Topics Covered : Distributed Databases: Introduction to Distributed Database Systems, Distributed Database System Architecture;

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NIT-Warangal:

Dept. Of Comp. Sc & Engg.

July – Nov 2023

Course Name (CS5305) : Advanced DataBases

Course Name (CS5309) : Advanced DataBases

Advanced Data Bases (References & Source for Presentation

The Presentation is prepared based on Author's experience on various research projects on Distributed Computing – Distributed Data Bases (NoSQL) well as references given in this presentation.

Source :

Text Books, Research Articles, Web Sites as indicated in many slides and References of this presentation

1. M T Ozsu, Patrick Valduriez, Principles of Distributed Database Systems, Prentice Hall, 3rd Edition 2011

NIT-Warangal: Dept. Of Comp. Sc & Engg. July – Nov 2023

Course Name : Advanced databases

M.C.A 2nd Year, July 2023

Syllabus:

UNIT 1 : Distributed Databases: Introduction to Distributed Database Systems, Distributed Database System Architecture;

UNIT 2 : Top-Down Approach, Distributed Database Design Issues, Fragmentation, Allocation, Database Integration, Bottom-up approach, Schema Matching, Schema Integration, Schema Mapping;

UNIT 3: Data and Access Control, View Management, Data Security; Query processing problem, Objectives of Query processing, Complexity of Relational Algebra Operations, Characterization of Query Processors, Layers of Query Processing;

UNIT 4 : Query Decomposition, Normalization, Analysis, Elimination of Redundancy and Rewriting;

UNIT 5 : Localization of Distributed Data, Reduction for primary Horizontal, Vertical, derived Fragmentation;

UNIT 6 : Distributed Query Execution, Query Optimization, Join Ordering, Static& Dynamic Approach, Semi-joins, Hybrid Approach;

NIT-Warangal: Dept. Of Comp. Sc & Engg. July – Nov 2023

Course Name : Advanced databases

Syllabus: **M.C.A 2nd Year, July 2023**

UNIT 7 : Taxonomy of Concurrency control Mechanisms, Lock-Based Concurrency Control, Timestamp-Based Concurrency Control, Optimistic Concurrency Control, Deadlock Management;

UNIT 8 : Heterogeneity issues Advanced Transaction Models, Distributed systems 2PC& 3PC protocols, Replication protocols, Replication and Failures, HotSpares;

UNIT 9: Parallel Databases: Introduction to Parallel Databases, Parallel Database System Architectures, Parallel Data Placement, Full Partitioning; Parallel Query Processing, Query Parallelism;

UNIT 10 : Parallel Query Optimization, Search Space, Cost Model, Search Strategy; Load Balancing.

Text Books/ Reference Books / Online Resources:

M T Ozsu, Patrick Valduriez, Principles of Distributed Database Systems, Prentice Hall, 1999.

S. Ceri and G. Pelaggati, Distributed Database System Principles and Systems, MGH, 1985.

Course Name : Advanced databases

Topics Covered in this Lecture

UNIT 1 : Distributed Databases: Introduction to Distributed Database Systems, Distributed Database System Architecture;

UNIT 2 : Top-Down Approach, Distributed Database Design Issues, Fragmentation, Allocation, Database Integration, Bottom-up approach, Schema Matching, Schema Integration, Schema Mapping;

Chapter-02 of Reference Book No. 1

Part-01

Background

1. Two technological bases for distributed database technology**: database management** and **computer networks**

2. Overview of the concepts in these two fields that **are more important from** the perspective of distributed database technology.

Overview of Relational DBMS

1. Define the terminology and framework used

2. Most of the distributed database technology has been developed using the relational mode

- ❖ Relational Database Concepts
  - Normalisation
  - Relational Data Languages

- ❖ Review of Computer Networks

Relational Database Concepts

A database is a structured collection of data related to some real-life phenomena that we are trying to model. A relational database is one where the database structure is in the form of tables. Formally, a relation **R** defined over **n** sets $D_1, D_2, : : : , D_n$ (not necessarily distinct) is a set of n-tuples (or simply tuples)

$$<d_1, d_2, : : : ; d_n>$$

such that

$$d_1 \in D_1, d_2 \in D_2, : , d_n \in D_n.$$

Relational Database Concepts

Example : Use a database that models an engineering company. The entities to be modelled are the employees (**EMP**) and projects (**PROJ**).

For each employee, keep track of the

- employee number (**ENO**),
- name (**ENAME**),
- title in the company (**TITLE**),
- Salary (**SAL**),
- identification number of the project(s) the employee is working on (**PNO**),
- responsibility within the project (**RESP**), and duration of the assignment to the project (**DUR**) in months.
- Similarly, for each project, to store the project number (**PNO**), the project name (**PNAME**), & the project budget (**BUDGET**).

