Introduction to Logical Design

Database Design

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Relational Database: Definitions

- Relational database: a set of relations
- Relation: made up of 2 parts:
  - Schema : specifies name of relation, plus name and type of each column.
    - e.g., Students(sid: string, name: string, login: string, age: integer, gpa: real).
  - Instance : a table, with rows and columns.
    #Rows = cardinality, #fields = degree / arity.
- Can think of a relation as a set of rows or tuples (all rows are distinct).

Example Instance of Students Relation

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

- Cardinality = 3, degree = 5, all rows distinct

Relational Query Languages

- A major strength of the relational model: supports simple, powerful *querying* of data.
- Queries can be written intuitively, and the DBMS is responsible for efficient evaluation.
  - The key: precise semantics for relational queries.
  - Allows the optimizer to extensively re-order operations, and still ensure that the answer does not change.

The SQL Query Language

- Developed by IBM (system R) in the 1970s
- Data Definition Language (DDL)
  - create, modify, delete relations
  - specify constraints
  - administer users, security, etc.
- Data Manipulation Language (DML)
  - Specify queries to find tuples that satisfy criteria
  - add, modify, remove tuples

Creating Relations in SQL

- Creates the Students relation. Observe that the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.
- As another example, the Enrolled table holds information about courses that students take.

```
CREATE TABLE Students
        (sid CHAR(20),
         name CHAR(20),
         login CHAR(10),
         age INTEGER,
         gpa REAL)

CREATE TABLE Enrolled
        (sid CHAR(20),
         cid CHAR(20),
         grade CHAR(2))
```

Destroying and Altering Relations

- DROP TABLE Students
  - Destroys the relation Students. The schema information and the tuples are deleted.

- ALTER TABLE Students
  ADD COLUMN firstYear: integer
  - The schema of Students is altered by adding a new field; every tuple in the current instance is extended with a null value in the new field.

Adding, Deleting and Updating Tuples

- Can insert a single tuple using
  - INSERT INTO Students (sid, name, login, age, gpa)
    VALUES (53688, 'Smith', 'smith@ee', 18, 3.2)

- Can delete all tuples satisfying some condition
  - DELETE
    FROM Students S
    WHERE S.name = 'Smith'

- Can modify the column values in an existing row
  - UPDATE Students S
    SET S.age = S.age + 1, S.gpa = S.gpa − 1
    WHERE S.sid = 53688

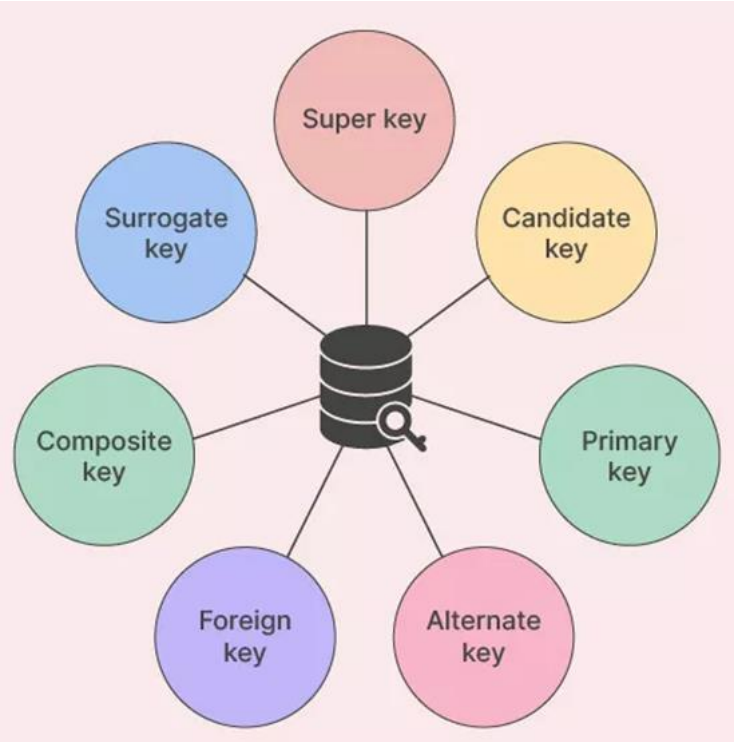
Integrity Constraints (ICs)

- IC: condition that must be true for *any* instance of the database; e.g., *domain constraints*.
  - ICs are specified when schema is defined.
  - ICs are checked when relations are modified.
- A *legal* instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- If the DBMS checks ICs, stored data is more faithful to real-world meaning.
  - Avoids data entry errors, too!

