Database Management Systems (25CS305)

UNIT– I

Introduction to Database and System Architecture:
Database Systems and their Applications, Database Vs File System, View of Data, Data Models, Database users and Administrator, Database System Structure.
Introduction to Database Design: ER Diagrams, Attributes, Entities and Entity sets, Relationships and Relationship sets, Extended ER Features, Conceptual Design with the ER Model, Logical database Design.

INTRODUCTION

Data: Data is a piece of information. Data can exist in a variety of forms:

- As numbers or text on pieces of paper
- As bits and bytes stored in computer memory
- As facts stored in a person's mind.

Data is raw information and it does not give correct meaning. The processed data becomes Information and it gives correct meaning.

Database: Database is a collection of inter-related data which is used to retrieve, insert, delete and manipulate the data efficiently.

Database Management System (DBMS): The software which is used to manage database is called Database Management System (DBMS).

Examples of popular DBMS:

- MySql
- Oracle
- Microsoft Access
- IBMDB2

DATA BASE SYSTEM APPLICATIONS

We use Database Management Systems in almost all application sectors. They are:

1. **Telecom**: A database is required to keep track of the information regarding calls history, network usage, customer details, generating monthly bills, maintaining balances on prepaid calling cards etc. Without the database systems it is hard to maintain that huge amount of data that keeps updating every millisecond. Ex: Airtel, IDEA, Jio, etc
2. **Banking System**: A database stores bank customer's information, maintain day to day credit and debit transactions, generate bank statements etc. Ex: SBI, HDFC, etc
3. **Online shopping**: The online shopping websites store the product information, your addresses and preferences, credit details and provide you the relevant list of products based on your query. Ex: Amazon, Flipkart etc.
4. **Airlines**: Passenger details, reservation in formation along with flight schedule is stored in database. Eg: Air India, Indigo, etc
5. **Education sector**: Database systems are used in schools, colleges and universities to store and retrieve the data regarding student details, staff details, course details, exam details, attendance details, fees details etc. Ex: JNTUH, IITB, etc
6. **Sales**: To store customer information, stock details and invoice details a database is needed. Ex: Reliance Fresh, D-Mart etc.
7. **Human resources:** For information about employees, salaries, payroll taxes, and benefits and for generation of paychecks a database is required.
8. **Credit card transactions:** For purchases on credit cards and generation of monthly statements.
9. **Stock market:** For storing information about holdings, sales, and purchases of stocks; also for storing real-time market data to enable online trading.

DIFFERENCE BETWEEN FILE SYSTEM AND DBMS

	File System	DBMS
Definition	A file system is a software that manages the data files in a computer	DBMS is a software used to create and manage databases.
Operations	Operations such as storing, retrieving and searching are done manually in a file system. Therefore, it is difficult to manage data.	Operations such as storing, retrieving and searching data is easier in DBMS because it allows using SQL query language.
Data Consistency	Data Inconsistency is more in file system.	Data Inconsistency is less in DBMS.
Data Redundancy	Data Redundancy is more in file system.	Data Redundancy is less in a DBMS.
Backup and Recovery Process	Backup and recovery process is not efficient in files system.	DBMS has a sophisticated backup and recovery techniques.
Concurrent access	Concurrent access to the data in the file system has many problems	DBMS takes care of Concurrent access using some form of locking.
Physical address	User can locates the physical address of the files to access data in File System.	In DBMS, user is unaware of physical address where data is stored.
Security	File system provides less security to the data as compared to DBMS.	DBMS provides more security to the data.
Example	FAT, NTFS and Ext are some examples of file systems.	MySQL, MS-Access, Oracle, and DB2 are some examples of DBMS.

View of Data: It means how users see and interact with the data stored in a database without knowing how the data is physically stored.

Need for Data Abstraction

Database systems are complex because they contain huge amounts of data. To simplify user interaction, DBMS hides unnecessary details from users.

Advantages

- Reduces complexity
- Improves security
- Provides data independence
- Easy maintenance
- Multiple users can access data according to their needs

Three Levels of Data Abstraction

1. Physical Level (Internal Level)
This is the lowest level of abstraction. It describes how data is actually stored in storage devices such as hard disks and SSDs.

2.Logical Level (Conceptual Level)
This is the middle level of abstraction. It describes what data is stored in the database and the relationships among data.

3. View Level (External Level)
This is the highest level of abstraction. It describes only the part of the database required by a particular use

View Level (External Level)

↑

|

Logical Level(Conceptual Level)

↑

|

Physical Level(Internal Level)

DBMS DATABASE MODELS

A Database model defines the logical design and structure of a database. It explains how data will be stored, accessed and updated in a DBMS. The different DBMS data models are:

- Network Model
- Hierarchical Model
- Entity-relationship Model
- Relational Model
- Object oriented data model

Network Data Model

Network model has the entities which are organized in a graphical representation and some entities in the graph can be accessed through several paths. The data in this model is represented as collection of records and the relationship among data are represented by links.

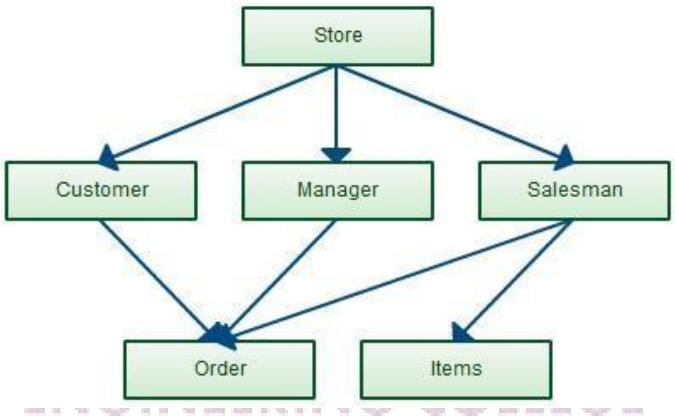


Figure: Network Model

Hierarchical Model

Hierarchical database model organizes data into a tree-like-structure, with a single root, to which all the other data is linked. In this model, a child node will only have a single parent node.