Relational Database Concepts

Sample Database Scheme

EMP

ENO	ENAME	TITLE	SAL	PNO	RESP	DUR

PROJ

PNO	PNAME	BUDGET

The ***relation schemas*** for this database can be defined as follows:

EMP(ENO, ENAME, TITLE, SAL, PNO, RESP, DUR)

PROJ(PNO,PNAME, BUDGET)

In relation scheme **EMP,** there are seven attributes: **ENO, ENAME, TITLE, SAL, PNO, RESP, DUR.** The values of **ENO** come from the domain of all valid employee numbers, say D_1, the values of **ENAME** come from the domain of all valid names, say D_2, and so on. Note that each attribute of each relation does not have to come from a distinct domain.

Relational Database Concepts

- Various attributes within a relation or from a number of relations may be defined over the same domain

- The ***key*** of a relation scheme is the minimum non-empty subset of its attributes such that the values of the attributes comprising the ***key*** uniquely identify each tuple of the relation.

- The attributes that make up ***key*** are called prime attributes. The
- superset of a ***key*** is usually called a ***superkey***. Thus in our example the ***key*** of ***PROJ*** is ***PNO***, and that of ***EMP*** is the set (***ENO, PNO***).

Relational Database Concepts

- Each relation has at least one ***key.*** Sometimes, there may be more than ***one possibility*** for the key.

- In such cases, each alternative is considered ***a candidate key***, and one of the candidate keys is chosen as the ***primary key***, which we denote by ***underlining.***

- The number of attributes of a relation defines its ***degree***, whereas the number of tuples of the relation defines its ***cardinality***.

- In tabular form, the example database consists of two tables, as shown in Figure. The columns of the tables correspond to the attributes of the relations; if there were any information entered as the rows, they would correspond to the tuples

Relational Database Concepts

- In tabular form, the example database consists of two tables, as shown in Figure. The columns of the tables correspond to the attributes of the relations;
- if there were any information entered as the rows, they would correspond to the tuples.
- The empty table, showing the structure of the table, corresponds to the relation schema; when the table is filled with rows, it corresponds to a relation instance.

Relational Database Concepts

EMP

ENO	ENAME	TITLE	SAL	PNO	RESP	DUR
E1	J. Doe	Elect. Eng.	40000	P1	Manager	12
E2	M. Smith	Analyst	34000	P1	Analyst	24
E2	M. Smith	Analyst	34000	P2	Analyst	6
E3	A. Lee	Mech. Eng.	27000	P3	Consultant	10
E3	A. Lee	Mech. Eng.	27000	P4	Engineer	48
E4	J. Miller	Programmer	24000	P2	Programmer	18
E5	B. Casey	Syst. Anal.	34000	P2	Manager	24
E6	L. Chu	Elect. Eng.	40000	P4	Manager	48
E7	R. Davis	Mech. Eng.	27000	P3	Engineer	36
E8	J. Jones	Syst. Anal.	34000	P3	Manager	40

PROJ

PNO	PNAME	BUDGET
P1	Instrumentation	150000
P2	Database Develop.	135000
P3	CAD/CAM	250000
P4	Maintenance	310000

Overview of Relational DBMS - Normalization

The aim of normalization is to eliminate various anomalies (or undesirable aspects) of a relation in order to obtain "better" relations. The following four problems might exist in a relation scheme:

- Repetition anomaly
- Update anomaly
- Insertion anomaly
- Deletion anomaly

Normalization transforms arbitrary relation schemes into ones without these problems. A relation with one or more of the above mentioned anomalies is split into two or more relations of a higher normal form.

Overview of Relational DBMS-Relational Data Languages

Data manipulation languages developed for the relational model (commonly called ***query languages***) fall into two fundamental groups: ***relational algebra languages*** and ***relational calculus languages***. The difference between them is based on how the user query is formulated.

- The relational algebra is procedural in that the user is expected to specify, using certain high-level operators, how the result is to be obtained.

- The relational calculus, on the other hand, is non-procedural; the user only specifies the relationships that should hold in the result.

Relational Data Languages - Relational Algebra

Relational Algebra

- Relational algebra consists of a set of operators that operate on relations.
- Each operator takes one or two relations as operands and produces a result relation, which, in turn, may be an operand to another operator.
- These operations permit the querying and updating of a relational database.

Relational Data Languages - Relational Algebra

Normalized Relations

EMP

ENO	ENAME	TITLE
E1	J. Doe	Elect. Eng
E2	M. Smith	Syst. Anal.
E3	A. Lee	Mech. Eng.
E4	J. Miller	Programmer
E5	B. Casey	Syst. Anal.
E6	L. Chu	Elect. Eng.
E7	R. Davis	Mech. Eng.
E8	J. Jones	Syst. Anal.

