EE6223
Computer Control Networks

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Contents To Be Covered

W1-W5

1) Basics of Local Area Networks (LAN)
2) Network Technologies (Bus, Ring, Star, Wireless LANs)
3) Connecting LANs (Repeaters, Bridges, Switches, Routers)
4) LAN Systems (Ethernet, CSMA/CD, Token Ring, FDDI, Wireless LAN)
5) Processes and threads

References: W. Stallings, "Data and Computer Communications," Prentice Hall

M. Subramanian, "Network Management: Principles and Practices"

Part 1

BASICS OF NETWORKS

Basics of Local Area Networks

- 👍 What's Local Area Network (LAN)
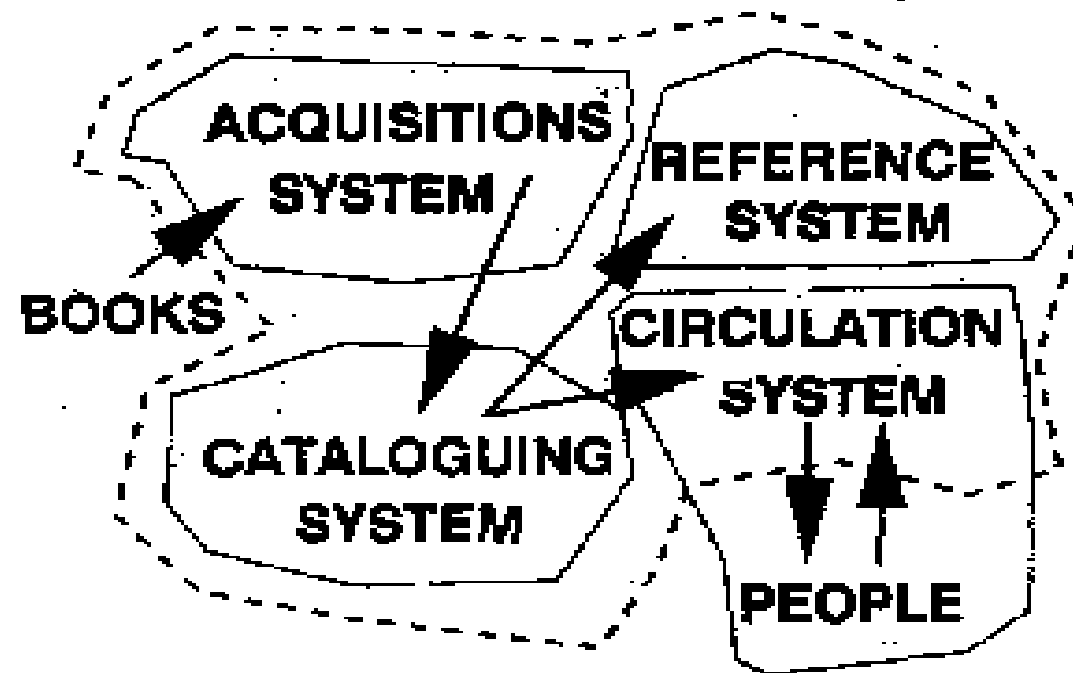
- 👍 What's Wide Area Network (WAN)

- 👍 What's Internet

- 👍 What's Control Network

What's a System?

System:
Set of components that interact to achieve common goal

eg: library system   & subsystems

Computer Systems

- A computer requires both hardware and software.
- Hardware
  - the physical, tangible parts of a computer
  - keyboard, monitor, disks, wires, chips, etc.

- Software
  - programs and data
  - a *program* is a series of instructions

- Each is essentially useless without the other

CD/DVD drive (storage)

floppy disk drive (storage)

hard disk drive (storage)

PC video camera (input)

monitor (output)

screen

pointer

modem (communications)

speaker (output)

speaker (output)

scanner (input)

system unit (processor, memory, and storage)

keyboard (input)

mouse (input)

card reader (storage)

digital camera (input)

microphone (input)

printer (output)

Digital Information

- Computers store all information digitally:
    - numbers
    - text
    - graphics and images
    - video
    - audio
    - program instructions

- In some way, all information is *digitized* - broken down into pieces and represented as numbers

Data Representation

☞ Once information is digitized, it is represented and stored in memory using the *binary number system.*

☞ A single binary digit (0 or 1) is called a **bit**.

  ✖ A bit has 2 states –

    ✔ 0,1

  ✖ 2 bits have 4 states - 2^2

    ✔ 00, 01, 10, 11

  ✖ 3 bits have 8 states – 2^3

    ✔ 000, 001, 010, 011, 100, 101, 110, 111

  ✖ …

Data Representation (Cont'd)

Char	7 bit ASCII	Char	7 bit ASCII	Char	7 bit ASCII	Char	7 bit ASCII
A	100 0001	N	100 1110	a	110 0001	n	110 1110
B	100 0010	O	100 1111	b	110 0010	o	110 1111
C	100 0011	P	101 0000	c	110 0011	p	111 0000
D	100 0100	Q	101 0001	d	110 0100	q	111 0001
E	100 0101	R	101 0010	e	110 0101	r	111 0010
F	100 0110	S	101 0011	f	110 0110	s	111 0011
G	100 0111	T	101 0100	g	110 0111	t	111 0100
H	100 1000	U	101 0101	h	110 1000	u	111 0101
I	100 1001	V	101 0110	i	110 1001	v	111 0110
J	100 1010	W	101 0111	j	110 1010	w	111 0111
K	100 1011	X	101 1000	k	110 1011	x	111 1000
L	100 1100	Y	101 1001	l	110 1100	y	111 1001
M	100 1101	Z	101 1010	m	110 1101	z	111 1010

ASCII - the American Standard Code for Information Interchange

Data Representation (Cont'd)

Char	7 bit ASCII	Char	7 bit ASCII
0	011 0000	+	010 1011
1	011 0001	$	010 0100
2	011 0010	*	010 1010
3	011 0011	)	010 1001
4	011 0100	-	010 1101
5	011 0101	/	010 1111
6	011 0110	,	010 1100
7	011 0111	=	011 1101
8	011 1000	RETURN	000 1101
9	011 1001	LNFEED	000 1010
blank	010 0000	0	011 0000
.	010 1110	0	011 0000
(	010 1000	0	011 0000

Data Representation (Cont'd)

How many items can be represented by

1 bit ? $2^1 = 2$ items

2 bits ? $2^2 = 4$ items

3 bits ? $2^3 = 8$ items

4 bits ? $2^4 = 16$ items

5 bits ? $2^5 = 32$ items

1 bit	2 bits	3 bits	4 bits	
0	00	000	0000	1000
1	01	001	0001	1001
	10	010	0010	1010
	11	011	0011	1011
		100	0100	1100
		101	0101	1101
		110	0110	1110
		111	0111	1111

Each additional bit doubles the number of possible permutations

Data Representation (Cont'd)

- 👍 1 bit = 1 Binary digit
- 👍 1 nibble = 4 bits
- 👍 1 byte = 8 bits
- 👍 1 Kilobyte = 1024 bytes (2^{10})
  - ✖ or c. 1000 bytes (10^3)
- 👍 1 megabyte = 1024Kb (2^{20})
  - ✖ or c. 1 million bytes (10^6)
- 👍 1 Gigabyte = 1024Mb (2^{30})
  - ✖ or c. 1 billion bytes (10^9)
- 👍 1 Terabyte = 1024Gb (2^{40})
- 👍 1 Petabyte = 1024Tb (2^{50})
- 👍 1 Exabyte = 1024Pb (2^{60})

What is Software?

- A software program is a series of statements or instructions to the computer. A program is loaded into memory (RAM). Its execution is referred to as a process.

- Software makes hardware do useful work.

- Layer framework for Software:
  - BIOS
  - System Software (Operating system)
  - Application Software

Software Layers

Users

Application Software

System Software

Hardware
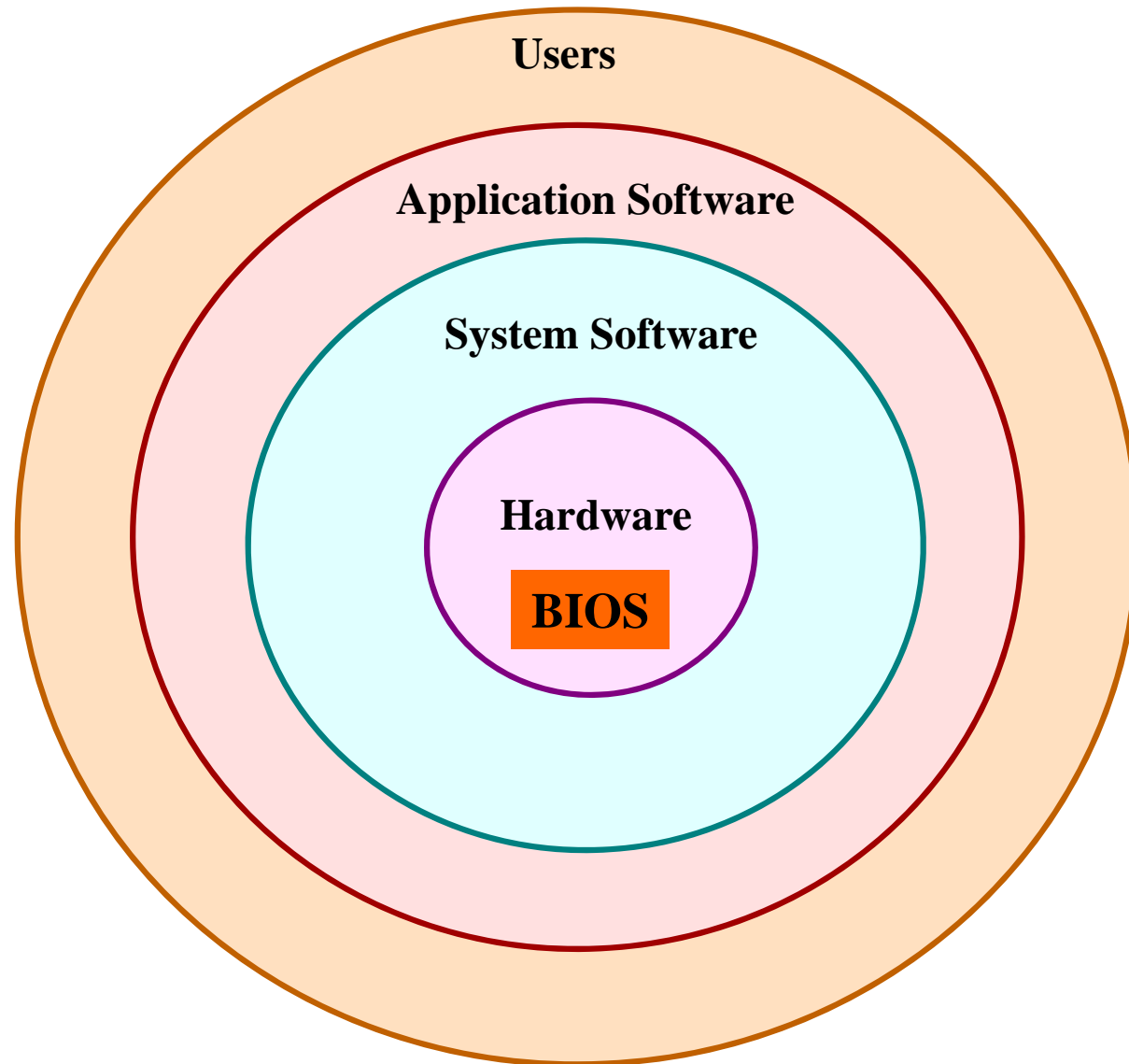
BIOS

Software Layers (Cont'd)

- ☝ BIOS (Basic Input Output System)
  - ✖ Set of routines stored in read-only memory that enable a computer to start the operating system and to communicate with the various devices in the system, such as disk drives, keyboard, monitor, printer, and communications ports.
- ☝ System Software (Operating System):
  - ✖ A piece of software between hardware and applications that allows user to communicate with the computer.
  - ✖ Manages resources such as CPU, RAM, secondary storage, printers, communication devices...
  - ✖ Windows XP, Windows 2000, Unix, Linux, Mac OS.
- ☝ Application Software
  - ✖ Performs a specific task on the computer
  - ✖ E.g. word processing, spreadsheets, program languages, games ...

