# The Relational Data Model

Textbook: chapter 5

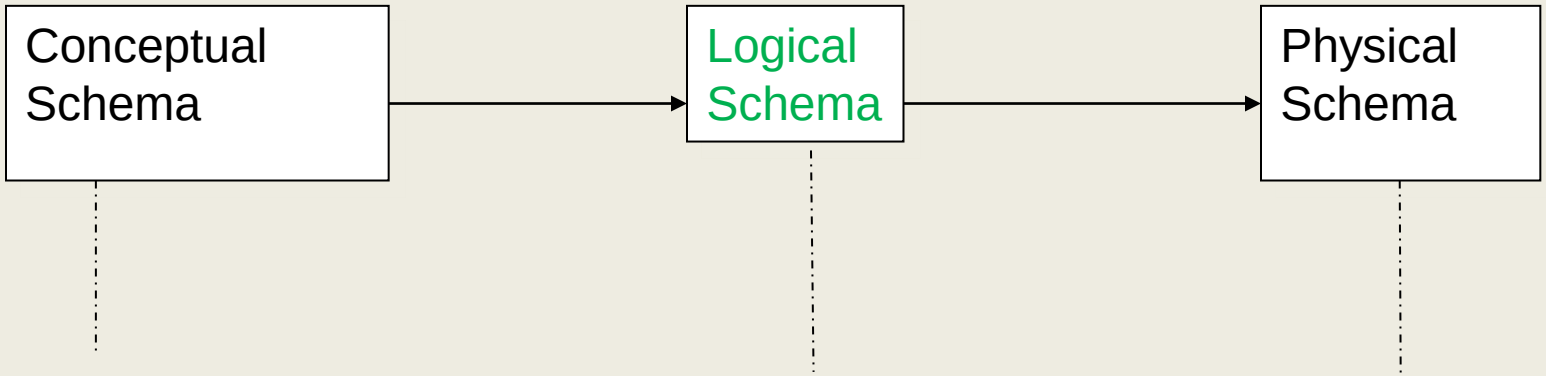
**Final exam**: plan to schedule 4PM – 8PM Sydney time to accommodate our students located in Asia and Europe. The exam content will be similar to original 2hr exam in previous years. The extra 2 hours compensate the time you spend on downloading exam paper and uploading your answers to the system, and typing your answers using a computer.

Please let me know if this will cause significant inconvenience to you. (I need to inform the university our plan by 28 Sep)

Exact date will be determined by the university centrally later.

# Relational Data Model

Different schemas are based on different levels of abstraction




ER:
- Entities,
- Relationships,
- Attributes

Relations:
- tuples,
- attributes
- domain

≈ Tables/columns/rows

File organisation:
- File types
- Index structures

# Relational Data Model Concepts

The relational data model is the most widely used data model for database systems.

The *relational data model* describes the world as

- a **collection** of inter-connected ***relations***

Goal of relational model:

- a simple, general data modelling formalism
- which maps easily to file structures (i.e. implementable)

Relational model has **two styles** of terminology:

- mathematical: relation, tuple, attribute, ...
- data-oriented: table, record, field/column, ...

Warning: textbooks alternate between the two; treat them as synonyms

# 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.

--- Each row of the table is called a tuple of the relation.

The set of allowed values for an attribute is called its domain.

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

# Relational Data Model

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!**

# Why Relational Model?

- Very simple model
- Often a good match for the way we think about our data
- Foundations in logic and set theory (will introduce in later parts of the course)
- Abstract model that underlies SQL, the most important language in DBMSs today

# 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

*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.

# Keys

| 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 |

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 (because {Name} is a key).

(*Assumption here is no two players have the same name*)

# Keys

| PLAYER | | | | | | |
|---|---|---|---|---|---|---|
| Person_ID | Name | Position | Goals | Age | Height | Weight |
| 1 | Heady | Half-forward | 17 | 24 | 183 | 83 |
| 2 | Sumich | Full-forward | 59 | 26 | 191 | 92 |
| 3 | Langdon | Utility | 23 | 23 | 189 | 86 |

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_ID.

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.

# Integrity constraints

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

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

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

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

# 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.

# Referential Integrity

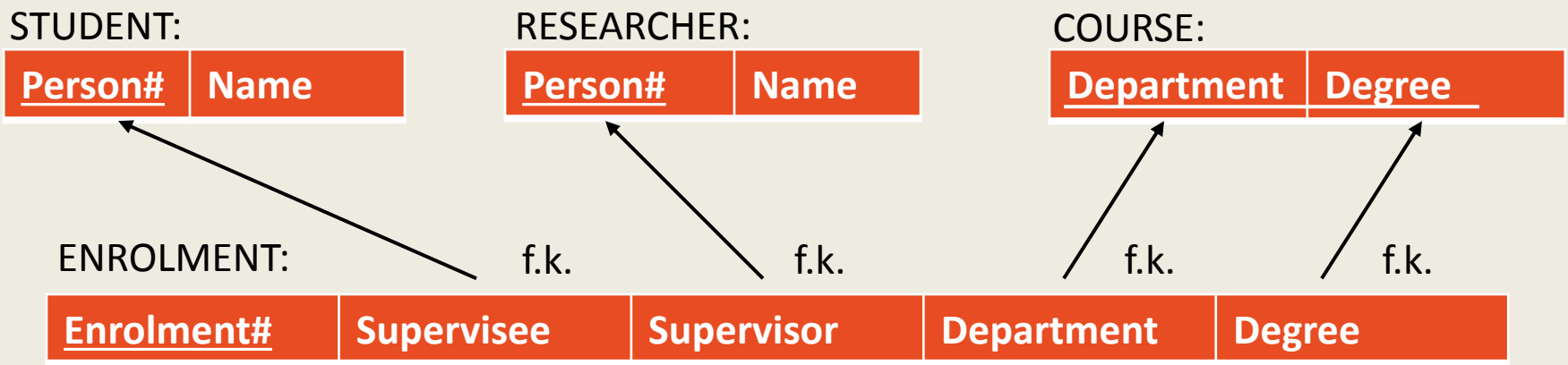
Foreign keys are critical in relational DBs; they provide ...

- the "glue" that links individual relations (we will see more about this in SQL part of the course)
- the way to assemble query answers from multiple tables
- the relational representation of ER relationships

# 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:



STUDENT:

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

RESEARCHER:

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

COURSE:

| Department | Degree |
|---|---|
| Psychology | Ph.D. |
| Comp.Sci. | Ph.D. |
| Comp.Sci. | M.Sc. |
| Psychology | M.Sc. |

ENROLMENT:

| Enrolment# | Supervisee | Supervisor | Department | Degree |
|---|---|---|---|---|
| 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. |

# Insertions

*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.