ASG

ENO	PNO	RESP	DUR
E1	P1	Manager	12
E2	P1	Analyst	24
E2	P2	Analyst	6
E3	P3	Consultant	10
E3	P4	Engineer	48
E4	P2	Programmer	18
E5	P2	Manager	24
E6	P4	Manager	48
E7	P3	Engineer	36
E8	P3	Manager	40

PROJ

PNO	PNAME	BUDGET
P1	Instrumentation	150000
P2	Database Develop.	135000
P3	CAD/CAM	250000
P4	Maintenance	310000

PAY

TITLE	SAL
Elect. Eng.	40000
Syst. Anal.	34000
Mech. Eng.	27000
Programmer	24000

Relational Data Languages - Relational Algebra

Normalized Relations

There are five fundamental relational algebra operators and five others that can be defined in terms of these. The fundamental operators are selection, projection, union, set difference, and Cartesian product.

The first two of these operators are unary operators, and the last three are binary operators.

The additional operators that can be defined in terms of these fundamental operators are intersection, θ - join, natural join, semi-join and division.

Relational Data Languages - Relational Algebra

Unary Relational Operations

SELECT (symbol: σ)
PROJECT (symbol: π)
RENAME (symbol: ρ)

Relational Algebra Operations From Set Theory

UNION (υ)
INTERSECTION (∩),
DIFFERENCE (-)
CARTESIAN PRODUCT (x)

Binary Relational Operations

JOIN
DIVISION

Relational Calculus

In Relational calculus-based languages, instead of specifying how to obtain the result, one specifies what the result is by stating the relationship that is supposed to hold for the result.

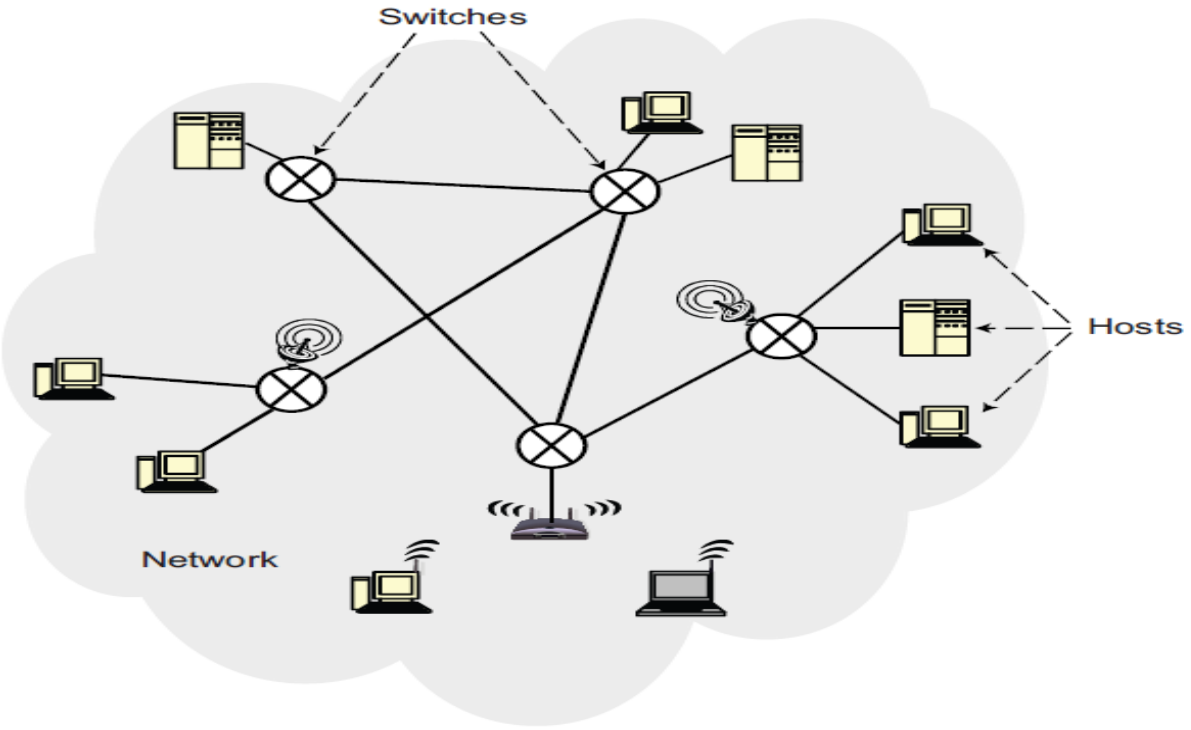
Relational calculus languages fall into two groups: tuple relational calculus and domain relational calculus. The difference between the two is in terms of the primitive variable used in specifying the queries.

Review of Computer Networks

Computer networking concepts relevant to distributed database systems

Define a **computer network as an interconnected collection of autonomous computers** that are capable of exchanging information among themselves (Figure).

The keywords :
connected and
autonomous.



Review of Computer Networks

- Computers to be autonomous so that each computer can execute programs on its own.
- The computers to be interconnected so that they are capable of exchanging information.
- Computers on a network are referred to as **nodes, hosts, end systems**, or **sites.**
- Note that sometimes the terms **host** and **end system** are used to refer simply to the equipment, whereas site is reserved for the equipment as well as the software that runs on it.

