Conceptual design

Database design

Database represents aspects of the part of real world (universe of discourse - miniworld)

- objects of the real world
- relationships between objects
- constraints

Primary goal is to design a successful **database application**

- database application is a collection of application programs
- design and testing of application programs is a part of software engineering
- therefore **database design** is closely related to software engineering methods

Database design

Database design

- identification of the organization of necessary parts of the real world which are important for our database applicaton
- transforming that organization to a database schema

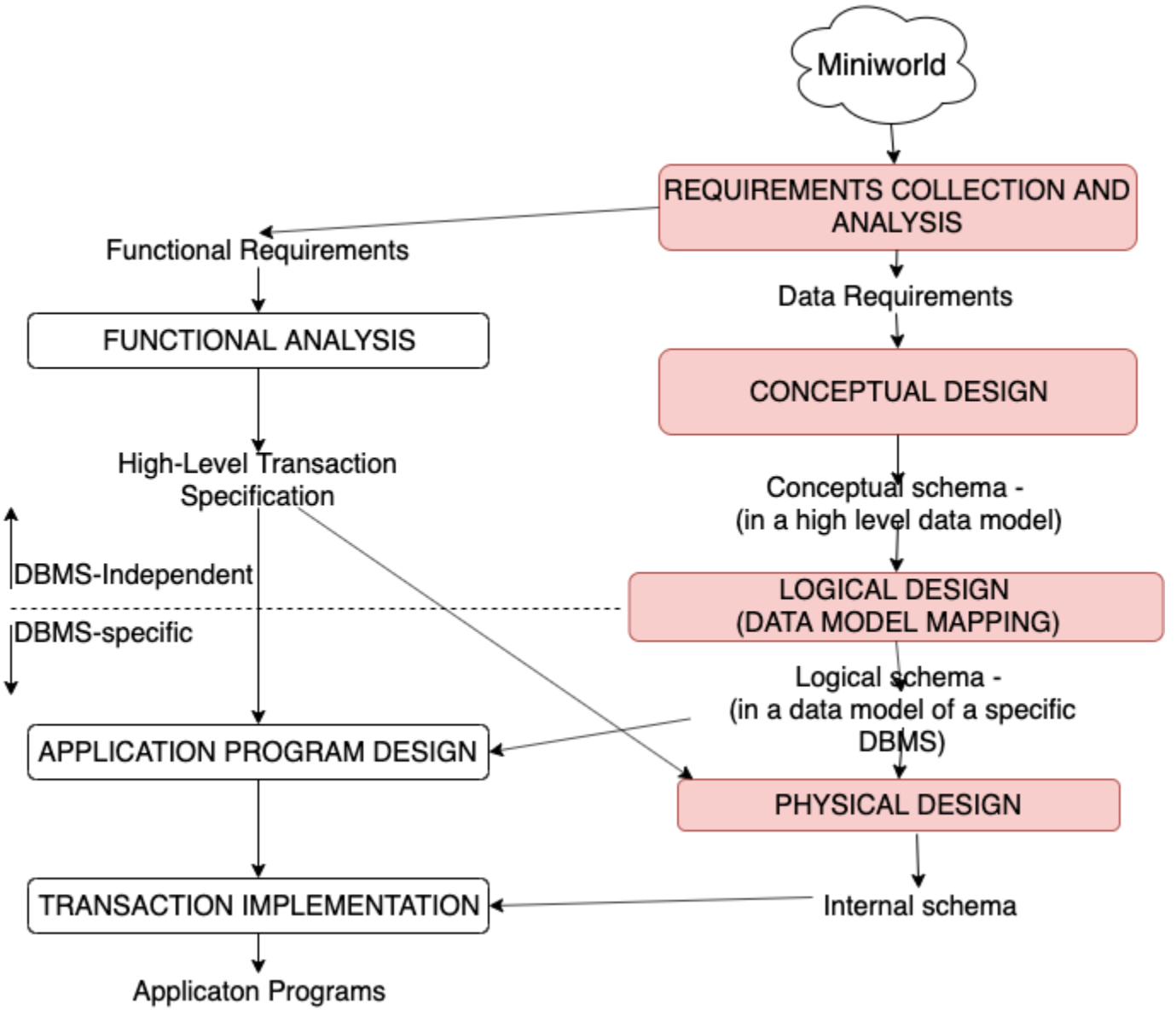
During database design it's important to:

- avoid redundancy - repeated data can easily lead to inconsistency
- completeness - an incomplete model which is insufficient to model the part of real world can lead to severe constraints during use of database application

Three **is not only one** successful database design.

- more correct database designs may exist for an aspect of a miniworld

Database design - simplified overview



Database design - process

1. **Requirements collection and analyses**
   - database designers interview prospective database users to understand and document their data requirements
   - documentation in different forms (textual documents, data flow diagrams, UML diagrams,…)
2. **Conceptual design**
   - transforming requirements to a conceptual schema
   - Output: **ER-diagrams**
3. **Logical design - data model mapping**
   - translation of the ER-model to an implementation data model of DBMS
   - relational data model (expressed in SQL)
4. **Physical design**
   - specifying internal storage structures, files, indexes, access paths and physical design parameters

ER modeling

Entity-Relationship (ER) model is a popular high level conceptual data model

- different variations of this model used for conceptual design of data applications
- represents a blueprint of a database
- **ER-diagrams** - diagrammatic notation associated with the ER model

Sample Database Application

Requirements collection for the COMPANY database (page 72 in the textbook):

- The company is divided into departments. Each department has a unique name, a unique number and particular employee who manages the department. A start date when that employee began managing the department should be tracked.
- Each department controls a number of projects, each of which has a unique name, a unique number, and a single location
- An employee has it's name, Social Security number, address, gender, salary and birth date. Employee is assigned to one department but may work on several projects, which are not necessarily controlled by the same department. We store the current number of hours per week that an employee works on each project. Each employee can have a direct supervisor who is another employee.
- Each employee can have it's dependents and we have to keep track of them for insurance purposes. Each dependent has first name, gender, birth date, and relationship to the employee

ER model elements

Main ER model elements are

- **Entities** which represents objects from the real world
  - physical objects: students, cars, employees
  - conceptual objects: projects, companies,…
- **Attributes** are properties that describe objects (entities)
  - an employee has attributes: name, surname, gender, birth date
- **Relationships** among entities

Entity types and sets

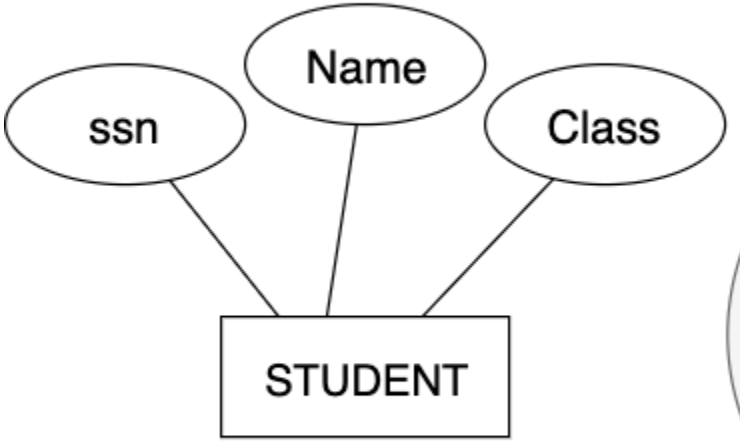
An **Entity type** is a *definition* of a collection of entities that have the same attributes.

