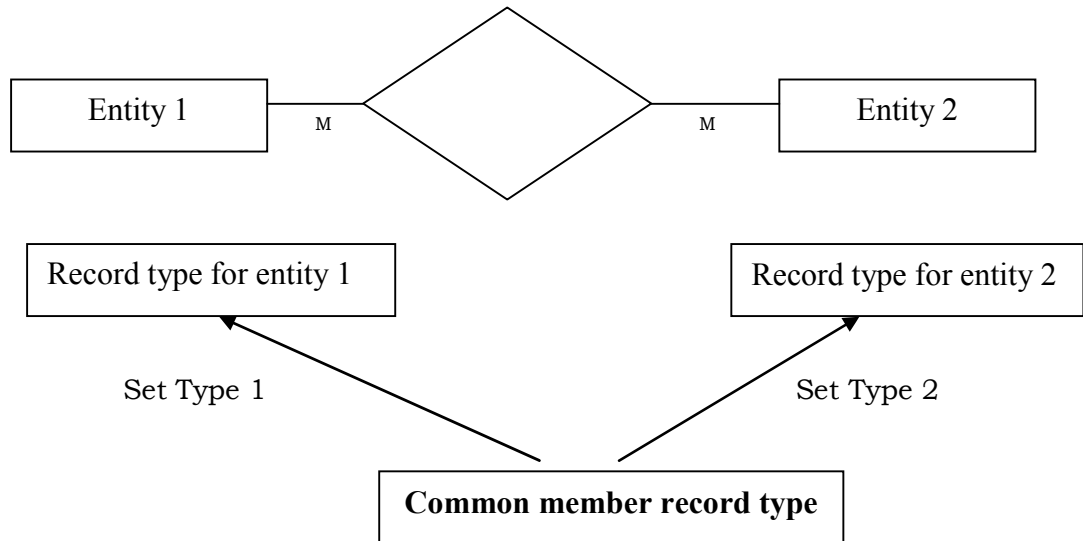
The data structure diagrams have been extended to include field names in the record type rectangle, and the arrow is used to clearly identify the data fields involved in the set association. A one-to-many (1:M) relationship is shown by a set type arrow that starts from the owner field in the owner record type. The arrow points to the member field within the member record type. The fields that support the relationship are clearly identified.

Each entity type in E-R Diagram is represented by a logical record with the same name. The attributes of the entity are represented by data fields of the record. We use the term *logical record* to indicate that the actual implementation may be quite different.

The conversion of the E-R Diagram into a Network database consists of converting each 1:M binary relationship into a set. If there is a 1:M binary relationship R_1 from entity type E_1 to the entity type E_2 , then the binary relationship is represented by a set. An instance of this would be S_1 with an instance of the record type corresponding to the entity E_1 as the owner and one or more instances of the record type corresponding to entity E_2 as the member. If a relationship has attributes, unless the attributes can be assigned to the member record type, they have to be maintained in a separate logical record type created for this purpose. The introduction of this additional record type requires that the original set be converted into two symmetrical sets, with the record corresponding to the attributes of the relationship as the member in both the sets and the records corresponding to the entities as the owners.

Each many-to-many relationship is handled by introducing a new record type to represent the relationship wherein the attributes, if any of the relationship are stored. We then create two symmetrical 1: M sets with the member in each of the sets being the

newly introduced record type. The conversion of a many-to-many relationship into two one-to-many sets using a common member record type as shown in figure below:



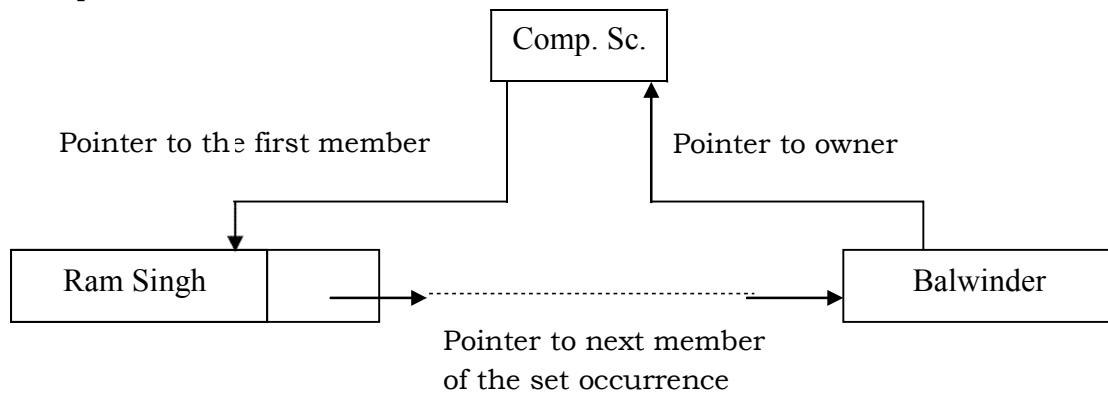
In the network model, the relationships as well as the navigation through the database are predefined at database creation time.

Implementation of the Network Data Model:

The record is basic unit to represent data in the DBTG network database model. The implementation of the one-to-many relationships of a set is represented by linking the members of a given occurrence of a set to the owner record occurrence. The actual method of linking the members of a given record occurrence to the owner is immaterial to the user of the database; however, we can assume that the set is implemented using a linked list. The list starts at the owner record occurrence and links all the member record occurrences with the pointer in the last record occurrence leading back to the owner record.

Figure below shows the implementation of the set occurrence DEPT-EMP where the owner record is Comp.Sc. And the member records are the instances Ram Singh and Balwinder. Note that for simplicity we have shown only one of the record fields of each record. This method of implementation assigns one pointer (link) in each record for each set type in which the record participates and, therefore allows a record occurrence to participate in only one occurrence of a given set type. Any other method of implementing

the set construct in a database management system based on the DBTG proposal is, in effect, equivalent to the linked list method.



A second form of network implementation, especially useful for M:M relationships, is a bit map, which is depicted in figure. A bit map is a matrix created for each relationship. Each row corresponds to the relative record number of a target record of a relationship. A 1 bit in a cell for row X and the column Y means that records corresponding to row X and column Y are associated in this relationship; a zero means no association.

	1	2	.....	Y	.....
1	1	0	.....	0	.....
2	1	0	.....	0	.....
.
.					
.					
X	1	0	.....	1	.....
.					
.					

For example, figure below indicates that PRODUCT with relative record number X is related to VENDOR with relative record numbers 1 and Y. Bit maps are powerful data structures for the following reasons:

1. Any record type(s) can be included in rows and columns.
2. 1:1, 1:M, M:1 relationship can all be represented.
3. Rows and columns can be logically manipulated by Boolean operators to determine records that satisfy complex associations.
4. A bit map can be manipulated equally as well in either a row or column access and can be easily extended for n-ary relationships.