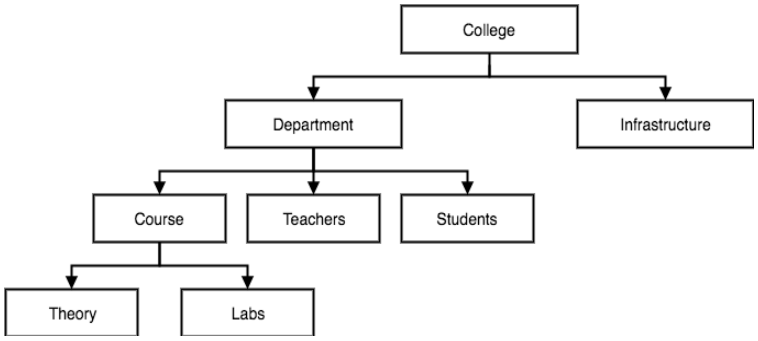
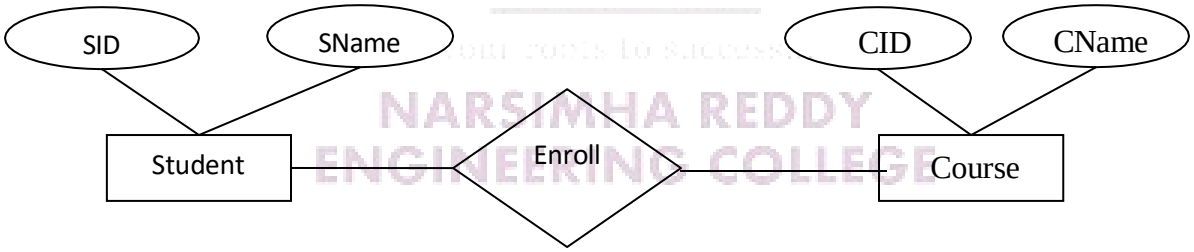


Figure: Hierarchical Data Model

Entity-Relationship Model

Entity-Relationship (ER) Model is based on the notion of real-world entities and relationships among them. ER Model is best used for the conceptual design of a database. While formulating real-world scenario into the database model, it depend on two important things. They are:

- Entity and their attributes
- Relationships among entities



Relational Model

The most popular data model in DBMS is the Relational Model. The relational model contains a set of tables (relations). Each table has a specified number of columns but can have any number of rows.

Admission No	Name	Age	Class
1001	Ram	15	9
1002	Ajay	14	9
1003	Jhon	14	9
1004	Akbar	15	10

Object oriented Data Model

Object oriented data model defines a database as a collection of objects with associated attributes and methods. This model can in corporates multimedia, such as images, audio, video. The object-oriented database model is the best known post-relational database model, since it incorporates tables, but isn't limited to tables. Such models are also known as hybrid database models.

Database users

Database Users and User Interfaces There are four different types of database-system users, differentiated by the way they expect to interact with the system. Different types of user interfaces have been designed for the different types of users.

Naive Users are unsophisticated users who interact with the system by invoking one of the application programs that have been written previously. For example, a clerk in the university who needs to add a new instructor to department A invokes a program called new hire. This program asks the clerk for the name of the new instructor, her new ID, the name of the department (that is, A), and the salary. The typical user interface for naive users is a forms interface, where the user can fill in appropriate fields of the form. Naive users may also simply read reports generated from the database. As another example, consider a student, who during class registration period, wishes to register for a class by using a Web interface. Such a user connects to a Web application program that runs at a Web server. The application first verifies the identity of the user, and allows her to access a form where she enters the desired information. The form information is sent back to the Web application at the server, which then determines if there is room in the class (by retrieving information from the database) and if so adds the student information to the class roster in the database.

Application programmers are computer professionals who write application programs. Application programmers can choose from many tools to develop user interfaces. Rapid application development (RAD) tools are tools that enable an application programmer to construct forms and reports with minimal programming effort.

Sophisticated users interact with the system without writing programs. Instead, they form their requests either using a database query language or by Apago PDF Enhancer using tools such as data analysis software. Analysts who submit queries to explore data in the database fall in this category

Specialized users are sophisticated users who write specialized database applications that do not fit into the traditional data-processing framework. Among these applications are computer-aided design systems, knowledge base and expert systems, systems that store data with complex data types (for example, graphics data and audio data), and environment- modelling systems.

Database Administrators: One of the main reasons for using DBMSs is to have central control of both the data and the programs that access those data. A person who has such central control over the system is called a database administrator (DBA).

The functions of a DBA include:

• Schema definition. The DBA creates the original database schema by executing a set of data definition.

statements in the DDL Storage structure and access-method definition.

• Schema and physical-organization modification. The DBA carries out changes to the schema and physical organization to reflect the changing needs of the organization, or to alter the physical organization to improve

Performance.

STRUCTURE OF A DBMS

The DBMS accepts SQL commands generated from a variety of user interfaces such as web forms, applications, SQL interface and etc. When a user issues a query, the parsed query is presented to a query optimizer, which uses information about how the data is stored to produce an efficient execution plan for evaluating the query. An execution plan is a blueprint for evaluating a query. It executes these plans against the database, and returns the answers to the user.