- each entity type is described by it's name and set of attributes
- represented as a rectangular box in ER diagrams
- represents schema or *intension* for a set of entities

An **Entity set** is a collection of all entities of a particular entity type in the database at any point in time.

- each entity has its own value for each attribute.
- represents extension of the entity type

Entity type and entity set - example



Student

(ssn, Name, Class)

$Student_1$

(668898123, John Brown, 1)

$Student_2$

(232888232, Christine Smith, 2)

$Student_3$

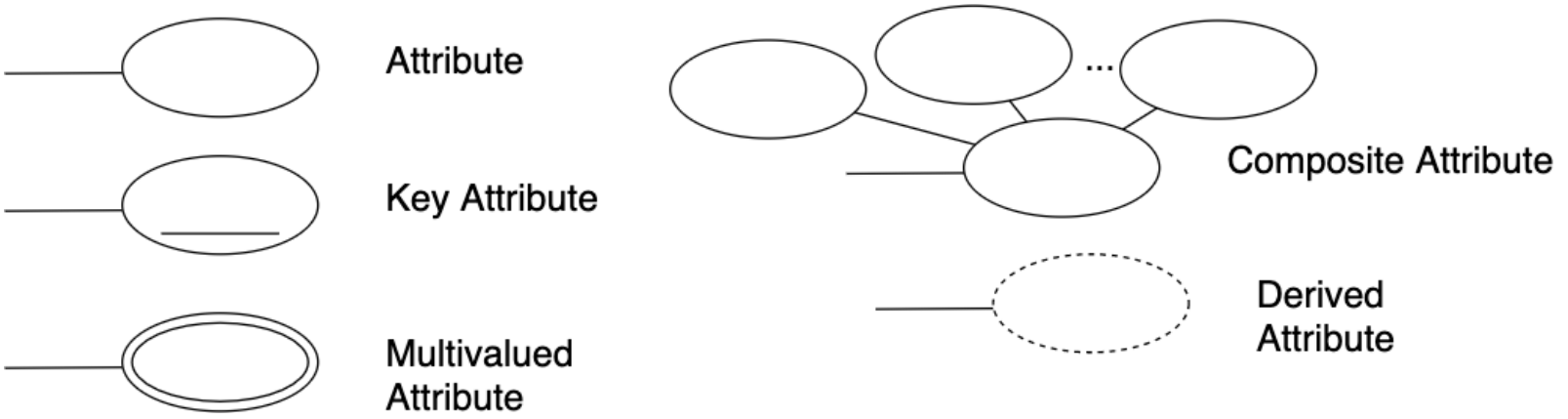
(987654331, Leslie Connor, 3)

...

Attribute categories

- **Atomic** attributes which are not divisible (ex. age, zip-code,…)
- **Composite** attributes (ex. Address - (Street_name, City, State and Zip-code))
- **Single-valued** attributes - at some point of time only one specific value exists (ex. age)
- **Multivalued** attributes - can contain more values at the same time (ex. College_degrees, Colors attribute for a two-tone car) number of values can be restricted
- **Stored** attributes - are stored in the database
- **Derived** attributes, whose values can be derived from other attributes (age can be derived from the birth date or number of employees from employee table)
- **null** values in attributes can have different meaning (unknown, not applicable, missing)

Key attribute - example



Key attributes

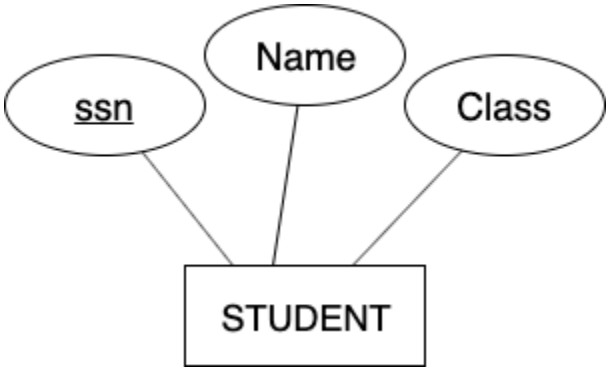
Key attributes is a set of attributes whose values are distinct for each individual entity in the entity set

- for the entity STUDENT, the attribute ssn is a key attribute
- this property is called uniqueness property
- composite attributes can have the uniqueness property but must be minimal
- in ER-diagrams key attributes are underlined inside the oval
- concept of primary key don't exist here - it is chosen during mapping to a relational schema

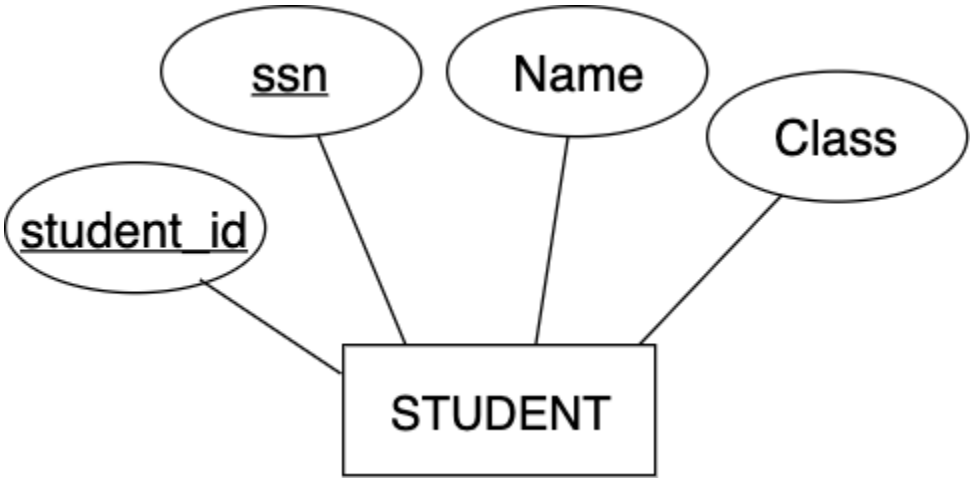
Domain of an attribute is a set of values that may be assigned to that attribute

