CPT-S 415

Big Data

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EME B45

Data dependencies and DBMS

- ✓ RDBMS design
  - the normal forms 1NF, 2NF, 3NF, BCNF
  - normal forms transformation
- ✓ DBMS: architecture

Database Management Systems (DBMS)

Database management systems (DBMS)

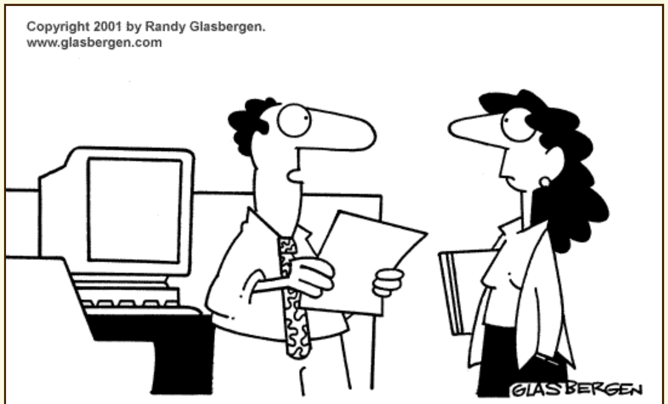
- A **Database** is a collection of stored operational data used by the application systems of some particular enterprise (C.J. Date)
- A **DBMS** is a computer software with the capability to 1) store data in an integrated, structured format and to 2) enable users to retrieve, manipulate and manage the data.
  - Paper “Databases”
    - Still contain a large portion of the world’s knowledge
  - File-Based Data Processing Systems
    - Early batch processing of (primarily) business data
  - Database Management Systems (DBMS)

Data ≠ Information ≠ Knowledge!

Importance of DBMS

- It helps make data management more efficient and effective.
- Its query language allows quick answers to *ad hoc* queries.
- It provides end users better access to more and better-managed data.
- It promotes an integrated view of organization's operations -- "big picture."
- It reduces the probability of inconsistent data.

RDBMS design



"The new automated ordering system has really speeded up our business. We're losing customers faster than ever."

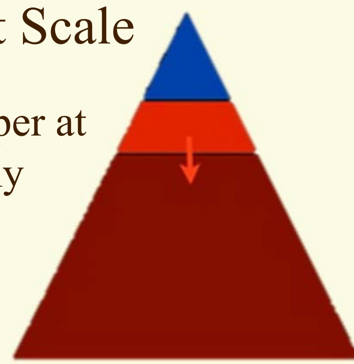
A Big data Fallacy

- “Database Design in the era of Big data is less important” (?)
  - New high-volume data streams
  - specialized hardware/softwares
  - Storage issues coped by hardware appliance
- **Fact:**
  - Most data is physically located in DBMS and new special-purpose appliance
  - Data loads, extract, transform, preprocessing ops continue as is
  - Database design for quality assurance

Big data a necessity at Largest Scale

A certain kind of developer at a certain kind of company

Most development still RDBMS



MySQL, Oracle, Mongo, Cassandra, some memcache, Some Hadoop…

Relational Databases Design

- ✓ Relational database design: The grouping of attributes to form "good" relation schemas
- ✓ Two levels of relation schemas:
  - The logical "user view" level
  - The storage "base relation" level
- ✓ Design is concerned mainly with base relations
- ✓ We have assumed schema *R* is given
  - *R* could have been generated when converting E-R diagram to a set of tables.
  - *R* could have been a single relation containing *all* attributes that are of interest (called **universal relation**).
  - **Normalization** breaks *R* into smaller relations.
  - *R* could have been the result of some ad hoc design of relations, which we then test/convert to normal form.

Database Tables and Normalization

Introduction to Normalization

- **Normalization**: Process of decomposing unsatisfactory "bad" relations by breaking up their attributes into smaller relations

- **Normal form**: Condition using keys and functional dependencies (FDs) of a relation to certify whether a relation schema is in a particular normal form
  - 2NF, 3NF, BCNF based on keys and FDs of a relation schema
  - 4NF based on keys, multi-valued dependencies

guarantees ↑

Normal form (1NF)

Second normal form (2NF)

Third normal form (3NF)

Boyce-Codd Normal Form (BCNF)

↓ stronger

The Need for Normalization

- Mixing attributes of multiple entities may cause problems
  - Information is stored redundantly wasting storage
  - Problems with update anomalies:
    - Insertion anomalies
    - Deletion anomalies
    - Modification anomalies
- The report may yield different results, depending on data anomaly
  - Primary keys?
  - Data redundancy
  - Possible data inconsistencies: JOB_CLASS: Elect.Engineer, Elect.Eng. El.Eng. EE

The Need for Normalization

- Example: company that manages building projects
  - Charges its clients by billing hours spent on each contract
  - Hourly billing rate is dependent on employee's position

TABLE 5.1 A Sample Report Layout

PROJ. NUM.	PROJECT NAME	EMPLOYEE NUMBER	EMPLOYEE NAME	JOB CLASS.	CHG/HOUR	HOURS BILLED	TOTAL CHARGE
15	Evergreen	103	June E. Arbough	Elec. Engineer	$84.50	23.8	$2,011.10
		101	John G. News	Database Designer	$105.00	19.4	$2,037.00
		105	Alice K. Johnson *	Database Designer	$105.00	35.7	$3,748.50
		106	William Smithfield	Programmer	$35.75	12.6	$450.45
		102	David H. Senior	Systems Analyst	$96.75	23.8	$2,302.65
				Subtotal			**$10,549.70**
18	Amber Wave	114	Annelise Jones	Applications Designer	$48.10	24.6	$1,183.26
		118	James J. Frommer	General Support	$18.36	45.3	$831.71
		104	Anne K. Ramoras *	Systems Analyst	$96.75	32.4	$3,135.70
		112	Darlene M. Smithson	DSS Analyst	$45.95	44.0	$2,021.80
				Subtotal			**$7,171.47**
22	Rolling Tide	105	Alice K. Johnson	Database Designer	$105.00	64.7	$6,793.50
		104	Anne K. Ramoras	Systems Analyst	$96.75	48.4	$4,682.70
		113	Delbert K. Joenbrood *	Applications Designer	$48.10	23.6	$1,135.16
		111	Geoff B. Wabash	Clerical Support	$26.87	22.0	$591.14
		106	William Smithfield	Programmer	$35.75	12.8	$457.60
				Subtotal			**$13,660.10**
25	Starflight	107	Maria D. Alonzo	Programmer	$35.75	24.6	$879.45
		115	Travis B. Bawangi	Systems Analyst	$96.75	45.8	$4,431.15
		101	John G. News *	Database Designer	$105.00	56.3	$5,911.50
		114	Annelise Jones	Applications Designer	$48.10	33.1	$1,592.11
		108	Ralph B. Washington	Systems Analyst	$96.75	23.6	$2,283.30
		118	James J. Frommer	General Support	$18.36	30.5	$559.98
		112	Darlene M. Smithson	DSS Analyst	$45.95	41.4	$1,902.33
				Subtotal			**$17,559.82**
				Total			**$48,941.09**

* Indicates project leader

A Table in the Report Format

Table name: RPT_FORMAT **Database name: Ch05_ConstructCo**

PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CLASS	CHG_HOUR	HOURS
15	Evergreen	103	June E. Arbough	Elect. Engineer	$84.50	23.8
		101	John G. News	Database Designer	$105.00	19.4
		105	Alice K. Johnson *	Database Designer	$105.00	35.7
		106	William Smithfield	Programmer	$35.75	12.6
		102	David H. Senior	Systems Analyst	$96.75	23.8
18	Amber Wave	114	Annelise Jones	Applications Designer	$48.10	24.6
		118	James J. Frommer	General Support	$18.36	45.3
		104	Anne K. Ramoras *	Systems Analyst	$96.75	32.4
		112	Darlene M. Smithson	DSS Analyst	$45.95	44.0
22	Rolling Tide	105	Alice K. Johnson	Database Designer	$105.00	64.7
		104	Anne K. Ramoras	Systems Analyst	$96.75	48.4
		113	Delbert K. Joenbrood *	Applications Designer	$48.10	23.6
		111	Geoff B. Wabash	Clerical Support	$26.87	22.0
		106	William Smithfield	Programmer	$35.75	12.8
25	Starflight	107	Maria D. Alonzo	Programmer	$35.75	24.6
		115	Travis B. Bawangi	Systems Analyst	$96.75	45.8
		101	John G. News *	Database Designer	$105.00	56.3
		114	Annelise Jones	Applications Designer	$48.10	33.1
		108	Ralph B. Washington	Systems Analyst	$96.75	23.6
		118	James J. Frommer	General Support	$18.36	30.5
		112	Darlene M. Smithson	DSS Analyst	$45.95	41.4

The Need for Normalization

- ✓ For most business database design, 3NF is highest we need to go in the normalization process
  - Highest level of normalization is not always most desirable
- ✓ Normalization should be part of design process
  - Make sure that proposed entities meet required normal form before table structures are created
  - Many real-world databases have been improperly designed or burdened with anomalies if improperly modified during course of time
  - You may be asked to redesign and modify existing databases

