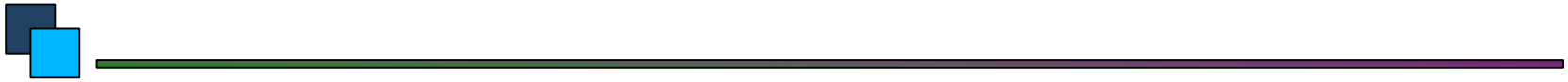
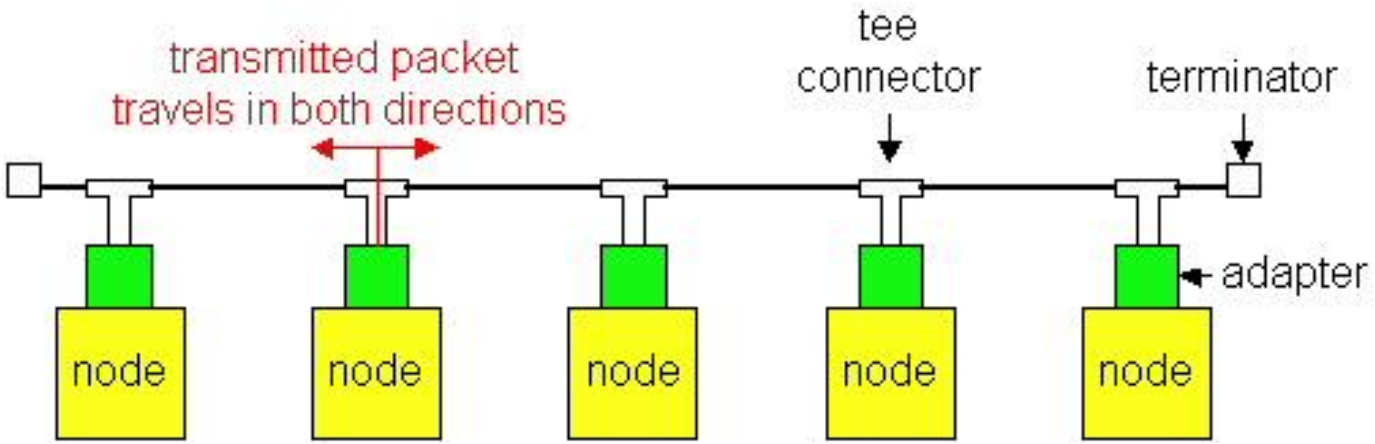


UNIT 4

Network Architecture

Media Access

- **Ethernet and Wi-Fi are both "multi-access" technologies**
  - Broadcast medium, shared by many hosts
  - Simultaneous transmissions will result in collisions
- **Media Access Control (MAC) protocol required**
  - Rules on how to share medium
- **The Data Link Layer is divided into two Part MAC Media Access Control) Sublayer and LLC (Logic Link Control) Sublayer**



802.3 Ethernet

- **Carrier-sense multiple access with collision detection (CSMA/CD).**
  - CS = carrier sense
  - MA = multiple access
  - CD = collision detection
- **Base Ethernet standard is 10 Mbps.**
  - 100Mbps, 1Gbps, 10Gbps standards came later

Ethernet CSMA/CD

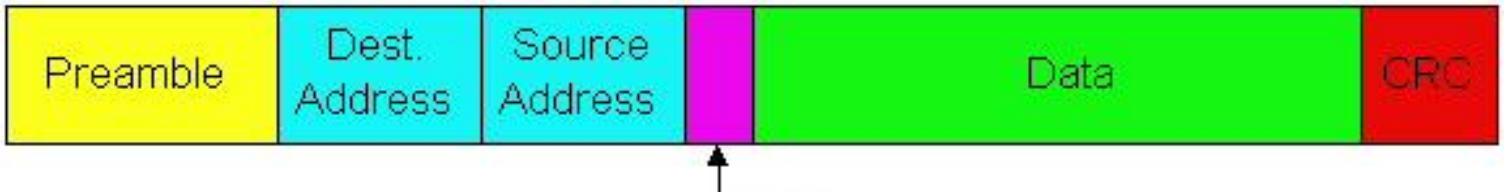
- **CSMA/CD (carrier sense multiple access with collision detection) media access protocol is used.**
  - Data is transmitted in the form of packets.
  - Sense channel prior to actual packet transmission.
  - Transmit packet only if channel is sensed idle; else, defer the transmission until channel becomes idle.
  - After packet transmission is started, the node monitors its own transmission to see if the packet has experienced a collision.
  - If the packet is observed to be undergoing a collision, the transmission is aborted and the packet is retransmitted after a random interval of time using Binary Exponential Backoff algorithm.

Ethernet Address

- End nodes are identified by their Ethernet Addresses (MAC Address or Hardware Address) which is a unique 6 Byte address.
- MAC Address is represented in Hexa Decimal format e.g 00:05:5D:FE:10:0A
- The first 3 bytes identify a vendor (also called prefix) and the last 3 bytes are unique for every host or device

Ethernet Frame Structure

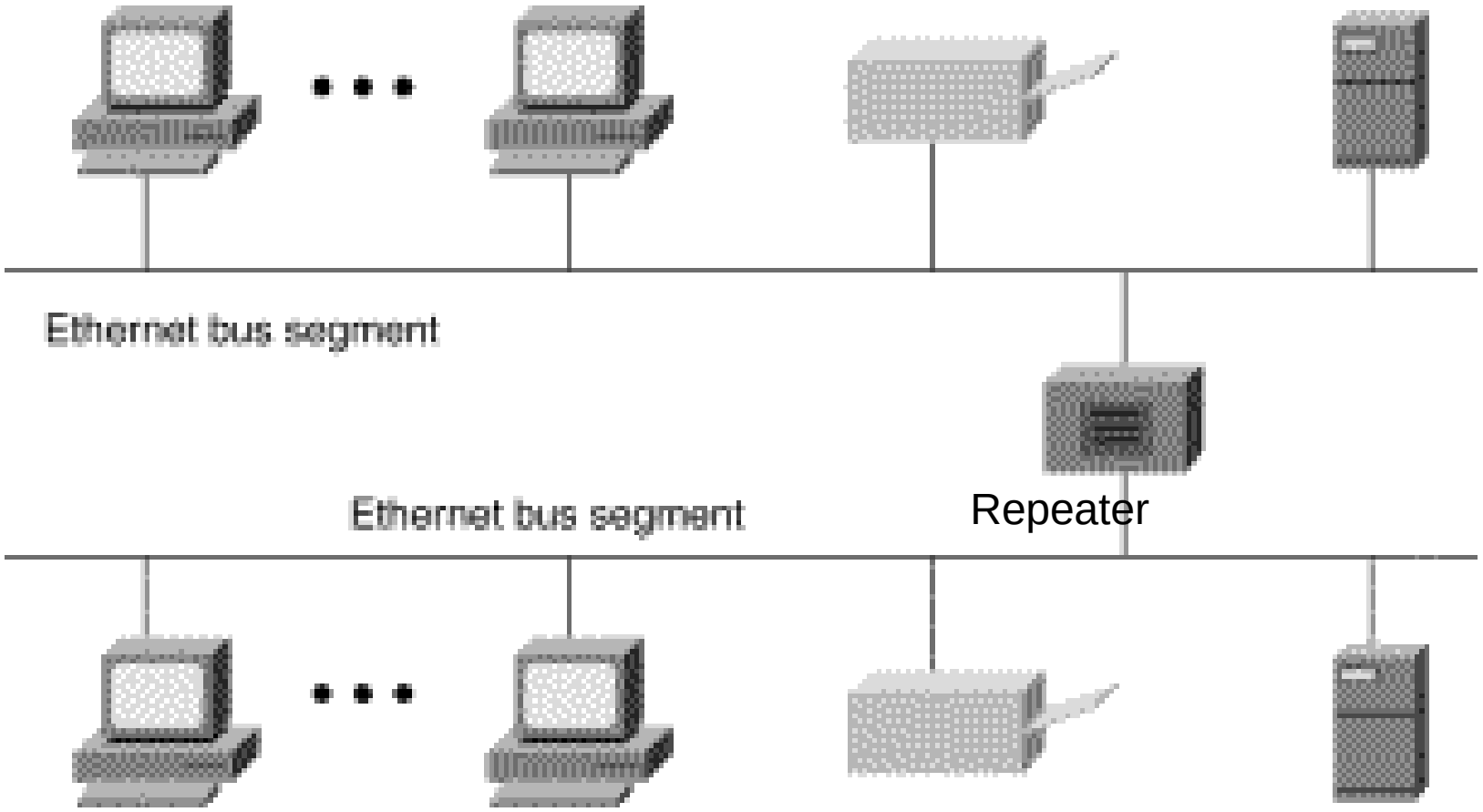
- **Preamble:**
  - 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
  - Used to synchronize receiver, sender clock rates
- **Addresses:** 6 bytes, frame is received by all adapters on a LAN and dropped if address does not match
- **Length:** 2 bytes, length of Data field
- **CRC:** 4 bytes generated using CR-32, checked at receiver, if error is detected, the frame is simply dropped
- **Data Payload:** Maximum 1500 bytes, minimum 46 bytes
  - If data is less than 46 bytes, pad with zeros to 46 bytes



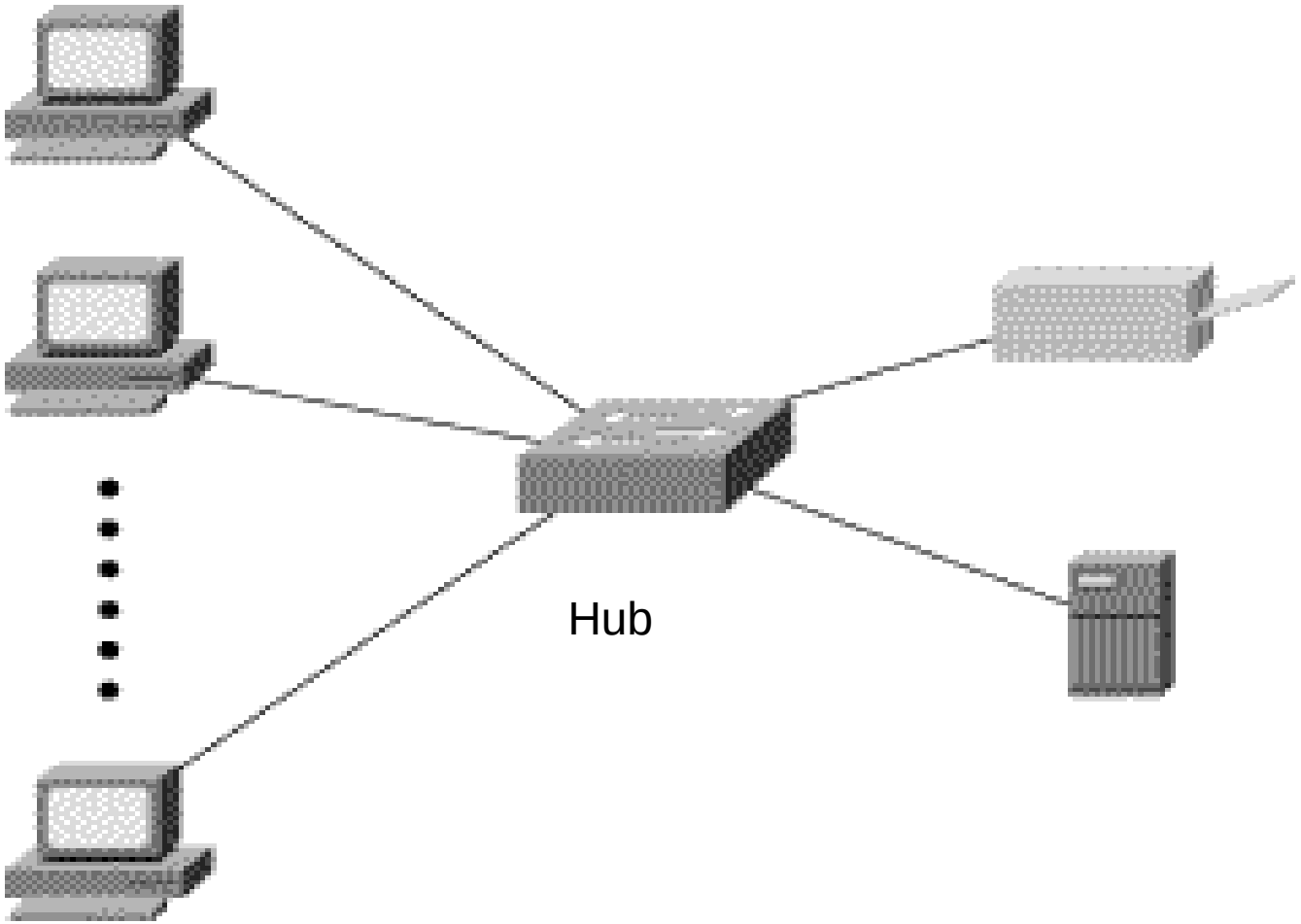
Ethernet

- 10 Base 5 (Thicknet) (Bus Topology)
- 10 Base 2 (Thinnet) (Bus Topology)
- 10 Base T (UTP) (Star/Tree Topology)
- 10 Base FL (Fiber) (Star/Tree Topology)

Ethernet BUS Topology



Ethernet STAR Topology



Ethernet

- **Physical Media :-**
  - 10 Base5 - Thick Co-axial Cable with Bus Topology
  - 10 Base2 - Thin Co-axial Cable with Bus Topology
  - 10 BaseT - UTP Cat 3/5 with Tree Topology
  - 10 BaseFL - Multimode/Singlemode Fiber with Tree Topology
- **Maximum Segment Length**
  - 10 Base5 - 500 m with at most 4 repeaters (Use Bridge to extend the network)
  - 10 Base2 - 185 m with at most 4 repeaters (Use Bridge to extend the network)
  - 10 BaseT - 100 m with at most 4 hubs (Use Switch to extend the network)

Fast Ethernet

- **100 Mbps bandwidth**
- **Uses same CSMA/CD media access protocol and packet format as in Ethernet.**
- **100BaseTX (UTP) and 100BaseFX (Fiber) standards**
- **Physical media :-**
  - 100 BaseTX - UTP Cat 5e
  - 100 BaseFX - Multimode / Singlemode Fiber
- **Full Duplex/Half Duplex operations.**

Fast Ethernet

- Provision for Auto-Negotiation of media speed: 10 Mbps or 100Mbps (popularly available for copper media only).

- Maximum Segment Length
  - 100 Base TX - 100 m
  - 100 Base FX - 2 Km (Multimode Fiber)
  - 100 Base FX - 20 km (Singlemode Fiber)

Gigabit Ethernet

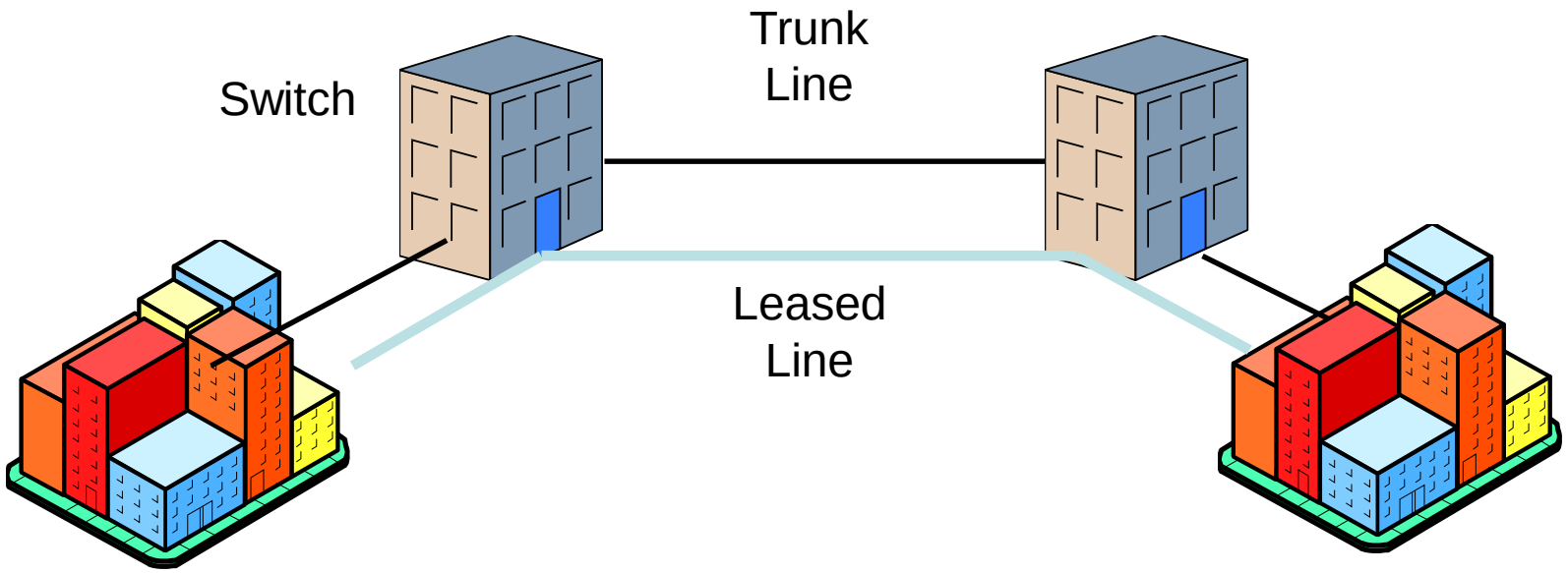
- **1 Gbps bandwidth.**
- **Uses same CSMA/CD media access protocol as in Ethernet and is backward compatible (10/100/100 modules are available).**
- **1000BaseT (UTP), 1000BaseSX (Multimode Fiber) and 1000BaseLX (Multimode/Singlemode Fiber) standards.**
- **Maximum Segment Length**
  - 1000 Base T - 100m (Cat 5e/6)
  - 1000 Base SX - 275 m (Multimode Fiber)
  - 1000 Base LX - 512 m (Multimode Fiber)
  - 1000 Base LX - 20 Km (Singlemode Fiber)
  - 1000 Base LH - 80 Km (Singlemode Fiber)

10 Gig Ethernet

- **10 Gbps bandwidth.**
- **Uses same CSMA/CD media access protocol as in Ethernet.**
- **Propositioned for Metro-Ethernet**
- **Maximum Segment Length**
  - 1000 Base-T - Not available
  - 10GBase-LR - 10 Km (Singlemode Fiber)
  - 10GBase-ER - 40 Km (Singlemode Fiber)

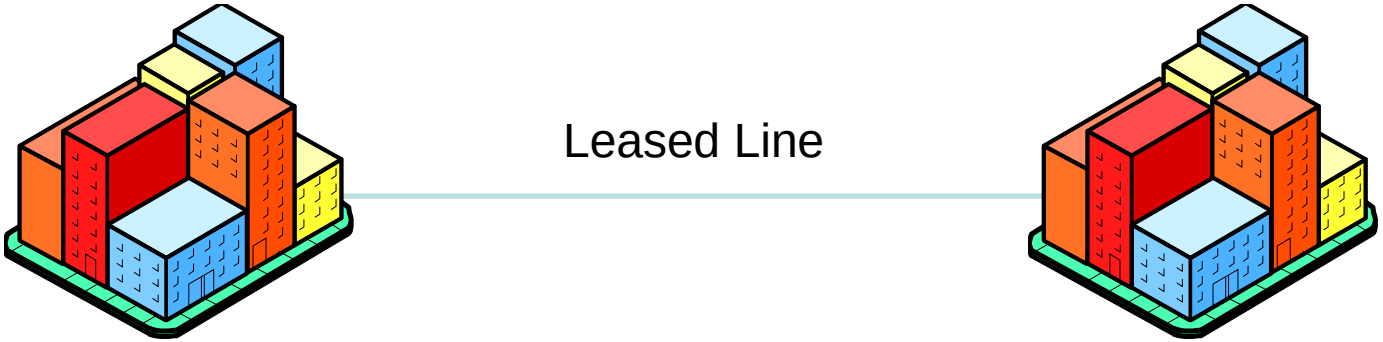
Leased Lines

- Leased Lines are *Circuits*
  - Often goes through multiple switches and trunk lines
  - Looks to user like a simple direct link



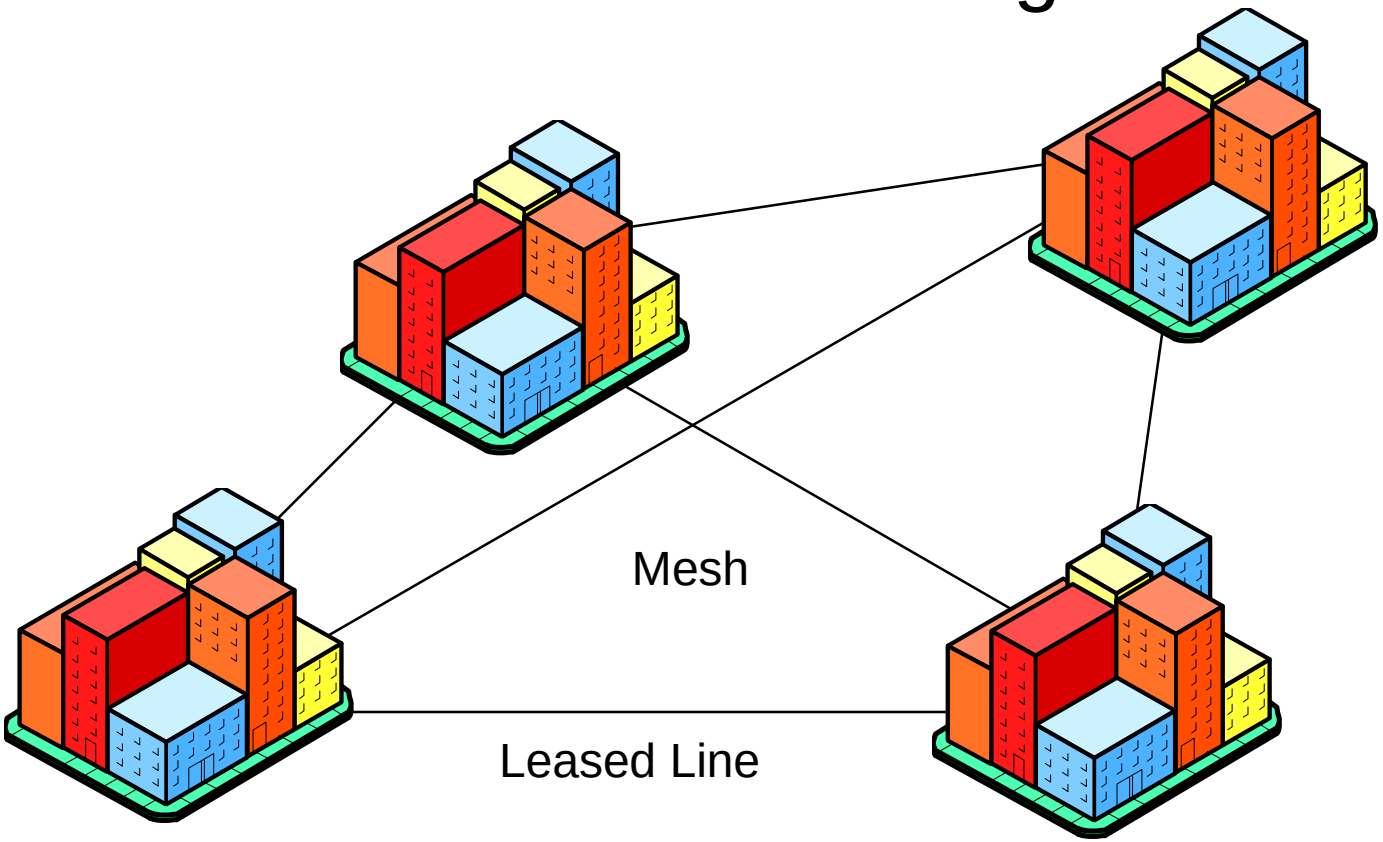
Leased Lines

- *Leased lines*
  - Limited to *point-to-point* communication
    - Limits who you can talk to
  - Carriers offer leased lines at an attractive price per bit sent *to keep high-volume customers*



Leased Line Meshes

- If you have several sites, you need a *mesh* of leased lines among sites



Leased Line Speeds

- Largest Demand is 56 kbps to a few Mbps
- 56 kbps (sometimes 64 kbps) digital leased lines
  - DS0 signaling
- T1 (1.544 Mbps) digital leased lines
  - 24 times effective capacity of 56 kbps
  - Only about 3-5 times cost of 56 kbps
  - DS1 signaling
- Fractional T1
  - Fraction of T1's speed and price
  - Often 128, 256, 384 kbps

Leased Line Speeds

- T3: is the next step
  - 44.7 Mbps in U.S.
- Europe has E Series
  - E1: 2.048 Mbps
  - E3: 34 Mbps
- SONET/SDH lines offer very high speeds
  - 156 Mbps, 622 Mbps, 2.5 Gbps, 10 Gbps

Lease Line

- A **leased line** is a private bidirectional or symmetric telecommunications line between two or more locations provided in exchange for a monthly rent. Sometimes known as a **private circuit** or **data line.**
- Unlike traditional PSTN lines it does not have a telephone number, each side of the line being permanently connected and dedicated to the other.
- Leased lines can be used for telephone, Internet, or other data services. Some are ringdown services, and some connect to a private branch exchange or router.

