The Relational Data Model

2. The Relational Data Model

- use a simple and uniform data structure: the relation
- has been implemented in most commercial database systems
- has a solid theoretic foundation.

2.1 Structures

- In the relational model, everything is described using relations.
- A relation can be thought of as a named table.
- Each column of the table corresponds to a named attribute.
- The set of allowed values for an attribute is called its domain.
- Each row of the table is called a tuple of the relation.
- N.B. There is no ordering of column or rows.

Example

PLAYER					
Name	Position	Goals	Age	Height	Weight
Heady	Half-forward	17	24	183	83
Sumich	Full-forward	59	26	191	92
Langdon	Utility	23	23	189	86

PLAYER					
Name	Age	Height	Weight	Goals	Position
Sumich	26	191	92	59	Full-forward
Langdon	23	189	86	23	Utility
Heady	24	183	83	17	Half-forward

Above two tables are the same relation ---- Player

- Mathematically,
  - a *domain D* is a set of atomic values (having some fixed data type) which represent some semantic meaning.
  - an *attribute*, *A*, is the name of a role played by a *domain*, *dom*(*A*).
  - a *relation schema R*, denoted by

    $R(A_1,A_2, ...,A_n)$, is a set of attributes

    $R = \{A_1,A_2, ...,A_n\}$.

Composite and multivalued attributes are disallowed!

- A *tuple*, $t(A_1,A_2, ...,A_n)$, is a point in $dom(A_1) \times \ldots \times dom(A_n)$ where each $dom(A_j)$ is the domain of A_j.

- A *relation (or a relation instance)* is a set of tuples: a subset of

$$dom(A_1) \times \ldots \times dom(A_n).$$

- A relation schema is used to describe a relation.

- The *degree* of a relation is the number of attributes of its relation schema.

Relational Data Model vs ER Model:

- Relation schema (intension) ⇄ entity or relationship type schema (intension).
- attributes ⇄ attributes
- tuple ⇄ instance of entity/relationship
- relation (instance, extension) ⇄ entity/relationship extension
- composite and multivalued attributes are allowed in ER model, but not allowed in relational data model.

- *Keys* are used to identify tuples in a relation.
- A *superkey* is a set of attributes that uniquely determines a tuple.
- Note that this is a property of the relation that does not depend on the current relation instance.
- A *candidate key* is a superkey, none of whose *proper* subsets is a superkey.
- Keys are determined by the applications.
- E.g. if {Name} is unique then it is a candidate key for PLAYER; otherwise we need to use the whole tuple or create a candidate key, say PID.
- {Goals} usually cannot not be a candidate key since different players *might* have the same number of goals.
- {Name, Goals} is a superkey but not a candidate key if {Name} is a key.

- A *primary key* is a designated candidate key.

- In many applications it is necessary to invent a primary key if there is no natural one - often this would be a non-negative integer

- e.g. Person_number.

- When a relation schema has several candidate keys, usually better to choose a primary key with a single attribute or a small number of attributes.

2.2 Integrity constraints

- There are several kinds of integrity constraints that are an integral part of the relational model:

- **2.2.1 Key constraint**: candidate key values must be unique for every relation instance.

- **2.2.2 Entity integrity**: an attribute that is part of a primary key cannot be NULL.

- **2.2.3 Referential integrity:** The third kind has to do with “foreign keys”.

- Foreign keys are used to refer to a tuple in another relation.

- A set, *FK*, of attributes from a relation schema R1 may be a foreign *key* if

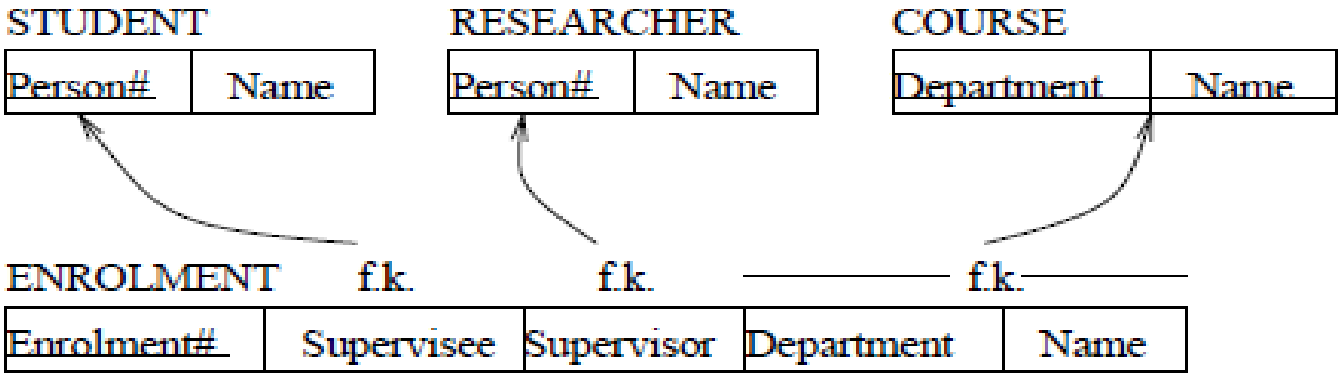
  - the attributes have the same domains as the attributes in the primary key of another relation schema R_2, and

  - a value of FK in a tuple t_1 of R_1 either occurs as a value of PK for some tuple t_2 in R_2 or is null.

- *Referential integrity*: The value of *FK* must occur in the other relation or be entirely NULL.

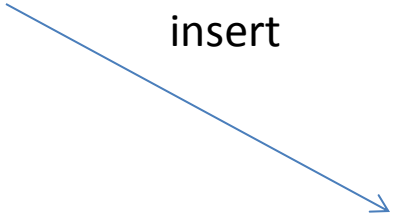
2.2.4 Checking constraints on updates

- To maintain the integrity of the database, we need to check that integrity constraints will not be violated before proceeding with an update.
- Example: Suppose we have the following schema with foreign keys as shown:



<2, Dr. V. Ciesielski>

insert



RESEARCHER	
Person#	Name
1	Dr.C.C.Chen
2	Dr.R.G.Wilkinson

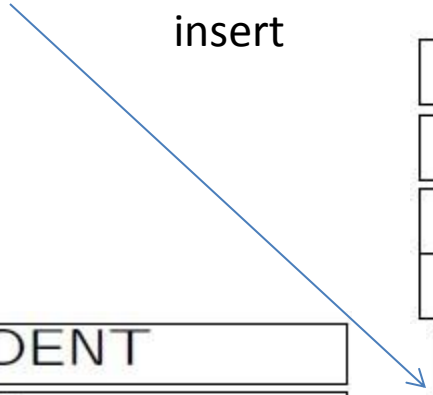
STUDENT	
Person#	Name
1	Dr.C.C.Chen
3	Ms.K.Juliff
4	Ms.J.Gledill
5	Ms.B.K.Lee

COURSE	
Department	Name
Psychology	Ph.D.
Comp.Sci.	Ph.D.
Comp.Sci.	M.Sc.
Psychology	M.Sc.

ENROLMENT				
Enrolment#	Supervisee	Supervisor	Department	Name
1	1	2	Psychology	Ph.D.
2	3	1	Comp.Sci.	Ph.D.
3	4	1	Comp.Sci.	M.Sc.
4	5	1	Comp.Sci.	M.Sc.