Functional Dependencies

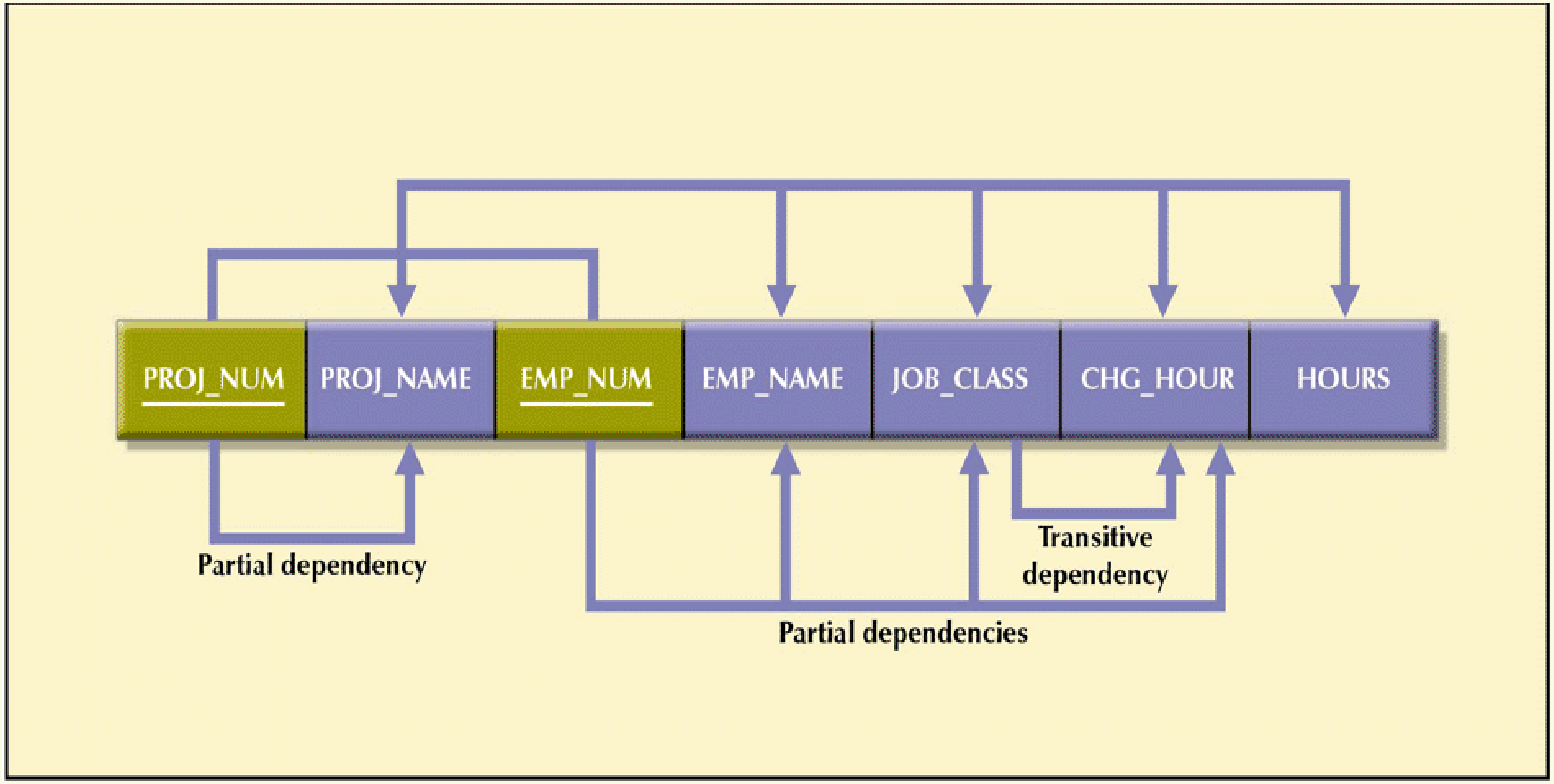
- **Functional dependencies** (FDs) are used to specify formal measures of the "goodness" of relational designs
- FDs and keys are used to define normal forms for relations
- FDs are constraints that are derived from the meaning and interrelationships of the data attributes

Functional Dependencies (2)

- A set of attributes X *functionally determines* a set of attributes Y if the value of X determines a unique value for Y
- X → Y holds if whenever two tuples have the same value for X, they *must have* the same value for Y

  If t1[X]=t2[X], *then* t1[Y]=t2[Y] in any relation instance r(R)
- a *constraint* on ***all*** relation instances r(R)
- FDs are derived from the real-world constraints on the attributes
  - SSN → ENAME
  - PNUMBER → {PNAME, PLOCATION}
  - {SSN, PNUMBER} → HOURS
  - what if LHS attributes is a **key**?
- A FD X → Y is a
  - **Full functional dependency** if removal of any attribute from X means the FD does not hold any more
  - **Transitive functional dependency**- if there a set of attributes Z that are neither a primary or candidate key and both X→ Z and Z → Y holds.

A Dependency Diagram



Inference Rules for FDs

- Given a set of FDs F, we can infer additional FDs that hold whenever the FDs in F hold

- Armstrong's inference rules

  A1. (Reflexive) If Y subset-of X, then $X \rightarrow Y$

  A2. (Augmentation) If $X \rightarrow Y$, then $XZ \rightarrow YZ$
  (Notation: XZ stands for X U Z)

  A3. (Transitive) If $X \rightarrow Y$ and $Y \rightarrow Z$, then $X \rightarrow Z$

- A1, A2, A3 form a *sound and complete* set of inference rules

First Normal Form

- ✓ Tabular format in which:
  - All key attributes are defined
  - There are no repeating groups in the table
  - All attributes are dependent on primary key
- ✓ Disallows composite attributes, multivalued attributes, and **nested relations**; attributes whose values *for an individual tuple* are non-atomic

1NF deals with the "shape" of the tables

Transform to 1NF

- ✓ Step 1: Eliminate repeating groups
- ✓ Step 2: Identify primary key
- ✓ (Step 3: Identify all dependencies)

FIGURE 5.2 DATA ORGANIZATION: FIRST NORMAL FORM

Table name: DATA_ORG_1NF   Database name: Ch05_ConstructCo

PROJ_NUM	PROJ_NAME	EMP_NUM	EMP_NAME	JOB_CLASS	CHG_HOUR	HOURS
15	Evergreen	103	June E. Arbough	Elect. Engineer	$84.50	23.8
15	Evergreen	101	John G. News	Database Designer	$105.00	19.4
15	Evergreen	105	Alice K. Johnson *	Database Designer	$105.00	35.7
15	Evergreen	106	William Smithfield	Programmer	$35.75	12.6
15	Evergreen	102	David H. Senior	Systems Analyst	$96.75	23.8
18	Amber Wave	114	Annelise Jones	Applications Designer	$48.10	24.6
18	Amber Wave	118	James J. Frommer	General Support	$18.36	45.3
18	Amber Wave	104	Anne K. Ramoras *	Systems Analyst	$96.75	32.4
18	Amber Wave	112	Darlene M. Smithson	DSS Analyst	$45.95	44.0
22	Rolling Tide	105	Alice K. Johnson	Database Designer	$105.00	64.7
22	Rolling Tide	104	Anne K. Ramoras	Systems Analyst	$96.75	48.4
22	Rolling Tide	113	Delbert K. Joenbrood *	Applications Designer	$48.10	23.6
22	Rolling Tide	111	Geoff B. Wabash	Clerical Support	$26.87	22.0
22	Rolling Tide	106	William Smithfield	Programmer	$35.75	12.8
25	Starflight	107	Maria D. Alonzo	Programmer	$35.75	24.6
25	Starflight	115	Travis B. Bawangi	Systems Analyst	$96.75	45.8
25	Starflight	101	John G. News *	Database Designer	$105.00	56.3
25	Starflight	114	Annelise Jones	Applications Designer	$48.10	33.1
25	Starflight	108	Ralph B. Washington	Systems Analyst	$96.75	23.6
25	Starflight	118	James J. Frommer	General Support	$18.36	30.5
25	Starflight	112	Darlene M. Smithson	DSS Analyst	$45.95	41.4