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

STUDENT:

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

RESEARCHER:

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1. Insert < 2, *Dr.V.Ciesielski* > into RESEARCHER
   Allowed? No. Violates a key constraint.
   Action? Reject or allow the user to correct.

STUDENT:

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

RESEARCHER:

| Person# | Name |
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| 4 | 5 | 1 | Comp.Sci. | M.Sc. |

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

STUDENT:

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

RESEARCHER:

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

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| Department | Degree |
|---|---|
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| 2 | 3 | 1 | Comp.Sci. | Ph.D. |
| 3 | 4 | 1 | Comp.Sci. | M.Sc. |
| 4 | 5 | 1 | Comp.Sci. | M.Sc. |

2. Insert < *Comp.Sci.,NULL* > into COURSE
   Allowed? No. Violates the entity integrity constraint.
   Action: Reject or correct.

STUDENT:

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

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| 2 | 3 | 1 | Comp.Sci. | Ph.D. |
| 3 | 4 | 1 | Comp.Sci. | M.Sc. |
| 4 | 5 | 1 | Comp.Sci. | M.Sc. |

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

STUDENT:

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

RESEARCHER:

| Person# | Name |
|---|---|
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| 2 | Dr R.G.Wilkinson |

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| 2 | 3 | 1 | Comp.Sci. | Ph.D. |
| 3 | 4 | 1 | Comp.Sci. | M.Sc. |
| 4 | 5 | 1 | Comp.Sci. | M.Sc. |

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

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

Examples:

RESEARCHER:

| Person# | Name |
|---|---|
| 1 | Dr C.C.Chen |
| ~~2~~ | ~~Dr R.G.Wilkinson~~ |

1. Delete tuple with Person# = 2 from RESEARCHER

   Allowed? No. Violates the referential integrity.

   Action: Reject, correct or modify the ENROLMENT tuple by the following actions:

# Deletions

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.

# 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.

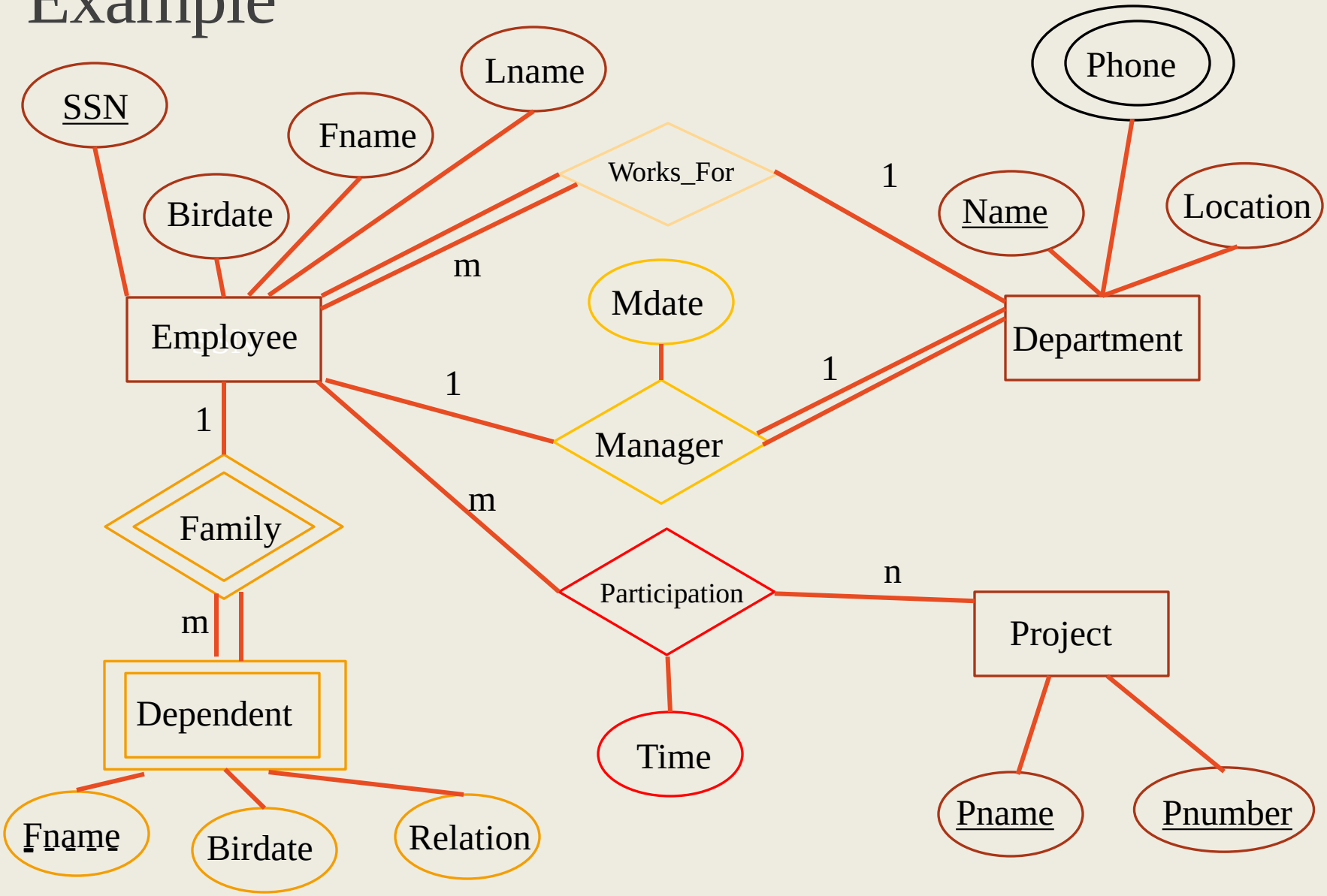
# ER to Relational Data Model Mapping

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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# ER to RDM