Review of Computer Networks

- The hosts are connected to the **network through switches** (represented as circles with an X in them)2, which are special-purpose equipment that route messages through the network.

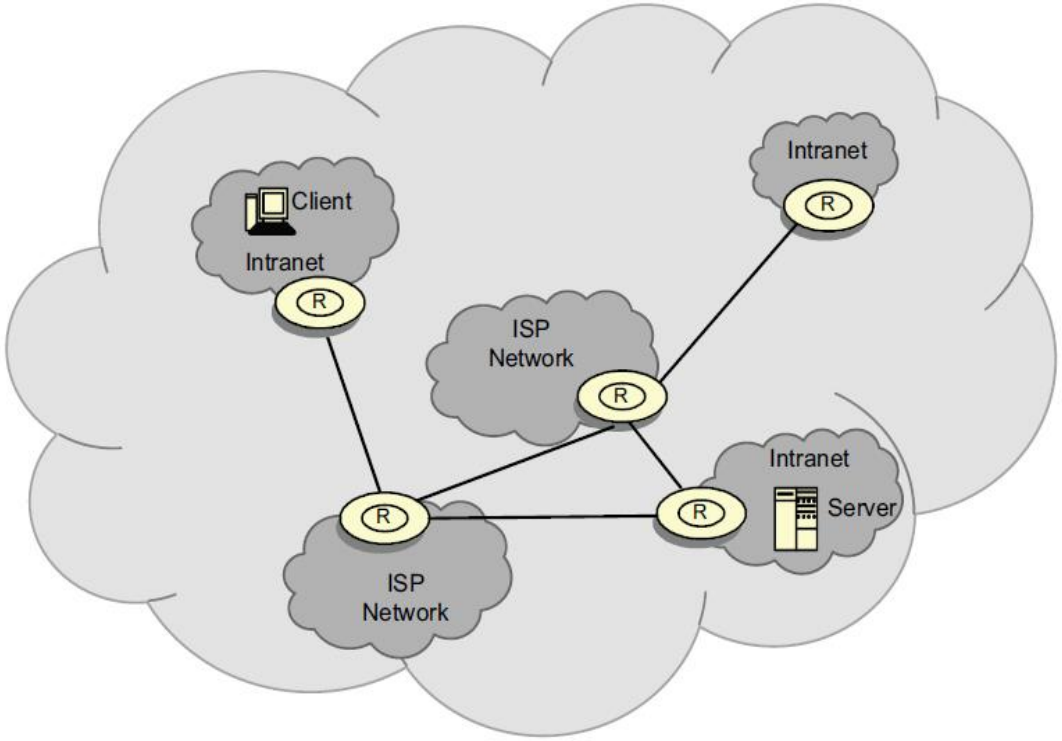
- Some of the hosts may be connected to the switches directly (using **fiber optic, coaxial cable or copper wire**) and some via wireless base stations.

- The switches are connected to each other by communication links that may be **fiber optics, coaxial cable, satellite links, microwave connections**, etc.

Review of Computer Networks

- Network of networks (Internet)
- Each of these networks is referred to as an intranet to highlight the fact that they are “internal” to an organization. An intranet, then, consists of a set of links and routers (shown as “R” in Figure

For instance, the routers and links at a university constitute a single administrative domain.



Review of Computer Networks

- Types of Networks: There are various criteria by which computer networks can be classified.
- **One criterion** is the geographic distribution
- **Second criterion** is the interconnection structure of nodes (also called topology), and the third is the mode of transmission.
- **Scale :**
  - A wide area network (**WAN**) is one where the link distance between any two nodes is greater than approximately 20 kilometers (km) and can go as large as thousands of kilometers.
  - WANs are typically characterized by the heterogeneity of the transmission media, the computers, and the user community involved. Early WANs had a limited capacity of less than a few megabits-per-second (Mbps)

Review of Computer Networks

❖ Scale :