- not displayed in ER diagrams

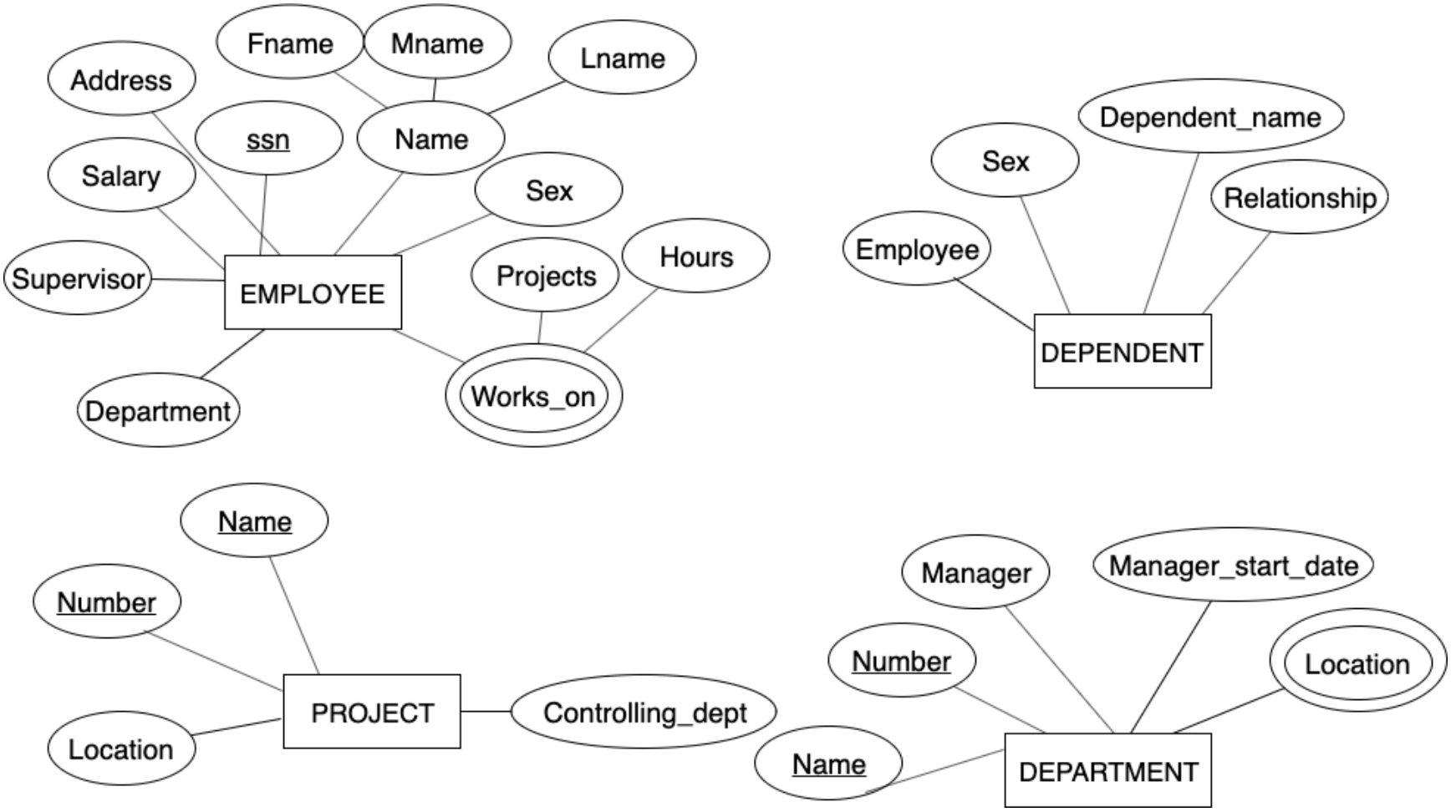
Key attribute - example



An artificial or **surrogate** key can be introduced - in our case student_id

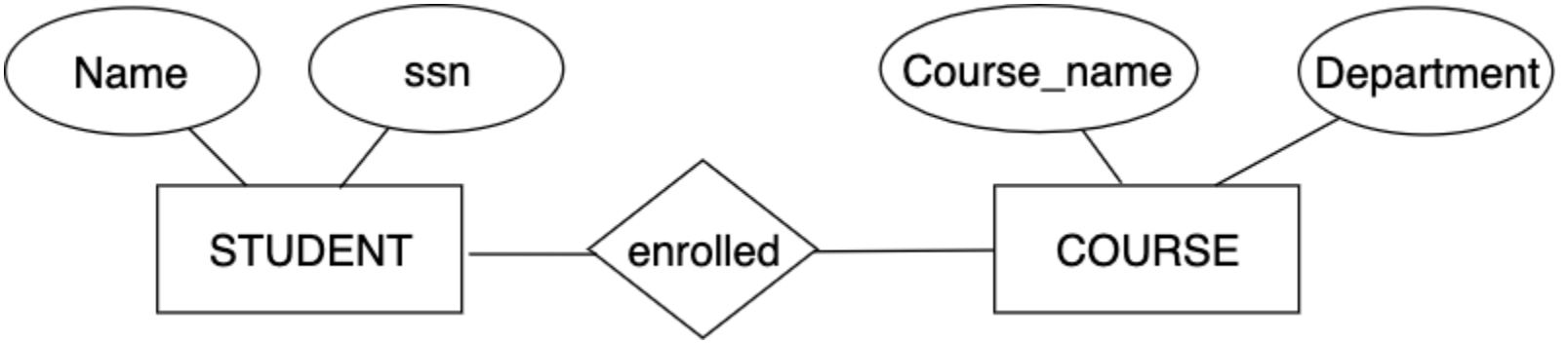


Preliminary design



Relationship types, relationship sets and instances

- A **relationship instance** represents an association among entities $(e_1, e_2, \ldots, e_n)$, where each $e_1, e_2, \ldots, e_n$ belongs to an entity set.
- A **relationship set** is a set of *relationship instances* - is a mathematical relation.
- A **relation type** defines a *relationship set*.
  - relationship types represented in ER diagrams as diamond-shaped boxes



