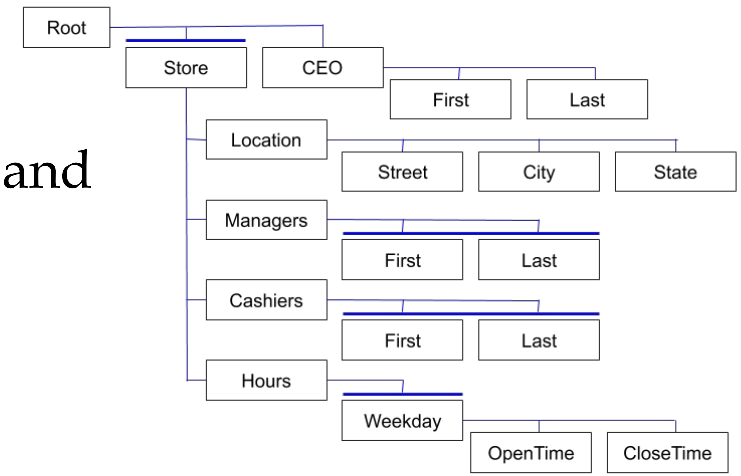
Data Modeling using the Entity-Relationship (ER) Model

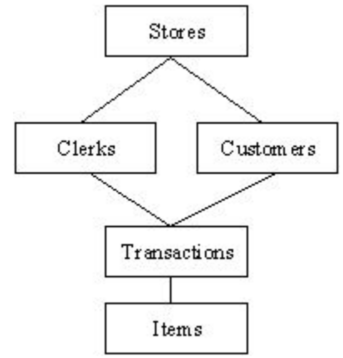
Overview of Database Design

- *"Conceptual Schema" design*:
  - What are the *Entities* and *Relationships* (ER) of the enterprise?
  - What information about these entities and relationships should be stored in the database?
  - What are the *integrity constraints* or *rules* that hold?
  - A database "model" can be represented pictorially (*ER diagrams*), but they are seldom used in practice.
  - ER models are often used to construct relational database.

Other Data Models

- Hierarchal
  - Tree-based
  - Data is partitioned into smaller and smaller groups to facilitate searching and enumeration
- Network
  - Graph-based
  - Datatypes are "linked" to other datatypes
  - Hierarchal and relational are specializations of network models
- Object-Oriented
  - Adds inheritance to the Network model to allow for new, related datatypes





