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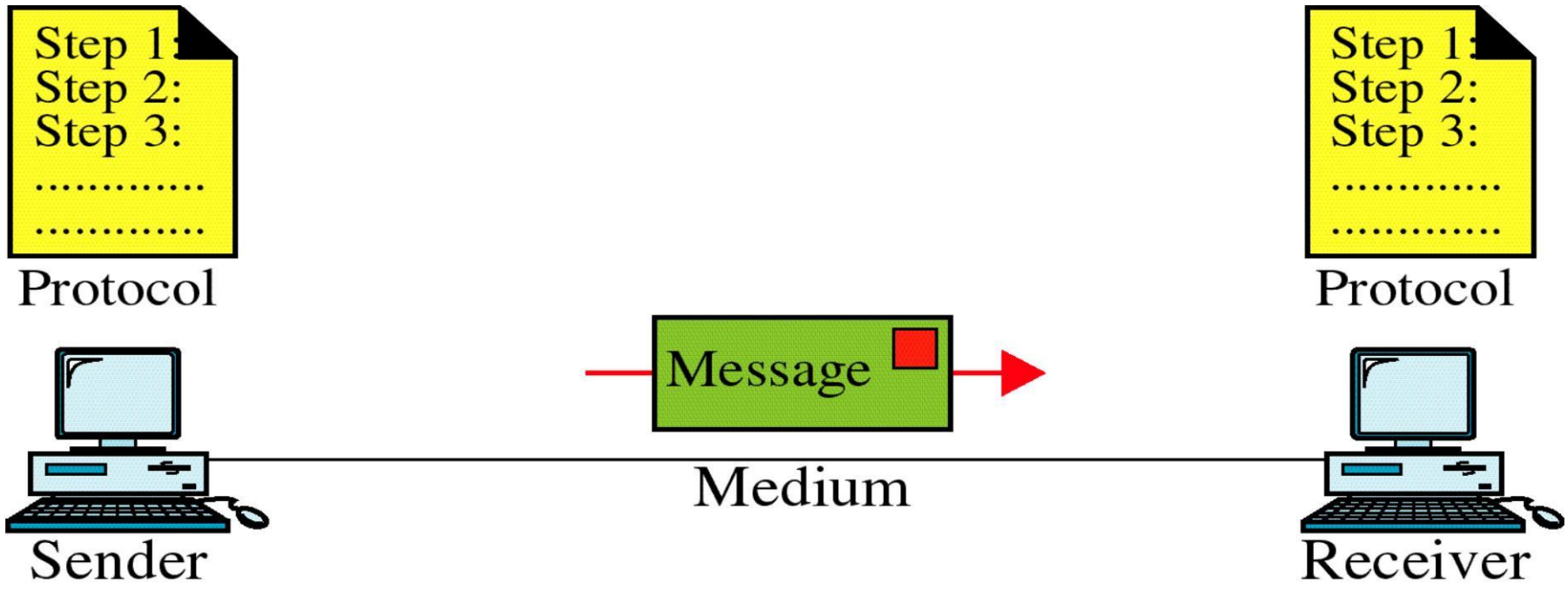
21CSC302J-COMPUTER NETWORKS



UNIT –I Contents

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- Evolution of Computer Networks
- Network Categories
- Data Transmission Modes
- Network Topologies
- Circuit Switching and Packet Switching
- Protocols and Standards
- OSI Layers and its functions
- TCP/IP Protocol Suite

Evolution of Computer Networks

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Computer Networks?

- A group of interconnected computers
- The evolution of two important scientific and technical branches of modern civilization
  - Computing and
  - Telecommunications technologies

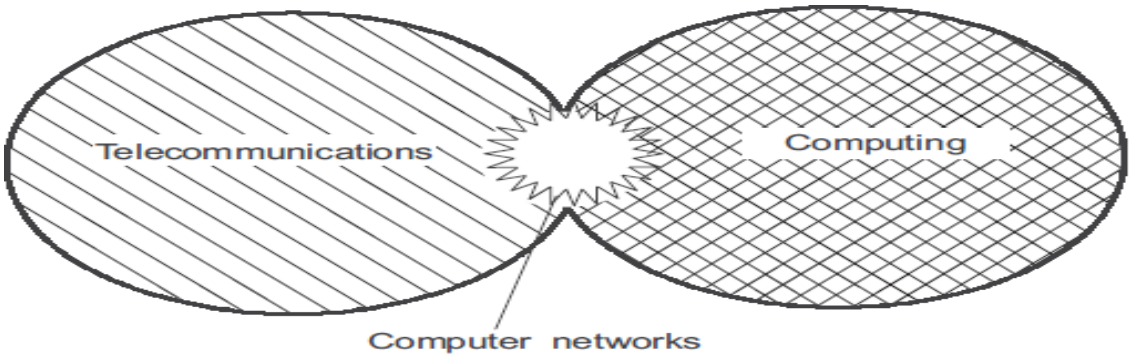

Figure 1.1 Evolution of computer networks at the interfaces of the computing and communications technologies

Evolution of Computer Networks

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Communication Network?

- A network of **links** and **nodes** arranged and the **messages** may be passed from one part of the network to another
- **What are nodes and links**?
  - Telephones and switches
  - Computers and routers
- What is a **message**?
  - **Useful Information**
- **What are the 5 essential components required to establish computer communication?**

1) Sender 2) Receiver 3) Link 4) Protocol 5) Message

Evolution of Computer Networks

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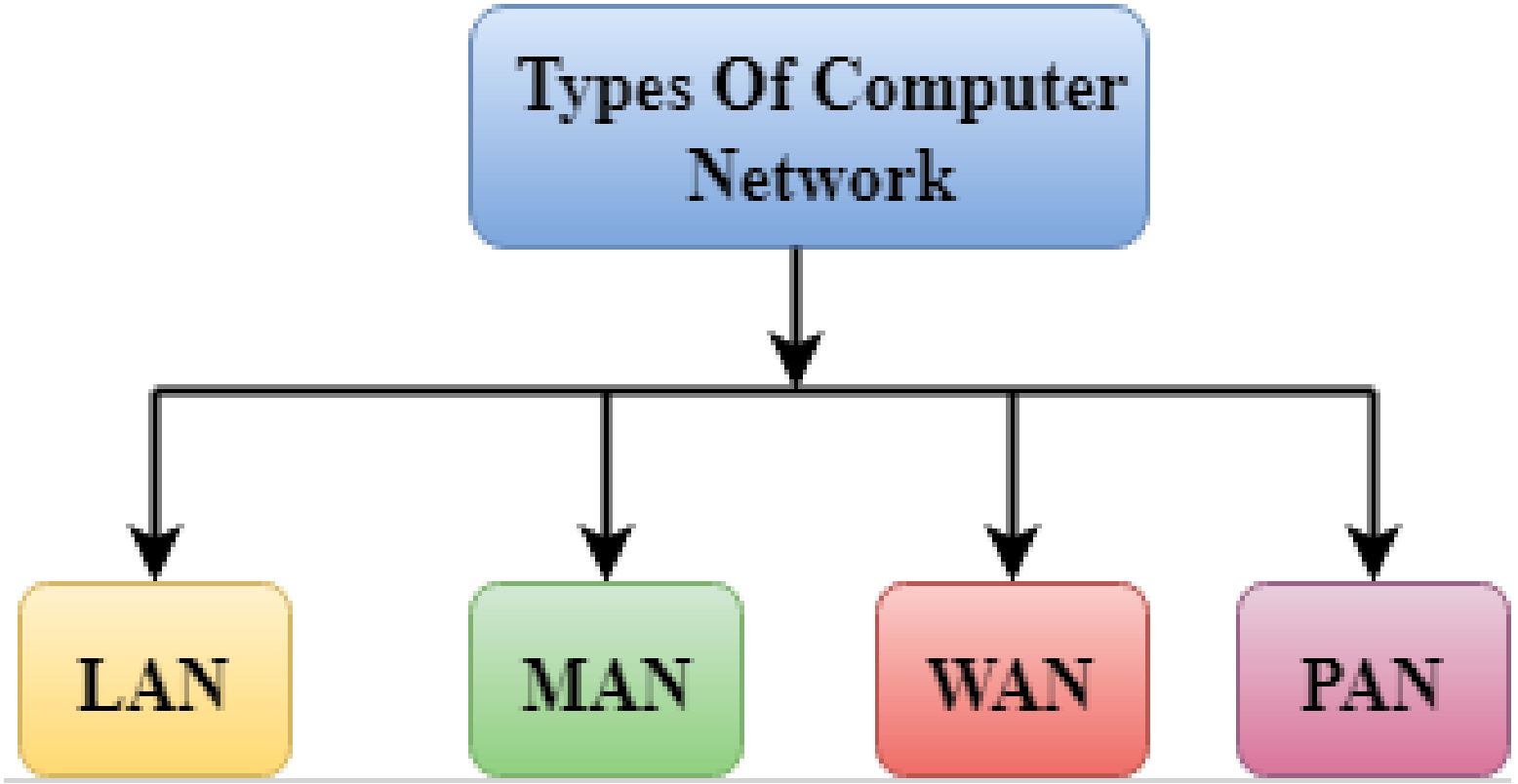
- Networks are Old
  - 2400 BC: courier networks in Egypt
  - 550 BC: postal service invented in Persia
- Problems
  - Speed
  - Reliability
  - Security
- 1837: Telegraph invented by Samuel Morse
  - Distance: 10 miles
  - Speed: 10 words per minute
  - In use until 1985!

Dr.M.Maranco, AP,SRMIST,KTR

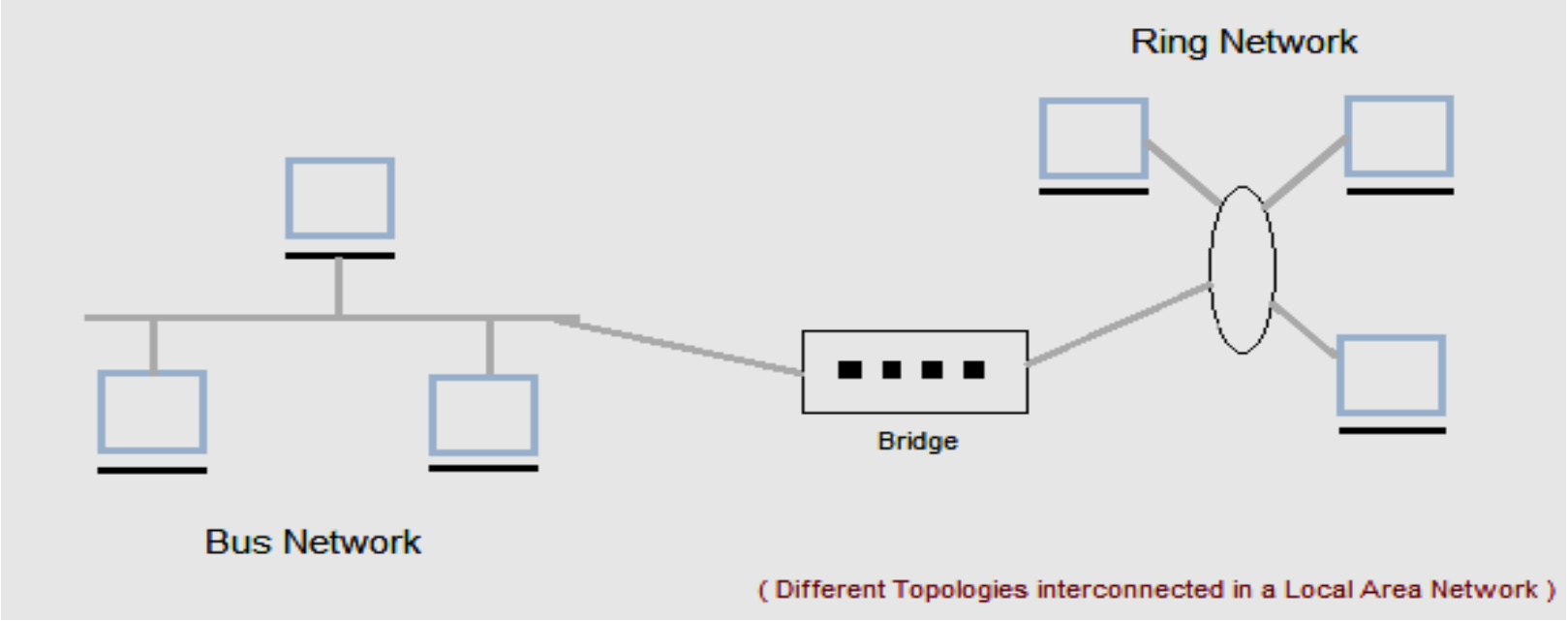
Network Categories



- LAN – Local Area Network
- MAN – Metropolitan Area Network
- WAN – Wide Area Network
- PAN – Personal Area Network

Network Categories

Local Area Network (LAN)



(Different Topologies interconnected in a Local Area Network)

LAN

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- Local Area Network (LAN) is a group of computers connected to each other in a small area such as building, office.
- LAN is used for connecting two or more personal computers through a communication medium such as twisted pair, coaxial cable, etc.
- It is less costly as it is built with inexpensive hardware such as hubs, network adapters, and Ethernet cables.
- The data is transferred at an extremely faster rate in Local Area Network.
- Local Area Network provides higher security.

Characteristics of LAN

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- LAN's are private networks, not subject to tariffs or other regulatory controls.
- LAN's operate at relatively high speed when compared to the typical WAN.
- There are different types of Media Access Control methods in a LAN, the prominent ones are Ethernet, Token ring.
- It connects computers in a single building, block or campus, i.e. they work in a restricted geographical area.

Applications of LAN

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- One of the computer in a network can become a server serving all the remaining computers called clients.
- Software can be stored on the server and it can be used by the remaining clients.
- Connecting Locally all the workstations in a building to let them communicate with each other locally without any internet access.
- Sharing common resources like printers etc are some common applications of LAN.

Advantages of LAN

Resource Sharing: Computer resources like printers, modems, DVD-ROM drives and hard disks can be shared with the help of local area networks. This reduces cost and hardware purchases.

Software Applications Sharing: It is cheaper to use same software over network instead of purchasing separate licensed software for each client a network.

Easy and Cheap Communication: Data and messages can easily be transferred over networked computers.

Centralized Data: The data of all network users can be saved on hard disk of the server computer. This will help users to use any workstation in a network to access their data. Because data is not stored on workstations locally.

Data Security: Since, data is stored on server computer centrally, it will be easy to manage data at only one place and the data will be more secure too.

Internet Sharing: Local Area Network provides the facility to share a single internet connection among all the LAN users. In Net Cafes, single internet connection sharing system keeps the internet expenses cheaper.

Disadvantages of LAN

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High Setup Cost: Although the LAN will save cost over time due to shared computer resources, but the initial setup costs of installing Local Area Networks is high.

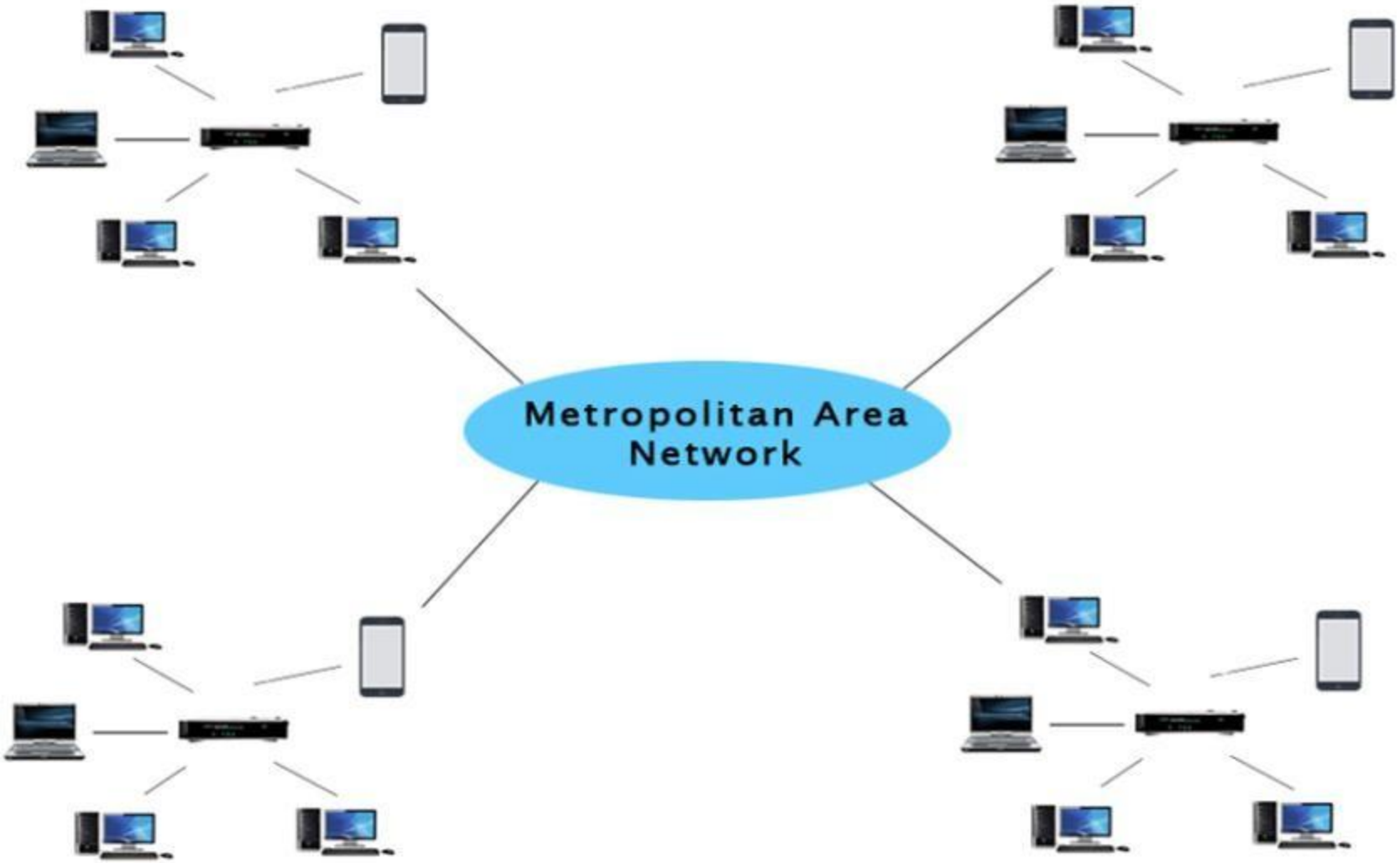
Privacy Violations: The LAN administrator has the rights to check personal data files of each and every LAN user. Moreover he can check the internet history and computer use history of the LAN user.

Data Security Threat: Unauthorized users can access important data of an organization if centralized data repository is not secured properly by the LAN administrator.

LAN Maintenance Job: Local Area Network requires a LAN Administrator because, there are problems of software installations or hardware failures or cable disturbances in Local Area Network. A LAN Administrator is needed at this full time job.

Covers Limited Area: Local Area Network covers a small area like one office, one building or a group of nearby buildings.

Metropolitan Area Network (MAN)



Metropolitan Area Network (MAN)

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- A metropolitan area network is a network that covers a larger geographic area by interconnecting a different LAN to form a larger network.
- Government agencies use MAN to connect to the cities and private industries.
- In MAN, various LANs are connected to each other through a telephone exchange line.
- The most widely used protocols in MAN are RS-232, Frame Relay, ATM, ISDN, OC-3, ADSL, etc.
- It has a higher range than Local Area Network(LAN).

Characteristics of MAN

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- It generally covers towns and cities (50 km)
- Communication medium used for MAN are optical fibers, cables etc.

Applications

- MAN is used in communication between the banks in a city.
- It can be used in an Airline Reservation.
- It can be used in a college within a city.
- It can also be used for communication in the military.

Advantages of MAN

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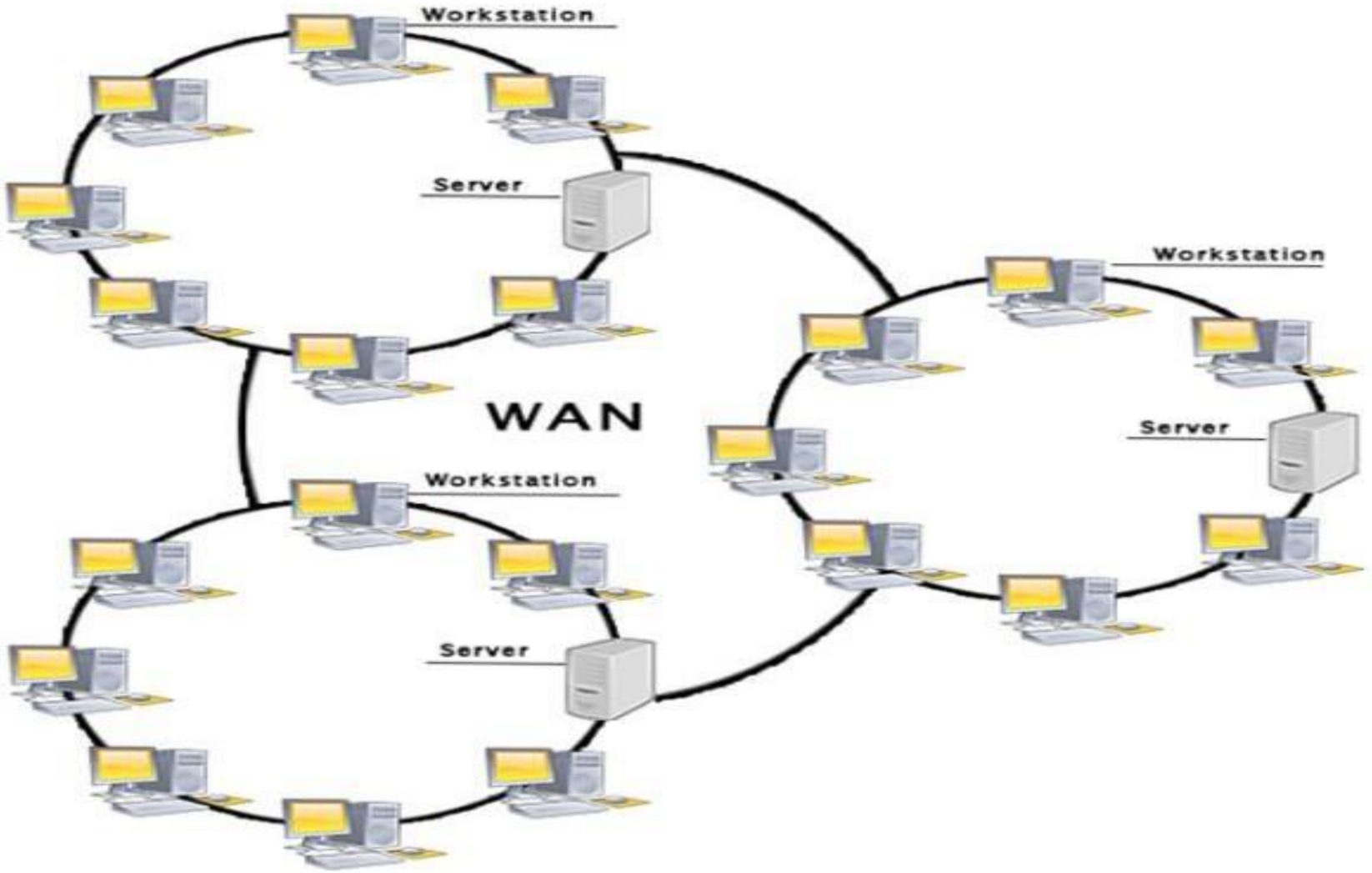
- Extremely efficient and provide fast communication via high-speed carriers, such as fiber optic cables.
- It provides a good back bone for large network and provides greater access to WANs.
- The dual bus used in MAN helps the transmission of data in both directions simultaneously.

Disadvantages:

- More cable required for a MAN connection from one place to another.
- It is difficult to make the system secure from hackers and industrial espionage (spying) graphical regions.

Wide Area Network (WAN)



Wide Area Network (WAN)

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- WAN can be private or it can be public leased network.
- It is used for the network that covers large distance such as cover states of a country.
- It is not easy to design and maintain.
- Communication medium used by WAN are PSTN(Public switched telephone network) or Satellite links.
- WAN operates on low data rates.

Examples for WAN

Mobile Broadband: A 4G network is widely used across a region or country.

Last mile: A telecom company is used to provide the internet services to the customers in hundreds of cities by connecting their home with fiber.

Private network: A bank provides a private network that connects all the offices. This network is made by using the telephone leased line provided by the telecom company.

Advantages of WAN

Geographical area: A Wide Area Network provides a large geographical area. Suppose if the branch of our office is in a different city then we can connect with them through WAN. The internet provides a leased line through which we can connect with another branch.