Lease Line

- An Internet leased line is a premium internet connectivity product, normally delivered over fiber, which provides uncontended, symmetrical speeds with full duplex.
- It is also known as an ethernet leased line, dedicated line, data circuit or private line.
- Unlike dial-up connections, a leased line is always active. The fee for the connection is a fixed monthly rate. The primary factors affecting the monthly fee are distance between end points and the speed of the circuit.
- Because the connection does not carry anybody else's communications, the carrier can assure a given level of quality.

Integrated Services Digital Network

- Introduction to ISDN
- History of ISDN
- Channels of ISDN
- Features of ISDN
- Use of ISDN

Introduction to ISDN

- It is a telephonic system. Which provide digital (not analog) telephone and data services.
- As it supports digital services (include digital voice), the ISDN telephone users enjoy Voice-free, CD Quality, Sound.
- Moreover with the ISDN no modem is necessary because it supports digital transmission of all types of data (including voice).
- This also results in very short call setup time between two ISDN subscribers.

Introduction to ISDN

- ISDN is a circuit –switched telephone network system, Which designed to allow digital transmission of voice and data over ordinary telephone copper wires, resulting in better voice quality than an analog phone.
- ISDN channels may use bonding to achieve a greater data rate, typically 3 or 4 BRIs (6 to 8 64 kbit/s channels) are bonded. ISDN is designed to provide access to voice and data services simultaneously.
- **Integrated Services refers to ISDN‘s** ability to deliver at minimum two simultaneous connections, in any combination of data, voice, video, and fax, over a single line. Multiple devices can be attached to the line, and used as needed.

ISDN elements

- **Digital refers to its purely digital** transmission. Use of an analog telephone modem for Internet access requires that the Internet service providers's (ISP) modem converts the digital content to analog signals before sending it and the user's modem then converts those signals back to digital when receiving. When connecting with ISDN there is no digital to analog conversion.
- **Network refers to the fact that ISDN is not** simply a point-to-point solution like a Leased line. ISDN networks extend from the local telephone exchange to the remote user and includes all of the telecommunications and switching equipment in between.

History of ISDN

- Developed by CCITT (Comate Consultative International Telephonique Telegraphs) to limitation of POTS (Plane old Telephone system).
- Original document was I.120 version in 1984.
- Early 1990s produced NI-1version.
- More recently NI-2 also manufactures worked with phone companies to simplify ordering.

Channels of ISDN

1. B Channel
2. D Channel
3. H Channel

- **B (Barrier) Channel:** It carries voice, data, video etc. This Channel functions at a constant 64 kbps. This channel can be used for packet and circuit switching applications.
- **D (Denial) channel:** It is used to convey user signaling messages. This type channel used out of band signaling. This means that network related signals are carried on a separate channel than used data.

Channels of ISDN

- **H channels:** They have a considerably higher transfer rate than B channels. These channels effectively meet the needs of real time video conferencing, digital quality audio and other services requiring a much higher bandwidth. H channel sustains rates of approximately 1920 mbps.

Features of ISDN

- In ISDN very short time to connect a calling between two users of ISDN.
- Signals, messages or data send in the digital form on the ISDN line. In which provide high quality database services.
- The user of ISDN also communicate information with all the general telephone user.

Use of ISDN

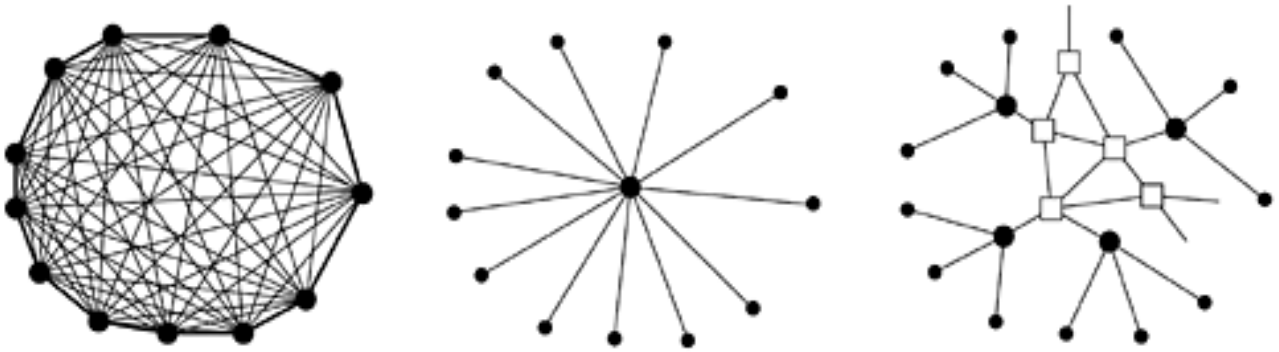
- Electronic library Inter connection.
- Electronic resources accessing.
- Images, sound and video retrieval.
- Video conferencing.
- Call center.
- Internet Access.

Public Switched Telephone Network (PSTN)

- Structure
- The Local Loop
- Trunks and Multiplexing
- Switching

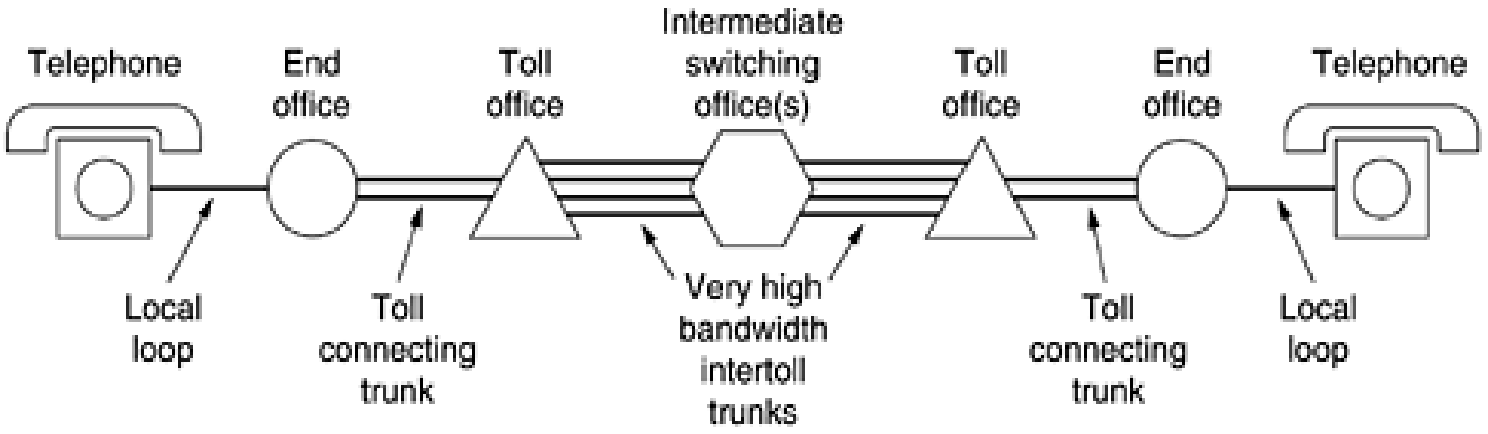
Network Structure

- minimize number of wires
- add multiple levels



Typical Circuit

- local loops
- trunks
- switching offices



The Local Loop

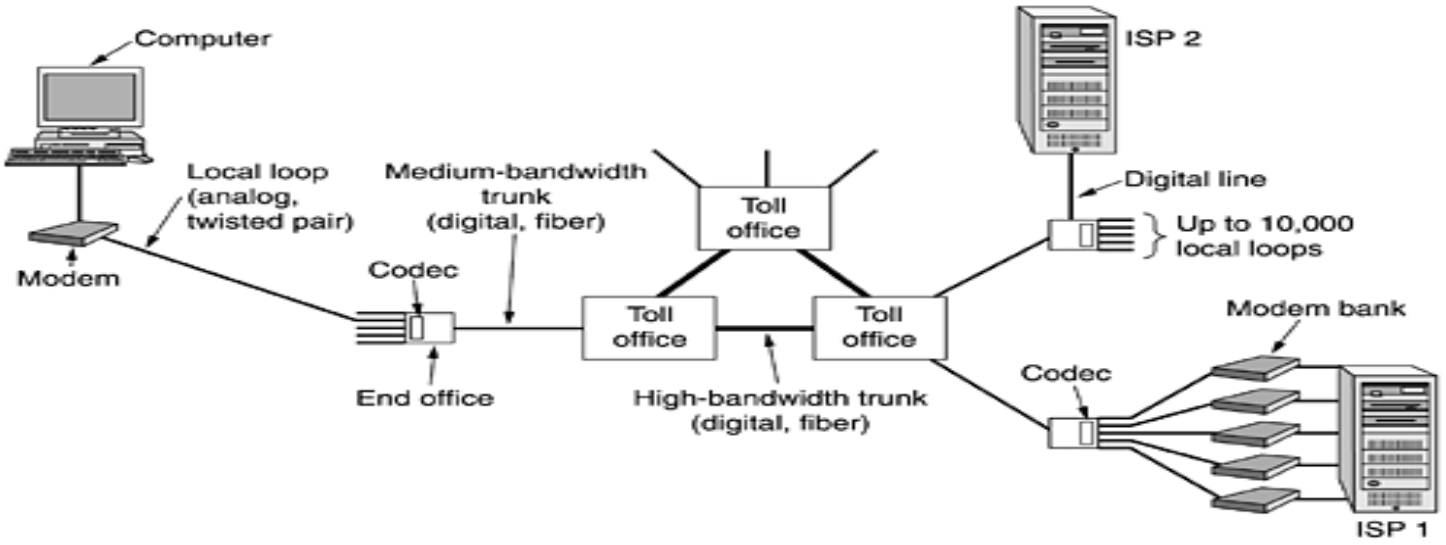
- Modems
- (A)DSL
- Wireless

Modems

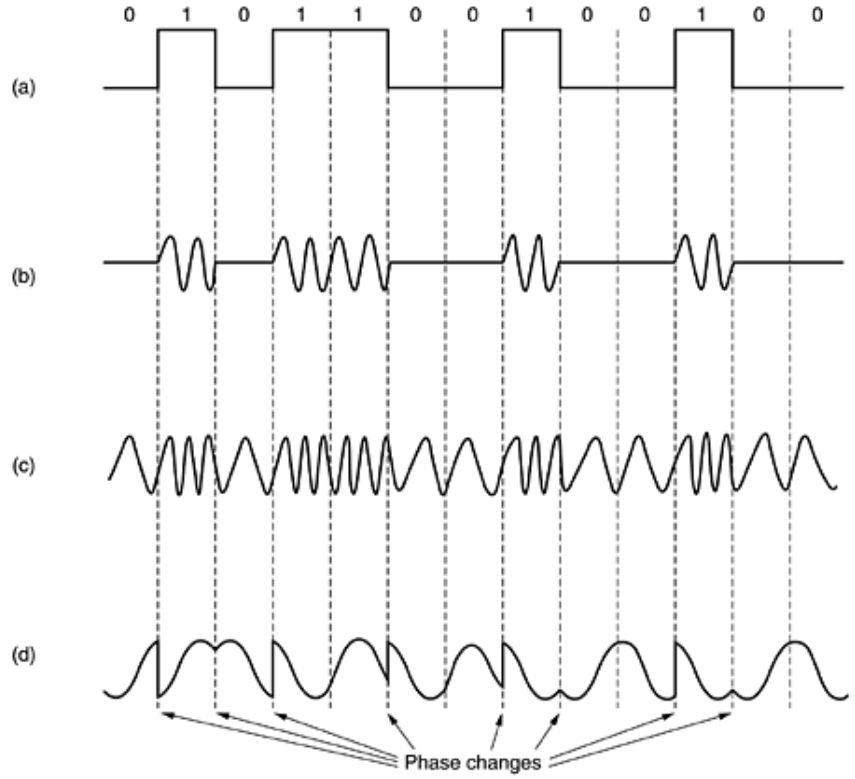
- Analog and digital transmission
- Sine wave carrier
- Baud
- Phase shift keying
- Limits

Analog and Digital Transmission

- modem – modulator, demodulator
- codec – coder, decoder



Modems – Sine Wave Carrier



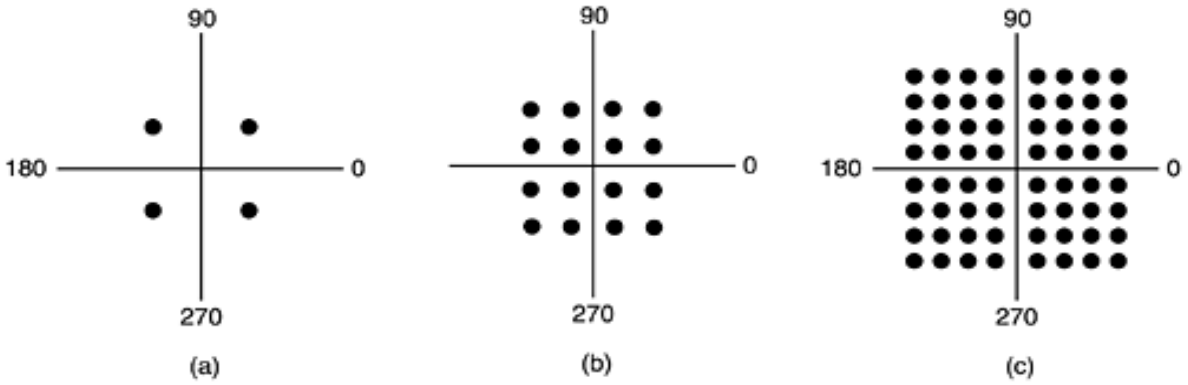
(a) binary, (b) AM, (c) FM, (d) phase modulation

Baud and Symbols

- Baud rate is the sampling rate
- Baud is the time to read one symbol
- When the number of symbols is 2, the baud rate is the bit rate
- Modern modems use large sets of symbols

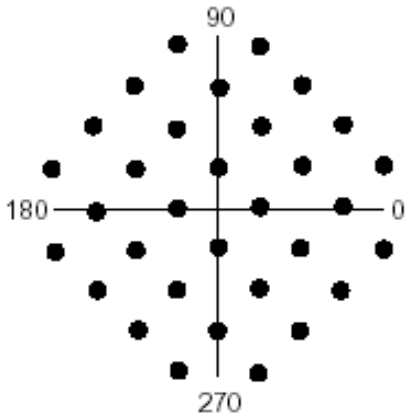
Quadrature Phase Shift Keying

- Constellation diagrams
- Amplitude (distance from origin)
- Phase
- QAM: Quadrature Amplitude Modulation

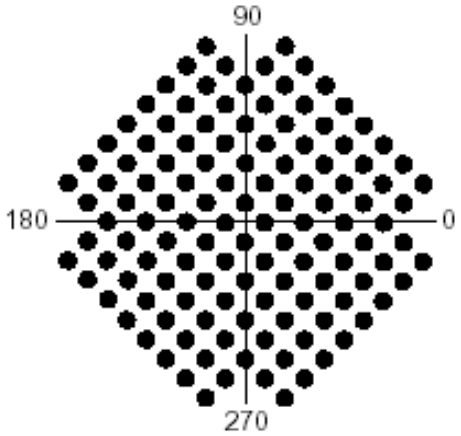


Trellis Coded Modulation

- add bits for error correction
- V.32: 32 constellation points, 4 data bits, 1 parity bit
- V.32bis: 6 data bits, 1 parity bit



(b)



(c)

Limits

- Base sampling rate – 2400 baud

Standard	Data bits	bps
V.32	4	9600
V.32bis	6	14,400
V.34	12	28,800
V.34bis	14	33,600

- Variations
  - handshake to determine line quality
  - compression
- 35 kbps is the Shannon limit, 56 kbps?
  - eliminate one local loop
  - V.90 56-kbps down stream, 33-kbps upstream
  - V.92 48-kbps down stream, 48-kbps upstream

Radio Frequency

- Radio frequency (RF) is a measurement representing the oscillation rate of electromagnetic radiation spectrum, or electromagnetic radio waves, from frequencies ranging from 300 GHz to as low as 9 kHz. With the use of antennas and transmitters, an RF field can be used for various types of wireless broadcasting and communications.

How radio frequency works

- Radio frequency is measured in units called hertz. One hertz equals one cycle per second; radio waves range from thousands (kilohertz) to millions (megahertz) to billions (gigahertz) of cycles per second. Microwaves are a type of radio wave with higher frequencies. Radio frequencies are not visible to the human eye.
- In a radio wave, the wavelength is inversely proportional to the frequency. If *f* is the frequency in megahertz and *s* is the wavelength in meters, then $s = 300/f$
- As the frequency is increased beyond that of the RF spectrum, electromagnetic energy takes the form of infrared (IR), visible, ultraviolet, X-rays and gamma rays.

RF technology

- Many types of wireless devices make use of RF fields. Cordless and cellphones, radio and television broadcast stations, Wi-Fi and Bluetooth, satellite communications systems, and two-way radios all operate in the RF spectrum.
- In addition, other appliances outside of communications, including microwave ovens and garage-door openers, operate at radio frequencies.
- Some wireless devices, like TV remote controls, some cordless computer keyboards and computer mice, operate at IR frequencies, which have shorter electromagnetic wavelengths.

RF technology

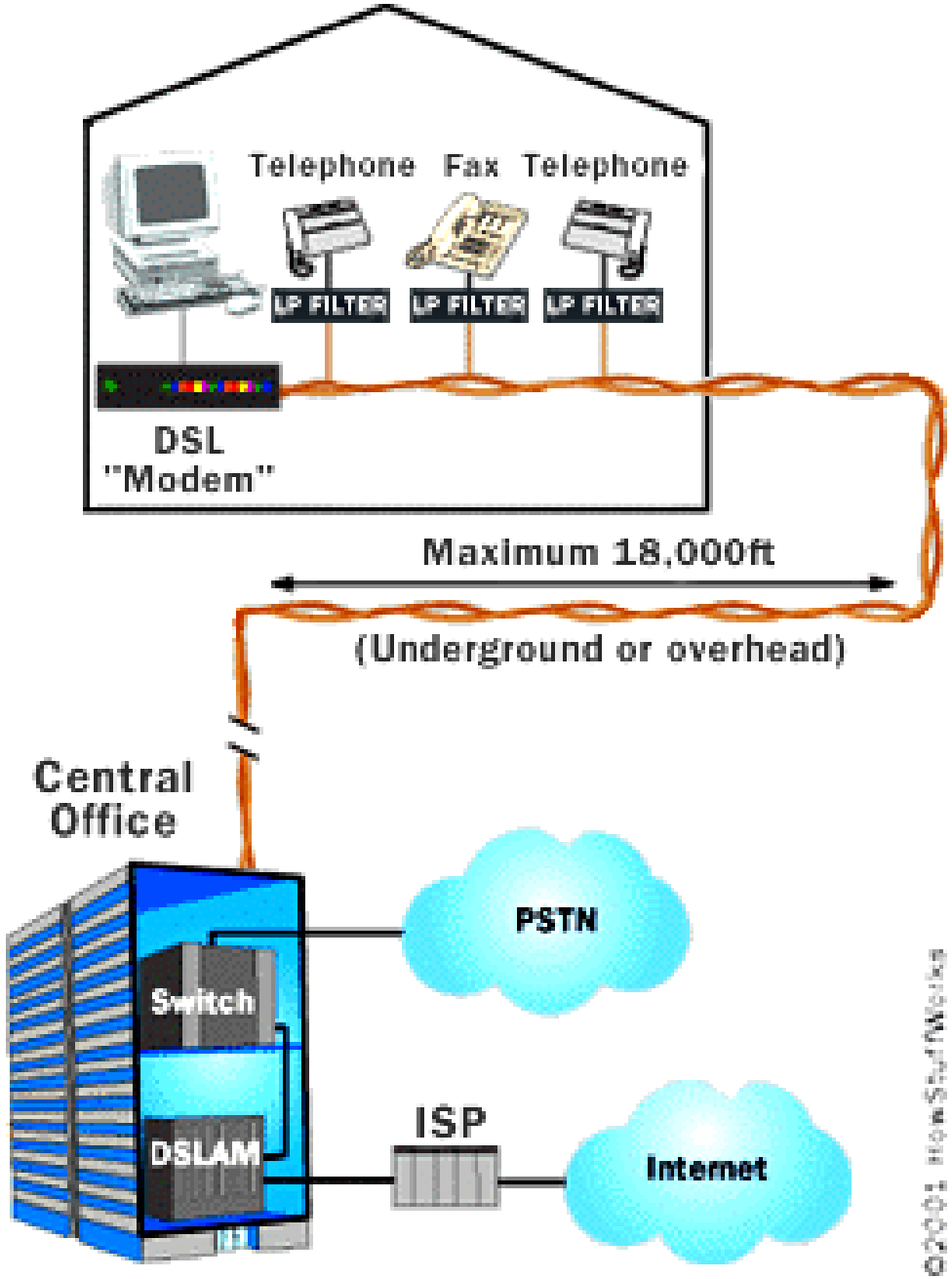
- The RF spectrum is divided into several ranges, or bands. With the exception of the lowest-frequency segment, each band represents an increase of frequency corresponding to an order of magnitude (power of 10).
- The following table depicts the eight bands in the RF spectrum, showing frequency and bandwidth ranges.
- The super high frequency (SHF) and extremely high frequency (EHF) bands are often referred to as the *microwave spectrum.*

Radio frequency spectrum bands

DESIGNATION	ABBREVIATION	FREQUENCIES	FREE-SPACE WAVELENGTHS
Very low frequency	VLF	9 kHz to 30 kHz	33 km to 10 km
Low frequency	LF	30 kHz to 300 kHz	10 km to 1 km
Medium frequency	MF	300 kHz to 3 MHz	1 km to 100 m
High frequency	HF	3 MHz to 30 MHz	100 m to 10 m
Very high frequency	VHF	30 MHz to 300 MHz	10 m to 1 m
Ultrahigh frequency	UHF	300 MHz to 3 GHz	1 m to 100 mm
Super-high frequency	SHF	3 GHz to 30 GHz	100 mm to 10 mm
Extremely high frequency	EHF	30 GHz to 300 GHz	10 mm to 1 mm

DIGITAL SUBSCRIBER LINE

DSL BLOCK DIAGRAM



Asymmetrical DSL (ADSL)

- ADSL divides up the available frequencies in a line on the assumption that most Internet users look at, or download, much more information than they send, or upload.
  - Under this assumption, if the connection speed from the **Internet to the user is three to four times faster than the connection from the user back to the Internet**, then the user will see the most benefit (most of the time).