Computer Data Storage

Relationships

| Hardware | ⟷ | System Software | ⟷ | Application Software |

Print on screen,
Read keyboard entries,
Write files on disk,…

Surf Web,
Format document,
Play games,…

User
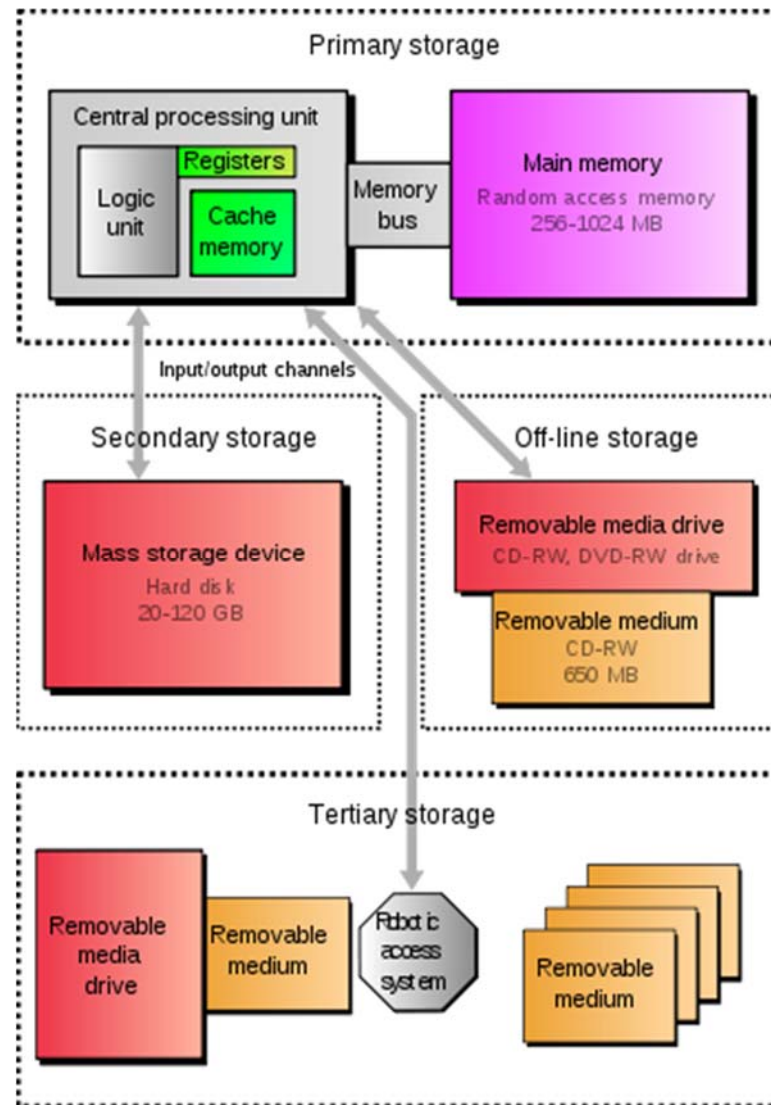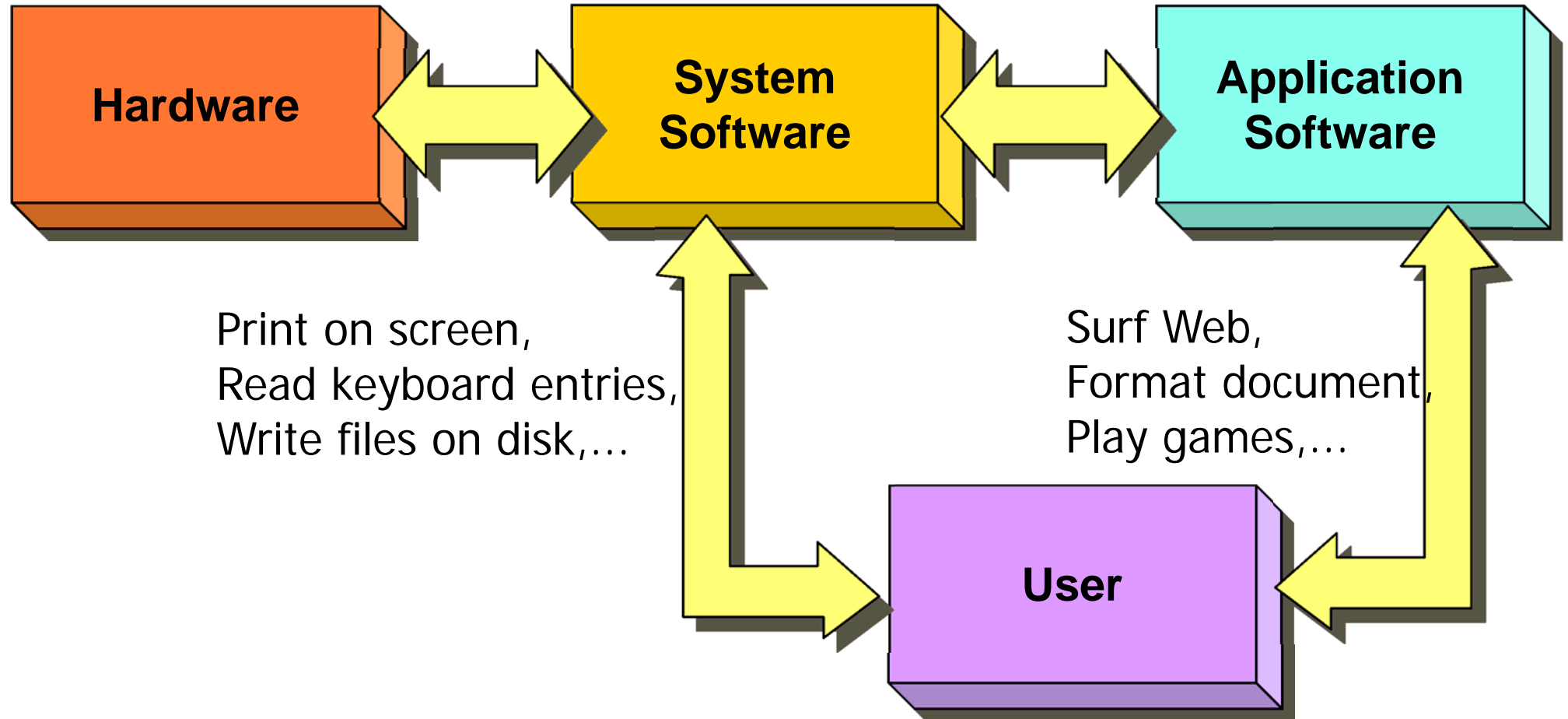
A Communication Model