Centralized data: data is centralized.

Get updated files: Software companies work on the live server. Therefore, the programmers get the updated files within seconds.

Advantages of WAN (Contd.)

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Exchange messages: In a WAN network, messages are transmitted fast. The web application like Facebook, WhatsApp, Skype allows you to communicate with friends.

Sharing of software and resources: In WAN network, we can share the software and other resources like a hard drive, RAM.

Global business: We can do the business over the internet globally.

High bandwidth: If we use the leased lines for our company then this gives the high bandwidth. The high bandwidth increases the data transfer rate which in turn increases the productivity of our company.

Disadvantages of WAN

Security issue: A WAN network has more security issues as compared to LAN and MAN network

Needs Firewall & antivirus software: The data is transferred on the internet which can be changed or hacked by the hackers, so the firewall needs to be used. Some people can inject the virus in our system so antivirus is needed to protect from such a virus.

High Setup cost: An installation cost of the WAN network is high as it involves the purchasing of routers, switches.

Troubleshooting problems: It covers a large area so fixing the problem is difficult.

Personal Area Network (PAN)

Personal Area Network (PAN)

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- Personal Area Network is used for connecting the computer devices for personal use.
- **Thomas Zimmerman** was the first research scientist to bring the idea of the Personal Area Network.
- Personal Area Network covers an area of **30 feet**.

Personal computer devices that are used to develop the personal area network are the laptop, mobile phones, media player and play stations.

Examples of PAN

Body Area Network: Body Area Network is a network that moves with a person. **For example**, a mobile network moves with a person. Suppose a person establishes a network connection and then creates a connection with another device to share the information.

Offline Network: An offline network can be created inside the home, so it is also known as a **home network**. A home network is designed to integrate the devices such as printers, computer, television but they are not connected to the internet.

Small Home Office: It is used to connect a variety of devices to the internet and to a corporate network using a VPN

Data Transmission Modes

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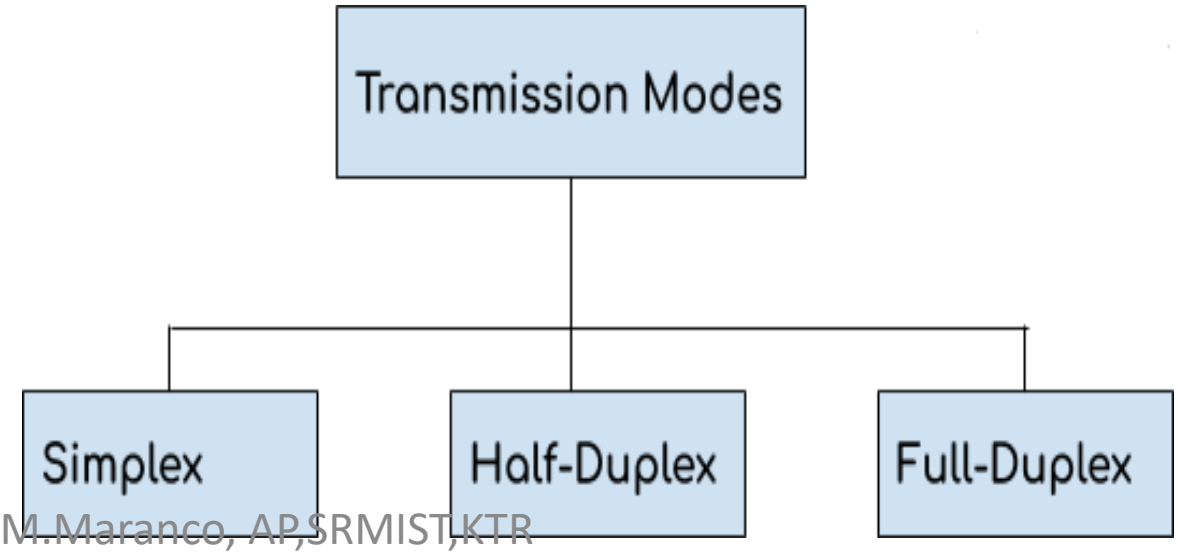
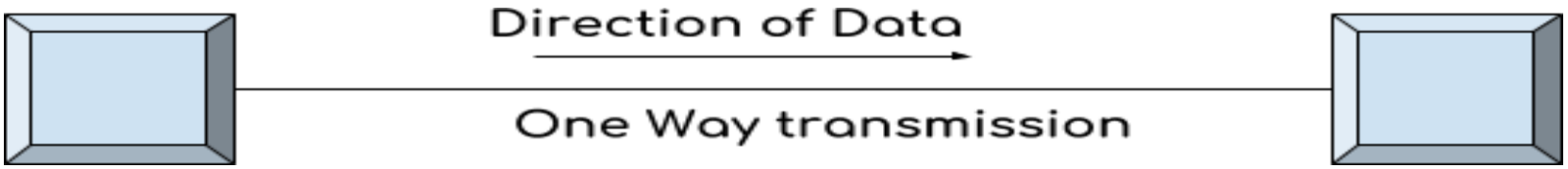
- The data is transmitted from one device to another device through a **transmission mode**.
- The transmission mode decides the **direction of data** in which the data needs to travel to reach the receiver system or node.
- The transmission mode is divided into three categories:
  1. Simplex
  2. Half-Duplex
  3. Full-Duplex



Simplex Mode



1.In simplex mode the data transmits in one direction only, from one system to another system.
2.The sender device that sends data can only send data and cannot receive it. On the other hand the receiver device can only receive the data and cannot send it.
3.Television is an example of simplex mode transmission as the broadcast sends signals to our TV but never receives signals back from our TV. This is a unidirectional transmission.

Simplex Mode

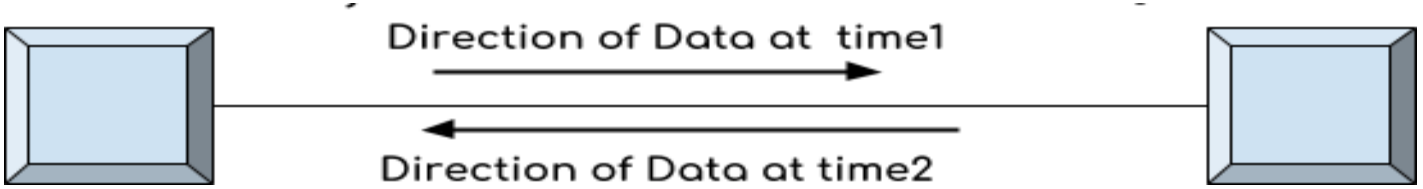
Advantages of Simplex Mode:

The full capacity of the transmission medium is utilized as the transmission is one way and cannot have traffic issues.

Disadvantages of Simplex Mode:

No bidirectional communication is possible. Two devices cannot communicate with each other using simplex mode of transmission.

Half-Duplex Mode



1) In half duplex mode transmission can be done both ways which means if two systems are connected with half-duplex mode of transmission, they both can send and receive data but not at the same time.
2) If one device is sending data then other device cannot send data until it receives the data which is already in transmission. You can say that the communication is not simultaneous.
3) The radio communication device that our soldiers use at the battle fields are the examples of half duplex mode transmission as they send message and then say over and then the person on other hand send his message and this way they communicate but not simultaneously like we used to do on mobile.

Half-Duplex Mode

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Advantages of Half-Duplex mode:

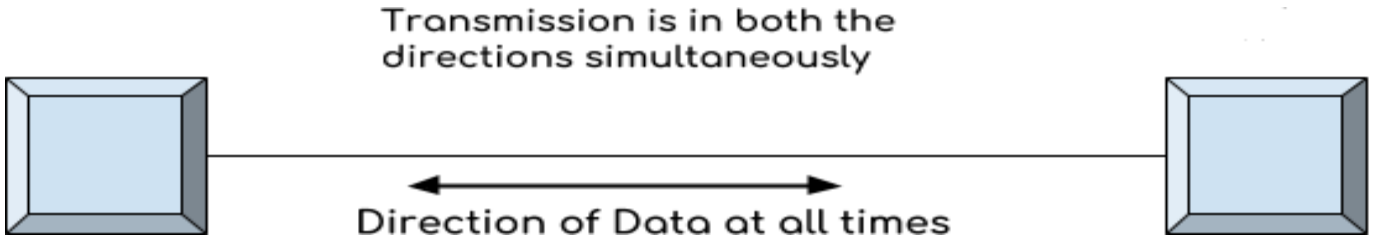
Both devices can send and receive data.

Whole bandwidth can be utilized as at a time only one signal transmits.

Disadvantages of Half-Duplex mode:

The disadvantage in half duplex mode is that the other device cannot send data until it receives the data which is already in transmission, this can cause delays to the communication.

Full-Duplex Mode



1.In full duplex mode both the connected devices can send and receive data simultaneously. The mobile phone we use is an example of full duplex mode where we can communicate simultaneously.

2.Both the devices can send and receive the data at the same time.

Full-Duplex Mode

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Advantages of Full Duplex mode:

No delays in communication as both can send and receive data simultaneously.

Disadvantages of Full Duplex mode:

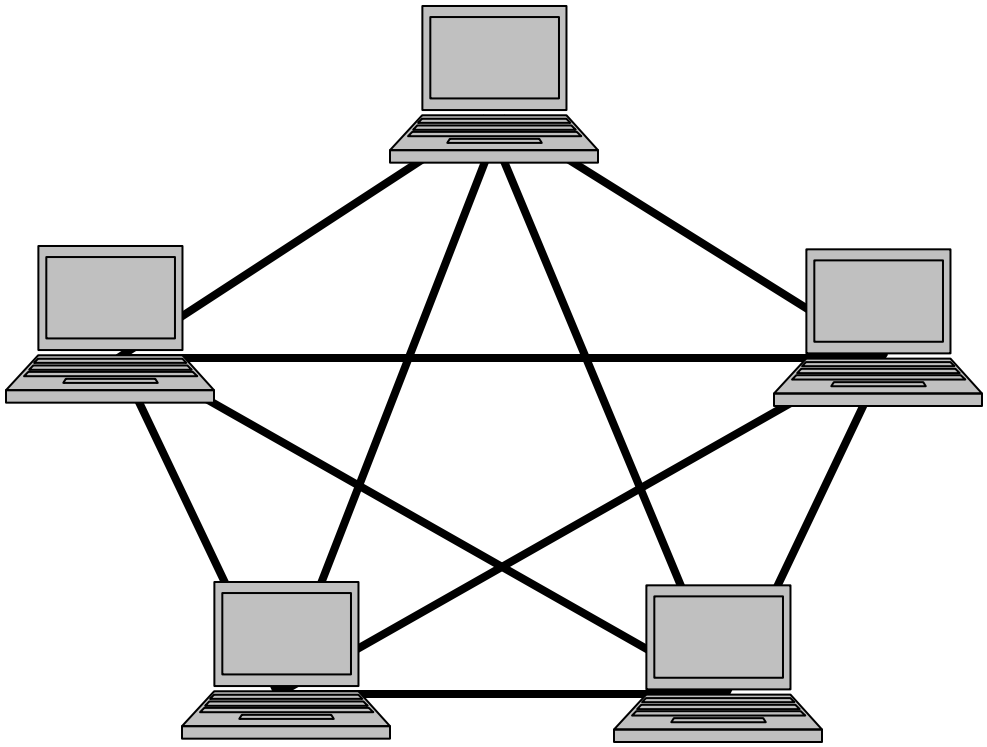
No proper bandwidth utilization as the same line is used for sending and receiving data at the same time.

Network Topology- Types

- Topology: physical or logical arrangement of devices
  - Point-to-point
  - Mesh
  - Star
  - Bus
  - Ring
  - Hybrid

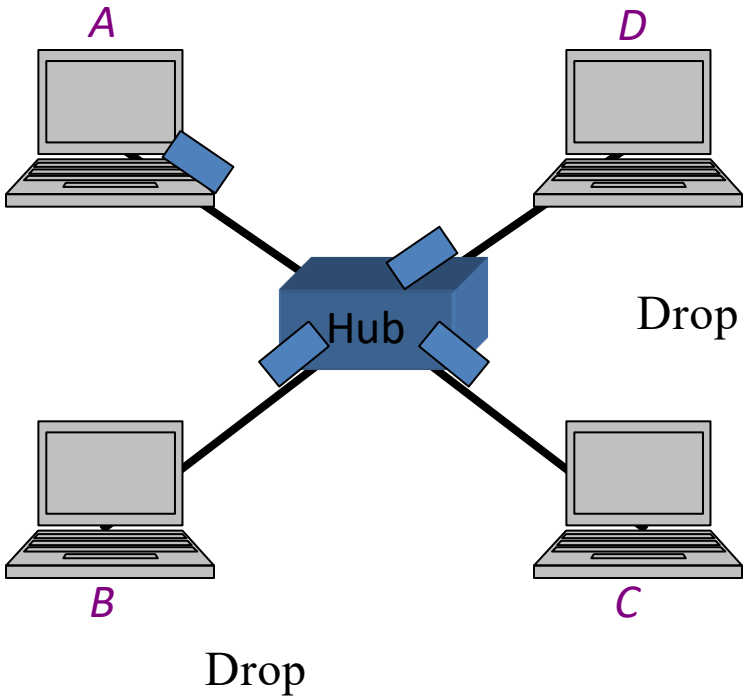
Point-to-Point Connection

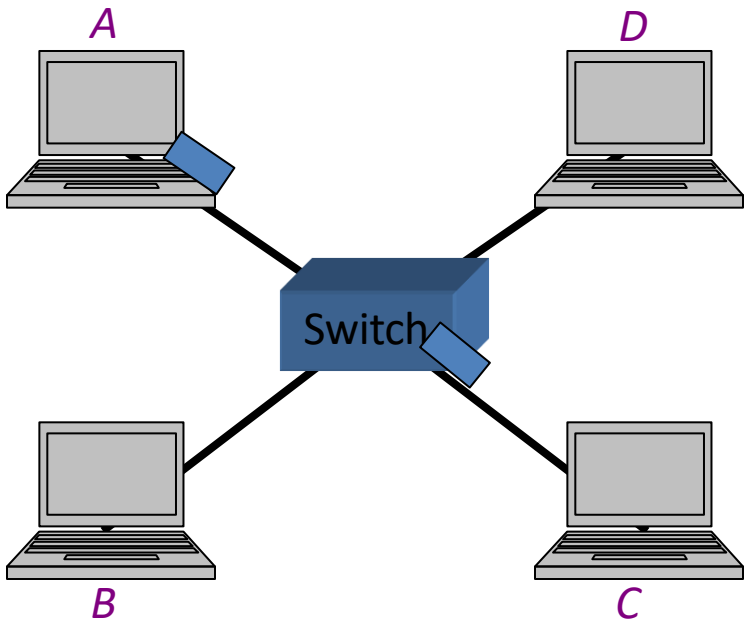
Fully Connected Mesh Topology



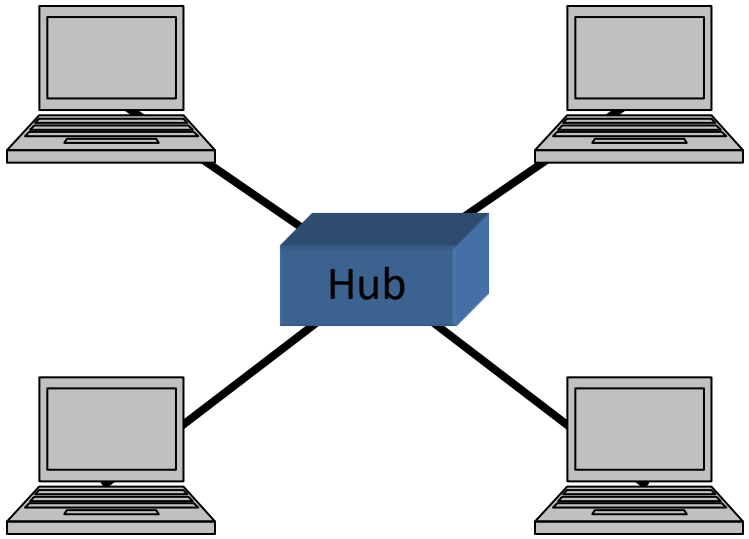
- **Pros:**
  - Dedicated links
  - Robustness
  - Privacy
  - Easy to identify fault
- **Cons:**
  - A lot of cabling
  - I/O ports
  - Difficult to move

Star Topology



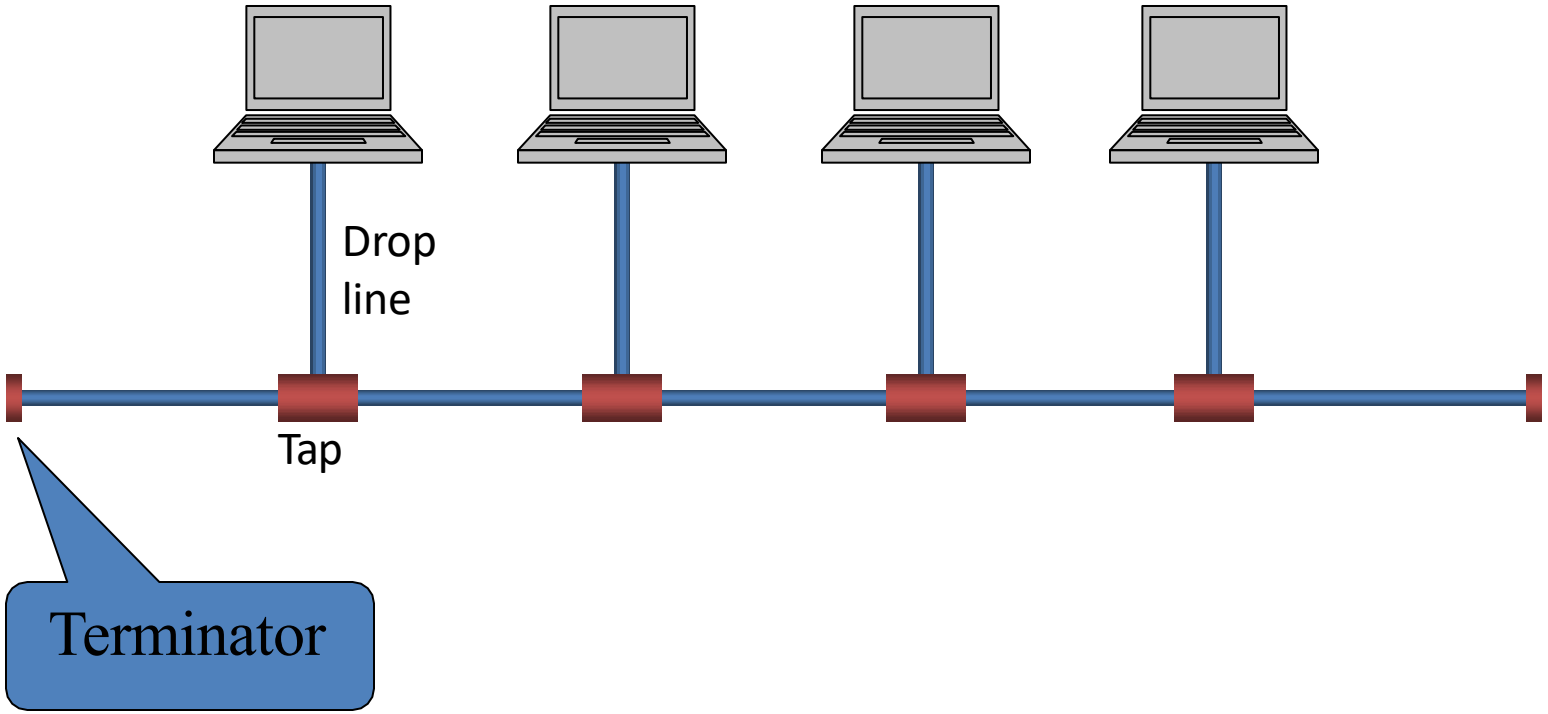


Star Topology

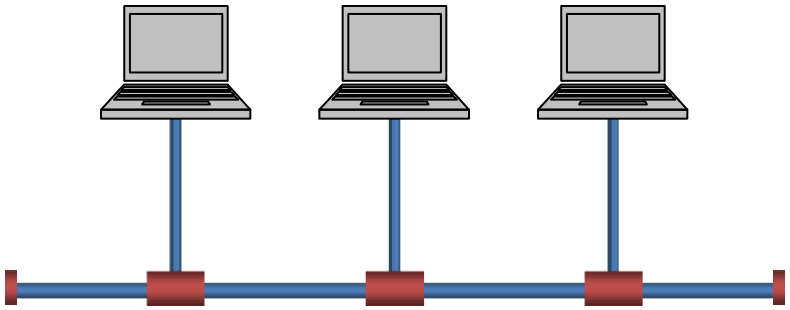


- **Pros:**
  - One I/O port per device
  - Little cabling
  - Easy to install
  - Robustness
  - Easy to identify fault
- **Cons:**
  - Single point of failure
  - More cabling still required

Bus Topology

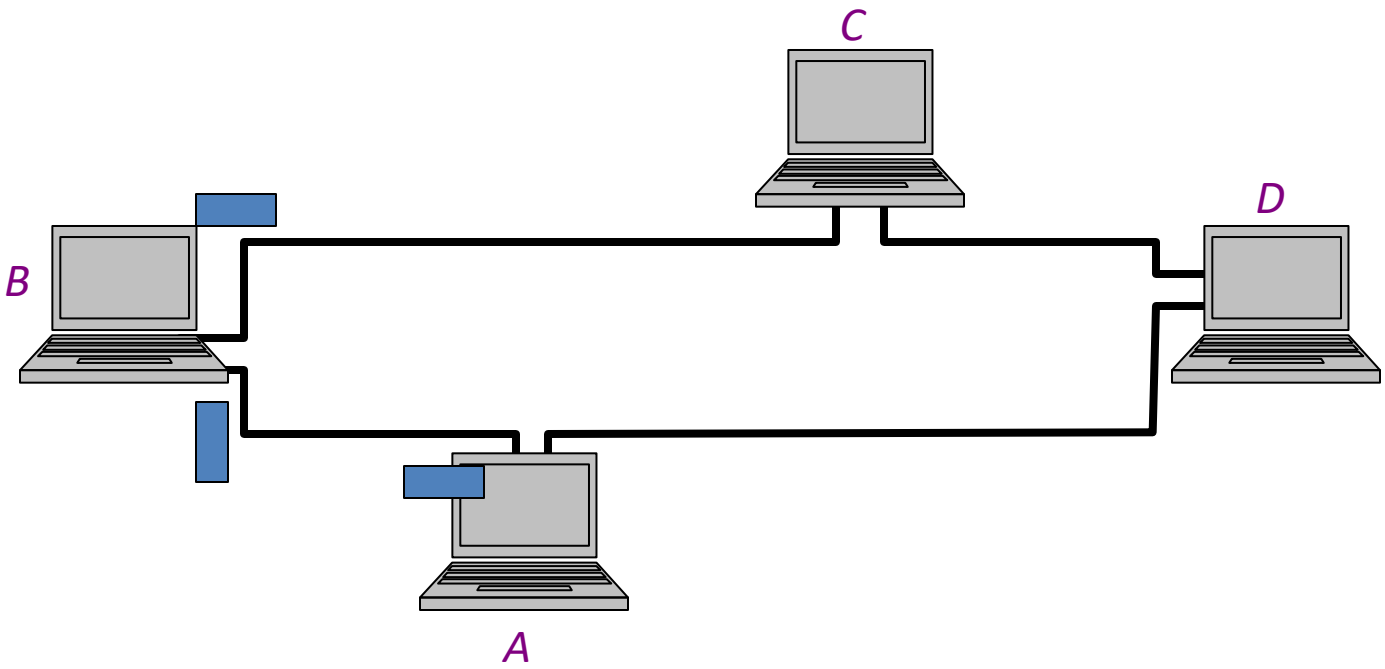


Bus Topology

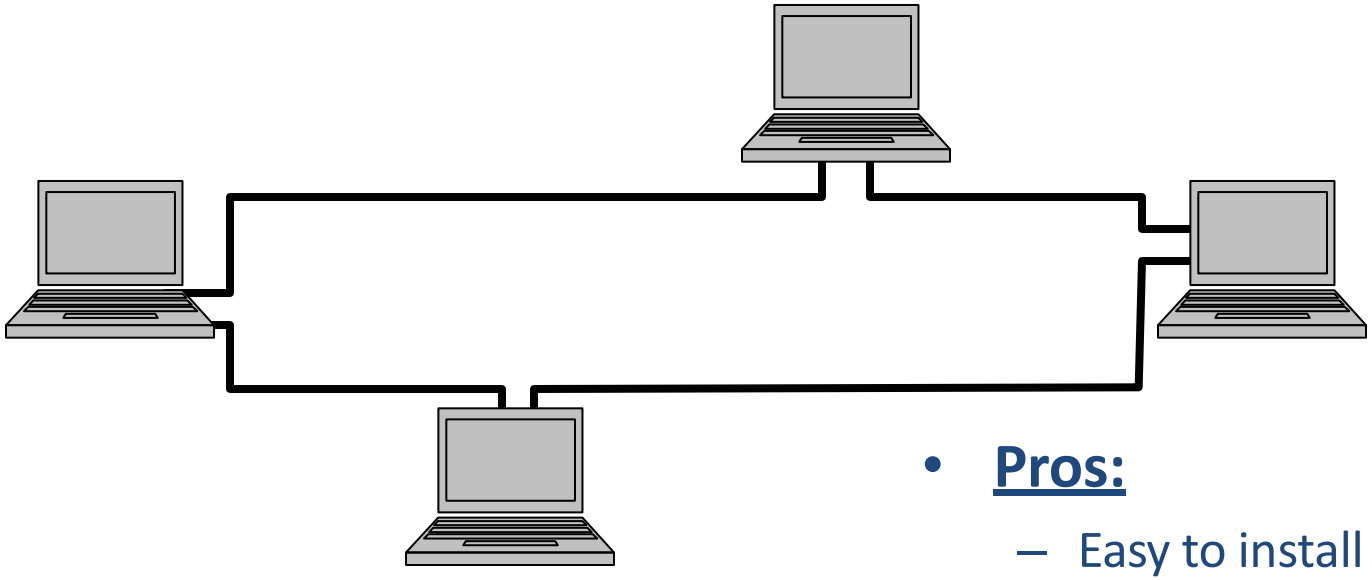


- **Pros:**
  - Little cabling
  - Easy to install
- **Cons:**
  - Difficult to modify
  - Difficult to isolate fault
  - Break in the bus cable stops all transmission