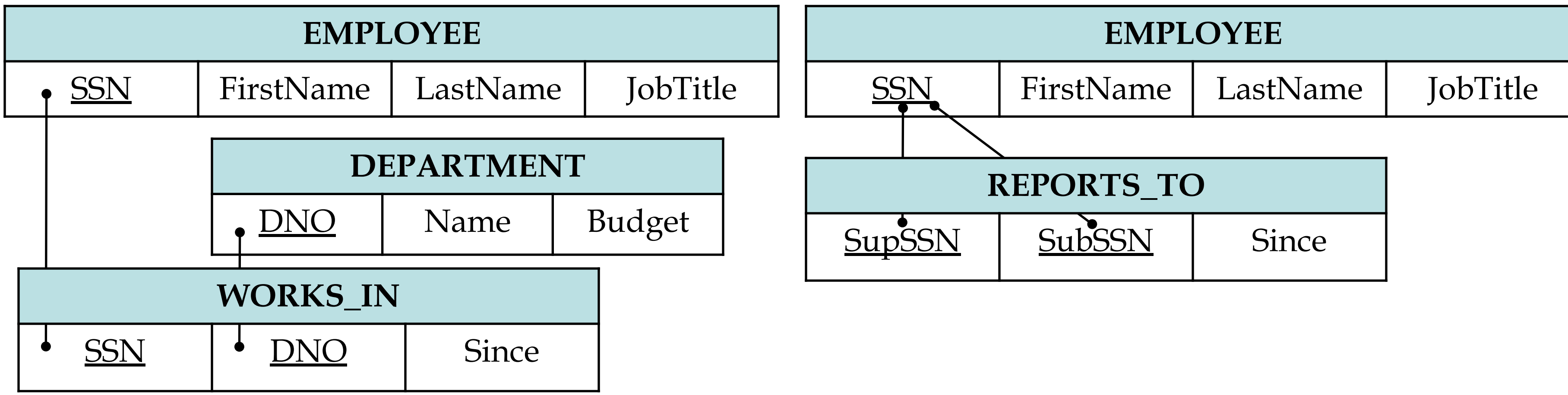
ER Modeling

- *Entity:* A thing distinguishable from other things. Entities are characterized by a set of *attributes*.
- *Entity Set*: A collection of entities. E.g., all employees.
  - All entities in an entity set have the same set of attributes. (Until we consider ISA hierarchies, anyway!)
  - Each entity set has one or more ***key*** attributes that uniquely identifies it. By convention, the key is indicated by underlining.
  - Each attribute has a ***domain***. (a *type* with possible contraints)

ENTITY		
Attribute$_1$	Attribute$_2$	Attribute$_3$

EMPLOYEE			
<u>SSN</u>	FirstName	LastName	JobTitle

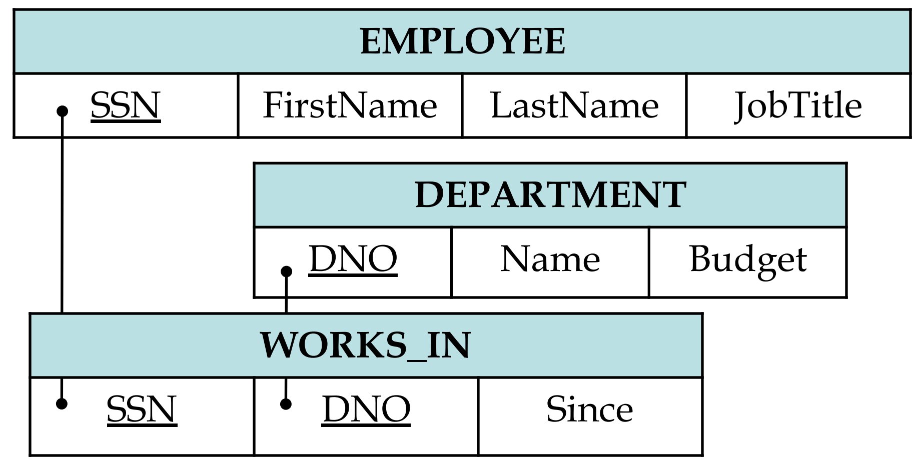
ER Model Basics

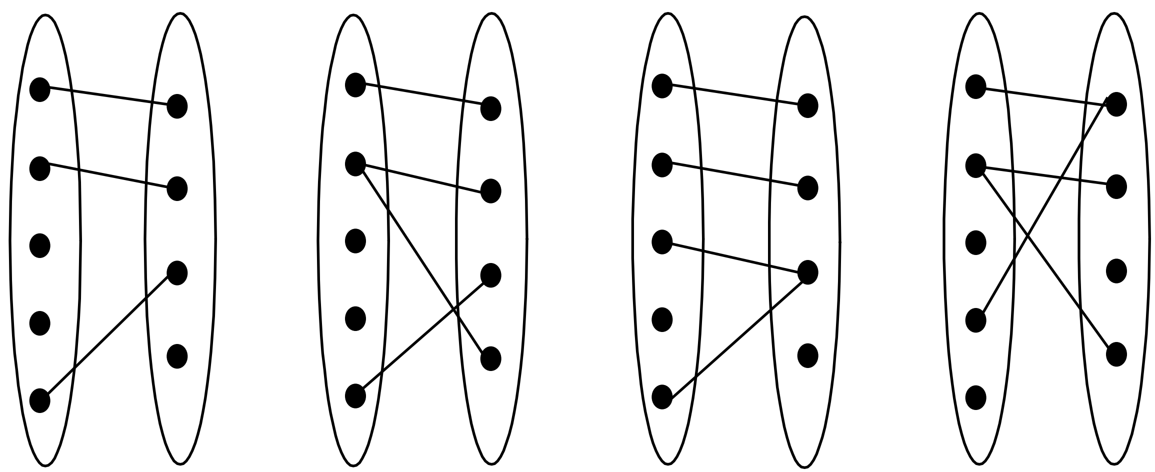


- *Relationship*: Associations between Entities.
  e.g., David works in the Math department.
- *Relationship Set*: Collection of similar relationships.
  - An *n-ary* relationship set, ***R***, relates n entity sets E_1 … E_n; each relationship in ***R*** involves entities $\{(e_1, \ldots, e_2) \mid e_1 \in E_1, \ldots, e_n \in E_n\}$ *a.k.a a tuple*
  - Same entity set could participate in different relationship sets (a member of multiple departments), or in different "roles" in same set (a manger is also an employee).