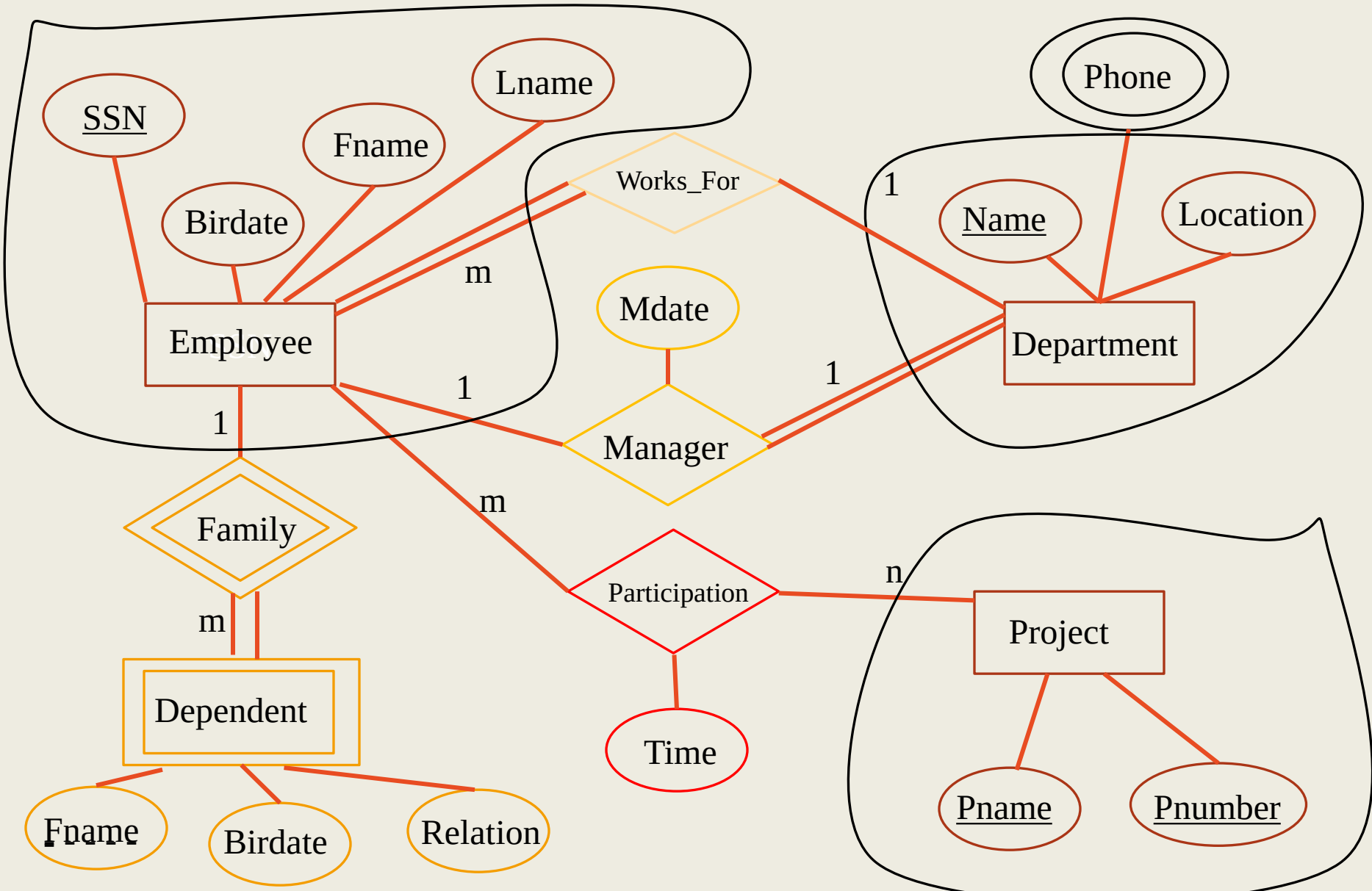
Step 1 : For each regular (not weak) entity type E, create a relation R with

- 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. In our example, **Pname** is a candidate key for **Project** relation, **Pnumber** is also a candidate key for **Project** relation, we choose **Pname** as the primary key.

# ER to RDM

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.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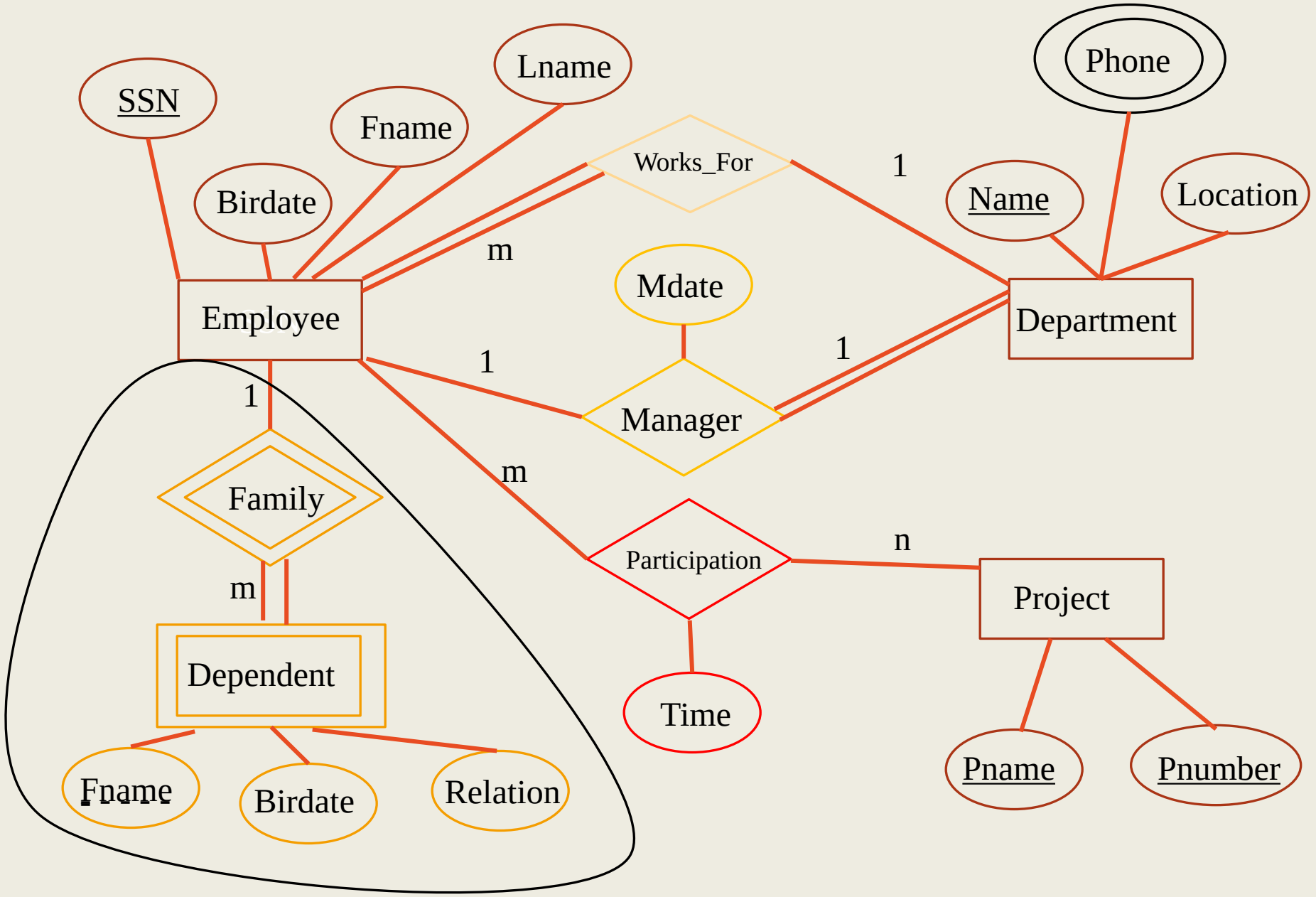
Project