Advantages and Disadvantages of Network model

The main advantages of network model are :

Simplicity

One of the basic advantages of network model is its simplicity . Network model is conceptually very simple to design

Capability to handle more relationship types :

The network model can handle the one-to-many (1 : M) and many to many relationships, which is a real help in modeling the real life situations.

Data Integrity

Integrity actually means that the data stored in the database is consistent. It actually ensures the accuracy and efficiency of data stored. Data integrity is also one of the advantages of network model. Network model does not allow member to exist without an owner. Thus a user must first define the owner record and then the member record, this ensures data integrity.

Data independence

Network model allows isolating the programs from complex physical storage details .

Database Standards

One of the major drawbacks of other models were the non-availability of universal standards for database design and modeling. The network model is based on the standards formulated by the DBTG and augmented by ANSI/SPARC (American National Standards Institute/ Standards Planning and Requirements Committee) in the 1970s. All the network database management systems conformed to these standards. These standards included a Data Definition Language (DDL) and Data Manipulation Language (DML), thus greatly enhancing database administration and portability.

Disadvantages of Network model

Even though network database model was significantly better than the early models it also had many drawbacks . Some of them are

System complexity:

All the records are maintained using pointers and hence the whole database structure becomes very complex.

Operational Anomalies

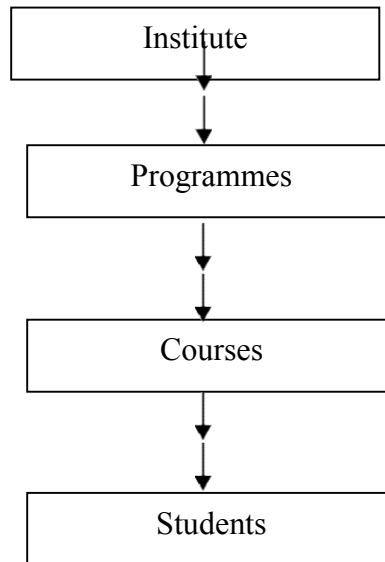
In network model insertion, deletion, and updating operations of any record require large number of pointer adjustments, which makes the implementation very complex and complicated .

Absence of structural independence

Since the data access method in the network database model is a navigational system, making structural changes to the database is very difficult in most cases and impossible in some cases. If changes are made to the database structure then all the application programs need to be modified before they can access data. Thus, even though the network database model succeeds in achieving data independence, it still fails to achieve structural independence.

9.3 THE HIERARCHICAL DATA MODEL

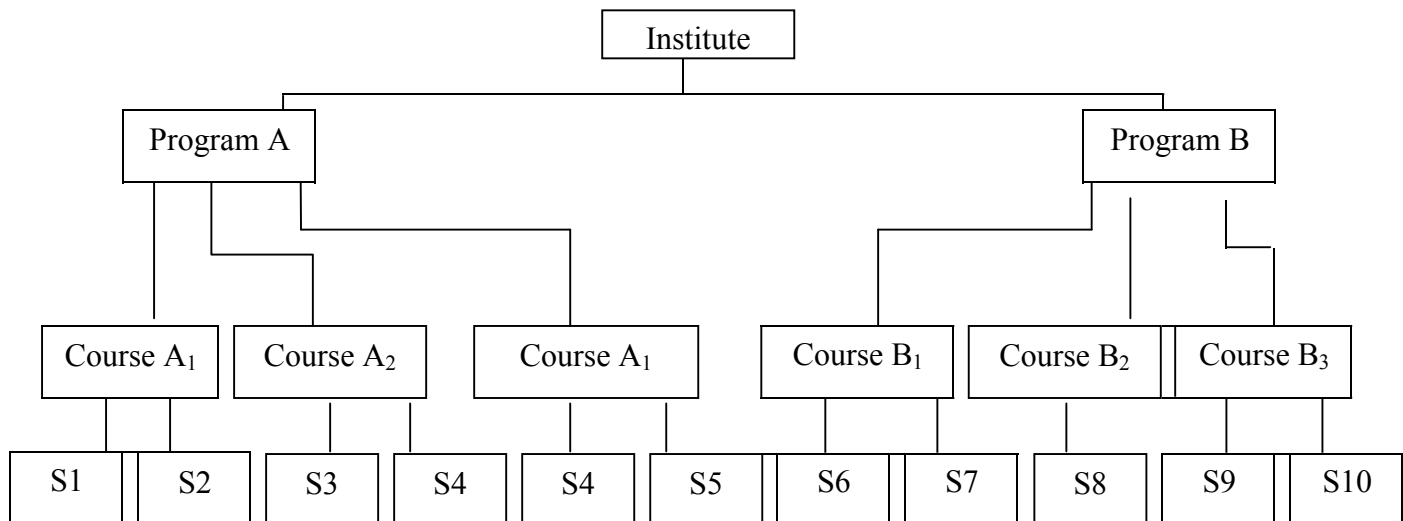
A DBMS belonging to the hierarchical data model uses tree structures to represent relationship among records. Tree structures occur naturally in many data organizations because some entities have an institute hierarchical order. For example, an institute has a number of programmes to offer. Each program has a number of courses. Each course has a number of students registered in it. The following figure depicts the four entity types Institute, Programmes, Courses and Students to make up the four different levels of hierarchical structure. The figure below shows an example of database occurrence for an institute. A database is a collection of database occurrence.



Definition: A hierarchical database therefore consists of a collection of records which are connected with each other through links. Each record is a collection of fields (attributes), each of which contains one data value. A link is an association between precisely two records.

A tree structure diagram serves the same purpose as an entity-relationship diagram; namely it specifies the overall logical structure of the database.

The following figure shows typical database occurrence of hierarchical structure (tree structure).



The hierarchical data model has the following features:

- Each hierarchical tree can have only one root record type and this record type does not have a parent record type.
- The root can have any number of child record types and each of which can itself be a root of a hierarchical sub tree.
- Each child record type can have only one parent record type; thus a M:M relationship cannot be directly expressed between two record types.
- Data in a parent record applies to all its children records.
- Each record occurrence must have a parent record occurrence; deleting a parent record occurrence requires deleting its entire children record occurrence.