- Source
  - generates data to be transmitted
- Transmitter
  - Converts data into transmittable signals
- Transmission System
  - Carries data
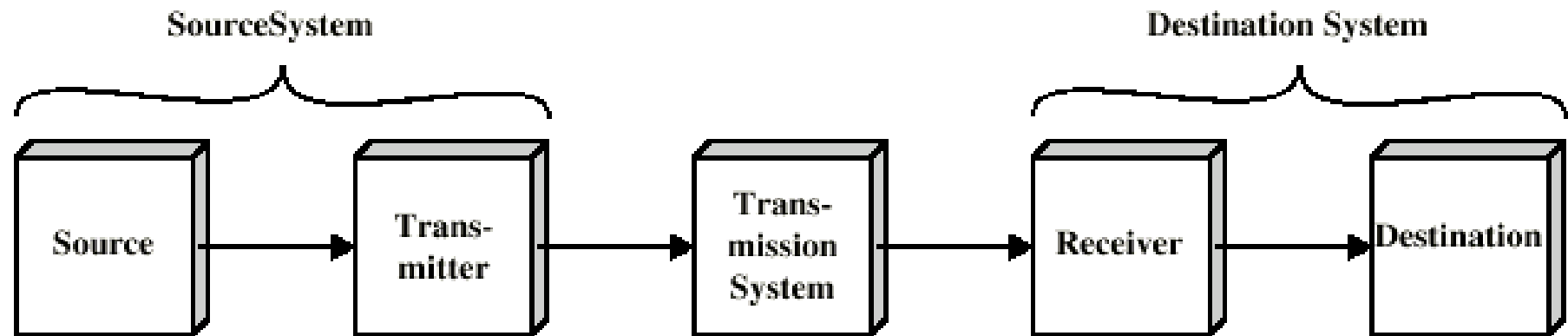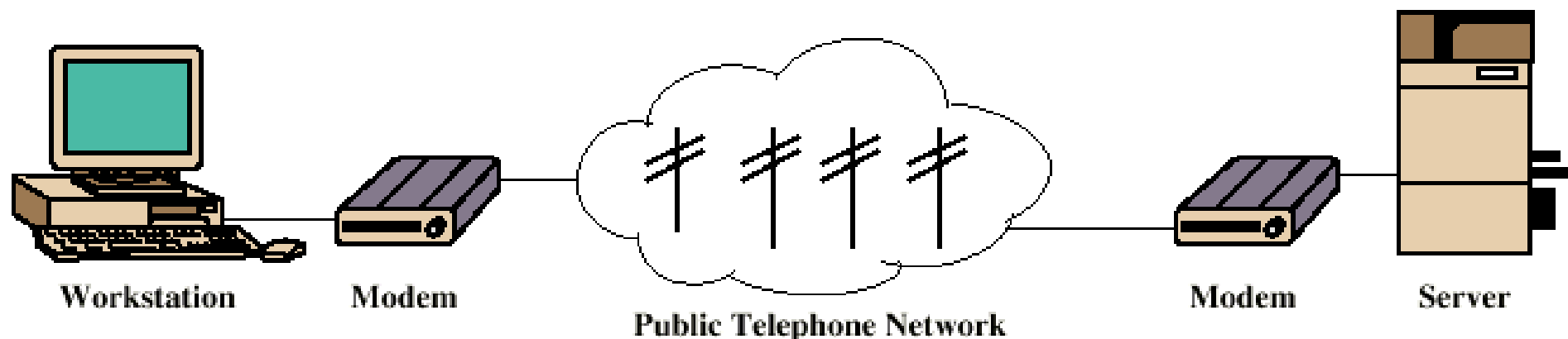- Receiver
  - Converts received signal into data
- Destination
  - Takes incoming data
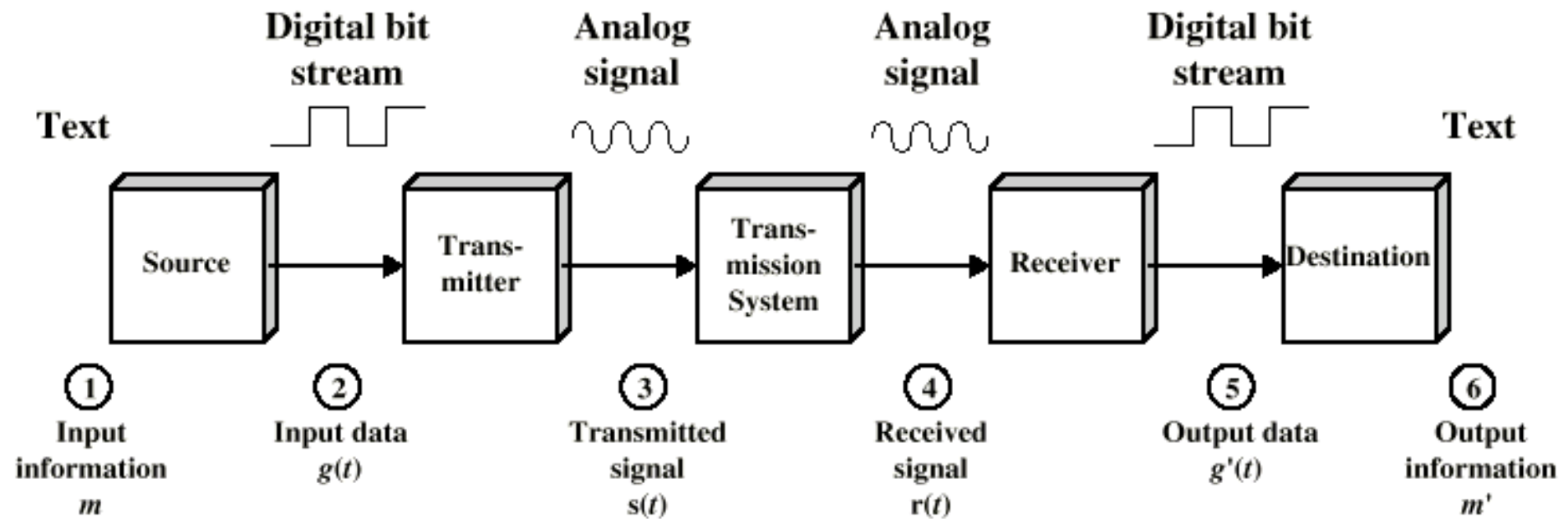
Simplified Communications Model - Diagram
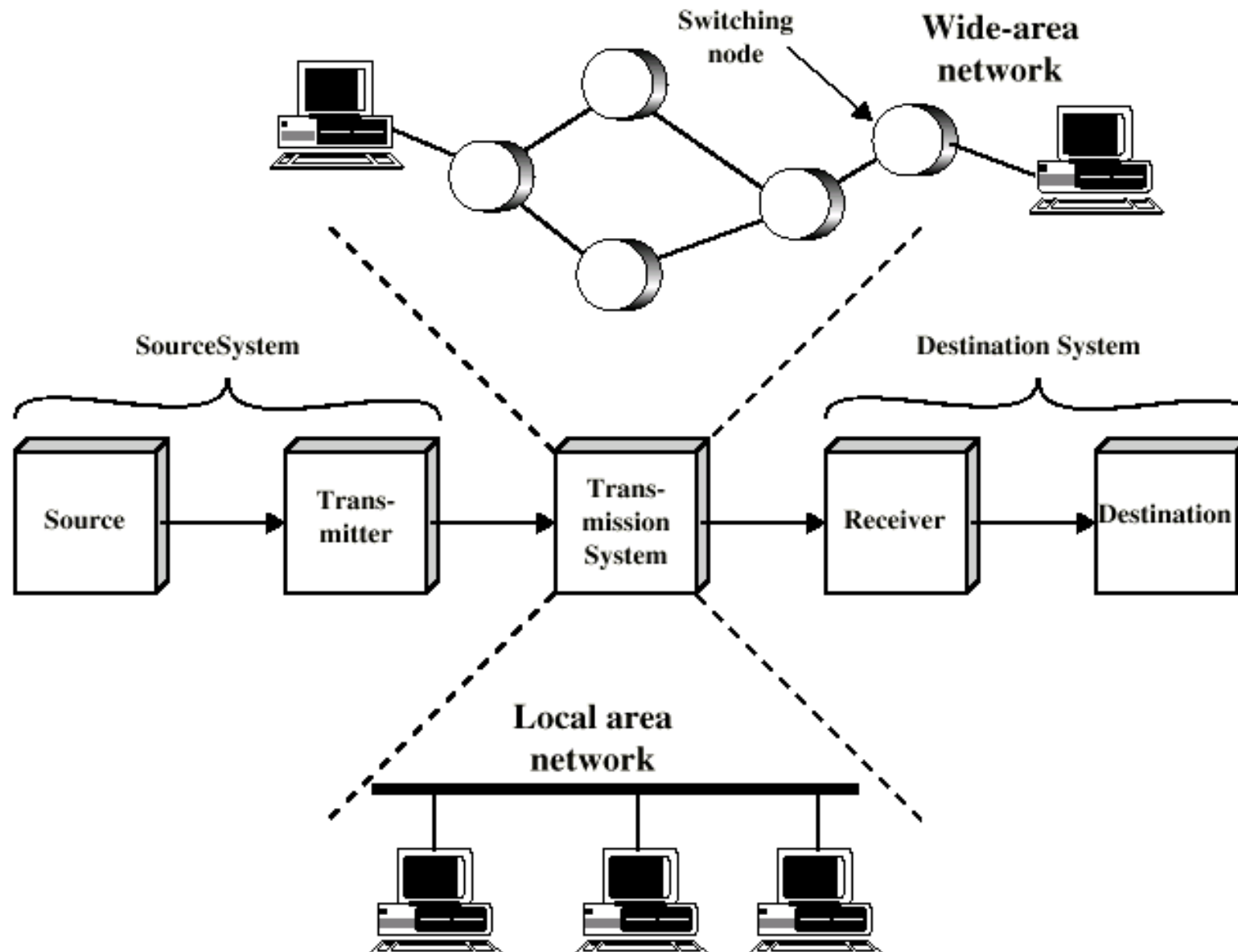
(a) General block diagram
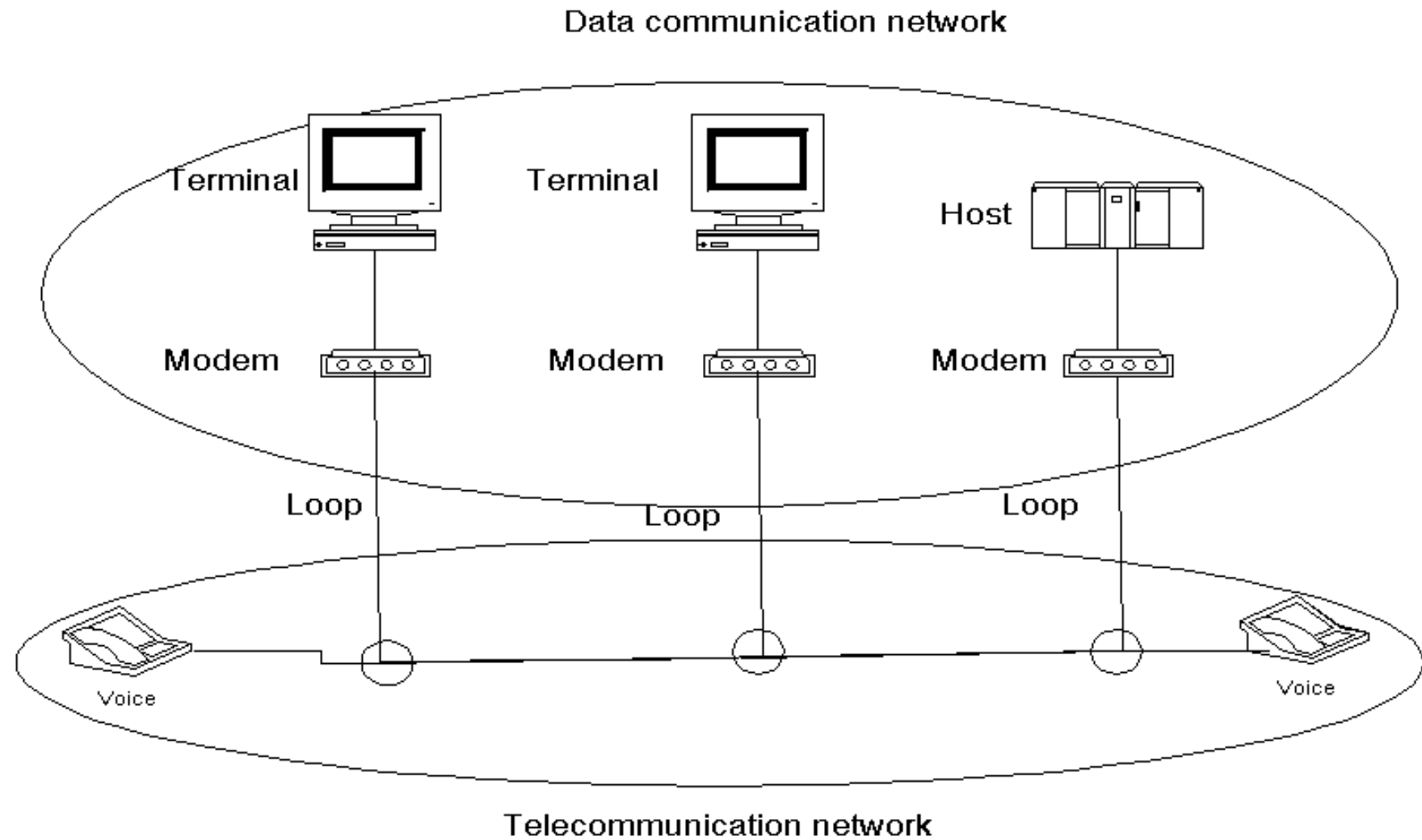
(b) Example