<Comp.Sci., NULL>

insert



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3	4	1	Comp.Sci.	M.Sc.
4	5	1	Comp.Sci.	M.Sc.

<5, 6, 2, Psychology, Ph.D>

insert

RESEARCHER	
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2	Dr.R.G.Wilkinson

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COURSE	
Department	Name
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Comp.Sci.	Ph.D.
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4	5	1	Comp.Sci.	M.Sc.

- *Insertions*: When inserting, we need to check
  - that the candidate keys are not already present,
  - that the value of each foreign key either
    - –is all null, or
    - – is all non-NULL and occurs in the referenced relation.

Examples:

1. Insert < 2, *Dr.V.Ciesielski* > into RESEARCHER

   Allowed? No. Violates a key constraint.

   Action? Reject or allow the user to correct.

2. Insert < *Comp.Sci.*,*NULL* > into COURSE

   Allowed? No. Violates the entity integrity

   constraint.

   Action: Reject or correct.

3. Insert < 5, 6, 2, *Psychology*, *Ph.D.* > into

   ENROLMENT

   Allowed? No. Violates a referential integrity

   constraint (There is no person number 6).

   Action: Reject, correct or accept after insertion

   of person number 6.

- *Deletions*: When deleting, we need to check referential integrity – check whether the primary key occurs in another relation.

Examples:

1. Delete tuple with Person# = 2 from RESEARCHER

   Allowed? No. Violates the referential integrity.

   Action: Reject, correct or modify the ENROLMENT tuple by

- deleting it (note that the this requires another integrity check, possibly causing a cascade of deletions), or
- setting the foreign key value to NULL (note this can’t be done if it is part of a primary key), or
- setting the foreign key value to another acceptable value.

Modifications:

If the modified attribute is a

- primary key: this is similar to deleting and then reinserting.
- foreign key: check that the new value refers to an existing tuple.
- neither: no problems can arise.

2.2.5 Relational database definition

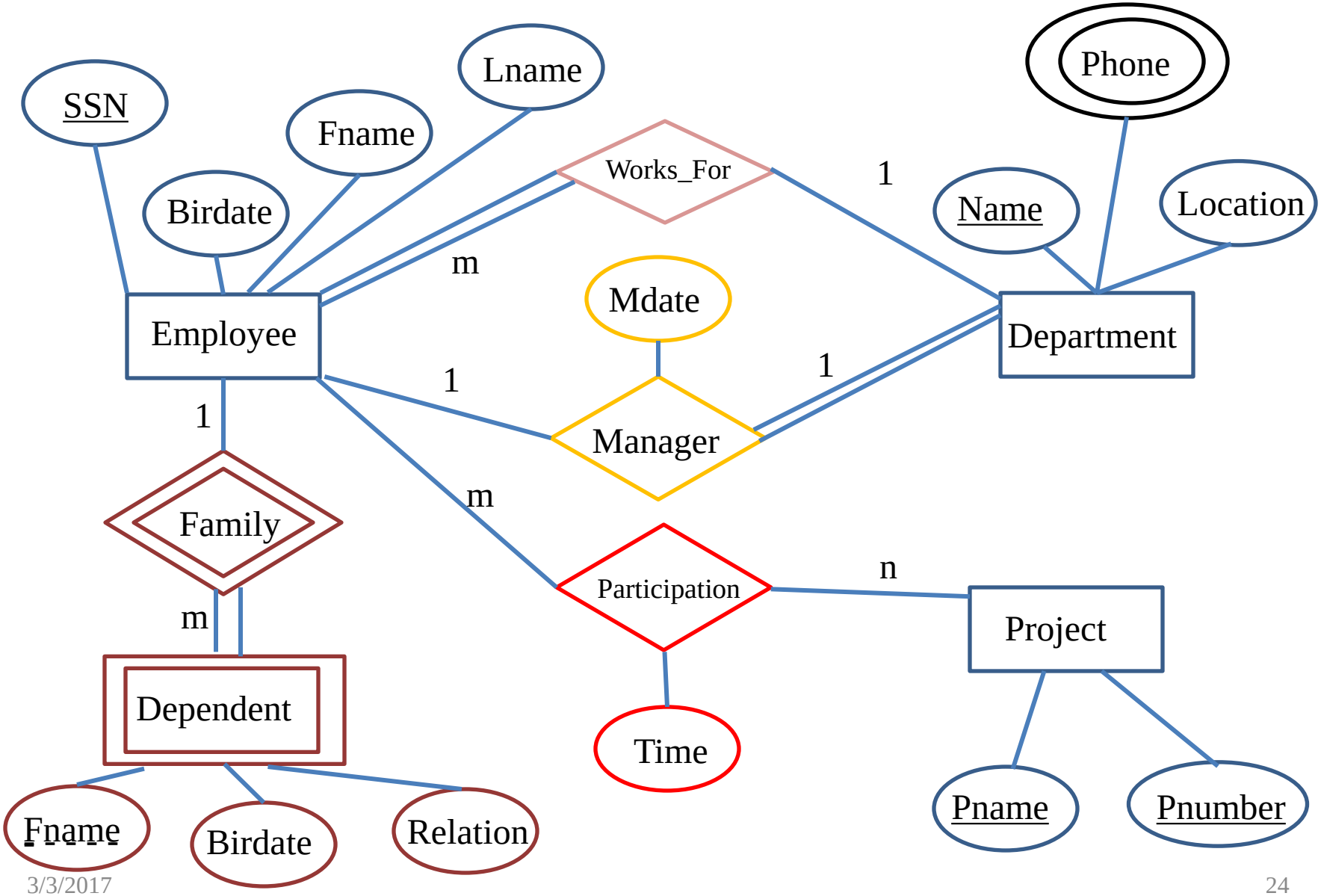
- A *relational database schema*, is a set of relation schema $\{R_1, \ldots, R_m\}$ and a set of integrity constraints.

- A relational database instance is a set of relation instances $\{r_1, \ldots, r_m\}$ such that each r_i is an instance of R_i , and the integrity constraints are satisfied.

2.3 ER to Relational Data Model Mapping

- One technique for database design is to first design a conceptual schema using a high-level data model, and then map it to a conceptual schema in the DBMS data model for the chosen DBMS.
- Here we look at a way to do this mapping from the ER to the relational data model.
- It involves the following 7 steps.