Asymmetrical DSL (ADSL)

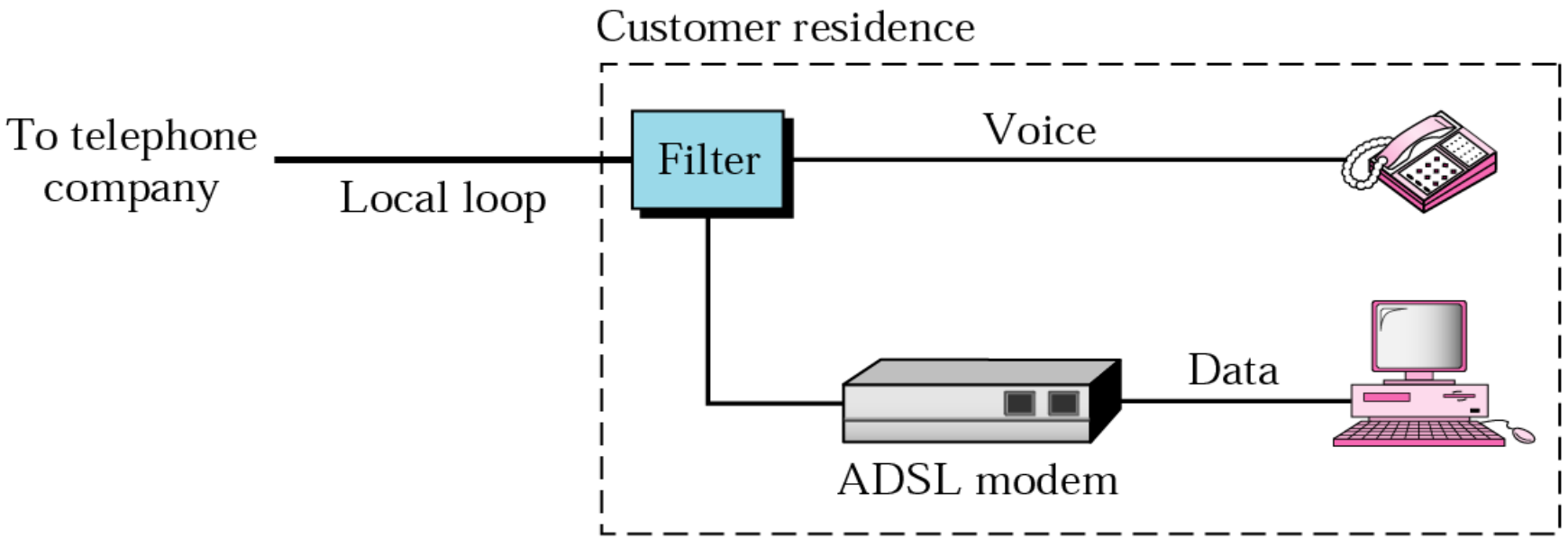
- *ADSL is an adaptive technology.*

- *The system uses a data rate based on the condition of the local loop line.*

- Speed:

  Most existing *local loops* can handle bandwidths up to 1.1 MHz.

ADSL Modem


Customer residence
To telephone company
Local loop
Filter
Voice
Data
ADSL modem

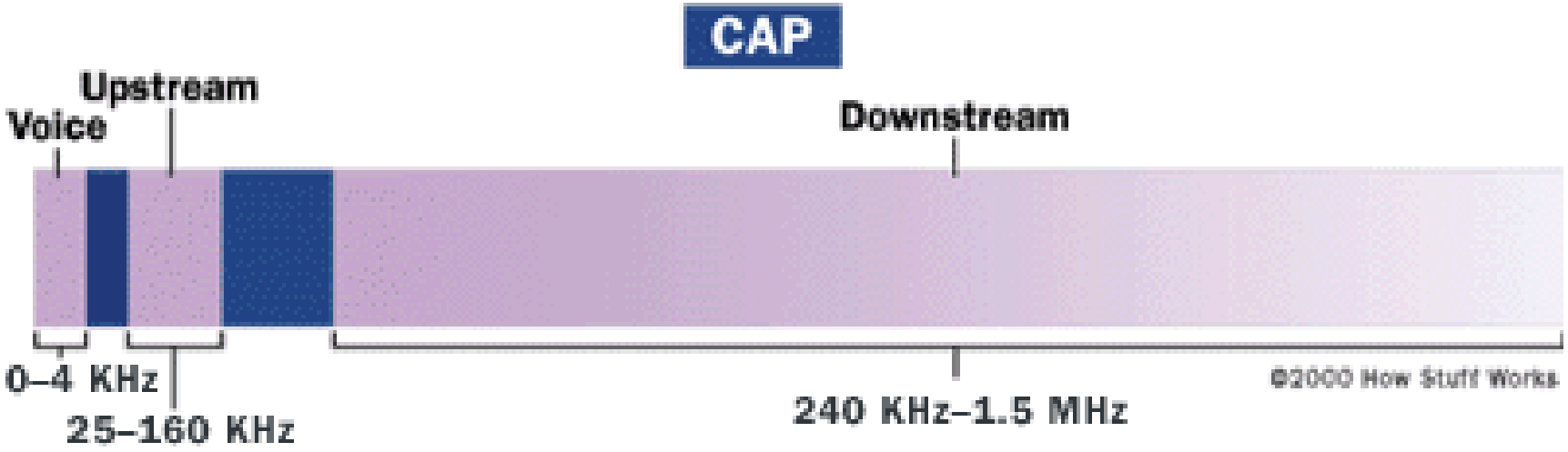
Two standards for ADSL

1. Discrete multitone (DMT)

2. Carrierless amplitude/phase (CAP)

CAP - three distinct bands:

1. **Voice channel - 0 to 4 KHz**
2. **Upstream channel - 25 and 160 KHz**
3. **Downstream channel - 1.5 MHz**

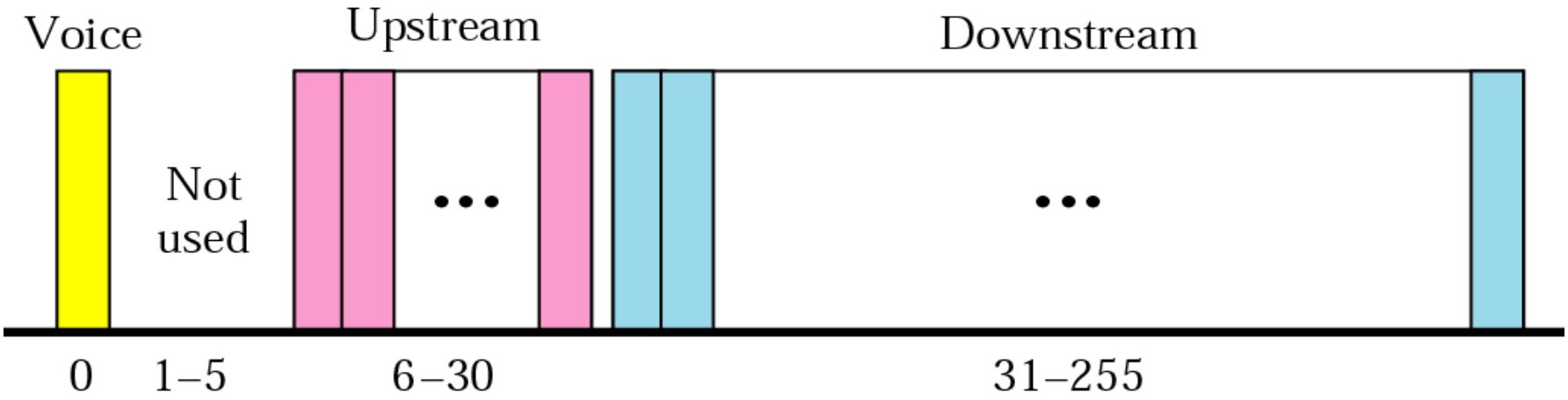


Carrierless amplitude/phase (CAP)

- Advantage:

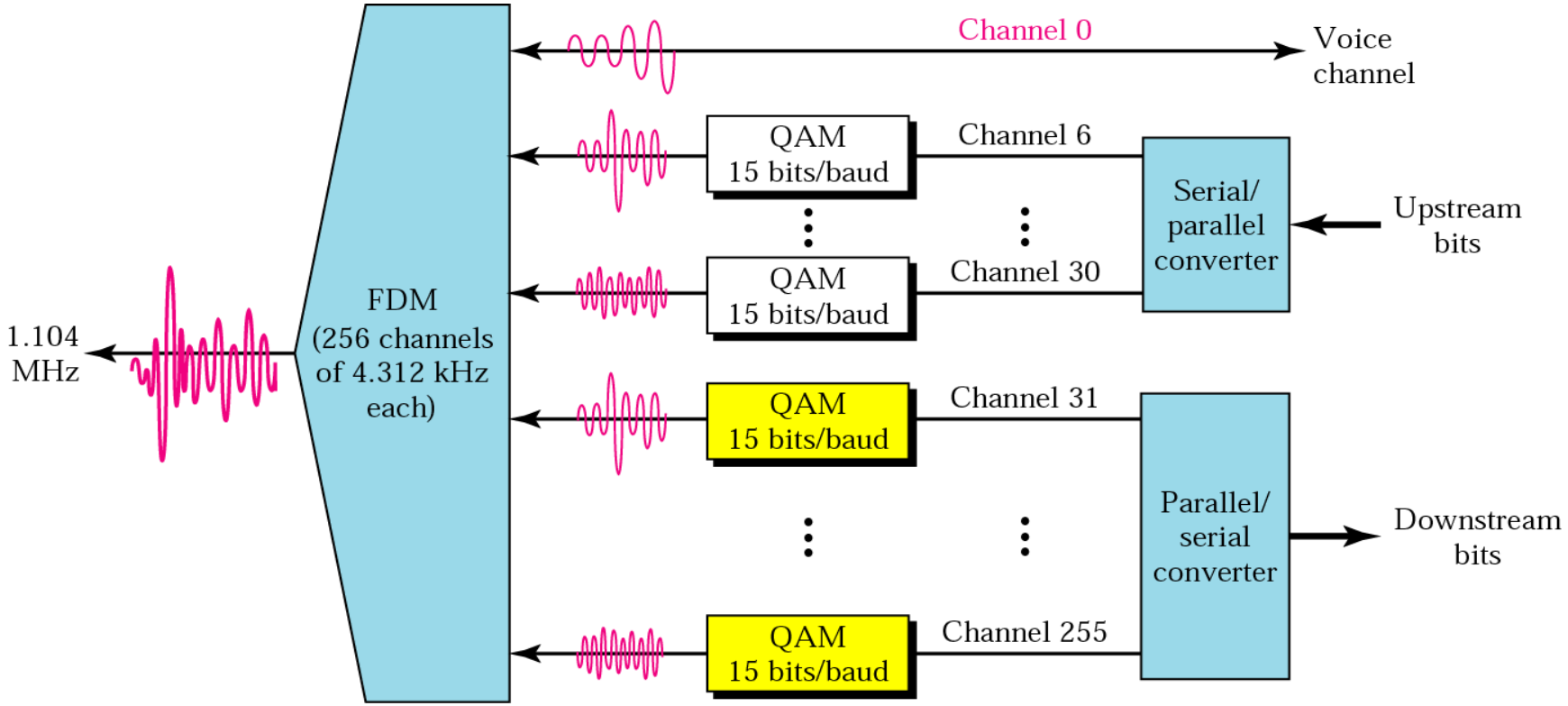
  Minimizes the possibility of interference between the channels on one line, or between the signals on different lines

Discrete multitone (DMT)



- Constantly shifts signals between different channels, searching for the best channels for transmission and reception

Discrete multitone (DMT)



Asymmetrical DSL (ADSL)

- ADSL is an asymmetric communication technology designed for residential users; it is not suitable for businesses.

Distance Limitations

- ADSL is a **distance-sensitive technology**
- The limit for ADSL service is **18,000 feet** (5,460 meters)
- At the extremes of the distance limits, ADSL customers may see speeds far below the promised maximums
- customers nearer the central office have faster connections and may see extremely high speeds

OTHER TYPES OF DSL

- Symmetric DSL (SDSL)
- High-bit-rate DSL (HDSL)
- Very high bit-rate DSL (VDSL)

Symmetric DSL (SDSL)

- Used mainly by small businesses and residential areas
- Bit rate of downstream is higher than upstream

High-bit-rate DSL (HDSL)

- Used as alternative of T-1 line
- Uses 2B1Q encoding
- Less susceptible to attenuation at higher frequencies
- Unlike T-1 line (AMI/1.544Mbps/1km), it can reach 2Mbps @ 3.6Km

Very high bit-rate DSL (VDSL)

- Uses DMT modulation technique
- Effective only for short distances(300-1800m)
- Speed:

  downstream : 50 - 55 Mbps

  upstream : 1.5-2.5 Mbps

Question!

- Distance is a limitation for DSL, why it's not also a limitation for voice telephone calls ?

Answer!

- The answer lies in small amplifiers called **loading coils** that the telephone company uses to boost voice signals
- these loading coils are incompatible with ADSL signals, so a voice coil in the loop between your telephone and the telephone company's central office will disqualify you from receiving ADSL.

VSAT

Introduction

- The old earth stations and antennas were large sizes.
- The Satellite was suffering from weak transmission and the impact of higher noise on the ground stations.
- So the receiving stations must be large size and complex installation.
- These satellites have developed and become a high transmitter.
- So the ground stations changed to small size Stations with less expensive and less complex and called VSAT.

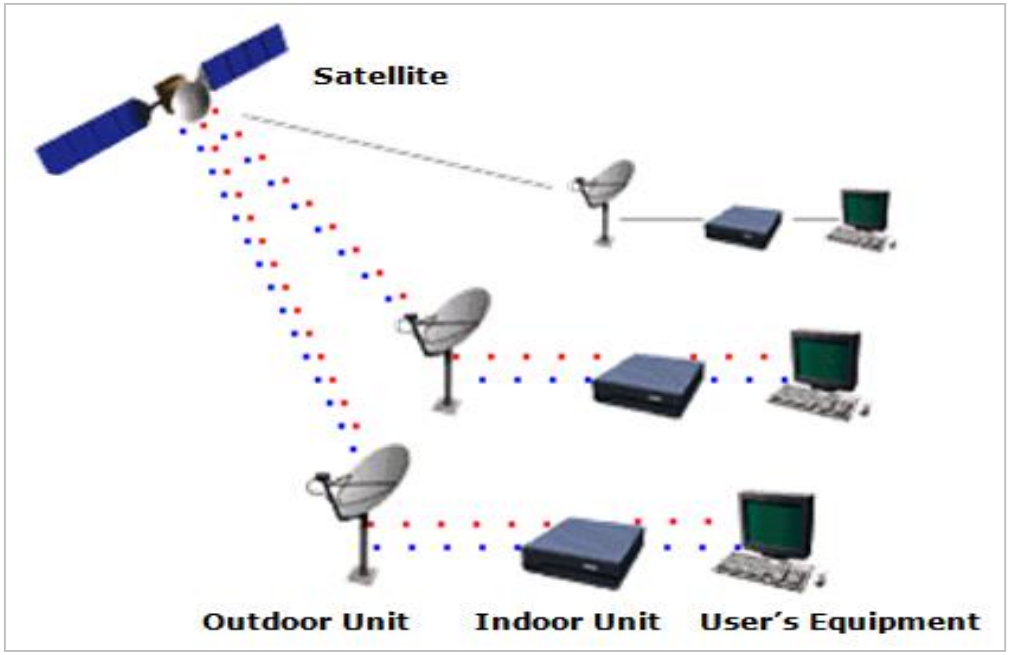
What is a VSAT?

- A **very small aperture terminal (VSAT)** is a small telecommunication earth station that receives and transmits data, video or voice via satellite.
- The **"very small"** component of the VSAT acronym refers to the size of the VSAT dish antenna-typically about 60 cm to 3.8 m.

Components of VSAT

It has two basic components:

- **Ground Segment** (earth segment), which is divided into:
  - Outdoor Unit (ODU), which contains the antenna.
  - Indoor Unit (IDU), which contains the interface between the VSAT and the customer's Equipment (PCs, TVs, Telephones).
- **Space Segment** namely satellite.



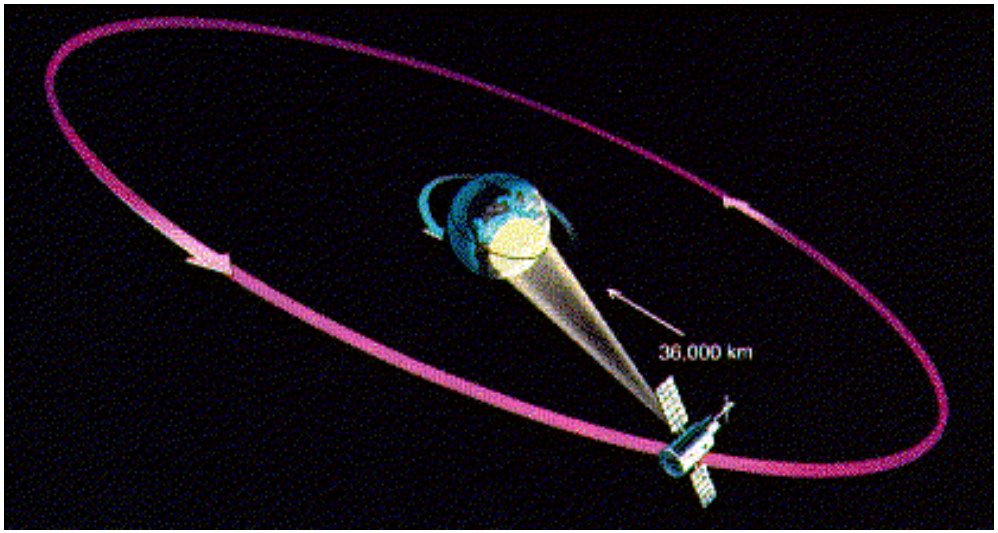
Uplink & Downlink

VSAT uses different frequencies:

- **Ku-band frequency:** is usually used in North America and Europe by using small VSAT antenna with uplink frequency about 18 GHz and downlink around 12 GHz.
- **C-band frequency:** is usually used in Asia, Africa and South America and operating with much larger antenna, with uplink frequency around 6 GHz as for downlink frequency around 4 GHz.
- The new **Ka-band frequency:** is typically in the downlink frequencies up to 22 GHz and uplink frequencies up to 31 GHz.

The satellites that are used in the VSAT system?

- VSAT system used geostationary earth orbit (GEO) satellites that revolve around the equator at the same rotational speed as the earth.
- Appearing as though they are not moving at all, GEOs are always in the same place above the earth. They also cover a large geographic area.
- Direction from earth: 36,000 km (22,282 miles).
- Speed: 11,300 Km/h.

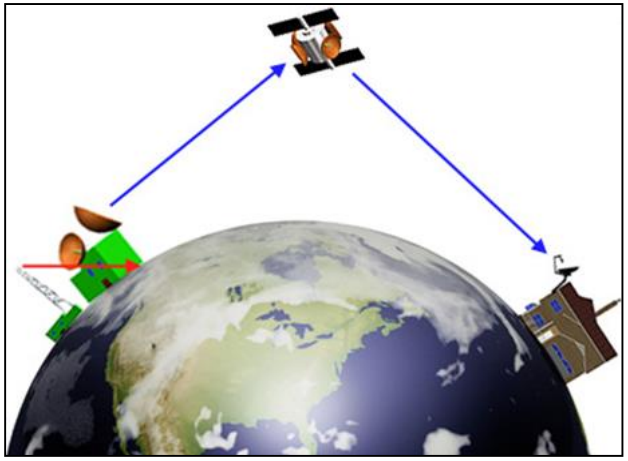


VSAT Advantages:

- High flexibility to increase the size of the network in the future.
- Able to integrate large number of the networks.
- Cover distant geographical locations.
- Ability to handle Voice, Video and Data.

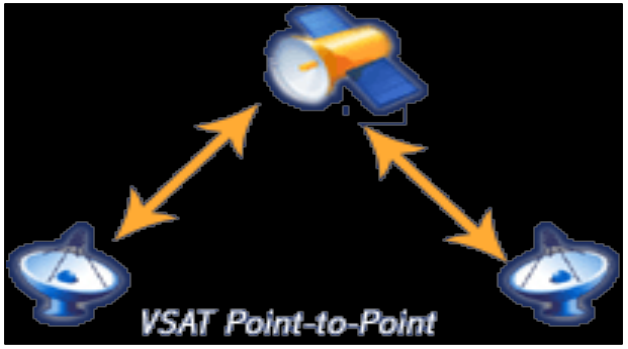
VSAT Disadvantages:

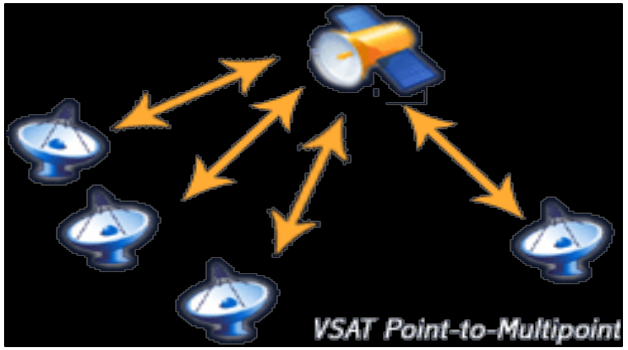
- Requires clear line of sight between dish and satellite.
- Outages in some cases, because of the weather. These outages normally last for a few minutes.