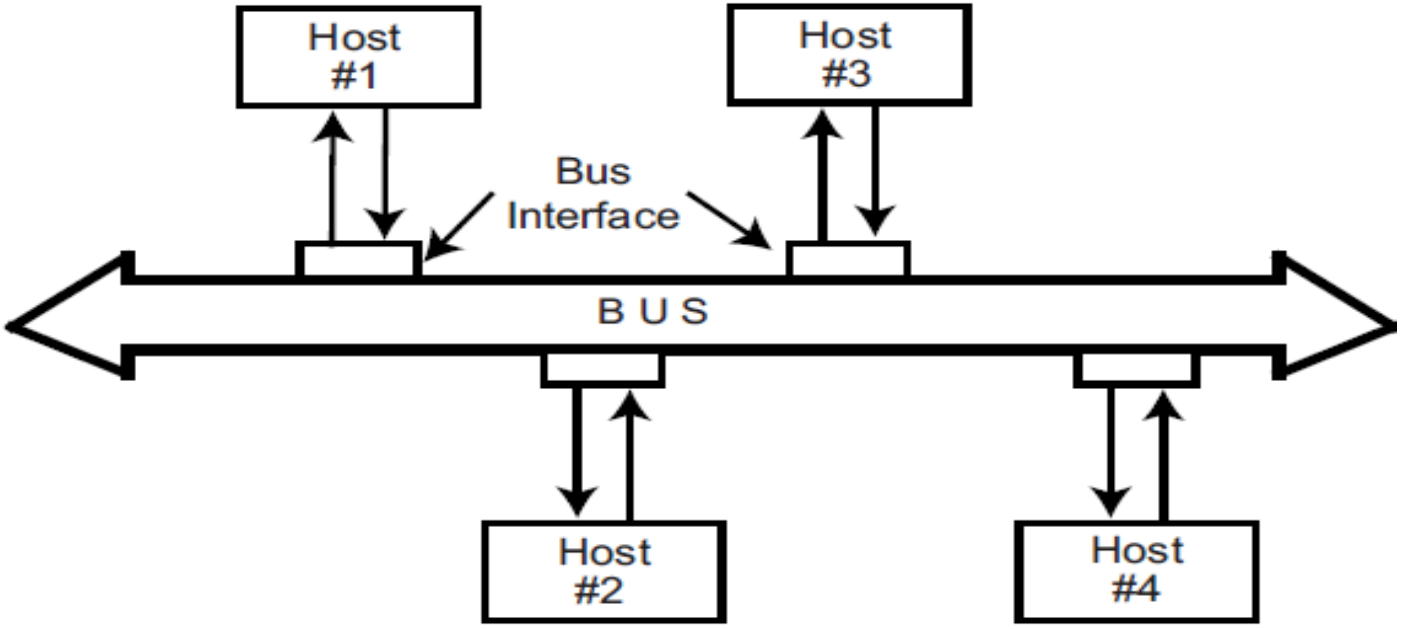
- **Local area networks (LANs)** are typically limited in geographic scope (usually less than 2 km). They provide higher capacity communication over inexpensive transmission media.
- The capacities are typically in the range of 10-1000 Mbps per connection.
- Higher capacity and shorter distances between hosts result in very short delays.

Metropolitan area networks (MANs) are in between LANs and WANs in scale and cover a city or a portion of it. The distances between nodes is typically on the order of 10 km.

Review of Computer Networks

Topology : The network in Figure is what is called an irregular network, where the interconnections between nodes do not follow any pattern. It is possible to find a node that is connected to only one other node, as well as nodes that have connections to a number of nodes. Internet is a typical irregular network.

Bus Network



Review of Computer Networks

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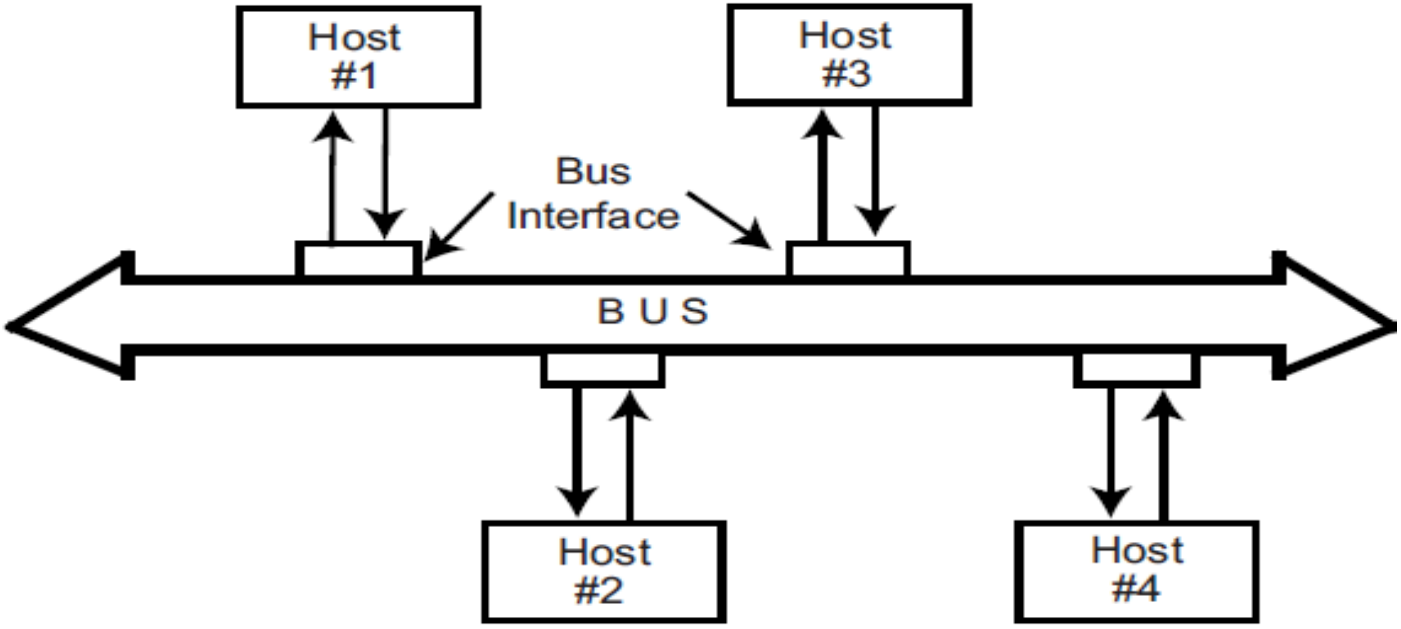
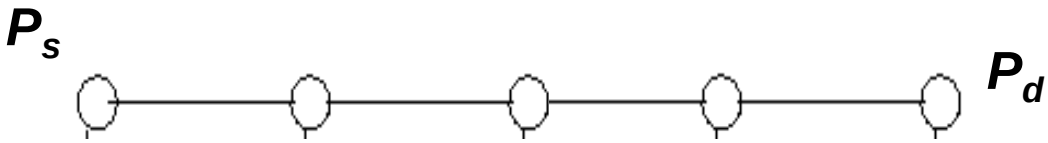
Bus Network