Ring Topology

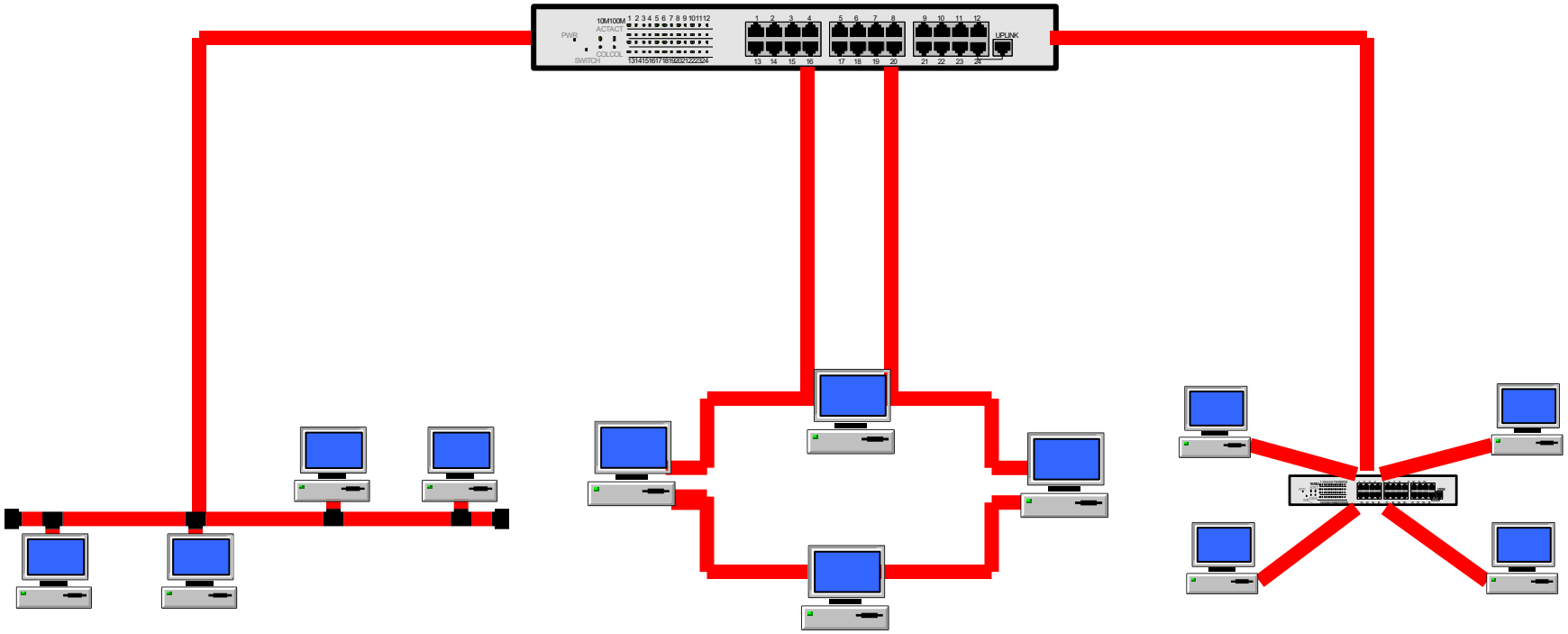


Ring Topology



- **Pros:**
  - Easy to install
  - Easy to identify fault
- **Cons:**
  - Delay in large ring
  - Break in the ring stops all transmission

Hybrid Topologies



Network Topology -Comparison

Parameters	Bus	Ring	Star	Mesh
Network Performance	Small	Small or Large	Small	Small
Cable Length Requirement	Less	Neither less nor	More	More
Traffic	Less	High	Medium	No
Dataflow Efficiency	More	Neither less nor more	More	More
Failure	Easy to solve	Difficult to solve	Easy to solve except hub/switch fails	Easy to solve
Cost	Low	High	High	High

Switching

1. INTRODUCTION
2. CIRCUIT-SWITCHED NETWORK
3. PACKET-SWITCHING

switched network consists of series of interlinked nodes, called switches.

Switches are the temporary node(some are used to connect end devices, others used for routing) creates connection between two or more devices.

- Mostly switches operate at Layer-2.

INTRODUCTION TO SWITCHING

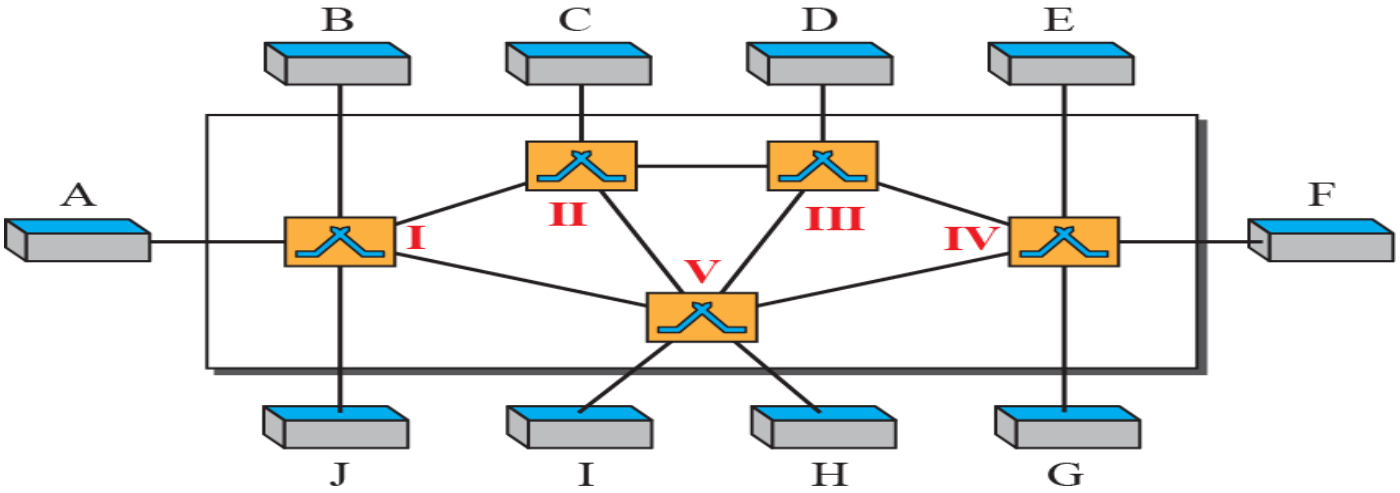


Figure 1: Switched network

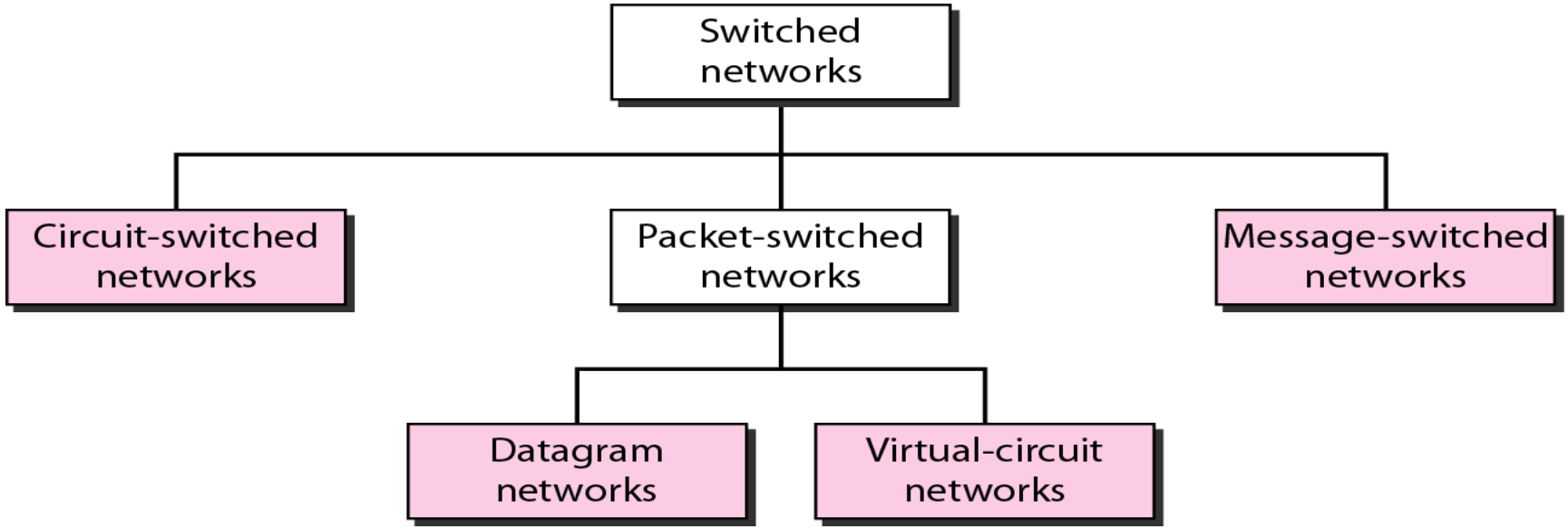
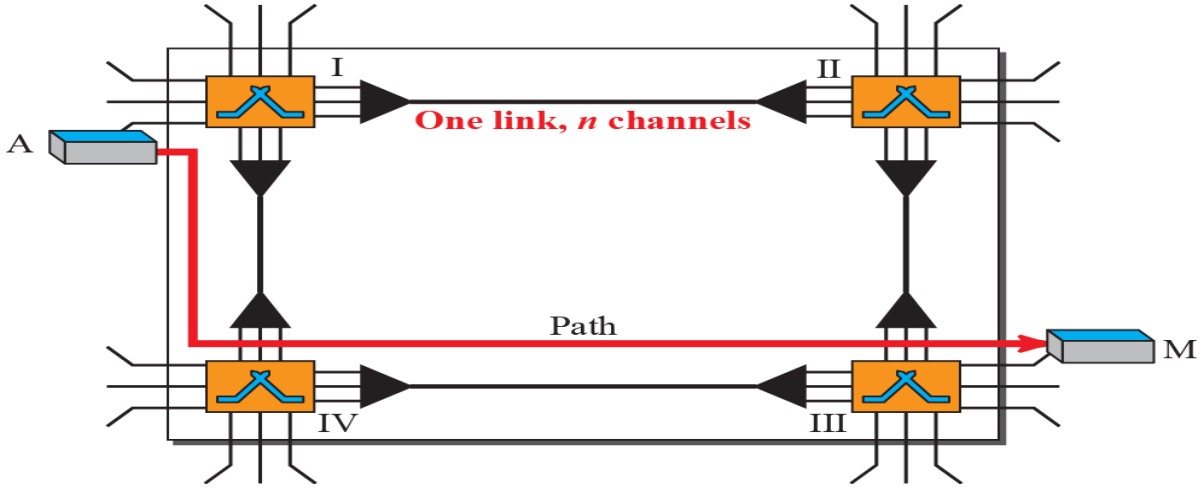


Figure 2: Taxonomy of Switched network

CIRCUIT-SWITCHED NETWORKS



•A circuit-switched network consists of a set of switches connected by physical links.

• A connection between two stations is a dedicated path made of one or more links but each connection uses only one dedicated channel on each link.

• Each link is divived into n channel using FDM or TDM.

•A circuit-switched network creates a dedicated path to complete a link between the sender and receiver.

CIRCUIT-SWITCHED NETWORKS

- When end system A needs to communicate with M, system A needs to get connection to M that must be accepted by all the switches in between as well as system M. This is called set-up phase.
- After the dedicated path of connected circuits is established, data transfer takes place, then circuits are tom down.
- Circuit switching takes place at the physical layer, stations must reserve the resources for the communication, data transfer are not packetized. There is no addressing involved, switches route the packet based on available bandwidth or time slot.
- Of-course addressing is done during set-up phase.

The actual communication in a circuit-switched network requires three phases:

- Connection setup,
- Data transfer, and
- Connection termination.

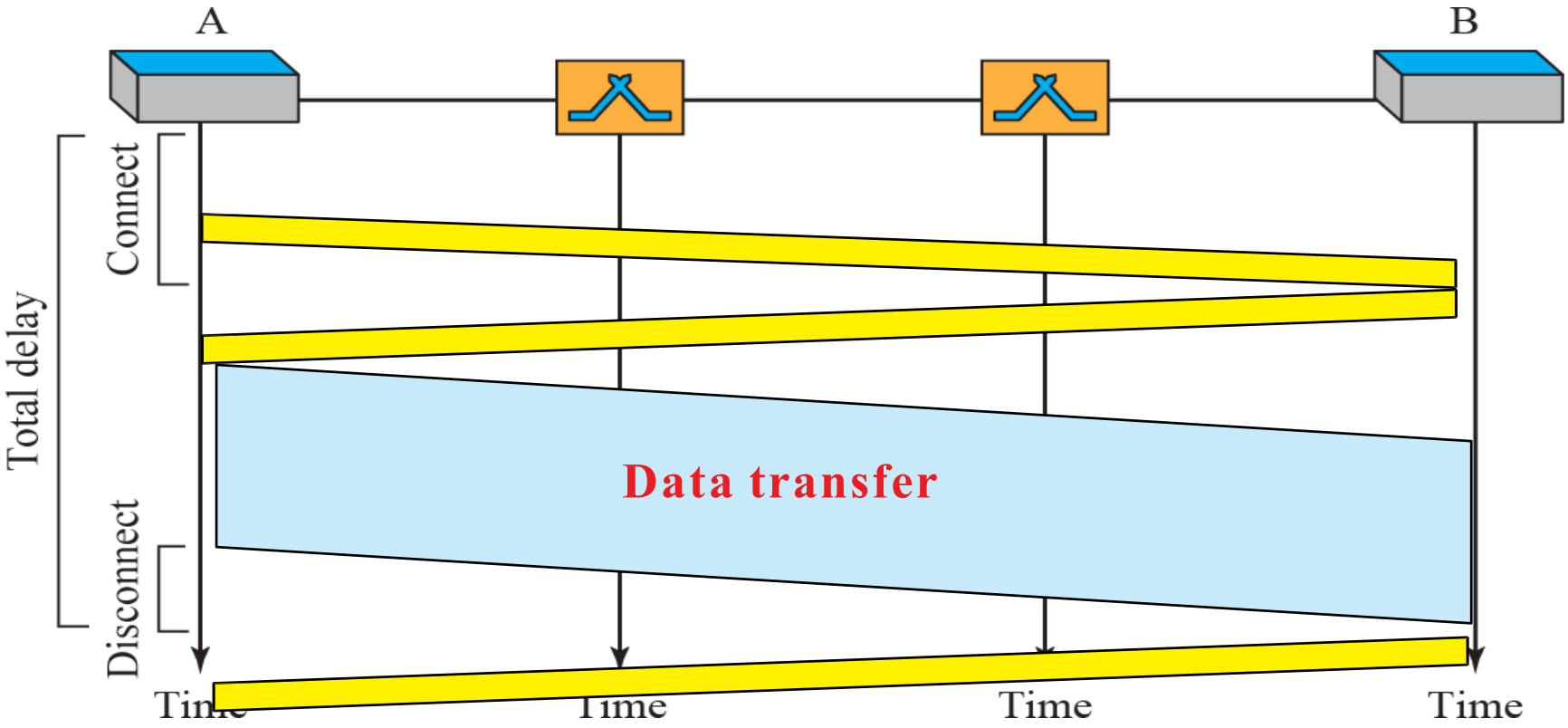


Figure 6 : circuit-switched network three phases

Efficiency

It can be argued that circuit-switched networks are not as efficient as the other two types of networks because resources are allocated during the entire duration of the connection.

These resources are unavailable to other connections, because resources are allocated during the entire duration of the connection.

Delay

Delay in this network is very minimal, there is no waiting time at each switch, total delay is due to time needed to create a connection, data transfer and disconnect the circuit.

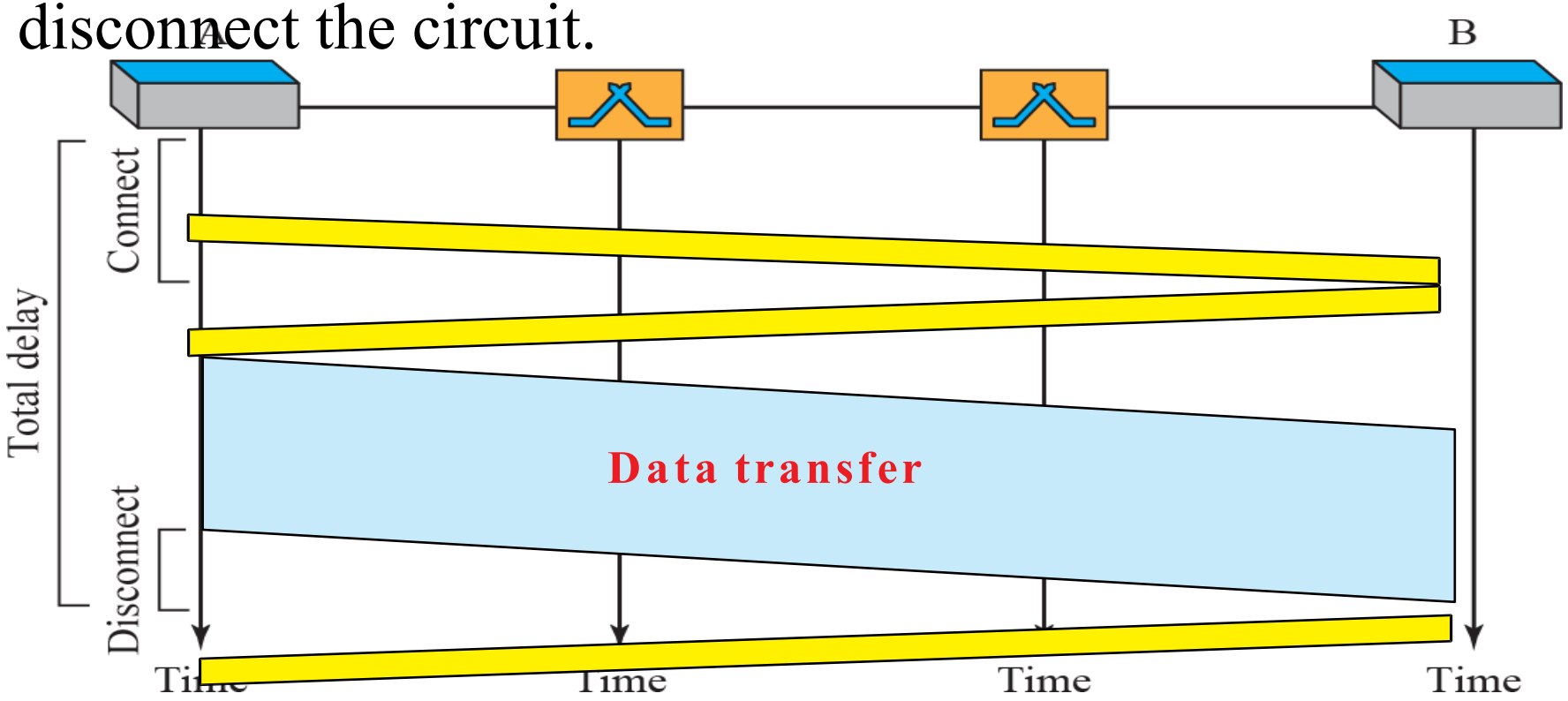


Figure 7: Delay in a circuit-switched network

PACKET SWITCHING

A packet-switched network divides the data into packets of fixed or variable size.

The size of the packet is determined by the network and the governing protocol.
There is no resource allocation for the packets, resource are allocated on-demand.
When a switch receive the packet, no matter what is the source or destination, packets must wait if there are packets being processed.

Datagram Networks

Packet switched networks are classified as

A. Datagram Networks
B. Virtual circuit Networks

- In a datagram network, each packet is treated independently of all others.
- A datagram network operates at the Network layer.
- Even if a packet is part of a multi-packet transmission, the network treats packets as though they existed alone.
- Each packet of one message can travel a different route towards their final destination.
- Packets in this approach are referred to as datagrams.

Datagram Networks

- Switches in the datagram network are referred as routers.
- Datagram of transmission arrive at the destination out of order and with delays between packets.
- Upper layer protocols do the reordering and ask for the lost packets before passing to the application.
- No set-up or tear down phase.