Replication Vs Virtual Record

The hierarchical model, like the network model cannot support a many-to many relationship directly. In the network model the many-to many relationship is implemented by introducing an intermediate record and two one-to-many relationship. In the hierarchical model, the many-to many relationship can be expressed using one of the following methods: replication or virtual record. When more than one employee works in a given department, then for the hierarchical tree with EMPLOYEE as the root node we have to replicate the record for the department and have this replicated record attached as a child to the corresponding occurrence of the EMPLOYEE record type.

Replication of data would mean a waste of storage space and could lead to data inconsistencies when some copies of replicated data are not updated. The other method for representing the many-to-many relationship in the hierarchical data model is to use an indirect scheme similar to the network approach. In the hierarchical model the solution is to use the so-called virtual record. A virtual record is essentially a record containing a pointer to an occurrence of an actual physical record type. This physical record type is called the logical parent and the virtual record is the logical child. When a record is to be replicated in several database trees, we keep a single copy of that record in one of the trees and replace, each other record with a virtual record containing a pointer to that physical record. To be more specified, let R be a record type that is replicated in several hierarchical diagrams say H_1, H_2, \dots, H_n . To eliminate replication we create a new virtual record type

Virtual record type virtual – R. Virtual –will contain no data.

The Accessing of Data Records in Hierarchical Data Structure

The tree type data structures used to represent hierarchical data model shows the relationships among the parents, children, cousins, uncles, aunts, and siblings. A tree is thus a collection of nodes. One node is designated as the root node; the remaining nodes form trees or subtrees.

An ordered tree is a tree in which the relative order of the subtrees is significant. This relative order not only signifies the vertical placement or level of the subtrees but also the left to right ordering. Figures (a) and (b) below give two examples of ordered trees with A as the root node and B,C, and D, in turn, are root nodes or subtree with children nodes (E,F), (G)and (H,I,J) respectively. The significance in the ordering of the subtrees in these diagrams is discussed below.

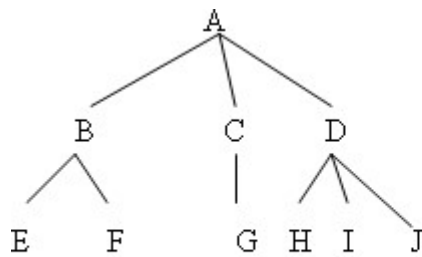


Figure (a)

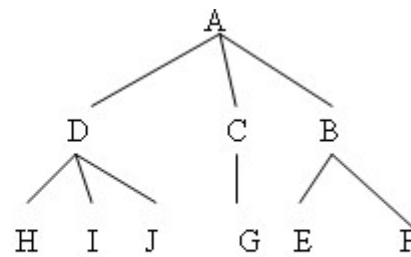


Figure (b)

Traversing an ordered tree can be done in a number of ways. The order of processing the nodes of the tree depends on whether or not one processes the node before the node's subtree and the order of processing the subtrees (left to right or right to left). The usual practice is the so-called preorder traversal in which the node is processed first, followed by the leftmost subtree not yet processed.

The preorder processing of the ordered tree of figure (a) below will process the nodes in the sequence A,B,E,F,C,G,D,H,I,J.

The significance of the ordered tree becomes evident when we consider the sequence in which the nodes could be reached when using a given tree traversing strategy. For instance, the order in which the nodes of the hierarchical tree of figure (b) are processed using the preorder processing strategy is not the same as the order for figure (a) above, even though the tree of part b contains the same nodes as the tree of part a.

Two distinct methods can be used to implement the preorder sequence in the ordered tree. The first method, shown in figure (c) below uses hierarchical pointers to implement the ordered tree of figure (a) above. Here the pointer in each record points to the next record in the preorder sequence.

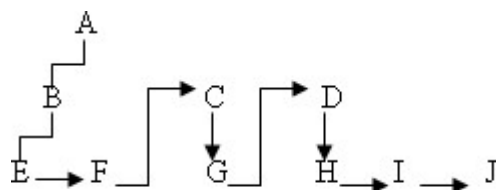


Figure (c): Preorder Traversal

The second method, shown in figure (d) uses two types of pointers; the child and the sibling pointers.

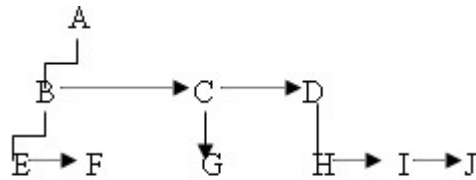


Figure (d): Child/ Sibling Pointers

The child pointer is used to point to the leftmost child and the sibling pointer is used to point to the right sibling. The siblings are nodes that have the same parent. Thus, the binary tree corresponding to tree in the figure (a) above is obtained by connecting together all siblings of a node and deleting all links from a node to its children except for the link to its leftmost child, using this transformation, we obtain the tree representation as shown in figure (d).

Implementation of the Hierarchical Data Model

Each occurrence of a hierarchical tree can be stored as a variable length physical record, the nodes of the hierarchy being stored in preorder. In addition the stored record contains a prefix field. This field contains control information including pointers, flags, locks and counters, which are used by DBMS to allow concurrent usage and enforce data integrity.

A number of methods could be used to store the hierarchical trees in the physical medium. It affects not only the performance of the system but also the operations that can be performed on the database, For example, if each occurrence of the hierarchical tree is stored as a variable length record on magnetic tape like device, the DBMS will allow only sequential retrieval and insertion or modification may be disallowed or performed lane by recreating the entire database. The insertion and modification storage of the hierarchical database on a direct access device allows an index structure to be supported for the root nodes and allows direct access to an occurrence of the hierarchical definition tree of figure (a) using the variable length record approach is given in the following figure:

$$\{a_1 \ b_1 \ e_{11} \ e_{12} \ f_1 \ a_1 \ b_2 \ e_{21} \ e_{22} \ f_2 \ c_1 \ g_1 \ d_1 \ h_1 \ I_1 \ J_1 \ d_2 \ h_{21} \ h_{22} \ I_2 \ J_2\}$$

Figure (e): Sequential storage of hierarchical database

The hierarchy can also be represented using pointer of either preorder hierarchical type or child/sibling type. In the hierarchical type of pointer, each record occurrence has a pointer that points to the next record in the pre order sequence. The child pointer points to its leftmost child record occurrence. The sibling pointer points to its right sibling (or twin). A record has one sibling pointer and its many child pointers as the number of child types associated with the node corresponding to the record. The following two figures (f) and (g) illustrate preorder hierarchical pointer and child sibling pointers respectively of hierarchical tree shown in figure (e):