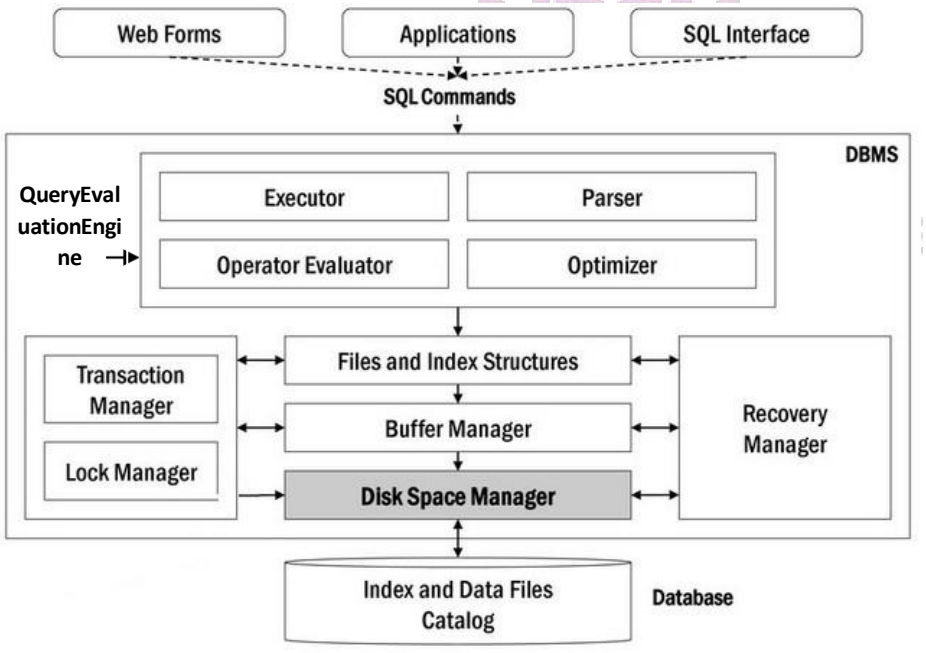


Figure:DBMSStructure

- DBMS consists of a **Query Evaluation engine** which accepts commands from the front end applications like web forms, SQL interfaces and evaluates the query to retrieve the requested data.
- **Query Evaluation engine** consists of the following components
    - **Parser:** It parses the received SQL commands.
    - **Operator evaluator:** It evaluates the operators used in the query.
    - **Plan executor:** It designs a plan to obtain the result.
    - **Optimizer:** It optimizes the query to improve the process of retrieving the result ant data.
- **File and access methods:** It is responsible for the abstraction of file structures stored and for creating indexes on the files for faster access.
- **Buffer Manager:** The purpose of buffer manager is to move pages in and out from a disk to main memory.
- **Disk-Space Manager:** It manages space on the disk by providing empty space for new requests, deleting space allocated for existing files which are deleted by the user.
- **Transaction Manager and lock manager:** It is responsible for maintaining concurrency of the data, when accessed by multiple users.

  Recovery manager: It is responsible for maintaining log files and supports crash recovery. When a system crashes recovery manager is responsible for bringing the system to a safe state.

INTRODUCTION TO DATABASE DESIGN

The database design process can be divided into six steps.

i. **Requirements Analysis:** The very first step in designing a database application is to gather information from different stake holders such as management, employees and end users. The development team conducts discussions with different user groups, study the current operating environment, analyze any available documentation on existing applications and gather all of the types of information that to be recorded in the database. The gathered information is documented properly.

ii. **Conceptual Database Design:** The information gathered in the requirements analysis step is used to develop Entity Relationship (ER) model. The ER model facilitates discussion among all the people involved in the design process, even those who have no technical background.

iii. **Logical Database Design:** The task in this stage is to convert the ER model into relational schemas. Each entity and each relationship is converted into a relation or a table.

iv. **Schema Refinement:** The fourth step in database design is to analyze the collection of relations in our relational database schema to identify potential problems, and to refine it. This process is called normalization.

v. **Physical Database Design:** In this step, the database design is refined to ensure that it meets desired performance criteria and satisfies the expected workload. This step may simply involve building indexes on some tables and clustering some tables, or it may involve a substantial redesign of parts of the database schema obtained from the earlier design steps.

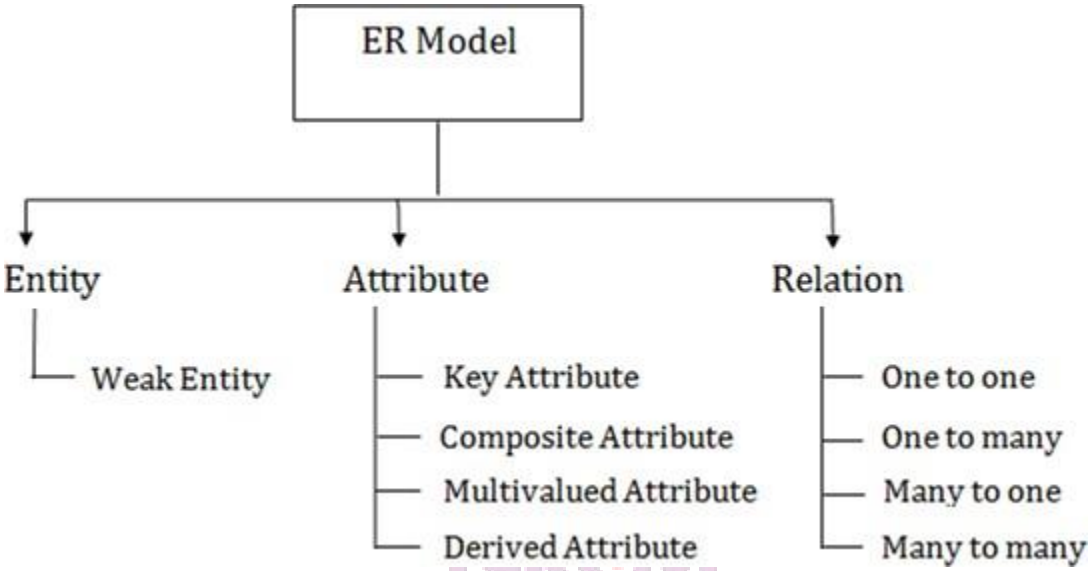
vi. **Application and Security Design:** Foreachrole(manager/accountant/clerk),some part of the database is accessible and other part of the database is not accessible. The software developer should enforce these accessing rules while developing the applications (using application languages like java) to access data using DBMS.

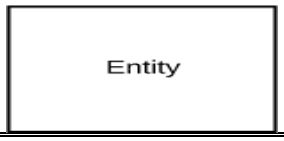
Realistically, all above six design steps are repeated until the design is satisfactory to complete database design.

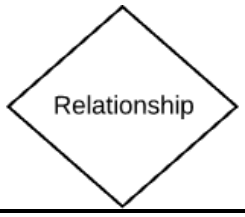
ER DIAGRAMS

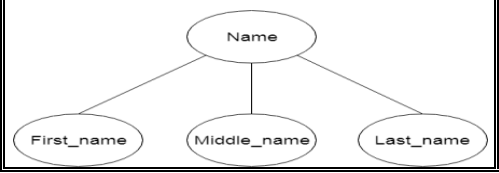
An *entity-relationship (ER) diagram* is a graphical representation of entities and their relationships to each other, typically used to the organization of data within databases. An *entity- relationship (ER) diagram* is also called as an *entity relationship model.*

Component of ER Diagram



Symbol	Name	Description
	Entity / Strong entity	An entity may be any object, class, person or place.
	Weak entity	Weak entities depend on some other entity type. They don't have primary keys, and have no meaning in the diagram without their parent entity.

	Relationship	Relationships are associations between or among entities.

Symbol	Name	Description
	Weak relationship	Weak Relationships are connections between a weak entity and its owner.
	Attribute	Attributes are characteristics of an entity. The attribute is used to describe the property of an entity.
	Key Attribute	A *key attribute* is the unique characteristic of the entity. It represents a primary key.
	Multi valued attribute	Multi valued attributes are those that are can take on more than one value.
	Derived attribute	Derived attributes are attributes whose value can be calculated from other attribute values.
	Composite attribute	An attribute that composed of many other attributes is known as a composite attribute.