Keys

- Keys help you to identify any row of data in a table. In a real-world application, a table could contain thousands of records. Moreover, the records could be duplicated. Keys in RDBMS ensure that you can uniquely identify a table record despite these challenges.
- Allows you to establish a relationship between and identify the relation between tables.
- Help you to enforce identity and integrity in the relationship.

Type of Keys


Super key
Surrogate key
Candidate key
Composite key
Primary key
Foreign key
Alternate key

Super Key

- A super key is a group of single or multiple keys which identifies rows in a table. A super key may have additional attributes that are not needed for unique identification.

EmpSSN	EmpNum	Empname
9812345098	AB05	Shown
9876512345	AB06	Roslyn
199937890	AB07	James

In the above-given example, EmpSSN and EmpNum name are superkeys.

Candidate Key

- Candidate Key: A super key such that no proper subset is a super key within the relation. A candidate key *K* for a relation *R* has two properties:
  - Uniqueness: In each tuple of R, the values of K uniquely identify that tuple.
  - Irreducibility: No proper subset of K has the uniqueness property.

```
Student{ID, Aadhar_ID, F_name, M_name, L_name, Age}
```

Here we can see the two candidate keys ID and Aadhar_ID. So here, there are present more than one candidate keys, which can uniquely identify a tuple in a relation.

Identifying a candidate key requires that we know the "real-world" meaning of the attribute(s) involved so that we can decide whether duplicates are possible.

Primary Key

- Primary Key is a set of attributes (or attribute) which uniquely identify the tuples in relation or table. The candidate key that is selected to identify tuples uniquely within the relation. The primary key is a minimal super key, so there is one and only one primary key in any relationship. For example,

```
Student{ID, Aadhar_ID, F_name, M_name, L_name, Age}
```

Here only ID or Aadhar_ID can be primary key because the name, age can be same, but ID or Aadhar_ID can't be same.

- Two rows can't have the same primary key value
- It must for every row to have a primary key value.
- The primary key field cannot be null.
- The value in a primary key column can never be modified or updated if any foreign key refers to that primary key.

Primary Key Constraints

- A set of fields is a (candidate) key for a relation if :
  1. No two distinct tuples can have same values in all key fields, and
  2. This is not true for any subset of the key.
  - Part 2 false? A superkey.
  - If there's >1 key for a relation, one of the keys is chosen (by DBA) to be the primary key.
- E.g., sid is a key for Students. (What about name?) The set {sid, gpa} is a superkey.