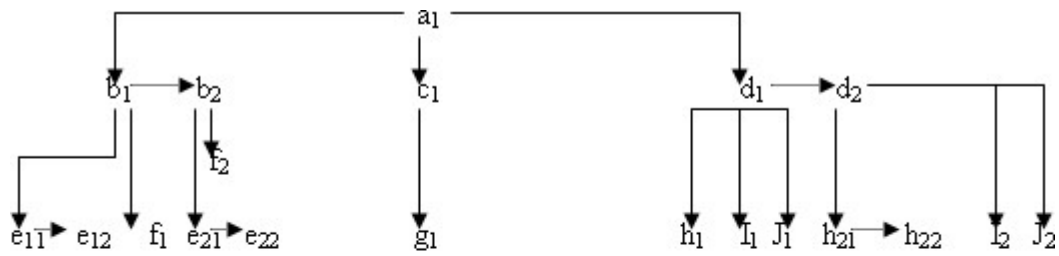


Figure (f)

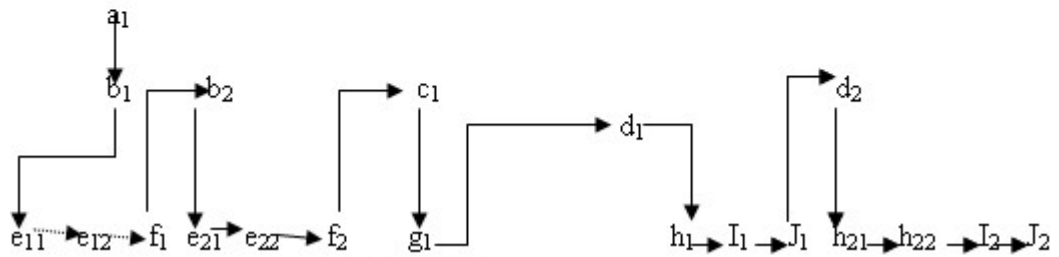


Figure (g)

Sample Database

In order to understand the hierarchical data model better, let us take the example of the sample database consisting of supplier, parts and shipments. The record structure and some sample records for supplier, parts and shipments elements are as given in following tables

The Supplier records

Sno	Name	Status	City
S1	Suneet	20	Qadian
S2	Ankit	10	Amritsar
S3	Amit	30	Amritsar

The Part records

Pno	Name	Color	Weight	City
P1	Nut	Red	12	Qadian
P2	Bolt	Green	17	Amritsar
P3	Screw	Blue	17	Jalandhar
P4	Screw	Red	14	Qadian

The Shipment records

Sno	Pno	Qty
S1	P1	250
S1	P2	300
S1	P3	500
S2	P1	250
S2	P2	500
S3	P2	300

We assume that each row in supplier table is identified by a unique SNo that uniquely identifies the entire row of the table. Likewise each part has a unique Pno. Also we assume that no more than one shipment exists for a given supplier/part combination in the shipments table.

Hierarchical view for the suppliers-parts database :

The following figure shows four individual trees , a tree for each part .

P3	Screw	Red	14	Gadian
S1	Saneet	20	Qadian	500

P1	Nut	Red	12	Qadian
S1	Suneet	20	Qadian	250
S2	Ankit	10	Amritsar	250

P2	Bolt	Green	17	Amritsar
S1	Suneet	20	Qadian	300
S2	Ankit	10	Amritsar	500
S3	Amit	30	Amritsar	300

P4	Screw	Red	14	Qadian
----	-------	-----	----	--------

The tree structure has parts record superior to supplier record. That is parts from the parent and supplier forms the children. Each of the four trees in above figure consists of one part record occurrence, together with a set of subordinate supplier record occurrences. There is one supplier record for each supplier of a particular part. Each supplier occurrences include the corresponding shipment quantity. For example, supplier S3 supplies 300 quantities of part P2. Note that the set of supplier occurrences for a given part occurrence may contain any number of members, including zero (for the case of part P4). Part P1 is supplied by two suppliers, S1 and S2. Part P2 is supplied by three suppliers, S1, S2 and S3 and part P3 supplied by only supplier S1.

Operations on Hierarchical Model

There are four basic operations Insert, Update, Delete and Retrieve that can be performed on each model. Now we consider in detail that how these basic operations are performed in hierarchical database model.

Insert Operation: It is not possible to insert the information of the supplier e.g. S4 who does not supply any part. This is because a node cannot exist without a root. Since, a part P5 that is not supplied by any supplier can be inserted without any problem, because a parent can exist without any child. So we can say that insert anomaly exists only for those children, which has no corresponding parents.

Update Operation : Suppose we wish to change the city of supplier S1 from Qadian to Jalandhar , then we will have to carry out two operations i.e. searching S1 for each part and then performing updations for different occurrences of S1 .But if we wish to change the city of part P1 from Qadian to Jalandhar, then these problems will not occur because there is only a single entry for part P1 and the problem of inconsistency will not arise . So we can say that update anomalies only exist for children not for parent because children may have multiple entries in the database.

Delete Operation: In hierarchical model, quantity information is incorporated into supplier record . Hence the only way to delete shipment (or supplied quantity) is to delete the corresponding supplier record. But such an action will lead to loss of information of the supplier, which is not desired.

For example : Supplier S2 stops supplying 250 quantity of part P1 , then the whole record of S2 has to be deleted under part P1 which may lead to loss of information of supplier . Another problem will arise if we wish to delete a part information and that part happens to be only part supplied by some supplier. In hierarchical model, deletion of parent causes the deletion of child records also and if the child occurrence is the only occurrence in the whole database then the information of child records will also be lost with the deletion of parent. For example: if we wish to delete the information of part P2 then we also lose information of S3, S2 and S1 supplier. The information of S2 and S1 can be obtained from P1, but the information about supplier S3 is lost with the deletion of record of P2.

Record Retrieval: Record retrieval methods for hierarchical model are complex and asymmetric which can be clarified with the following queries:

Query 1: Find the supplier number for suppliers who supply part P2.

Solution: In order to get this information, first we search the information of parent P2 from database, since parent occurs only once in the whole database, so we obtain only a single record for P2 . Then, a loop is constructed to search all suppliers under this part

and supplier numbers are printed for all suppliers.

Algorithm

```
get [next] part where PNO =P2;
do until no more shipments under this part;
get next supplier under this part;
print SNO;
end;
```

Query2: Find part numbers for parts supplied by supplier S2 .

Solution: In order to get required part number we have to search S2 under each part. If supplier S2 is found under a part then the corresponding part number is printed, otherwise we go to next part until all the parts are searched for supplier S2.

Algorithm

```
do until no more parts ;
    get next part;
    get [next] supplier under this part where SNO=S2;
    if found then print PNO;
end;
```

In above algorithm “next” is interpreted relative to the current position (normally the row most recently accessed; for the initial case we assume it to be just prior to the first row of the table). We have placed square brackets around “next” in those statements where we expect at the most one occurrence to satisfy the specified conditions.