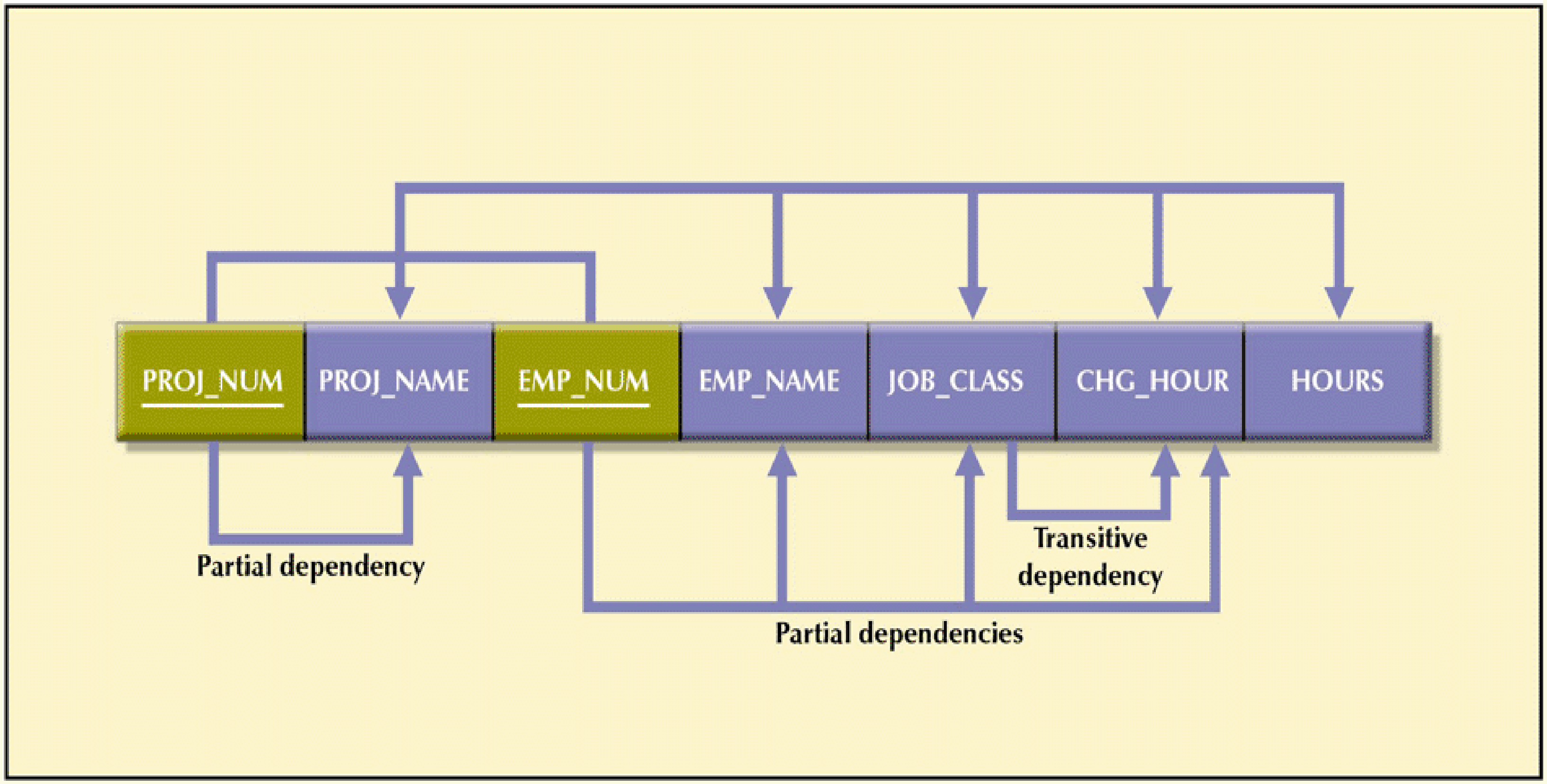
Second Normal Form

- ✓ Table is in second normal form (2NF) if:
  - It is in 1NF and
  - It includes no partial dependencies:
    - No attribute is dependent on only a portion of the primary key = every attribute A not in PK is fully functionally dependent on PK

2NF deals with the relationship between non-key and key attributes

A Dependency Diagram: First Normal Form (1NF)

FIGURE 5.3 A DEPENDENCY DIAGRAM: FIRST NORMAL FORM (1NF)

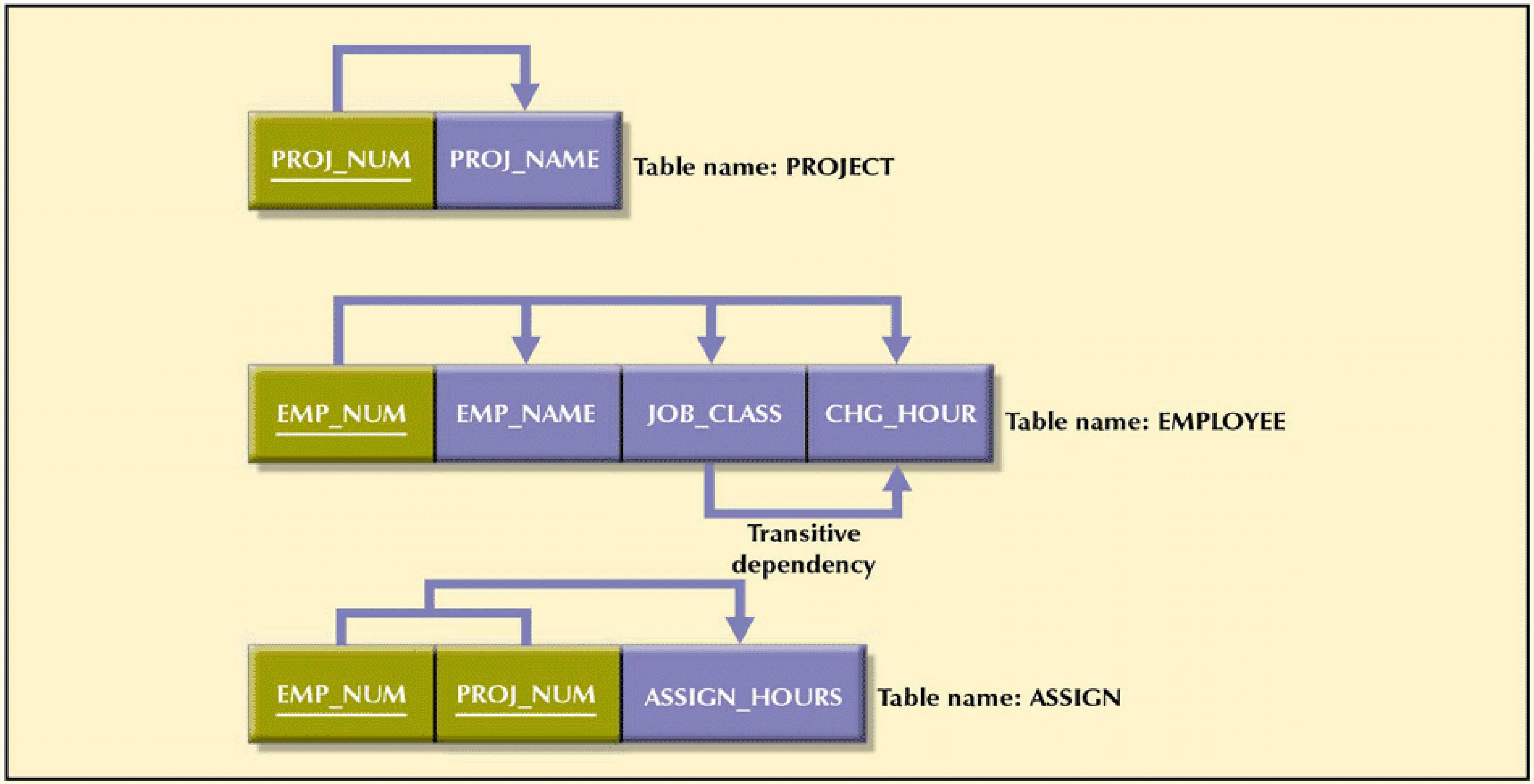


Conversion to Second Normal Form

- Relational database design can be improved by converting the database into second normal form (2NF)
- Two steps
  - Step 1: Write each key attribute on separate line, and then write the original (composite) key on the last line; Each component will become the key in a new table
  - Step 2: Determine which attributes are dependent on which other attributes (remove anomalies)

Second Normal Form (2NF) Conversion Results

FIGURE 5.4 Second Normal Form (2NF) Conversion Results



Third Normal Form

- ✓ A table is in third normal form (3NF) if:
  - It is in 2NF and
  - It contains no transitive dependencies