Relationship degree, Role names

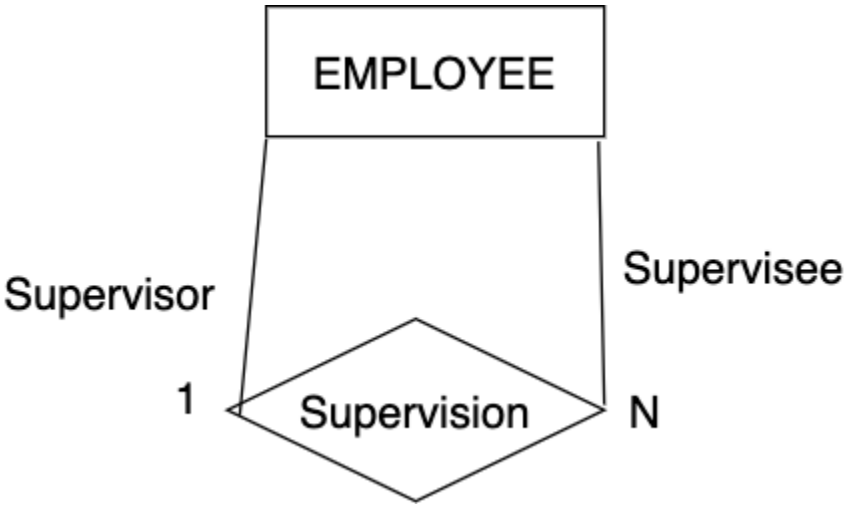
A **relationship degree** is the number of participating entity types in a relationship.

- relationship enrolled in the last example is of degree two (**binary**)
- relationship of degree three is called **ternary** (example: relationship supply - a supplier supplies a product to a project)
- relationships can be of any degree but the most popular are binary relationships
- each participating entity plays a role in the relationship

Recursive relationships

A **recursive relationship** is a relationship in which some entity participates more than once

- role of an entity is important (specifies the meaning that each participating entity plays)
- an entity participates twice in an relationship - supervisor



Constraints on binary relationship types

Constraints limit the possible combination of entities in a relation and are determined from the miniworld

The following main types of constraints can be distinguished:

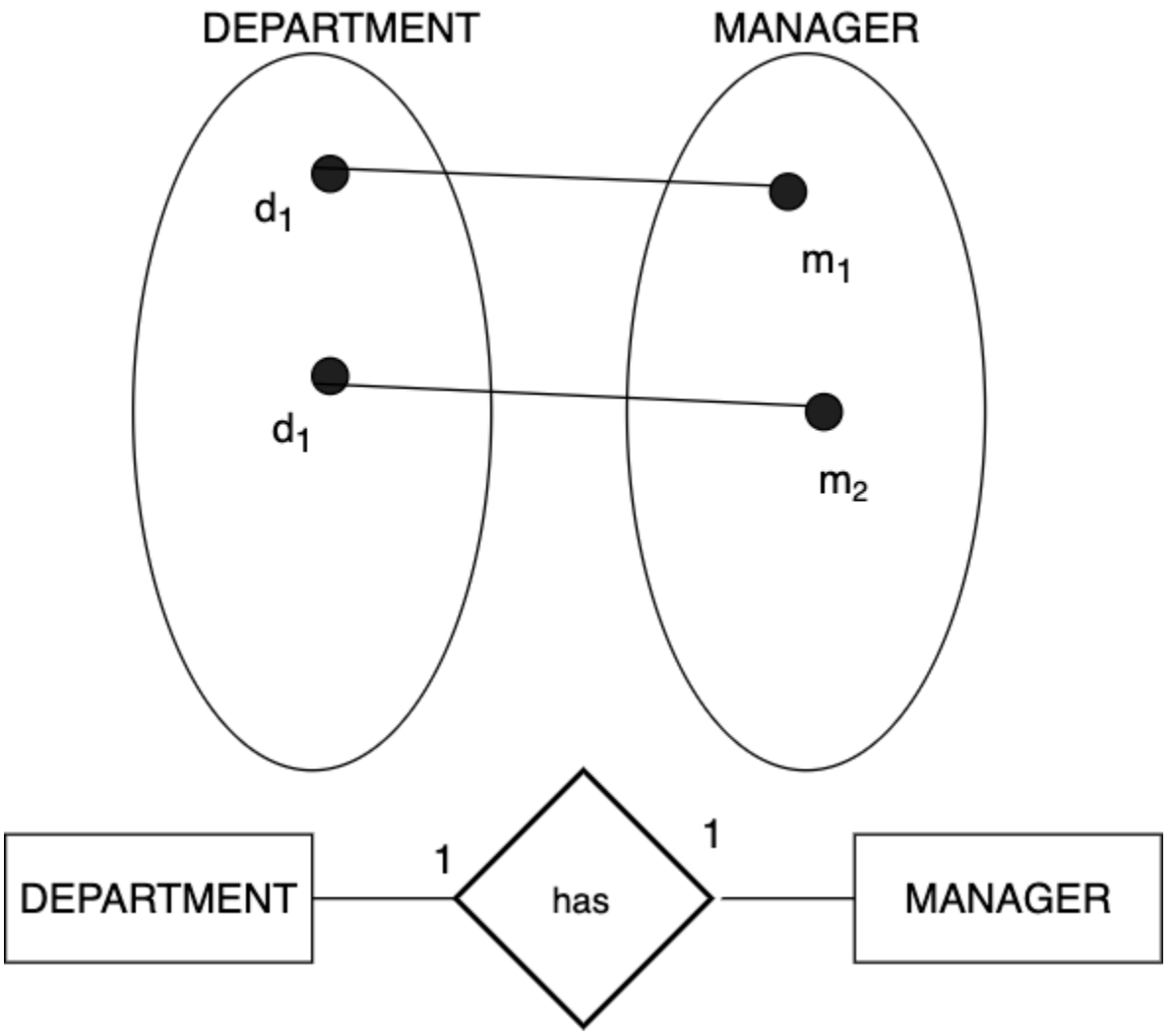
1. **cardinality ratio** constraints
   - specify the maximum number of relationship instances that an entity can participate in
   - possible cardinality rations are **1:1, 1:N, N:1, M:N**
2. **participation** constraints
   - specify the minimum number of relationship instances that each entity can participate in
   - possible participation constraint values are **total** and **partial**