9.4 Summary

The Network Data Model (NDM) represents data for any entity set by a logical record type. The data for an instance of the entity set is represented by a record occurrence of the record type. The DBTG model uses two different structures to represent the database entities and relationships between the entities, namely record type and set type. A record type is used to represent an entity type. It is made up of a number of data items that represent the attributes of the entity. A set type is used to represent a directed relationship between two records types, the so called owner record type, and the member record type. In the DBTG model, a data structure diagram consists of two record types and is linked to each other through many-to-one relationships. This structure is referred to as DBTG set. Bachman introduced a graphical means called a data structure diagram to denote the logical relationship implied by a set. Here a labeled rectangle represents the corresponding entity or record type. An arrow that connects two labeled rectangles represents the corresponding entity or record type. The arrow direction is from the owner record type to the member record type.

The hierarchical data model consists of a set of record types. The relationship between two record types is of the parent/child form, expressed using links or pointers. The records thus connected form an ordered tree, the so-called hierarchical definition tree. The hierarchical model provides a straightforward method of implementing a one-to-many relationship. However, a many-to-many relationship between record types cannot be expressed directly in the hierarchical model. Such a relationship can be expressed by using data replication or virtual records.

The disadvantages of data replication are waste of storage space and the problem of maintaining data consistencies. A virtual record is a mechanism to point to an occurrence

of a physical record. Thus, instead of replicating a record occurrence, single record occurrence is stored and virtual record points to this record wherever the record is required.

Comparison of Network and Hierarchical Model

S.No	Hierarchical Data Model	Network Data Model
1	Relationship between records is of the parent child type.	Relationship between records is expressed in the form of pointers or in the forms of links
2	Many to many relationship is not possible to represent in case of hierarchical data model	Many to many relationship can be very easily implemented in case of network data model.
3	It is a simple straight forward and natural method of implementing record relationship	Record relationship implementation is very complex due to the use of pointers.
4	This type of model is useful only when there is some hierarchical character in the database.	Network model is useful for representing such records which have many to many relationships.
5	In order to represent links among records, pointers are used. Thus relations among records are physical.	In network model also the record relations are physical.
6	Searching for a record is very difficult since one can retrieve a child only after going through its parent record.	Searching a record is easy since there are multiple access paths to a data element.
7	Hierarchical model suffers from insert anomaly as we cannot insert the information of a child who does not have any parent.	Network model does not suffer from insert anomaly as we can insert the information of a new supplier by showing a record set pointer to itself.

8	There are multiple occurrences of child records, which lead to problem of inconsistency during the update operation.	Network model is free from update anomalies because there is only a single occurrence for each record set.
9	It is based on parent child relationship and deletion of parent results in deletion of child records also.	It is based on many to many relationship (m:m) which make it free from delete anomalies .
10	Retrieve algorithms in case of hierarchical data model are complex and asymmetric.	Retrieve algorithms in case of network data model are complex and symmetric.

9.5 Questionnaires

1. What are features of Network data model?
2. Write short note on DBTG model.
3. Define DBTG Set, record type, set occurrence, set type, owner record type, and member record type.
4. List down the features of Hierarchical model.
5. Explain the ways of implementing the Hierarchical Data Model.
6. Explain the ways of implementing the Network Data Model.

RELATIONAL DATA MODEL**Introduction****Relational Data Model Concepts****Constraints****Summary****Questionnaires****10.1 Introduction**

The relational data model is an abstract theory of data that is based on certain aspects of mathematics (principally set theory and predicate logic).

The principles of relational model were originally laid down in 1969-70 by Dr. E.F. Codd at that time a member of IBM. Relational model is a way of looking at data. Relational model stores data in the form of tables. A relational model database is defined as a database that allows you to group its data items into one or more independent tables that can be related to one another by using fields common to each related table.

10.2 Relational Data Model Concepts

The relational model is concerned with three aspects of data :

- 1) Structures
- 2) Data integrity
- 3) Manipulation

Structure aspects: The data in the database is perceived by the user as a table. It means database is arranged in the form of tables and collection of tables is called database. Structure means design view of database like data type, its size etc.

Integrity aspect: Those tables that satisfy certain integrity constraints like domain constraints, entity constraints, referential integrity and operational constraints.

Manipulative aspects: The operators available for the user for manipulating those tables into database e.g. for purpose of retrieval of data like projection, join and restrict.

Characteristics of Relational Database

Relational database system have the following characteristics:

- 1) The whole data is conceptually represented as an orderly arrangement of data into rows and columns called a relation or a table.
- 2) All values are scalar. That is, at any given time for each row/column position in the relation there is one and only one value.
- 3) All operations performed on an entire relation and result is an entire relation, a concept known as closure.

Dr Codd when formulating the relational model, chose the term "relation" because it was comparatively free of connotations , unlike, for example, the word "table". It is a common misconception that the relational model is so called because relationships are established between tables. In fact the name is derived from the relations on whom it is

based. Notice that the model requires only that data be conceptually represented as a relation; it does not specify how the data should be physically implemented. A relation is a relation provided that it is arranged in row and column format and its values are scalar. Its existence is completely independent of any physical representation.

Emp_Code	Name	Year
21130	Amar Jain	1
30143	Kuldeep	3
41894	Manoj	2
51207	Rita Bajaj	6

Basic Terminology used in Relational Model

Tuples of a relation

Each row of data is tuple. Actually, each row is n-tuple, but the “n-“ is actually dropped.

Cardinality of a relation

The number of tuples in a relation determines its cardinality. In this case, the relation in above figure has a cardinality of 4.

Degree of a relation

Each column in the tuple is called an attribute. The number of attributes in a relation determines its degree. The relation in above figure has degree 3.

Domains

A domain definition specifies the kind of data represented by the attribute. More particularly, a domain is a set of all possible values that an attribute may validly contain.

Domains are often confused with data types, but this is inaccurate. Data type is a physical concept while domain is a logical one. “Number “ is a data type and “Age” is a domain .

To give another example “Street name” and “Sur name” might both be represented as text fields but they are obviously different kinds of text fields, they belong to different domain.

Domains is also a broader concept than data type in that domain definition includes a more specific description of the valid data. For example, the domain Degree Awarded, which represents the degrees awarded by a university in the database schema, this attribute might be defined as Text[3], but it’s not just any three-character string, it’s a member of the set {BS, BA, MA, MS, PhD, LLB, MD}, of course not all hundred or so values if we are talking about mauseums exhibit. In such instances it’s useful to define the domain in terms of the rules, which can be used to determine the membership of any specific value in the set of all valid values.