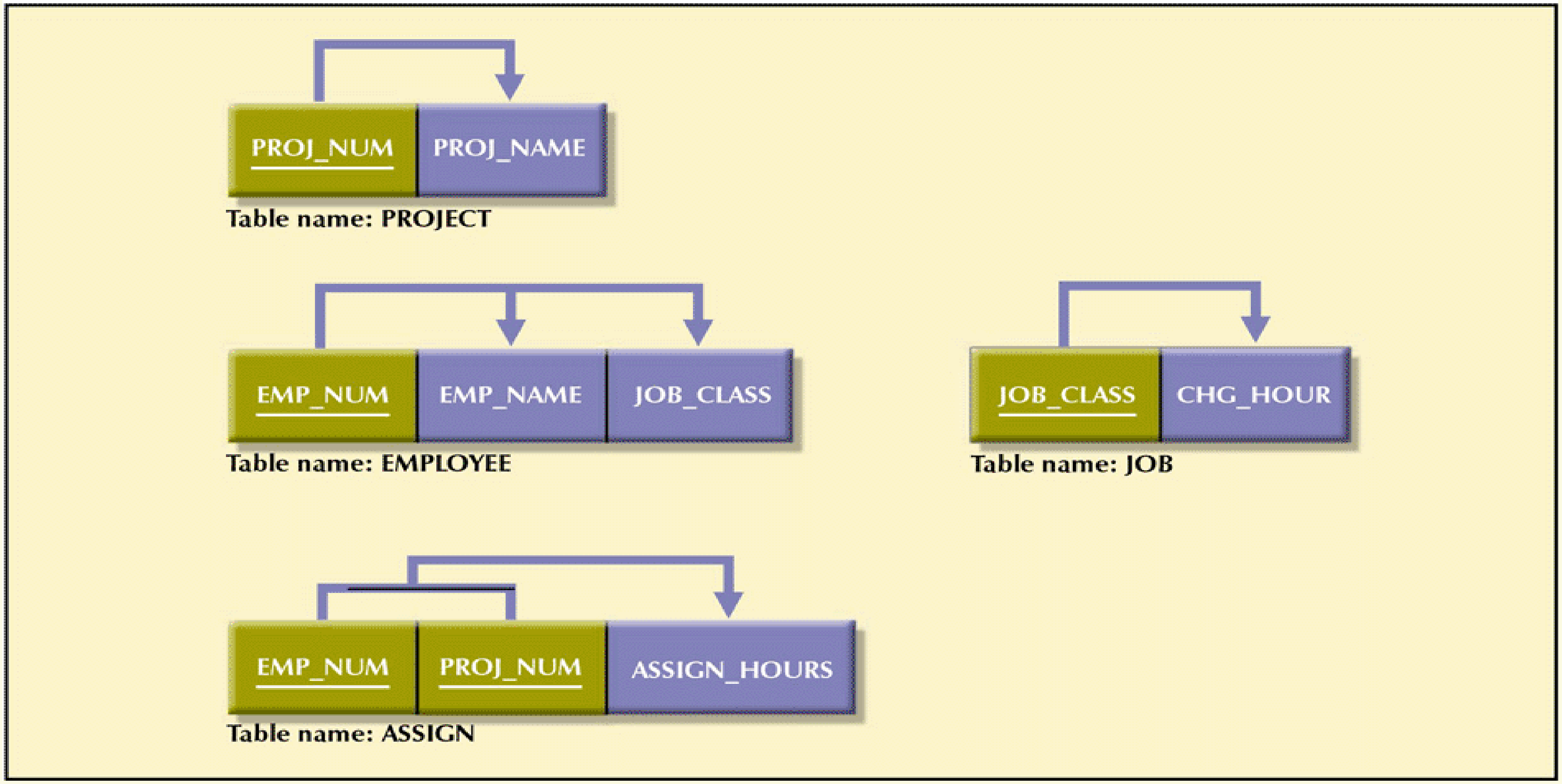
3NF removes transitive dependencies

Conversion to Third Normal Form

- ✓ Data anomalies created are easily eliminated by completing three steps
  - **Step 1: find new fact:** For every transitive dependency X-Y, write fact Z as a PK for a new table where X->Z and Z->Y
  - **Step 2: Identify the Dependent Attributes** - Identify the attributes dependent on each Z identified in Step 1 and identify the dependency; Name the table to reflect its contents and function
  - **Step 3: Remove X->Y from Transitive Dependencies**

Third Normal Form (3NF) Conversion Results

FIGURE 5.5 Third Normal Form (3NF) Conversion Results



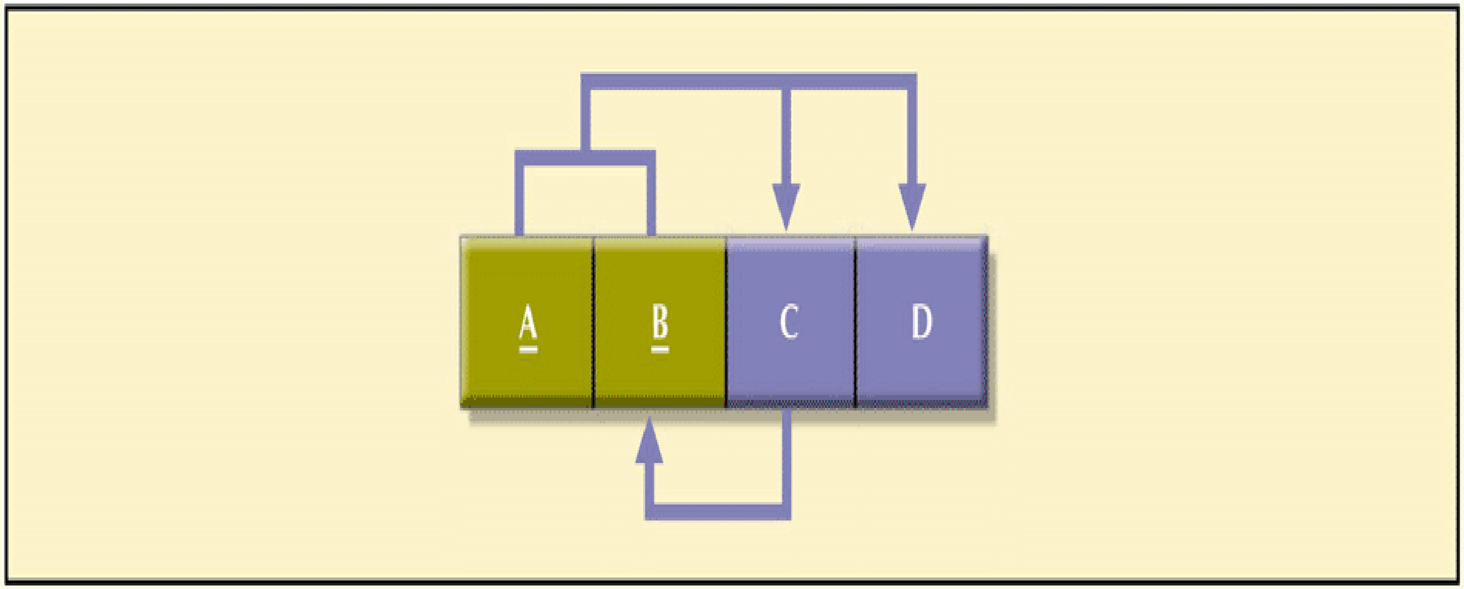
data depends on the key [1NF], the whole key [2NF] and nothing but the key [3NF]

BCNF (Boyce-Codd Normal Form)

- ✓ A relation schema R is in **Boyce-Codd Normal Form** (BCNF), aka 3.5NF, if whenever an FD X → A holds in R, then X is a superkey of R
  - Each normal form is strictly stronger than the previous one:
    - Every 2NF relation is in 1NF
    - Every 3NF relation is in 2NF
    - Every BCNF relation is in 3NF
  - There exist relations that are in 3NF but not in BCNF
  - The goal is to have each relation in BCNF (or 3NF)
  - Why not 4NF? 4 and 5NF deal with multi-valued attributes
  - Just slightly stricter than 3NF