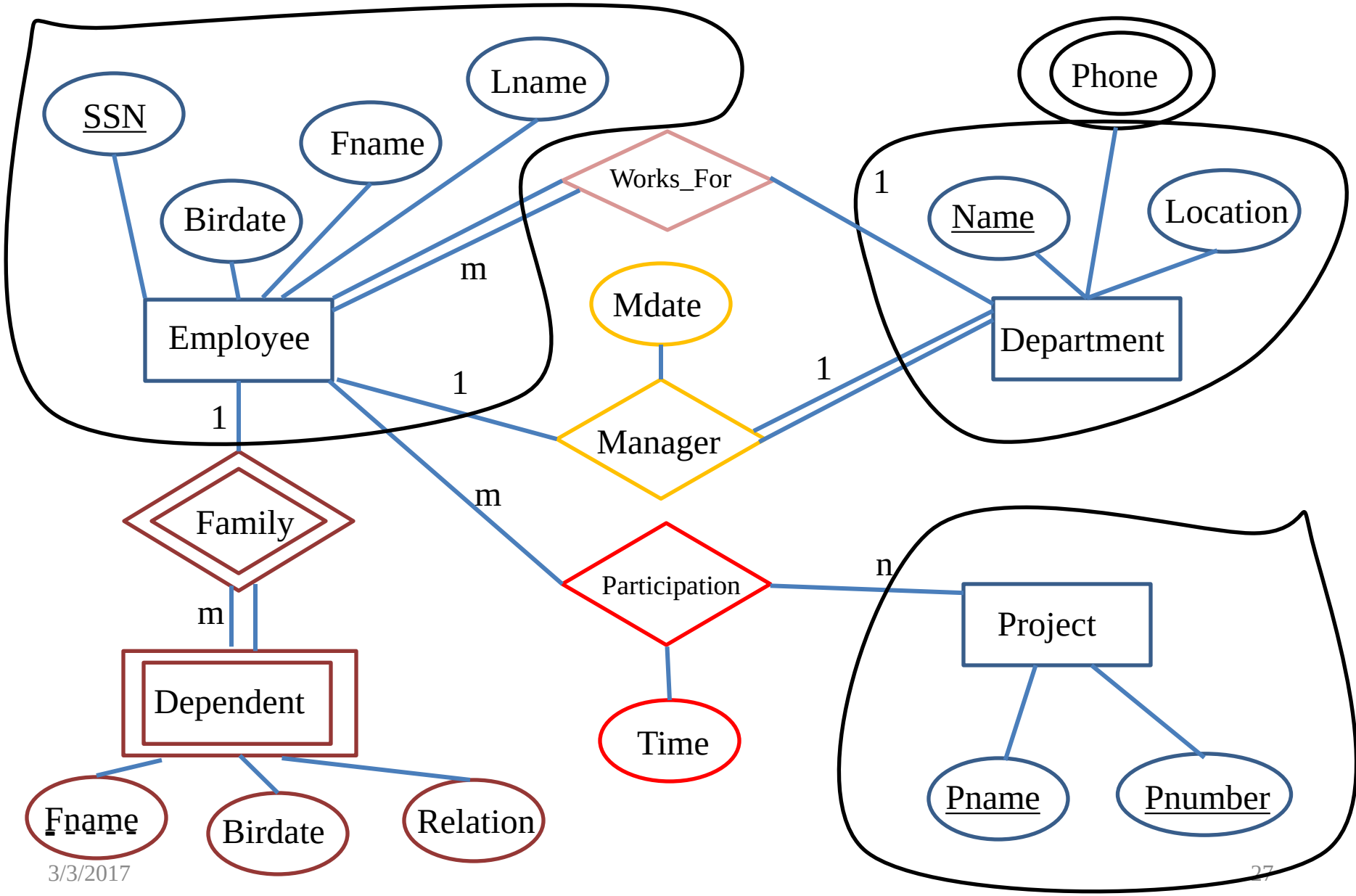
- Example: ER → RDB



- Step 1 : For each regular (not weak) entity type E, create a relation R with
  - Attributes : All simple attributes (and simple components of composite attributes) of E.
  - Key : Choose one of the keys of E as the primary key for the relation.

- Step 1a : For each specialised entity type E, with parent entity type P, create a relation R with
  - Attributes : The attributes of the key of P, plus the simple attributes of E.
  - Key : The key of P.