Types of relationship areas follows:

The ***cardinality*** of a relationship is the number of instances of entity B that can be associated with entity A. Based on the cardinality; the relationships are classified into four types. They are:

a. One-to-One Relationship: When only one instance of an entity is associated with the relationship, then it is known as one to one relationship.

Example: A female can marry to one male, and a male can marry to one female.

b. One-to-many relationship: When only one instance of the entity on the left, and more than one instance of an entity on the right associates with the relationship then this is known as a one-to-many relationship.

Example: Scientist can invent many inventions, but the invention is done by the only specific scientist.

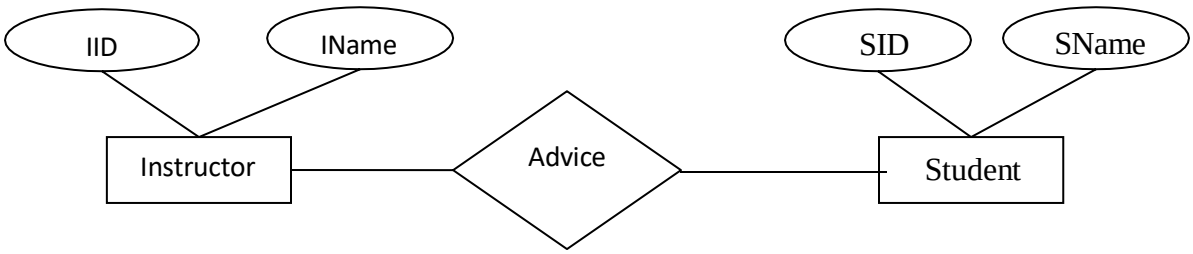
c. Many-to-one relationship: When more than one instance of the entity on the left, and only one instance of an entity on the right associates with the relationship then it is known as a many- to-one relationship.

Example: Student enrolls for only one course, but a course can have many students.

d. Many-to-many relationship: When more than one instance of the entity on the left, and more than one instance of an entity on the right associates with the relationship then it is known as a many-to-many relationship.

Example: Employee can assign by many projects and project can have many employees.

Entity Set and Relationship Set



Entity Set: An *Entity set* is a *set* of *entities* of the same type that share the same properties.

The above diagram contains two entities; *Instructor* and *Student*. In the below figure, *Instructor* entity contains six different instructor values (rows) called as *Instructor entity* set and *Student* entity contain seven different student values (rows) called as *Student entity set*.

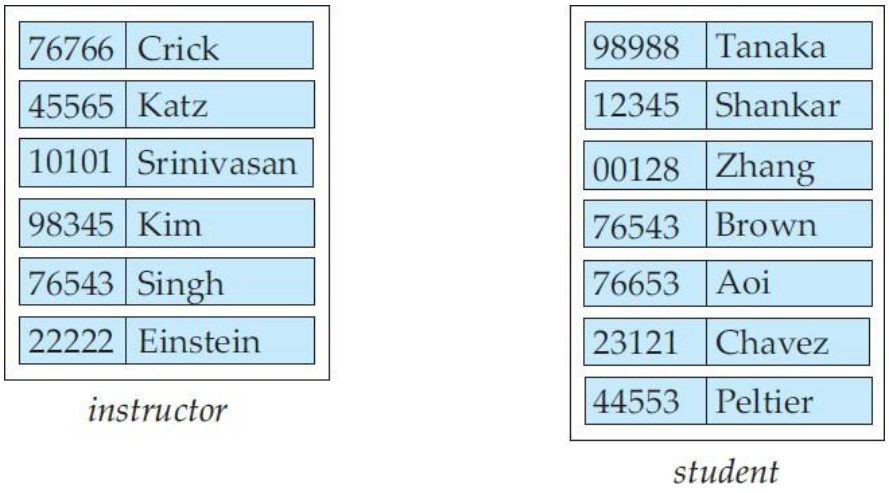


Figure: Entity set Instructor and Student

Relationship Set: A *relationship set* is a *set* of *relationships* of the same type. In the below figure one instructor can advice many students but every student is advised by only one instructor. This relationship is called as many-to-one relationship.

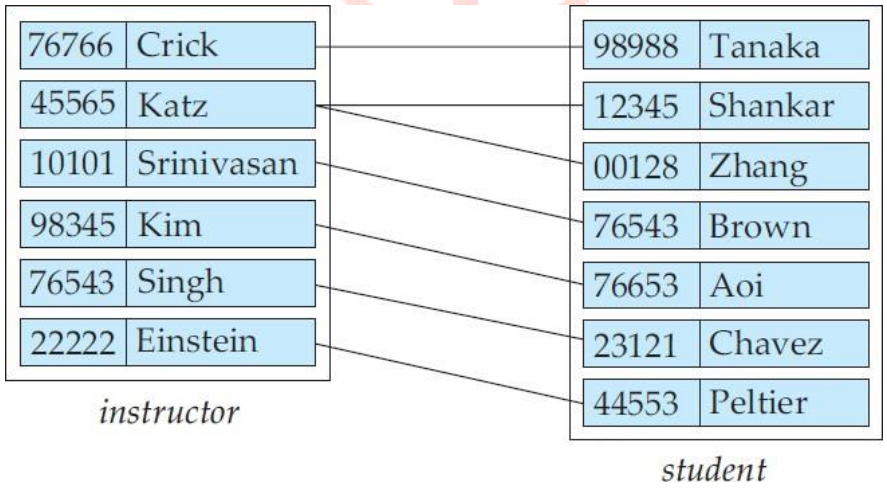


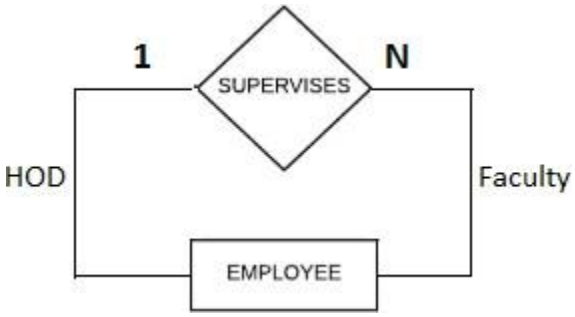
Figure: Relationship set advisor

ADDITIONAL FEATURES OF THE ER MODEL

N-**array relationship**

In an n-ary relationship, then shows the number of entities in the relationship. It can be anything but the most popular relationships are unary, binary and ternary relationship.