Key Constraints

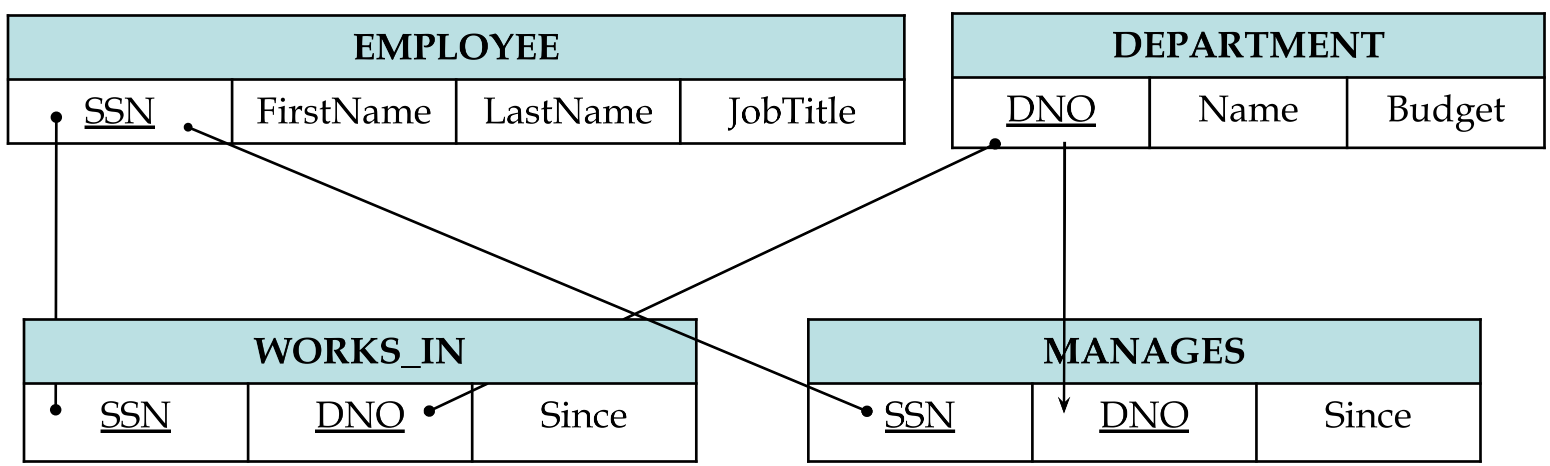
- Consider Works_In: An employee can work in many departments; a dept can have many employees.
- In contrast, each dept might have only one manager, placing *constraints* on Reports_To.





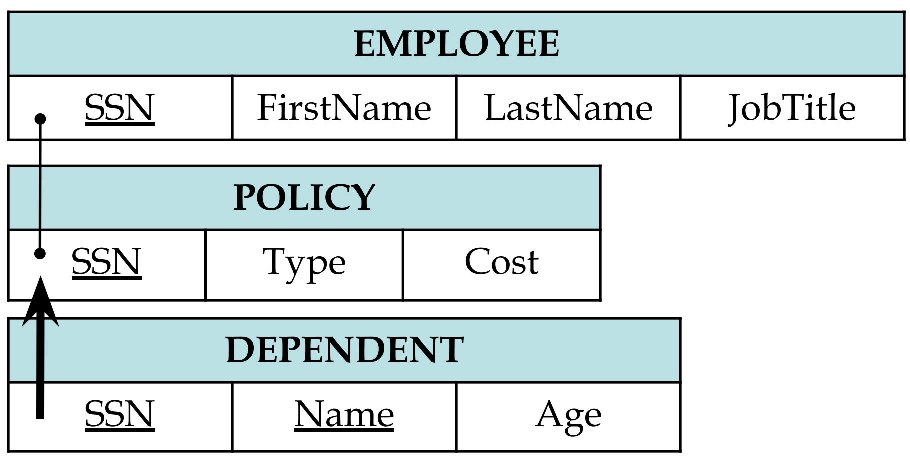
Participation Constraints

- Must every department have a manager?
  - If so, this is a *participation constraint*: the participation of Departments in Manages is said to be *total* (vs. *partial*).
  - Every Departments entity must appear in an instance of the Manages relationship, which relates each department to the employee who manages it.