Cardinality ratio constraints

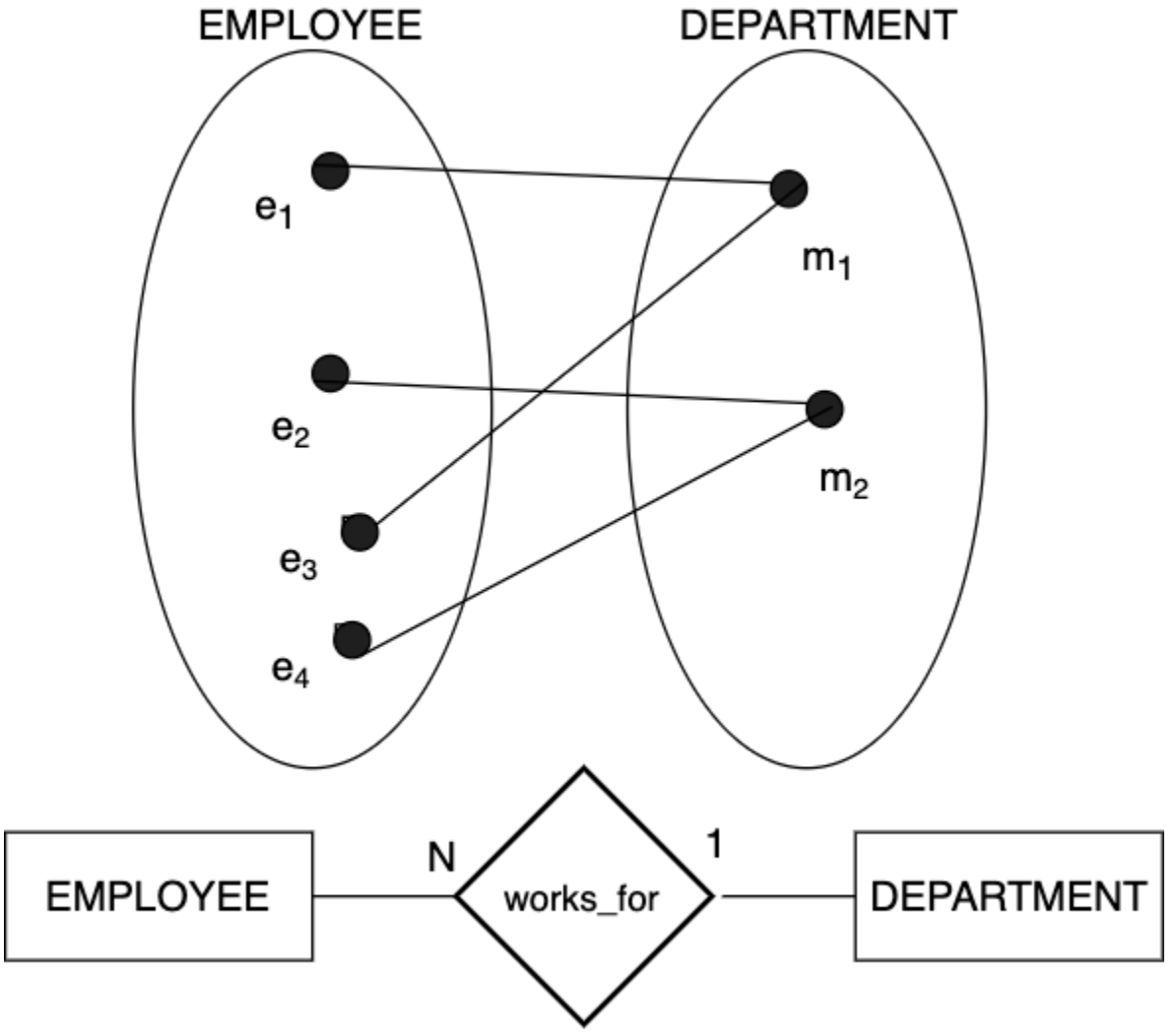
- **1:1** an department has only one manager (an employee can manage one department only and a department can be managed by one manager only)
- **1:N** each can be related to any number on the other side (a department can have many employees but one employee can work for only one department)
- **M:N** each student can be enrolled in many courses, and each course can have many enrolled students

In ER-diagrams, cardinality is represented by numbers next to the diamond representing the relationship