- Example: ER → RDB



Employee

SSN	Fname	Lname	Birdate

Department

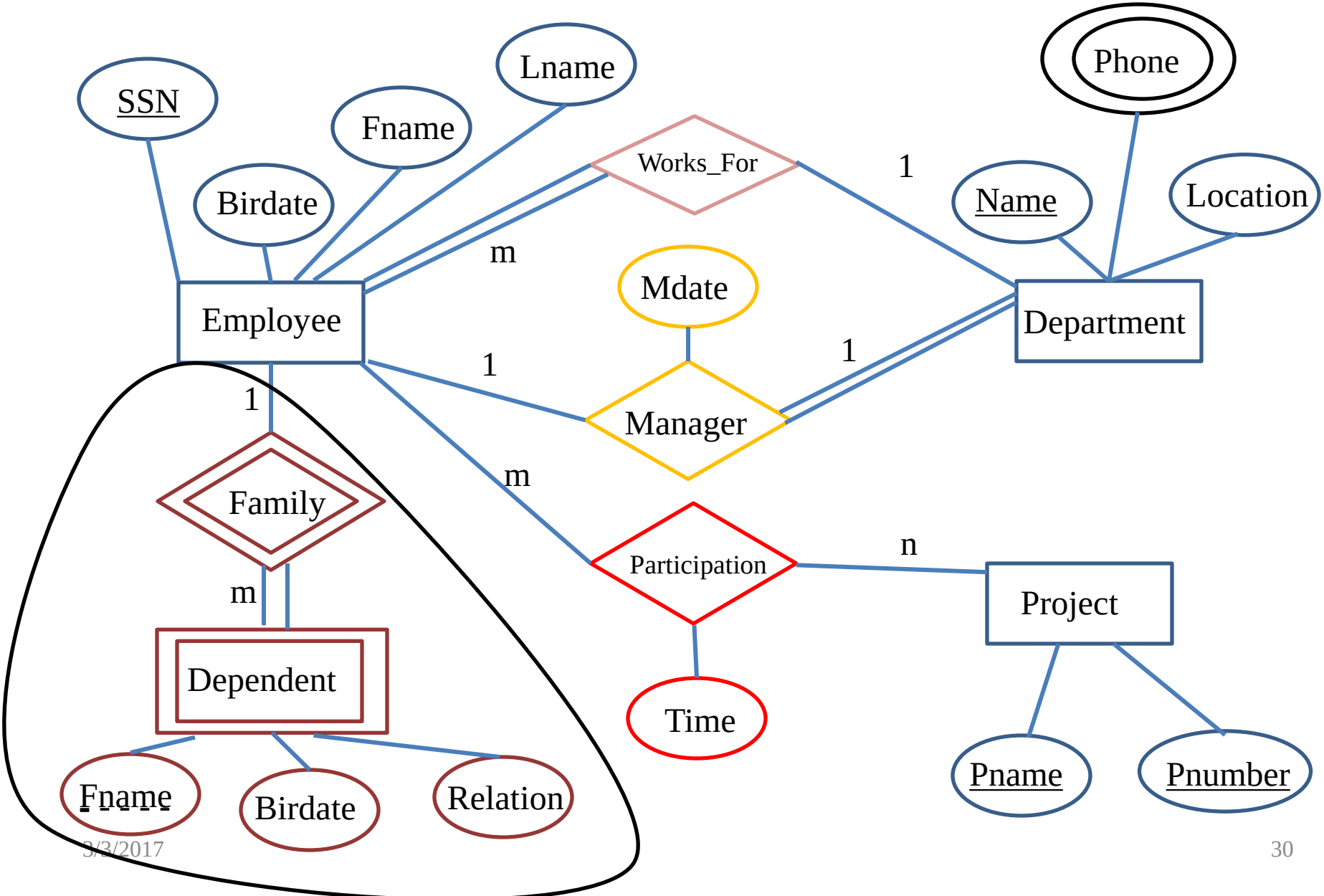
Name	Location

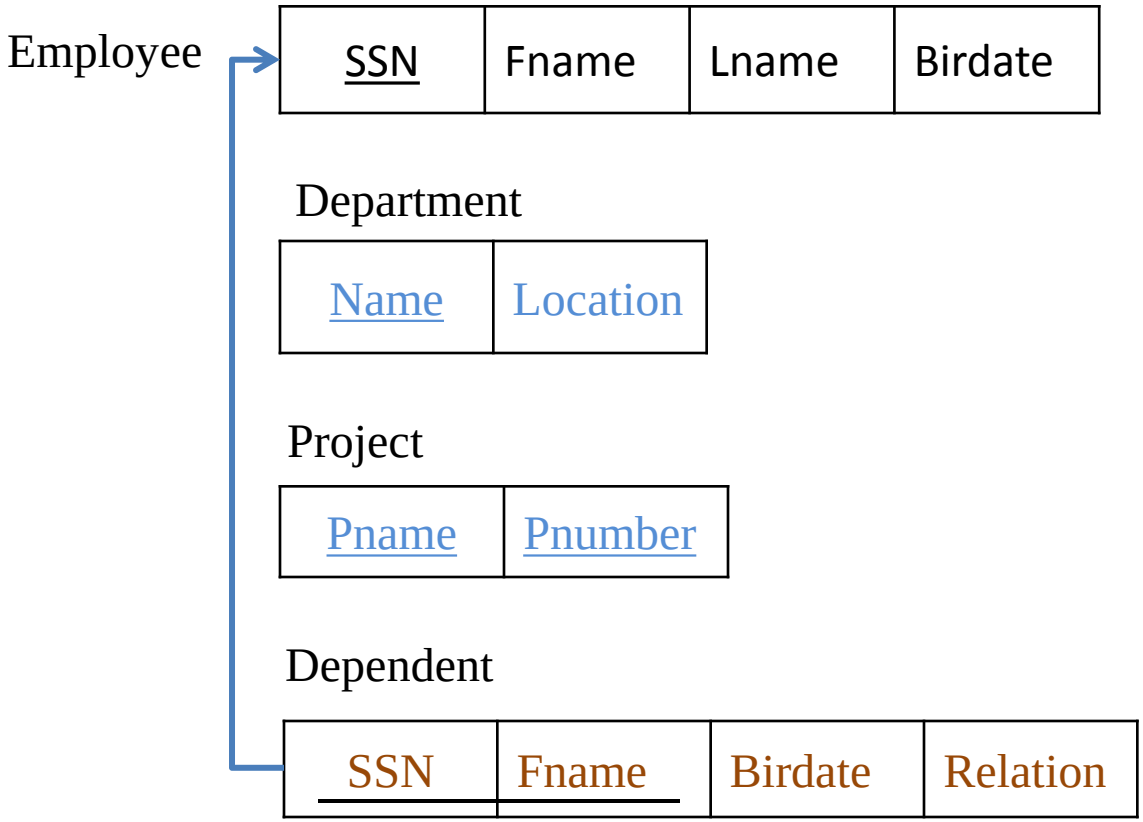
Project

Pname	Pnumber

- Step 2 : For each weak entity type W, with owner entity type E, create a relation R with
  - Attributes : All simple attributes (and simple components of composite attributes) of W, and include as a foreign key the prime attributes of the relation derived from E.
  - Key : The foreign key plus the partial key of W.

- Example: ER → RDB



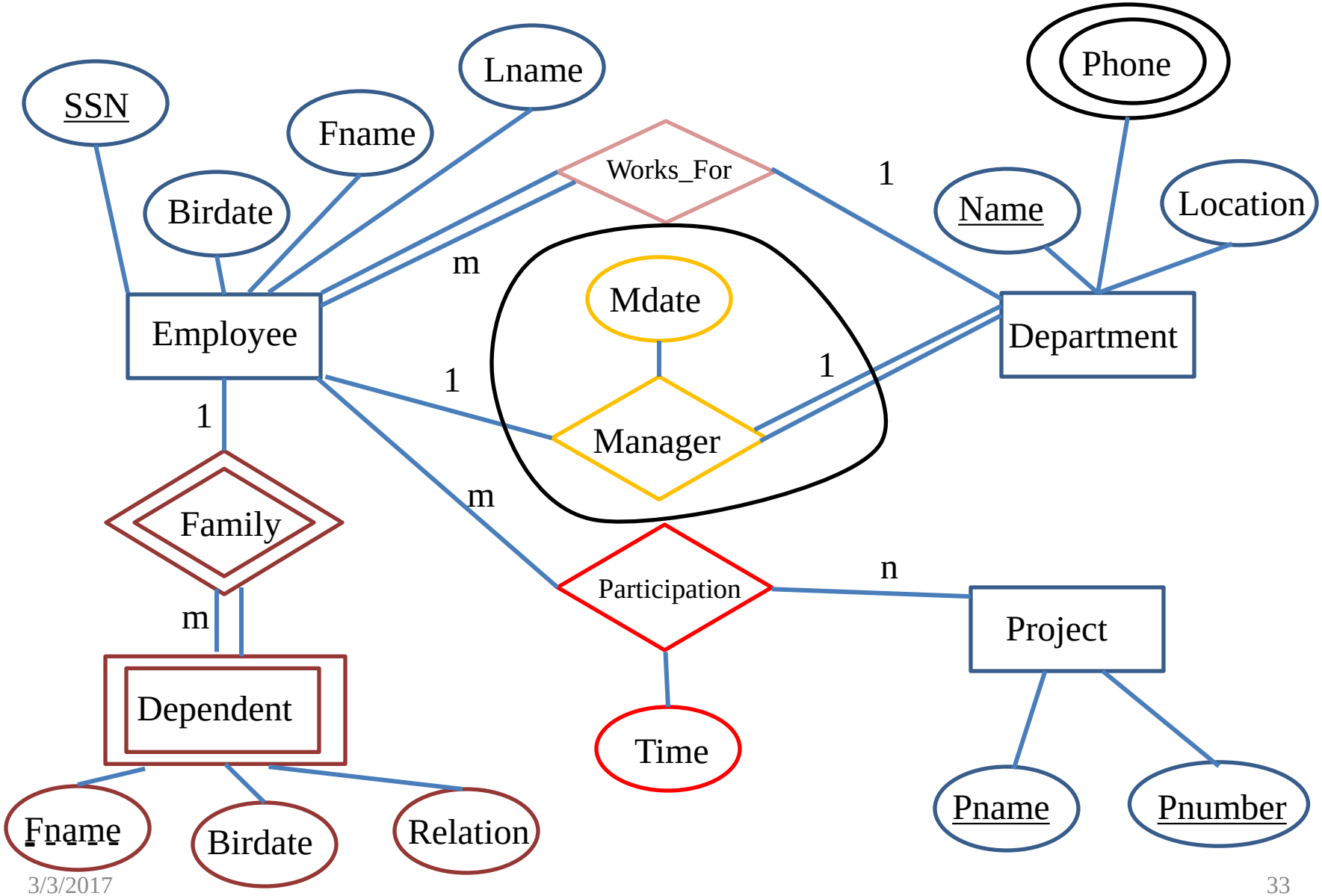

Employee
SSN
Fname
Lname
Birdate
Department
Name
Location
Project
Pname
Pnumber
Dependent
SSN
Fname
Birdate
Relation