VSAT Network Topologies

- The connection between Terminal and Terminal called (Point to Point).
- The connection between Hub and Terminals called (Point to Multipoint).

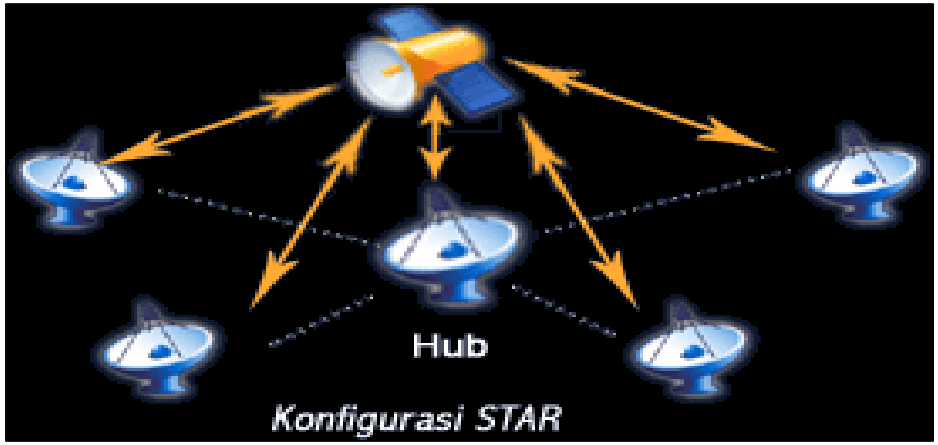




- The most important types of link are:
  - Star Topology.
  - Mesh Topology.

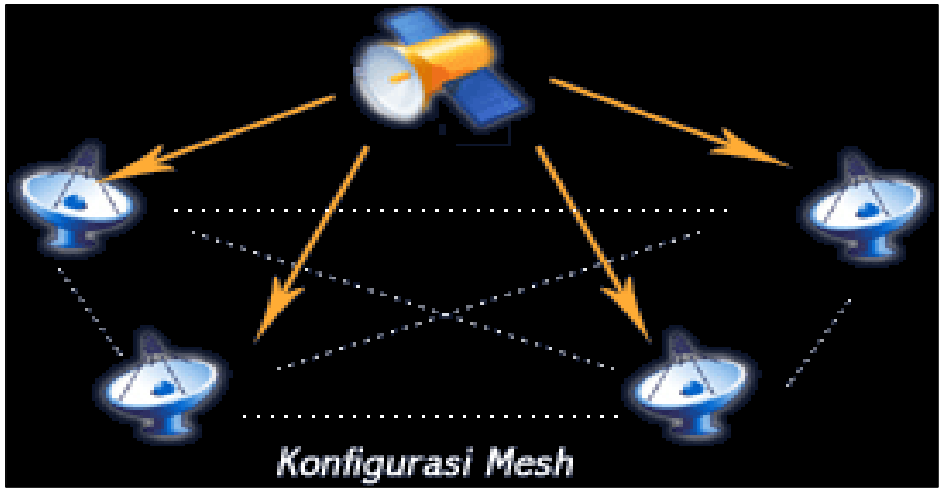
Star Topology

- VSAT terminals cannot communicate directly with each other, they have to go through the hub.
- It is commonly used for internet connection purpose.
- Smaller VSAT antenna sizes (1.8 m typically).
- The performance of the network is directly dependent on the performance of the hub.



Mesh Topology

- This network enables direct communication from one point to another.
- Its usually found in telephone and data lines.
- larger VSAT antenna sizes (3.8 m typically).
- If one of the components fails there is another line.



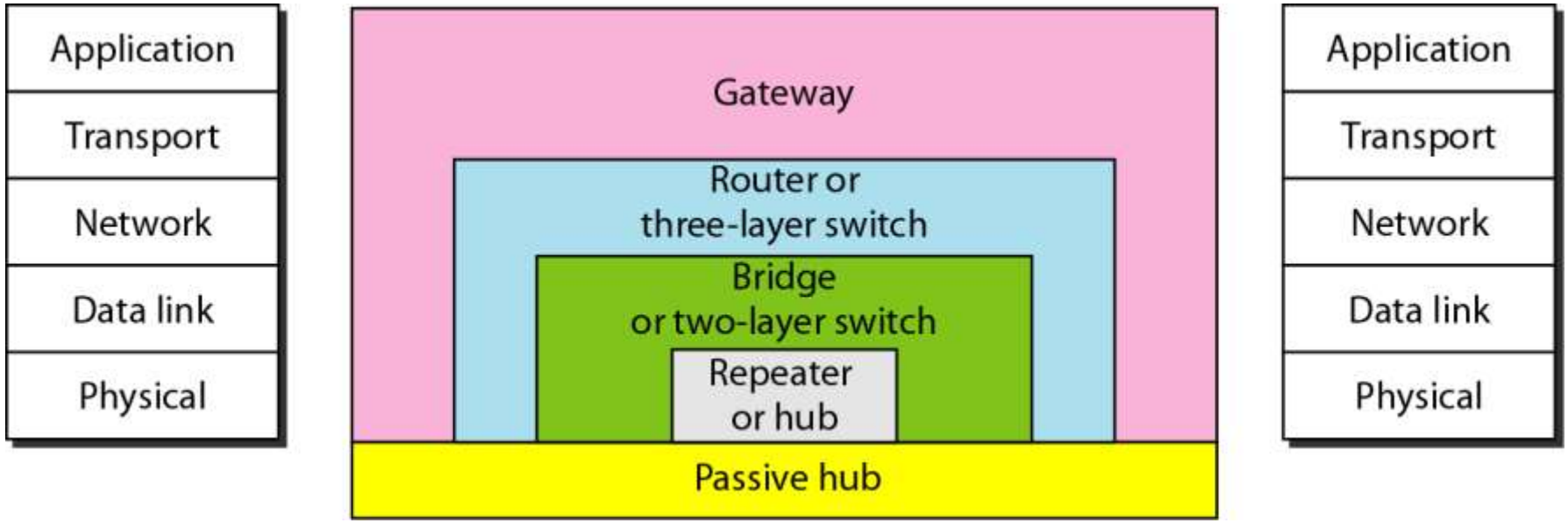
❖ Summary

- VSAT is a perfect solution in answering voice, data and video, especially in the absence of terrestrial transmission coverage.
- Utilizing VSAT offers maximum benefit, which enables company to expand very fast without affected by lack of local telecommunication network infrastructure.
- VSAT is available anywhere in the Kingdom with the ability to connect remote areas.

UNIT 5: Connectivity Devices

- Different connecting devices
  - Repeaters
  - Hubs
  - Bridges
  - Switches
  - Routers
  - Gateway

Figure 5.1 *Five categories of connecting devices*



Repeaters

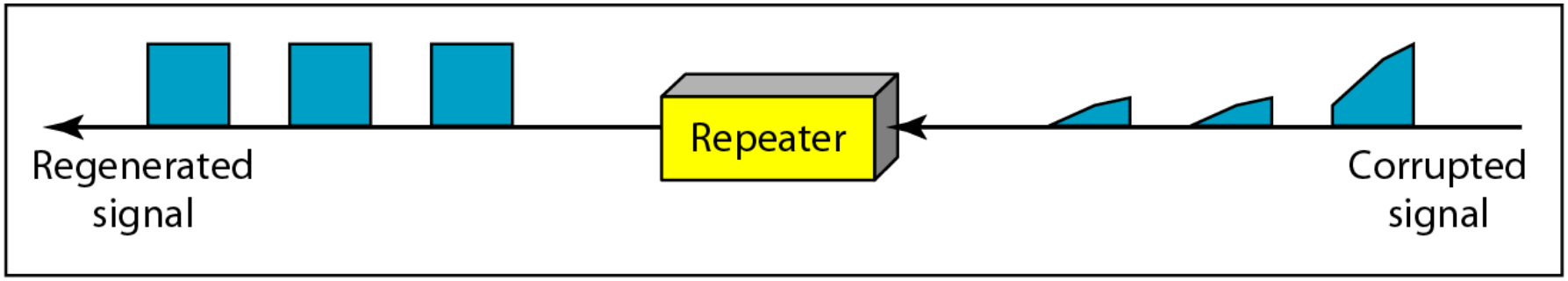
- A **physical layer** device that acts on **bits** not on **frames** or packets
- Can have two or more interfaces
- When a bit (0,1) arrives, the repeater receives it and **regenerates** it, the transmits it onto all other interfaces
- Used in LAN to **connect cable segments** and **extend** the **maximum cable length** ➔ extending the **geographical LAN range**
  - Ethernet 10base5 – Max. segment length 500m – 4 repeaters (5 segments) are used to extend the cable to **2500m**)
  - Ethernet 10Base2- Max. segment length 185m - 4 repeaters (5 segments) are used to extend the cable to **925m**
- Repeaters do not implement any **access method**
  - If any two nodes on any two connected segments transmit at the same time **collision** will happen

Repeaters

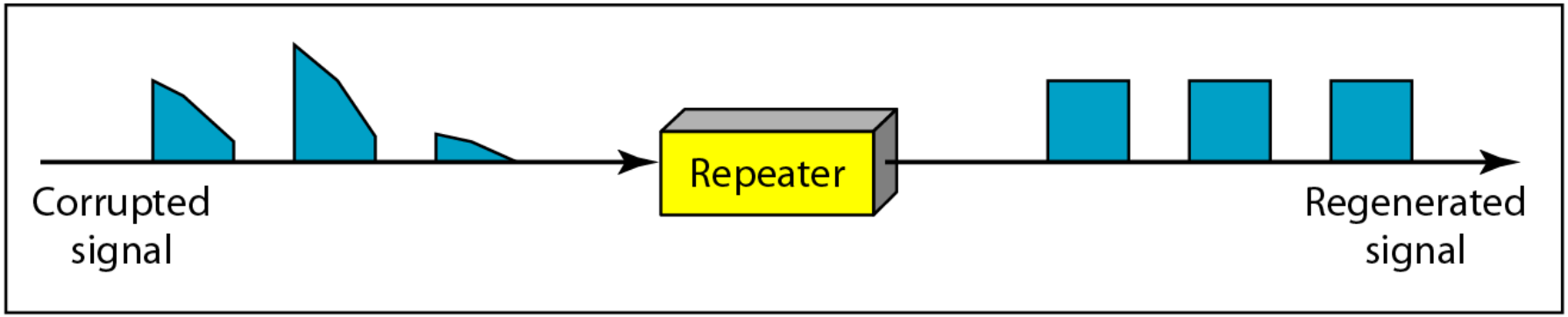
Important features of a repeater are as follows:

- A repeater connects different segments of a LAN
- A repeater forwards every frame it receives
- A repeater is a regenerator, not an amplifier
- It can be used to create a single extended LAN

Figure 5.2 *Function of a repeater*

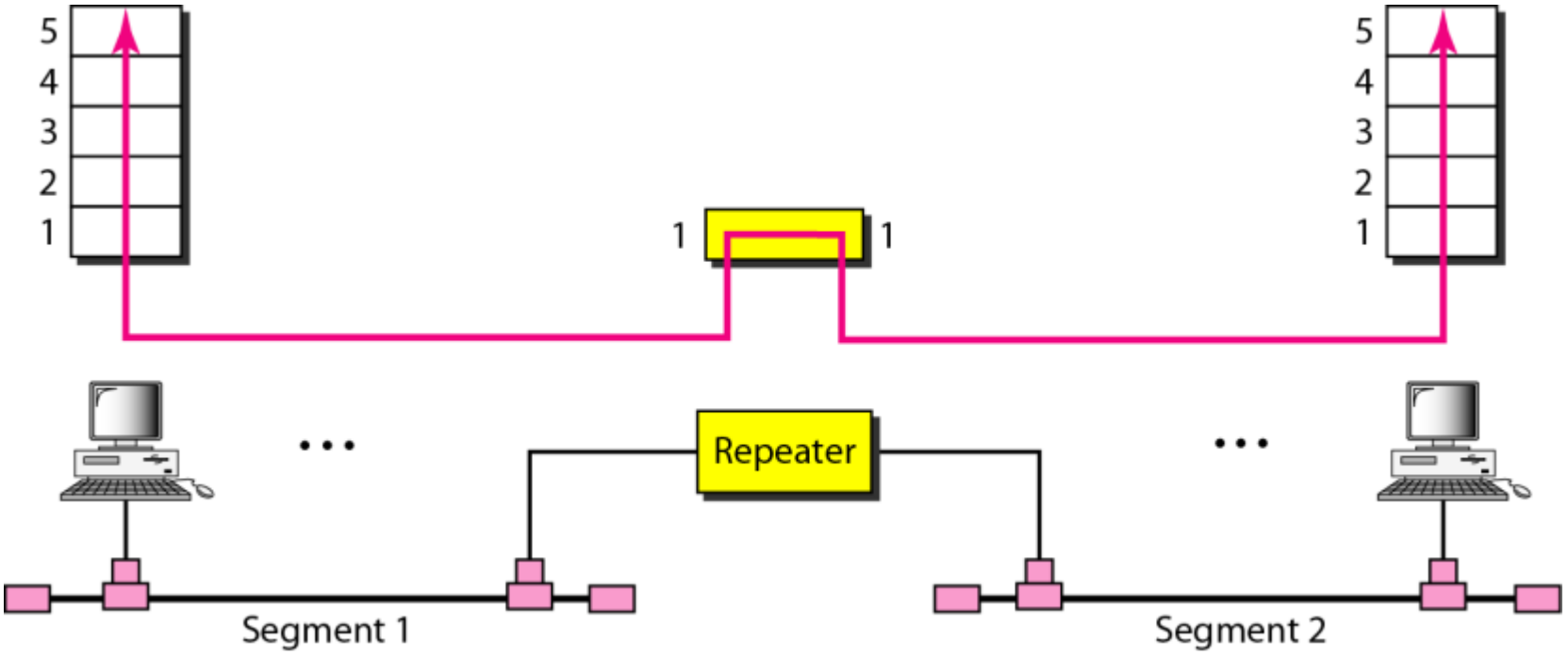


a. Right-to-left transmission.



b. Left-to-right transmission.

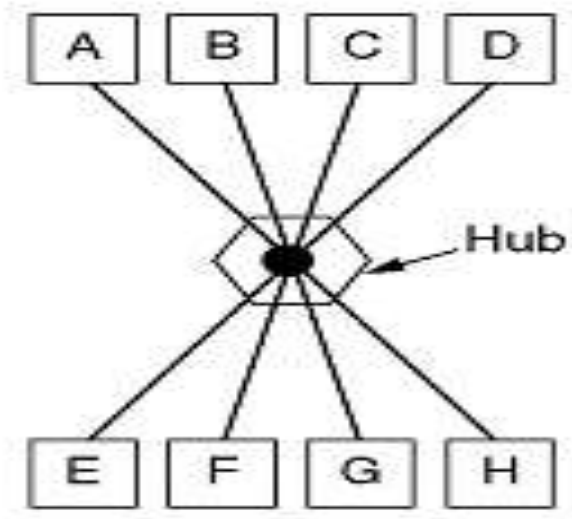
Figure 5.3 *A repeater connecting two segments of a LAN*

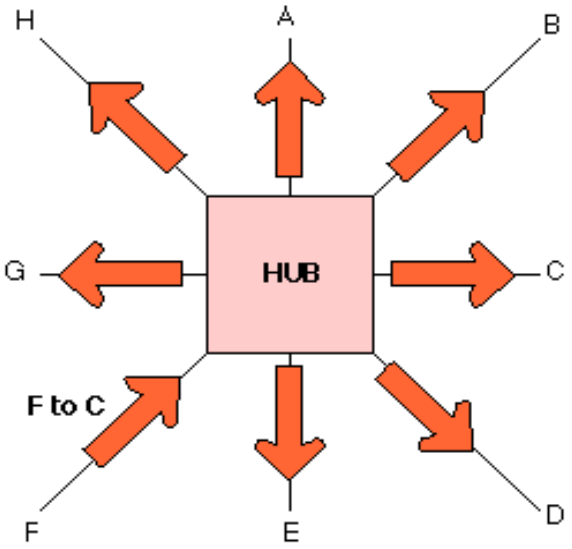


Hubs

- Acts on the **physical layer**
- Operate on bits rather than frames
- Also called **multiport repeater**
- Used to connect stations adapters in a **physical** star topology but **logically** bus
- Connection to the hub consists of **two pairs of twisted pair wire** one for **transmission** and the other for **receiving**.
- Hub receives a bit from an adapter and sends it to **all** the other adapters without implementing any access method.
- does not do **filtering** (forward a frame into a specific destination or drop it) just it copy the received frame onto **all other links**
- The entire hub forms **a single collision domain**, and **a single Broadcast domain**
  - **Collision domain**: is that part of the network (set of **NICs**) when two or more nodes transmit at the same time collision will happen.
  - **Broadcast domain:** is that part of the network (set of NIC) where each NIC can 'see' other NICs' traffic **broadcast messages.**
- Multiple Hubs can be used **to extend** the network length
- For 10BaseT and 100BaseT the maximum length of the connection between an adapter and the hub is 100 meters ➔ the maximum length between any two nodes is 200 m = maximum network length

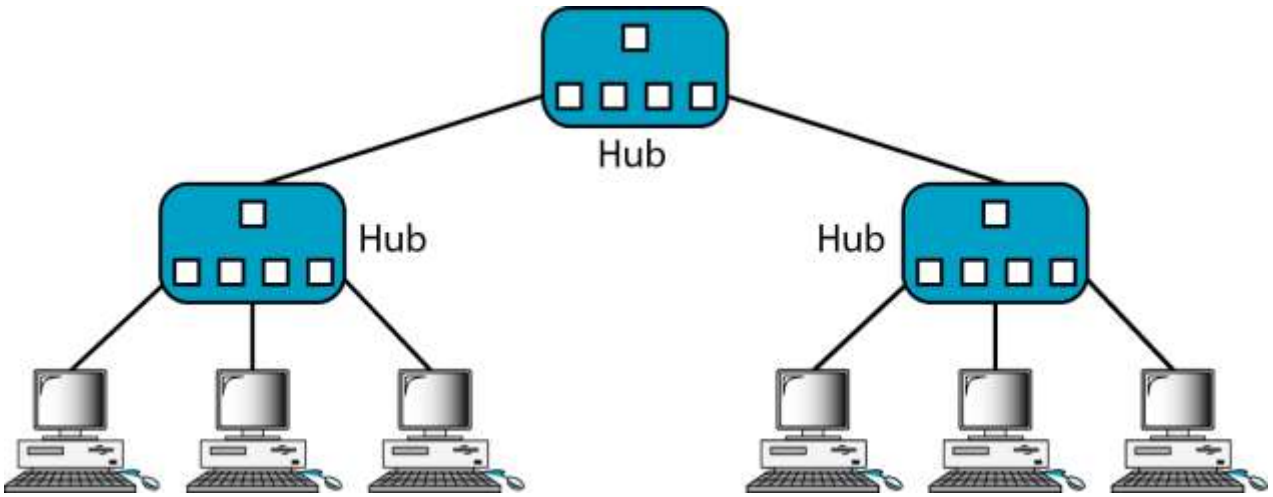
Figure 5.4 Hubs





Interconnecting with hubs

- Backbone hub interconnects LAN segments
- **Advantage**:
  - Extends max distance between nodes
- **Disadvantages**
  - Individual segment collision domains become one large collision domain ➔ (**reduce the performance**)
  - Can't interconnect different Ethernet technologies(like 10BaseT & 100BaseT) because **no buffering** at the hub



Here we have a single collision domain and a single broadcast domain

Hubs Vs. Repeaters

- Hub are different than repeaters in the following:
  - The provide **network management features** by gathering information about the network and report them to a monitoring host connected to the hub so some statistics about the network (bandwidth usages, collision rates, average frame sizes) can be generated.
  - If an adapter is not working the hub can **disconnect** it internally and the network will not be affected.

Bridges

- Acts on the **data link** layer (MAC address level)
- Used to **divide** (segment) the LAN into smaller LANs segments, or to **connect** LANs that use identical physical and data link layers protocol (see figure in next slide)
- Each LAN segment is a **separate collision domain**
- Bridge does not send the received frame to all other interfaces like hubs and repeaters, but it performs **filtering** which means:
  - Whether a frame should be **forwarded** to another interface that leads to the destination or **dropped**
- This is done by a bridge table (**forwarding table**) that contains entries for the nodes on the LAN
  - The bridge table is **initially empty** and **filled automatically** by **learning from frames movements** in the network
  - An entry in the bridge table consists of : Node LAN (**MAC) Address, Bridge Interface to which the node is connected to**, **the record creation time**

Address	Interface	Time
62-FE-F7-11-89-A3	1	9:32
7C-BA-B2-B4-91-10	3	9:36
...	...	...