| Pname | Pnumber |
|---|---|

# ER to RDM

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.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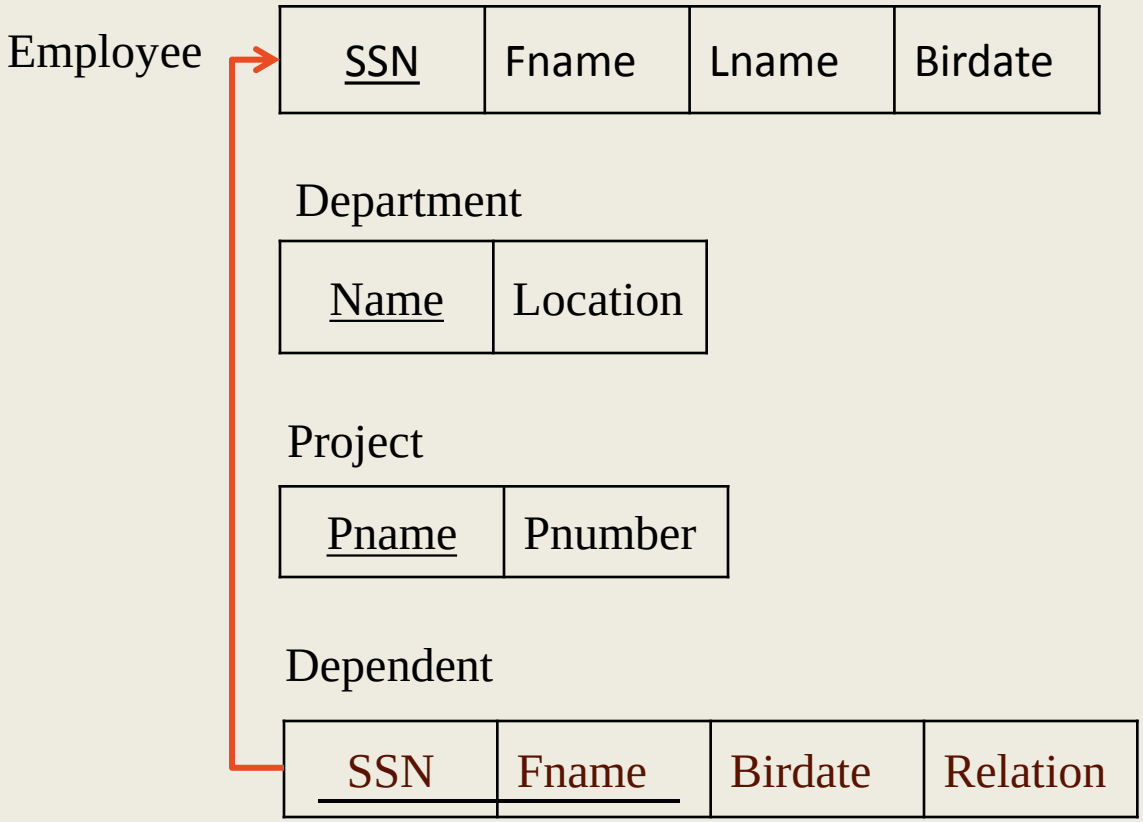
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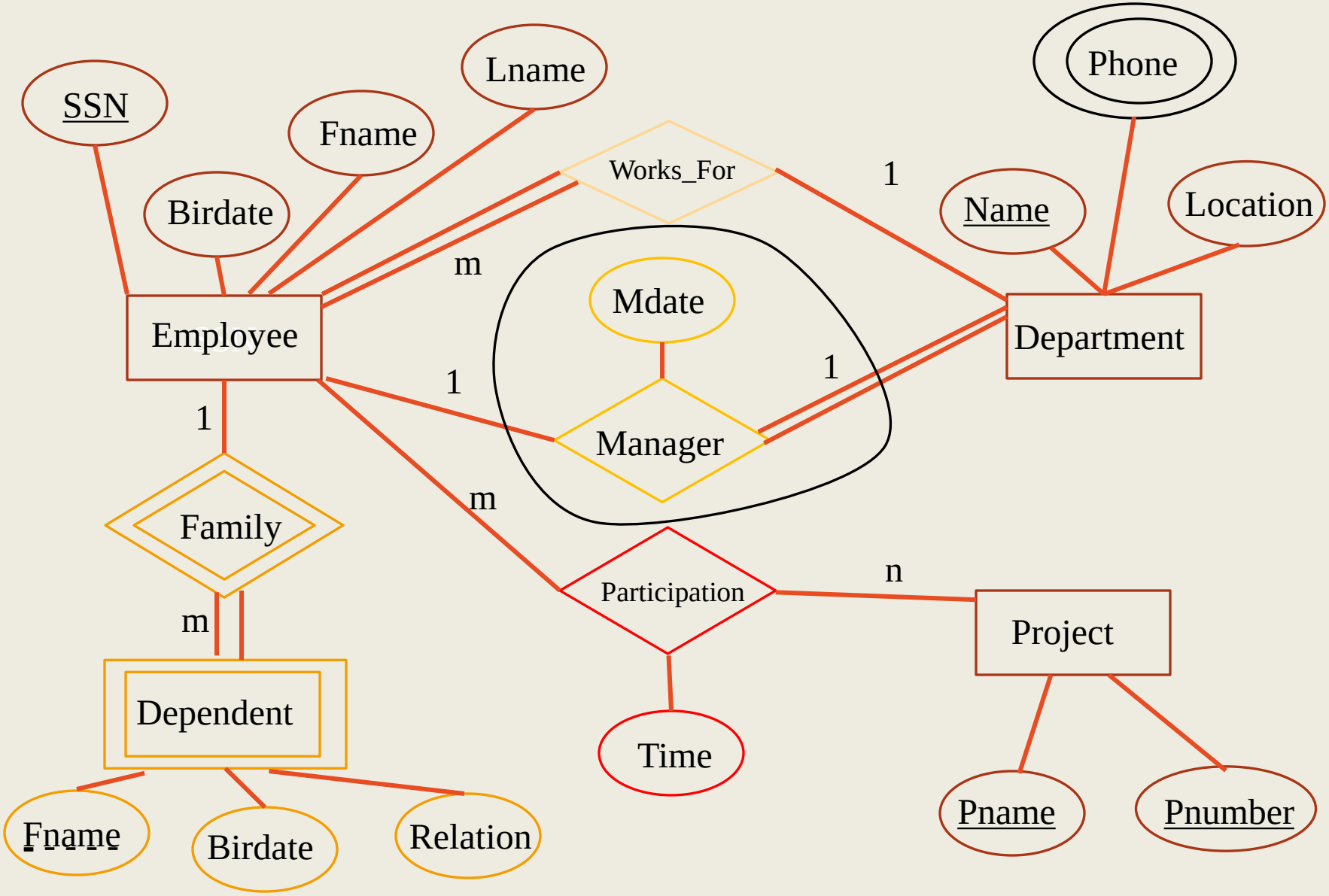
# ER to RDM