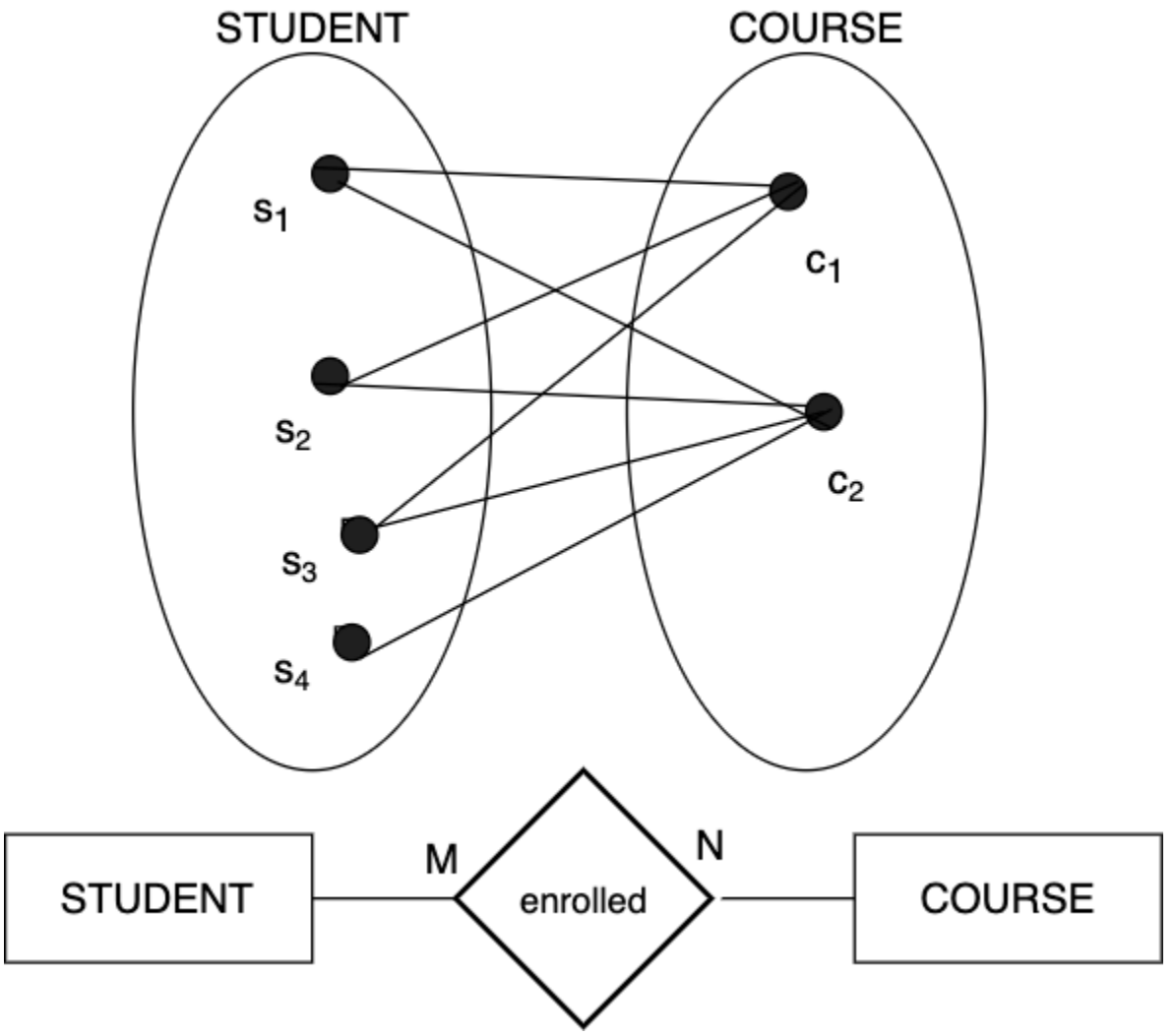
1-1 cardinality relationship



1-N cardinality relationship



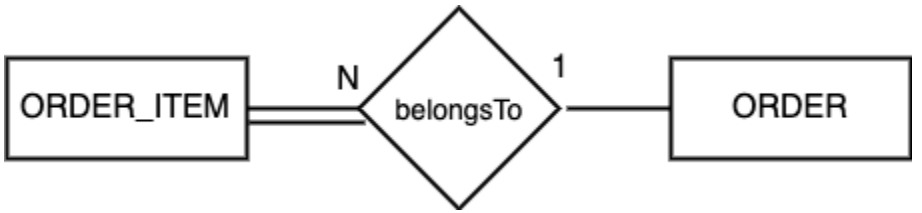
M-N cardinality relationship



Participation constraints

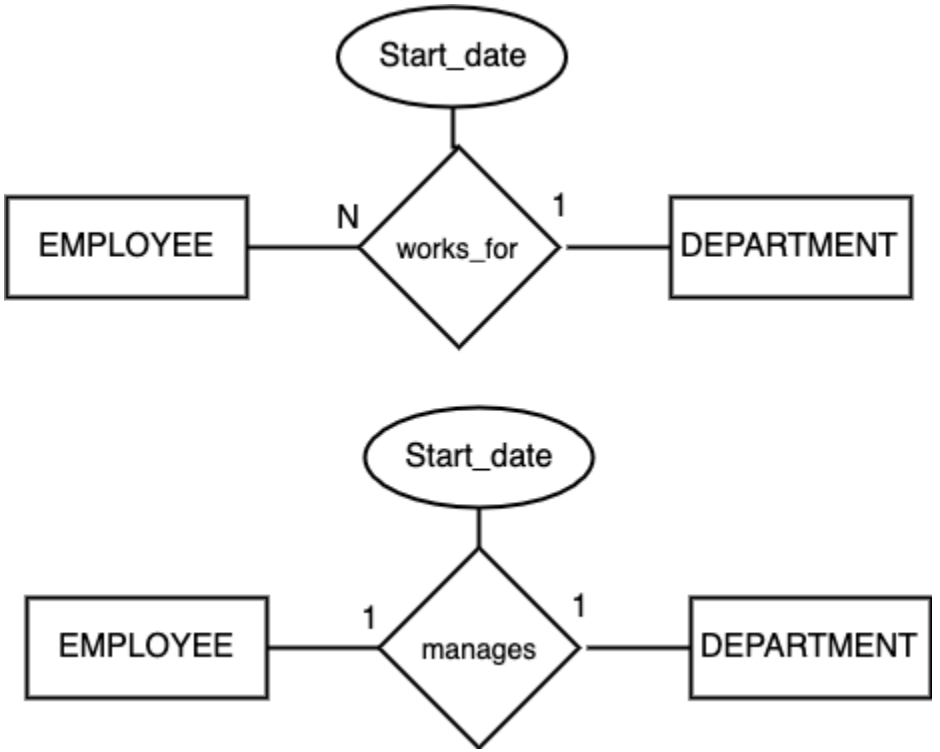
Participation constraints are called minimum cardinality constraints

- **total participation** (or *existence dependency*) and is displayed in ER diagrams as a double line connecting participating entity type to the relationship
  - in our example every ORDER_ITEM must belong to some ORDER entity



- **partial constraint** is represented as a single line which means that there is no minimum constraint (in our example an ORDER entity can exist without ORDER_ITEM entities)