For example, Person Age could be defined as “an integer in the range 0 to 120” whereas Exhibit Age (age of any object for exhibition) might simply by “an integer equal to or greater than 0”.

Body of a Relation

The body of the relation consists of an unordered set of zero or more tuples. There are some important concepts here. First the relation is unordered. Record numbers do not apply to relations. Second a relation with 0 tuples still qualifies as a relation. Third, a relation is a set. The items in a set are, by definition uniquely identifiable. Therefore for a

table to qualify as a relation each record must be uniquely identifiable and the table must contain no duplicate constraints.

Keys of a Relation

It is a set of one or more columns whose combined values are unique among all occurrences in a given table. A key is the relational means to specify uniqueness.

10.3 Constraints :

Constraints are used to validate data entered for the specified column(s) namely :

There are two types of constraints

- 1) Table Constraint
- 2) Column Constraint

Table Constraint

If the constraint spans across multiple columns , the user will have to use table level constraints . If the data constraint attached to a specific cell in a table references the contents of another cell in the table , then the user will have to use table level constraints.

Primary Key as table level constraint :

E.g Create table sales_order_details(s_order_no varchar2(6), Product_no varchar2(6),
PRIMARY KEY (s_order_no, product no));

Column Level Constraint

If the constraints are defined with the column definition, it is called as a column level constraint. They are local to a specific column.

Primary Key as a column level constraint

Create table client (client_no varchar2(6) Primary Key...);

Features of Constraint

- 1) NOT NULL CONDITION
- 2) UNIQUENESS
- 3) PRIMARY KEY identification
- 4) FOREIGN KEY
- 5) CHECK the column value against a specified condition

Some important constraints features and their implementation have been discussed below

Primary Key Constraints

A PRIMARY KEY constraint designates a column or combination of columns as the table's primary key. To satisfy a PRIMARY KEY constraint, both the following conditions must be true :

- 1) No primary key value can appear in more than one row in the table.
- 2) No column that is the part of the primary key can contain null value.

A table can have only one primary key.

A primary key column cannot be of data type LONG OR LONG ROW. You cannot designate the same column or combination of columns as both a primary key and a unique key or as both a primary key and a cluster key. However, you can designate the same column or combination of columns as both a primary key and a foreign key.

Defining Primary Keys

You can use the column_constraint syntax to define a primary key on a single column.

Example

The following statement creates the DEPT table and defines and enables a primary key on the DEPTNO column :

```
CREATE TABLE dept
  ( deptno NUMBER (2) CONSTRAINT pk_dept PRIMARY KEY,
    dname VARCHAR2(10));
```

The pk_dept constraint identifies the deptno column as the primary key of the dept table . This constraint ensures that no two departments in the table have the same department number and that no department number is NULL .

Alternatively, you can define and enable this constraint with table constraint syntax :

```
CREATE TABLE dept
  (deptno NUMBER(2),
  dname VARCHAR2(9),
  loc VARCHAR2(10),
  constraint PK_DEPT PRIMARY KEY (deptno));
```

Defining Composite Primary Keys

A composite primary key is a primary key made up of a combination of columns. Because Oracle creates index on the columns of a primary key, a composite primary key can contain a maximum of 16 columns. To define a composite primary key, you must use the table_constraint syntax, rather than the column_constraint syntax.

Example

The following statement defines a composite primary key on the combination of the SHIP_NO and CONTAINER_NO columns of the SHIP_CONT table :

```
ALTER TABLE ship_cont
  ADD PRIMARY KEY(ship_no, container_no) DISABLE
```

This constraint identifies the combination of the SHIP_NO and CONTAINER_NO columns as the primary key of the SHIP_CONTAINER. The constraint ensures that no two rows in the table have the same values for both SHIP_NO column and the CONTAINER_NO column.

The CONSTRAINT clause also specifies the following properties of the constraint .

- 1) Since the constraint definition does include a constraint name, Oracle generates a name for the constraint .
- 2) The DISABLE option causes Oracle to define the constraint but not enforce it.

Referential Integrity Constraints

A referential integrity constraint designates a column or combination of columns as a foreign key and establishes a relationship between that foreign key and a specified primary or unique key, called the referenced key. In this relationship, the table containing the foreign key is called the child table and the table containing the referenced key is called the parent table. Note the following:

- 1) The child and parent tables must be on the same database. They cannot on different nodes of a distributed database.
- 2) The foreign key and the referenced key can be in the same table. In this

case, the parent and child tables are the same.

- 3) To satisfy a referential integrity constraint, each row of the child table must meet one following conditions:
 - a) The value of the row's foreign key must appear as a referenced key value in one of the parent table's rows . The row in the child table is said to depend on the referenced key in the parent table.
 - b) The value of one of the columns that makes up the foreign key must be null.

A referential integrity constraint is defined in the child table. A referential integrity constraint definition can include any of the following key words:

- 1) **Foreign Key** : Identifies the column or combination of columns in the child table that makes up the foreign key . Only use this keyword when you define a foreign key with a table constraint clause.
- 2) **Reference** : Identifies the parent table and the column or the combination of columns that make up the referenced key. If you only identify the parent table and omit the column names, the foreign key automatically references the primary key on the parent table. The corresponding columns of the referenced key and the foreign key must match in number and data types.

On Delete Cascade : Allows deletion of referenced key values in the parent table that have dependent rows in the child table and causes Oracle to automatically delete dependent rows from the child table to maintain referential integrity . If you omit this Option, Oracle forbids deletions or referenced key in the parent table that have dependent rows in the child table.

In the first example, we defined a referential integrity constraint in a CREATE TABLE statement that contains as clause. Instead, you can create the table without the constraint and then add it later with an ALTER TABLE statement.

You can define multiple foreign keys in a table . Also , a single column can be part of more than one foreign key .

Defining Referential Integrity Constraints

You can use column_constraint syntax to define a referential integrity constraint in which the foreign key is made up of a single column .

Example

The following statement creates the EMP table and defines and enables a foreign key on the DEPTNO column that references the primary key on the DDPTNO column of the DEPT table :

```
CREATE TABLE emp
(Empno NUMBER (4) ,
ename VARCHAR2 (10) ,
job VARCHAR2 (9) ,
ngr NUMBER (4) ,
hiredate DATE ,
sl NUMBER (7,2) ,
deptno CONSTRAINT fk_deptno REFERENCES dept (deptno));
```

The constraint FK_DEPTNO ensures that all employees in the EMP table work in a department in the DEPT table. However, employees have null department numbers.