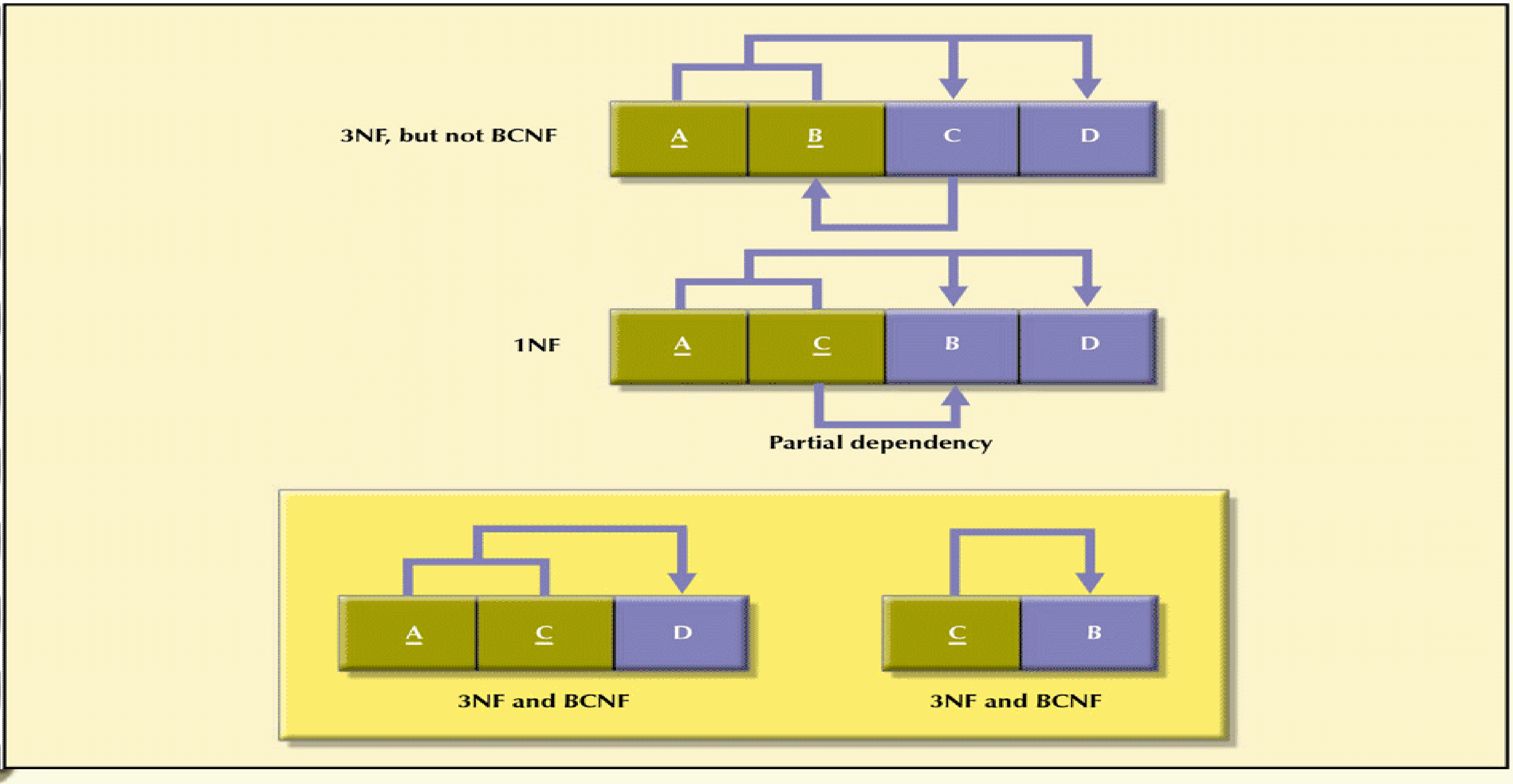
A Table That is in 3NF but not in BCNF

FIGURE 5.7 A TABLE THAT IS IN 3NF BUT NOT IN BCNF



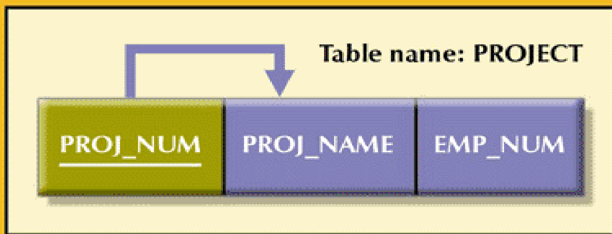
Decomposition to BCNF

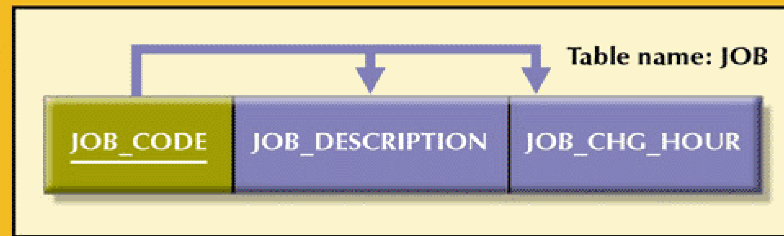
FIGURE 5.8 DECOMPOSITION TO BCNF



The Completed Database

FIGURE 5.6 THE COMPLETED DATABASE





Database name: Ch05_ConstructCo

Table name: PROJECT

PROJ_NUM	PROJ_NAME	EMP_NUM
15	Evergreen	105
18	Amber Wave	104
22	Rolling Tide	113
25	Starflight	101

Table name: JOB

JOB_CODE	JOB_DESCRIPTION	JOB_CHG_HOUR
500	Programmer	$35.75
501	Systems Analyst	$96.75
502	Database Designer	$105.00
503	Electrical Engineer	$84.50
504	Mechanical Engineer	$67.90
505	Civil Engineer	$55.78
506	Clerical Support	$26.87
507	DSS Analyst	$45.95
508	Applications Designer	$48.10
509	Bio Technician	$34.55
510	General Support	$18.36

FIGURE 5.6 THE COMPLETED DATABASE (CONTINUED)

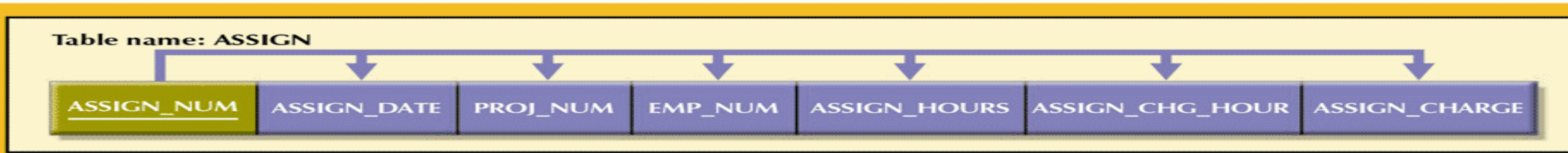


Table name: ASSIGN **Database name: Ch05_ConstructCo**

ASSIGN_NUM	ASSIGN_DATE	PROJ_NUM	EMP_NUM	ASSIGN_HOURS	ASSIGN_CHG_HOUR	ASSIGN_CHARGE
1001	04-Mar-04	15	103	2.6	$84.50	$219.70
1002	04-Mar-04	18	118	1.4	$18.36	$25.70
1003	05-Mar-04	15	101	3.6	$105.00	$378.00
1004	05-Mar-04	22	113	2.5	$48.10	$120.25
1005	05-Mar-04	15	103	1.9	$84.50	$160.55
1006	05-Mar-04	25	115	4.2	$96.75	$406.35
1007	05-Mar-04	22	105	5.2	$105.00	$546.00
1008	05-Mar-04	25	101	1.7	$105.00	$178.50
1009	05-Mar-04	15	105	2.0	$105.00	$210.00
1010	06-Mar-04	15	102	3.8	$96.75	$367.65
1011	06-Mar-04	22	104	2.6	$96.75	$251.55
1012	06-Mar-04	15	101	2.3	$105.00	$241.50
1013	06-Mar-04	25	114	1.8	$48.10	$86.58
1014	06-Mar-04	22	111	4.0	$26.87	$107.48
1015	06-Mar-04	25	114	3.4	$48.10	$163.54
1016	06-Mar-04	18	112	1.2	$45.95	$55.14
1017	06-Mar-04	18	118	2.0	$18.36	$36.72
1018	06-Mar-04	18	104	2.6	$96.75	$251.55
1019	06-Mar-04	15	103	3.0	$84.50	$253.50
1020	07-Mar-04	22	105	2.7	$105.00	$283.50
1021	08-Mar-04	25	108	4.2	$96.75	$406.35
1022	07-Mar-04	25	114	5.8	$48.10	$278.98
1023	07-Mar-04	22	106	2.4	$35.75	$85.80

Table name: EMPLOYEE

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIREDATE	JOB_CODE
101	News	John	G	08-Nov-98	502
102	Senior	David	H	12-Jul-87	501
103	Arbough	June	E	01-Dec-94	503
104	Ramoras	Anne	K	15-Nov-85	501
105	Johnson	Alice	K	01-Feb-91	502
106	Smithfield	William		22-Jun-03	500
107	Alonzo	Maria	D	10-Oct-91	500
108	Washington	Ralph	B	22-Aug-89	501
109	Smith	Larry	W	18-Jul-95	501
110	Olenko	Gerald	A	11-Dec-93	505
111	Wabash	Geoff	B	04-Apr-89	506
112	Smithson	Darlene	M	23-Oct-92	507
113	Joenbrood	Delbert	K	15-Nov-94	508
114	Jones	Annelise		20-Aug-91	508
115	Bawangi	Travis	B	25-Jan-90	501
116	Pratt	Gerald	L	05-Mar-95	510
117	Williamson	Angie	H	19-Jun-94	509
118	Frommer	James	J	04-Jan-04	510

DBMS architecture: overview

DBMS architectures

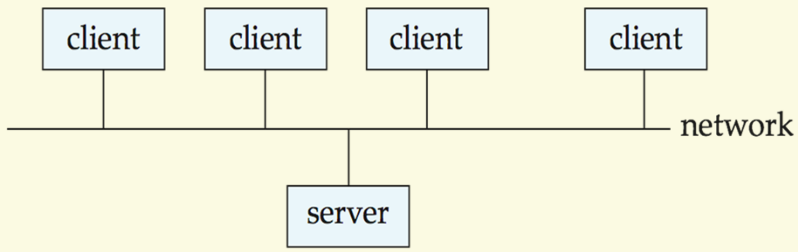
- ✓ Centralized and Client-Server Systems
- ✓ Parallel Systems
- ✓ Distributed Systems

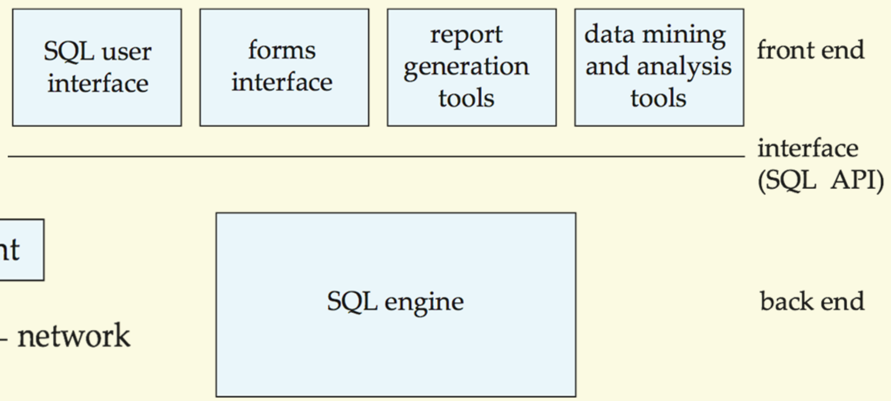
Centralized Systems

- ✓ Run on a single computer system and do not interact with other computer systems.
  - Single-user system (e.g., personal computer or workstation): desk-top unit, single user, usually has only one CPU and one or two hard disks; the OS may support only one user.
  - Multi-user system: more disks, more memory, multiple CPUs, and a multi-user OS. Serve a large number of users who are connected to the system vie terminals. Often called *server* systems.