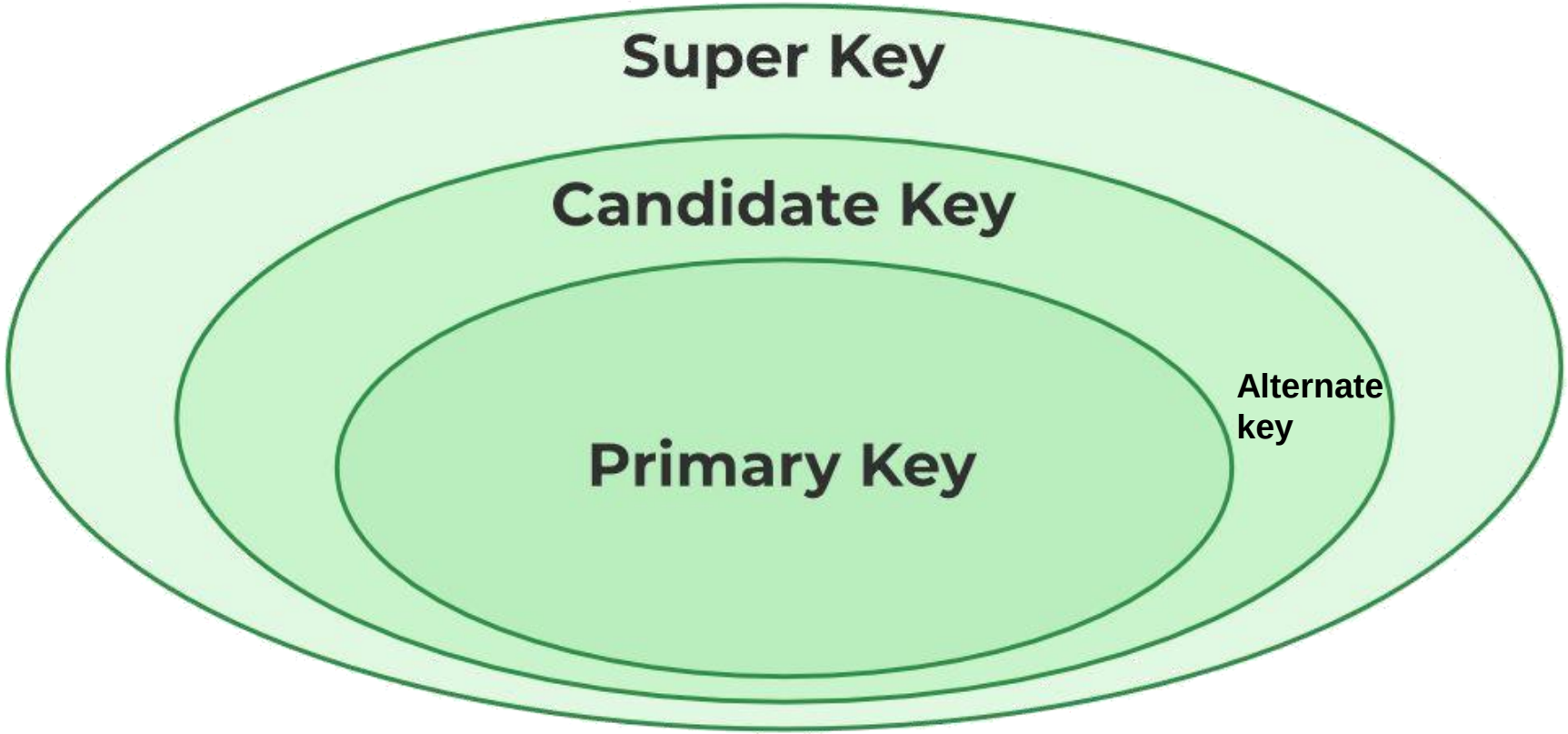
Alternate Key

- **Alternate Key:** The candidate keys that are not selected to be the primary key are called alternate keys. This is a column or group of columns in a table that uniquely identify every row in that table. A table can have multiple choices for a primary key but only one can be set as the primary key. All the keys which are not primary key are called an Alternate Key.
- Alternate key = candidate key − primary key

In this table, StudID, Roll No, Email are qualified to become a primary key. But since StudID is the primary key, Roll No, Email becomes the alternative key.

StudID	Roll No	First Name	LastName	Email
1	11	Tom	Price	abc@gmail.com
2	12	Nick	Wright	xyz@gmail.com
3	13	Dana	Natan	mno@yahoo.com

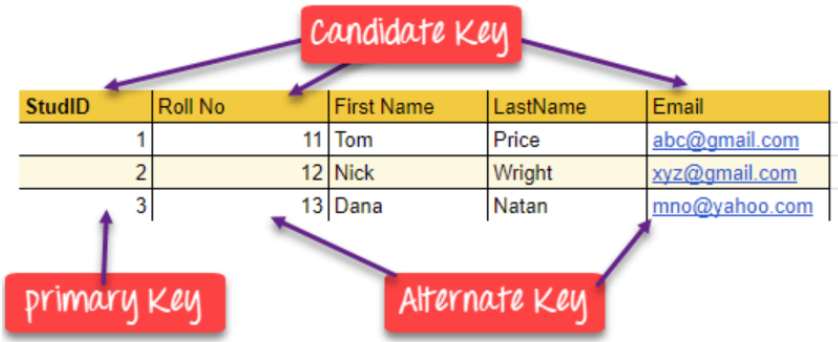
Conclusion



Example

Candidate key Example: In the given table Stud ID, Roll No, and email are candidate keys which help us to uniquely identify the student record in the table.

StudID	Roll No	First Name	LastName	Email
1	11	Tom	Price	abc@gmail.com
2	12	Nick	Wright	xyz@gmail.com
3	13	Dana	Natan	mno@yahoo.com



Candidate Key in DBMS

Foreign Key

- Foreign Key: is a column that creates a relationship between two tables. The purpose of Foreign keys is to maintain data integrity and allow navigation between two different instances of an entity. An attribute, or set of attributes, within one relation that matches the candidate key of some (possibly the same) relation.