Unary Relationship: When there is a relationship between two entities of the same type, it is known as a unary or recursive relationship. This means that the relationship is between different instances of the same entity type.

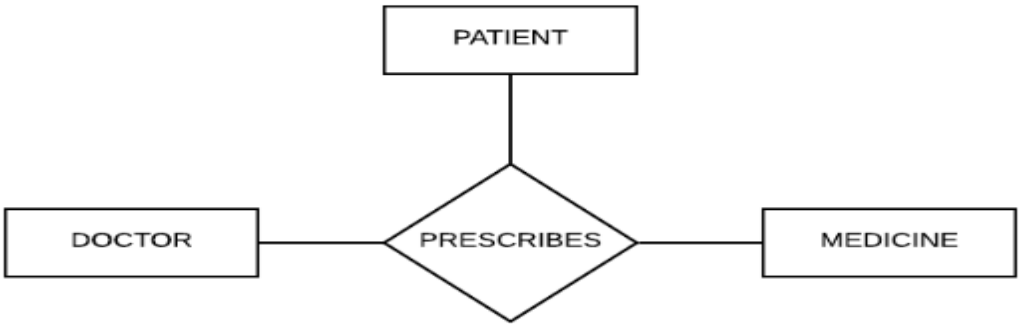


For example, an employee can supervise multiple employees. The role of one employee is HOD and the role and other employees is faculty. That is, one HOD supervises many faculties.

Binary Relationship: When there is a relationship between two different entities, it is known as a binary relationship.

Each employee only has a single ID card. Hence this is a one to one binary relationship where 1 employee has 1 ID card.

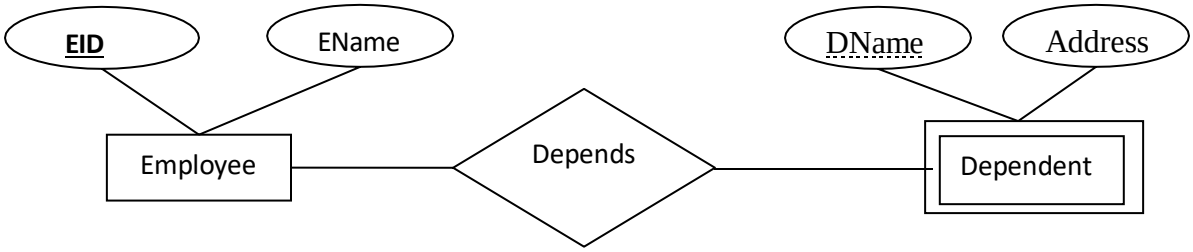
Ternary Relationship: When there is a relationship between three different entities, it is known as a ternary relationship. An example of a ternary relationship can be shown as follows:



In this example, there is a ternary relationship between Doctor, Patient and Medicine.

Weak Entity

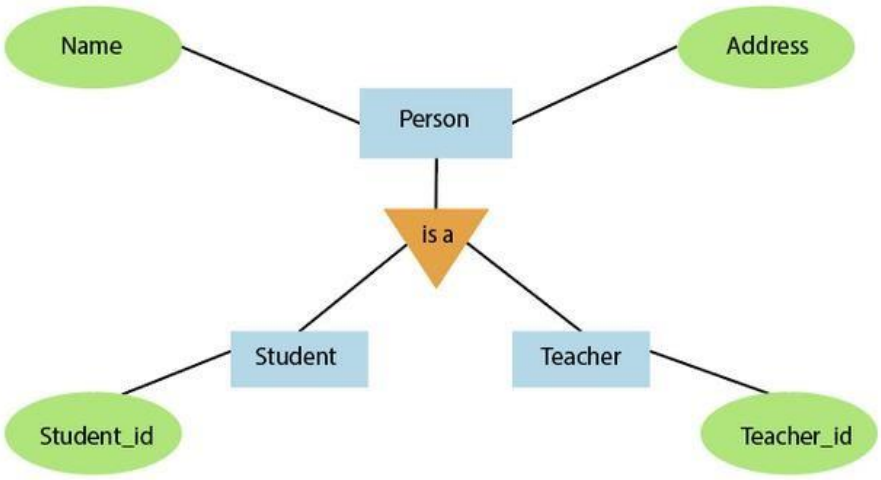
A **Weak entity** is the one that depends on its owner entity for its existence. A weak entity is denoted by the **double rectangle**. Weak entity does **not** have the **primary key**. The **primary key of a weak entity** is a composite key formed from the **primary key of the strong entity** and **partial key of the weak entity**.



There can be an employee without a dependent in the Company but there will be no record of the Dependent in the company systems without any association with an Employee.

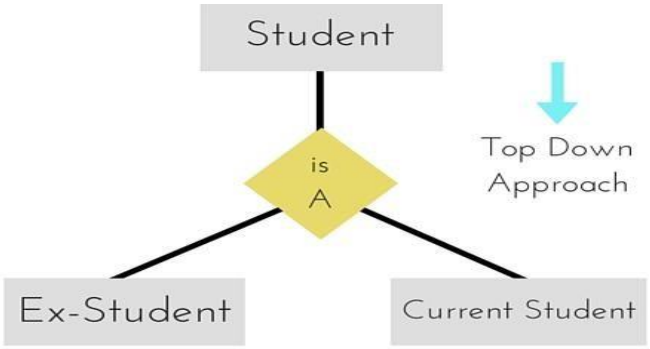
Generalization

Generalization is a bottom-up approach in which two or more lower-level entities combines to form a new higher-level entity. In generalization, the generalized entity of higher level can also combinewithentitiesofthelower-leveltomakefurtherhigher-levelentity. It is like a super class and subclass system, but the only difference is that it uses the bottom-up approach. In this process, the common attributes of two or more lower level entities are given to higher level entity



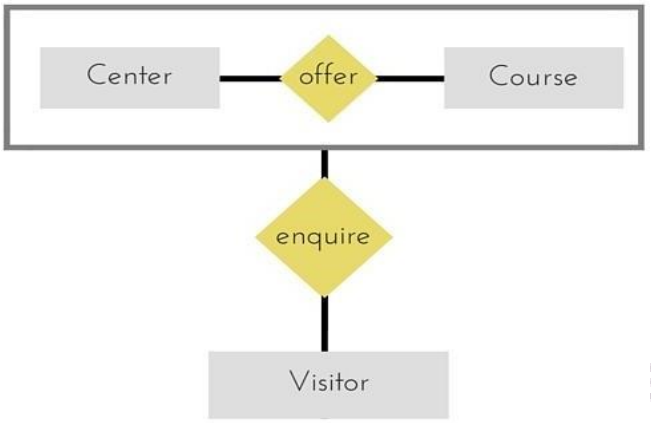
Specialization

Specialization is opposite to Generalization. It is a top-down approach in which one higher level entity can be broken down into two or more lower level entity.