Client-Server Systems

- Database functionality can be divided into:
  - **Back-end**: manages access structures, query evaluation and optimization, concurrency control and recovery.
  - **Front-end**: consists of tools such as *forms*, *report-writers*, and graphical user interface facilities.
- The interface between the front-end and the back-end is through SQL or through an application program interface.





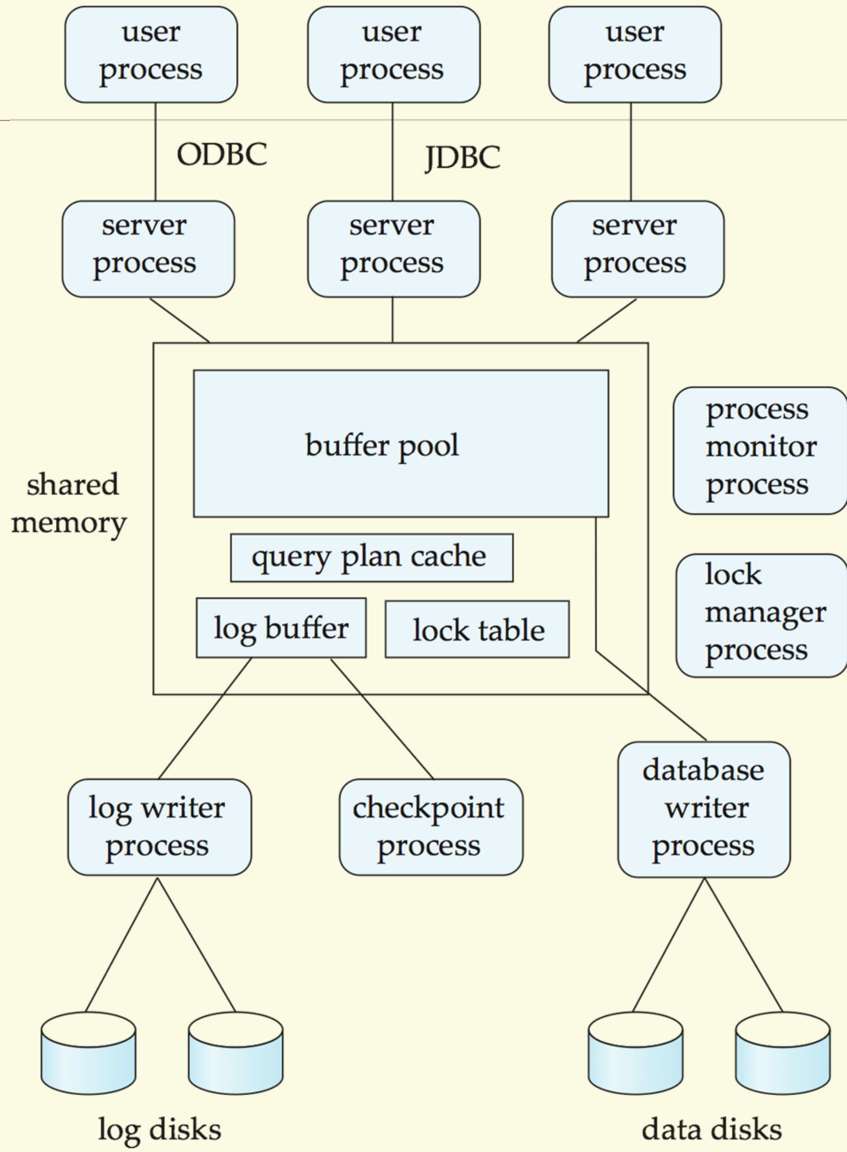
Server System Architecture

- Server systems can be broadly categorized into :
  - **transaction servers** which are widely used in relational database systems, and
  - **data servers**, used in object-oriented database systems

Transaction Servers

- ✓ Also called **query server** systems
  - Clients send requests to the server
  - Transactions are executed at the server
  - Results are shipped back to the client.
- ✓ Requests are specified in e.g., SQL, and communicated to the server through a *remote call* mechanism..
- ✓ *Open Database Connectivity* (ODBC) is a C language application program interface standard from Microsoft for connecting to a server, sending SQL requests, and receiving results.
- ✓ JDBC standard is similar to ODBC, for Java

Transaction System Processes (Cont.)



Data Servers

- ✓ Used in high-speed LANs, in cases where
  - The clients are comparable in processing power to the server
  - The tasks to be executed are compute intensive.
- ✓ Data are shipped to clients where processing is performed, and then shipped results back to the server.
- ✓ This architecture requires full back-end functionality at the clients.
- ✓ Used in many object-oriented database systems

Parallel Systems

- Parallel database systems consist of multiple processors and multiple disks connected by a fast interconnection network.
- A **coarse-grain parallel** machine consists of a small number of powerful processors
- A **massively parallel** or **fine grain parallel** machine utilizes thousands of smaller processors.
- Two main performance measures:
  - **throughput** --- the number of tasks that can be completed in a given time interval
  - **response time** --- the amount of time it takes to complete a single task from the time it is submitted

Speed-Up and Scale-Up

- ✓ **Speedup**: a fixed-sized problem executing on a small system is given to a system which is *N*-times larger.
  - Measured by:

    $$\textit{speedup} = \frac{\textit{small system elapsed time}}{\textit{large system elapsed time}}$$

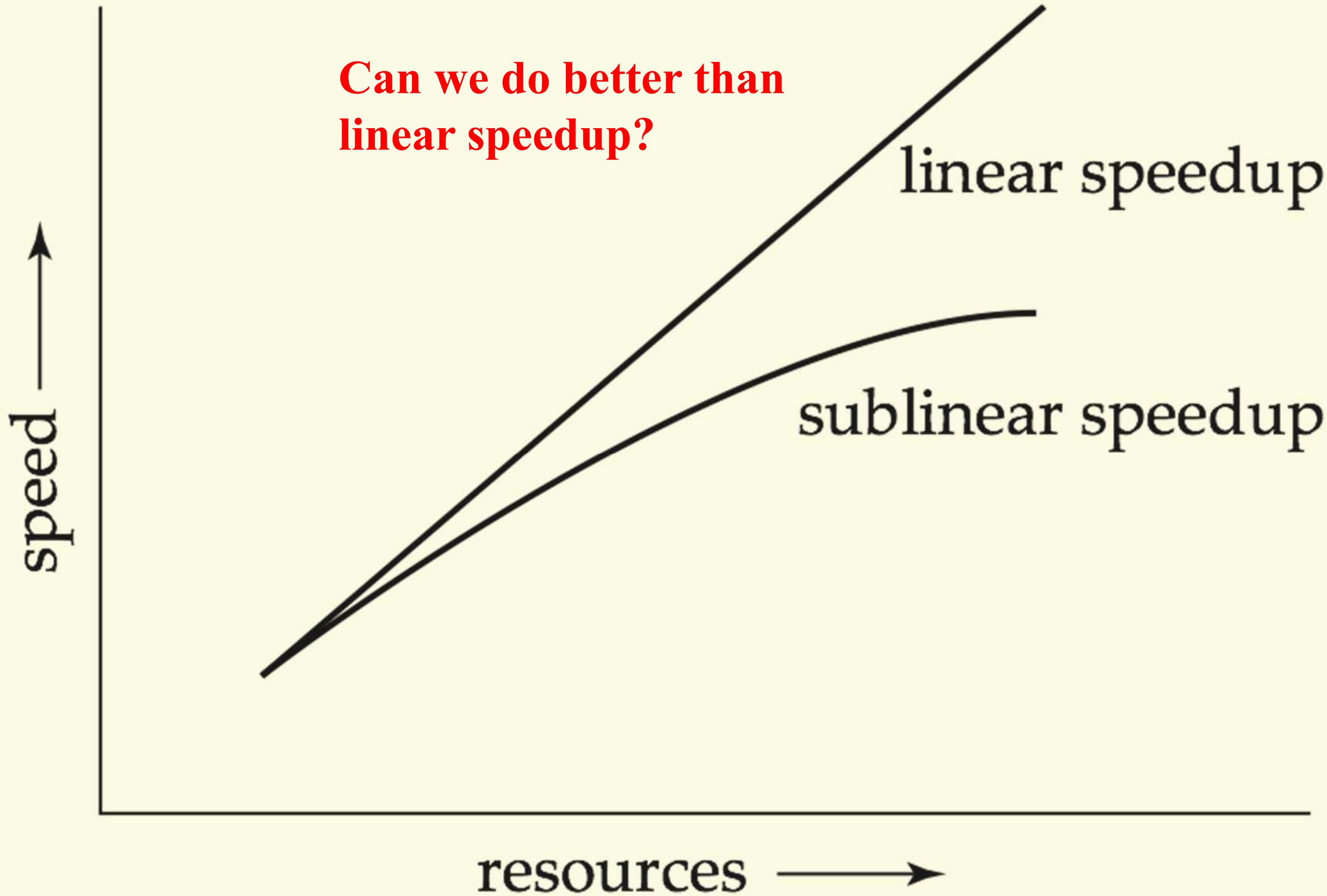
  - Speedup is **linear** if equation equals N.
- ✓ **Scaleup**: increase the size of both the problem and the system
  - *N*-times larger system used to perform *N*-times larger job
  - Measured by:

    $$\textit{scaleup} = \frac{\textit{small system small problem elapsed time}}{\textit{big system big problem elapsed time}}$$