Attributes of relationship types

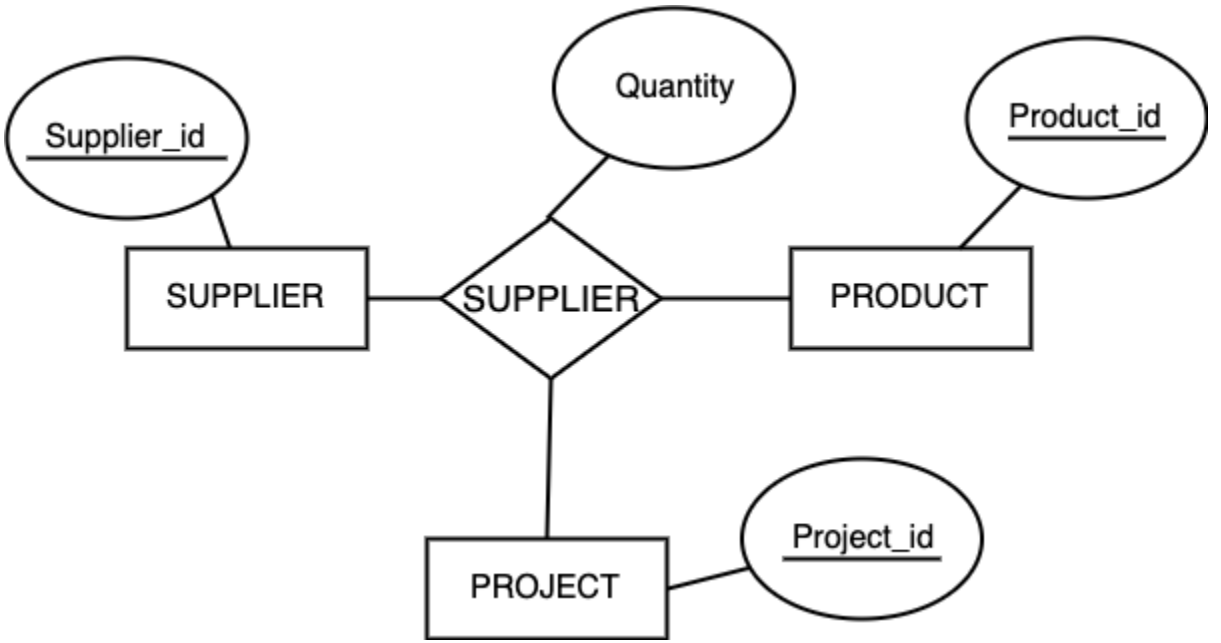


- Attributes of relationship types 1:N and 1:1 can migrate to participating entities.
  - for 1:1 relationships to any of the two entities
  - for 1:N relationships can migrate only to the entity on the N-side
  - for M:N relationships must be specified as relationship attributes

Ternary or higher degree relationships

In general, relationship type of degree n has n edges in an ER diagram

- n-ary relationship can be broken down into more relationships of smaller degree
- sometimes by introducing an artificial surrogate key ternary relationship is transformed to a regular entity type.

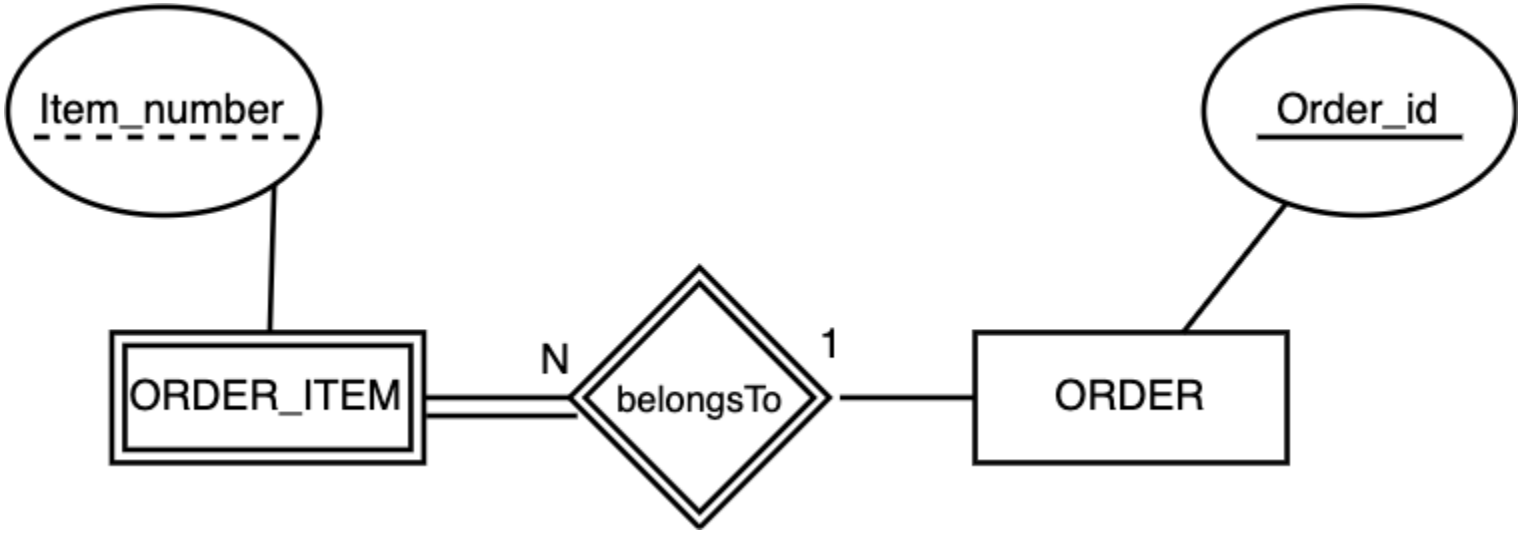


Weak entity types

A **weak entity type** is an entity type that does not have key attributes

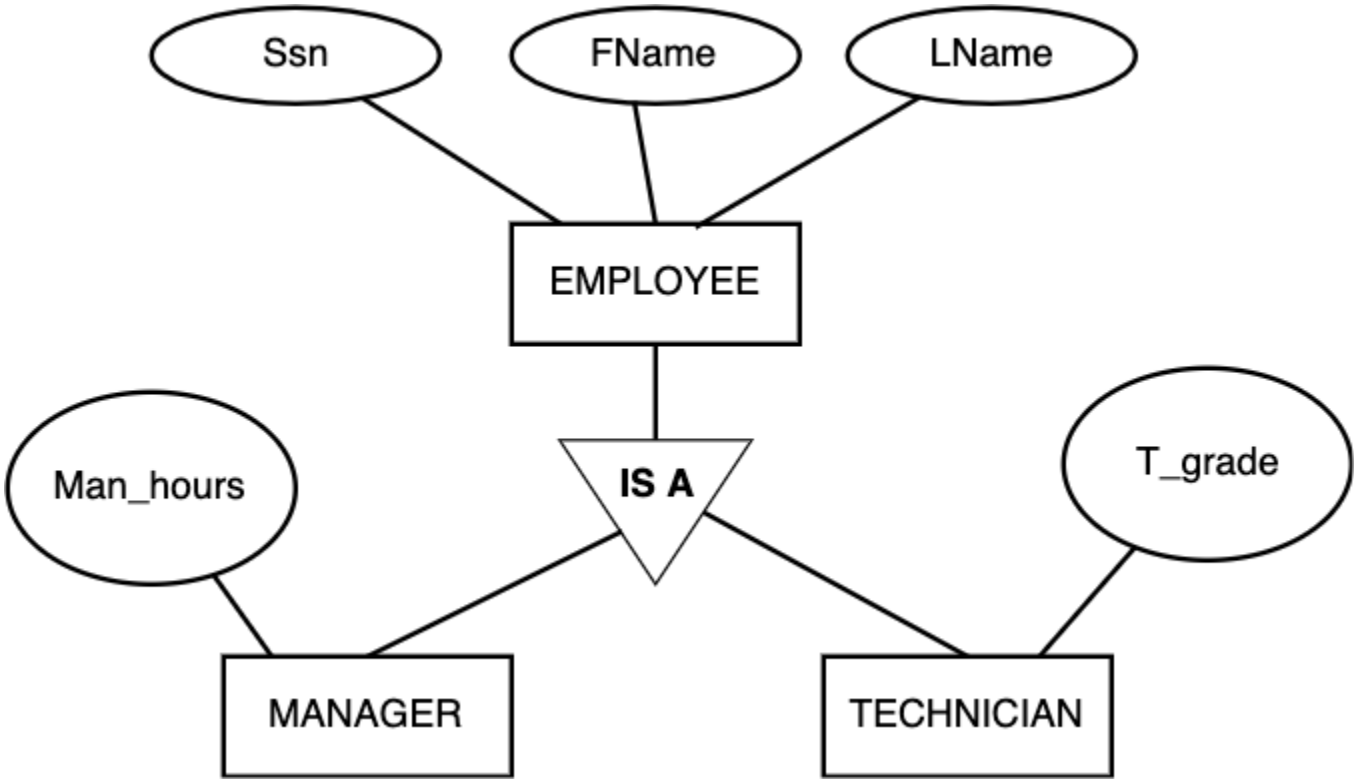
- entities belonging to a weak entity type are identified by being related to specific entities from another entity type (in combination with one of their attribute values)
- that entity type is called **identifying** or **owner entity type** and relation is called identifying relation of the weak entity type.
- weak entity type has always *total participation* with respect to its identifying relationship
- a weak entity type has a **partial key** which uniquely identifies weak entities to some owners entity
- In ER diagrams weak entity types and their identifying relationship are denoted by boxes and diamonds with **double lines** or they can be displayed as composite attributes