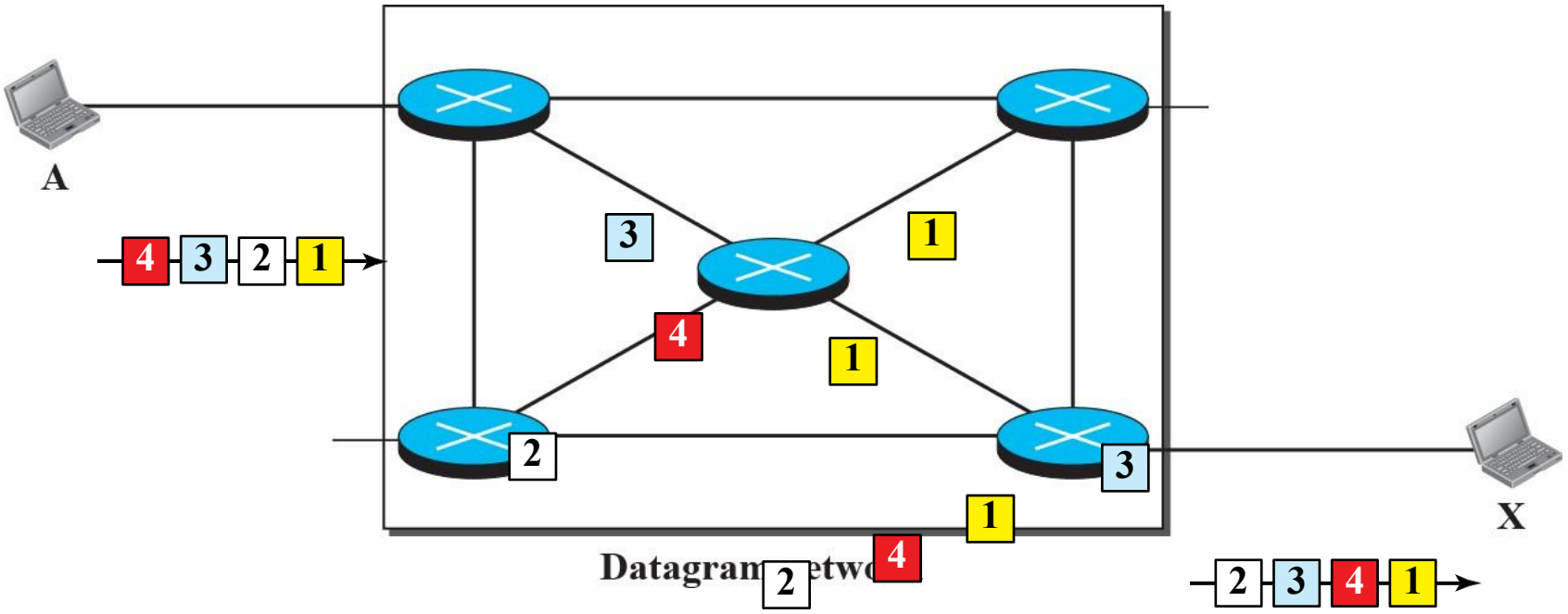
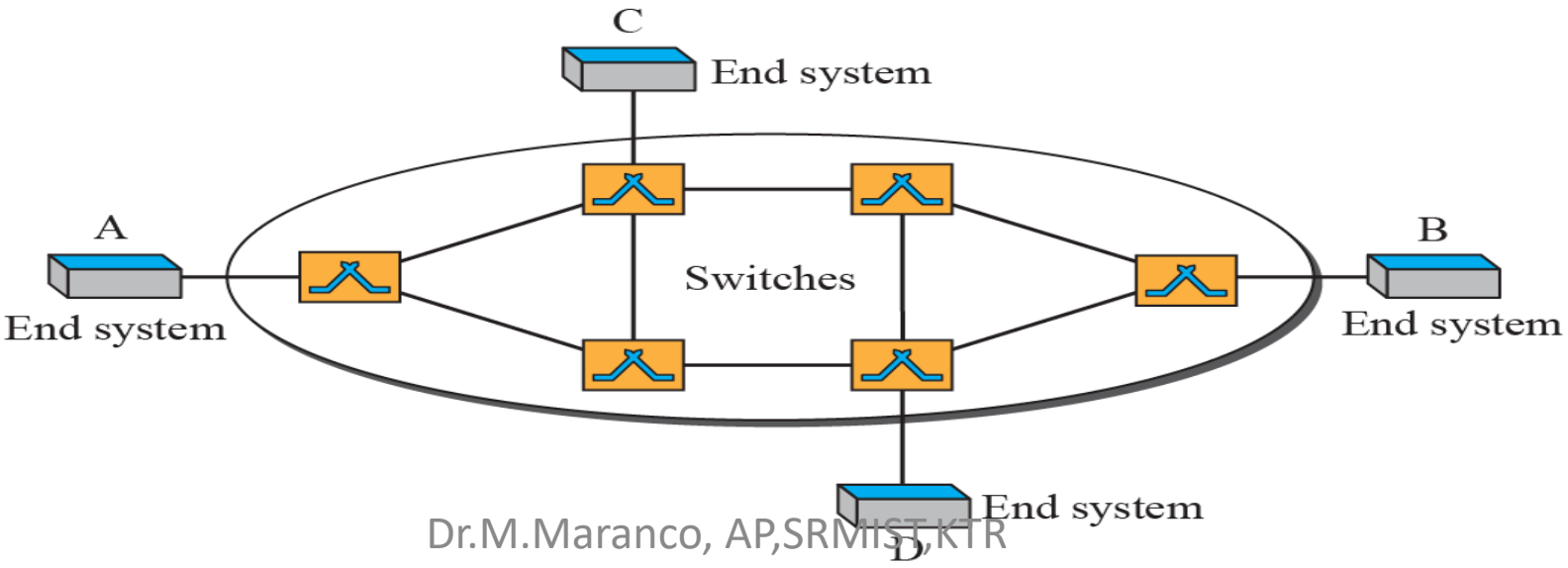


Figure 8: A Datagram network with four 3-level switches

Virtual-Circuit Networks

- A virtual-circuit network is a cross between a circuit-switched network and a datagram network.
- The virtual-circuit shares characteristics of both.
- The virtual-circuit network operates at the data-link layer.



Virtual-Circuit Networks

- There are setup and tear down phase, in addition to data transfer data.
- Resources are allocated during the setup time, or on demand
- Data are packetized and each packet carries an address in the header.
- All packets follow the same path established during the connection.

Virtual-Circuit Networks

Addressing:
Two types:1) Global and 2) Local addressing
Global: an address that can be unique in the scope of the network. It is used to create virtual- circuit identifier.
Virtual-Circuit Identifier:
is a small number that has only switch scope; it is used by a frame between two switches
When a frame arrives at a switch, it has a VCI; when it leaves, it has a different VCl.

Virtual-Circuit Networks

A virtual-circuit network uses a series of special temporary addresses known as virtual circuit identifiers (VCI).

The VCI at each switch, is used to advance the frame towards its final destination.

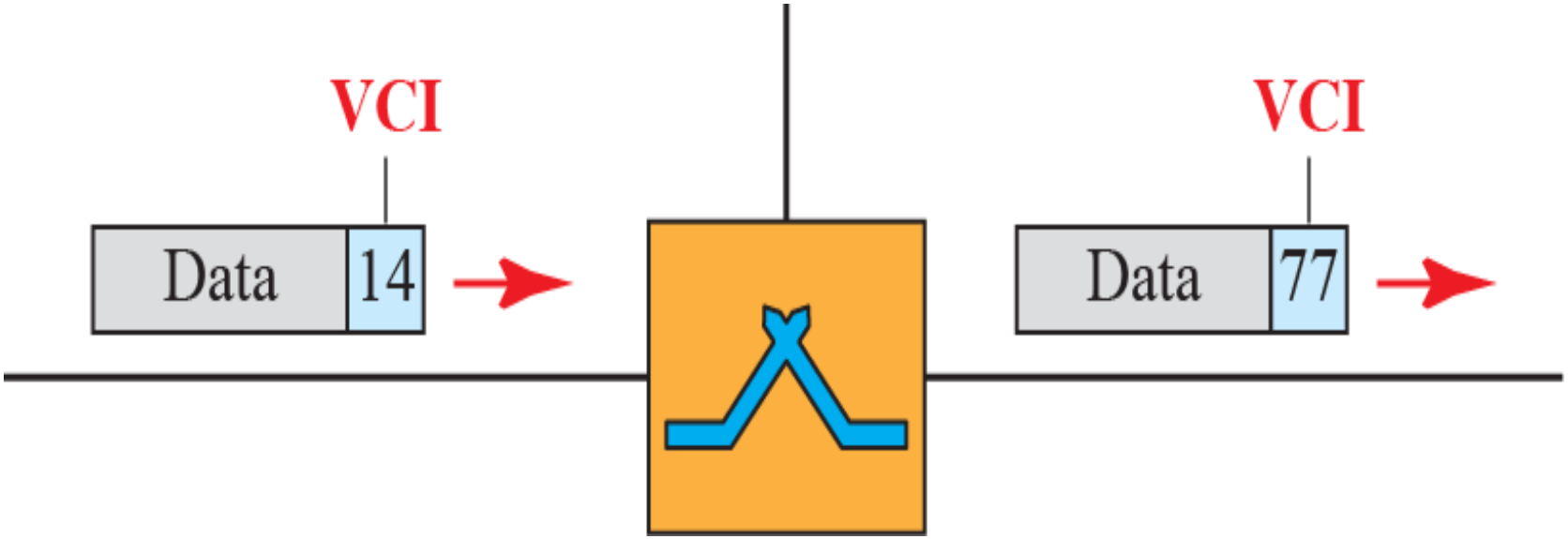


Figure 13: Virtual-circuit identifier (compare the VCI to a Datagram destination address)

Virtual-Circuit Networks

Data Transfer Phase

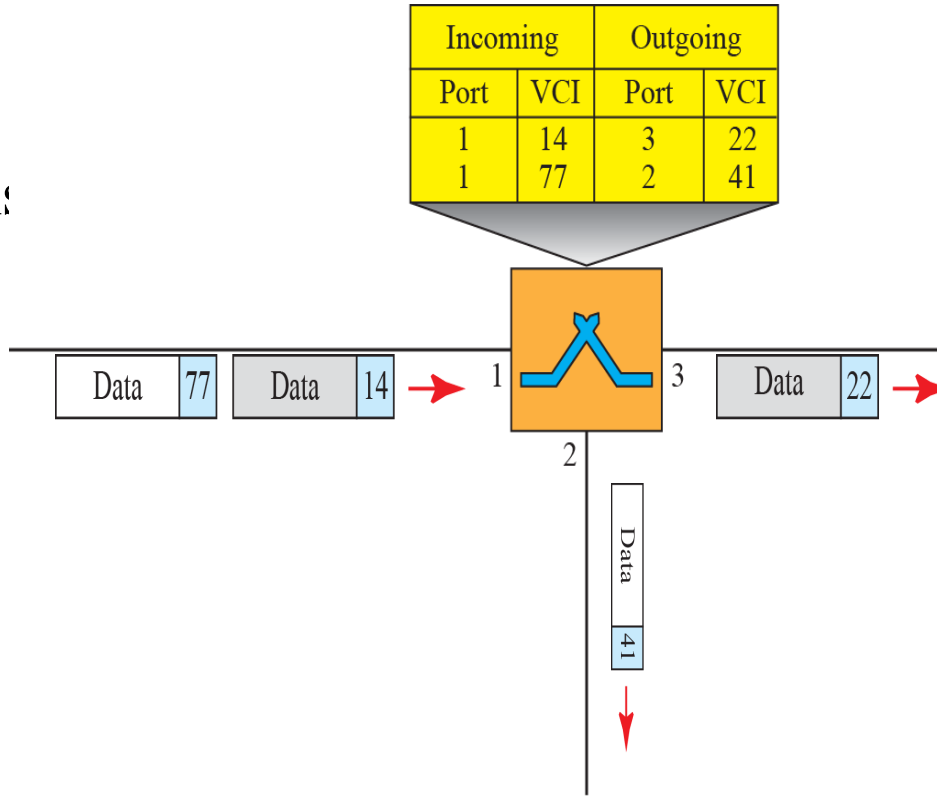
To transfer a frame from a source to its destination, all switches need to have a table entry for this virtual circuit.

The table, in its simplest form, has four columns.

The switch has a table with 4 columns

a) Inputs half
   - Input Port Number
   - Input VCI

b) Outputs half
   - Output Port Number
   - Output VCI



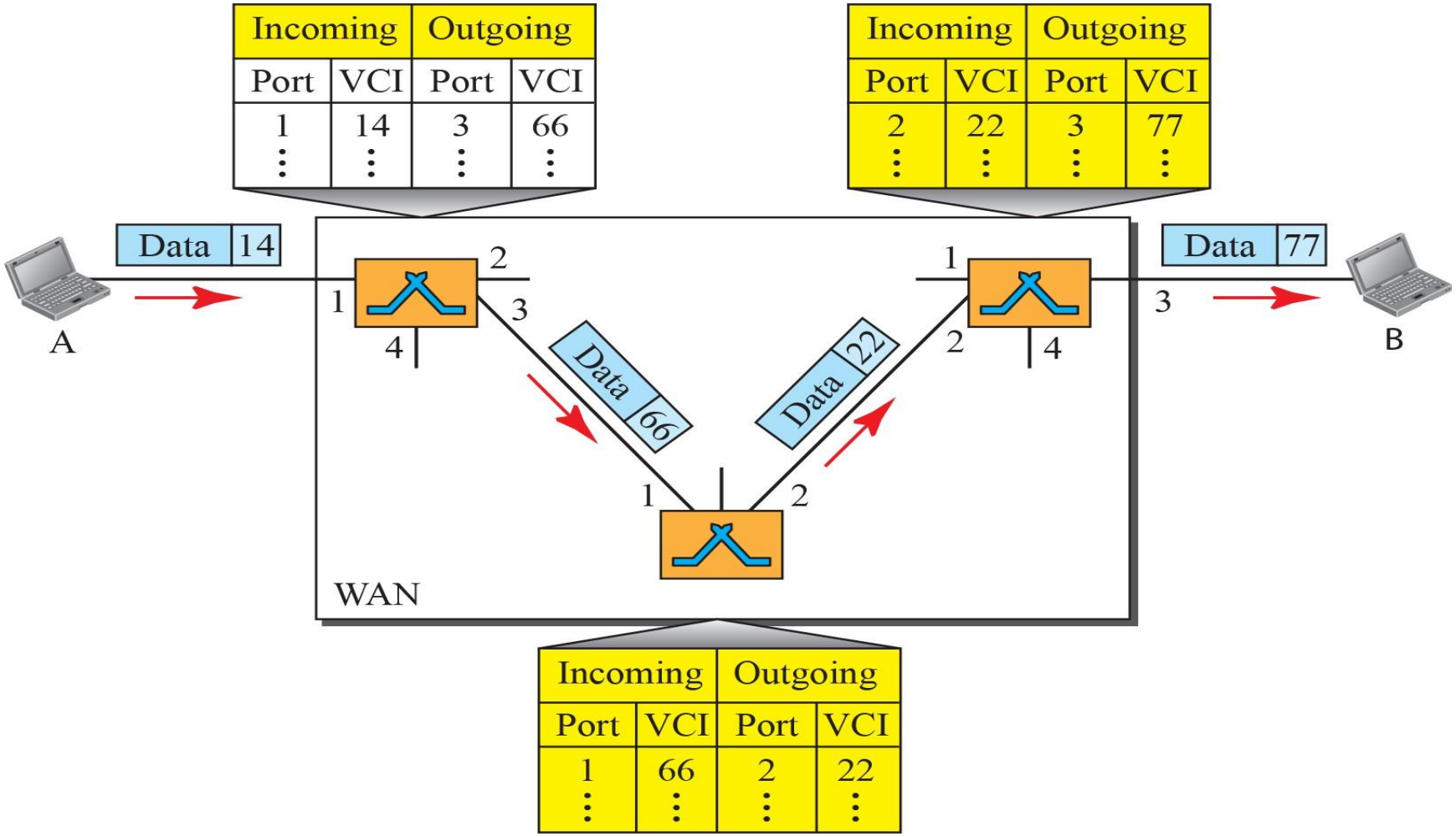


Figure15: Source-to-destination data transfer in a circuit-switch network

Virtual Circuit Networks

- The VCN behaves like a circuit switched net because there is a setup phase to establish the VCI entries in the switch table. the setup request and the acknowledgment.
- There is also a data transfer phase and teardown phase.

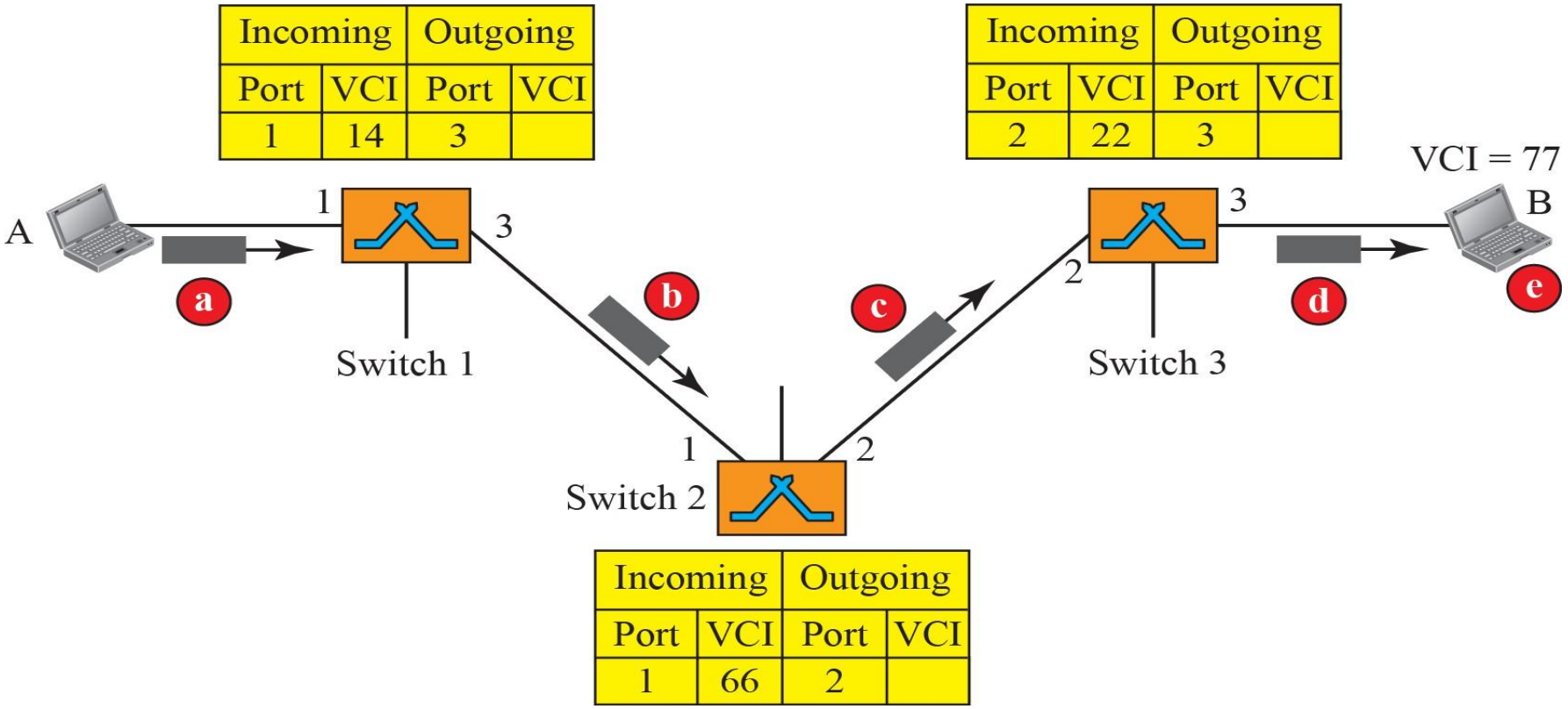


Figure16: Setup request in a virtual-circuit network all nodes have a VCI

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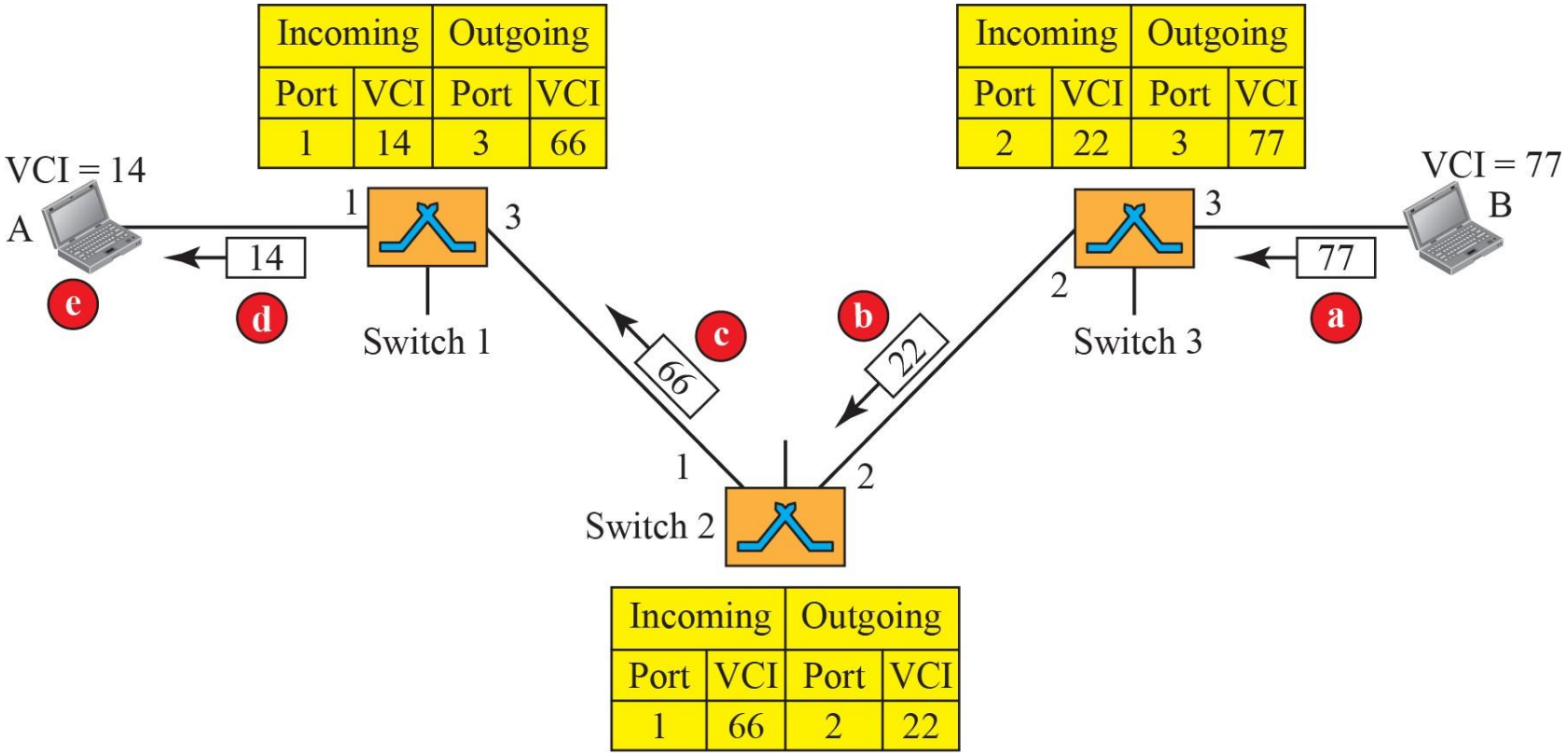


Figure17: Setup acknowledgment in a virtual-circuit network

Efficiency

The source can check the availability of the resources, without actually reserving it.

Delay in Virtual-Circuit Networks

- In a virtual-circuit network, there is a one-time delay for setup and a one-time delay for teardown. If resources are allocated during the setup phase, there is no wait time for individual packets.
- The packet is traveling through two switches (routers). There are three transmission times (3T), three propagation times (3't), data transfer depicted by the sloping lines, a setup delay and a teardown delay

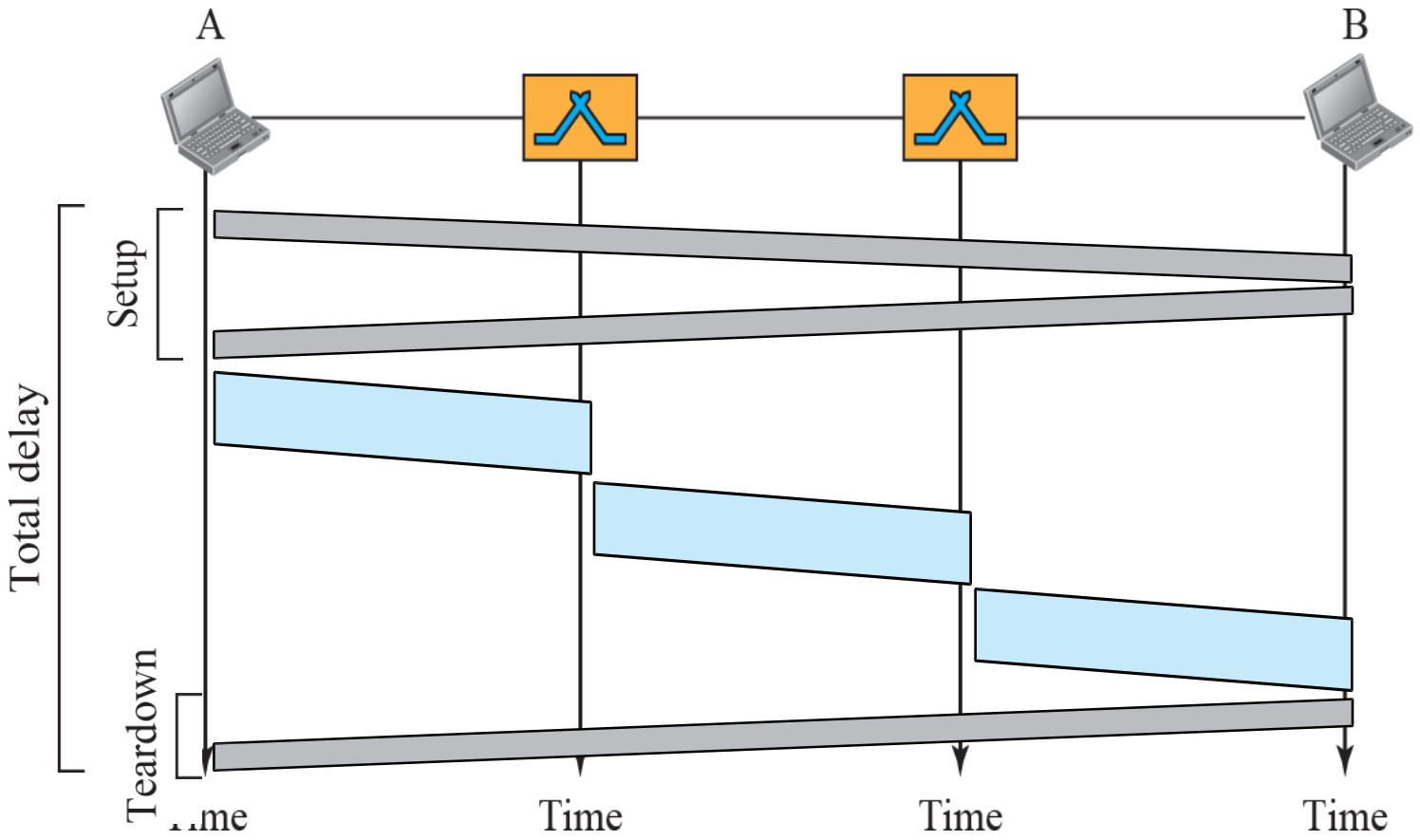


Figure 18: Delay in a virtual-circuit network

Comparison Chart

BASIS	CIRCUIT SWITCHING	PACKET SWITCHING
Orientation	Connection oriented.	Connectionless.
Purpose	Initially designed for Voice communication.	Initially designed for Data Transmission.
Flexibility	Inflexible, because once a path is set all parts of a transmission follows the same path.	Flexible, because a route is created for each packet to travel to the destination.
Order	Message is received in the order, sent from the source.	Packets of a message are received out of order and assembled at the destination.
Technology/Approach	Circuit switching can be achieved using two technologies, either Space Division Switching or Time-Division Switching.	Packet Switching has two approaches Datagram Approach and Virtual Circuit Approach.
Layers	Circuit Switching is implemented at Physical Layer.	Packet Switching is implemented at Network Layer.