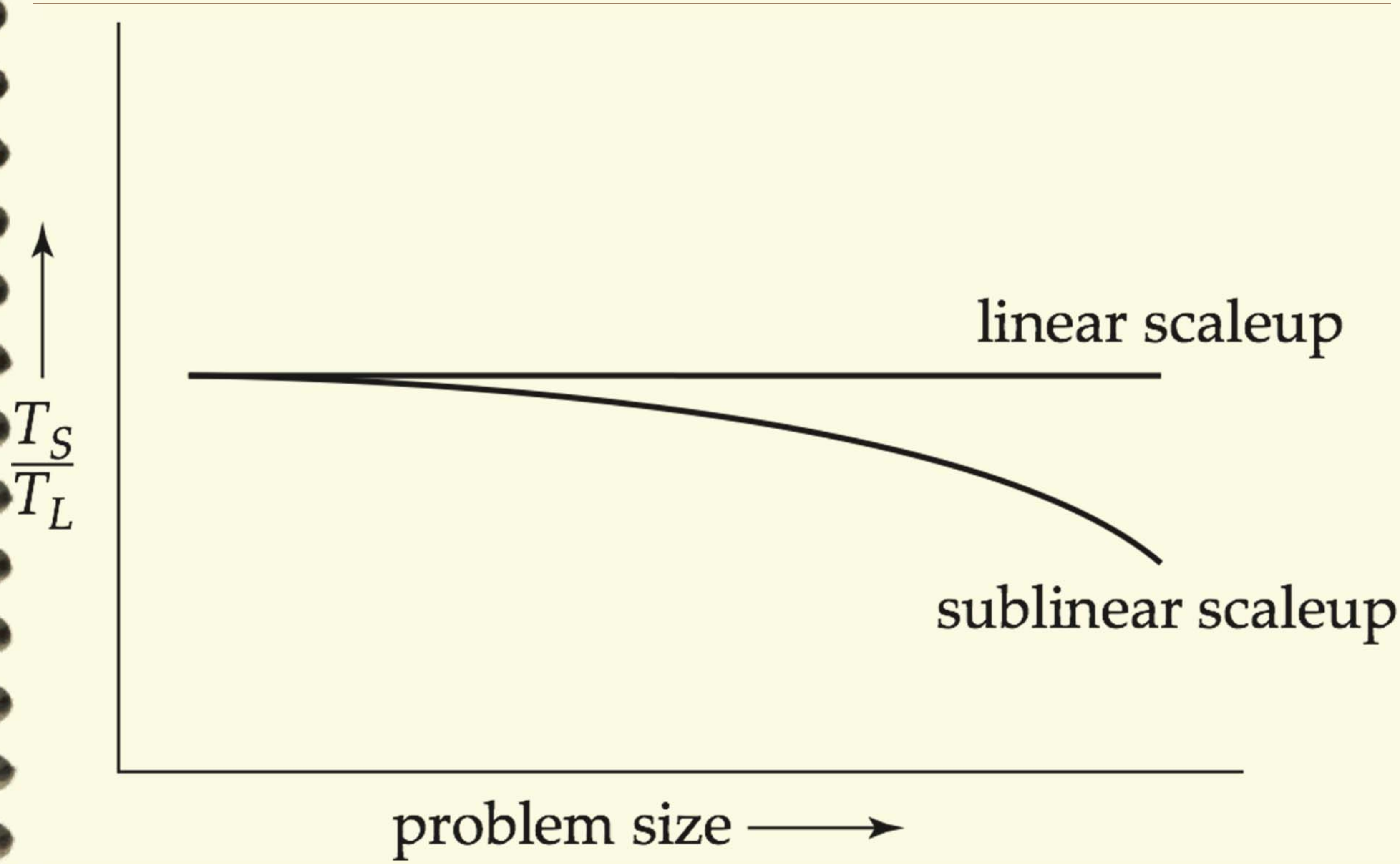
  - Scale up is **linear** if equation equals 1.

Speedup

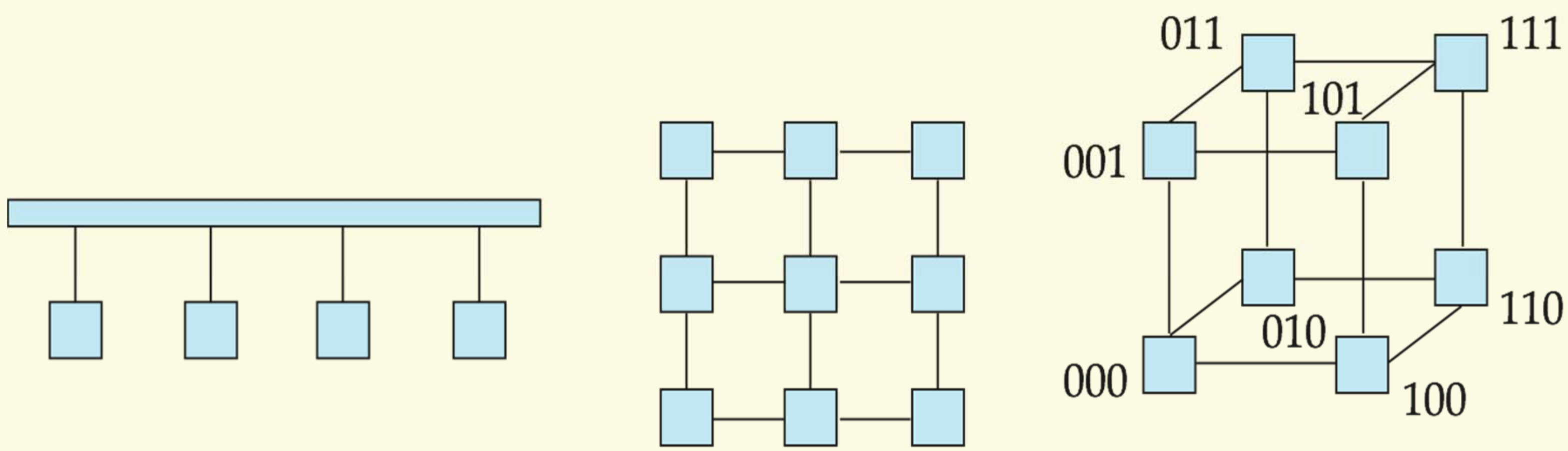
Can we do better than linear speedup?



Scaleup



Interconnection Architectures



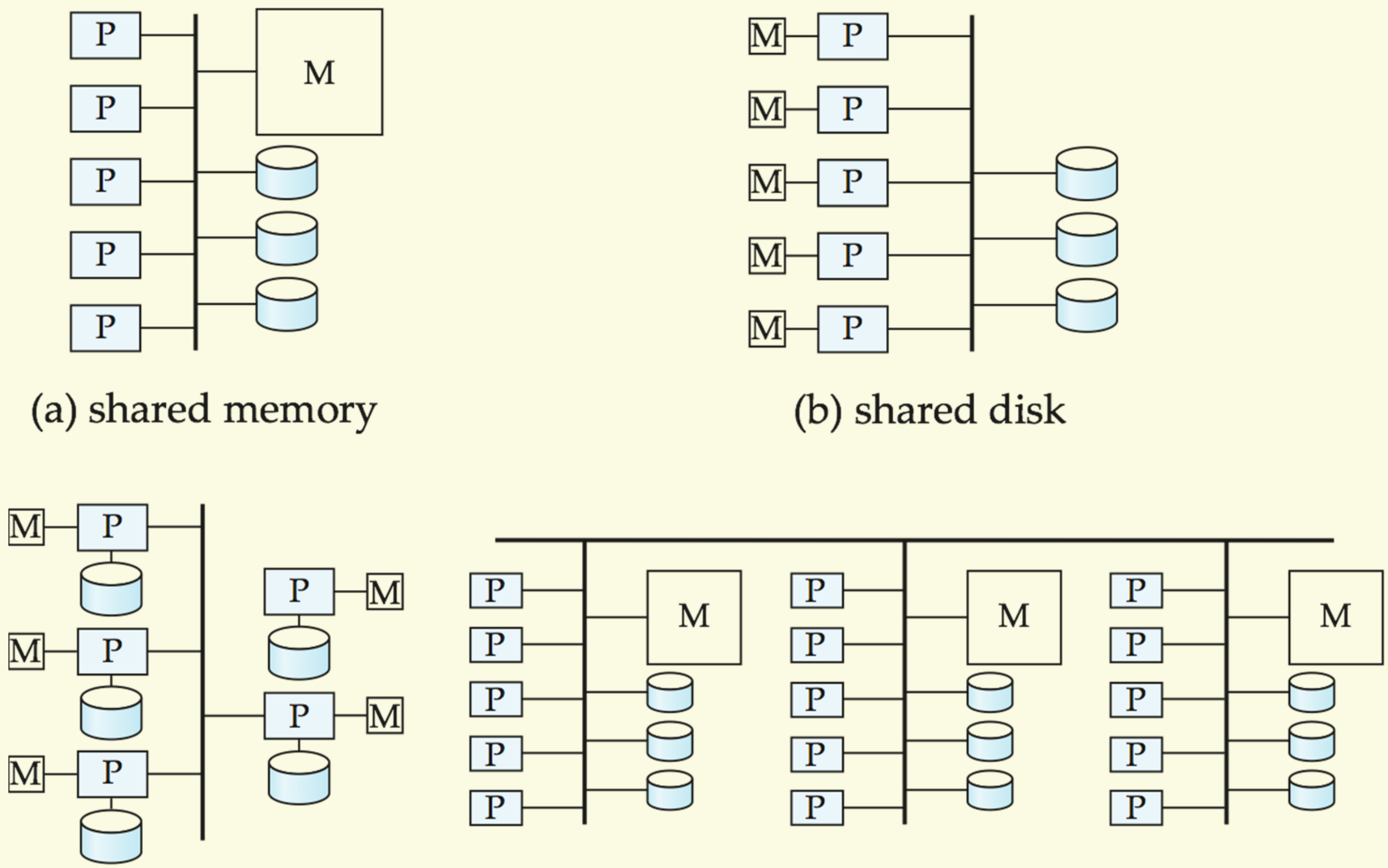
(a) bus (b) mesh (c) hypercube

send data on and receive data from a single communication bus; Does not scale well with increasing parallelism.