- A bridge runs **CSMA/CD before sending a frame** onto the link not like the hub or repeater
- Bridge frame handling is done in **software**

Bridges

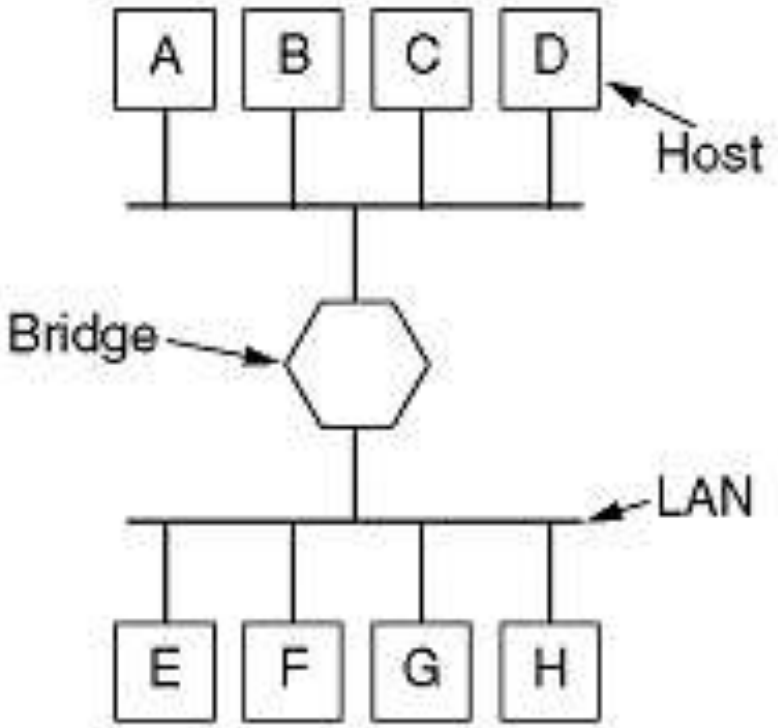
Key features of a bridge are mentioned below:

- A bridge operates both in physical and data-link layer
- A bridge uses a table for filtering/routing
- A bridge does not change the physical (MAC) addresses in a frame
- A bridge must contain addressing and routing capability
- Types of bridges:

  i) Transparent Bridges: produced as an extension of IEEE 802.1 and applicable to all IEEE 802 LANs

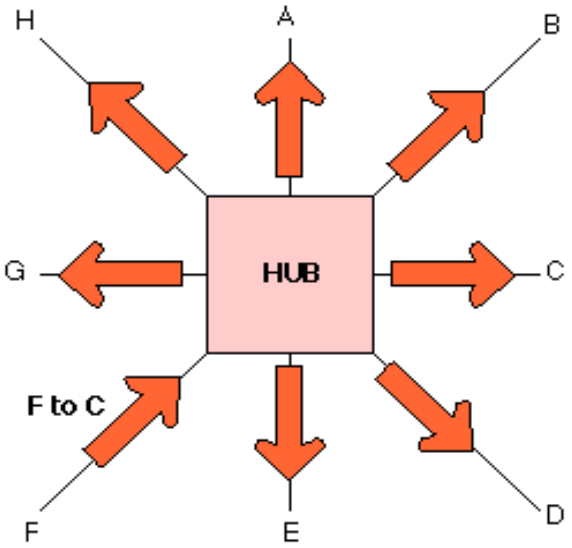
  ii) Source routing bridges: developed for the IEEE 802.5 token rings, is based on source routing approach. It applies to many types of LAN including token ring, token bus and CSMA/CD bus

Bridges

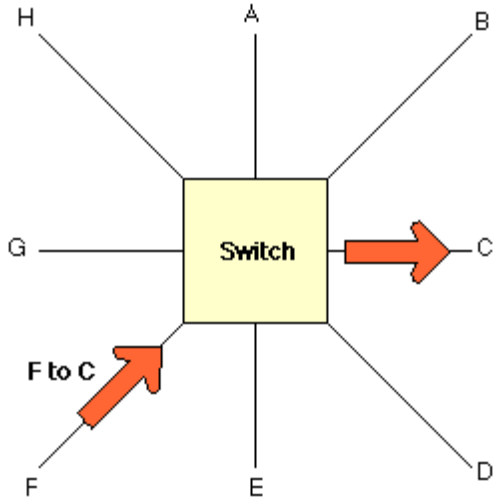


Connecting two or more LAN segments together

Bridges (Switches) Vs. Hubs

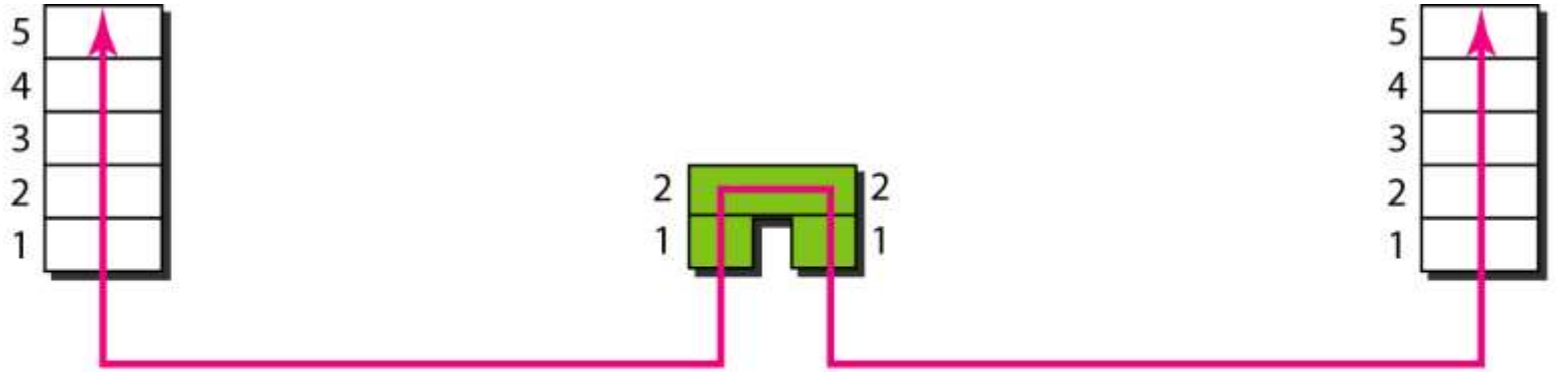


A Hub sending a packet form F to C.



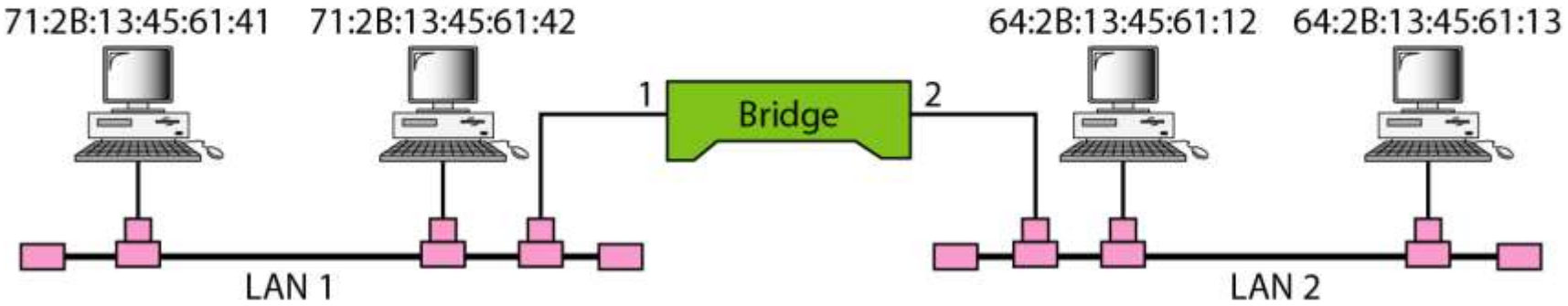
A Switch sending a packet from F to C

Figure 5.5 *A bridge connecting two LANs*



Address	Port
71:2B:13:45:61:41	1
71:2B:13:45:61:42	1
64:2B:13:45:61:12	2
64:2B:13:45:61:13	2

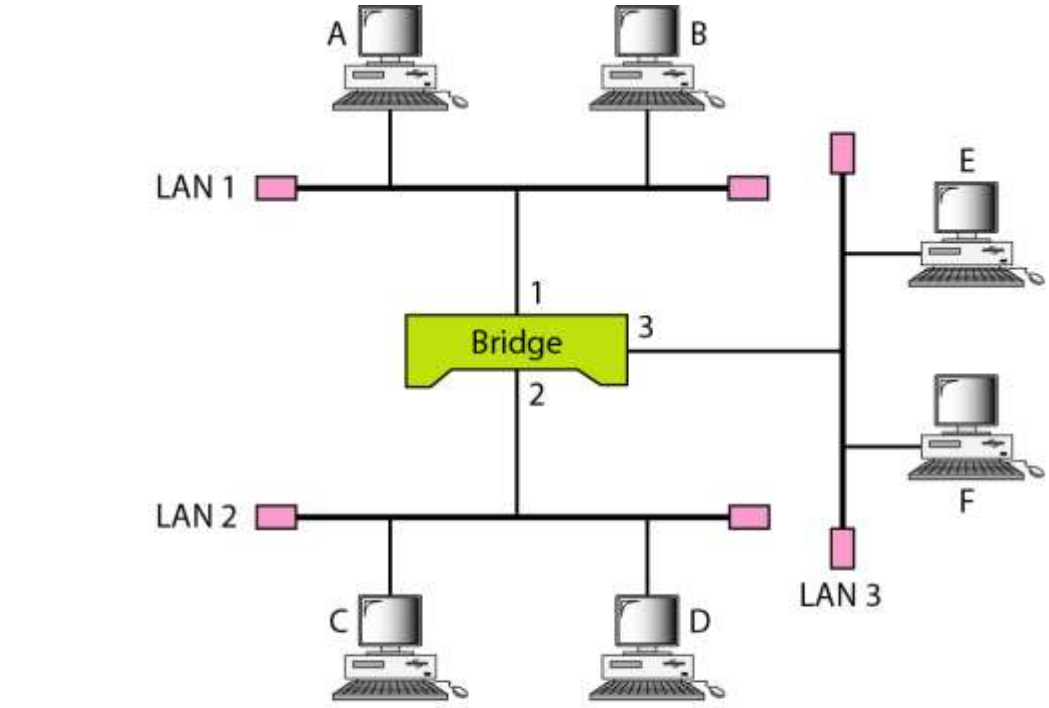
Bridge Table



Switch learning process

- When the switch receives a frame, it compares the **source address** of the frame with each entry in the forwarding table
  - If **No match is found**, the bridge will **add** to the table the frame **source address** and the **Interface** on which the frame **was received.**
  - If a **match is found**, the bridge **updates** the **Interface number** on which the frame was received if **it is different** from the one in the table also it **updates** the **record time**
- Then, the switch compares the **destination address** of the frame with each entry in the **forwarding table (MAC table)**
  - If a match is found then
    - The bridge compares the **interface number** on which the frame was received and the interface number in the table, if they are **different** the bridge **forwards** the frame through the interface number stored in the table. Otherwise, if they are the **same** the switches **discards** (**drops**) the frame.
  - If no match is found, the switch **floods the frame** on **all interfaces** except the one on which the frame was received.

Figure 5.6 *A learning switch and the process of learning*



Address	Port

a. Original

Address	Port
A	1

b. After A sends a frame to D

Address	Port
A	1
E	3

c. After E sends a frame to A

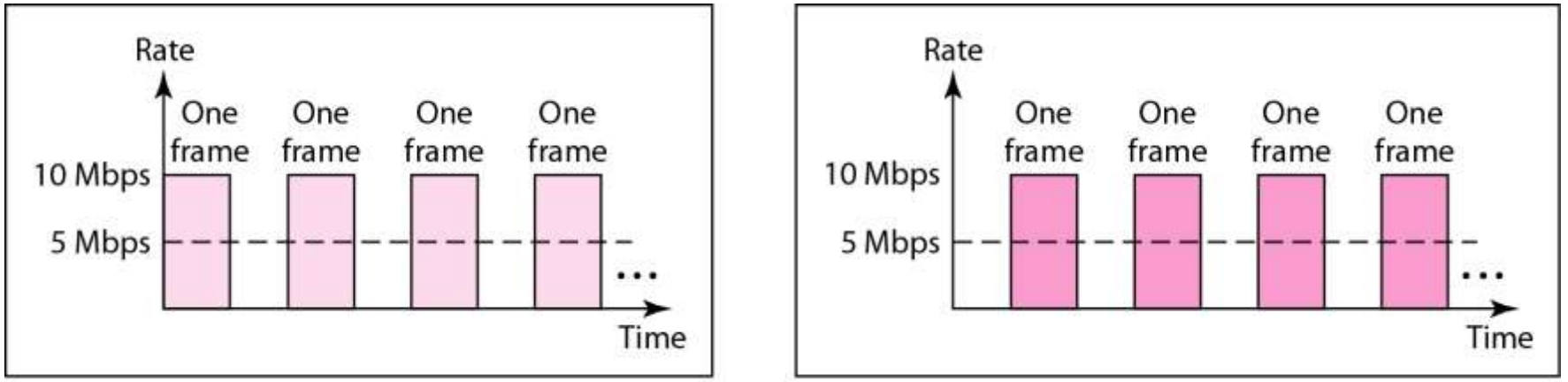
Address	Port
A	1
E	3
B	1

d. After B sends a frame to C

Some switch features

- Implements CSMA/CD
- switches Isolates collision domains (each LAN segment is a separate collision domain), THIS WILL REDUCE THE POSSIBILITY OF COLLISIONS AND result in **higher total max throughput (see next slide)**
- switch forwards a frame with **broadcast address** to **all** devices attached to the whole network (**single broadcast domain**)
- Can be used to combine Ethernet segments using different Ethernet technologies (10Base2 and 100BaseT and 10BaseT) because it has buffering capabilities
- Increases reliability (how?), performance (how?), and security (how?)
- Increases geographical coverage
  - No limit on the size of the LANs connected through switches
- **Transparent**: installing or removing a switch does not require the stations networking software to be reconfigured.
- ("**plug-and-play**"): *no configuration necessary* at installation of switch /switch or when a host is removed from one of the LAN segments
- **Disadvantage**: switch does not allow multiple paths between LAN segments or between any two devices.

Figure 5.7 *Sharing bandwidth*

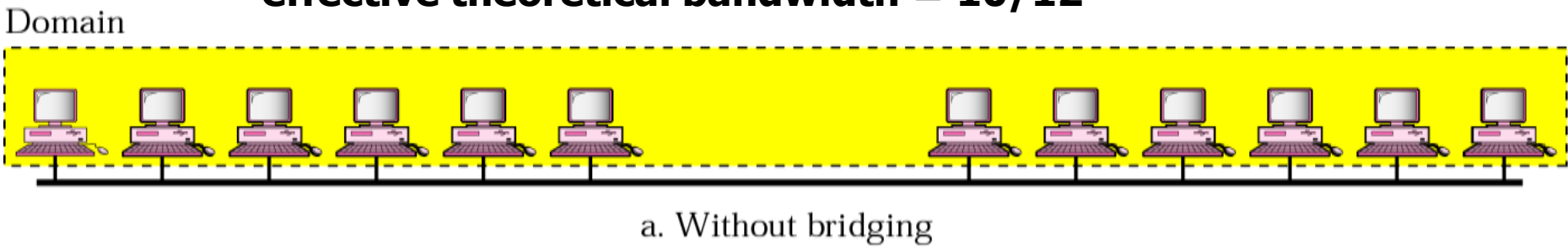


a. First station

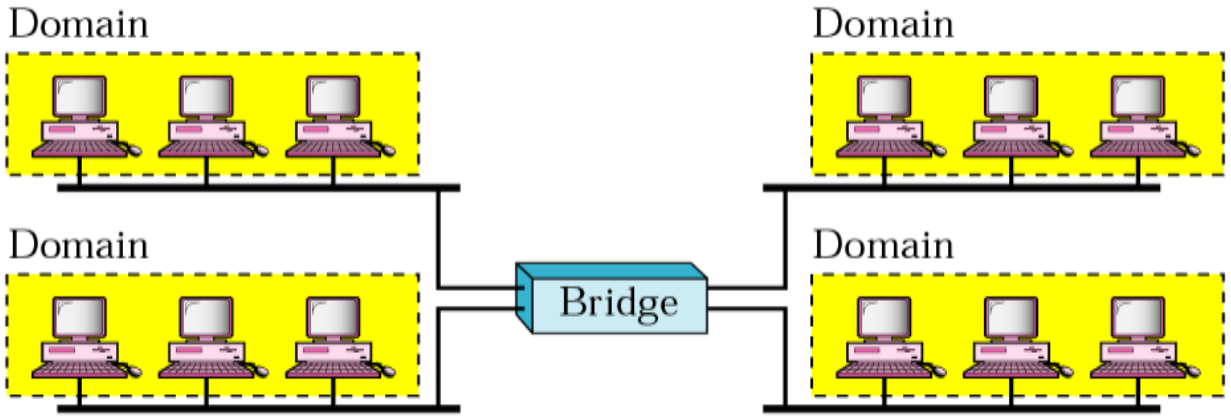
b. Second station

Collision domains in a nonbridged and bridged network

In heavy load, each station has an average effective theoretical bandwidth = 10/12

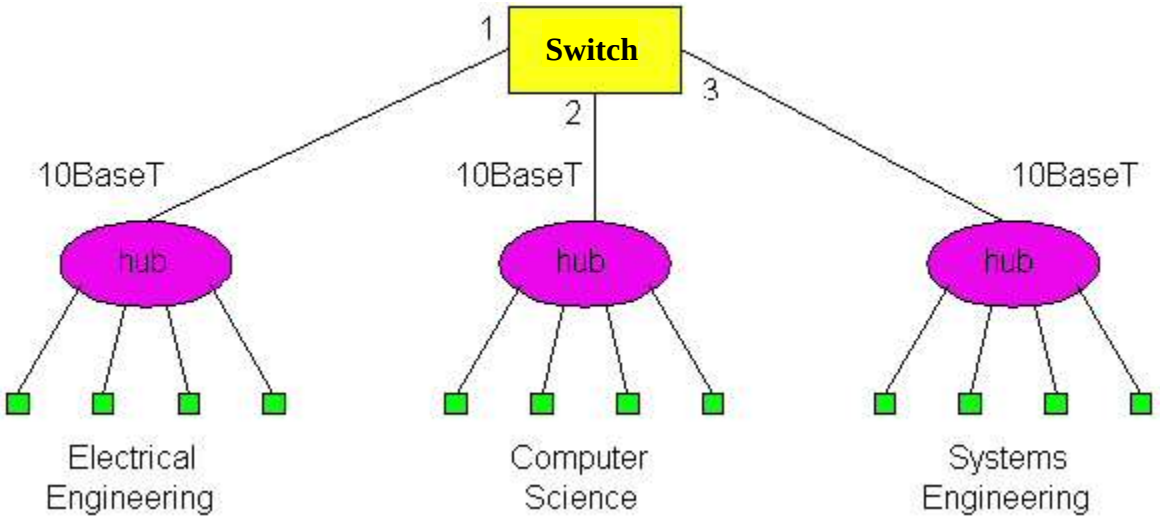


a. Without bridging



b. With bridging

Each station has an average effective bandwidth equal =10/3

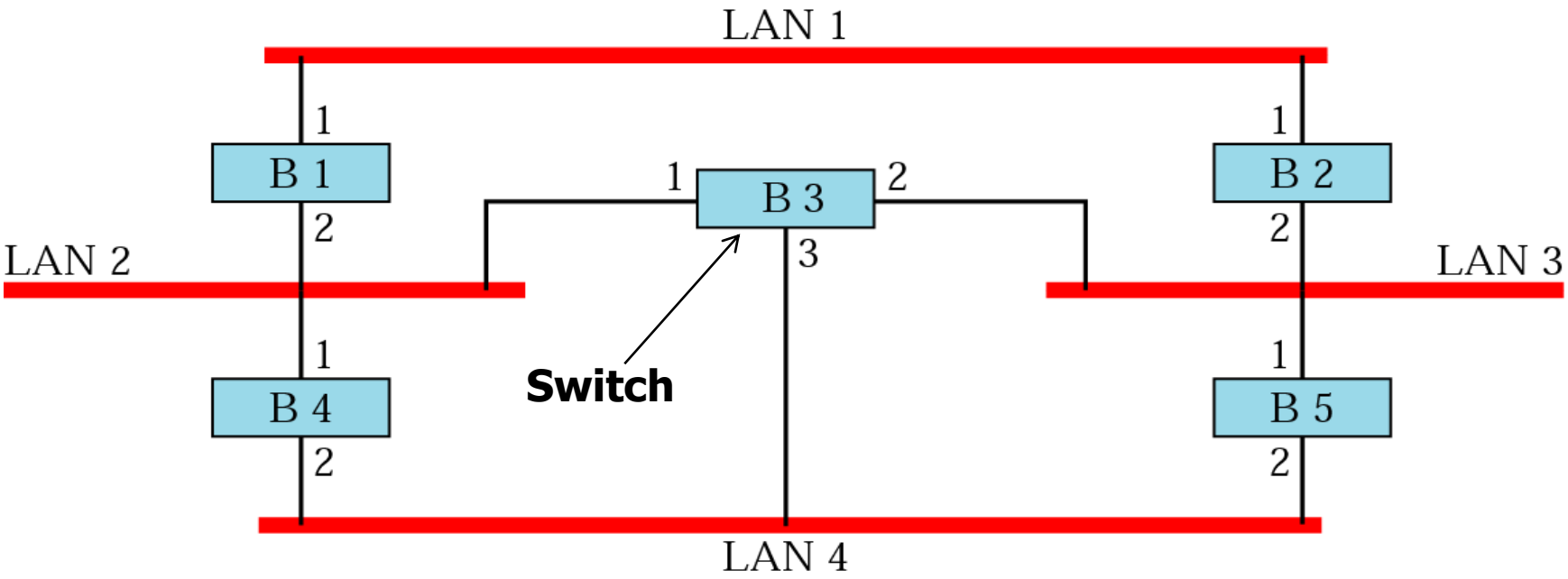


Example:

Three LANs connected through a bridge

Note: here we have *three collision* domains and *a single broadcast* domain

Figure 5.8 Prior to spanning tree application



- When using switches, the network should not contain any loop (there should be exactly one path from any LAN to any other LAN
- Loops can cause number of frames in the LAN to increase *indefinitely*