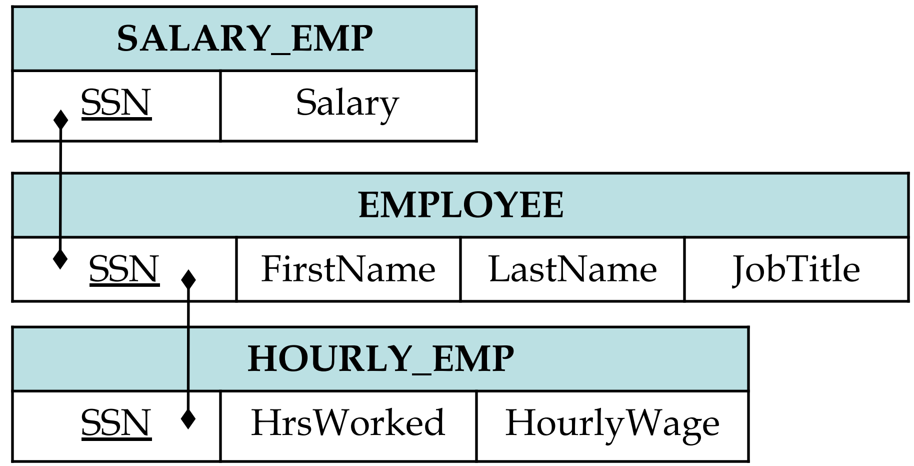


Weak Entities

- A *weak entity* can be identified uniquely only by considering the primary key of another (*owner*) entity.
  - Owner entity set and weak entity set must participate in a one-to-many relationship set (one owner, many weak entities).
  - Weak entity set must have total participation in this *identifying* relationship set.