Simplified Data Communications Model

Simplified Network Model

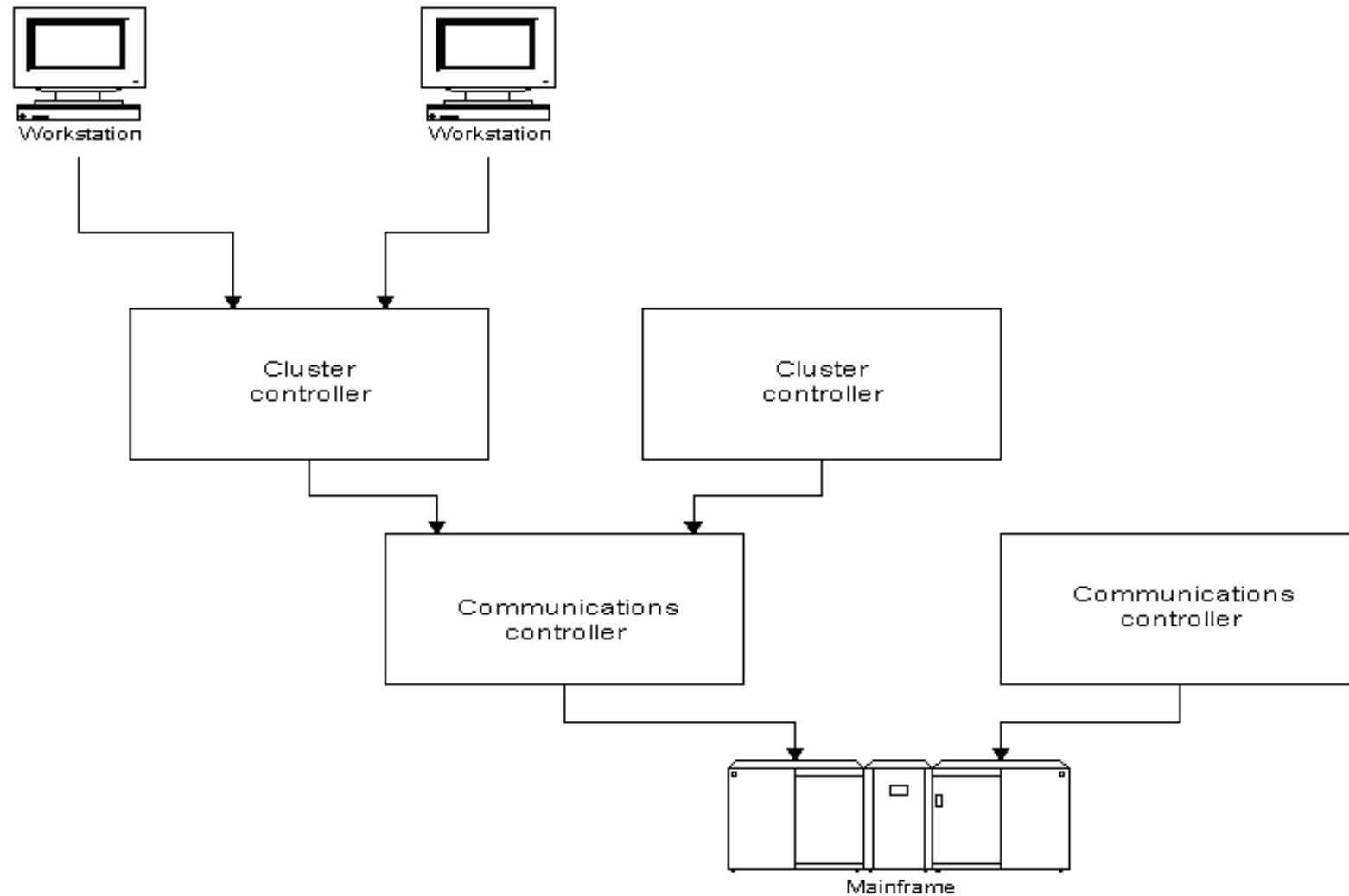# Data and Telecommunication Network

Data communication network
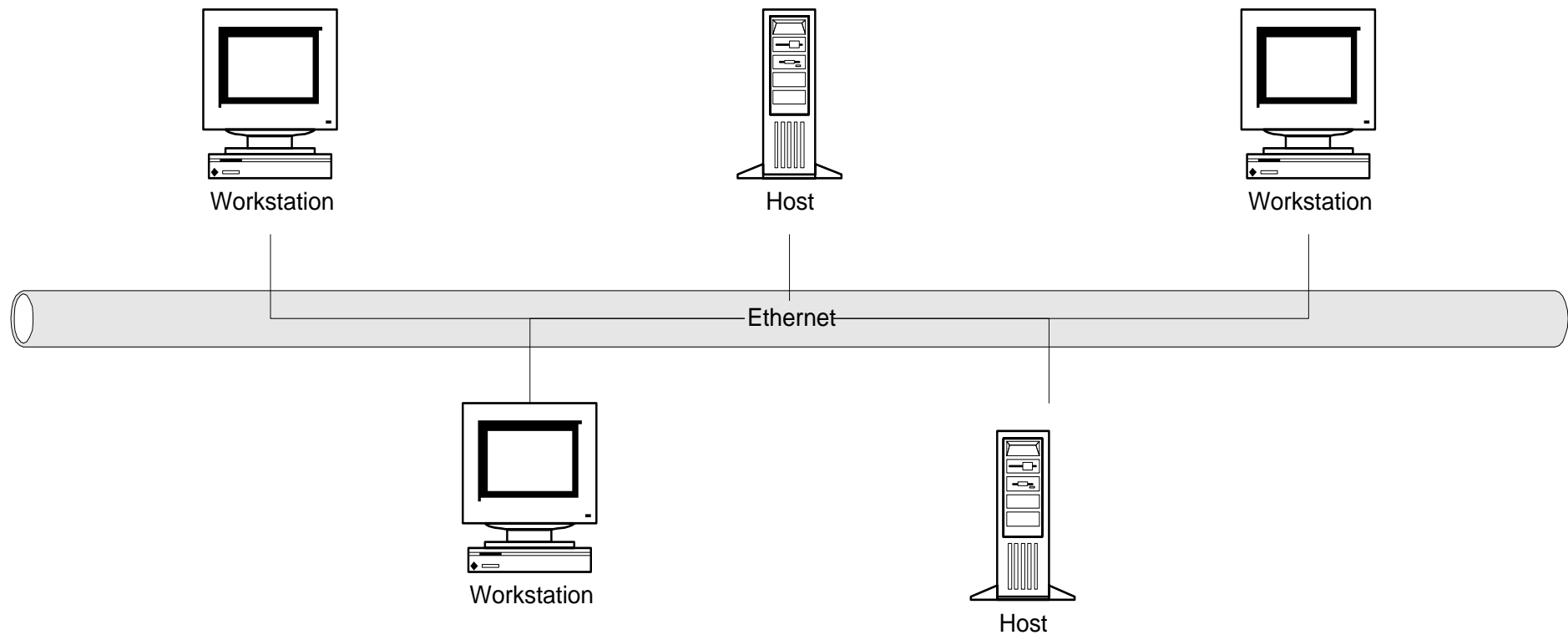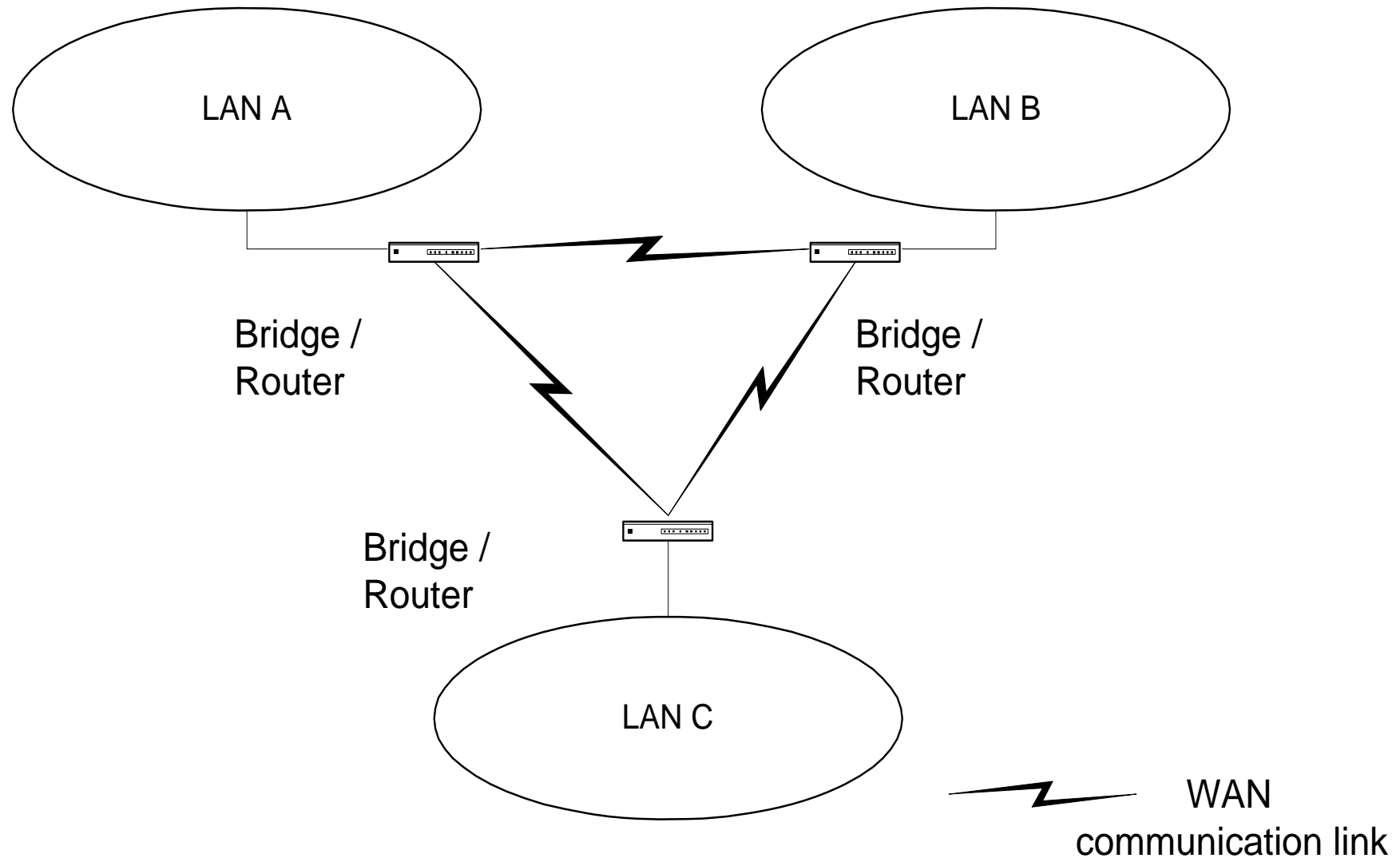
Telecommunication network

IBM SNA Architecture

DCE with LAN

DCE: Distributed Computing Environment

(a) Hosts and Workstations on Local LAN

LAN-WAN Network

LAN A

LAN B

Bridge /
Router

Bridge /
Router

Bridge /
Router

LAN C

WAN
communication link

Client/Server Model
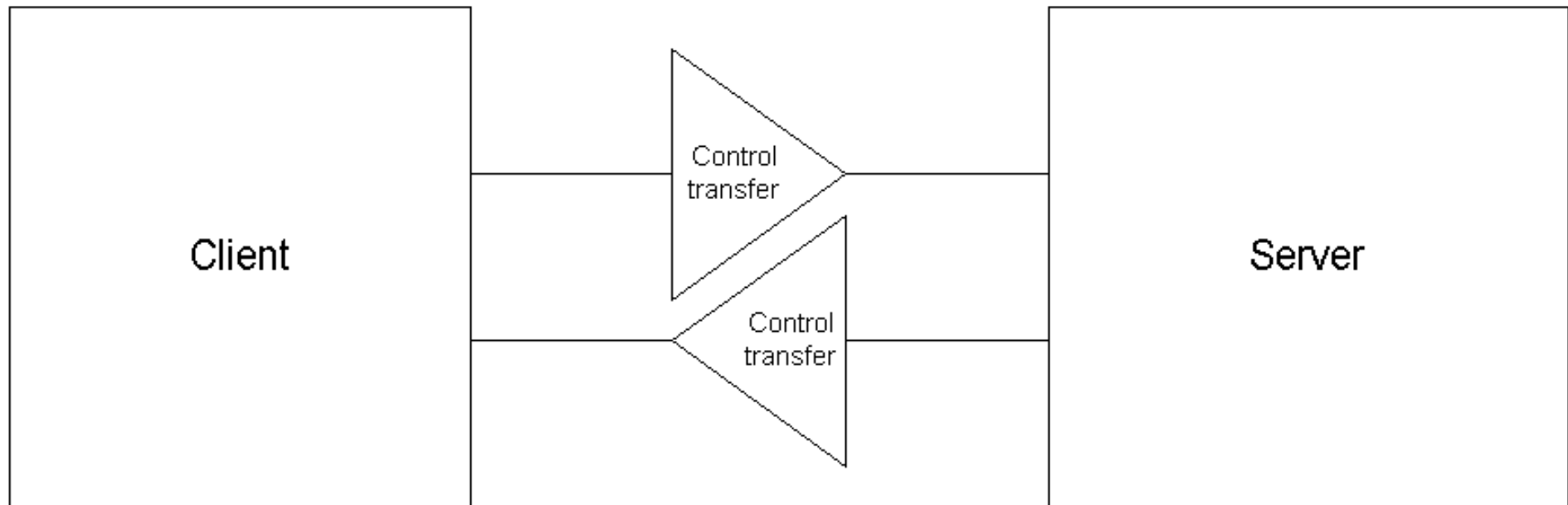
Client/Server Examples