Aggregation

Aggregation is a process when relation between two entities is treated as a **single entity**.



In the diagram above, the relationship between **Center** and **Course** together, is acting as an Entity, which is in relationship with another entity **Visitor**. Now in real world, if a Visitor or a Student visits a Coaching Center, he/she will never enquire about the center only or just about the course, rather he/she will ask enquire about both.

CONCEPTUAL DESIGN WITH THE ER MODEL

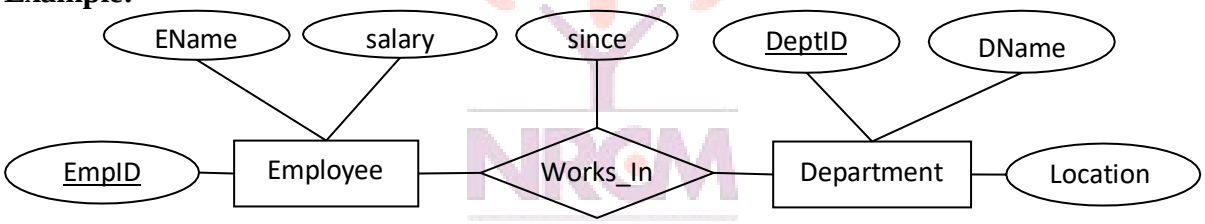
The document prepared in the requirement analysis phase is used to generate ER Model by following below six steps:

- **Find the entities:** Look for general nouns in requirement specification document which are of business interest to business users.
- **Identify relevant attributes:** Identify all attributes related to each entity.
- **Find the key attributes for every entity:** Identify the attribute or set of attributes which can identify each entity instance uniquely.
- **Find the relationships:** Identify the natural relationship and their cardinalities between all possible combinations of the entities.
- **Complete E-R diagram:** Draw E-R diagram along with all attributes and entities.
- **Review your results with your business users:** Show the completed ER diagram to your business user and make necessary changes.

1. LOGICAL DATABASE DESIGN

1. Each entity in the ER model will become a table and all attributes of that entity will become columns of the table. Key attribute of the entity will become primary key in the table.

Example:



Employee

EmpID	EName	salary

Department

DeptID	DName	Location

```
CREATE TABLE
 Employee (
     EmpID
     NUMBER(3),
     EName
     VARCHAR(20),
     Salary  NUMBER(5),
     PRIMARYKEY(Em
     pID)
);
```

```
CREATE TABLE
 Department (
     DeptID
     NUMBER(3),
     DName
     VARCHAR(15),
     Location
     VARCHAR(15),
     PRIMARYKEY(Dept
     ID)
);
```

2. Each relationship in the ER model will become a table. Key attributes of participating entities in the relationship will become columns of the table. If the relationship has any attributes, then

they also will become columns of the table.

Example: From the above ER diagram, the Works_In relationship converted as

Employee

EmpID	EName	Salary

Department

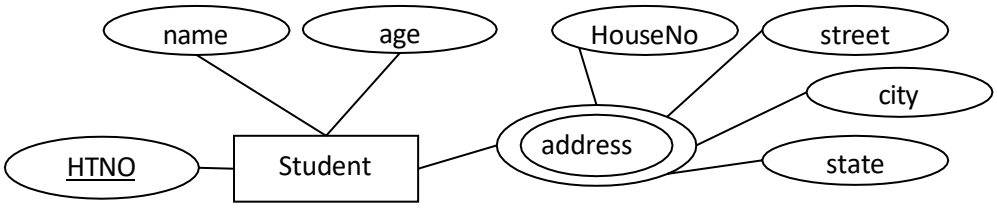
DeptID	DName	Location

Works_In

EmpID	DeptID	since

```
CREATE TABLE
 Works_In (
    EmpIDNUMBER
    (3),
    DeptIDNUMBER
    (3),
    Since   DATE,
    PRIMARYKEY(EmpID, DeptID),
    FOREIGNKEY(EmpID) REFERENCES Employee(EmpID),
    FOREIGNKEY(DeptID) REFERENCES Department(DeptID),
);
```

3. Any multi-valued attribute is converted into new table. The primary key of the entity will be added as column in the new table.



Student

HTNO	name	age

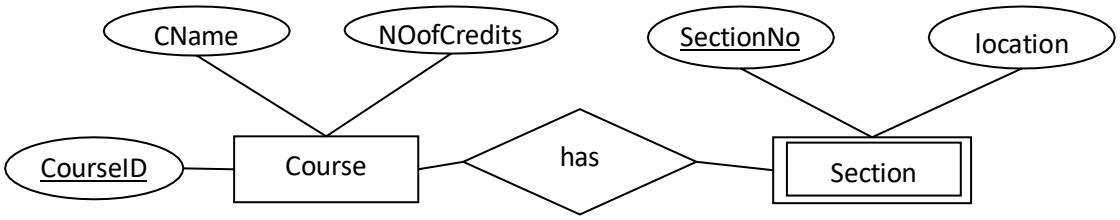
Address

HTNO	houseNo	street	city	state

```
CREATE TABLE
    Student (
        HTNOCHAR(10),na
        me
                VARCHAR(2
        0), age
        NUMBER(2),
        PRIMARYKEY(HT
        NO)
    );
```

```
CREATE TABLE
 Address (
        HTNOCHAR(10),
        houseNo
        NUMBER(3), street
                VARCHAR(20
        ),
        cityVARCHAR(15),
        state
                VARCHAR(15
        ),
        PRIMARYKEY(HT
        NO),
        FOREIGNKEY(HTNO)REFERENCES Student(HTNO),
);
```


4. Each weak entity is converted into a table with all its attributes as columns and primary key of the strong entity acts as a foreign key in this table.