Standard Protocol Architectures

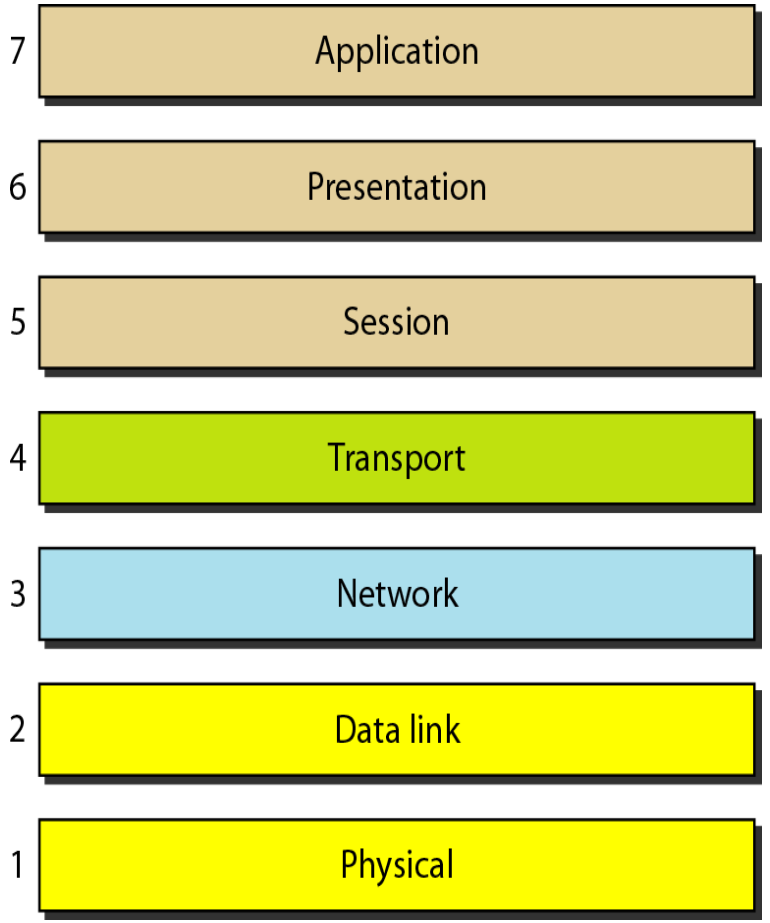
- Two approaches (standard)
  - OSI Reference model
    - never used widely
    - but well known
  - TCP/IP protocol suite
    - Most widely used
- Another approach (proprietary)
  - IBM's Systems Network Architecture (SNA)

OSI Reference Model

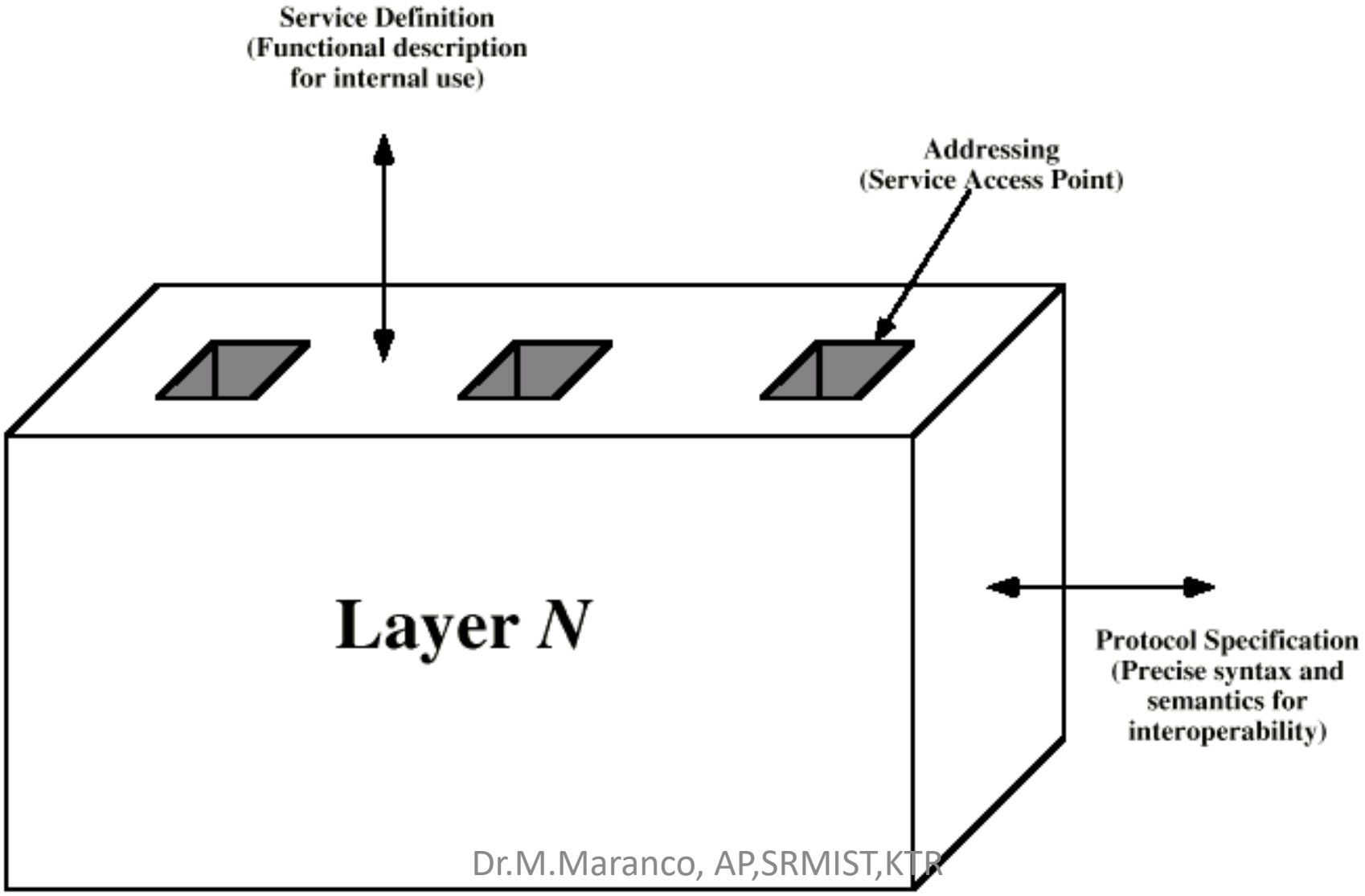
- Open Systems Interconnection (OSI)
- Reference model
  - provides a general framework for standardization
  - defines a set of layers and services provided by each layer
  - one or more protocols can be developed for each layer
- Developed by the International Organization for Standardization (ISO)
  - also published by ITU-T (International Telecommunications Union)
- A layered model
  - Seven layers – seven has been presented as the optimal number of layer
- Delivered too late (published in 1984)!
  - by that time TCP/IP started to became the de facto standard
- Although no OSI-based protocol survived, the model is still valid (in the textbooks)
  - For Data Link Layer (that we will see later) OSI protocols are still valid

OSI - The Layer Model

- The term “Open” denotes the ability to connect any 2 devices which conforms to the reference model and the associated standards.
- Each layer performs a subset of the required communication functions
- Each layer relies on the next lower layer to perform more primitive functions
- Each layer provides services to the next higher layer.
- Changes in one layer should not require changes in other layers



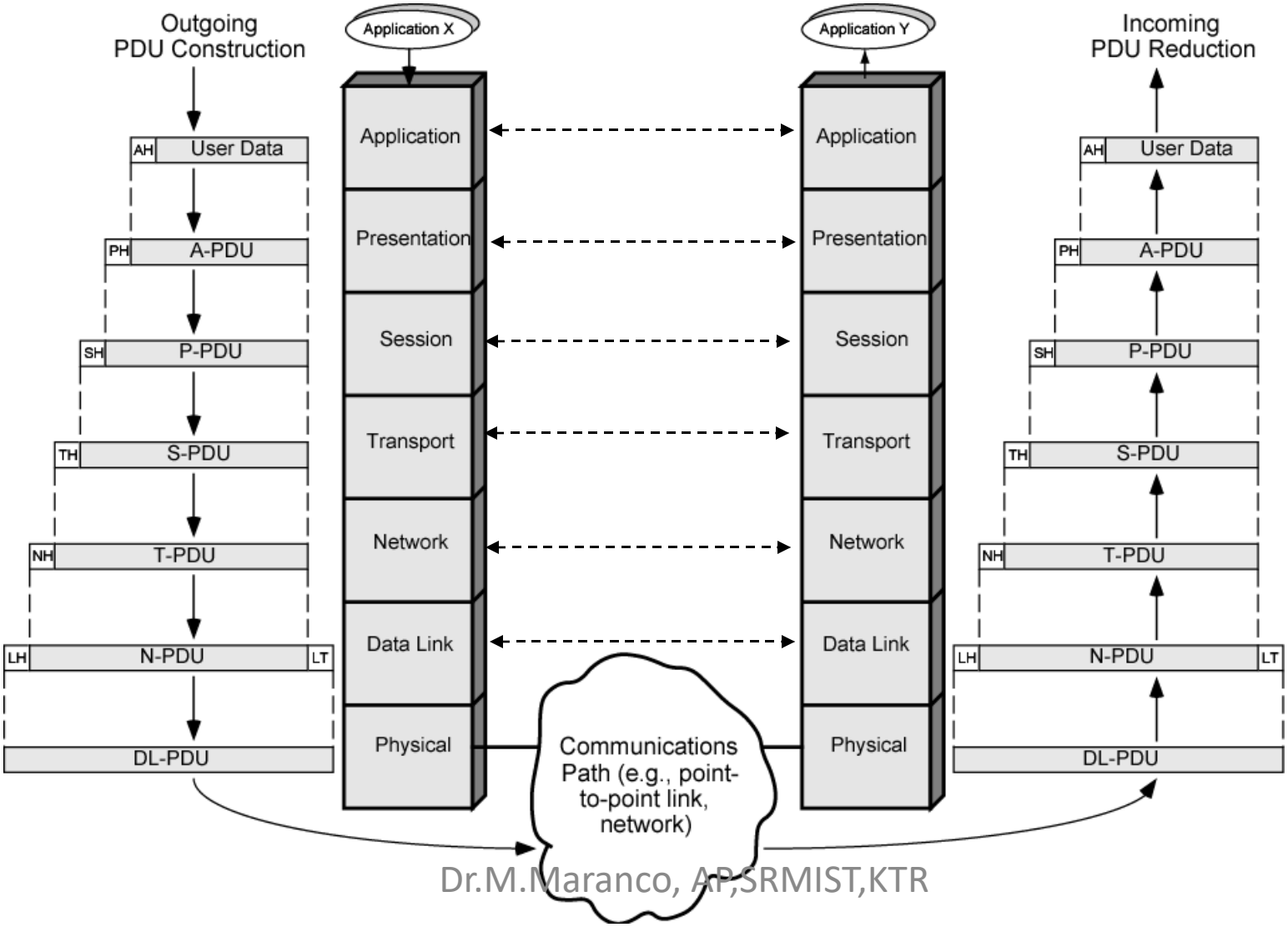
Layer Specific Standards



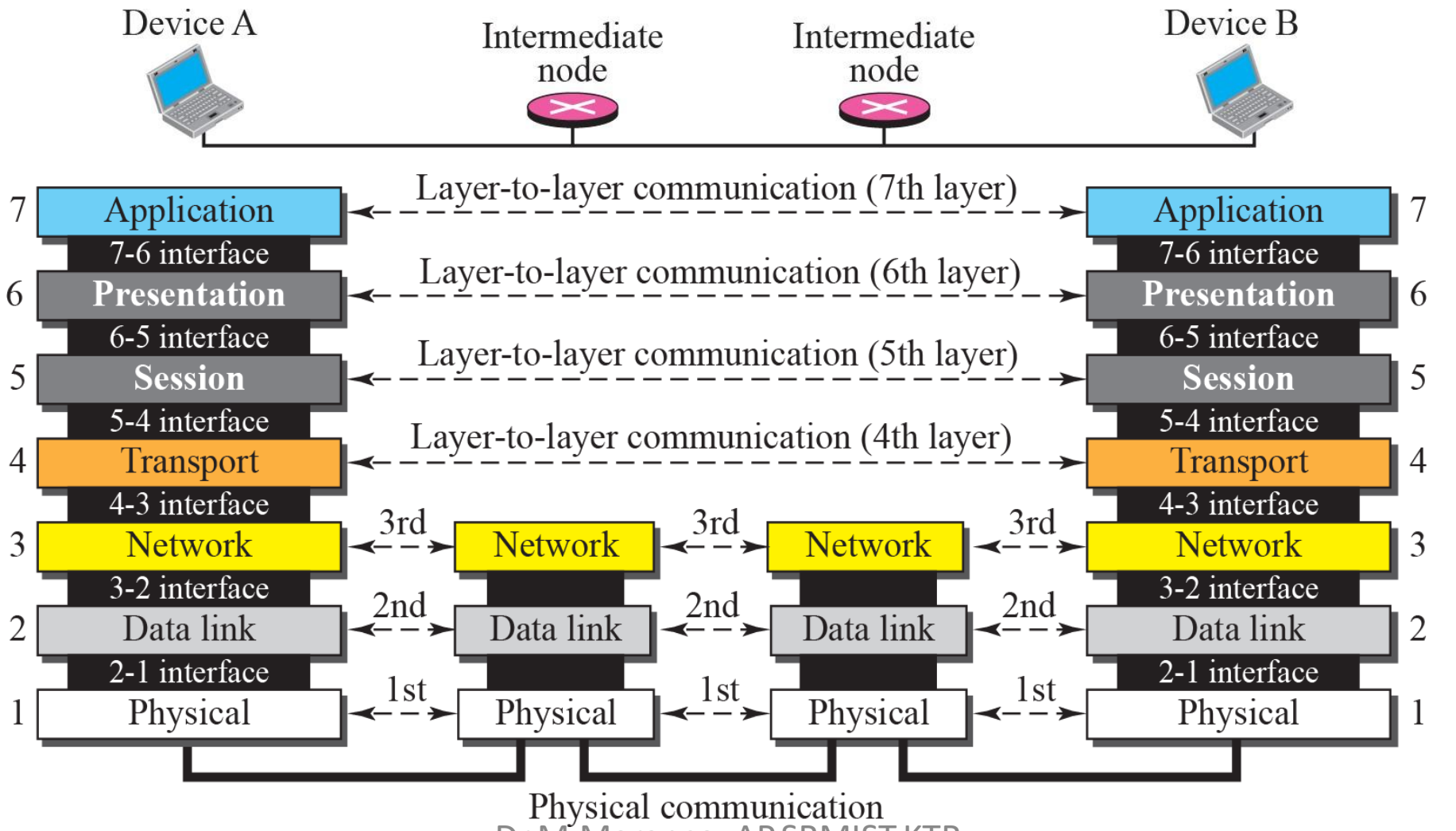
Elements of Standardization

- Protocol specification
  - Operates between the same layer on two systems
    - May involve different platforms
  - Protocol specification must be precise
    - Format of data units
    - Semantics of all fields
- Service definition
  - Functional description of what is provided to the next upper layer
- Addressing
  - Referenced by SAPs

The OSI Architecture



Layer to Layer Communication



Physical Layer

- Provides interface for transmission of information.
- There is no interpretation at this level, a stream of 1's and 0's are put into a form convenient for transmission.
  - Waves (with little regard for their information content) are sent and received.
- This level is the most hardware oriented. It includes specifications about
  - NIC card speeds
  - Types and lengths of cable
  - Voltage characteristics (range, level or edge)
- The physical layer involves protocols for actual transmission
  - Ethernet
  - FDDI
  - RS232
  - ATM
- These protocols also involve the interface with the next higher layer.

Data Link Layer (DLL)

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(Deemed to be University u/s 3 of UGC Act, 1956)

- At this layer one begins to consider bytes instead of just bits, one examines some of the information content of the signal (at least the address and some of the error detection sequencing)
- Recall that bridges operate at this level
  - They know where a packet is headed.
  - They know whether or not it has been involved in a collision.
  - Bit stuffing occurs at this level.
- Data packets are encoded and decoded into bits.
- It directs packets and handles errors from the physical layer.

Data Link Layer (DLL)

- It handles synchronization (timing).
  - It must know where one bit ends and the next one begins.
  - It must know where one byte ends and the next one begins
- The data link layer is divided into two sub-layers:
  - The **MAC** (Media Access Control) sub-layer: takes the signal from or puts the signal onto the transmission line ("touches" physical layer).
  - The **LLC** (Logical Link Control) sub-layer: starts to interpret the signal as data, includes timing (synchronization) and error checking.

Network Layer

- The router acted at this layer.
- One of the main functions of the layer is routing. Store and forward are network layer functions.
- In a connection-oriented scheme, the virtual circuit is established at the network layer.
- Building the routing tables, troubleshooting the routing tables when there is a lot of traffic or if a connection goes down.
- The network layer also gathers related packets (packet sequencing).

Transport Layer

- As stated before, Layer 4 is the dividing line between inter-computer transactions and intra-computer transactions.
- Layer 4 manages end-to-end verification.
  - The lower layers make a "best effort" but if data is lost so be it. Layer 4 must ensure that the information was received intact.
- It does a higher-order error-checking.
- The transfer should be "transparent." The higher layers do not know the data came from another computer.
- At a node Layer 3 collects associated packets if one was dropped it may throw them all away.
- It is the responsibility of the source's Layer 4 to look for some acknowledgement that all packets arrived. If no acknowledgment is received, it should retransmit

Session Layer

- Recall when discussing connection-oriented schemes, we mentioned the idea of a “session.”
- It is an agreement between a source and destination to communicate.
- This layer establishes, manages and terminates sessions between applications (they could be on the same computer or on different computers).

Presentation Layer

- This layer provides independence from differences in data representation (e.g., encryption) by translating from application to network format, and vice versa.
- The presentation layer works to transform data into the form that the application layer can accept.
- This layer formats and encrypts data to be sent across a network, providing freedom from compatibility problems. It is sometimes called the "syntax layer."

Application Layer

- This layer supports application and end-user processes.
- Communication partners are identified, quality of service is identified, user authentication and privacy are considered, and any constraints on data syntax are identified
- Everything at this layer is application-specific. This layer provides application services for file transfers, e-mail, and other network software services. Telnet and FTP are applications that exist entirely in the application level.
- These are **not applications** (like Word and Excel) but **services for** such **applications**

Mnemonic

- Please Do Not Throw Sausage Pizza Away
  - **P**lease → Physical
  - **D**o → Data Link
  - **N**ot → Network
  - **T**hrow → Transport
  - **S**ausage → Session
  - **P**izza → Presentation
  - **A**way → Application

TCP/IP Protocol Suite

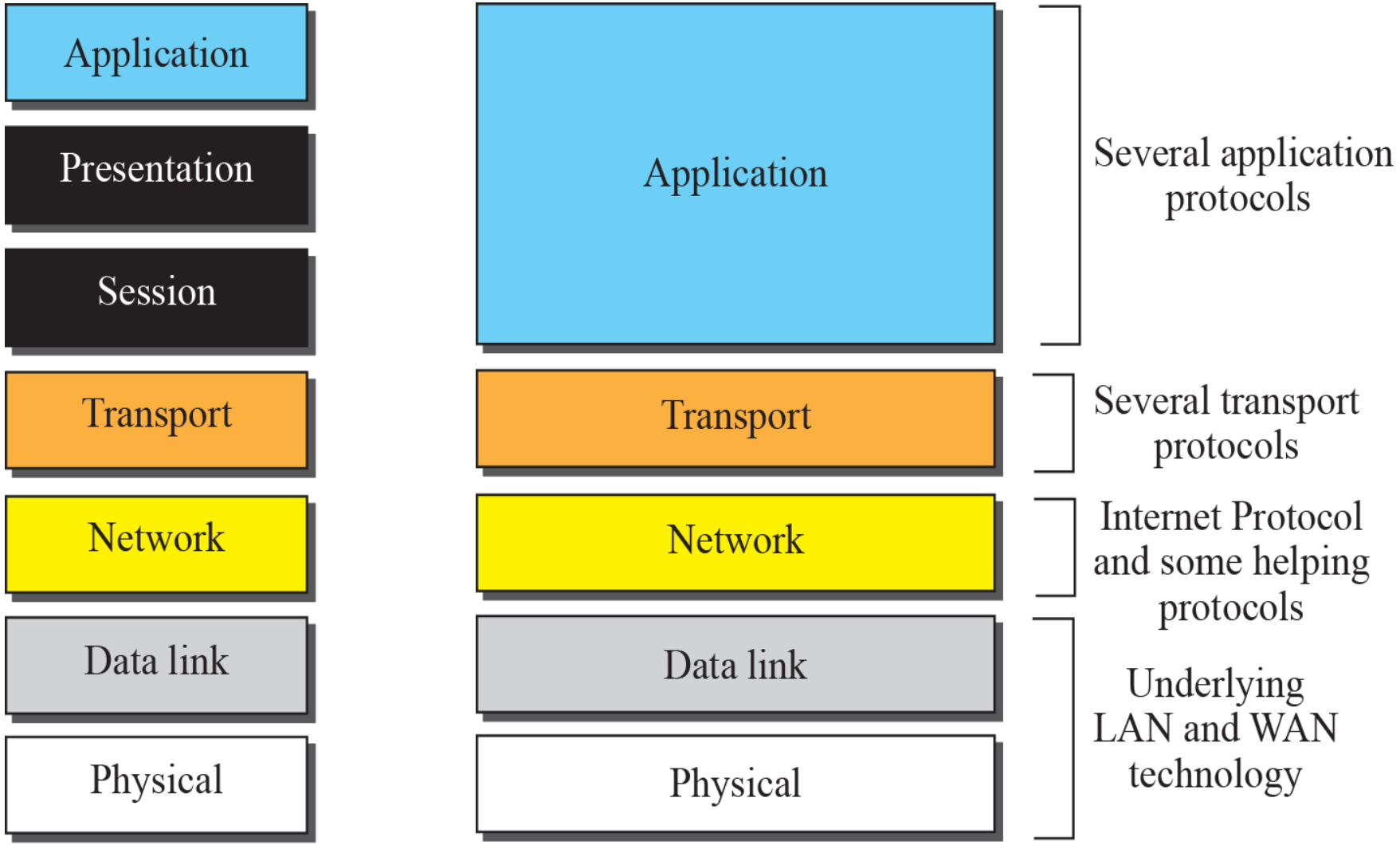
- Most widely used interoperable network protocol architecture
- Specified and extensively used before OSI
  - OSI was slow to take place in the market
- Funded by the US Defense Advanced Research Project Agency (DARPA) for its packet switched network (ARPANET)
  - DoD (Department of Defense) automatically created an enormous market for TCP/IP
- Used by the Internet and WWW
- The TCP/IP protocol suite was developed prior to the OSI model. Therefore, the layers in the TCP/IP protocol suite do not match exactly with those in the OSI model.
- The original TCP/IP protocol suite was defined as four software layers built upon the hardware.
- Today, however, TCP/IP is thought of as a five-layer model with the layers named similarly to the ones in the OSI model

TCP/IP Protocol Suite

- The Layers used in the TCP/IP protocol
  - Application layer
  - Transport (host to host / end to end) layer
  - Internet layer
  - Network access layer
  - Physical layer

- Actually TCP/IP reference model has been built on its protocols
  - That is why that reference model is only for TCP/IP protocol suite
  - and this is why it is not so important to assign roles to each layer in TCP/IP; understanding TCP, IP and the application protocols would be enough

OSI vs. TCP/IP


Application
Presentation
Session
Transport
Network
Data link
Physical
OSI Model
Application
Transport
Network
Data link
Physical
TCP/IP Protocol Suite
Several application protocols
Several transport protocols
Internet Protocol and some helping protocols
Underlying LAN and WAN technology

Network Access and Physical Layers

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- TCP/IP reference model does not discuss these layers too much
  - the node should connect to the network with a protocol such that it can send IP packets
  - this protocol is not defined by TCP/IP
  - mostly in hardware
  - a well known example is Ethernet

Internet Layer

- Connectionless, point to point internetworking protocol (uses the datagram approach)
  - takes care of routing across multiple networks
  - each packet travels in the network independently of each other
    - they may not arrive (if there is a problem in the network)
    - they may arrive out of order
  - a design decision enforced by DoD to make the system more flexible and responsive to loss of some subnet devices
- Implemented in end systems and routers as the Internet Protocol (IP)

Transport Layer

- End-to-end data transfer
- Transmission Control Protocol (TCP)
  - connection oriented
  - reliable delivery of data
  - ordering of delivery
- User Datagram Protocol (UDP)
  - connectionless service
  - delivery is not guaranteed
- Can you give example applications that use TCP and UDP?