Foreign Key

DeptCode	DeptName
001	Science
002	English
005	Computer

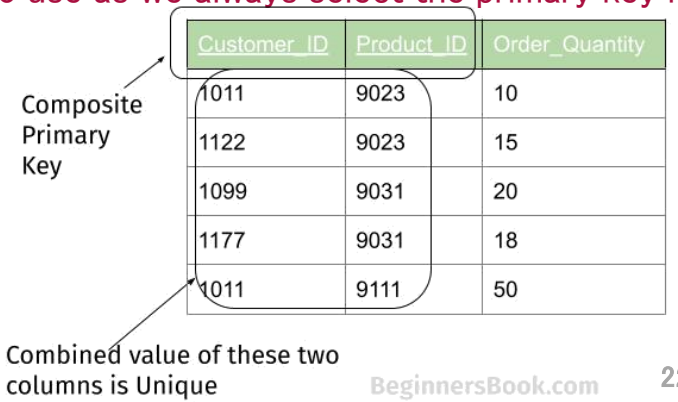
Teacher ID	Fname	Lname
B002	David	Warner
B017	Sara	Joseph
B009	Mike	Brunton

In this table, adding the foreign key in Deptcode to the Teacher name, we can create a relationship between the two tables.

Teacher ID	DeptCode	Fname	Lname
B002	002	David	Warner
B017	002	Sara	Joseph
B009	001	Mike	Brunton

Composite Key

- Composite Key: a candidate key that consists of two or more attributes, (table columns) that together uniquely identify an entity occurrence (table row). Composite key cannot be null and should be unique.
  - The main difference between the primary key and the composite key is the primary key is derived from a unique column. Composite is derived by a combination of two or columns. Individually they are not unique but when combined they provide uniqueness.
  - After getting the composite key, we mention it as the primary key Which will be used for the identification of the rows from the table.
  - If a table already consists of a primary key having a single attribute as an entity for uniquely identifying the records in a table, then the composite key is of no use as we always select the primary key having minimum attributes (or columns).



Compound Key

- Compound Key: **is a composite key for which each attribute that makes up the key is a foreign key in its own right.**
  - A compound key is where two or more attributes are used to uniquely identify each record in a table.
  - Each attribute from the compound key is a primary key from a different table.
  - A compound key is used when no single attribute in a table can be used as a primary key.

Compound Key

Example

Two-Wheel-Rental Inc hires bikes to customers for one day. They have a relational database with three tables as shown below:

Members	Bikes	Hire
MemberID	BikeID	MemberID*
Name	Make	BikeID*
Address	Colour	HireDate
Telephone	MT338X440	

The Hire table needs a compound key of MemberID, BikeID and HireDate.

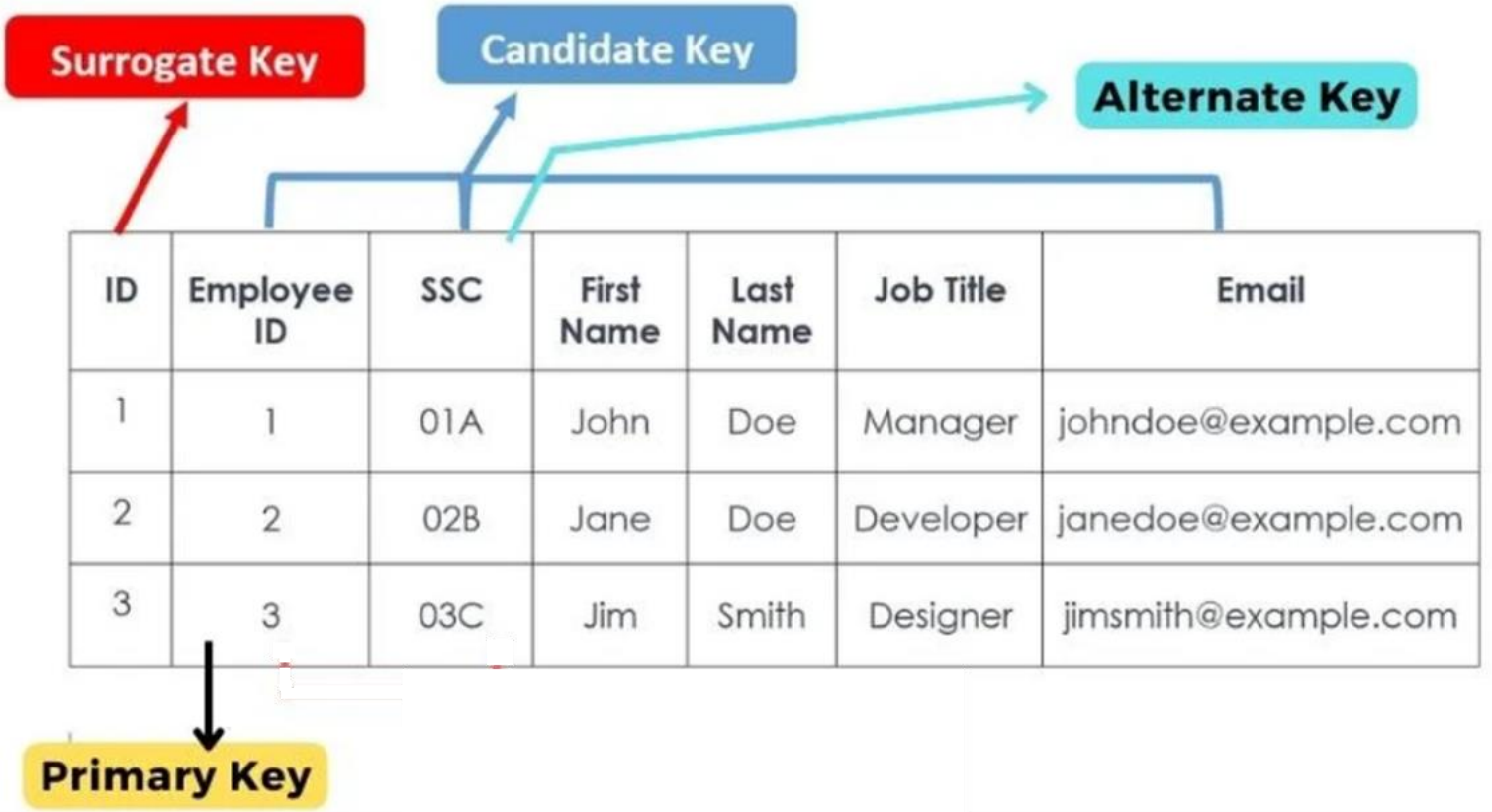
- MemberID alone can't be used – a member can make more than one hire
- BikeID alone can't be used – a bike can be hired by more than one member
- MemberID and BikeID can't be used – a member could hire the same bike on a different day