Course

CourseID	CName	NOofCredits

Section

CourseID	SectionNo	location

```
CREATE TABLE Course (
        Course ID NUMBER(2), CName      VARCHAR(20),
        NO  of Credits NUMBER(2), PRIMARYKEY(CourseID)
);
```

```
CREATE TABLE Section (
  Section No CHAR (2), Course ID NUMBER (2),
  location   VAR CHAR (15),
  PRIMARY KEY (Course ID, Section No),
FOREIGNKEY(CourseID)REFERENCES Course(CourseId)
);
CREATE TABLE Section (
  Section No CHAR (2), Course ID NUMBER (2),
  location   VAR CHAR (15),
  PRIMARY KEY (Course ID, SectionNo),
FOREIGNKEY(CourseID)REFERENCES Course(CourseId)
```

PROBLEM: UNIVERSITY CASE STUDY

A University has many departments. Each department has a name and location. Each department has multiple instructors; one among them is the head of the department. Every instructor has a name, mobile number and room number. An instructor belongs to only one department. Each department offers multiple courses, each of which is taught by a single instructor. Each course has unique course number, name, duration and pre-requisite course. A student may enroll for many courses offered by different departments. Every student has a ID, name and date of birth.

SOLUTION

Step1: Identify the Entities

1. DEPARTMENT
2. COURSE
3. INSTRUCTOR
4. STUDENT

Step 2: Identify all relevant attributes

1. For the "Department" entity, the relevant attribute are "Department Name "is" Location".
2. For the "Course" entity, the relevant attributes are "Course Number" are "Course Name", "Duration" and "Pre Requisite".
3. For the "Instructor" entity, the relevant attributes are" Instructor Name "are" Room Number" and "Telephone Number".
4. For the "Student" entity, the relevant attributes are "Student Number" are "Student Name" and "Date of Birth".

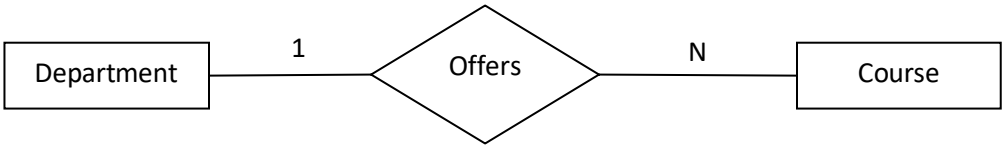
Step3: Identify the key attributes

1. DName (Department Name) which identifies the department uniquely will be the key attribute for "DEPARTMENT" entity.
2. STUDENT# (Student Number) which identifies the student entity uniquely will be the key attribute for "STUDENT" entity.
3. IName(Instructor Name)is the key attribute for "INSTRUCTOR" entity.
4. COURSE#(Course Number)is the key attribute for COURSE entity.

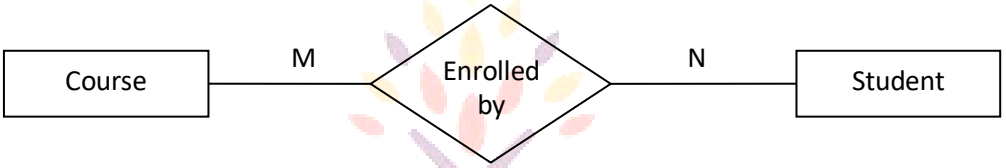
STEP4: Find relationships.

We can derive the following relationships:

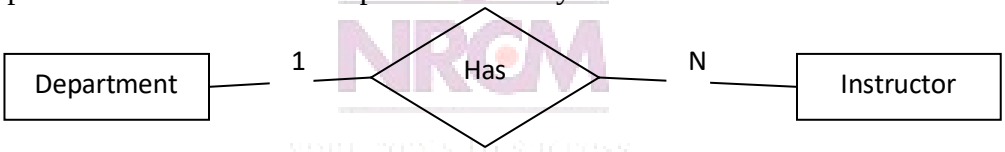
1. The department offers multiple courses and each course belongs to only one department. So the cardinality between department and course is one to many.



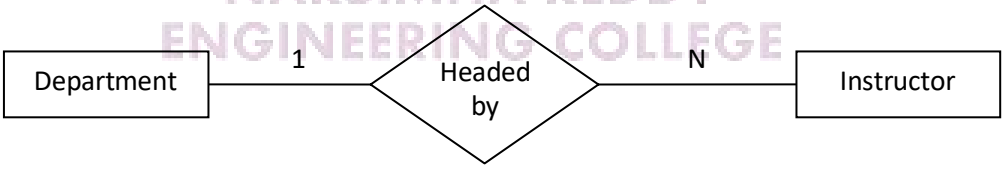
2. Onecourseisenrolledbymultiplestudentsandalsoonestudentenrollsformultiple courses. So the relationship is many to many.



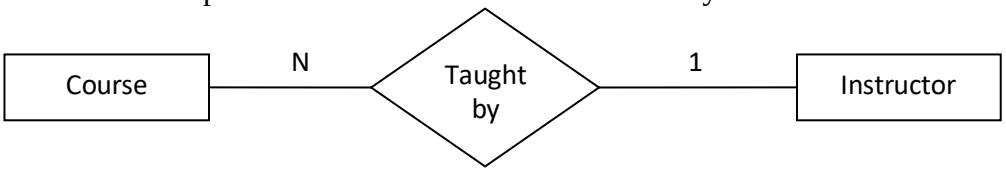
3. One department has multiple instructors and also one instructor belongs to one and only one department. So the relationship is one to many.



4. Each department has one "Head of Department" and one Instructor is Department" for only one department, hence the relationship is one to one.



5. One course is taught by only one instructor but one instructor teaches many courses, hence the relationship between course and instructor is many to one.