Application Layer

- Support for user applications
- A separate module for each different application
  - e.g. HTTP, SMTP, telnet

Transmission Media

Transmission Media

→The physical path between transmitter and receiver is called transmission medium. It is a pathway that carries information from sender to receiver.

→In One type of transmission medium , transmission occurs through a solid medium, such as copper twisted pair, copper coaxial cable, and optical fiber

→For second type of transmission medium , transmission occurs wireless through the atmosphere, outer space, or water.

→It is located below the physical layer and are directly controlled by the physical layer.

→Data is transmitted normally in electrical or electromagnetic signals.

→Signals are transmitted in the form of electromagnetic energy.

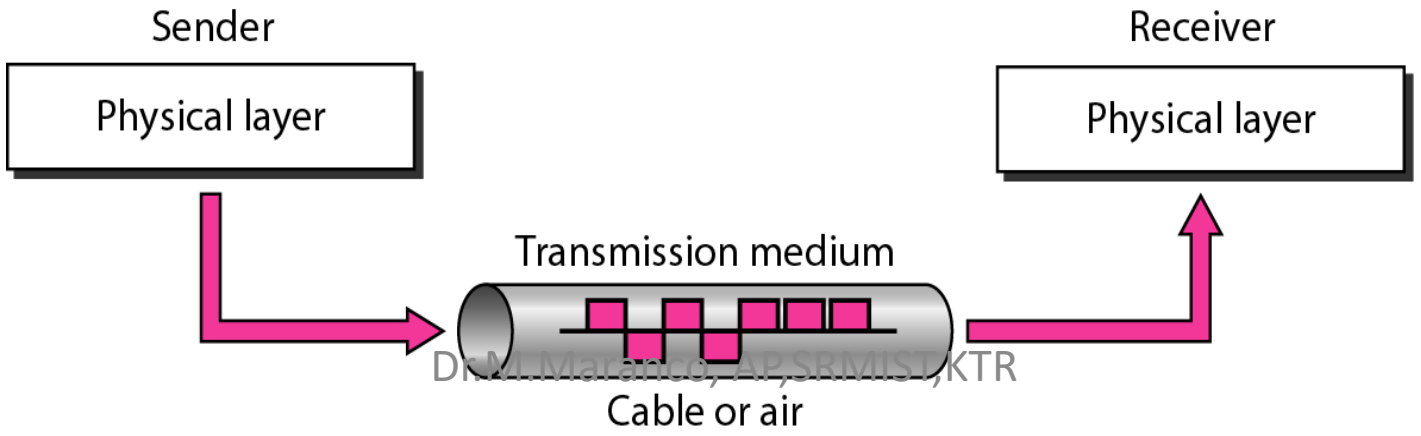

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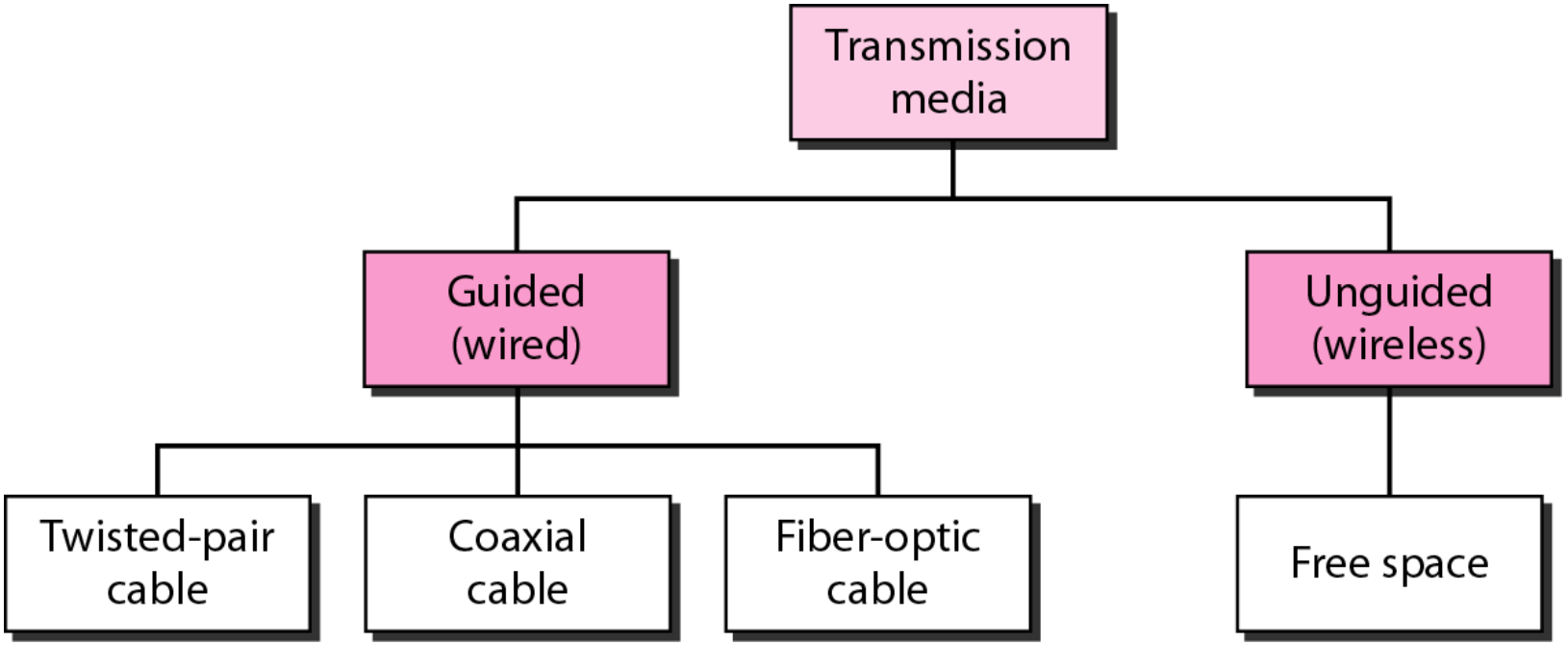
Figure 7.2 *Classes of transmission media*



GUIDED MEDIA

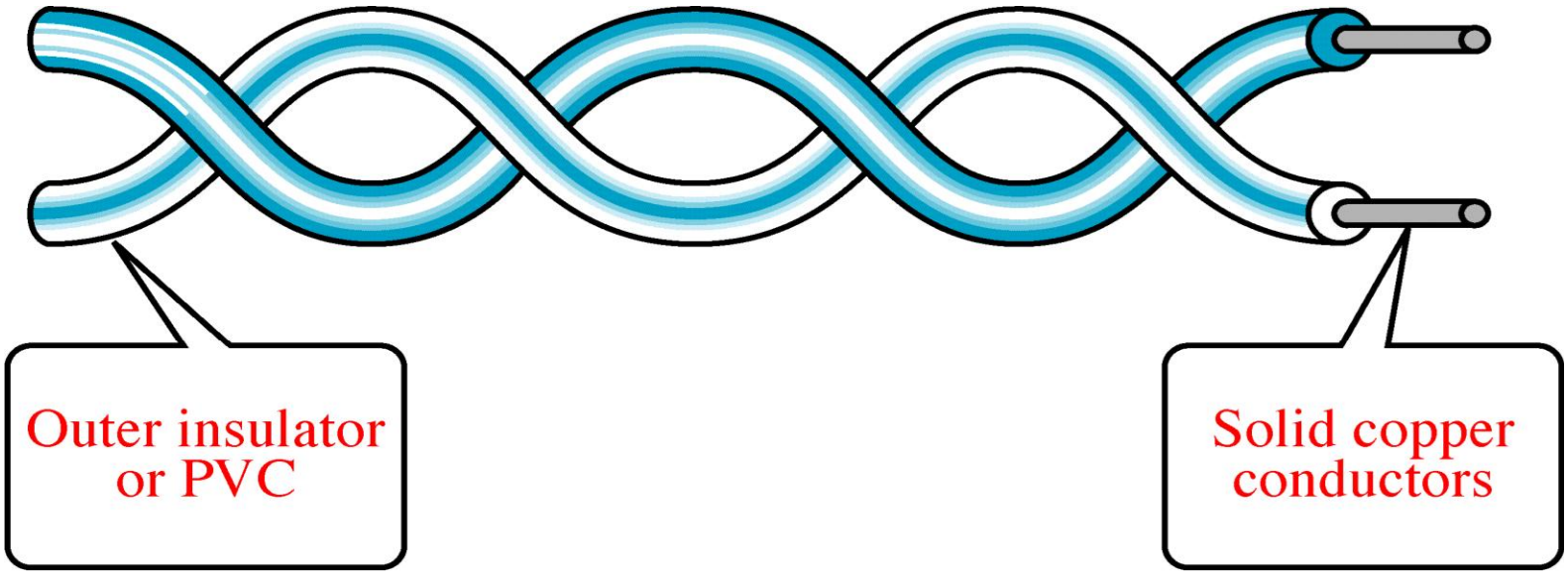
Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

Topics discussed in this section:

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

❖**Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current.**
❖**Optical fiber is a cable that accepts and transports signals in the form of light.**

Figure 7.3 *Twisted-pair cable*



Twisted-pair cable

A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together.

One of the wires is used to carry **signals** to the receiver, and the other is used only as a **ground reference.**

The receiver uses the difference between the two.

In addition to the signal sent by the sender on one of the wires, **interference (noise) and crosstalk** may affect both wires and create unwanted signals.

Twisted-pair cable

If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources (e,g., one is closer and the other is farther). This results in a difference at the receiver.

By twisting the pairs, a balance is maintained.

For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true.

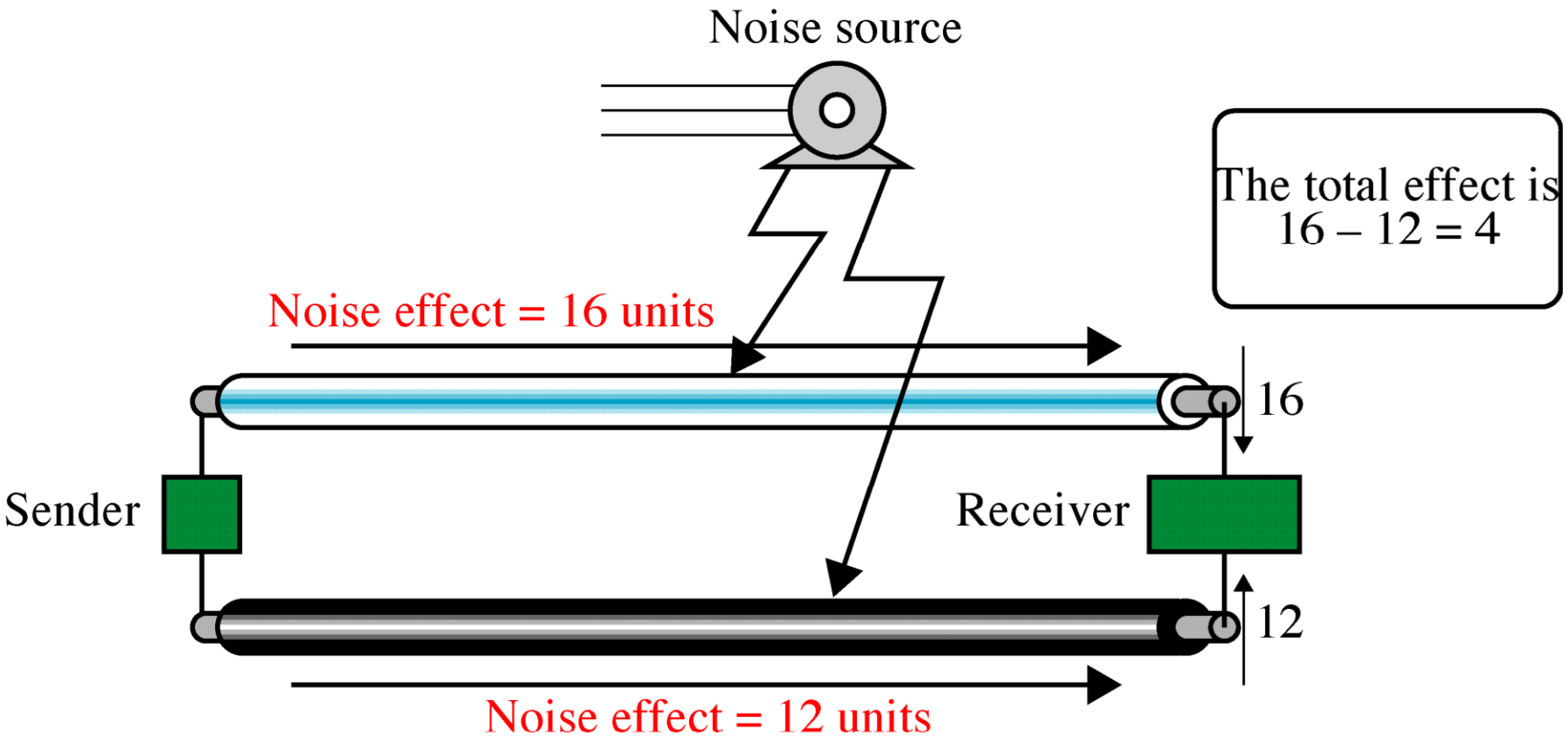
Twisted-pair cable

Twisting makes it probable that both wires are equally affected by external influences (noise or crosstalk).

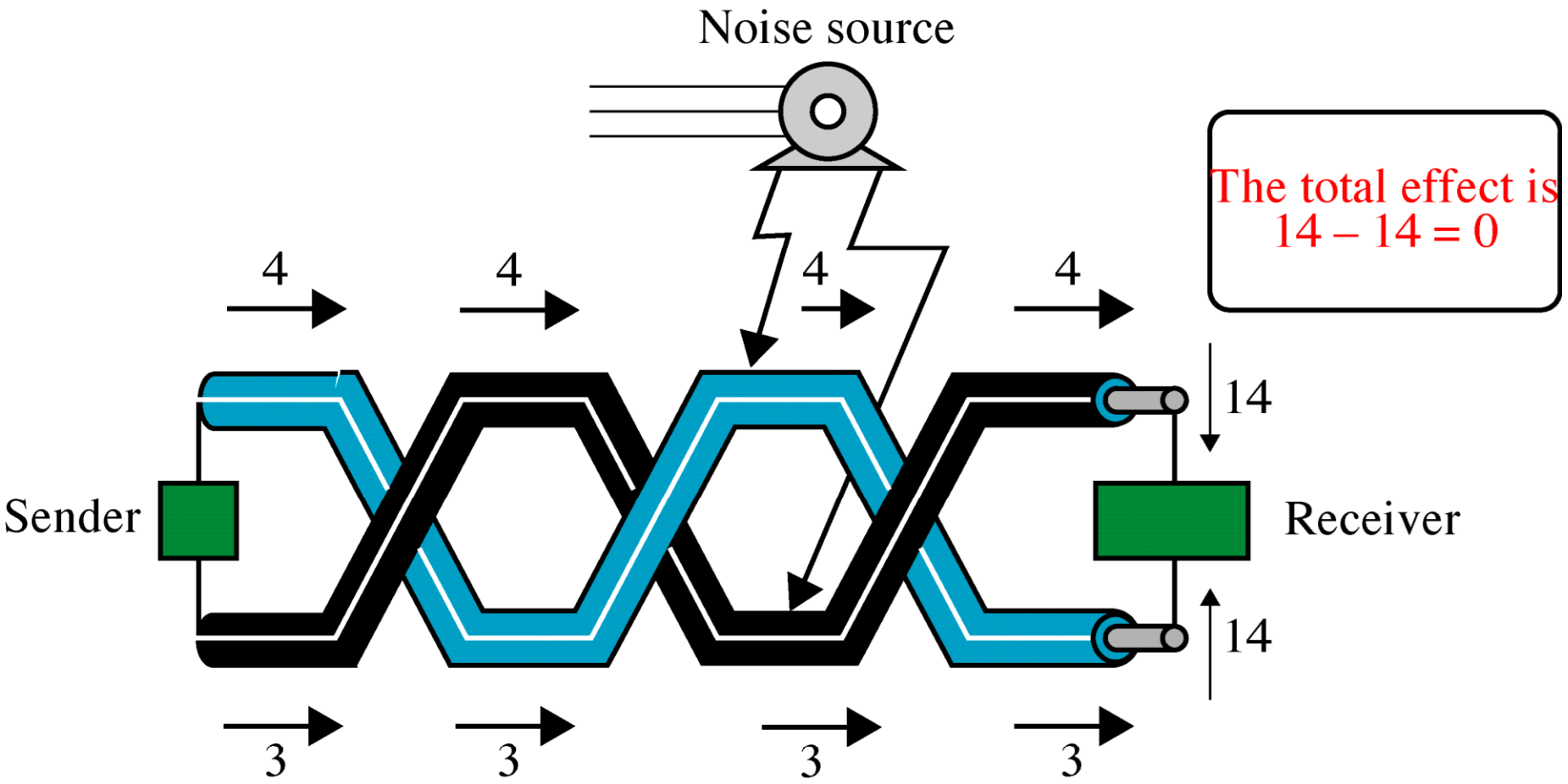
This means that the receiver, which calculates the difference between the two, receives no unwanted signals. The unwanted signals are mostly cancelled out.

From the above discussion, it is clear that the number of twists per unit of length (e.g., inch) has some effect on the quality of the cable.

Effect of Noise on Parallel Lines



Noise on Twisted-Pair Lines



Unshielded Twisted Pair (UTP)

- Ordinary telephone wire
- Cheapest
- Easiest to install
- Suffers from external EM interference

Advantages of UTP:

- Affordable
- Most compatible cabling
- Major networking system

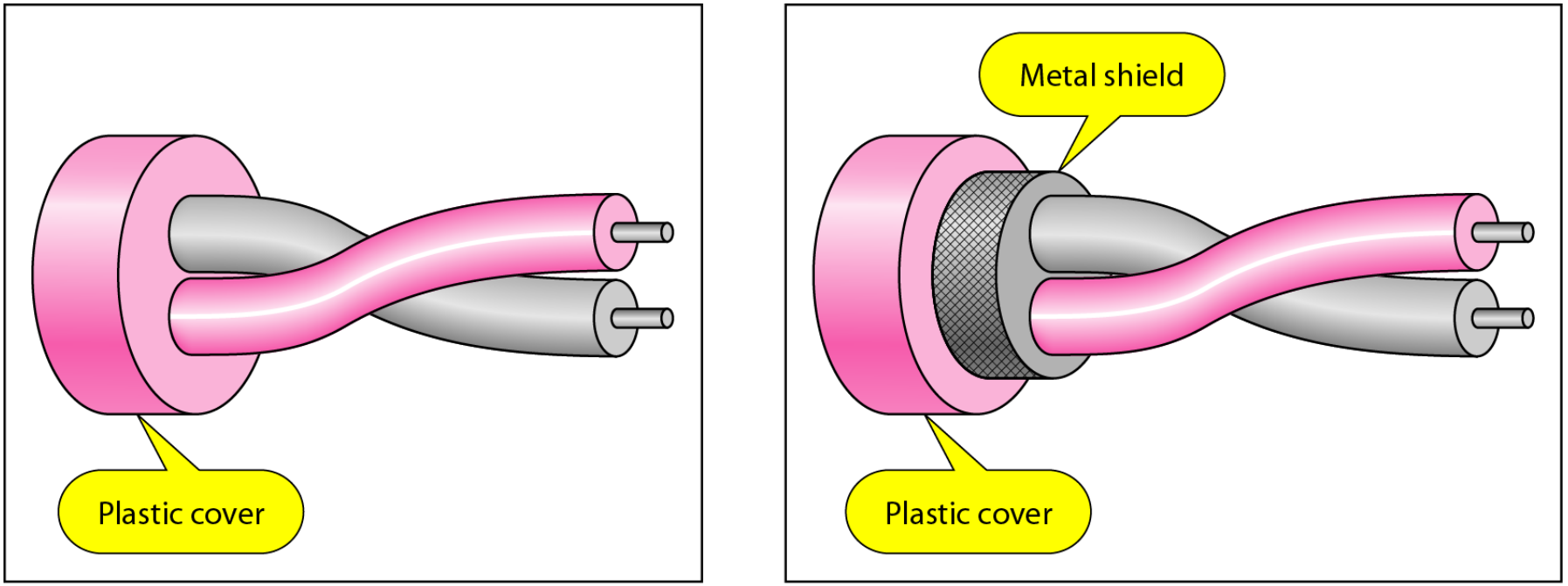
Disadvantages of UTP:

- Suffers from external Electromagnetic interference

Applications:

- Telephone lines connecting subscribers to the central office
- DSL lines
- LAN – 10Base-T and 100Base-T

Figure 7.4 *UTP and STP cables*



a. UTP

b. STP

Unshielded Versus Shielded Twisted-Pair Cable

The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP).

IBM has also produced a version of twisted-pair cable for its use called shielded twisted-pair (STP).

STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.

Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.

Table 7.1 *Categories of unshielded twisted-pair cables*

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

Applications

- Twisted-pair cables are used in telephone lines to provide voice and data channels.
- The local loop-the line that connects subscribers to the central telephone office---commonly consists of unshielded twisted-pair cables.
- The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.

Coaxial Cable

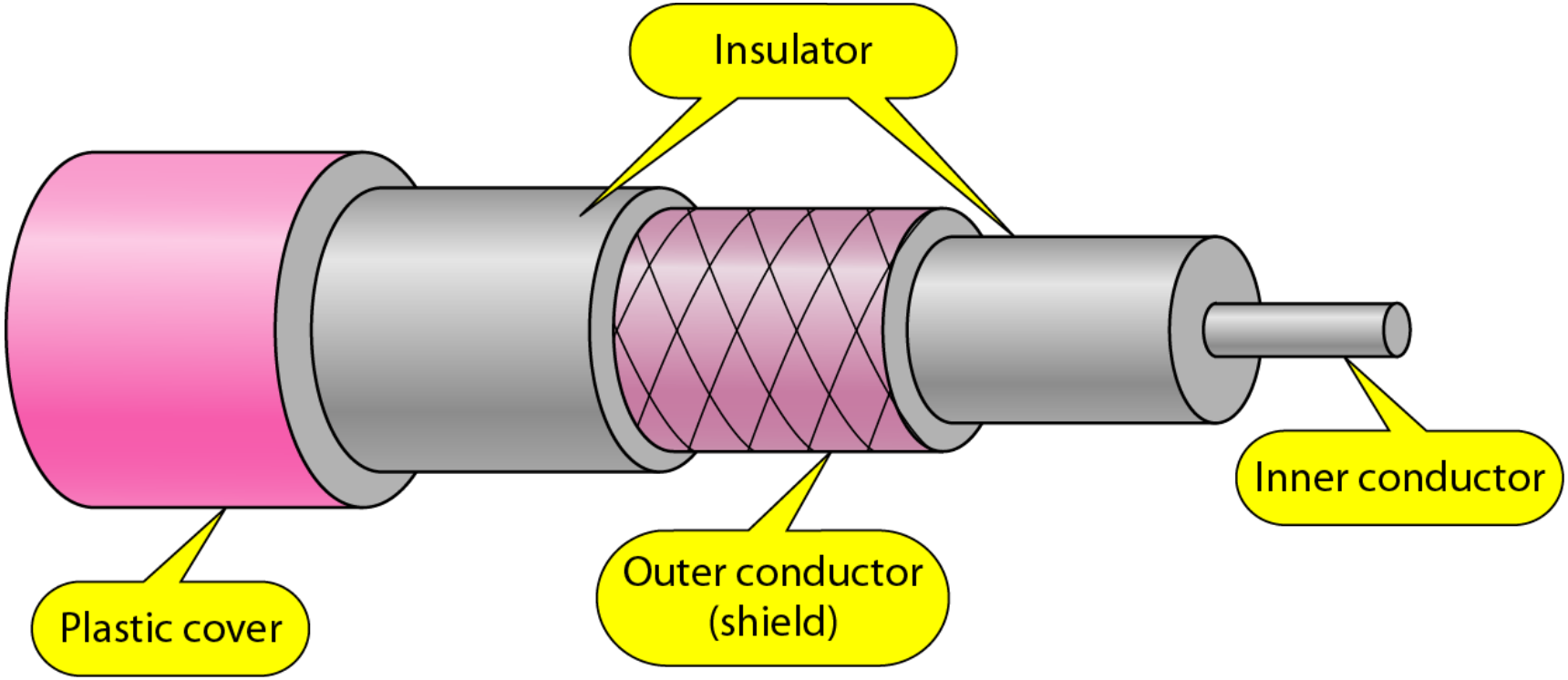
Coaxial cable (or *coax) carries signals of higher frequency ranges than those in twisted pair* cable, in part because the two media are constructed quite differently.