Members	Bikes	Hire
MemberID	BikeID	MemberID*
Name	Make	BikeID*
Address	Colour	HireDate
Telephone	MT338X440	

Surrogate Key

- Surrogate Key: An artificial key which aims to uniquely identify each record is called a surrogate key. These kind of key are unique because they are created when you don't have any natural primary key.
  - A common example of surrogate key is auto-incrementing integer as primary key in a table.

Type of Keys



ID	Employee ID	SSC	First Name	Last Name	Job Title	Email
1	1	01A	John	Doe	Manager	johndoe@example.com
2	2	02B	Jane	Doe	Developer	janedoe@example.com
3	3	03C	Jim	Smith	Designer	jimsmith@example.com

Primary and Candidate Keys in SQL

- Possibly many candidate keys (specified using UNIQUE), one of which is chosen as the primary key.
  - "For a given student and course, there is a single grade."
  - "Students can take only one course, and receive a single grade for that course; further, no two students in a course receive the same grade."
  - Used carelessly, an IC can prevent the storage of database instances that arise in practice!

```
CREATE TABLE Enrolled
  (sid CHAR(20)
    cid  CHAR(20),
    grade CHAR(2),
    PRIMARY KEY (sid,cid))
```

```
CREATE TABLE Enrolled
  (sid CHAR(20)
    cid  CHAR(20),
    grade CHAR(2),
    PRIMARY KEY  (sid),
    UNIQUE (cid, grade))
```

Foreign Keys, Referential Integrity

- Foreign key : Set of fields in one relation that is used to `refer' to a tuple in another relation. (Must correspond to primary key of the second relation.) Like a `logical pointer'.
- E.g. sid is a foreign key referring to Students:
  - Enrolled(sid: string, cid: string, grade: string)
  - If all foreign key constraints are enforced, referential integrity is achieved, i.e., no dangling references.
- Foreign key attributes in R1 referring to R2 have the following rules:
  - The FK attributes in R1 have the same domain(s) as the primary key attributes if R2
  - The value of FK in tuple t1 in R1 must reference an existing PK value in tuple t2 of R2

Foreign Keys in SQL

- Only students listed in the Students relation should be allowed to enroll for courses.

```
CREATE TABLE Enrolled
  (sid CHAR(20),  cid CHAR(20),  grade CHAR(2),
    PRIMARY KEY (sid,cid),
    FOREIGN KEY (sid) REFERENCES Students )
```