Client A   Client Z

Server
(a) Server with Multiple Clients

Client
(joe.stone)

to sally.jones@dest.com

Bridge

Mail server

Domain
Name
Server

(b) Dual Role of Client-Server
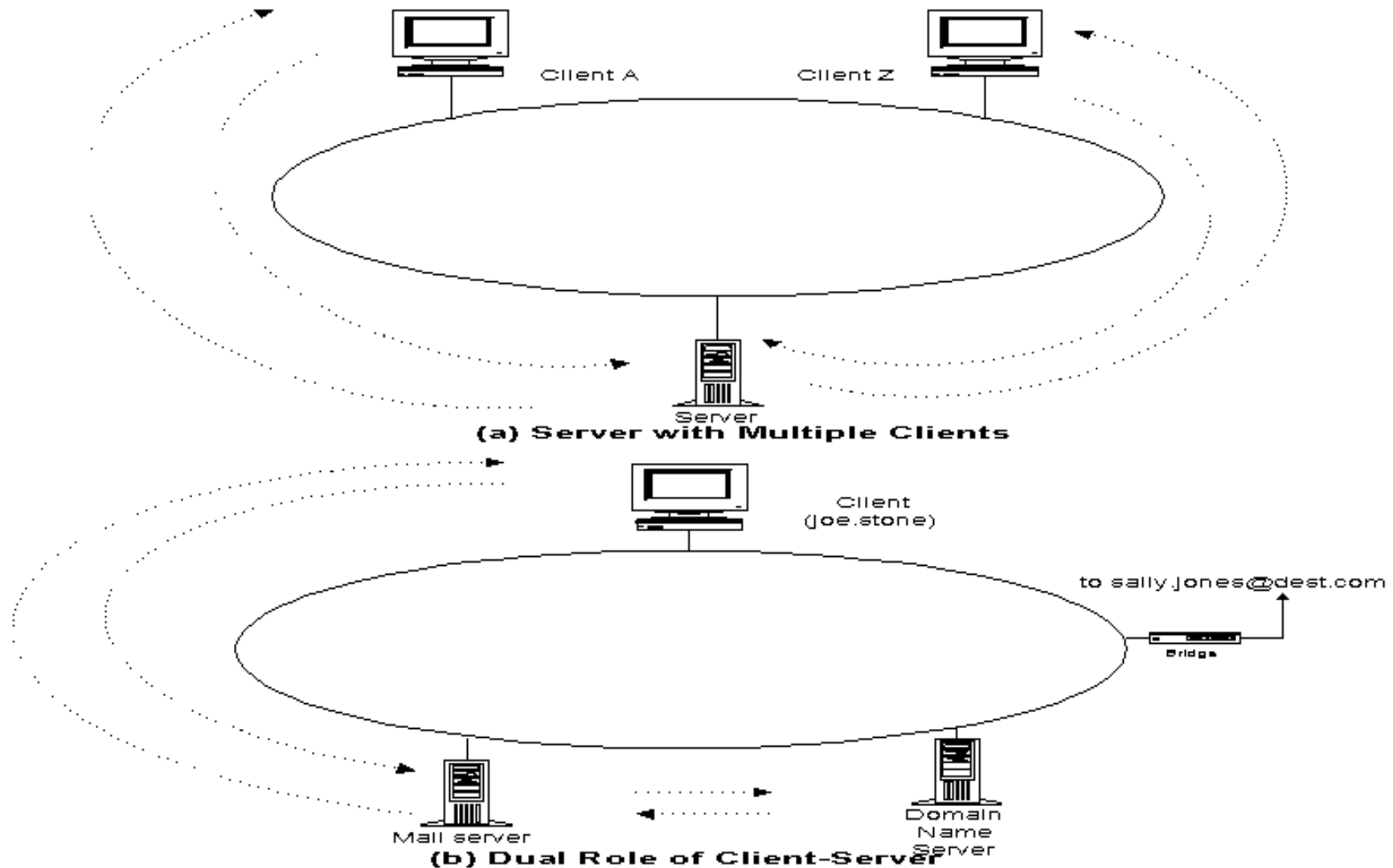
Client-Server Applications

- 👍 telnet icis-sun.icis.ntu.edu.sg
- 👍 NTU Mark Entry System (MES)
- 👍 Web Applications
- 👍 E-Mail
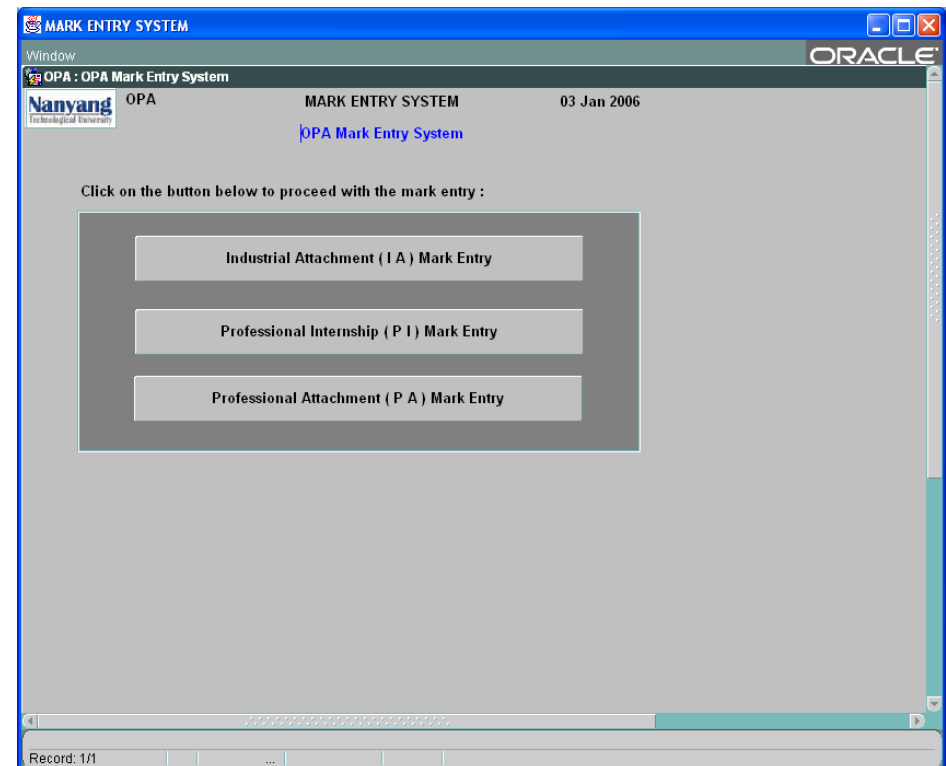
Wide Area Networks

- Large geographical area
- Rely in part on common carrier circuits
- Alternative technologies
  - Circuit switching
  - Packet switching

Local Area Networks

- Smaller scope
  - Building or small campus
- Usually owned by same organization as attached devices
- Data rates much higher
- Usually broadcast systems

Architecture, Protocols and Standards

- Communication architecture
  - Modeling of communication systems, comprising functional components, operations, and interfaces between them
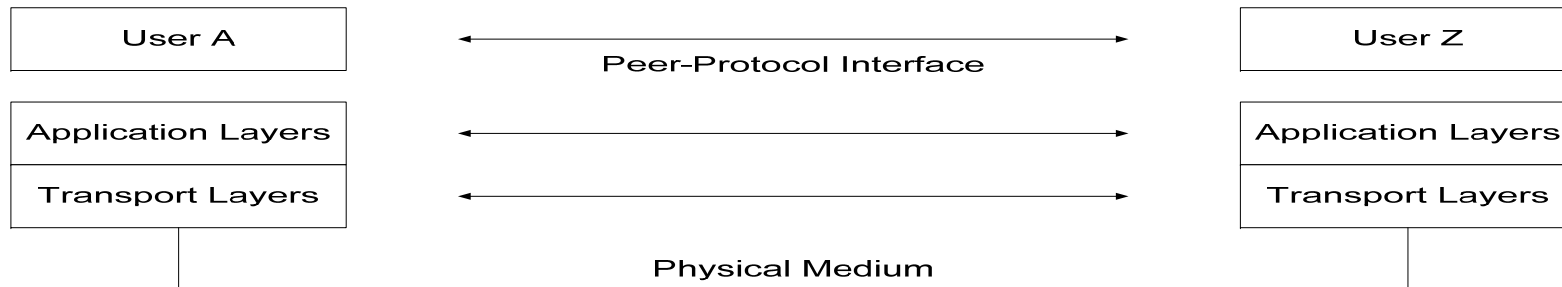
- Communication protocols
  - Operational procedures
    - ✓ intra- and inter-modules

- Communication standards
  - Agreement between manufacturers on protocols of communication equipment on
    - ✓ physical characteristics and
    - ✓ operational procedures

Communication Architecture

User A		User Z

Peer-Protocol Interface

Application Layers		Application Layers
Transport Layers		Transport Layers

Physical Medium

(a) Direct Communication between End Systems

System A   Intermediate system   System Z

User A		User Z

Peer-Protocol Interface

Application Layers		Application Layers
Transport Layers	Transport Layer Conversion	Transport Layers

Physical Medium   Physical Medium
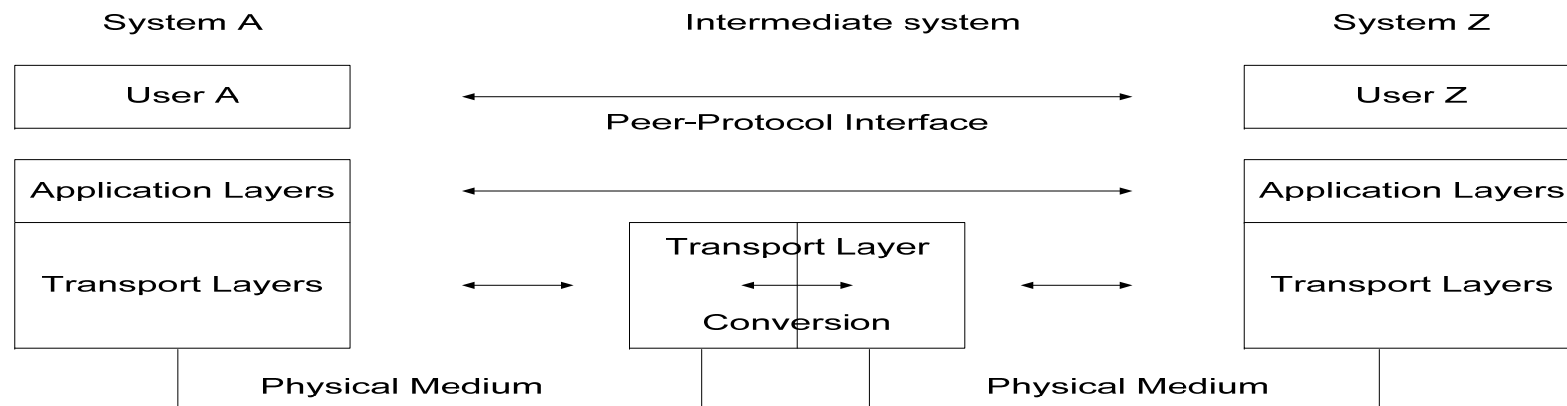
(b) Communication between End Systems via an Intermediate System

OSI Reference Model

	User / Application program

Layer 7	Application
Layer 6	Presentation
Layer 5	Session
Layer 4	Transport
Layer 3	Network
Layer 2	Data link
Layer 1	Physical