Instead of having two wires, coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two.

The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.

This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover

Figure 7.7 *Coaxial cable*



Coaxial Cable Standards

Coaxial cables are categorized by their **radio government (RG) ratings.**

Each RG number denotes a unique set of physical specifications, including the *wire gauge of the inner conductor, the thickness and type of the inner insulator, the construction of the shield, and the size and type of the outer casing*.

Each cable defined by an RG rating is adapted for a specialized function, as shown in following Table

Table 7.2 ***Categories of coaxial cables***

Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

Coaxial Cable Connectors

To connect coaxial cable to devices, we need coaxial connectors.

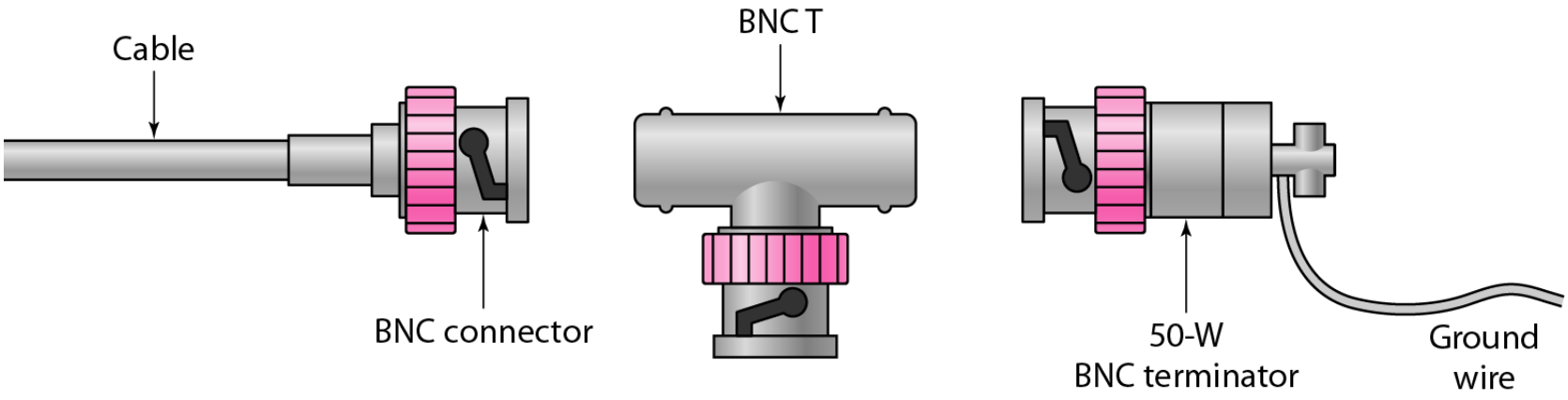
The most common type of connector used today is the Bayone-Neill-Concelman (BNC) connector.

The BNC connector is used to connect the end of the cable to a device, such as a TV set.

The BNC T connector is used in Ethernet networks to branch out to a connection to a computer or other device.

The BNC terminator is used at the end of the cable to prevent the reflection of the signal.

Figure 7.8 *BNC connectors*



Applications

Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.

Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps.

However, coaxial cable in telephone networks has largely been replaced today with fiber-optic cable.

Cable TV networks also use coaxial cables. In the traditional cable TV network, the entire network used coaxial cable.

Later, however, cable TV providers replaced most of the media with fiber-optic cable;

Hybrid networks use coaxial cable only at the network boundaries, near the consumer premises.

Cable TV uses RG-59 coaxial cable.

Fiber-Optic Cable

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.

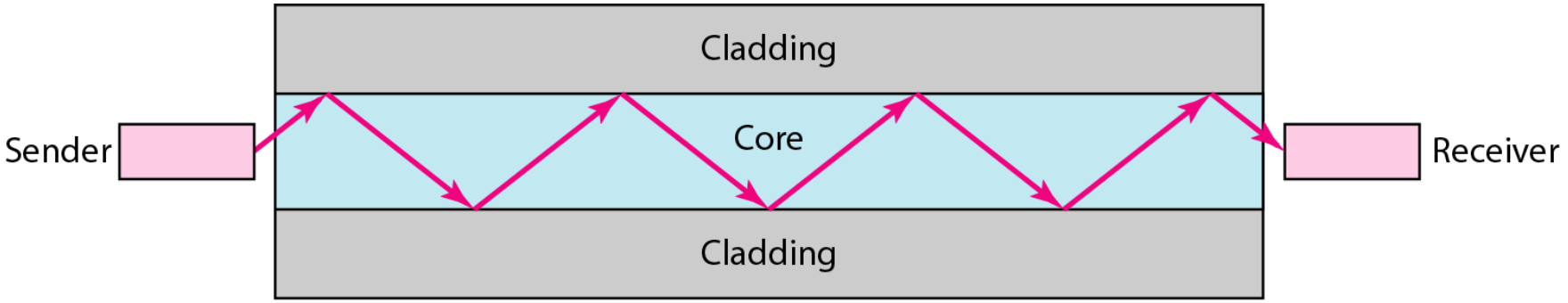
To understand optical fiber, we first need to explore several aspects of the nature of light.

Light travels in a straight line as long as it is moving through a single uniform substance.

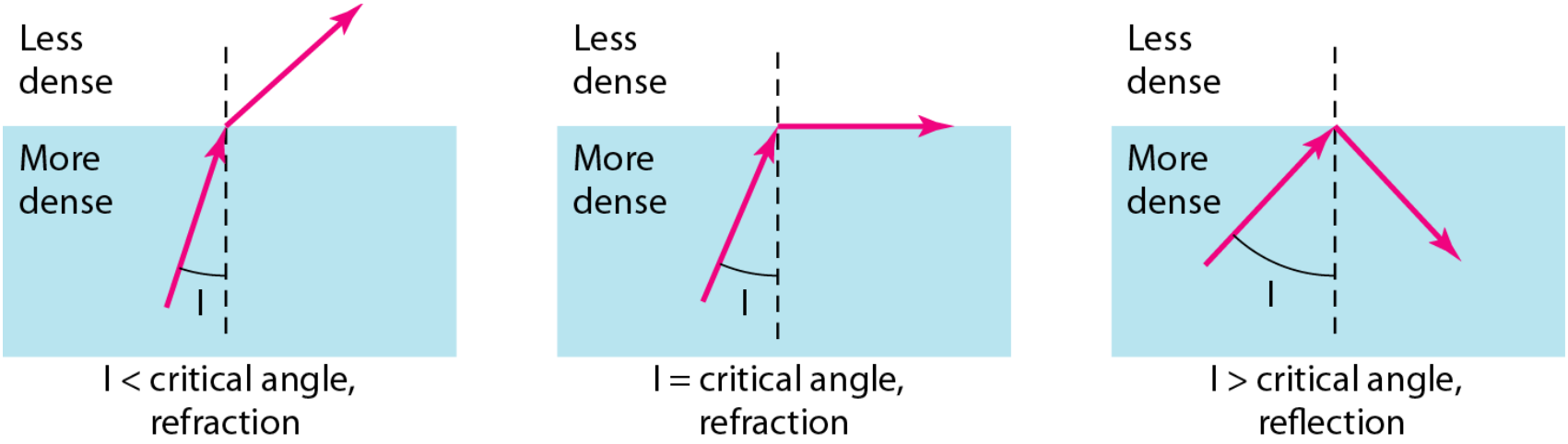
If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.

The following figure shows how a ray of light changes direction when going from a more dense to a less dense substance.

Optical fiber



Fiber optics: *Bending of light ray*



Fiber-Optic Cable

If the angle of incidence I (the angle the ray makes with the line perpendicular to the interface between the two substances) is less than the critical angle, the ray refracts and moves closer to the surface.

If the angle of incidence is equal to the critical angle, the light bends along the interface.

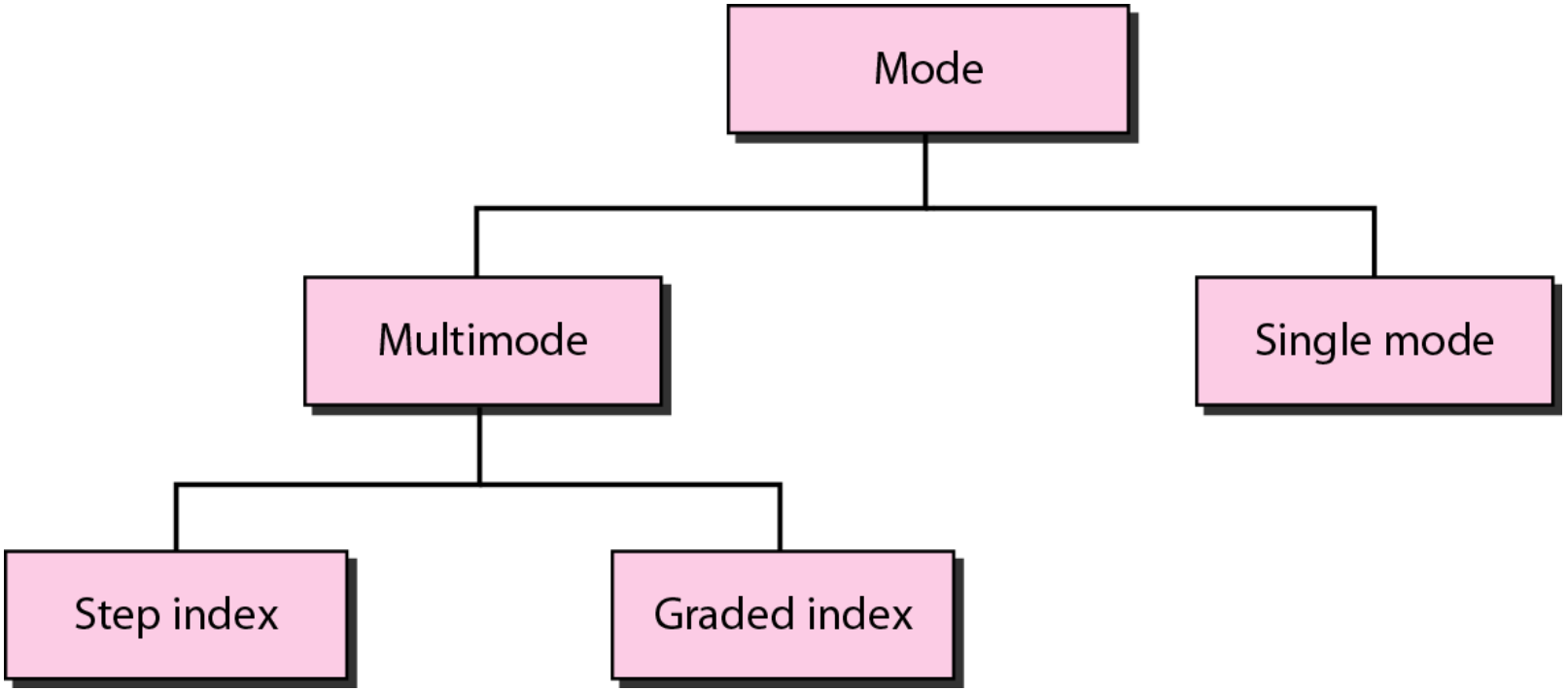
If the angle is greater than the critical angle, the ray reflects (makes a turn) and travels again in the denser substance.

Note that the critical angle is a property of the substance, and its value differs from one substance to another.

Optical fibers use reflection to guide light through a channel.

A glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it.

Figure 7.12 *Propagation modes*



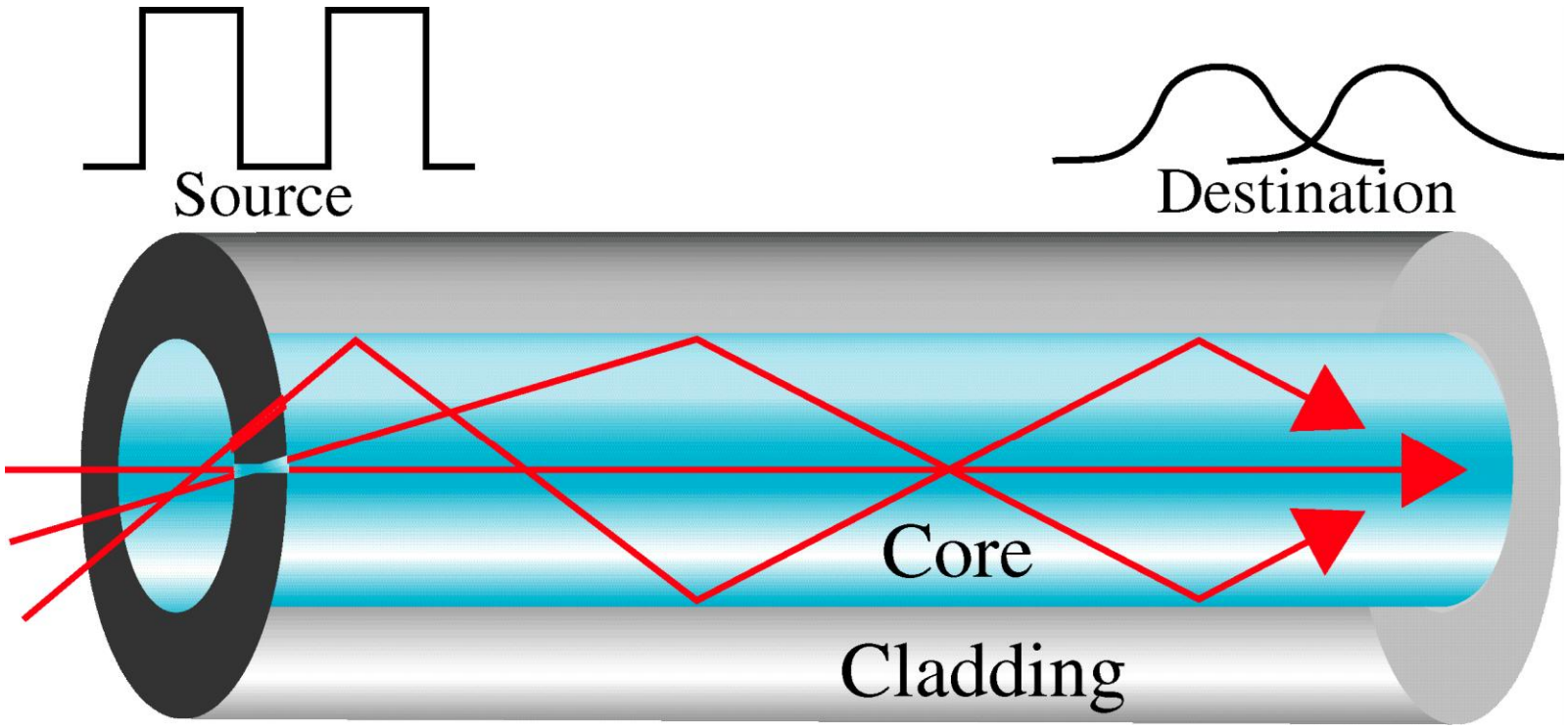
Multimode – Step index

Multimode is so named because multiple beams from a light source move through the core in different paths. How these beams move within the cable depends on the structure of the core, as shown in Figure 7.13.

In multimode step-index fiber, the density of the core remains constant from the center to the edges. A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding. At the interface, there is an abrupt change due to a lower density; this alters the angle of the beam's motion.

The term step index refers to the suddenness of this change, which contributes to the distortion of the signal as it passes through the fiber

Multimode Step-Index

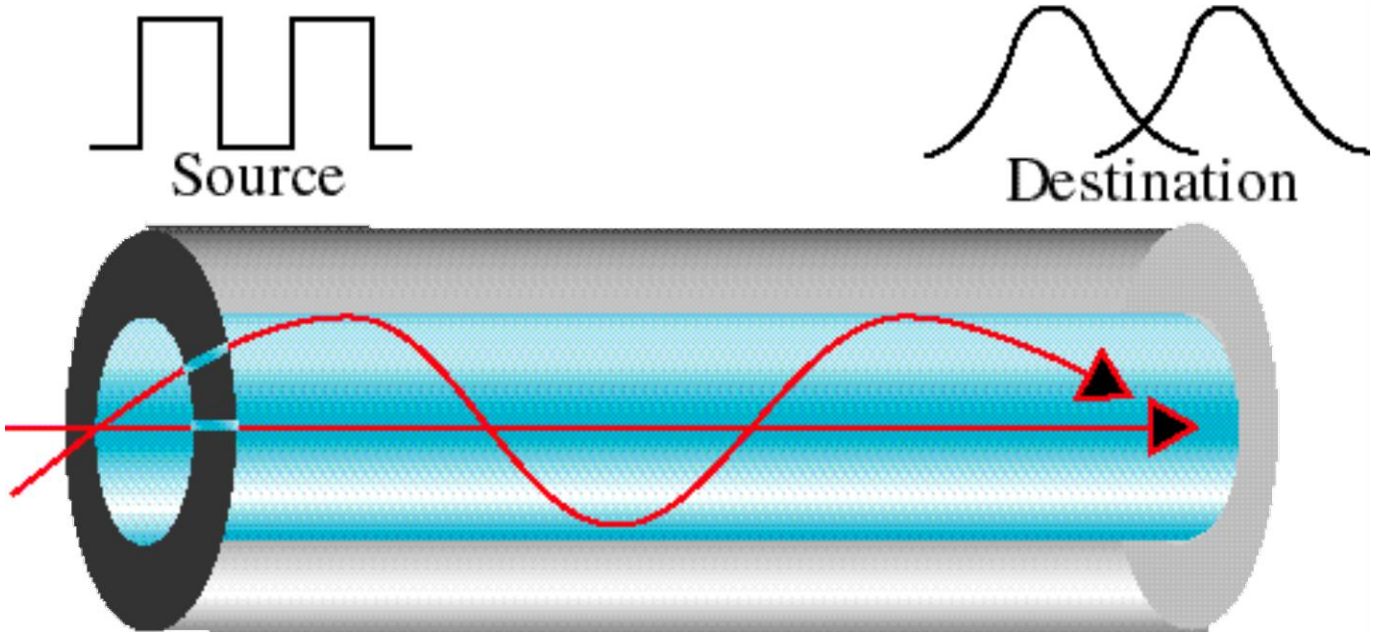


Multimode – Graded Index

A second type of fiber, called **multimode graded-index fiber,** decreases this distortion of the signal through the cable. The word index here refers to the index of refraction.

As we saw above, the index of refraction is related to density. A graded-index fiber, therefore, is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge.

Multimode Graded-Index



Single-Mode

Single-mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal.

The single mode fiber itself is manufactured with a much smaller diameter than that of multimode fiber, and with substantially lower density (index of refraction).

The decrease in density results in a critical angle that is close enough to 90° to make the propagation of beams almost horizontal.

In this case, propagation of different beams is almost identical, and delays are negligible. All the beams arrive at the **destination "together" and can be recombined with little distortion to the signal**

Single Mode

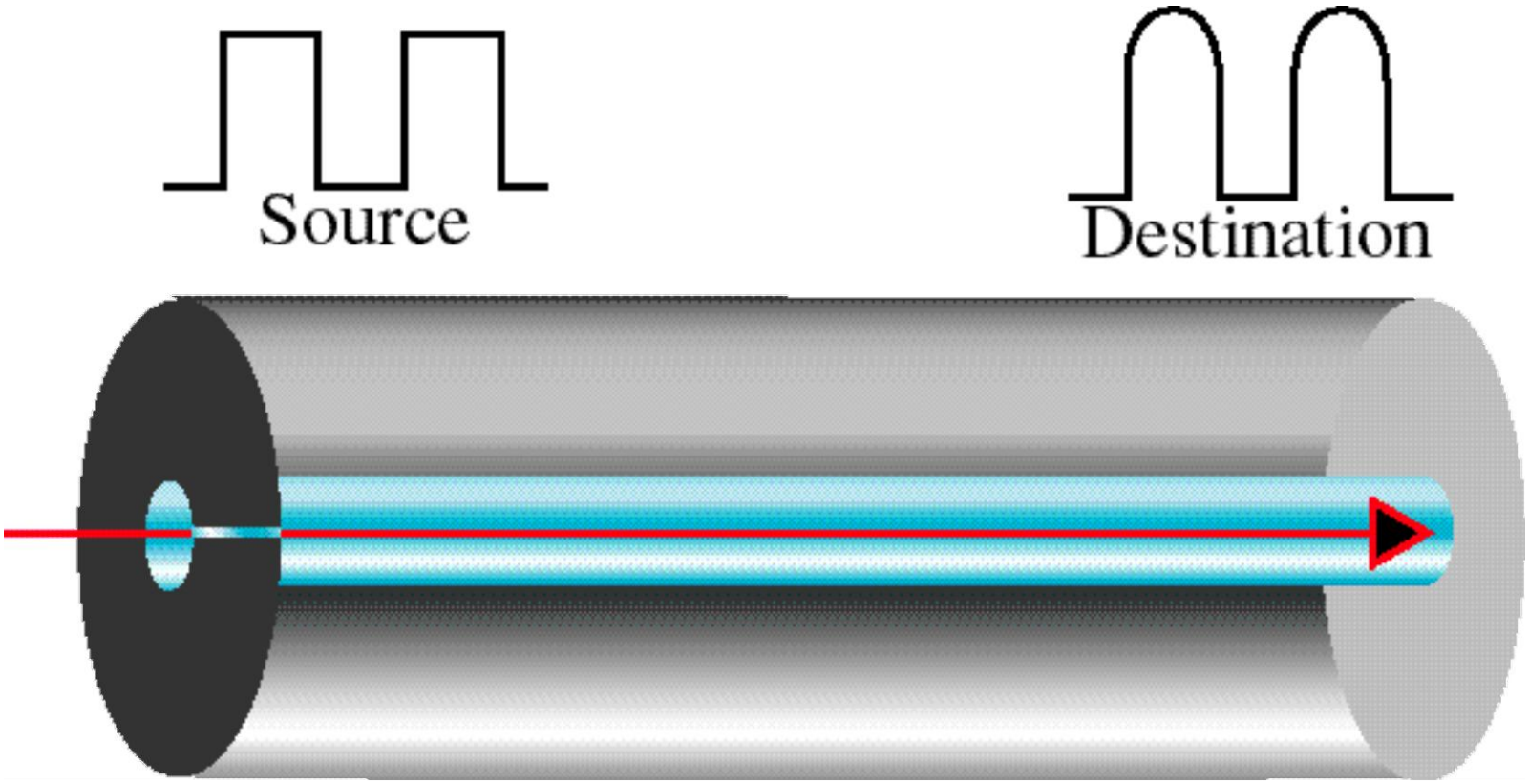


Table 7.3 *Fiber types*

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

Cable Composition

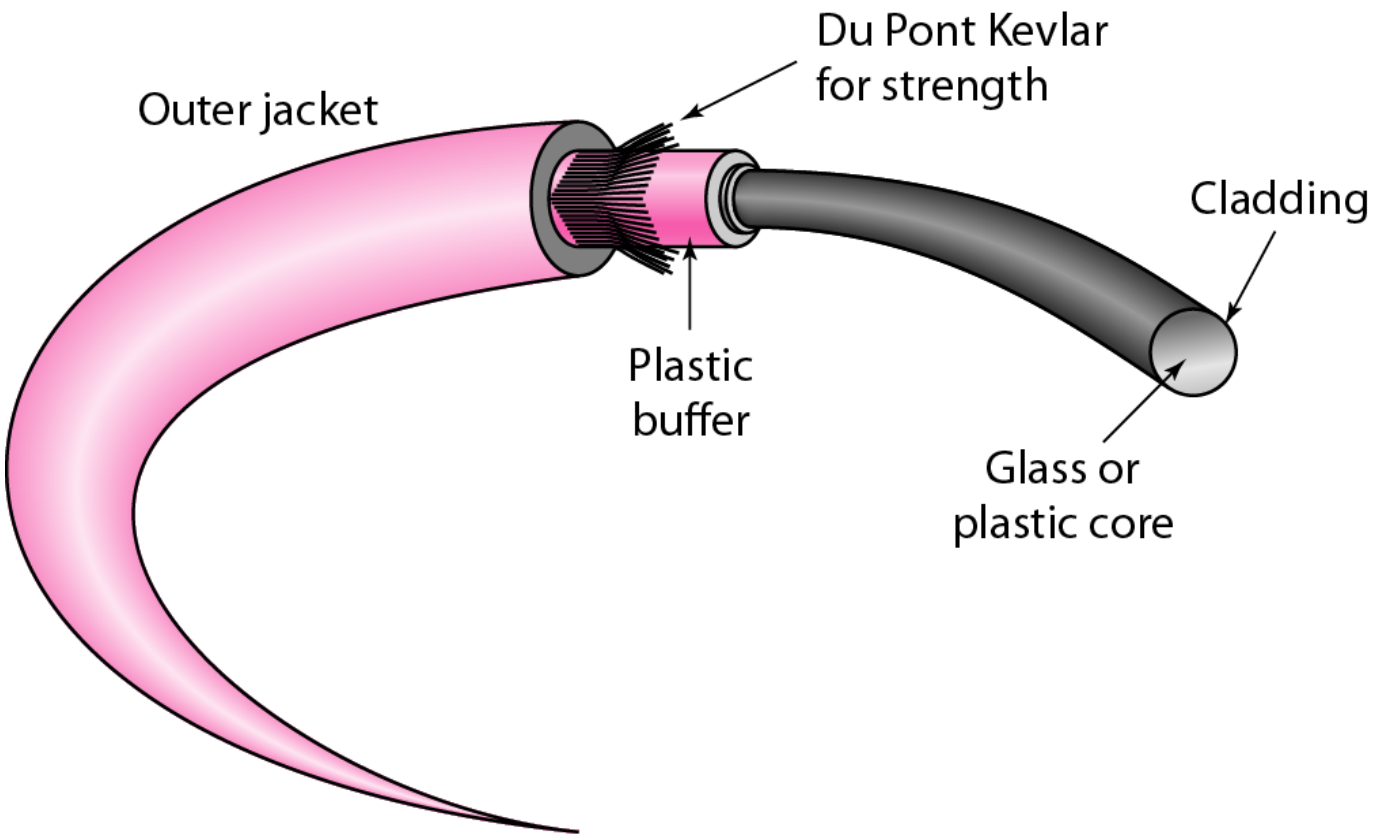
Figure 7.14 shows the composition of a typical fiber-optic cable.