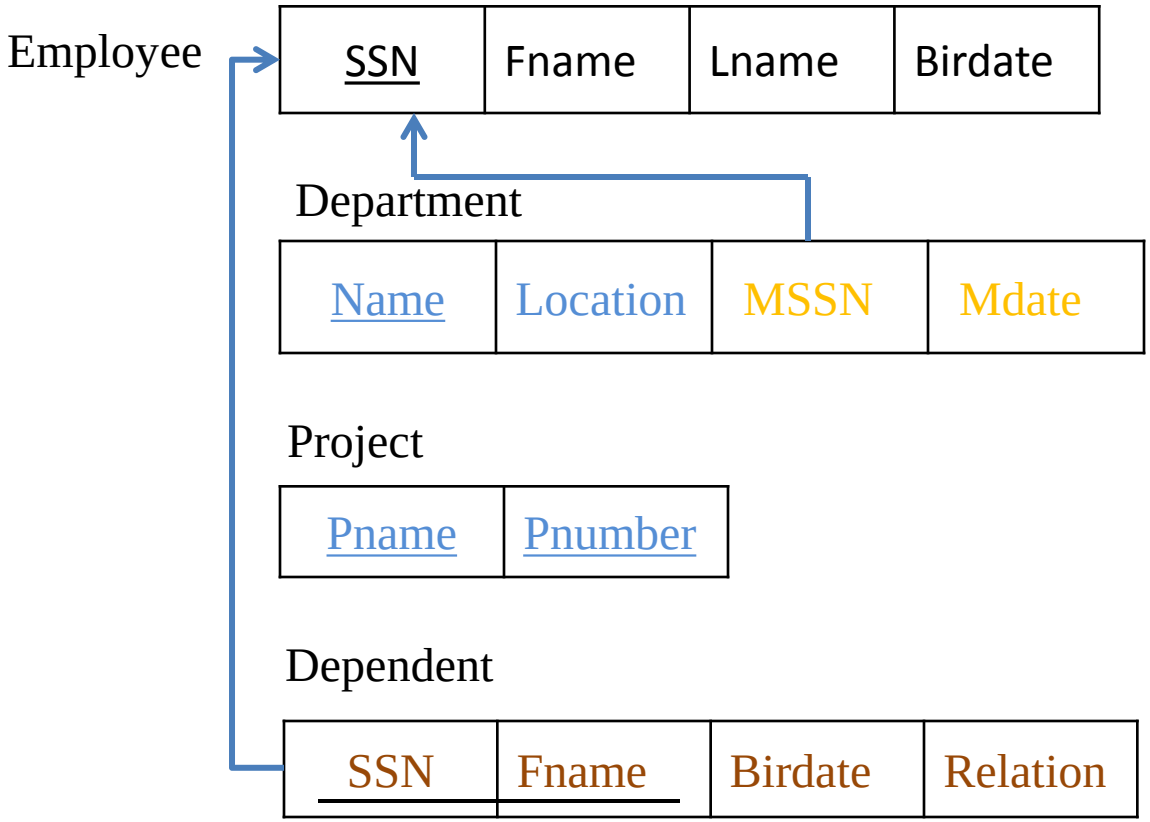
- Step 3 : For each 1:1 relationship type B. Let E and F be the participating entity types. Let S and T be the corresponding relations.

  - Choose one of S and T (prefer one that participates totally), say S.
  - Add the attributes of the primary key of T to S as a foreign key.
  - Add the simple attributes (and simple components of composite attributes) of B as attributes of S.

(Alternative: merge the two entity types and the relationship into a single relation, especially if both participate totally and do not participate in other relationships).