Physical medium
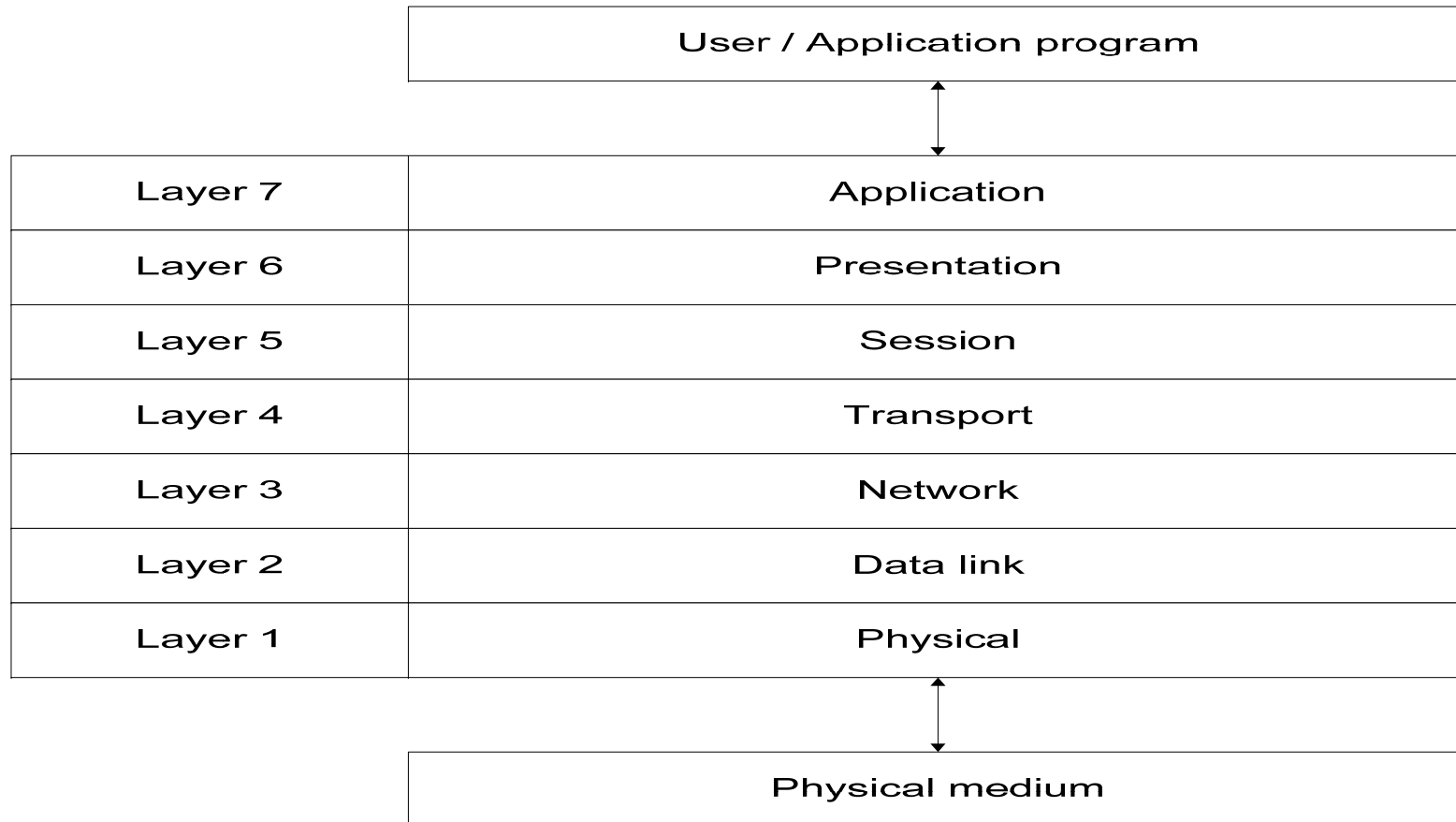
OSI Layers and Services

Layer No.	Layer Name	Salient services provided by the layer
1	Physical	-Transfers to and gathers from the physical medium raw bit data -Handles physical and electrical interfaces to the transmission medium
2	Data link	-Consists of two sublayers: Logical link control (LLC) and Media access control (MAC) -LLC: Formats the data to go on the medium; performs error control and flow control -MAC: Controls data transfer to and from LAN; resolves conflicts with other data on LAN
3	Network	Forms the switching / routing layer of the network
4	Transport	-Multiplexing and de-multiplexing of messages from applications -Acts as a transparent layer to applications and thus isolates them from the transport system layers -Makes and breaks connections for connection-oriented communications -Flow control of data in both directions
5	Session	-Establishes and clears sessions for applications, and thus minimizes loss of data during large data exchange
6	Presentation	-Provides a set of standard protocols so that the display would be transparent to syntax of the application -Data encryption and decryption
7	Application	-Provides application specific protocols for each specific application and each specific transport protocol system

PDU Communication Model

End System A

End System Z

| User A | UD | | User Z |

Application	(A) PCI	UD		Application
Presentation	(P) PCI	(A) PDU		Presentation
Session	(S) PCI	(P) PDU		Session
Transport	(T) PCI	(S) PDU		Transport
Network	(N) PCI	(T) PDU		Network
Data link	(D) PCI	(N) PDU		Data link
Physical			Physical

(D)PDU Data stream

Physical Medium

Gateway

DTE-A — (A) — (N) — (Z)

DTE-N1 — (N1) — (N2)

(N3)

A-N-Z Standard Network
N-N1-N2-N3 Subnetwork under Node N
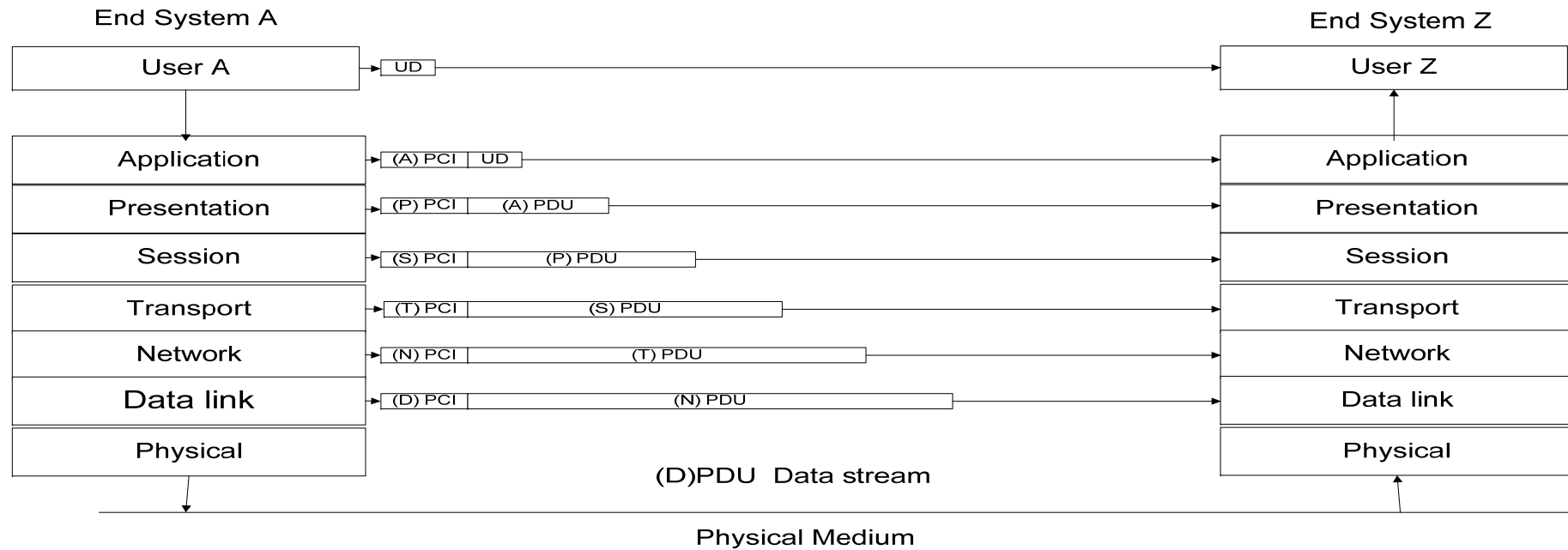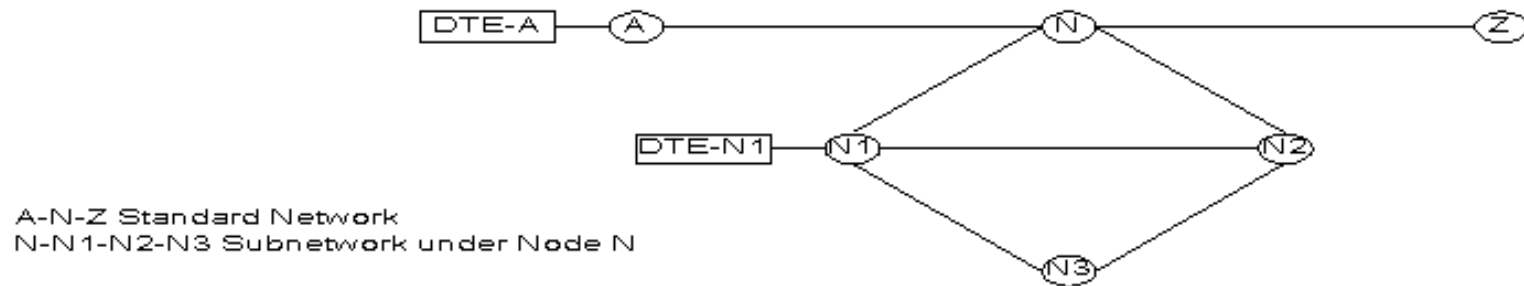
(a) Network configuration

System A	Gateway System N		Subnet system N1
Transport	Transport		Transport
SNICP	SNICP		SNICP
SNDCP	SNDCP	SNDCP-SN	SNDCP-SN
SNDAP	SNDAP	SNDAP-SN	SNDAP-SN
Data link	Data link	Data link-SN	Data link-SN
Physical	Physical	Physical-SN	Physical-SN