each connected to all adjacent components; scales better. But may require $2\sqrt{n}$ hops to send message to a node

numbered in binary; connected to one another if binary differ in exactly 1bit; *n components* connected to *log(n)* other components. can reach each other via at most *log(n)* links

Parallel Database Architectures

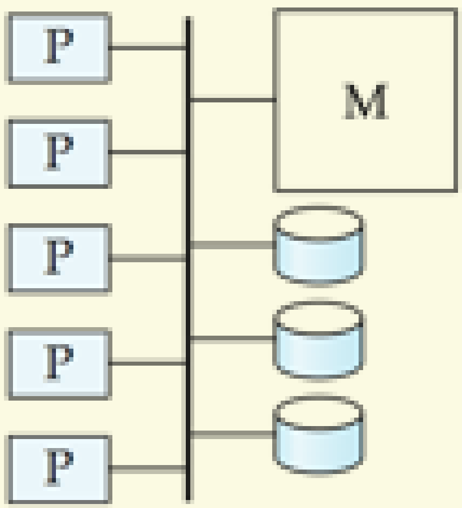


(a) shared memory (b) shared disk

(c) shared nothing (d) hierarchical

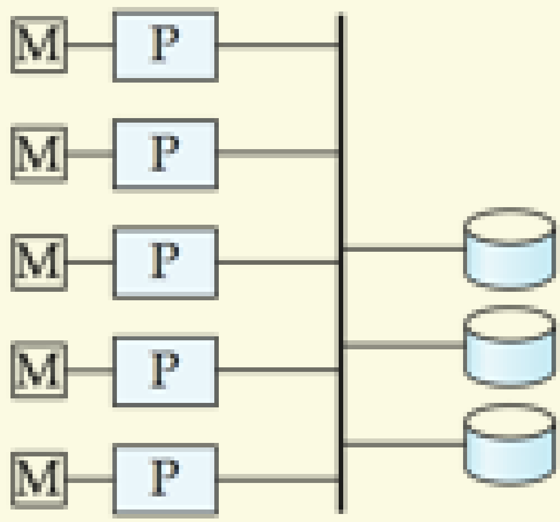
Shared Memory

- Processors and disks have access to a common memory, typically via a bus or through an interconnection network.
- Extremely efficient communication between processors — data in shared memory can be accessed by any processor without having to move it using software.
- Downside – architecture is not scalable beyond 32 or 64 processors since the bus or the interconnection network becomes a bottleneck
- Widely used for lower degrees of parallelism (4 to 8).



Shared Disk

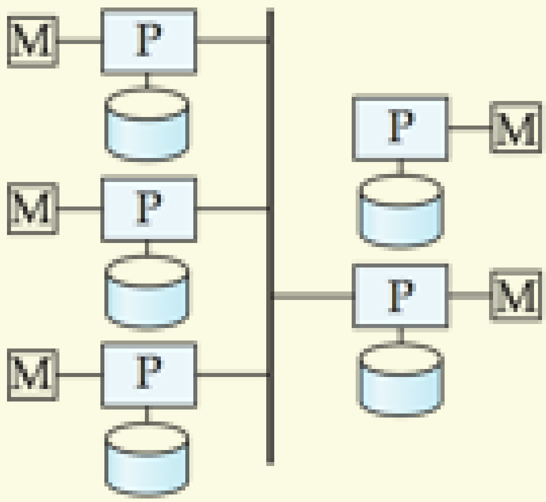
- All processors can directly access all disks via an interconnection network, but the processors have private memories.
  - The memory bus is not a bottleneck
  - Architecture provides a degree of **fault-tolerance**
- Downside: bottleneck now occurs at interconnection to the disk subsystem.
- Shared-disk systems can scale to a somewhat larger number of processors, but communication between processors is slower.



IBM Sysplex and DEC clusters (now part of Compaq) running Rdb (now Oracle Rdb

Shared Nothing

- Node consists of a processor, memory, and one or more disks. Processors at one node communicate with another processor at another node using an interconnection network.
- minimizing the interference of resource sharing.
- Shared-nothing multiprocessors can be scaled up to thousands of processors without interference.
- Main drawback: cost of communication and non-local disk access; sending data involves software interaction at both ends.



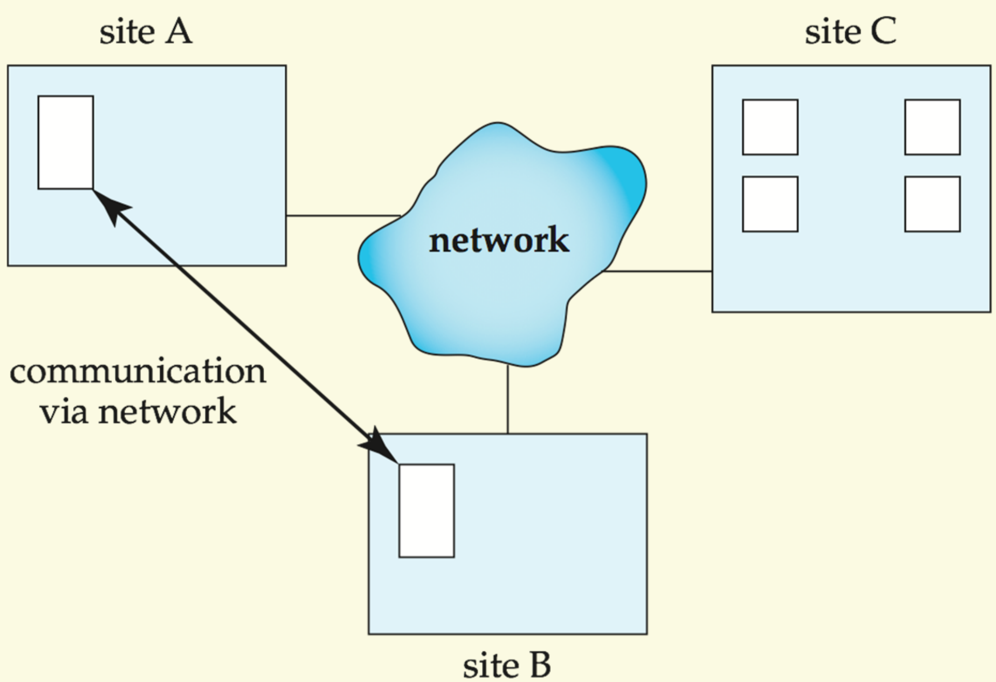
Teradata, Tandem, Oracle-n CUBE

Hierarchical

- Combines characteristics of shared-memory, shared-disk, and shared-nothing architectures.
- Top level is a shared-nothing architecture – nodes connected by an interconnection network, and do not share disks or memory with each other.
- Each node of the system could be a shared-memory system with a few processors.
- Alternatively, each node could be a shared-disk system, and each of the systems sharing a set of disks could be a shared-memory system.
- Reduce the complexity of programming such systems by **distributed virtual-memory** architectures
  - Also called **non-uniform memory architecture (NUMA)**

Distributed Systems

- ✓ Data spread over multiple machines (also referred to as **sites** or **nodes**).
- ✓ Network interconnects the machines
- ✓ Data shared by users on multiple machines



Distributed Databases

- Homogeneous distributed databases
  - Same software/schema on all sites, data may be partitioned among sites
  - Goal: provide a view of a single database, hiding details of distribution
- Heterogeneous distributed databases
  - Different software/schema on different sites
  - Goal: integrate existing databases to provide useful functionality
- Differentiate between *local* and *global* transactions
  - A **local transaction** accesses data in the *single* site at which the transaction was initiated.
  - A **global transaction** either accesses data in a site different from the one at which the transaction was initiated or accesses data in several different sites.

Trade-offs in Distributed Systems

- ✓ Sharing data – users at one site able to access the data residing at some other sites.
- ✓ Autonomy – each site is able to retain a degree of control over data stored locally.
- ✓ Higher system availability through redundancy — data can be replicated at remote sites, and system can function even if a site fails.
- ✓ Disadvantage: added complexity required to ensure proper coordination among sites.
  - Software development cost.
  - Greater potential for bugs.
  - Increased processing overhead.

Summary

- ✓ RDBMS design process
  - Normalization
  - the normal forms 1NF, 2NF, 3NF, BCNF, and 4NF
  - normal forms transformation
- ✓ DBMS architectures