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).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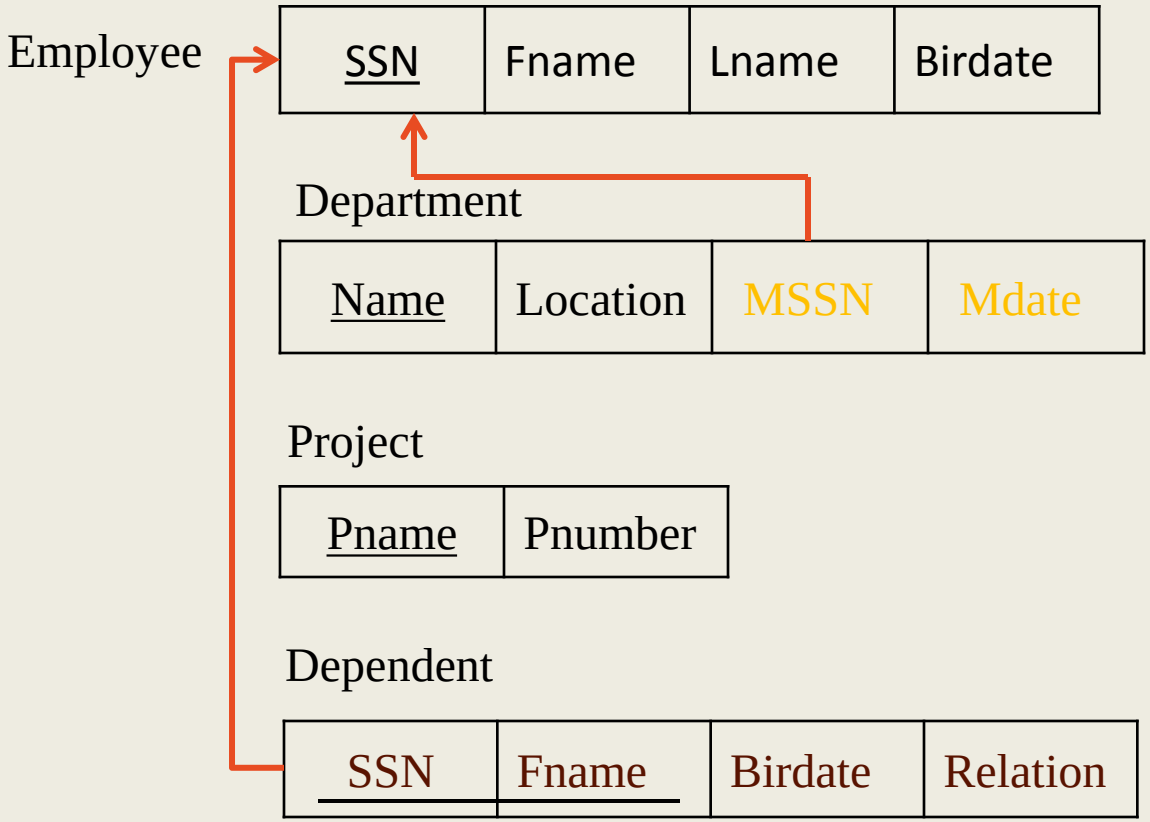
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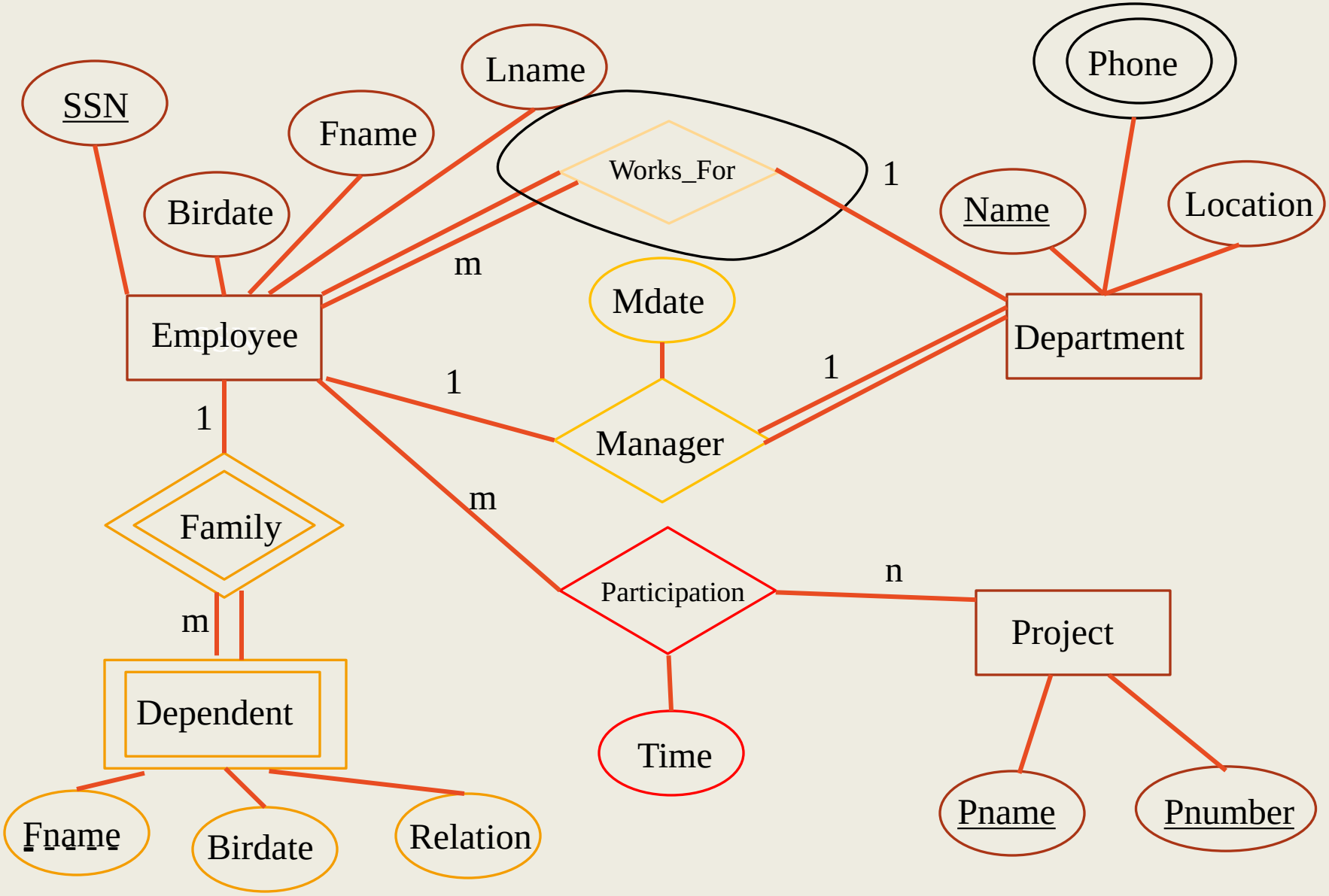
# ER to RDM