The outer jacket is made of either **PVC or Teflon**. Inside the jacket are Kevlar strands to strengthen the cable.

Kevlar is a strong material used in the fabrication of bulletproof vests.

Below the Kevlar is another plastic coating to cushion the fiber. The fiber is at the center of the cable, and it consists of cladding and core.

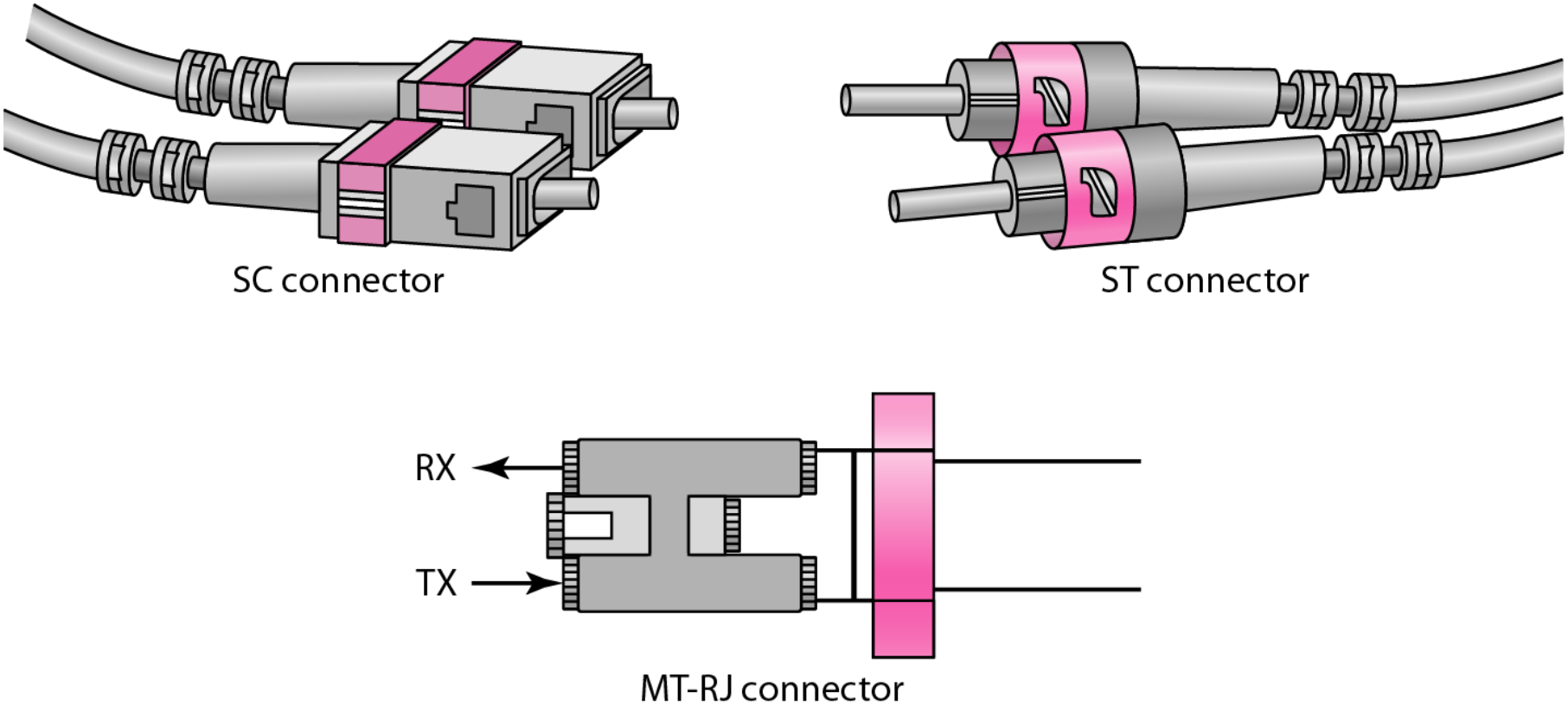
Figure 7.14 *Fiber construction*



Fiber-optic cable connectors

- The **subscriber channel (SC) connector** is used for cable TV. It uses a push/pull locking system.
- The **straight-tip (ST) connector** is used for connecting cable to networking devices.
- It uses a bayonet locking system and is more reliable than SC.
- MT-RJ is a connector that is the same size as RJ45.

Figure 7.15 *Fiber-optic cable connectors*



Applications

Fiber-optic cable is often found in **backbone networks** because its wide bandwidth is cost-effective.

Some **cable TV companies** use a combination of optical fiber and coaxial cable, thus creating a hybrid network.

Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises. This is a cost-effective configuration since the narrow bandwidth requirement at the user end does not justify the use of optical fiber.

Local-area networks such as **100Base-FX network (Fast Ethernet) and 1000Base-X** also use fiber-optic cable.

Advantages of Optical Fiber

Higher bandwidth. Fiber-optic cable can support dramatically higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable. Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available.

Less signal attenuation. Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.

Advantages of Optical Fiber

Immunityto electromagnetic interference. Electromagnetic noise cannot affect fiber-optic cables.

Resistance to corrosive materials. Glass is more resistant to corrosive materials than copper.

Light weight. Fiber-optic cables are much lighter than copper cables.

Greater immunity to tapping. Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped.

Disadvantages

Installation and maintenance. Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.

Unidirectional light propagation. Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.

Cost. The cable and the interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified.

7-2 UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

Topics discussed in this section:

Radio Waves
Microwaves
Infrared

Figure 7.17 *Electromagnetic spectrum for wireless communication*

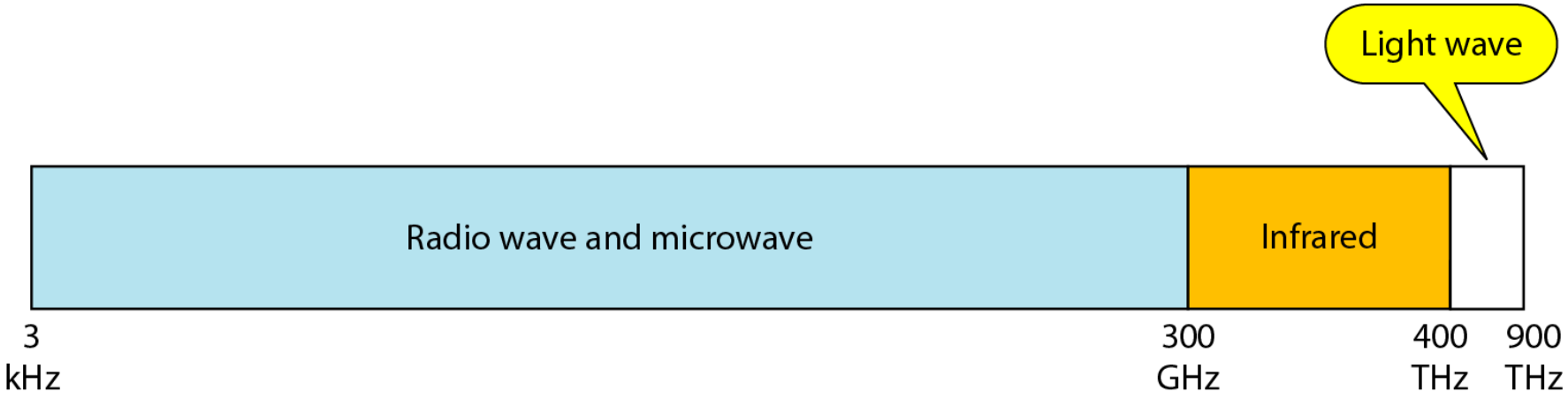
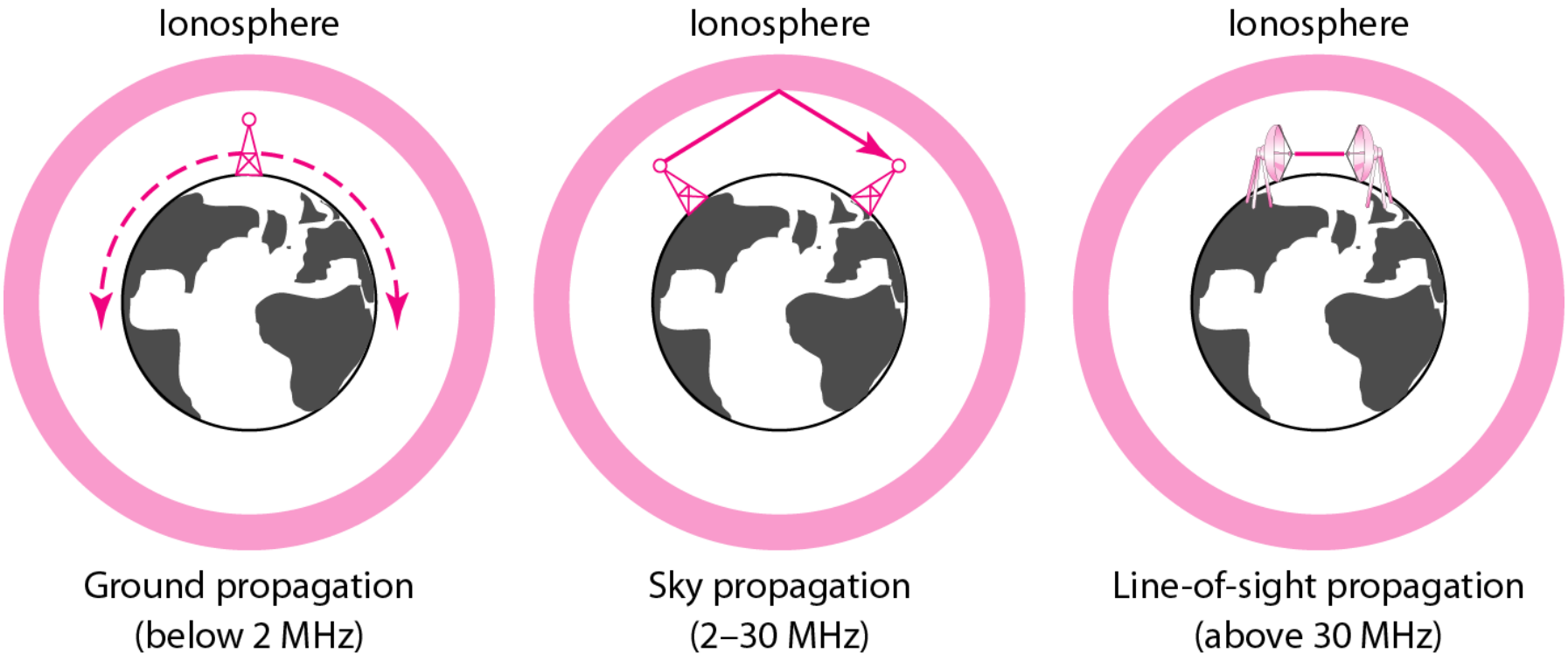


Figure 7.18 *Propagation methods*



Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation

In ground propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet. Distance depends on the amount of power in the signal: The greater the power, the greater the distance.

In sky propagation, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth. This type of transmission allows for greater distances with lower output power.

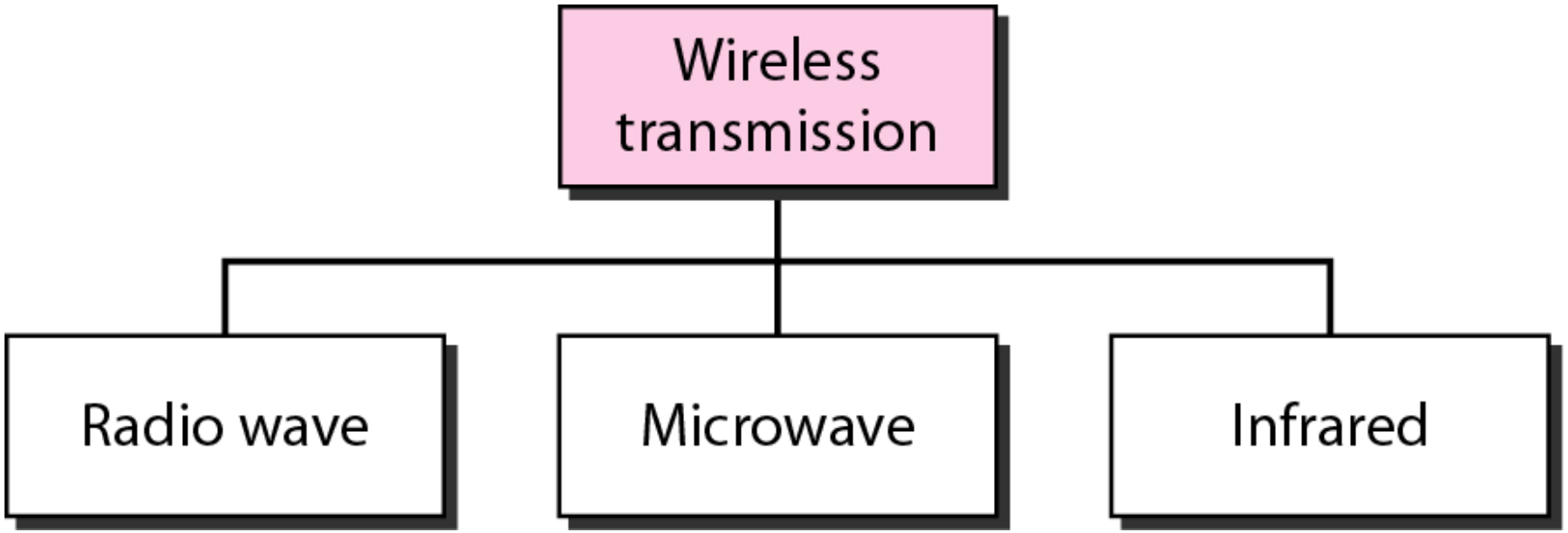
In line-or-sight propagation, very high-frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other, and either tall enough or close enough together not to be affected by the curvature of the earth. Line-of-sight propagation is tricky because radio transmissions cannot be completely focused.

- The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called BANDS, each regulated by government authorities.
- These bands are rated from very low frequency (VLF) to extremely highfrequency (EHF).

Table 7.4 *Bands*

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

Figure 7.19 *Wireless transmission waves*



Radio Vs Micro Waves

Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves;

Waves ranging in frequencies between 1 and 300 GHz are called microwaves.

However, the behavior of the waves, rather than the frequencies, is a better criterion for classification.

Note

Radio waves are used for multicast communications, such as radio and television, and paging systems. They can penetrate through walls. Highly regulated. Use omni directional antennas

RADIO WAVES

Radio waves, for the most part, are **omnidirectional.**

When an antenna transmits radio waves, they are propagated in all directions.

This means that the sending and receiving antennas do not have to be aligned.

A sending antenna sends waves that can be received by any receiving antenna.

Disadvantage:

The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.

Radio waves, particularly those waves that propagate in the sky mode, can travel long distances.

Radio waves, particularly those of low and medium frequencies, can penetrate walls.

This characteristic can be both an advantage and a disadvantage.

Advantage: An AM radio can receive signals inside a building.

Disadvantage : We cannot isolate a communication to just inside or outside a building.

The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band.

When this band is divided into subbands, the subbands are also narrow, leading to a low data rate for digital communications.

Almost the entire band is regulated by authorities (e.g., the FCC in the United States). Using any part of the band requires permission from the authorities.

Applications

The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers.

AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

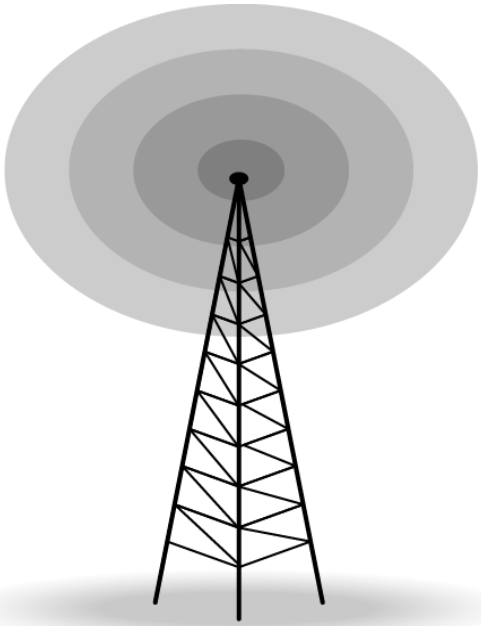


Figure 7.20 *Omnidirectional ante*

Dr.M.Mahanandhi,AP,SRMIST,KTR

MICROWAVES

- Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.
- Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.
- The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas.

CHARACTERISTICS OF MICROWAVE PROPAGATION:

- Microwave propagation is line-of-sight. Since the towers with the mounted antennas need to be in direct sight of each other, towers that are far apart need to be very tall. The curvature of the earth as well as other blocking obstacles do not allow two short towers to communicate by using microwaves. Repeaters are often needed for longdistance communication.
- Very high-frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside buildings.
- The microwave band is relatively wide, almost 299 GHz. Therefore wider subbands can be assigned, and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

Note

Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Higher frequency ranges cannot penetrate walls.

Use unidirectional antennas - point to point line of sight communications.

Unidirectional Antenna

Microwaves need unidirectional antennas that send out signals in one direction.

Two types of antennas are used for microwave communications**: the parabolic dish and the horn.**

A parabolic dish antenna is based on the geometry of a parabola: Every line parallel to the line of symmetry (line of sight) reflects off the curve at angles such that all the lines intersect in a common point called the focus. The parabolic dish works as funnel, catching a wide range of waves and directing them to a common point.

In this way, more of the signal is recovered than would be possible with a single-point receiver.

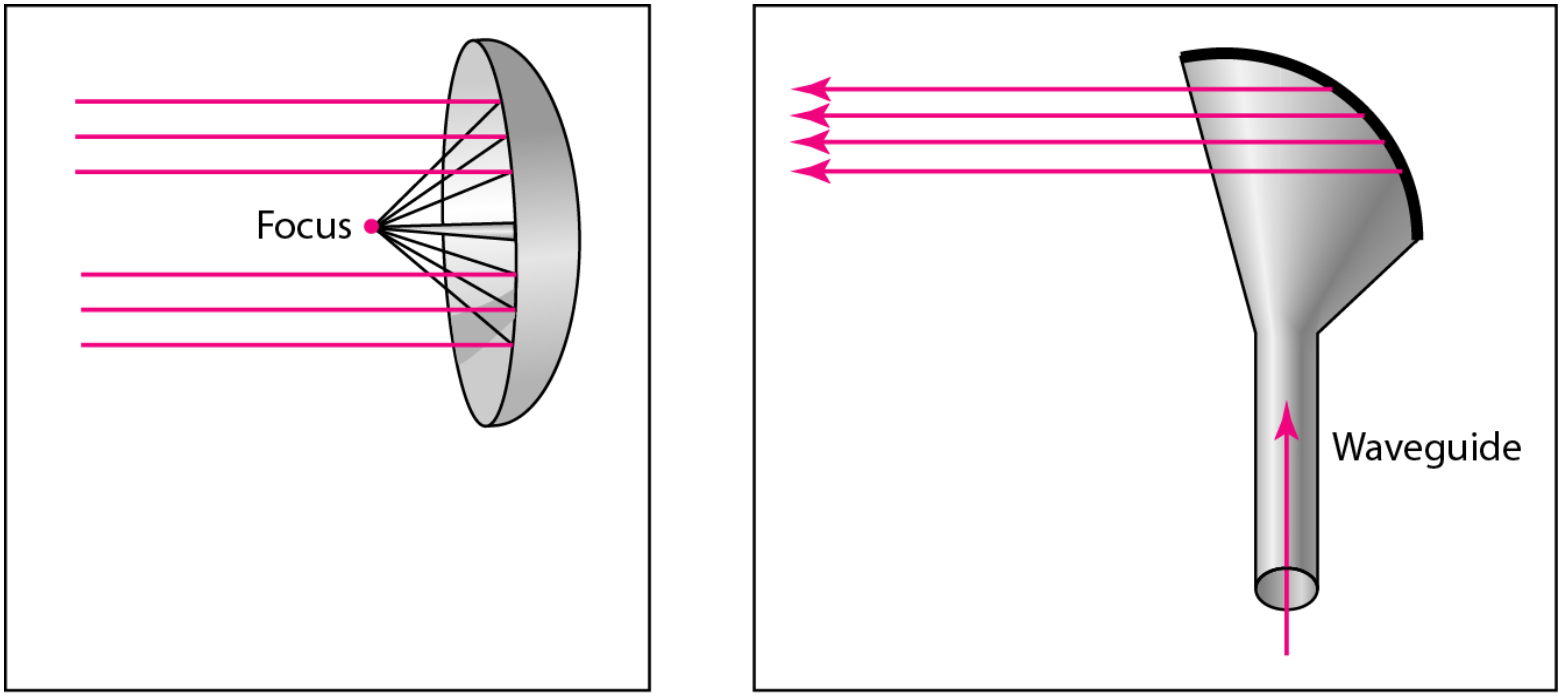
Horn antenna

A horn antenna looks like a gigantic scoop.

Outgoing transmissions are broadcast up a stem (resembling a handle) and deflected outward in a series of narrow parallel beams by the curved head.

Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and are deflected down into the stem.

Figure 7.21 *Unidirectional antennas*



a. Dish antenna

b. Horn antenna

Applications

Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed between the sender and the receiver.

They are used in cellular phones, satellite networks and wireless LANs.

Wireless Channels

Are subject to a lot more errors than guided media channels.
Interference is one cause for errors, can be circumvented with high SNR.
The higher the SNR the less capacity is available for transmission due to the broadcast nature of the channel.
Channel also subject to fading and no coverage holes.

Unit – I End