Weak entity type and identifying relationship type

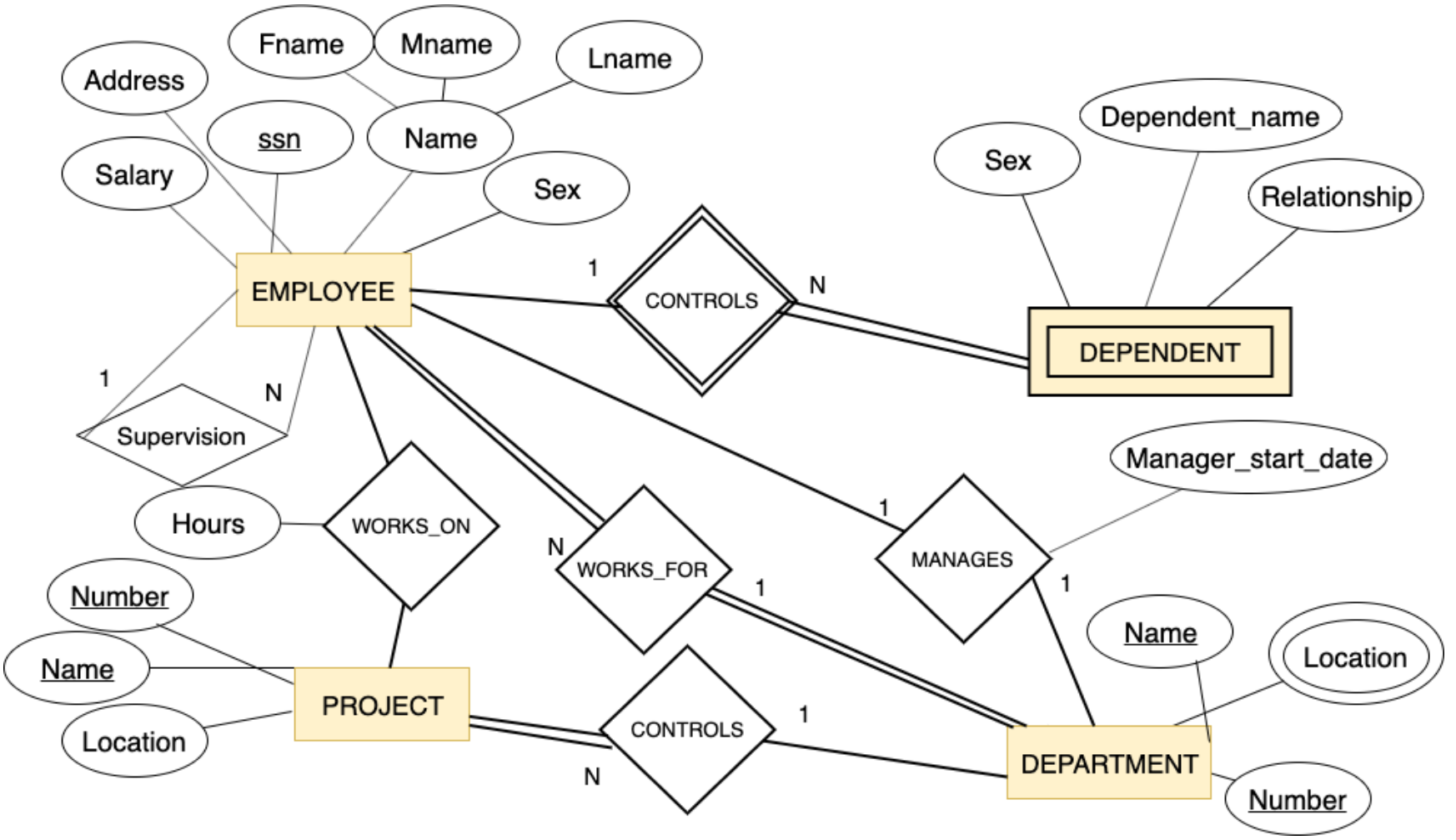


Generalization/ specialization

- **Generalization** is a way to represent subgroups of an entity type which are important for the database application.
  - an entity cannot exists just in a subclass
  - generalization/specialization is denoted as **is-a** or **part-of**



Refinement the ER Diagram



The final solution to our modeling

Conceptual design choices

The names should convey the meanings of constructs

- entity types should have singular names
- sometimes is difficult to decide whether a particular concept should be modeled as an entity type, an attribute, or a relationship type.

Database design is an iterative refinement process

- Refinement process from an initial design
  - attribute is transformed to a relationships
  - attribute existing in several entity types promoted to an entity type
- Inverse refinement
  - entity type demoted to an attribute

Different notations

- Chen-notation (notation that we use, proposed by Peter Chen 1976)
- UML notation
  - similar to class diagrams
  - inheritance
  - there are no relationships with degree n>2
- Crow's Feet notation
  - similar to UML notation

Review questions

- When an attribute of a binary relationship type can become an attribute of the participating entity types?
- What is a recursive relationship type?
- What is a weak entity type?
- What is a composite attribute?