- Example: ER → RDB

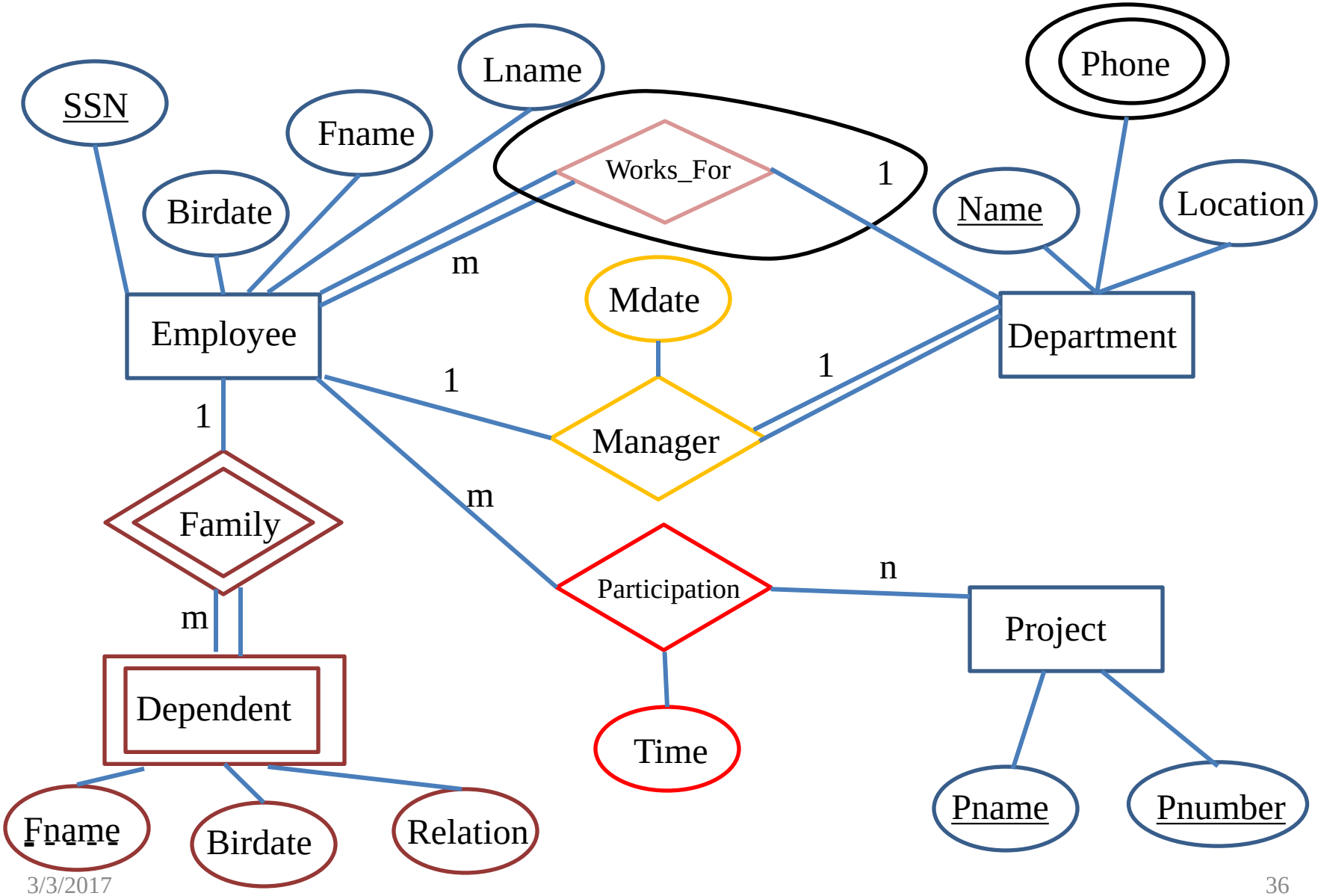


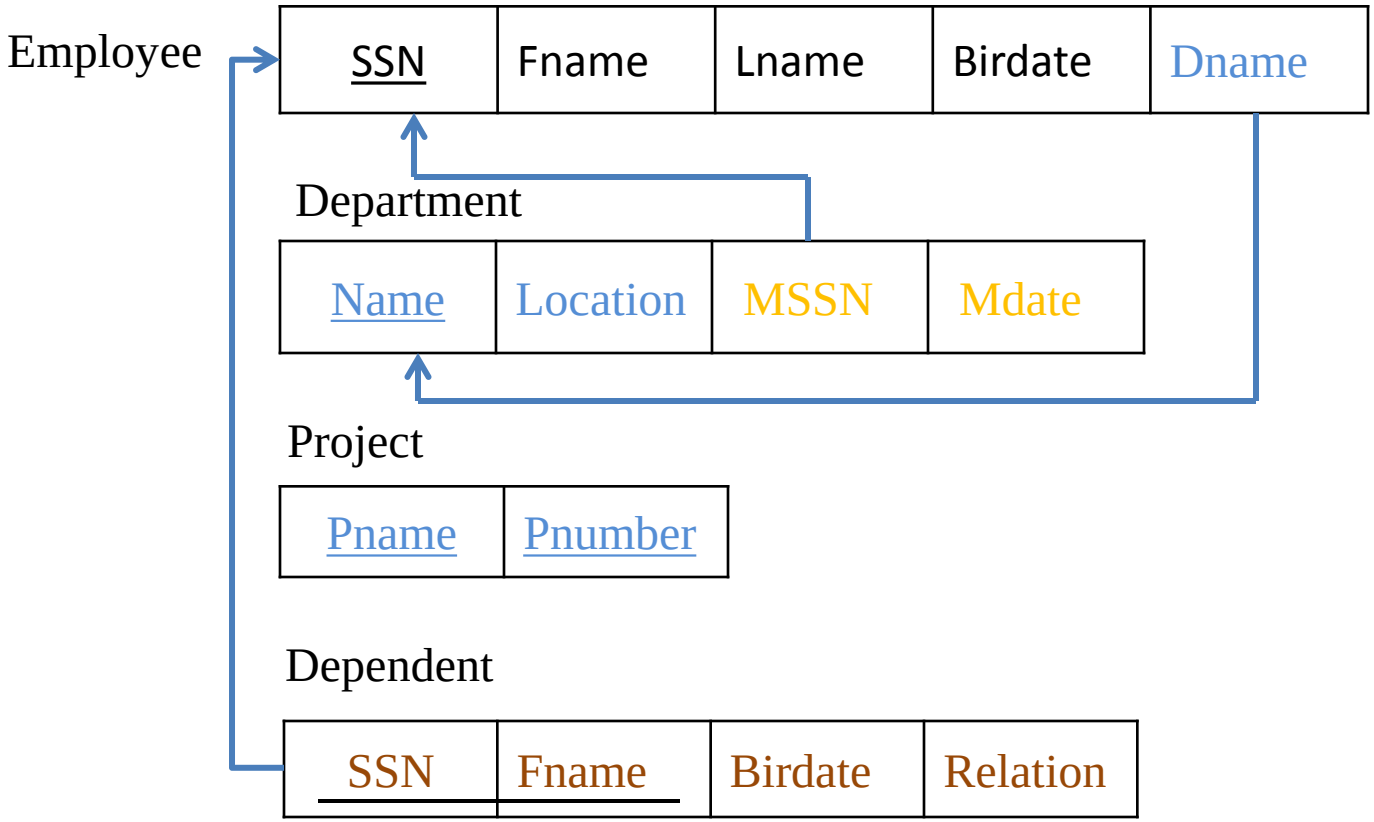

Employee
SSN
Fname
Lname
Birdate
Department
Name
Location
MSSN
Mdate
Project
Pname
Pnumber
Dependent
SSN
Fname
Birdate
Relation

- Step 4 : For each regular 1:N relationship type B.
  - Let E and F be the participating entity types.
  - Let E by the entity type on the 1 side, F the one on the N side.
  - Let S and T be the corresponding relations.
  - Add the attributes of the primary key of S to T as a foreign key.
  - Add to T any simple attributes (or simple components of composite attributes) of the relationship.

(Notice that this doesn’t add any new tuples, just attributes.)

- Example: ER → RDB




Employee
SSN
Fname
Lname
Birdate
Dname
Department
Name
Location
MSSN
Mdate
Project
Pname
Pnumber
Dependent
SSN
Fname
Birdate
Relation

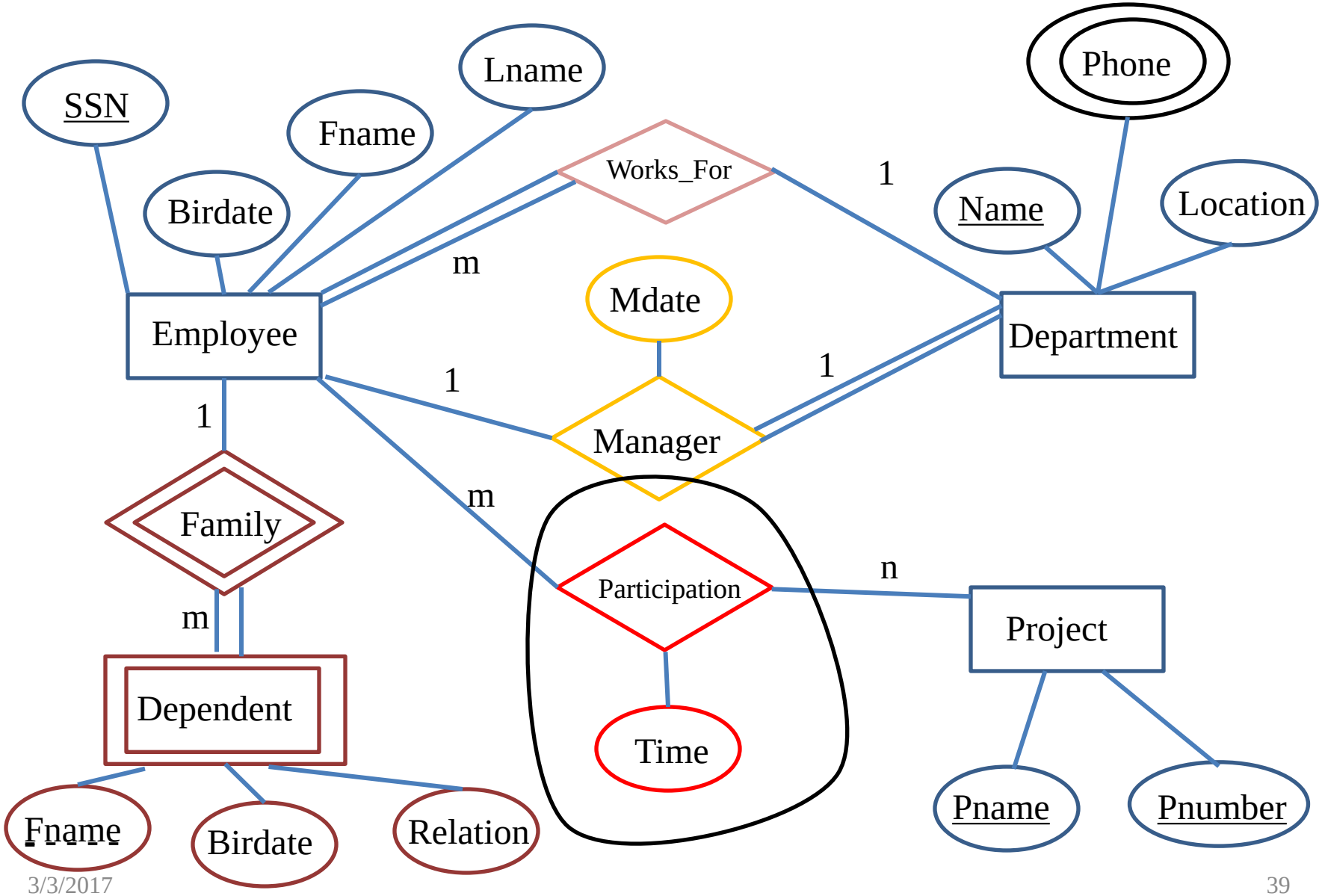
- Step 5 : For each N:M relationship type B. Create