Before you define and enable this constraint you must define and enable a constraint that designates the DEPTNO column of the DEPT table as a primary or unique

key .Note that the referential integrity constraint definition does not use the FOREIGN KEY keyword to identify the columns that make up the foreign key. Because the constraint is defined with a column constraint clause on the DEPTNO column, the foreign key is automatically on the DEPTNO column.

Note that the constraint definition identifies both the parent table and the columns of the referenced key. Because the referenced key is the parent table's primary key, the referenced key column names are optional.

Note that the above statement omits the DEPTNO column's data type. Because this column is a foreign key, Oracle automatically assigns it the data type DEPTNO column to which the foreign key refers.

Alternatively, you can define a referential integrity constraint with table_constraint syntax :

```
CREATE TABLE emp
( empno NUMBER (4) ,
  ename VARCHAR2 (10) ,
  job VARCHAR2(9) ,
  ngr VARCHAR2(9) ,
  Hiredate DATE ,
  SI NUMBER(7,2) ,
  Comm NUMBER(7,2) ,
  Deptno CONSTRAINT fk_deptno FOREIGN KEY
  (deptno) REFERENCES dept(deptno));
```

Note that the foreign key definitions in both the above statements omit the ON DELETE CASCADE option , causing Oracle to forbid the deletion of a department if any employee works in that department .

Now if we take a simple example with following relations based on which we see the various operations in relational model. Relations are

- 1) Supplier records
- 2) Part records
- 3) Shipment records

The Supplier records

SNo	Name	Status	City
S1	Suneet	20	Qadian
S2	Ankit	10	Amritsar
S3	Amit	10	Amritsar

The Part records

PNo	Name	Color	Weight	City
P1	Nut	Red	12	Qadian
P2	Bolt	Green	17	Amritsar
P3	Screw	Blue	17	Jalandhar

P4	Screw	Red	14	Qadian
-----------	--------------	------------	-----------	---------------

The Shipment records

Sno	Pno	Qty
S1	P1	250
S1	P2	300
S1	P3	500
S2	P1	250
S2	P2	500
S3	P2	300

As we discussed earlier , in this context we assume that each row in the Supplier table is identified by a unique SNo (Supplier Number), which uniquely identifies the entire row in the table . Likewise each part has a unique PNo (Part Number) .Also we assume that no more than one shipment exists for a given supplier/part combination in the shipments table .

Note that the relations Parts and Shipments have PNo (Part Number) in common and Supplier and Shipments relations have SNo (Supplier Number) in common. The Supplier and Parts relation have City in common. For example, the fact that supplier S3 and part P2 are located in the same city is represented by the appearance of the same value, Amritsar, in the city column of the two tuples in relations.

Operations in Relational Model

There are four basic operations :

- 1) Insert
- 2) Delete
- 3) Modify
- 4) Retrieve

Insert Operation :

Suppose we wish to insert the information of supplier who does not supply any part, it can be inserted in S table without any anomaly e.g. S4 can be inserted in S table. Similarly, if we wish to insert information of a new part that is not supplied by any supplier, it can be inserted into a P table. If a supplier starts supplying any new part, then this information can be stored in shipment table SP with the supplier number, part number and supplied quantity. So we can say that insert operations can be performed in all the cases without any anomaly.

Modify Operation

Suppose supplier S1 has moved from Qadian to Jalandhar. In that case we need to make changes in the record so that the supplier table is up-to-date. Since supplier number is the primary key in the S table. so there is only a single entry of S1, which needs a single update and problem of data inconsistencies would not arise. Similarly, part and shipment information can be updated by a single modification in the tables P and SP respectively without the problem of inconsistency. Update operation in relational model is very simple and without any anomaly in case of relational model.

Delete Operation:

Suppose if supplier S3 stops the supply of part P2, then we have to delete the shipment connecting part P2 and supplier S3 from shipment table SP. This information can be deleted from SP table without affecting the details of supplier of S3 in supplier

table and part P2 information in part table. Similarly, we can delete the information of parts in P table and their shipments in SP table and we can delete the information of suppliers in S table and their shipments in SP table.

Record Retrieval:

Record retrieval methods for relational model are simple and symmetric which can be clarified with the following queries :

Query 1: Find the supplier numbers for suppliers who supply part P2

In order to get this information we have to search the information of part P2 in the SP table. For this a loop is constructed to find the records of P2 and on getting the records, corresponding supplier numbers are printed.

Algorithm

```
do until no more shipments;
  get next shipment where PNO=P2;
  print SNO;
end;
```

Query 2 : Find part numbers for parts supplied by supplier S2.

In order to get this information we have to search the information of supplier S2 in the SP table. For this a loop is constructed to find the records of S2 and on getting the records corresponding part numbers are printed.

Algorithm

```
do until no more parts ;
  get next shipment where SNO=S2;
  print PNO;
end;
```

Since both the queries involve the same logic and are very simple, so we can conclude that retrieval operation of this model is simple and symmetric.

Structured Query Language (SQL)

Structured query language (SQL) pronounced as “sequel” is the set of commands that all programs and users must use to access data within the database. Application programmers and Oracle tools often allow users to access the database without directly using SQL, but these applications in turn must use SQL when executing the user’s request.

Historically, the paper, “ A Relational Model of Data for Large Shared Data Banks,” by Dr E F Codd, was published in June 1970 in the Association of Computer Machinery (ACM) journal, Communications of the ACM. Codd’s model is now accepted as the definitive model for relational database management systems (RDBMS). The language, Structured English Query Language (SEQUEL) was developed by IBM Corporation, Inc .to use Codd’s model. SEQUEL, later became SQL. In 1979, Relational Software, Inc introduced the first commercially available implementation of SQL. Today, SQL is accepted as the standard RDBMS language. The latest SQL standard published by ANSI and ISO is often called SQL-92 (and sometimes SQL2).

Benefits of SQL

This section describes many of the reasons for SQL’s widespread acceptance by relational

database vendors as well as end users. The strengths of SQL benefit all ranges of users including application programmers, database administrators, and management and end users.

Non-Procedural Language

SQL is a non-procedural language because it :

- 1) Processes sets of records rather than just one at a time ;
- 2) Provides automatic navigation to the data .
- 3) System administrators
- 4) Database administrators
- 5) Security administrators
- 6) Application programmers
- 7) Decision support system personnel
- 8) Many other types of end users

Unified Language

SQL provides commands for a variety of tasks including :

1. Querying data;
2. Inserting, updating and deleting rows in a table ;
3. Creating ,replacing , altering and dropping objects ;
4. Controlling access to the database and its object ;
5. Guaranteeing database consistency and language .