Enrolled

sid	cid	grade
53666	Carnatic101	C
53666	Reggae203	B
53650	Topology112	A
53666	History105	B

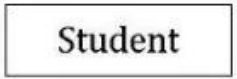
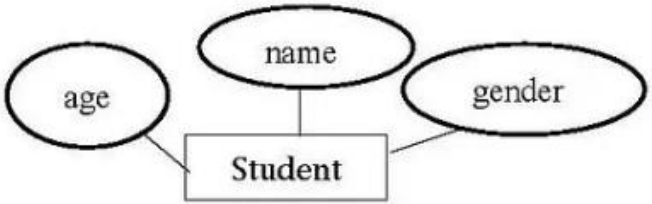
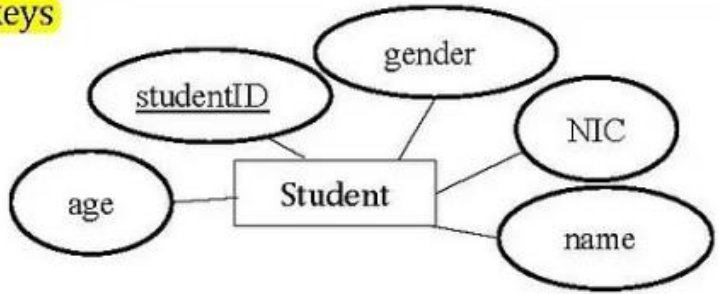
FOREIGN Key

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

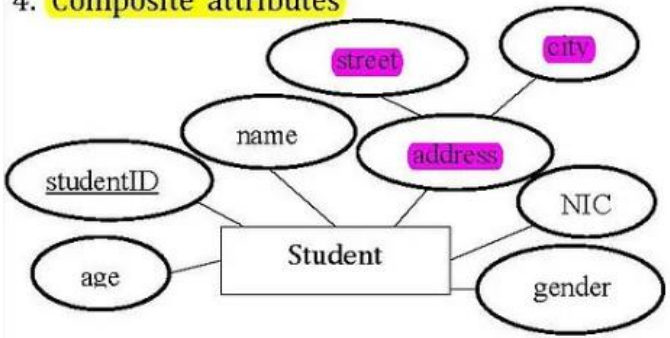
PRIMARY Key

Mapping Entities and Attributes

1. Entity 	Student table
2. simple attributes 	Student (name,age, gender)
3. keys 	Student (studentID, NIC, name, age, gender)

Mapping Entities and Attributes

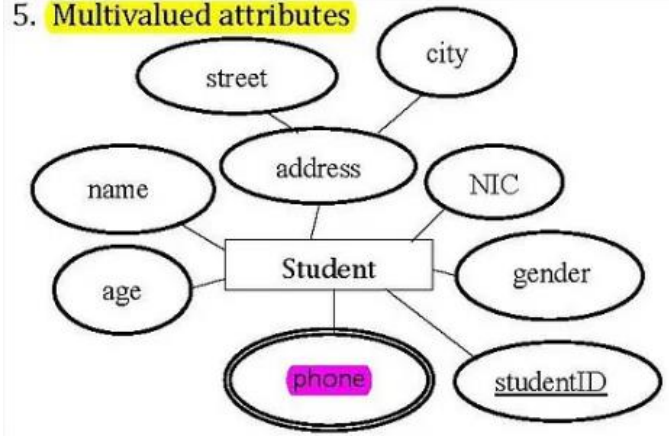
4. Composite attributes



Student (studentID, NIC, name, age, gender, street,city)

A strong entity set with any number of composite attributes will require only one table in relational model.

5. Multivalued attributes



p.k

Student (studentID, NIC, name, age, gender, street,city)

Student_phone (studentID, phone)

f.k. p.k

- One table will contain all the simple attributes with the primary key.
- Other table will contain the primary key and all the multi valued attributes.

Mapping Entities and Attributes

Note on multivalued attribute:

- Create separate table for each multivalued attribute requires join on two tables which is time consuming.

- If maximum number of multivalued attributes is known as #a, so the entity table should have #a columns.

  - Student(studentID,NIC,name,age,gender,street.city,phone1,phone2,phone3)
  - There will be no joining
  - There are many null values in the data

Derived Attribute

- We do not include derived attributes in logical design.
- We can use views, we will see this more later.

References

- Chapter 9 of FUNDAMENTALS OF Database Systems, SEVENTH EDITION
- Chapter 4 of Database Systems A Practical Approach to Design, Implementation, and Management, SIXth edition