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.)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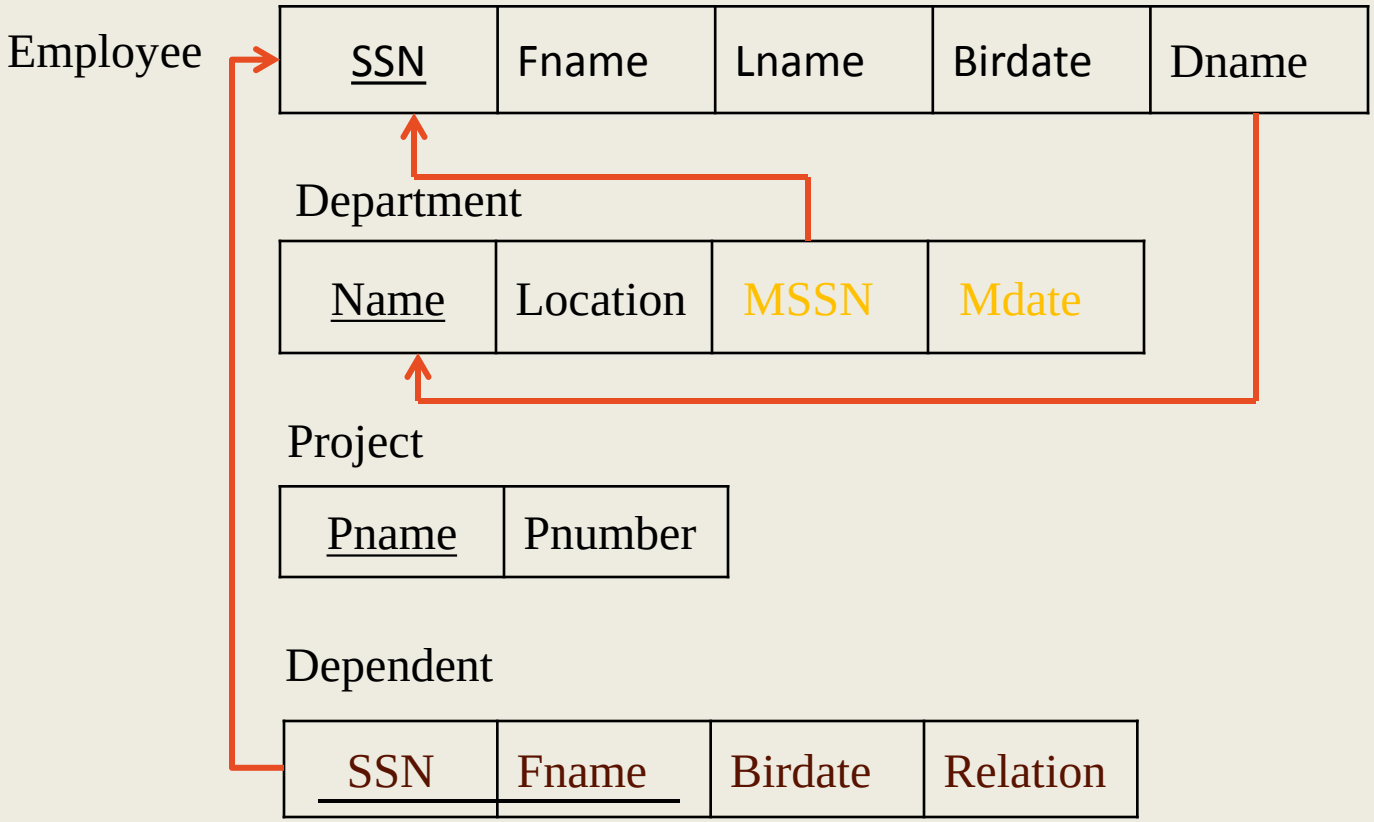
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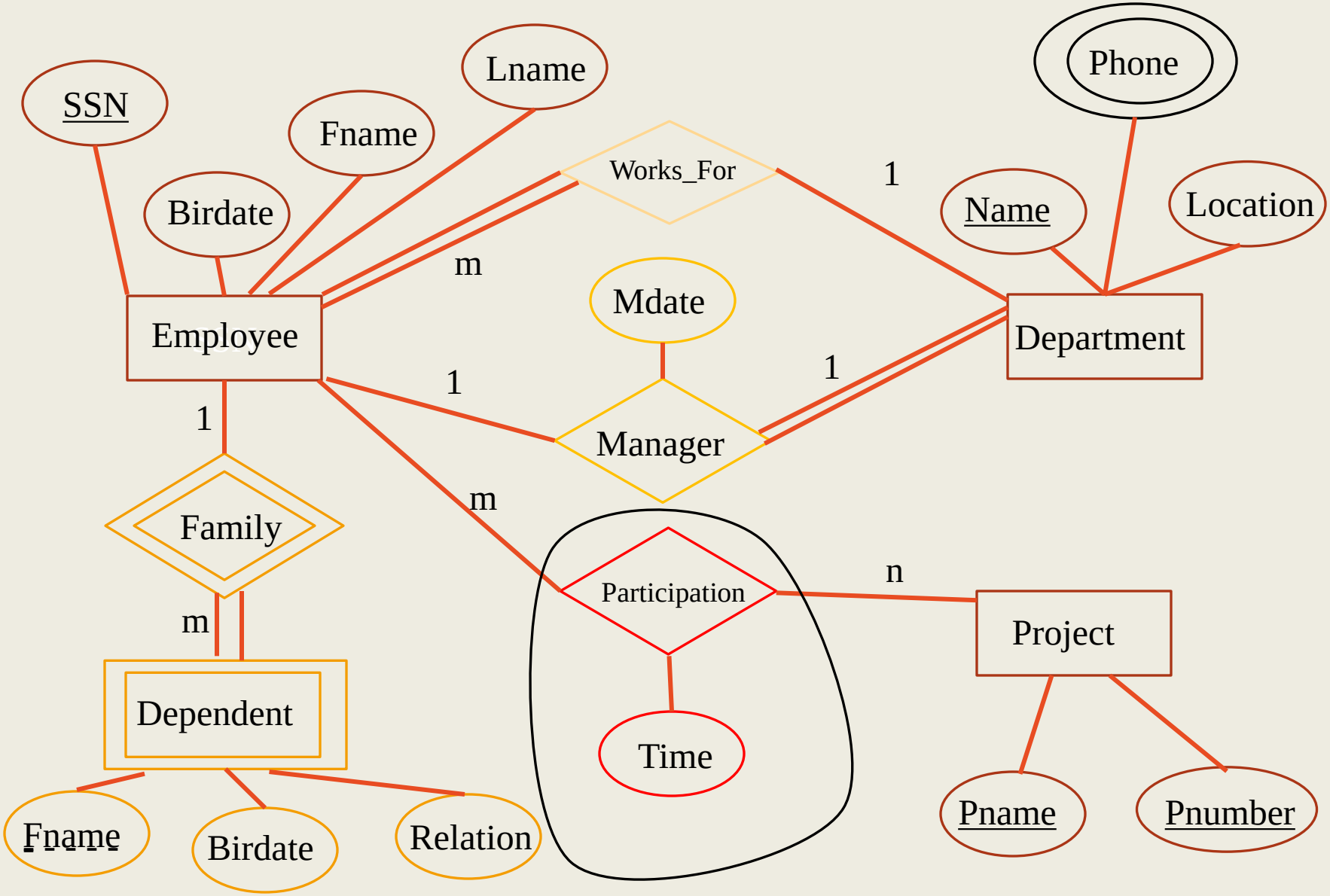
Relation