SQL unifies all the above tasks in one consistent language .

Common Language for all Relational Databases

Because all major relational database management systems support SQL, you can transfer all skills you have gained with SQL from one database to another. In addition, since all programmes written in SQL are portable, they can often be moved from one database to another with very little modification.

Embedded SQL

Embedded SQL refers to the use of standard SQL commands embedded within a procedural programming language. Embedded SQL is a collection of these commands:

All SQL commands, such as SELECT and INSERT, available with SQL with interactive tools;

Flow control commands, such as PREPARE and OPEN, which integrate the standard SQL, commands with a procedural programming language.

The Oracle precompilers support embedded SQL. The Oracle precompilers interpret embedded SQL statements and translate them into statements that can be understood by procedural language compilers. Each of these Oracle precompilers translate embedded SQL programmes into a different procedural language:

- The Pro *Ada precompiler
- The Pro *C/C++ Precompiler
- The Pro * COBOL precompiler
- The Pro * FORTRAN precompiler
- The Pro * Pascal precompiler
- The Pro * PL/I precompiler

Database Objects :

Oracle supports two types of data objects .

Schema Objects : A schema is a collection of logical structures of data, of schema objects. A schema is owned by a database user and has the same name as the user. Each user owns a single schema. Schema objects can be created and manipulated with SQL and include the following types of objects.

Cluster triggers	database links	database
Indexes sequences		Packaged
Snapshots functions	snapshot logs	shared
Stored procedures	synonyms	tables
Views		

Non-schema Objects : Other types of objects are also stored in the database and can be created and manipulated with SQL , but are not contained in a schema .

Profiles	Rates
Rollback segments	table spaces
Users	

Objects Naming Conventions

The following rules apply when naming objects :

- 1) Names must be from 1 to 30 characters long with the following exceptions :
- 2) Names of database are limited to 8 characters. Names of database links can be as long as 128 characters.
- 3) Names cannot contain quotation marks.
- 4) Names are not case sensitive.
- 5) A name must begin with an alphabetic character from your database character set unless surrounded by double quotation marks.
- 6) Names can only contain alphanumeric characters from your database character set and the character _, \$ and #. You are strongly discouraged from using \$ and #.
- 7) If your database character set contains multi-byte characters, it is recommended that each name for a user or a role contain at least one single-byte character.
- 8) Names of databases links can also contain periods (.) and ampersand &.
- 9) Columns in the same table or view cannot have the same name. However, column in different tables or views can have the same name.
- 10) Procedures or functions contained in the same package can have the same name, provided that their arguments are not of the same number and data types.

Creating multiple procedures or functions with the same name in the same package with different arguments is called overloading the procedure or function.

Objects Naming Guidelines

There are several helpful guidelines for naming objects and their parts :

- 1) Use full, descriptive, pronounceable names (or well-known abbreviations).
- 2) Use consistent naming rules.
- 3) Use the same name to describe the same entity or attributes across tables.
- 4) When naming objects, balance the objective of keeping names short and easy to use with the objective of making names as long and descriptive as possible. When in doubt, choose the more descriptive name because many people may use the objects in the database over a period of time. Your counterpart ten years from now may have difficulty understanding a database with names like PMDD instead of PAYMENT_DUE_DATE.
- 5) Using consistent naming rules helps understand the part plays in your application. One such rule might be to begin the names of all tables belonging to the FINANCE application with FIN_.
- 6) Use the same names to describe the same things across tables. For examples, the department number columns of the EMP and DEPT tables should be named DEPTNO.

Advantages and Disadvantages of Relational Model

The major advantages of the relational model are :

Structural independence

In relational model changes in the database structure do not affect the data access. When it is possible to make change to the database structure without affecting the DBMS's capability to access data, we can say that structural independence has been achieved. So, relational database model has structural independence.

Conceptual simplicity:

We have seen that both the hierarchical and the network database models were conceptually simple. But the relational database model is even simpler at the conceptual level. Since the relational data model frees the designer from the physical data storage details, the designers can concentrate on the logical view of the database.

Design, implementation, maintenance and usage case:

The relational database model achieves both data independence and structure independence making the database design, maintenance, administration and usage much easier than the other models.

Ad hoc query capability:

The presence of very powerful, flexible and easy-to-use query capability is one of the main reasons for the immense popularity of the relational database model. The query language of the relational database models structured query language or SQL makes ad hoc queries a reality. SQL is a fourth generation language. A 4GL allows the user to specify what must be done without specifying how it must be done. So, using SQL the users can specify what information they want and leave the details of how get the information to the database.

Disadvantages of Relational Model

The relational model's disadvantages are very minor as compared to the advantages and their capabilities far outweigh the shortcomings . Also the drawbacks of the relational

database systems could be avoided if proper corrective measures are taken. The drawbacks are not because of the shortcomings in the database model, but the way it is being implemented.

Some of the disadvantages are :

Hardware overheads:

Relational database system hides the implementation complexities and the physical data storage details from the users. For doing this, for making things easier for the users, the relational database systems need more powerful hardware computers and data storage devices. So the RDBMS needs powerful machines to run smoothly. But as the processing power of modern computers is increasing at an exponential rate and in today's scenario, the need for more processing is no longer a very big issue.

Ease of design can lead to bad design

The relational database is an easy to design and use. The users need not know the complex details of physical data storage. They need not know how the data is actually stored to access it. This ease of design and use can lead to the development and implementation of very poorly designed databases. Since the database is efficient, these design inefficiencies will not come to light when the database is designed and when there is only a small amount of data. As the database grows, the poorly designed databases will slow the system down and will result in performance degradation and data corruption.

Information island phenomenon

As we have said before, the relational database systems are easy to implement and use. This will create a situation where too many people or departments will create their own databases and applications.

These information islands will prevent the information integration that is essential for the smooth and efficient functioning of the organization. These individual databases will also create problems like data inconsistency, data duplication, data redundancy and so on.

But as we have said all these issues are minor when compared to the advantages and all these issues could be avoided if the organization has a properly designed database and has enforced good database standards.

10.4 Summary

The relational data model was first introduced by Dr. E.F. Codd, an Oxford trained mathematician while working in IBM Research Center in 1970's. He represented this idea in a classic paper and attracted immediate attention due to its simplicity and mathematical foundations. It also drew immediate attention of the computing industry because of its simple way in which it represented information by well understood convention of tables of values as its building block. The relational model is considered one of the most popular developments in the database technology because it can be used for representing most of the real world objects and the relationships between them.

10.5 Questionnaires

- Q1. Explain the various concepts of relational data model.
- Q2. Explain the various constraints in relational data model.