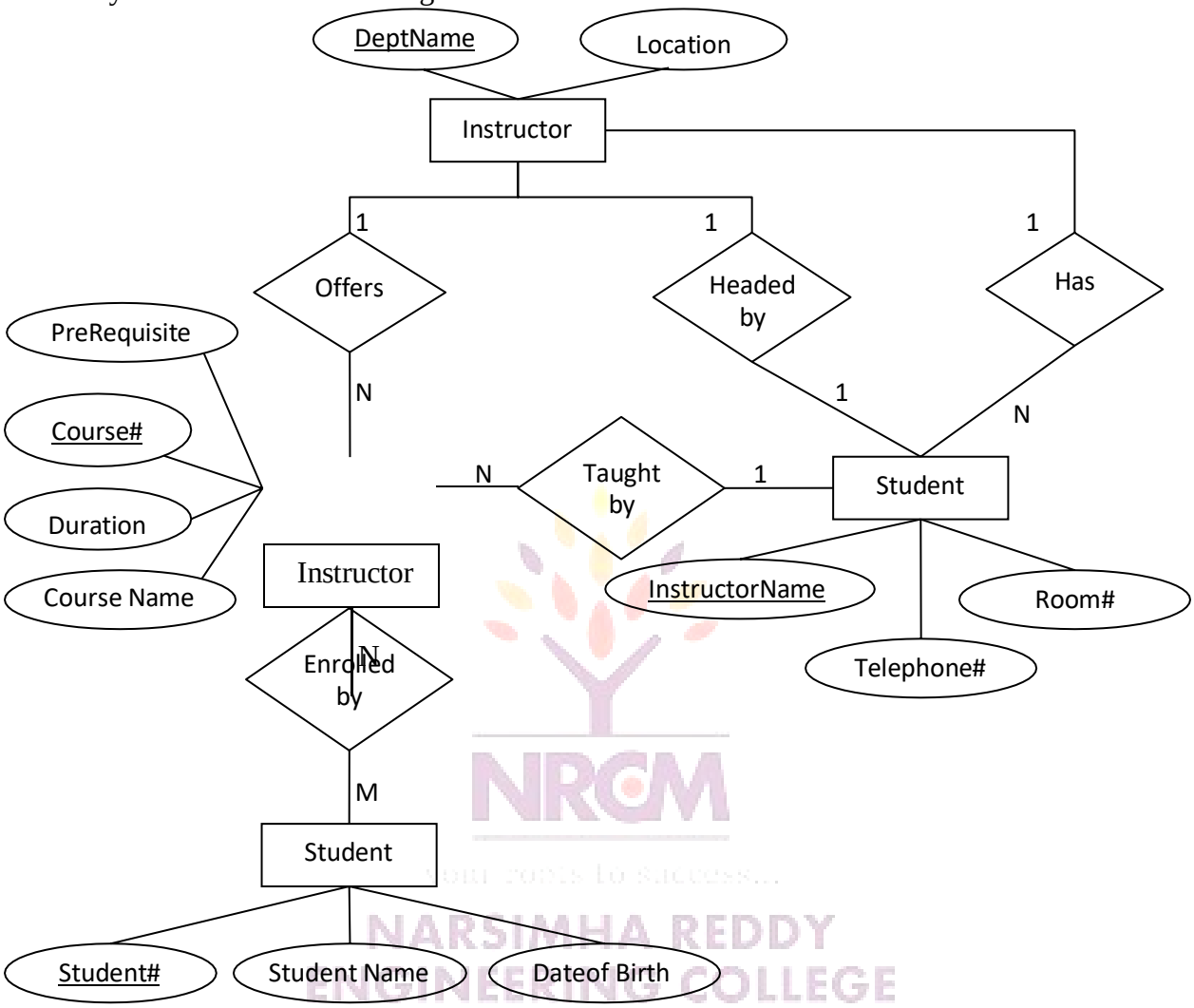


The relationship between instructor and student need NOT be defined in the diagram.The reasons are as follows:

1. There is no business significance of this relationship.
2. We can always derive this relationship indirectly through course and instructor, and course and students.

Step5: Complete E-R diagram

After considering all the above mentioned guidelines one can generate the E-R Model for the university database as shown in Figure.



DESIGN CHOICES IN CONCEPTUAL DESIGN

a. Should a concept be modeled as an entity or an attribute?

b. Should a concept be modeled as an entity or a relationship?

c. Identifying relationships: Binary or ternary? Aggregation?

Entity vs. Attribute

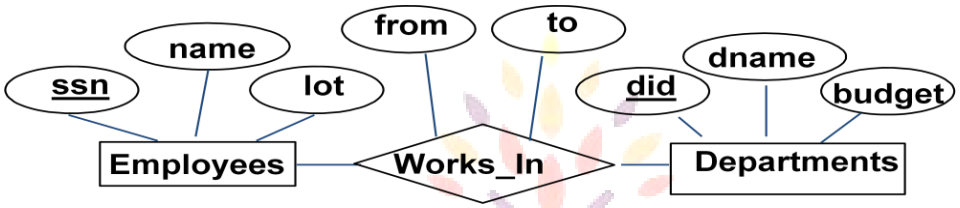
- Should *address* be an attribute of Employees or an entity (related to Employees)?

- Depends up on how we want to use address information, and the semantics of the data:

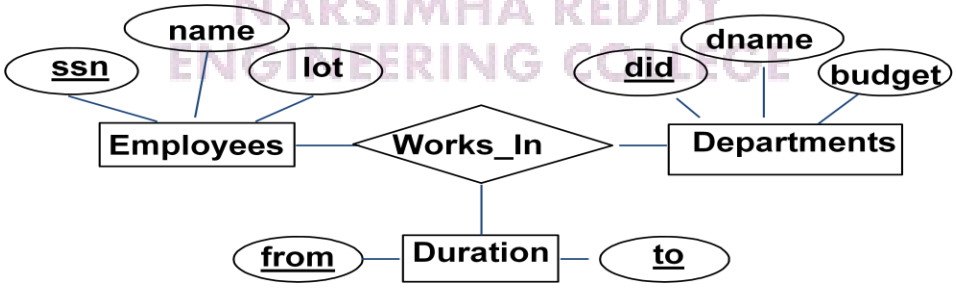
- If we have several addresses per employee, *address* must be an entity
- If the structure of address is important (plotNo, street, city, state, country and pin Code values are compulsory for each address) then, *address* must be modeled as an entity.
- Otherwise address can be modeled as an attribute.

Binary vs. Ternary Relationship

- A relationship can also have attributes.
- If an employee work in a department for a period time, then it can be modeled as given below.
- This is a binary relationship diagram



- If an employee work in a department for two or more periods , then it should be remodeled as given below.
- Then it becomes as a ternary relationship diagram



When to use aggregation?

When an entity maintains a common relationship with two or more entities, not individually then aggregation need to be used.

MULTIPLE CHOICE QUESTIONS

1. An entity set that does not have sufficient attributes to form a primary key is a _____
   a) Strong entity set b) Variant set c) Weak entity set d) Variable set
2. In the relational model, cardinality is termed as:
   a) no.of tuples b)no. of attributes c)no.of tables d) no.of constraints
3. In a relational model, relations are termed as
   a) Tuples. b) Attributes c) Tables. d) Rows.
4. In an E-R diagram attributes are represented by
   a) rectangle b) square c) ellipse d) triangle.
5. An abstraction concept for building composite object from their component to bject is called:
   a).Specialization b).Normalization c).Generalization d).Aggregation