ISA ('is a') Hierarchies

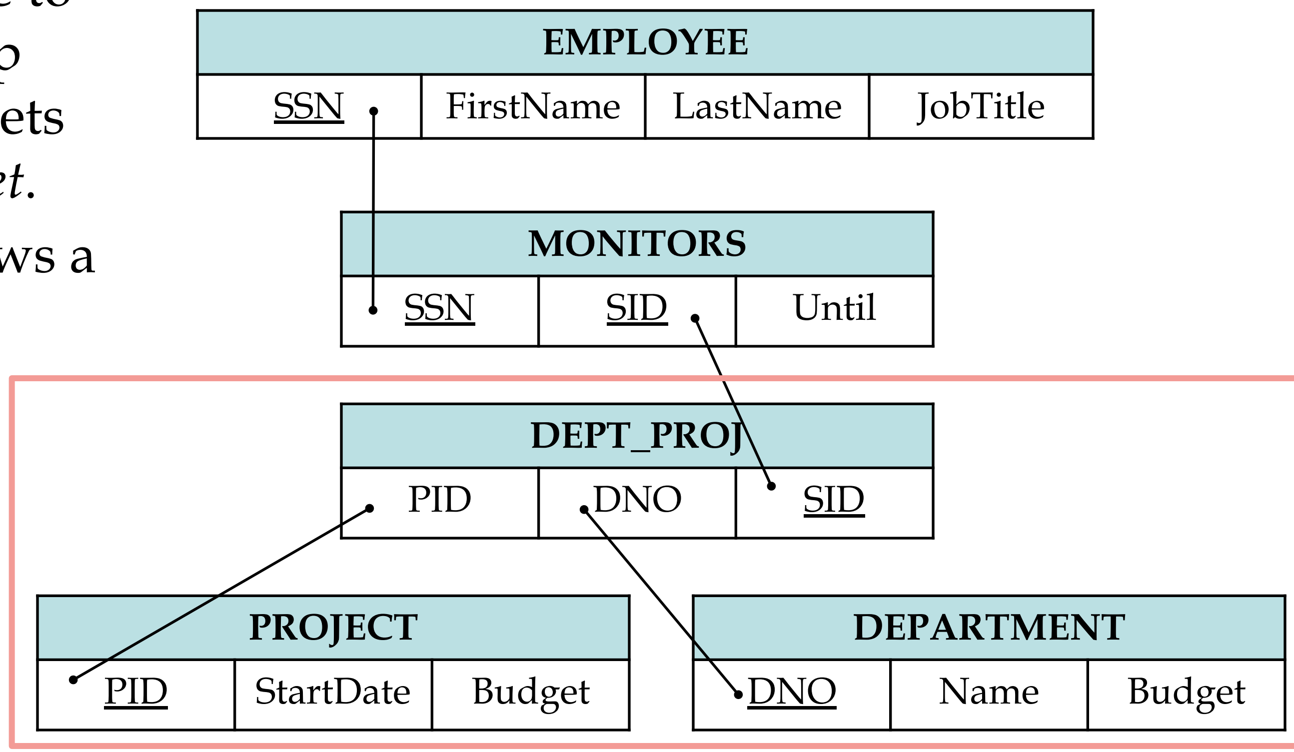


- It is often useful to partition entities into classes, like in an OOL
- If we declare A **ISA** B, every A entity is also considered to be a B entity.

- *Overlap constraints*: Can Joe be an Salary_Emp as well as a Hourly_Emp entity? *(Allowed/disallowed)*
- *Covering constraints*: Does ***every*** Employee entity also have to be either an Salary_Emp or a Hourly_Emp entity? *(Yes/no)*
- Reasons for using ISA:
  - To add descriptive attributes specific to a subclass.
  - To identify entitities that participate in a relationship.

Aggregation

- Used when we have to model a relationship involving (entitity sets and) a *relationship set*.
  - *Aggregation* allows a ***relationship to be treated as an entity*** for purposes of participation in (other) relationships.



Aggregation vs. ternary or higher order relationships:

- Monitors is a distinct relationship with its own descriptive attributes.
- Allows constraints on attribute subsets. A project is monitored by one employee.

Conceptual Design Using the ER Model

- Design choices:
  - Should a concept be modeled as an entity or an attribute?
  - Should a concept be modeled as an entity or a relationship?
  - Identifying relationships: Binary or ternary? Aggregation?
- Constraints in the ER Model:
  - A lot of data semantics can (and should) be captured.
  - But some constraints cannot be captured in ER models.

Entity vs. Attribute

- Should *address* be an attribute of Employees or an entity (connected to Employees by a relationship)?
- Depends upon the use we want to make of address information, and the semantics of the data:
  - If we have several addresses per employee, *address* must be an entity (since attributes cannot themselves be sets (multivalued)).
  - If the structure (city, street, etc.) is important, e.g., we want to retrieve employees from a given city, *address* must be modeled as an entity (since attribute values are atomic).

Entity vs. Attribute (Contd.)

- Works_In does not allow an employee to work in a department for two or more periods, or track historical information.
- Similar to the problem of wanting to record several addresses for an employee: We want to record *several values of the descriptive attributes for each instance of this relationship.* Accomplished by introducing new entity set, Duration.