Network Medium   Subnetwork Medium
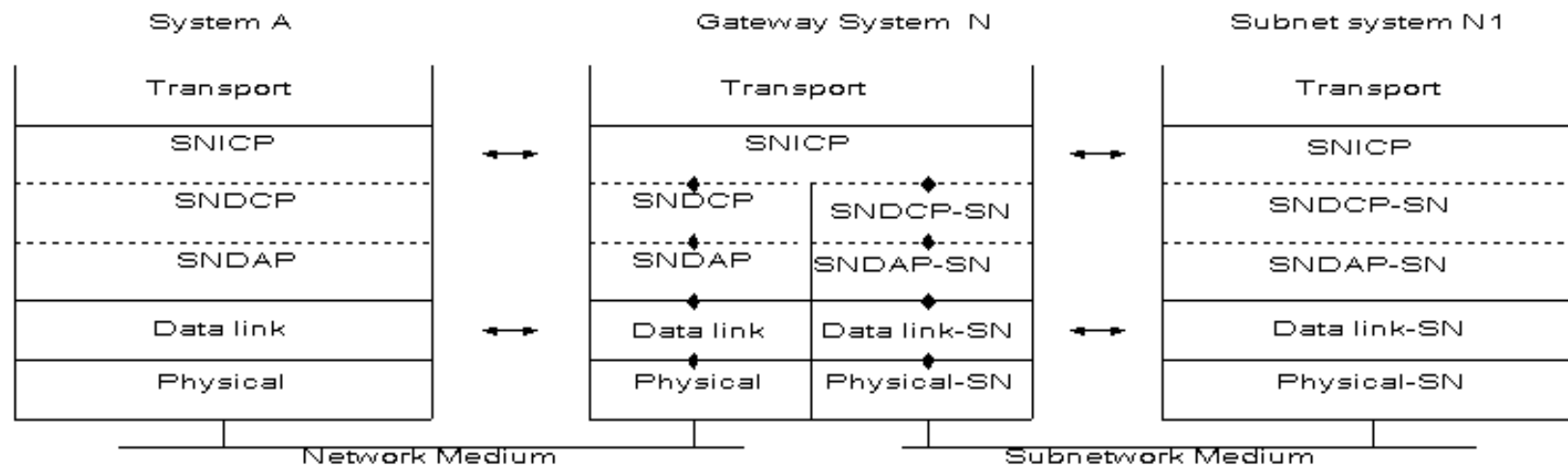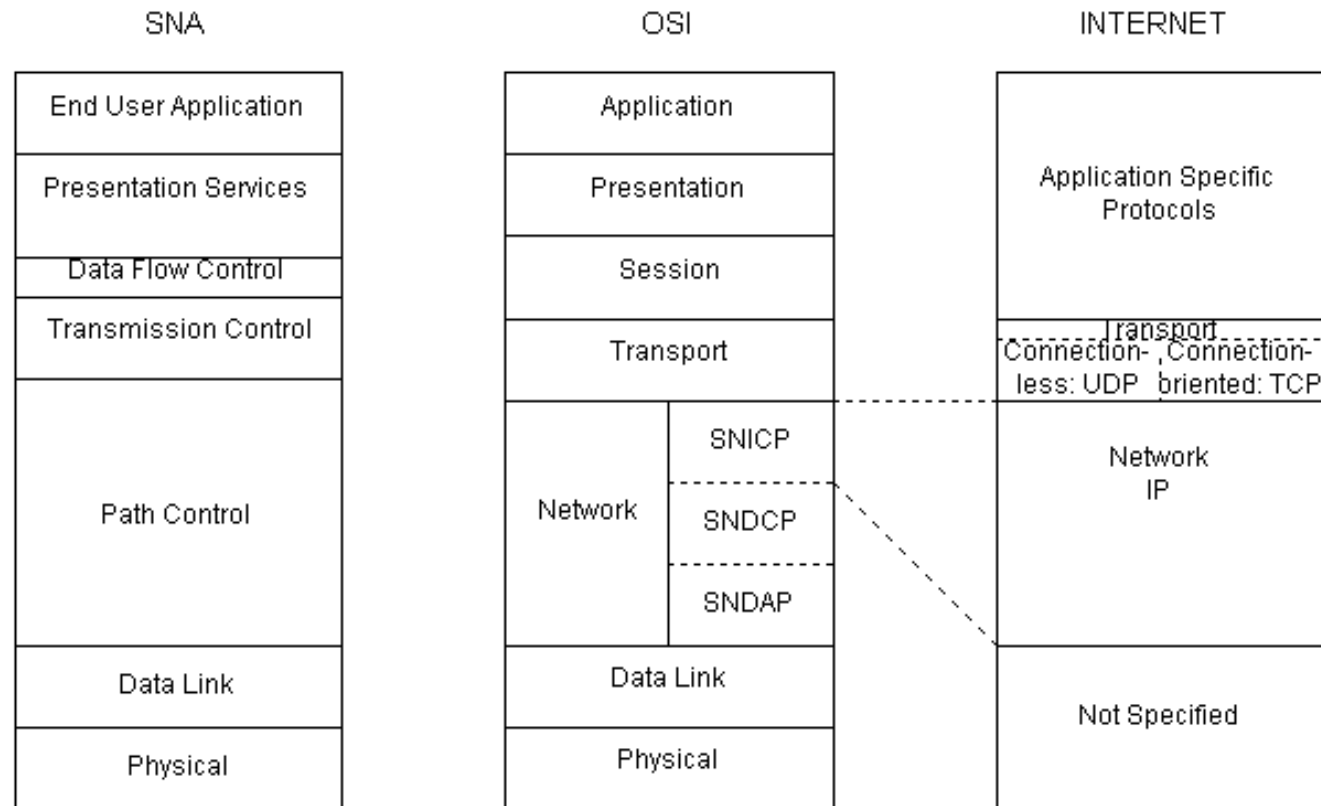
(b) Protocol Communication

✍ cc:mail from a station in Novel IPX network to an Internet station with SMTP e-mail

SNA, OSI, and Internet

	SNA	OSI	INTERNET
	End User Application	Application	Application Specific Protocols
	Presentation Services	Presentation	
	Data Flow Control	Session	
	Transmission Control	Transport	Transport Connection-less: UDP, Connection-oriented: TCP
	Path Control	Network — SNICP / SNDCP / SNDAP	Network IP
	Data Link	Data Link	Not Specified
	Physical	Physical	

👍 Similarity between SNA and OSI

👍 Simplicity of Internet; specifies only layers 3 and 4

👍 Integrated application layers over Internet

👍 Commonality of layers 1 and 2 - IEEE standard

Internetworking Terms

- Communications Network
  - Facility that provides data transfer service

- An internet
  - Collection of communications networks interconnected by bridges and/or routers

- The Internet - note upper case I
  - The global collection of billions of individual machines and networks

- Intranet
  - Corporate internet operating within the organization
  - Uses Internet (TCP/IP and http) technology to deliver documents and resources
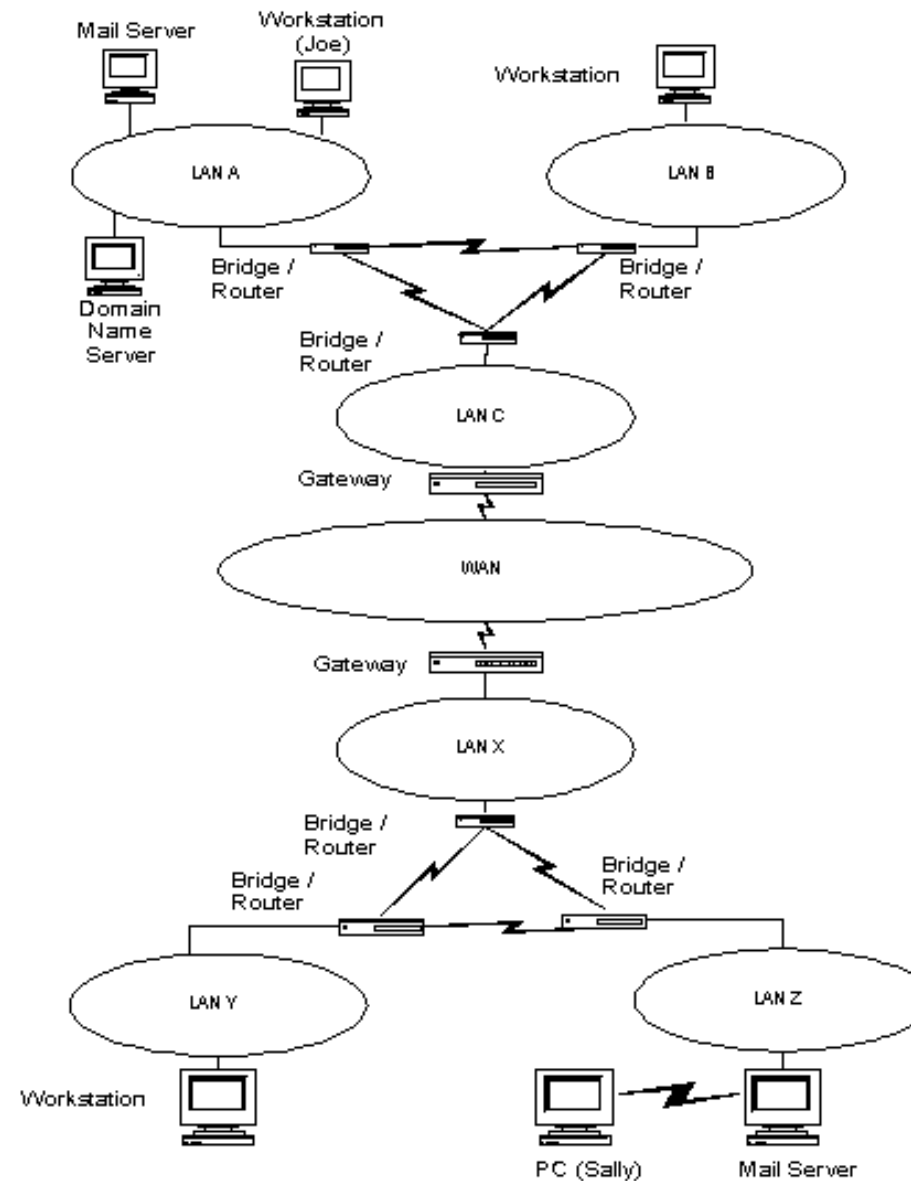
Requirements of Internetworking