Effect of Loop of switches

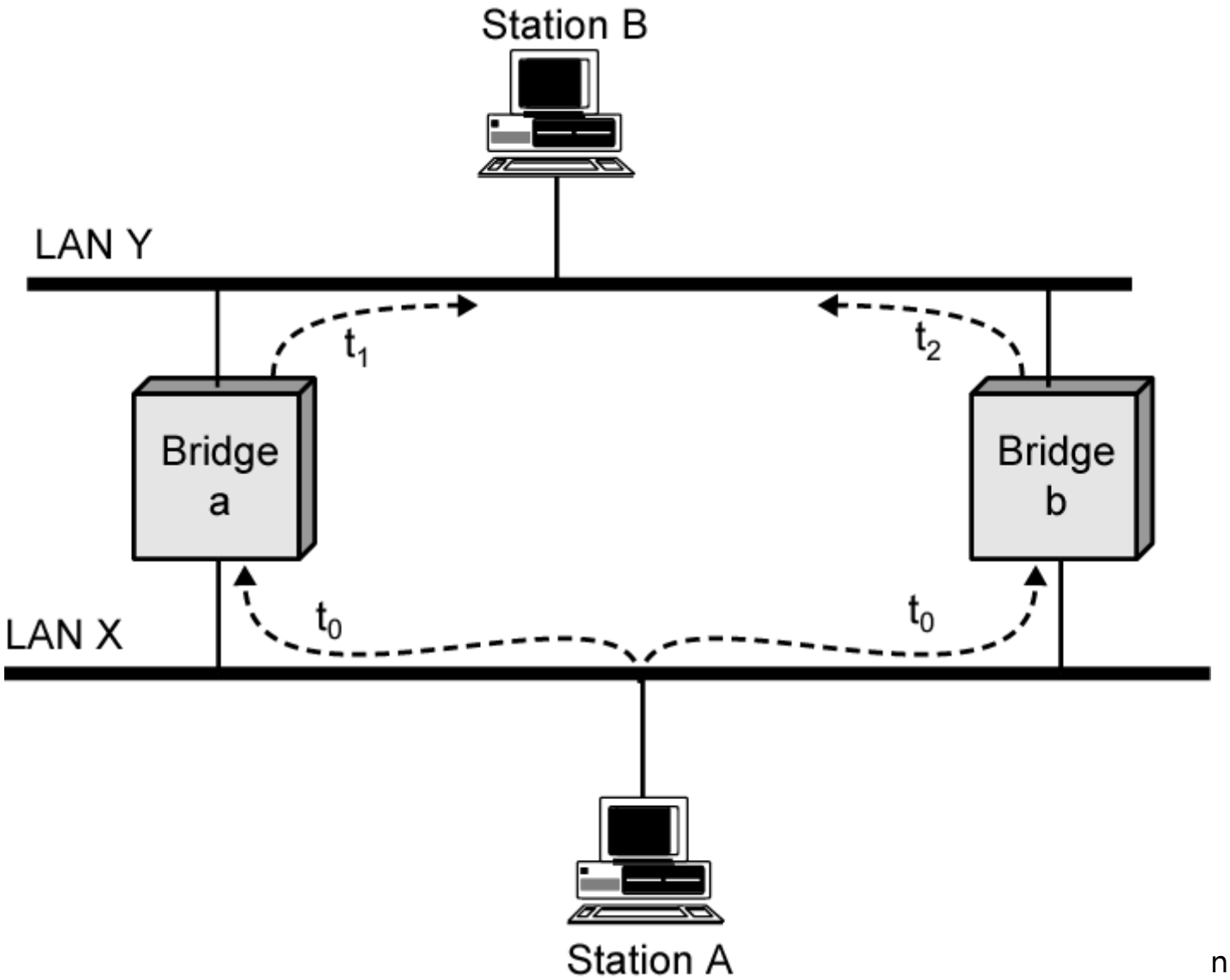
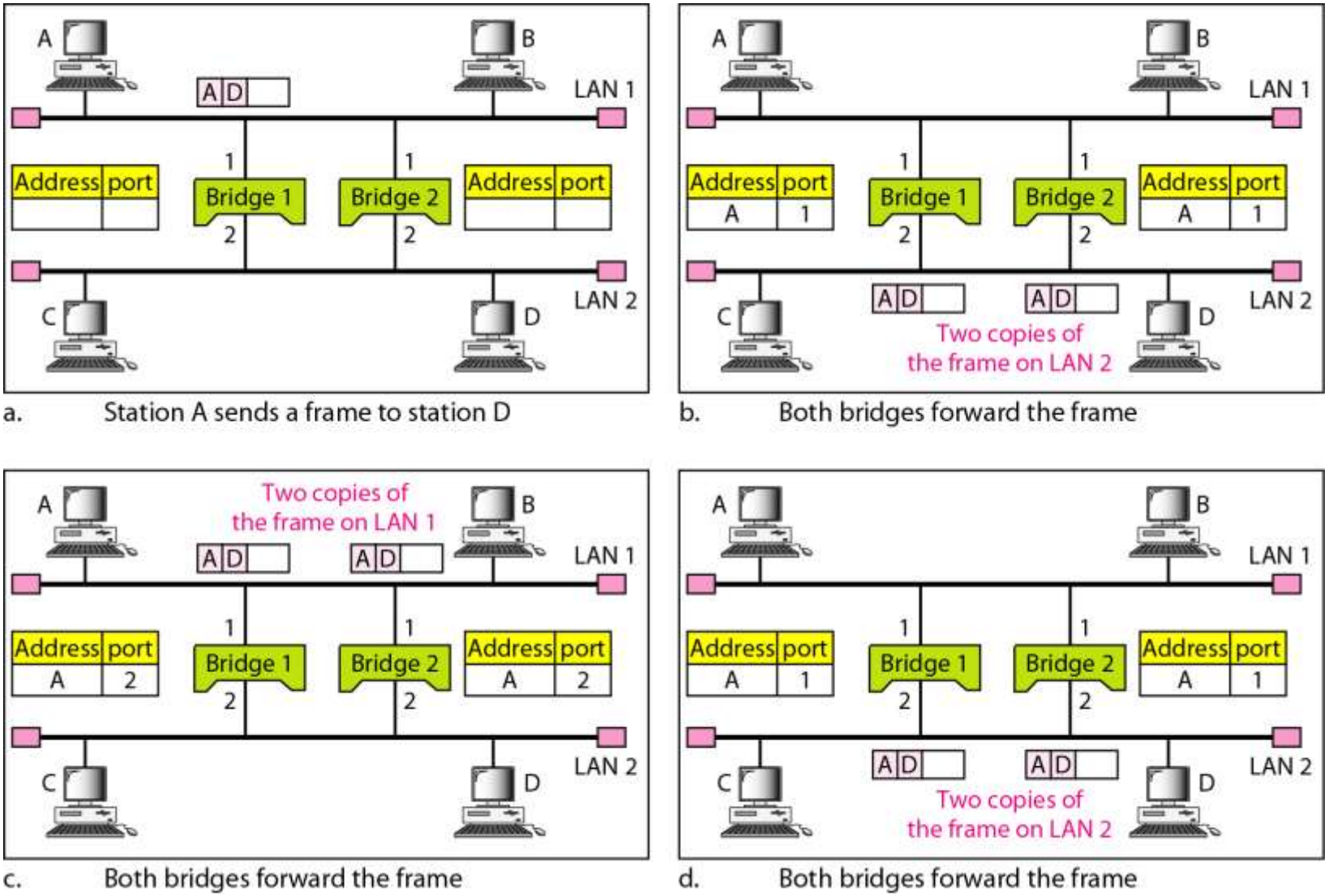


Figure 5.9 *Loop problem in a learning switch*



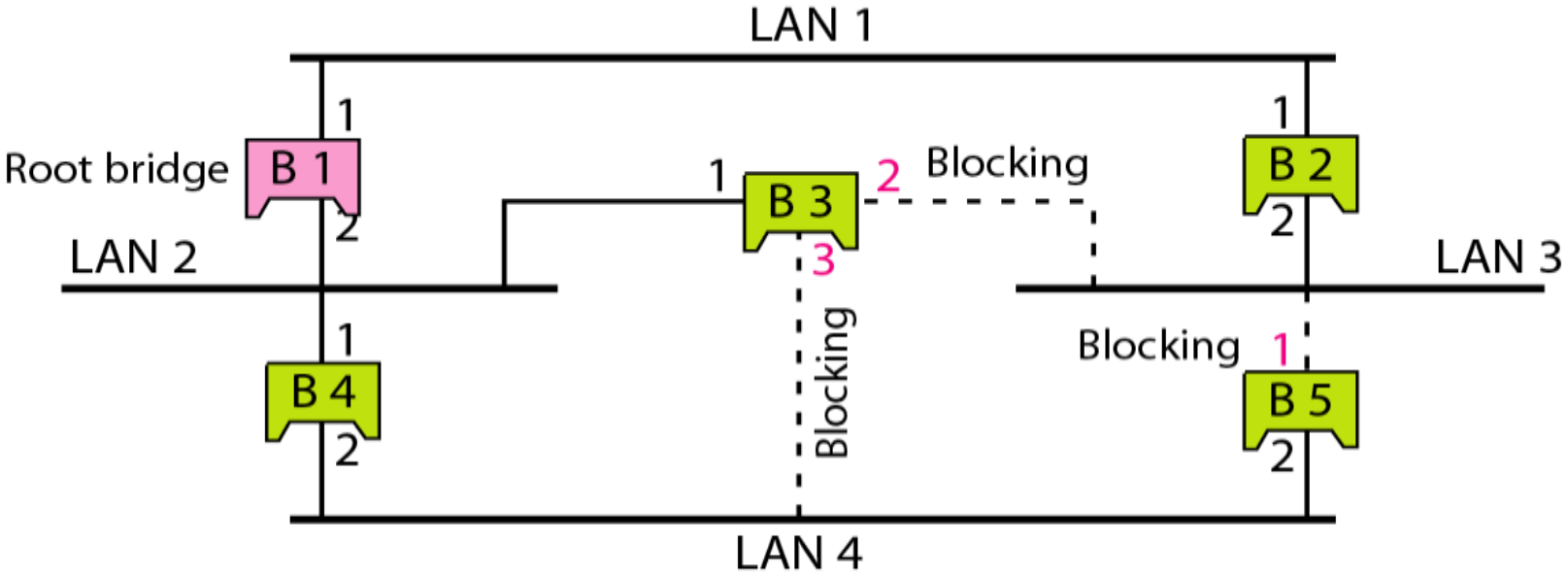
a. Station A sends a frame to station D

b. Both bridges forward the frame

c. Both bridges forward the frame

d. Both bridges forward the frame

Figure 5.10 *Forwarding and blocking ports after using spanning tree algorithm*



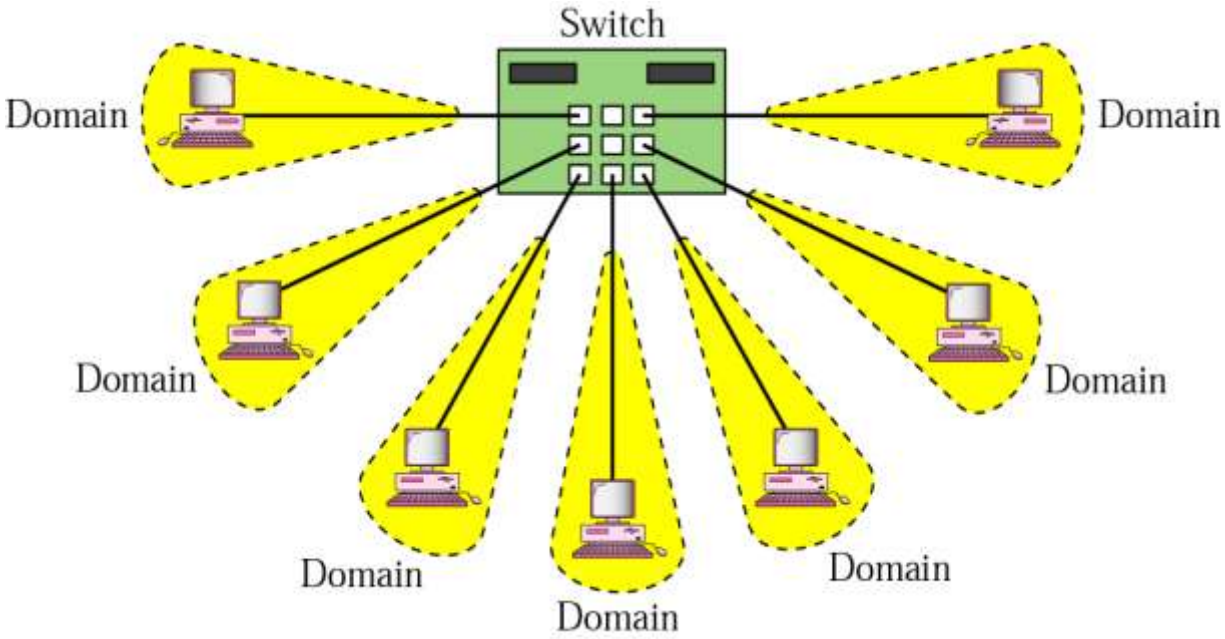
Ports 2 and 3 of bridge B3 are blocking ports (no frame is sent out of these ports). Port 1 of bridge B5 is also a blocking port (no frame is sent out of this port).

- For any connected graph there is a spanning tree that maintains connectivity but contains no closed loops
- Loops are logically disabled by the minimum spanning tree algorithm

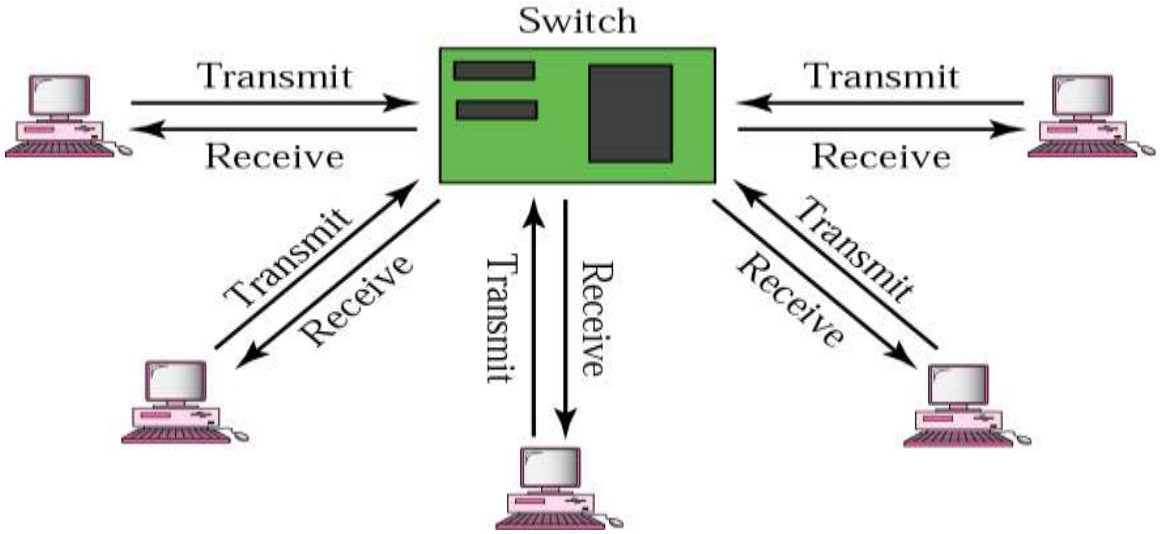
Switches

- N-Port bridge where N is equal to number of stations
- Usually used to connect individual computers not LANs like bridge
- Allows more than one device connected to the switch directly to transmit **simultaneously**
- Can operates in **Full-duplex** mode (can send and receive frames at the same time over the same interface)
- Performs MAC address recognition and frame forwarding in **hardware** (bridge in software)
- *Two types :*
  - ***Store-and-forward***: switch receives the whole a frame on the input line, buffers it briefly , performs error checking, then routes it to the appropriate output line (similar to bridge). **Buffering** will cause some **delay**.
  - **Cut-through**: based on the fact that the destination address appears at the beginning of the MAC frame, so once the address is recognized the frame is directly sent to the appropriate output line if the output buffer is empty (no need to buffer it). ➔ no buffering delay ➔ NO ERROR CHECKING

Isolated collision domains



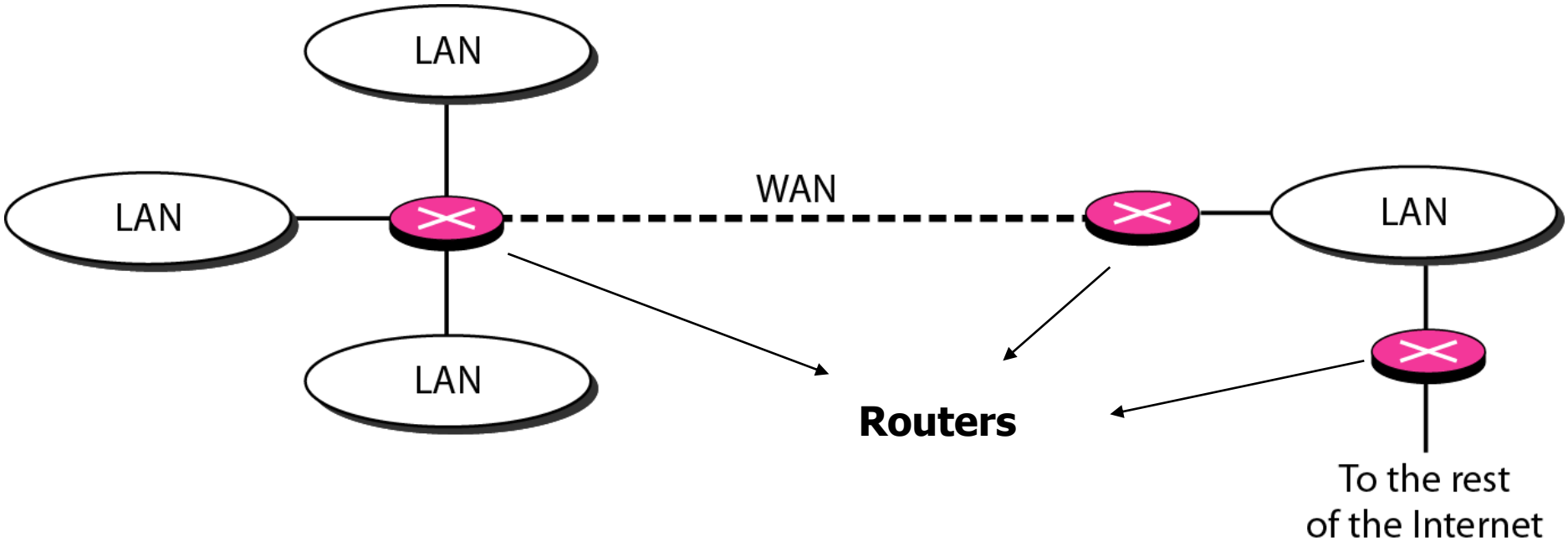
Full-Duplex operation



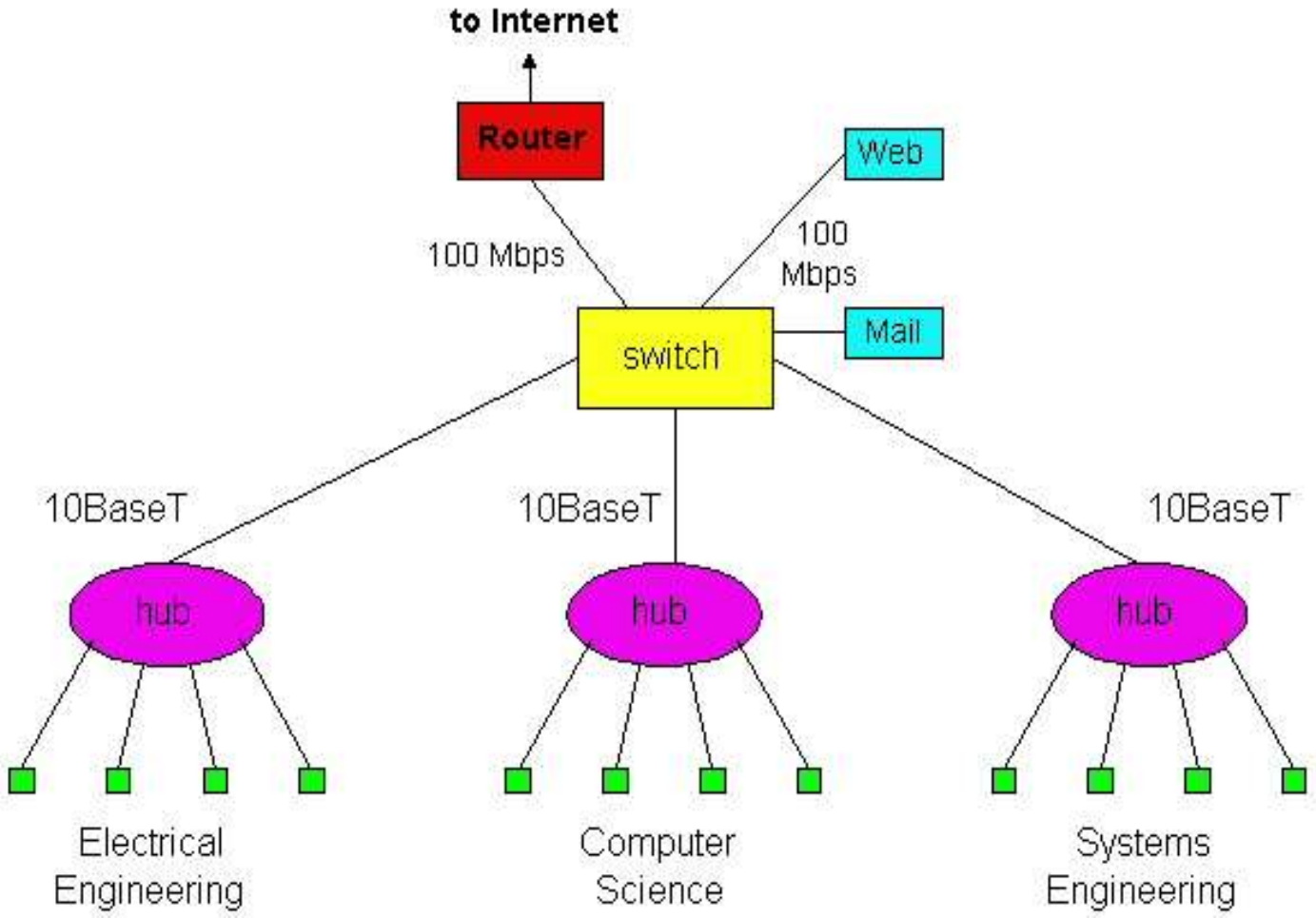
Routers

- Operates at network layer = deals with **packets** not **frames**
- Connect LANs and WANs with similar or different protocols together
- Switches and bridges **isolate collision domains** but forward broadcast messages to **all LANs** connected to them. Routers **isolate both** *collision* domains and *broadcast* domains
- Acts like normal stations on a network, but have **more than one** network address (an address to each connected network)
- Deals with global address (network layer address (IP)) not local address (MAC address)
- Routers **Communicate with each other** and exchange routing information
- Determine best route using **routing algorithm** by special software installed on them
- **Forward traffic if information on destination** is available otherwise **discard** it (not like a switch or bridge)

Figure 5.11 *Routers connecting independent LANs and WANs*



An Institutional Network Using Hubs, Ethernet Switches, and a Router



Summary comparison

	hubs	bridges	routers	switches
traffic isolation	no	yes	yes	yes
plug & play	yes	yes	no	yes
optimal routing	no	no	yes	no
cut through	yes	no	no	yes

Gateways

- A gateway works above the network layer, such as application layer. As a consequence, it is known as a Layer-7 relay.
- The application level gateways can look into the content application layer packets such as email before forwarding it to the other side. This property has made it suitable for use in Firewalls.

Queries

Q1. Why a repeater is called level-1 relay?

Ans: A repeater operates in the physical layer. Data received on one of its ports is relayed on the remaining port bit-by-bit without looking into the contents. That is why repeater is called a level-1 relay.

Q2. What is bridge? How it operates in the internetworking scenario?

Ans: A bridge operates in the Data link layer. It looks into various fields of a frame to take various actions. For example, it looks at the destination address field so that it can forward the frame to a port where destination stations is connected. It also looks at the FCS field to check error in the received frame, it any. A bridge helps to create a network having different collision domains.

Queries

Q3. Why spanning tree topology is necessary for routing using a bridge?

Ans: If there exit more than one path between two LANs through different bridges, there is a possibility of continuous looping of a frame between the LANs. To avoid the loop problem, spanning tree topology is used. It is essentially an overlay of tree topology on the physical graph topology, providing only one path between any two LANs.

Q4. What is discovery frame?

Ans: In the source routing protocol, a host can discover a route by sending a *discovery frame, which spreads through the entire network using all possible paths to the destination. Each frame gradually gathers addresses as it goes. The destination responds to each frame and the source host chooses an appropriate route from these responses.*

Queries

Q5. What limitation of transparent bridge protocol is overcome by the source routing protocol?