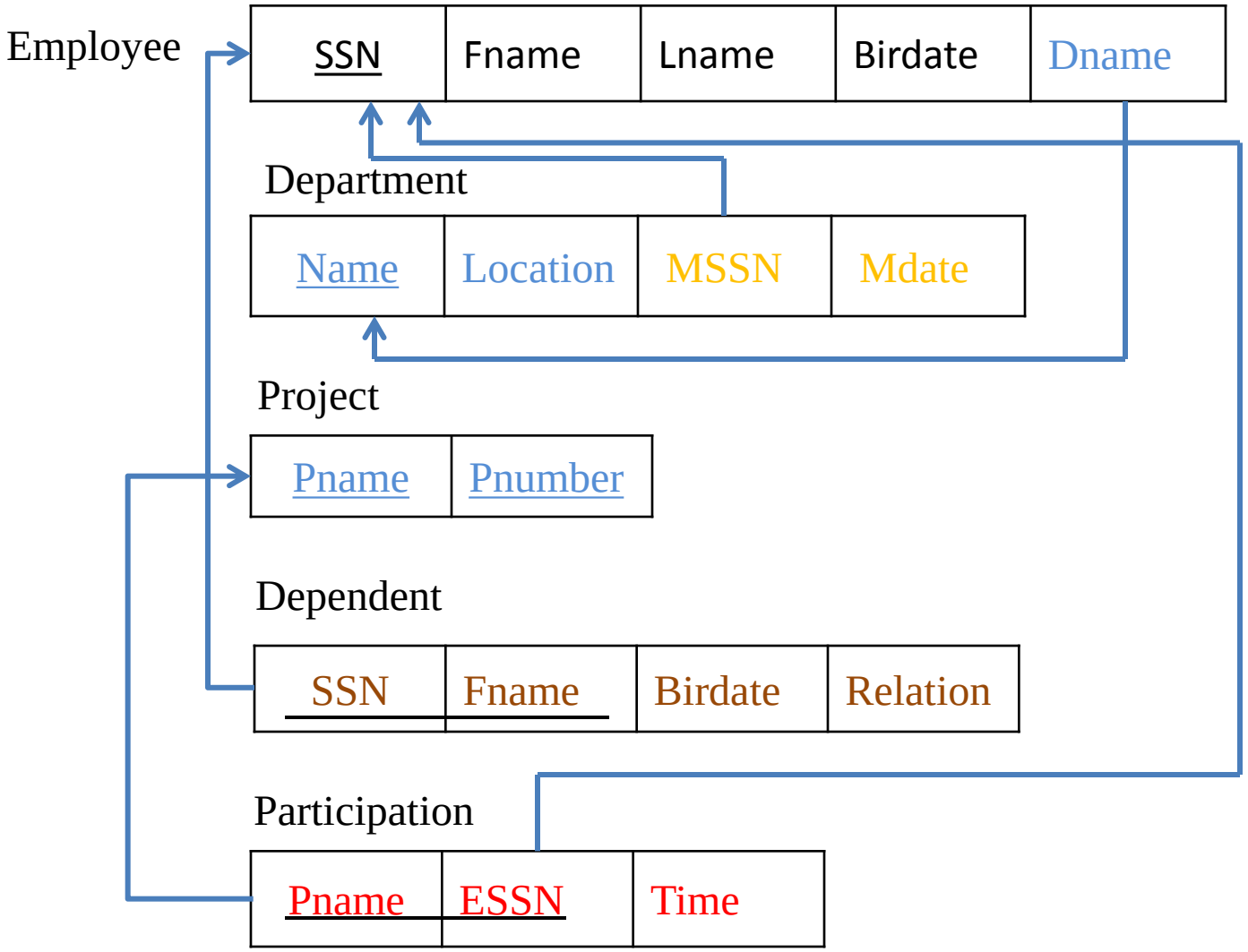
a new relation R. Let E and F be the participating entity types. Let S and T be the corresponding relations.

  - Attributes : The key of S and the key of T as foreign keys, plus the simple attributes (and simple components of composite attributes) of B.

  - Key : The key of S and the key of T.