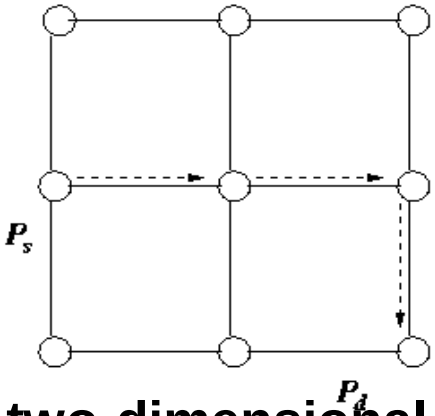


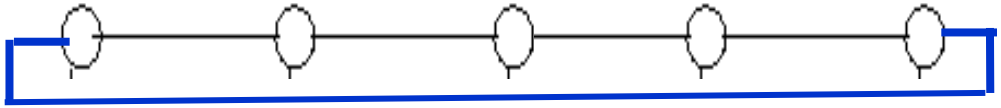
Interconnection Networks -Network Topologies

Other common alternatives are star, ring, bus, and mesh networks.



A Linear array mesh with an illustration of routing a message from processor of P_s to processor P_d,

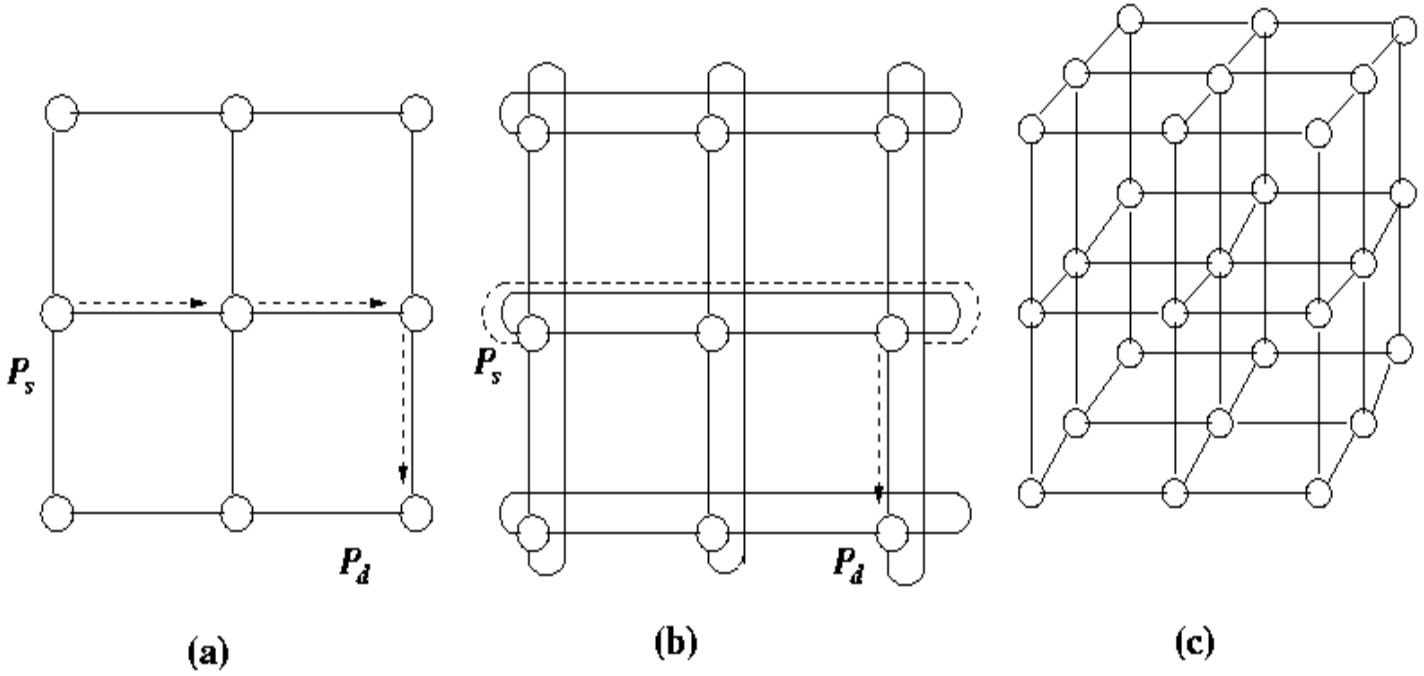




Linear array with wrap-around mesh (Ring)

(a) A two-dimensional mesh with an illustration of routing a message from processor of P_s to processor P_d,

Interconnection Networks -Network Topologies

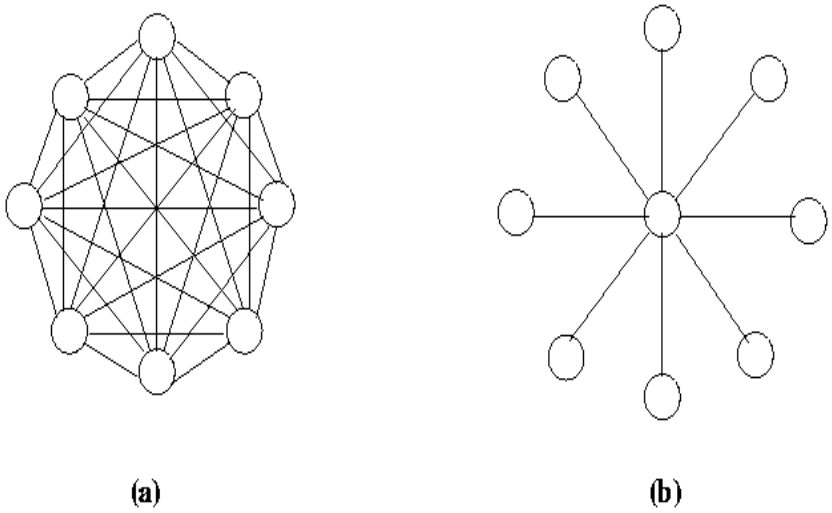


(a) A two-dimensional mesh with an illustration of routing a message from processor of P_s to processor P_d, (b) a two-dimensional wraparound mesh with an illustration of routing a message from processor P_s to processor P_d, (c) a three-dimensional mesh.

Interconnection Networks -Network Topologies

Message-passing architectures use static interconnection networks to connect processors

- Completely Connected Network
- Linear array ring
- Mesh net work
- HyperCube network



(a) (b)

(a) A complete-connected network of eight processors and
(b) A star-connected network of nine processors

Data Communication Concepts

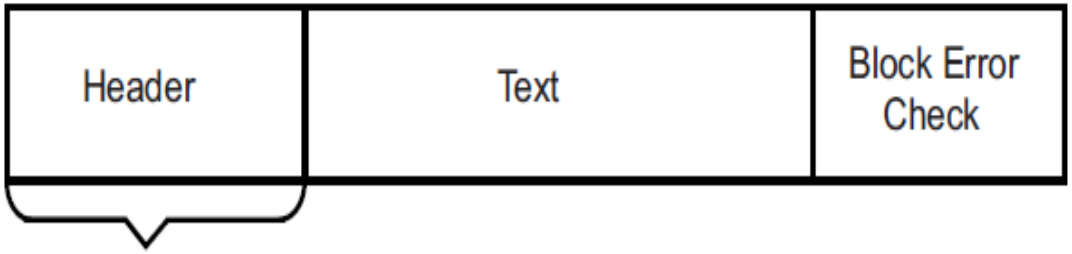
- Hosts are connected by *links*, each of which can carry one or more channels. *Link* is a physical entity whereas channel is a *logical* one.

- Each communication channel has a ***capacity***, which can be defined as the amount of information that can be transmitted over the channel in a given time unit. This capacity is commonly referred to as the ***bandwidth*** of the channel

- The actual rate at which data are transmitted across the network is known as the ***data transfer rate*** and this rate is usually less than the actual bandwidth of the transmission channel. The software issues, that generally are referred as ***network protocols,***

Data Communication Concepts

- In computer-to-computer communication, data are usually transmitted in packets.
- Usually, upper limits on frame sizes are established for each network and each contains data as well as some control information, such as the *destination* and *source addresses*, *block error check code*s, and so on



- Source address
- Destination address
- Message number
- Packet number
- Acknowledgment
- Control information

Data Communication Concepts

- Another form of switching used in computer communication is packet switching, where a message is broken up into packets and each packet transmitted individually.