# ER to RDM

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.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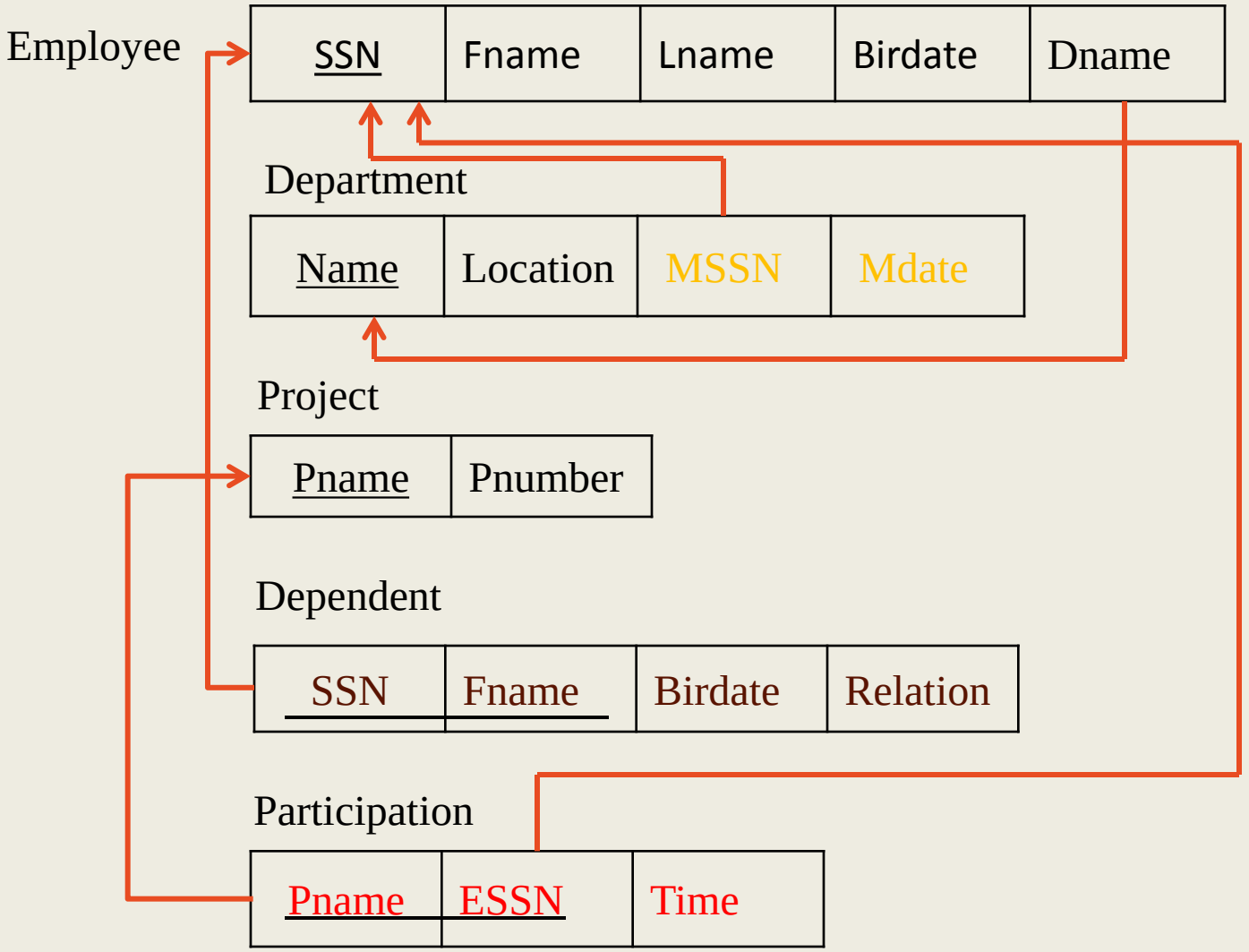
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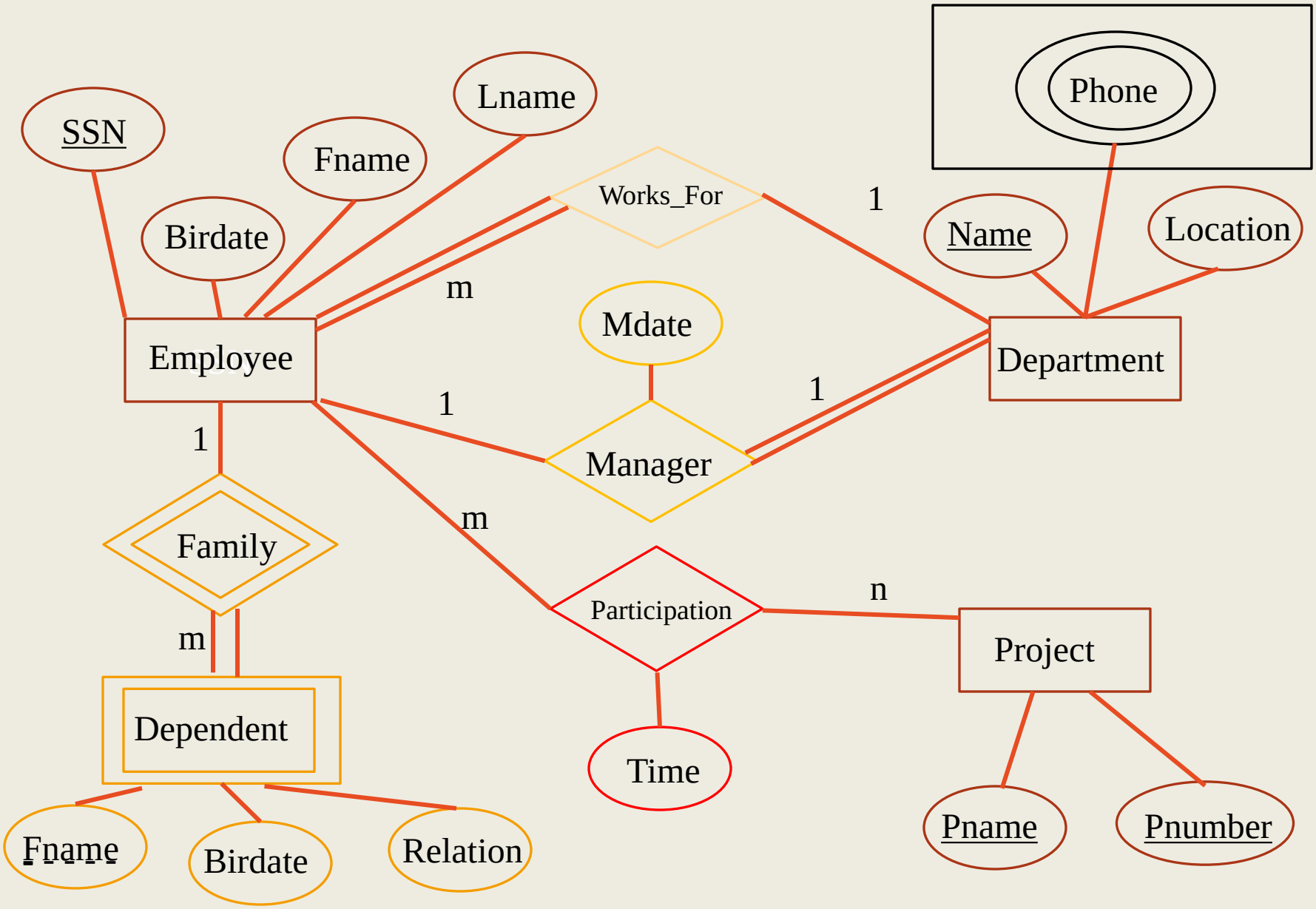
Participation
Pname
ESSN
Time