- Example: ER → RDB



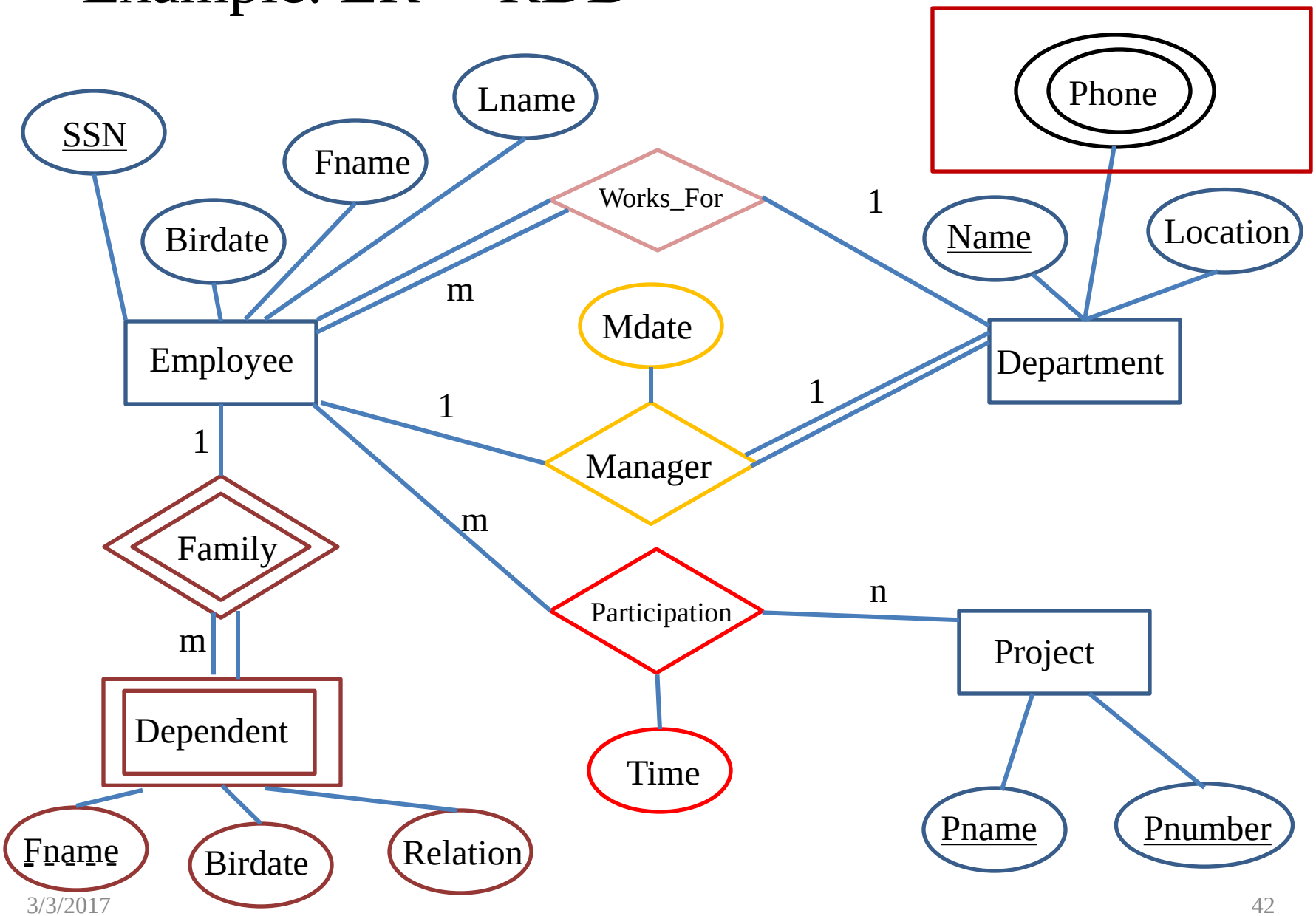

Employee
SSN
Fname
Lname
Birdate
Dname
Department
Name
Location
MSSN
Mdate
Project
Pname
Pnumber
Dependent
SSN
Fname
Birdate
Relation
Participation
Pname
ESSN
Time

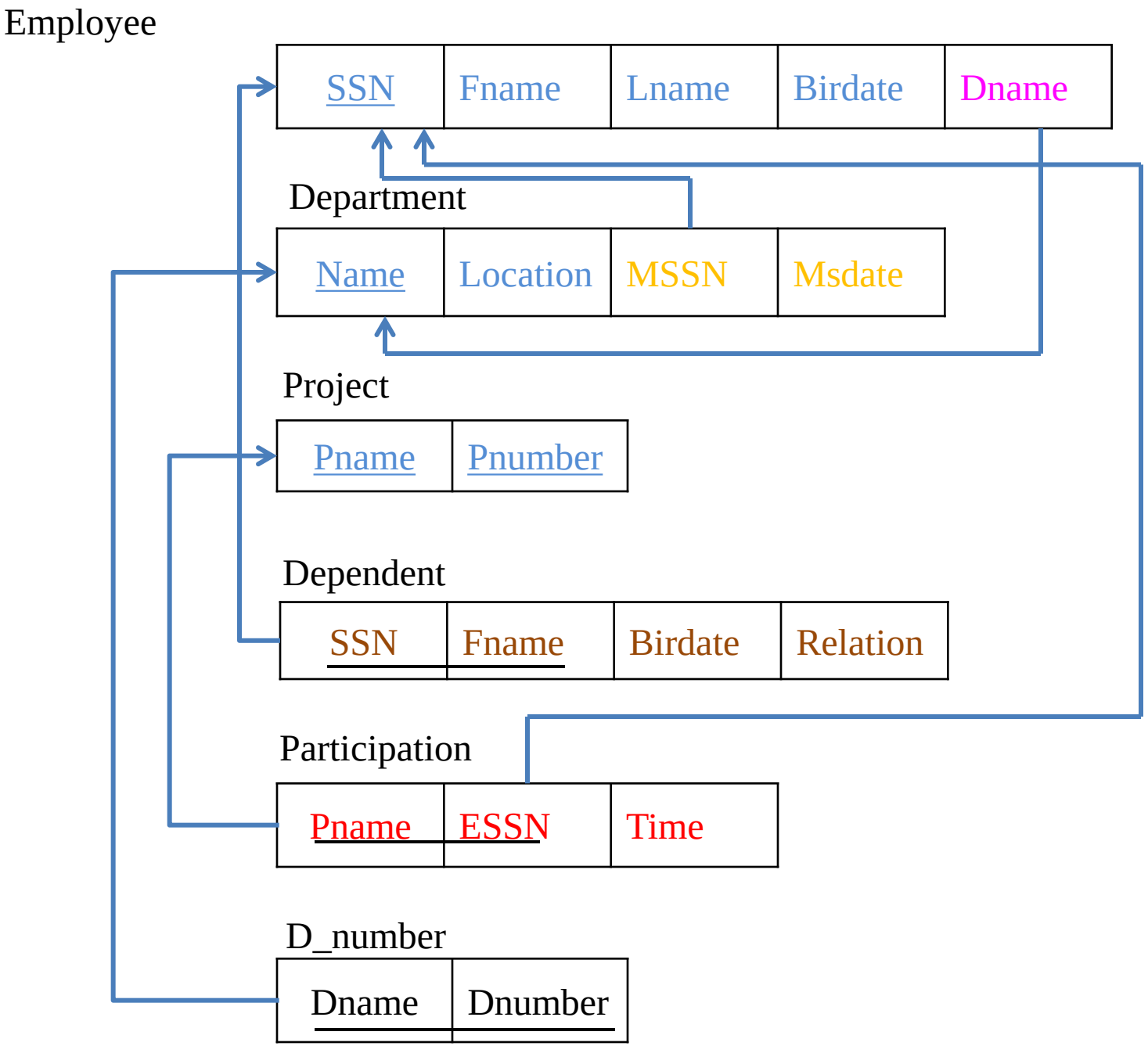
- Step 6 : For each multivalued attribute A. Create a new relation R. Let A be an attribute of E.

– Attributes :
  1. A (if A is a simple attribute) together with the key of E as a foreign key.
  2. The simple components of A (if A is a composite attribute), together with the key of E as a foreign key.

– Key : All attributes.

- Example: ER → RDB




Employee
SSN
Fname
Lname
Birdate
Dname
Department
Name
Location
MSSN
Msdate
Project
Pname
Pnumber
Dependent
SSN
Fname
Birdate
Relation
Participation
Pname
ESSN
Time
D_number
Dname
Dnumber

- Step 7 : For each n-ary relationship type (n > 2). Create a new relation with

  - Attributes : as for Step 5.

  - Key : as for Step 5, except that if one of the participating entity types has participation ratio 1, its key can be used as a key for the new relation.