Ans: Transparent bridge protocol uses spanning tree algorithm, where a unique path is used for communication between two stations. As a consequence, it does not make use of other paths leading to lesser utilization of network resources. This problem is overcome in source routing algorithm.

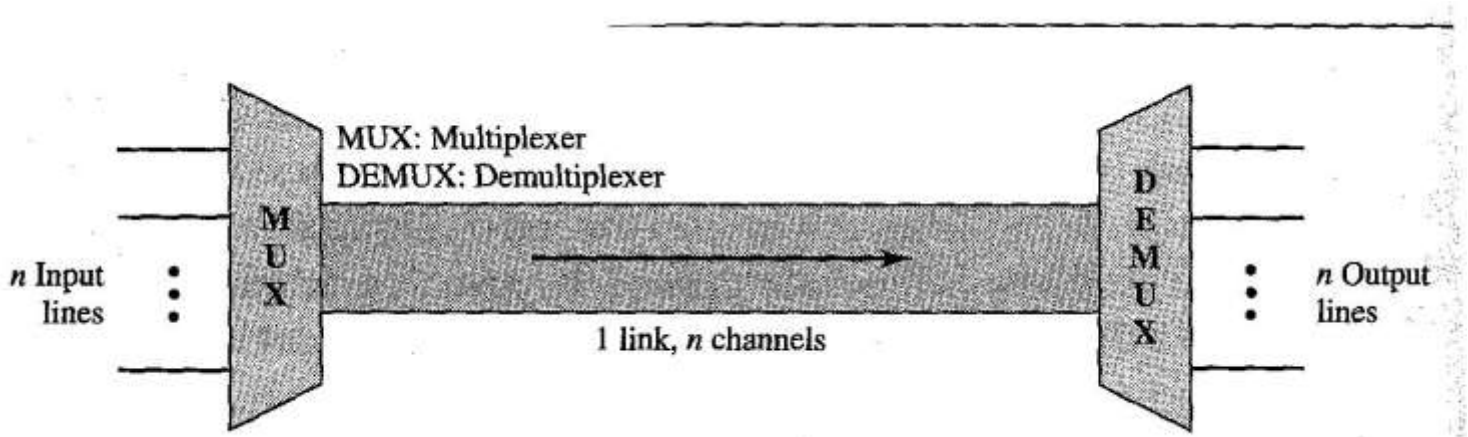
Q6. What limitations of a bridge are overcome by a router?

Ans: A router overcomes the following limitations of a bridge:

- Linking of two dissimilar networks
- Routing data selectively and efficiently
- Enforcement of security
- Vulnerability to broadcast storm

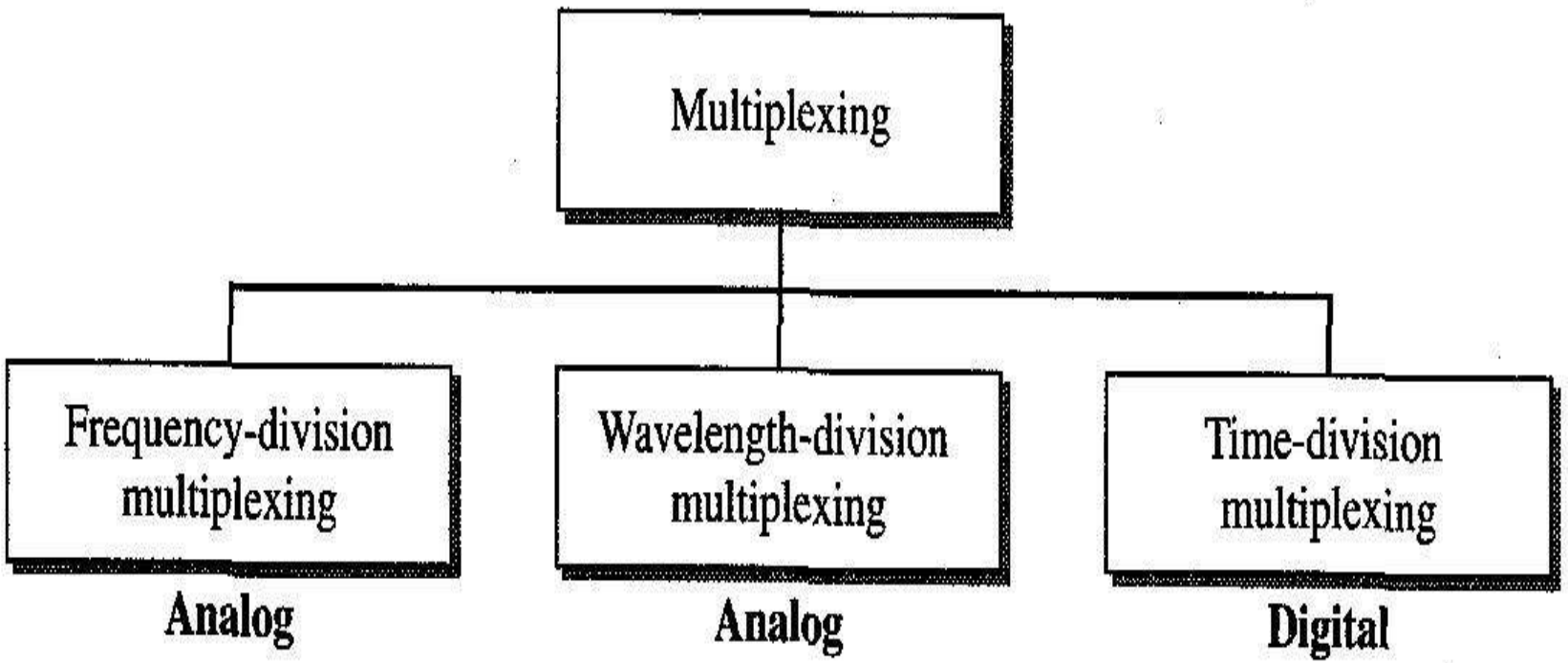
Multiplexing: allows simultaneous transmission of multiple signals across a single data link to gain efficiency

- Bandwidth is one of the most precious resources in communication
- Link refers to the physical path
- Channel refers to portion of a link that carries transmission between a given pair of lines



Categories of multiplexing

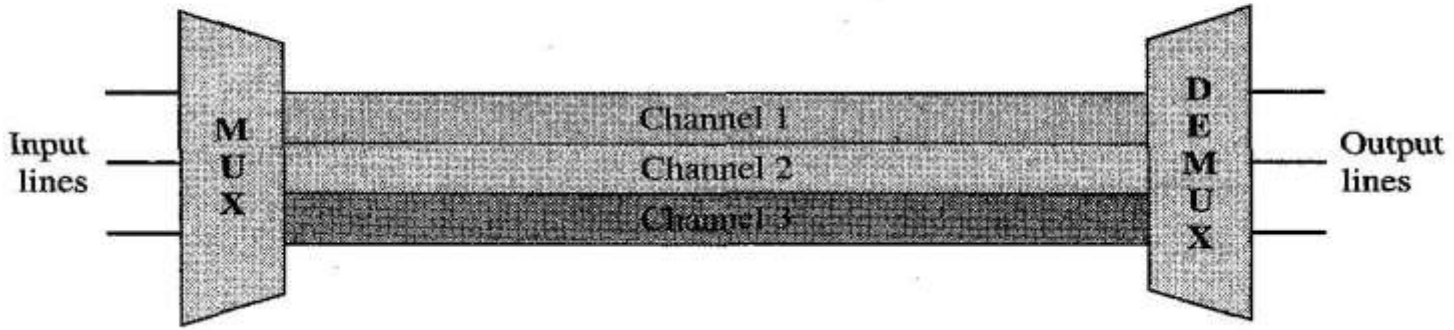
FDM & WDM are for analog signals, while TDM is for digital signals



Frequency Division Multiplexing

- Signals generated by each sending device modulate different carrier frequencies
- These modulated signals then combined into a single composite signal that can be transported by the link

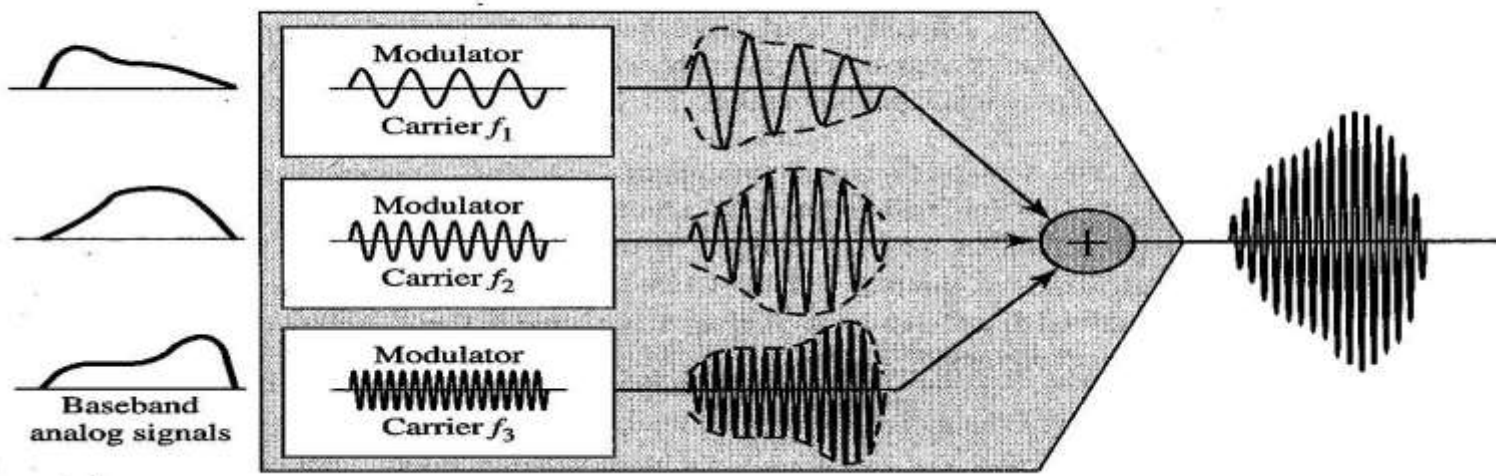
6.3 *Frequency-division multiplexing*



FDM multiplexer view

- Each source generates a signal of a similar frequency range
- These similar signals modulate different carrier frequencies (f1,f2,f3)
- Resulting modulated signals are combined into a single composite signal

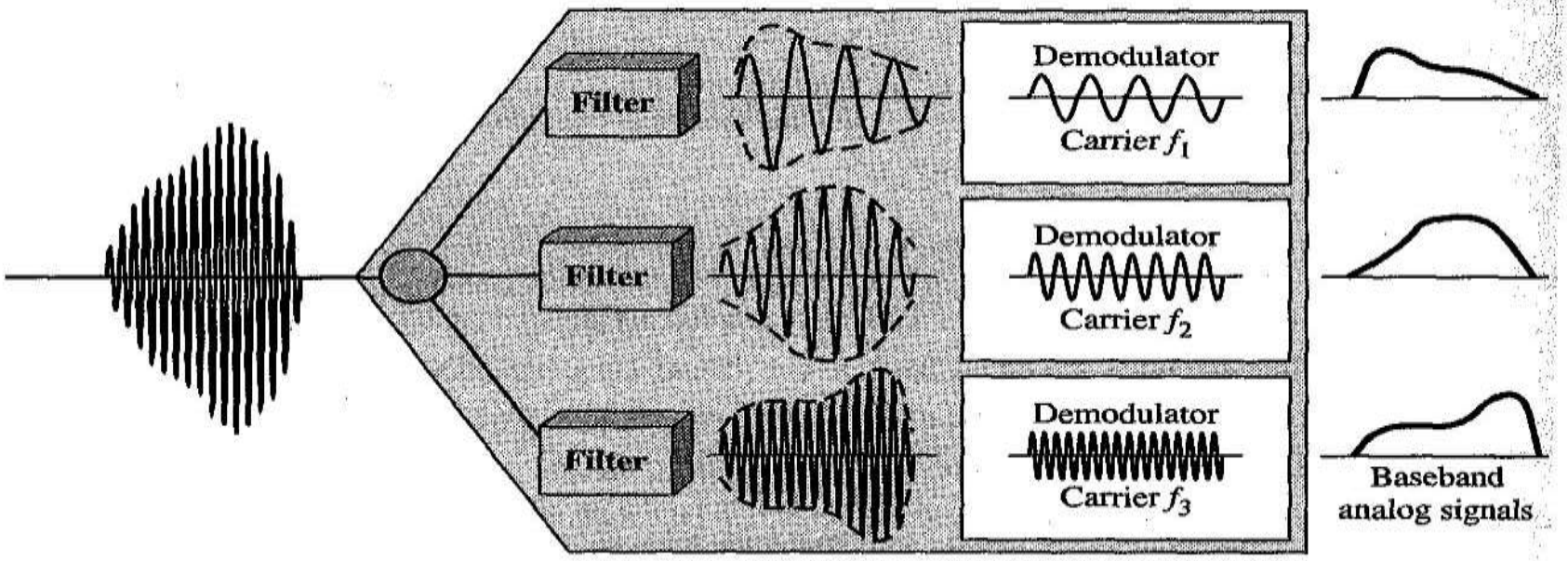
re 6.4 *FDM process*



FDM Demultiplexing

- Filters are used to decompose multiplexed signal into its component signals
- Individual signals are separated from their carriers and passed to output lines

gure 6.5 *FDM demultiplexing example*



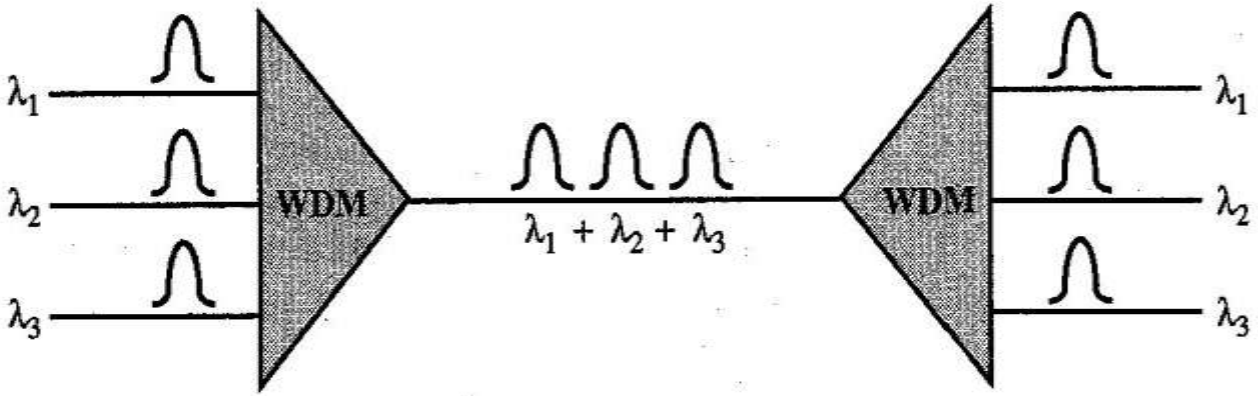
Applications of FDM

- AM Radio: Assigned band from 530 to 1700 KHz. Each AM station needs 10 KHz BW. Each station uses a different carrier frequency.
- Without multiplexing, only one AM station could broadcast to the air
- FM Radio: Wider band of 88 to 108 MHz, each having BW of 200 KHz
- TV Broadcasting: Each TV channel has BW of 6 MHz

Wavelength Division Multiplexing

- Used for high data rate capability of OFC
- It is same as FDM, except that mux & demux involve optical signals through OFC
- Application is SONET (Synchronous Optical Network), a WAN to carry n/w traffic from other WANs

Figure 6.10 *Wavelength-division multiplexing*

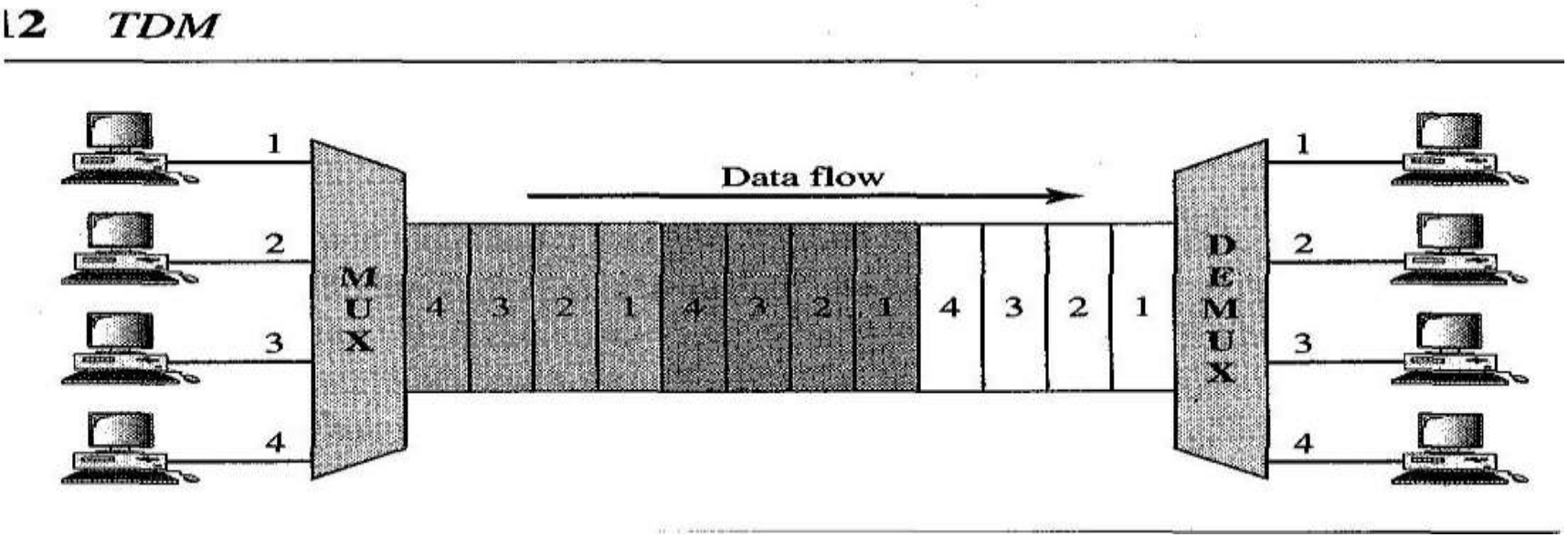


Time Division Multiplexing

It is a digital process in which each process occupies a portion of time in link.

All the data in a message from source 1 always go to one specific destination, be it 1,2,3,4

It is divided in 2 schemes: synchronous & statistical TDM



Unit 7

LAN/WLAN World

- LANs provide connectivity for interconnecting computing resources at the local levels of an organization
- Wired LANs
  - Limitations because of physical, hard-wired infrastructure
- Wireless LANs provide
  - Flexibility
  - Portability
  - Mobility
  - Ease of Installation

Wireless LAN Applications

- Medical Professionals
- Education
- Temporary Situations
- Airlines
- Security Staff
- Emergency Centers

IEEE 802.11 Wireless LAN Standard

- In response to lacking standards, IEEE developed the first internationally recognized wireless LAN standard – IEEE 802.11
- IEEE published 802.11 in 1997, after seven years of work
- Scope of IEEE 802.11 is limited to Physical and Data Link Layers.

Benefits of 802.11 Standard

- Appliance Interoperability
- Fast Product Development
- Stable Future Migration
- Price Reductions
- The 802.11 standard takes into account the following significant differences between wireless and wired LANs:
  - Power Management
  - Security
  - Bandwidth

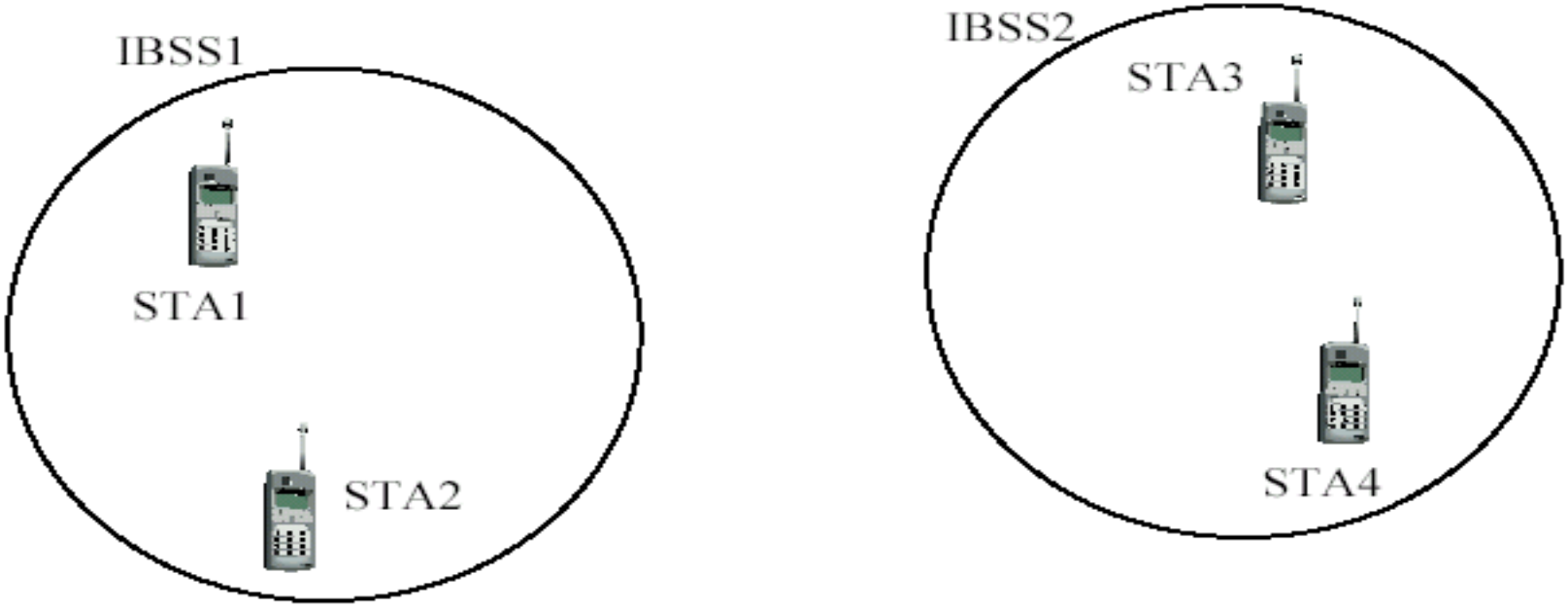
IEEE 802.11 Terminology

- Access point (AP): A station that provides access to the DS.
- Basic service set :

  a set is of stationary or mobile wireless stations and an optional central base station, known as the access point (AP).
- Distribution system (DS): A system used to interconnect a set of BSSs to create an ESS.
  - DS is implementation-independent. It can be a wired 802.3 Ethernet LAN, 802.4 token bus, 802.5 token ring or another 802.11 medium.
- Extended service set (ESS):Two or more BSS interconnected by DS
  - extended service set uses two types of stations: mobile and stationary
  - The mobile stations are normal stations inside a BSS. The stationary stations are AP stations that are part of a wired LAN.