# ER to RDM

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.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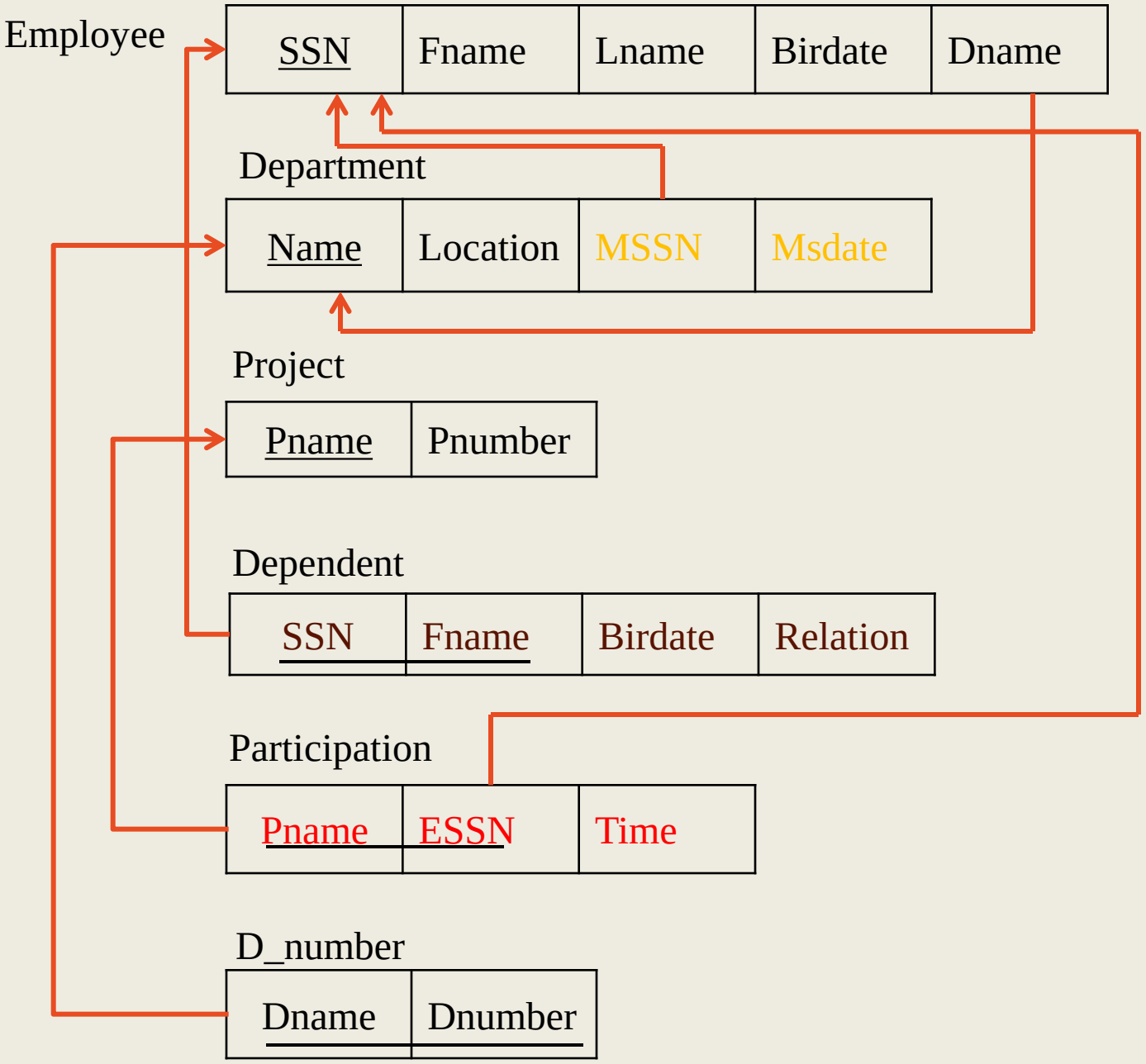
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Pnumber
Dependent
SSN
Fname
Birdate
Relation
Participation
Pname
ESSN
Time
D_number
Dname
Dnumber

# ER to RDM

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.

# Learning Outcome

1. Understanding of relational model
2. Given an ERD, convert the ERD to relational model.