- 👍 Link between networks

  - ✖ Minimum physical and link layer

- 👍 Routing and delivery of data between processes on different networks

- 👍 Accounting services and status info

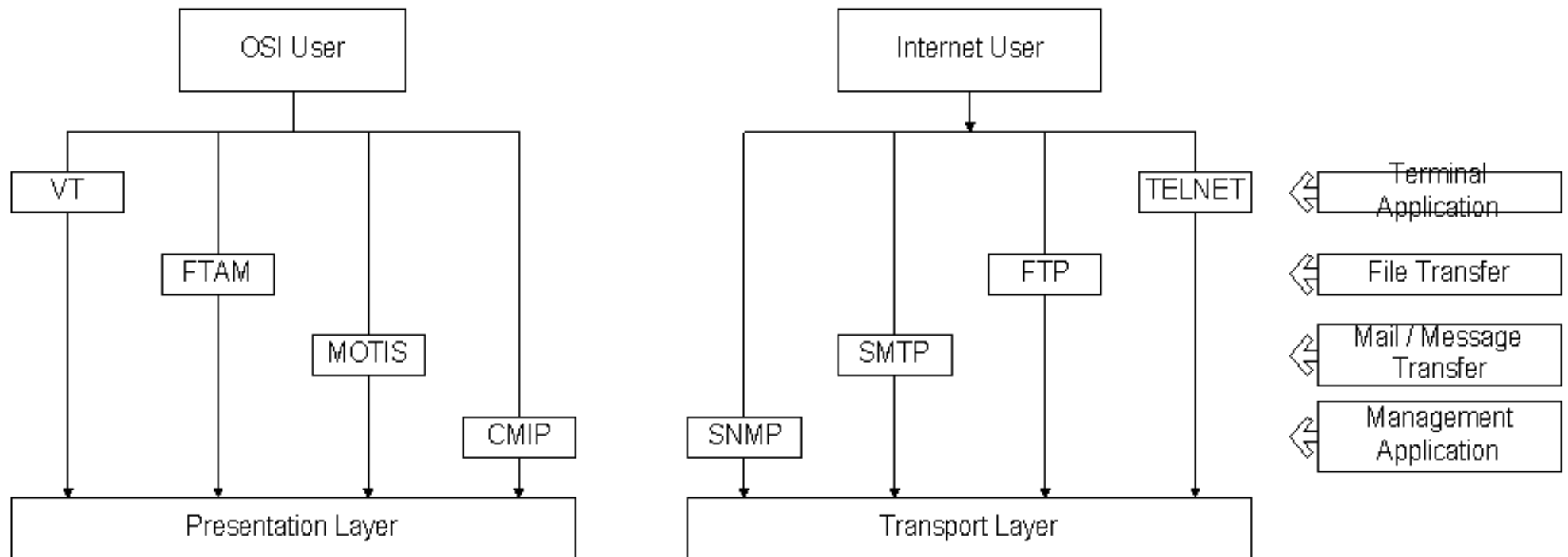- 👍 Independent of network architectures

TCP/IP Based Networks

- ☞ TCP/IP is a suite of protocols
- ☞ Internet is based on TCP/IP
- ☞ IP is Internet protocol at the network layer level
- ☞ TCP is connection-oriented transport protocol and ensures end-to-end connection
- ☞ UDP is connectionless transport protocol and provides datagram service
- ☞ Internet e-mail and much of the network management messages are based on UDP/IP
- ☞ ICMP part of TCP/IP suite
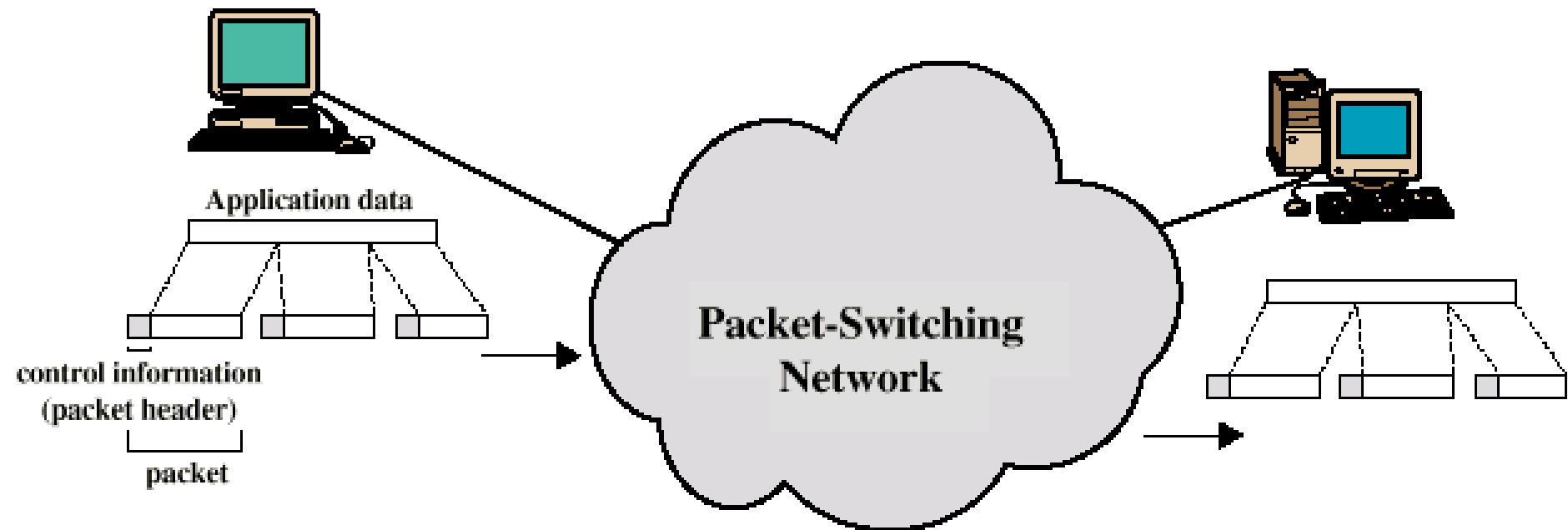
Internet Configuration

Application Protocols

OSI User

VT

FTAM

MOTIS

CMIP

Presentation Layer

Internet User

TELNET — Terminal Application

FTP — File Transfer

SMTP — Mail / Message Transfer

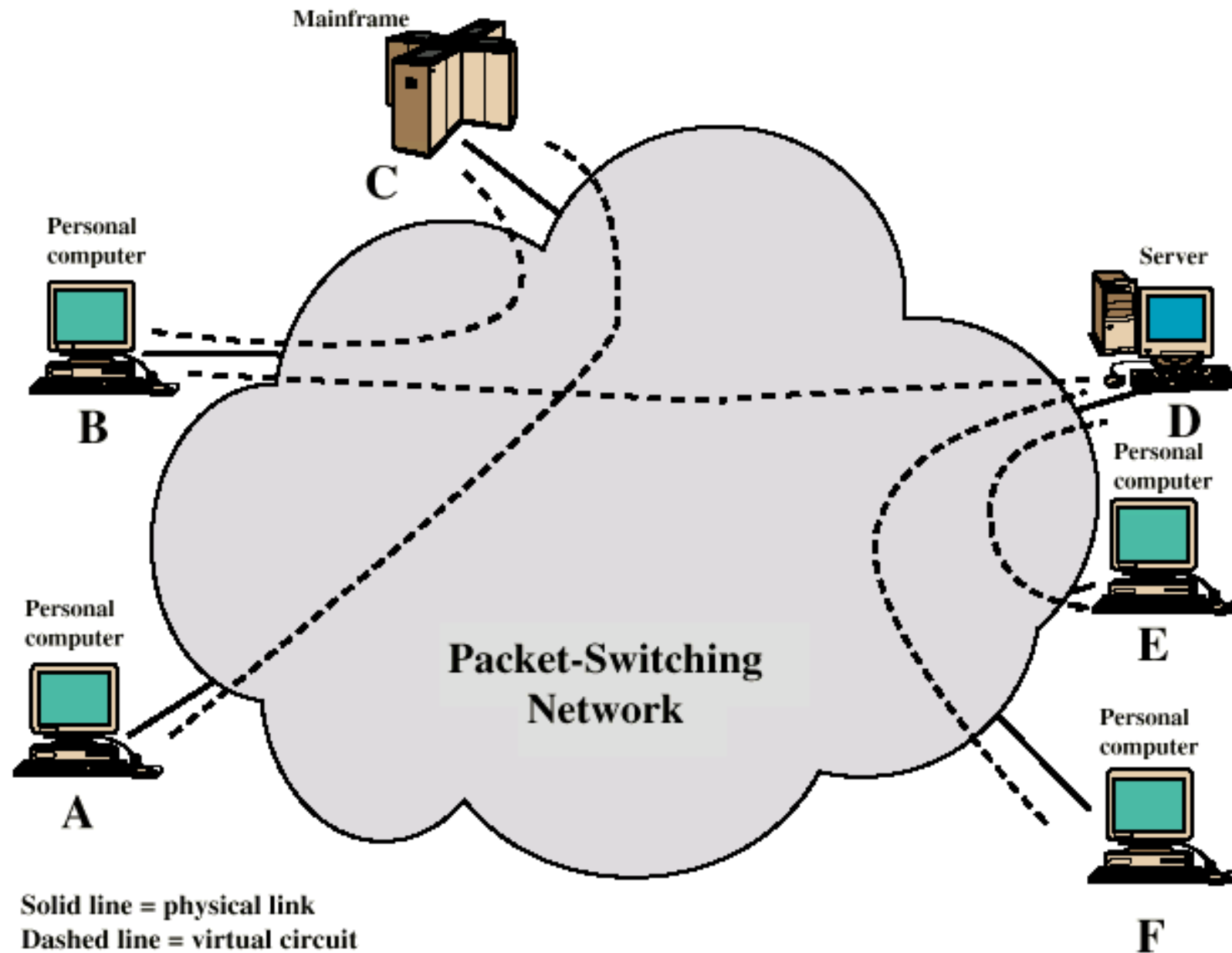SNMP — Management Application

Transport Layer

Network Architecture Features

- 👍 Addressing

- 👍 Packet size

- 👍 Access mechanism

- 👍 Timeouts

- 👍 Error recovery

- 👍 Status reporting

- 👍 Routing

- 👍 User access control

- 👍 Connection based or connectionless
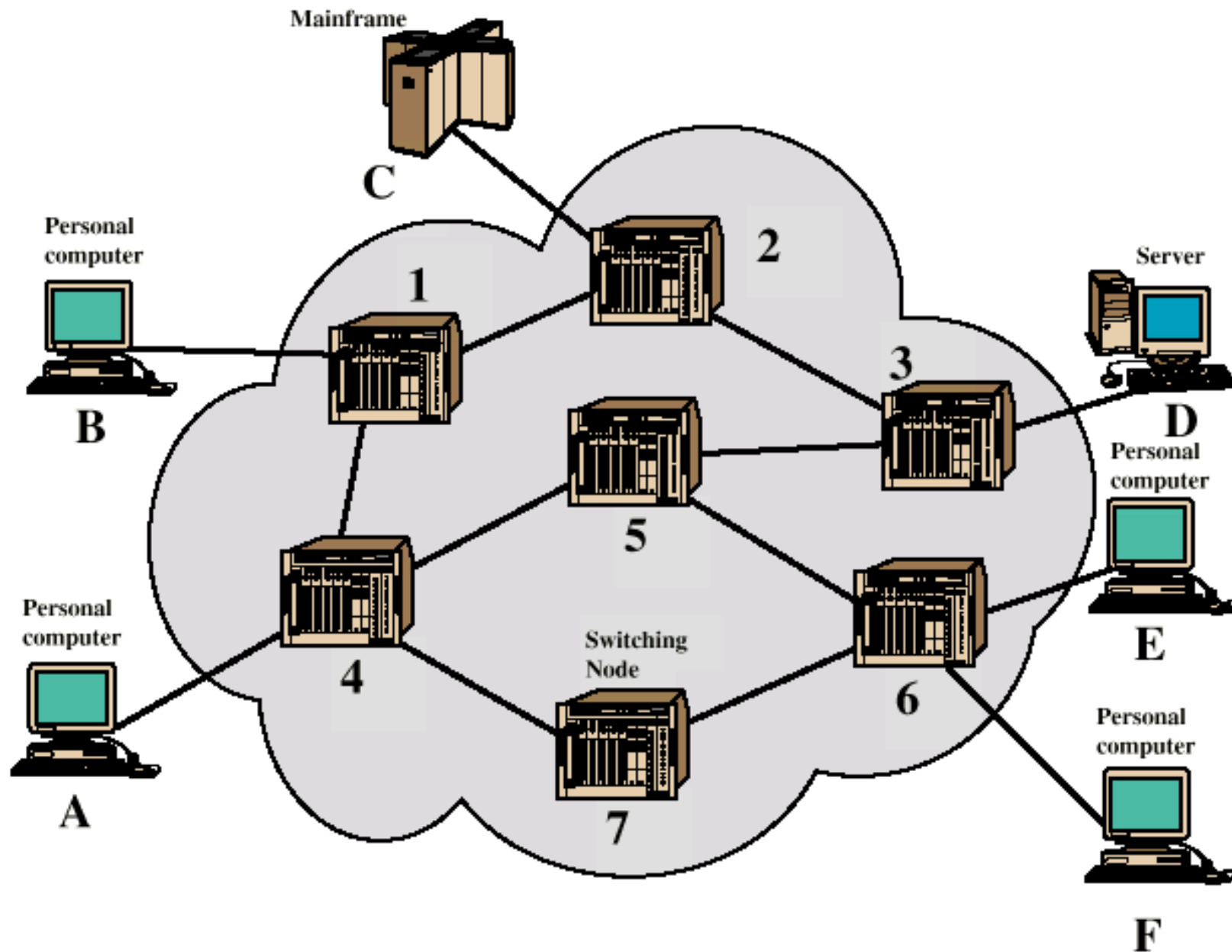
Use of Packets

Application data

control information
(packet header)

packet

Packet-Switching
Network

Use of Packets

Mainframe

C

Personal
computer

B

Personal
computer

A

Server

D

Personal
computer

E

Personal
computer

F

Packet-Switching
Network

Solid line = physical link
Dashed line = virtual circuit

Switching Networks

- ☝ Long distance transmission is typically done over a network of switched nodes

- ☝ Nodes not concerned with content of data

- ☝ End devices are stations

  - ✖ Computer, terminal, phone, etc.

- ☝ A collection of nodes and connections is a communications network

- ☝ Data routed by being switched from node to node

Simple Switched Network

Public Circuit Switched Network

Long-distance office

Long-distance office

End Office

Subscriber Loop

End Office

Connecting Trunk

Intercity Trunk

Subscriber Loop

Digital PBX