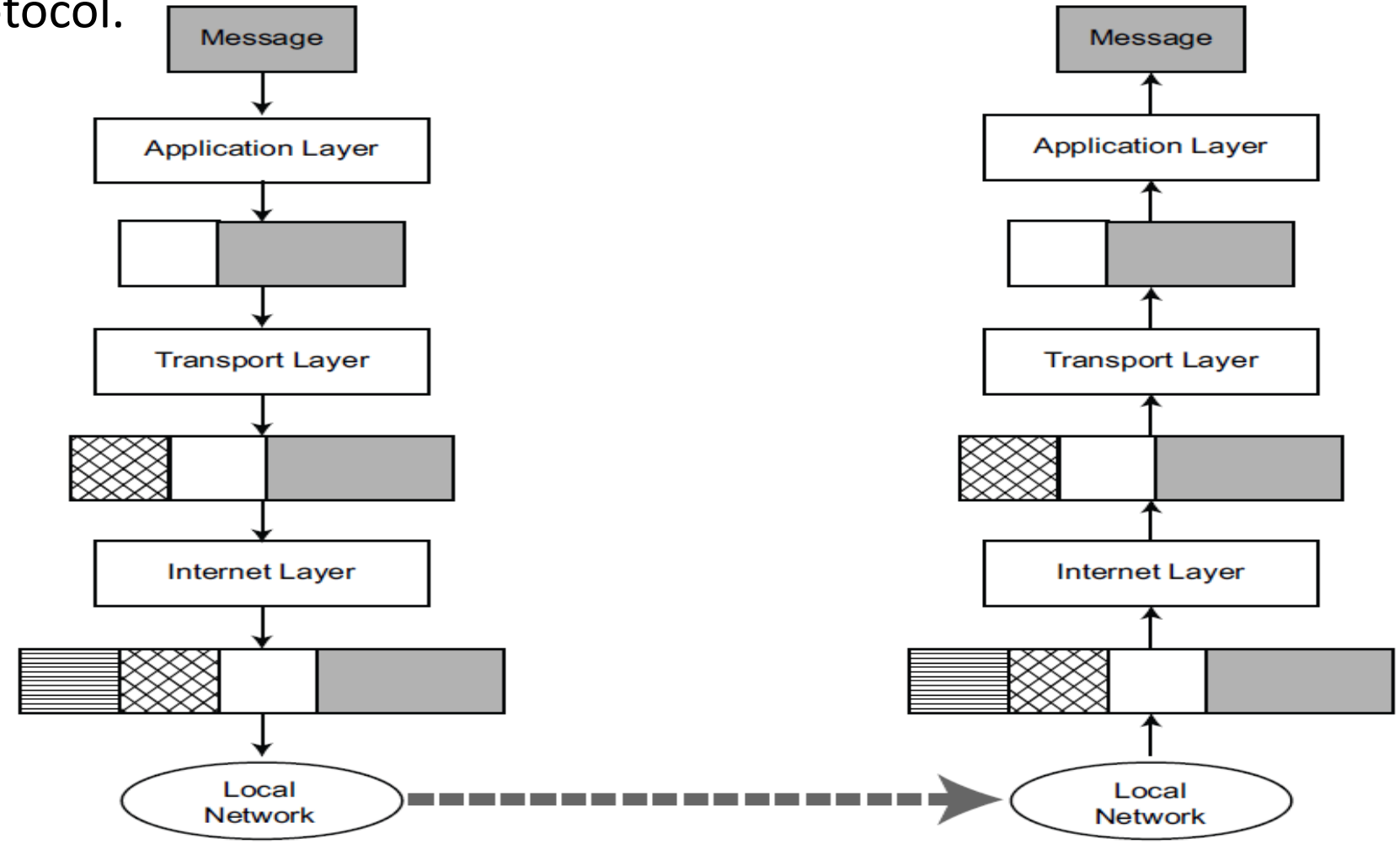
- TCP/IP protocol : referred to messages being transmitted; in fact the TCP protocol (or any other transport layer protocol) takes each application package and breaks it up into fixed sized packets.

- Therefore, each application message may be sent to the destination as multiple packets.

- There are different protocol stacks for different types of networks; however, for communication over the Internet, the standard one is what is referred to as TCP/IP that stands for “Transport Control Protocol/Internet Protocol”.

Data Communication Concepts :TCP/IP

how a message from a process on host C in Figure is transmitted to a process on server S, assuming both hosts implement the TCP/IP protocol.



Data Communication Concepts :TCP/IP

TCP/IP is in fact a family of protocols, commonly referred to as the protocol stack. It consists of two sets of protocols, one set at the transport layer and the other at the network (Internet) layer