EMPLOYEE

<u>SSN</u>	FirstName	LastName	JobTitle

WORKS_IN

<u>SSN</u>	<u>DNO</u>	From	To

DEPARTMENT

<u>DNO</u>	Name	Budget

EMPLOYEE

<u>SSN</u>	FirstName	LastName	JobTitle

WORKS_IN

<u>SSN</u>	<u>DNO</u>	<u>DID</u>

DURATION

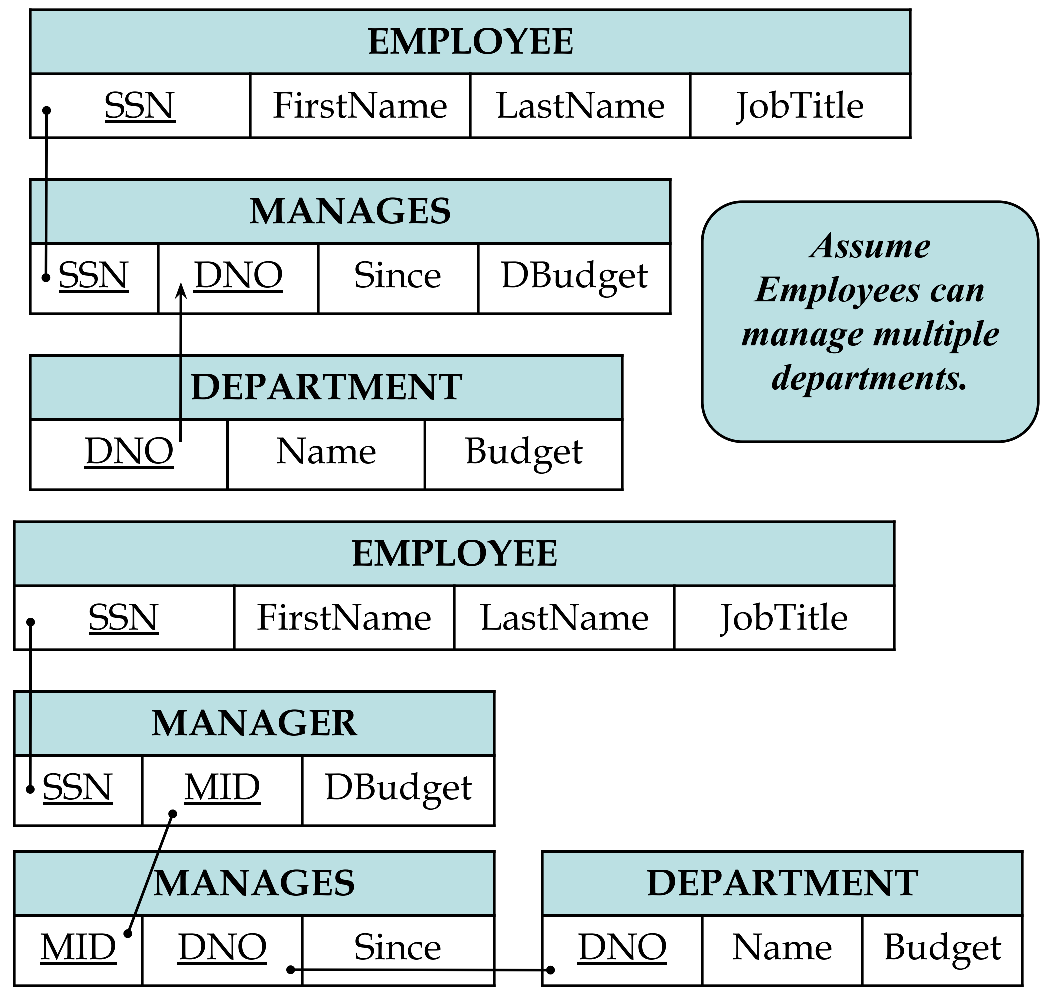
<u>DID</u>	From	To

DEPARTMENT

<u>DNO</u>	Name	Budget

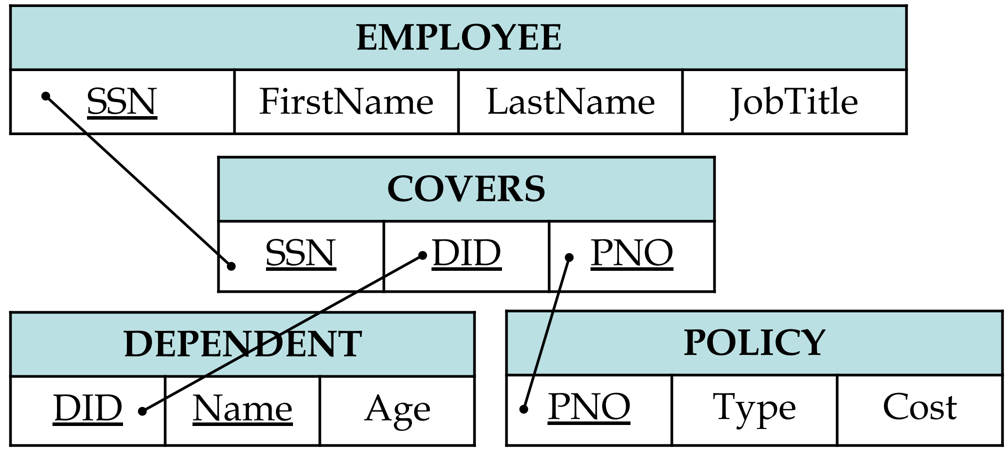
Entity vs. Relationship

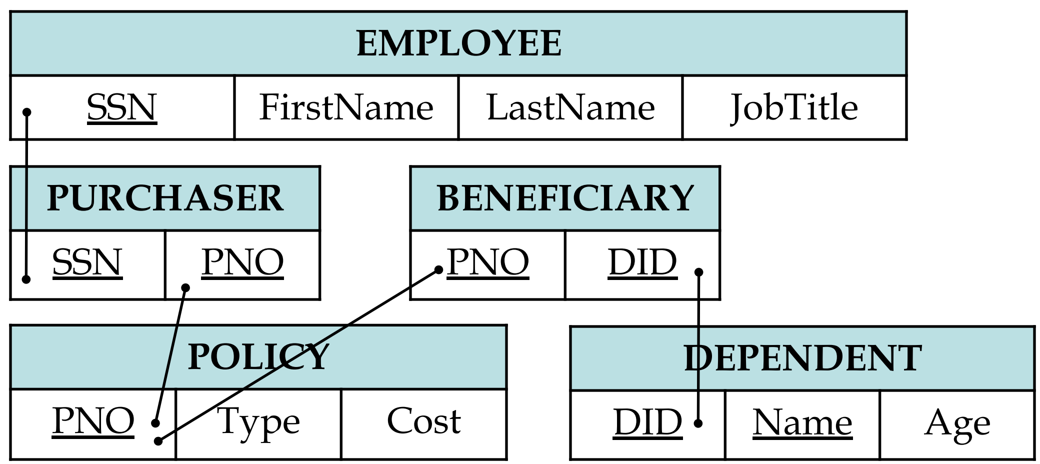
- First ER set OK if a manager gets a separate discretionary budget for each dept.
- What if a manager gets a discretionary budget that covers *all* managed depts?
  - Redundancy: *dbudget* stored for each dept managed by manager.
  - Misleading: Suggests *dbudget* associated with department-mgr combination.



Binary vs. Ternary Relationships

- If each policy is owned by just 1 employee, and each dependent is tied to the covering policy, first diagram is inaccurate.
- What are the additional constraints in the 2nd design?





Binary vs. Ternary Relationships (Contd.)

- Previous example illustrated a case when two binary relationships were better than one ternary relationship.
- An example in the other direction: a ternary relation Contracts relates entity sets Parts, Departments and Suppliers, and has descriptive attribute *qty*. No combination of binary relationships is an adequate substitute:
  - S "can-supply" P, D "needs" P, and D "deals-with" S does not imply that D has agreed to buy P from S.
  - Where do we record *qty*?

Summary of Conceptual Design

- *Conceptual design* follows *requirements analysis,*
  - Yields a high-level description of data to be stored
- ER model popular for conceptual design
  - Constructs are expressive, close to the way people think about their applications.
- Basic constructs: *entities*, *relationships*, and *attributes* (of entities and relationships).
- Some additional constructs: *weak entities*, *ISA hierarchies*, and *aggregation*.
- Note: There are many variations on ER model.

Summary of ER (Contd.)

- Several kinds of integrity constraints can be expressed in the ER model: *key constraints, participation constraints*, and *overlap/covering constraints* for ISA hierarchies. Some *foreign key constraints* are also implicit in the definition of a relationship set.
  - Some constraints (notably, *functional dependencies*) cannot be expressed in the ER model.
  - Constraints play an important role in determining the best database design for an enterprise.

Summary of ER (Contd.)

- ER design is *subjective*. There are often many ways to model a given scenario! Analyzing alternatives can be tricky, especially for a large enterprise. Common choices include:
  - Entity vs. attribute, entity vs. relationship, binary or n-ary relationship, whether or not to use ISA hierarchies, and whether or not to use aggregation.
- Ensuring good database design: resulting relational schema should be analyzed and refined further. FD information and normalization techniques are especially useful.

Next Time

- Setup an environment
- Look at files
- Basic file "model"
- Think about how scan and process data