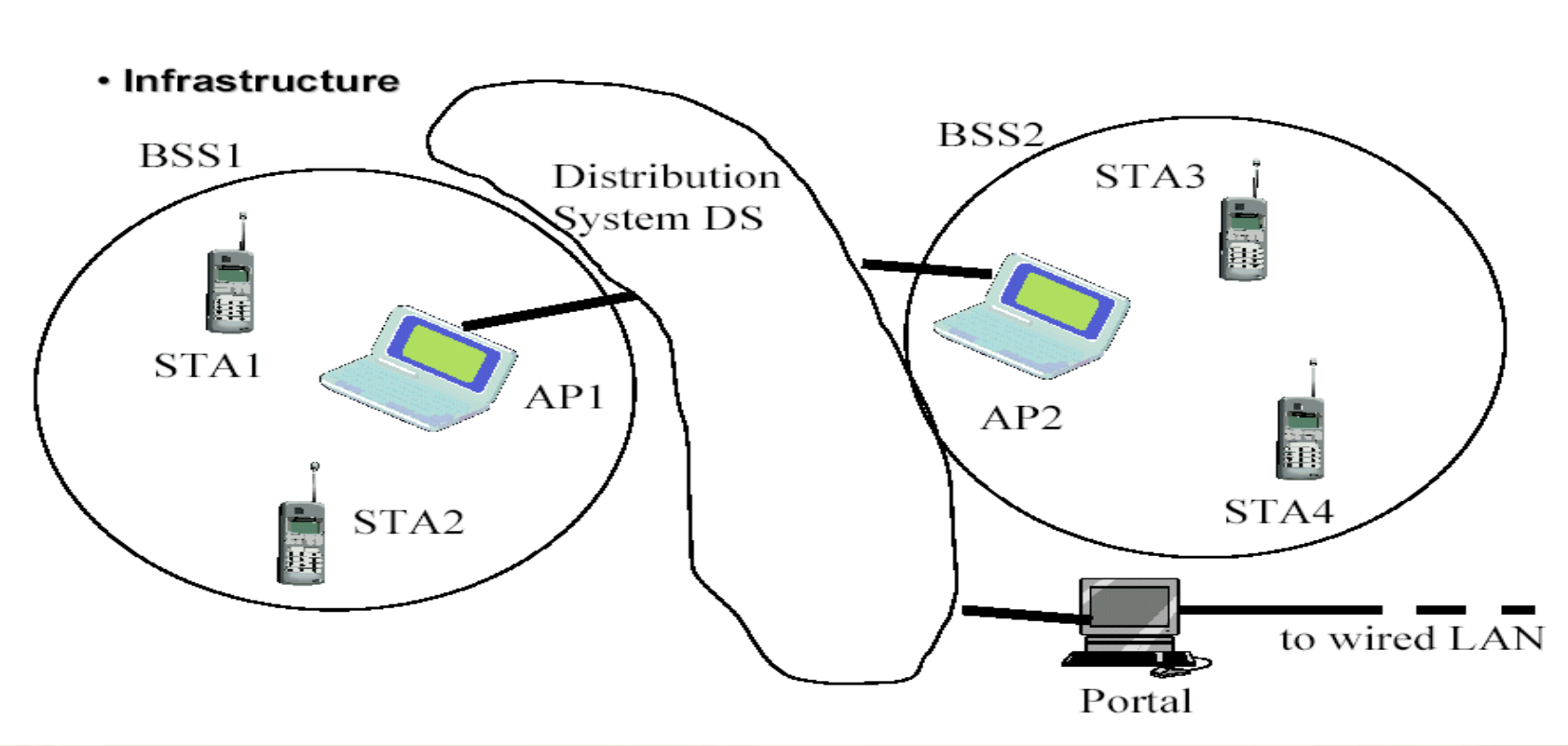
WLAN Topology
Ad-Hoc Network

- **Ad-Hoc-Network**



The BSS without an AP is a stand-alone network and cannot send data to other BSSs. they can locate one another and agree to be part of a BSS.

WLAN Topology Infrastructure

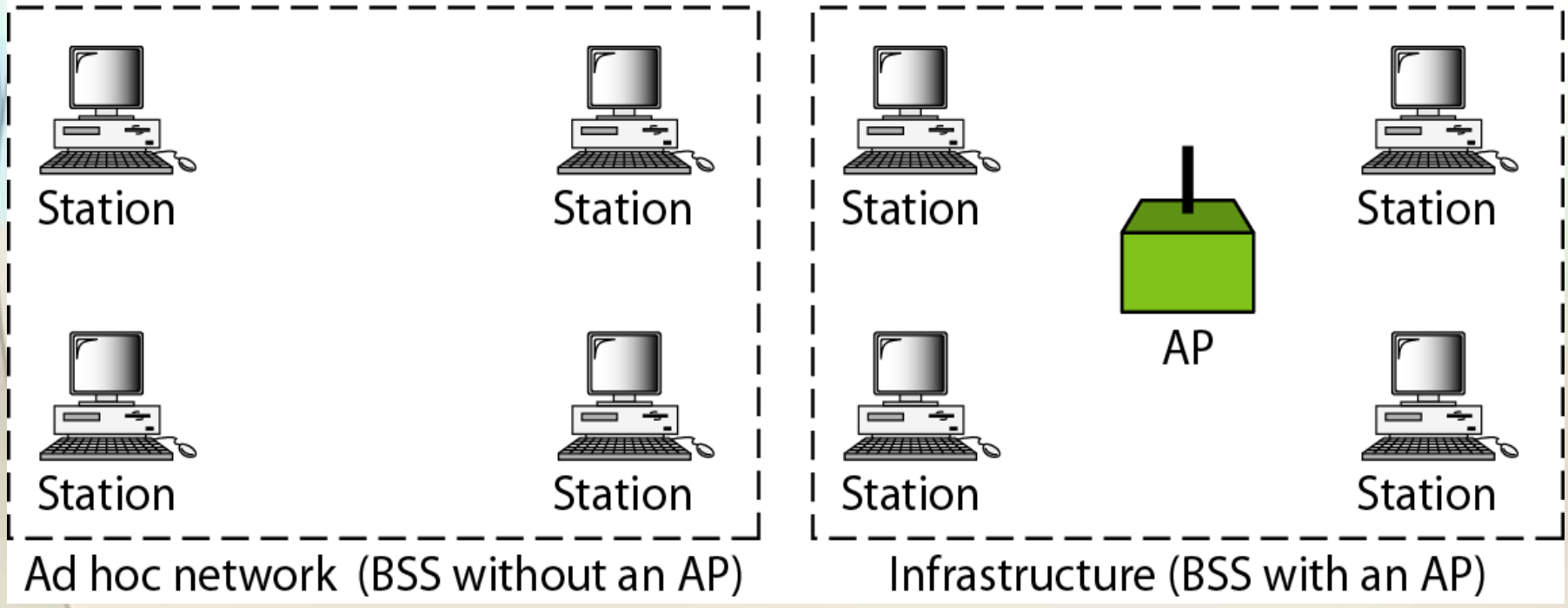


EX: cellular network if we consider each BSS to be a cell and each AP to be a base station.

Basic service sets (BSSs)

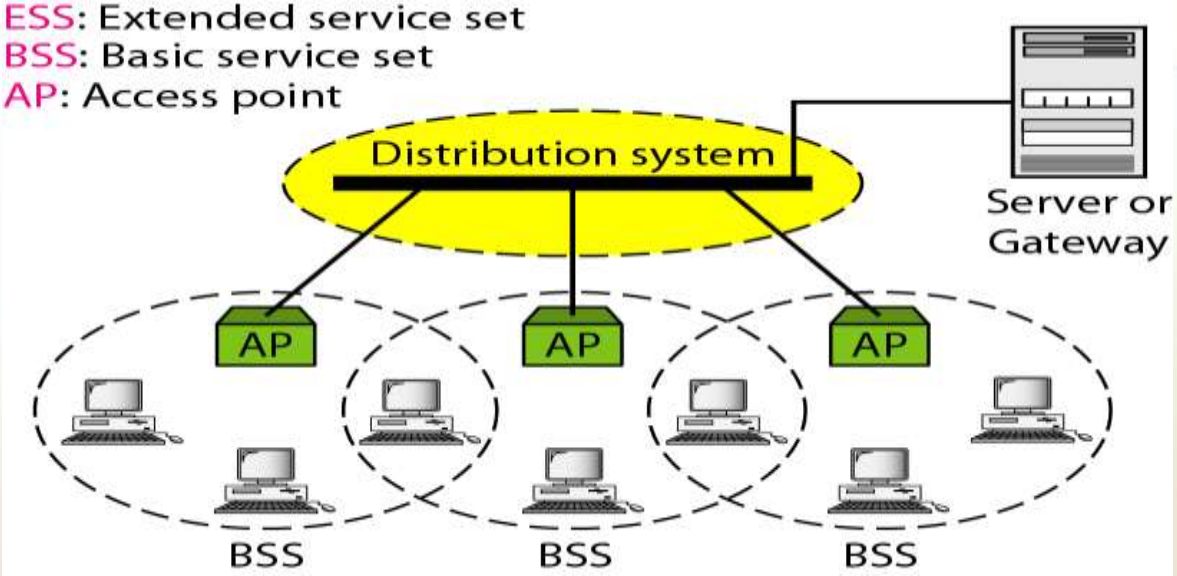
BSS: Basic service set

AP: Access point



Distribution of Messages

- Distribution service (DS)
  - Used to exchange MAC frames from station in one BSS to station in another BSS



- When BSSs are connected, the stations within reach of one another can communicate without the use of an AP.
- Note that a mobile station can belong to more than one BSS at the same time

Station Types

IEEE 802.11 defines three types of stations based on their mobility in a wireless LAN:

- no-transition

  A station is either stationary (not moving) or moving only inside a BSS

- BSS-transition

  station can move from one BSS to another, but the movement is confined inside one ESS.

- and ESS-transition mobility.

  A station can move from one ESS to another

IEEE 802.11 Medium Access Control

- MAC layer covers three functional areas:
  - Reliable data delivery
  - Access control
  - Security

MAC Sublayer

IEEE 802.11 defines two MAC sublayers:

- the distributed coordination function (DCF).
- and point coordination function (PCF).

MAC Sublayer

- Distributed Coordination Function (DCF)
  - Distributed access protocol
  - Contention-Based
  - Makes use of CSMA/CA rather than CSMA/CD for the following reasons:
  - Wireless LANs cannot implement *CSMA/CD for three reasons:*

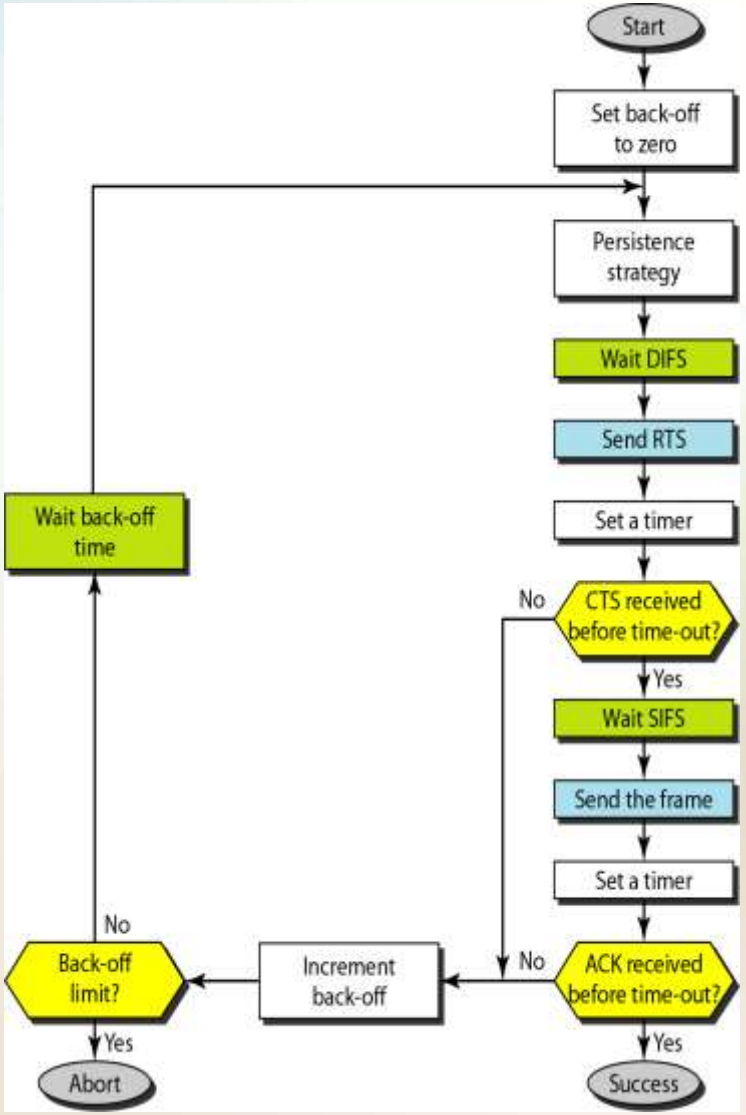
1. For collision detection a station must be able to send data and receive collision signals at the same time(costly stations and increased bandwidth requirements).
2. Collision may not be detected because of the hidden station problem.
3. The distance between stations may result in Signal fading which prevent a station at one end from hearing a collision at the other end.

  - Suited for ad hoc network and ordinary asynchronous traffic

CSMAICA in wireless LAN

1. station senses the medium(checking the energy level
   a. uses a persistence strategy with back-off
      until the channel is idle.
   b. if idle channel , waits for of time called
      distributed interframe space (DIFS);
   then sends a request to send (RTS) Control frame .
2. the destination station receive RTS and waits
   for short interframe space (SIFS), than send
clear to send (CTS) control frame,(ready to receive data)

3. The source station sends data after waiting an
   amount of time equal to SIFS.
4. The destination station, after waiting for time
   equal to SIFS, sends an acknowledgment



collision avoidance CSMAICA

- network allocation vector (NAV) used to avoid collision.
  - RTS frame includes the duration of time that it needs to occupy the channel.
  - stations affected by this transmission create a timer called (NAV)
  - the network allocation vector (NAV) shows the time must pass before these stations allowed to check the channel for idleness.
- there is no mechanism for collision detection, if the sender has not received a CTS frame from the receiver, assumes there has been a collision ,the sender tries again.

MAC Sublayer

- Point Coordination Function (PCF)
  - an optional access method on top of DCF
  - Implemented in an infrastructure network (not in an ad hoc network).
  - Contention-Free
  - mostly for time-sensitive transmission services like voice or multimedia.
  - The AP performs polling stations one after another, sending any data they have to the AP.

MAC Sublayer

- To give priority to PCF over DCF, another set of interframe spaces has been defined:

❖ SIFS - Short Inter Frame Spacing

  ❖ Used for immediate response actions e.g ACK, CTS

❖ PIFS - Point Inter Frame Spacing

  ❖ PIFS (PCF IFS) is shorter than the DIFS.

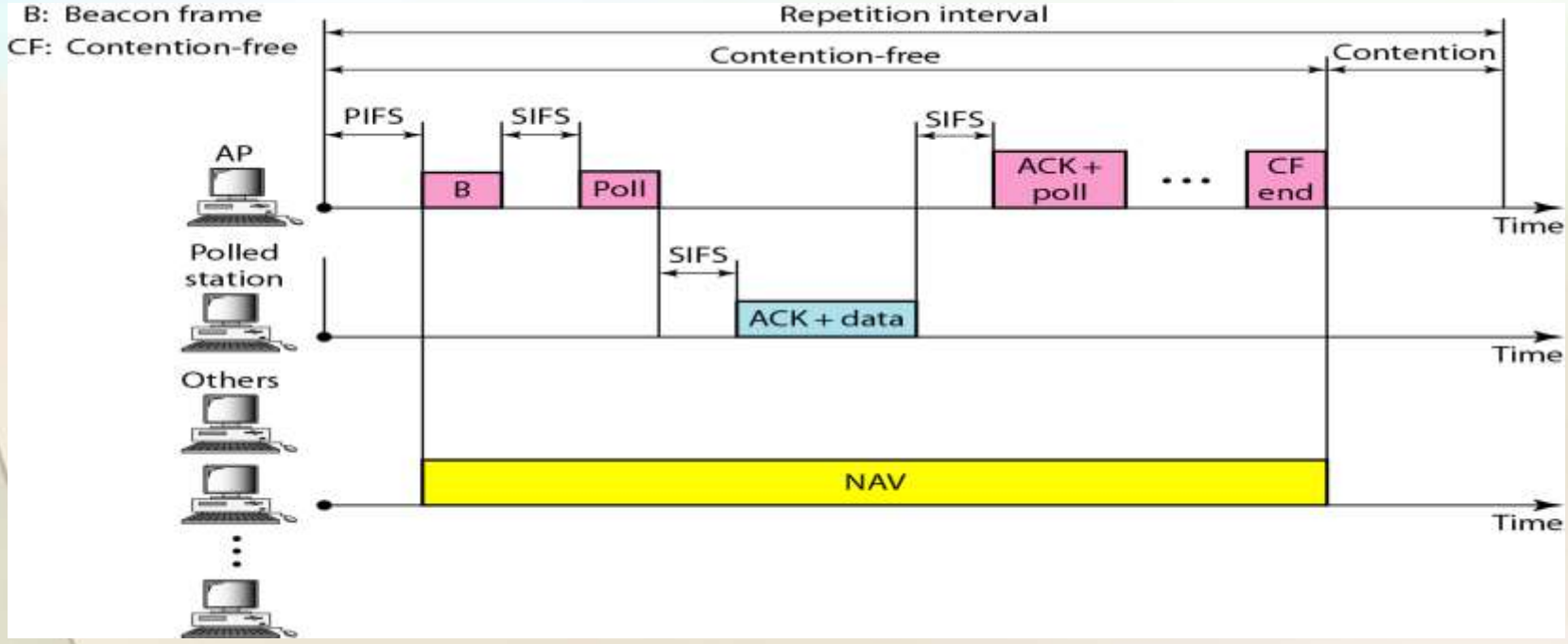
- if, at the same time, a station wants to use only DCF and an AP wants to use PCF, the AP has priority.

MAC Sublayer

- Repetition interval has been designed to cover both contention-free (PCF) and contention-based (DCF) traffic to allow DCF accessing the media.
- The repetition interval starts with control frame, called a beacon frame.
- When the stations hear the beacon frame, they start their NAV for the duration of the contention-free period of the repetition interval.

MAC Sublayer

- repetition interval used by the PC (point controller) stations.
- At the end of the contention-free period, the PC sends a CF end (contention-free end) frame to allow the contention-based stations to use the medium.

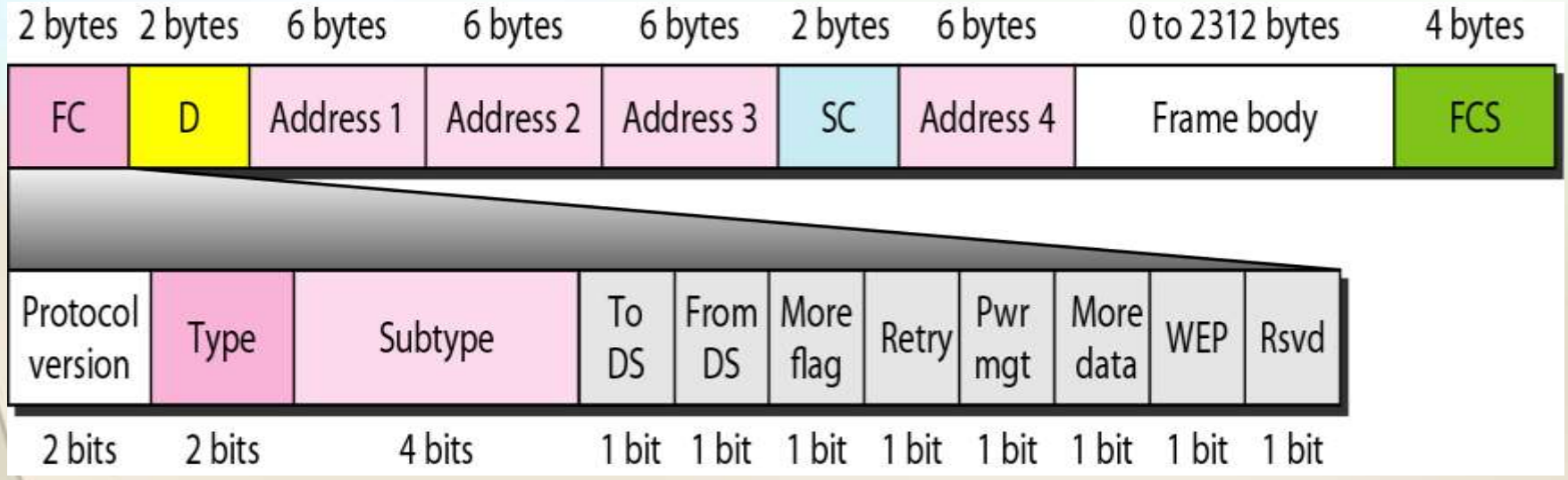


Fragmentation

- The wireless environment is very noisy.
- corrupt frame has to be retransmitted.
- Fragmentation is recommended.
  - the division of a large frame into smaller ones.
- It is more efficient to resend a small frame than a large one.

MAC Frame Format

- The MAC layer frame consists of nine fields



MAC Frame Format

- Frame control : 2 bytes long and defines the type of frame and some control information.

- D: In all frame types except one, this field defines the duration of the transmission that is used to set the value of NAV. In one control frame, this field defines the frame ID.

- Addresses: There are four address fields, each 6 bytes long. The meaning of each address field depends on the value of the *To DS and From DS subfields* .

MAC Layer Frames

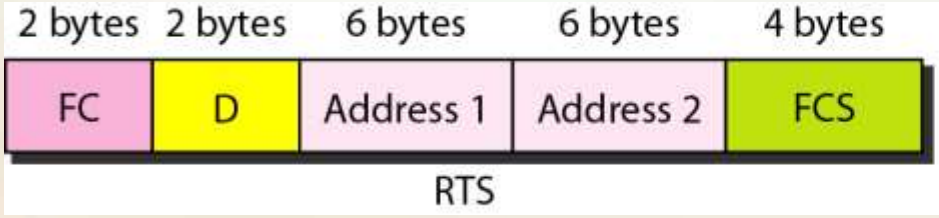
- Sequence control: This field defines the sequence number of the frame to be used in flow control.
- Frame body: This field can be between 0 and 2312 bytes, it contains information based on the type and the subtype defined in the FC field.
- FCS: The FCS field is 4 bytes long and contains a CRC-32 error detection sequence.

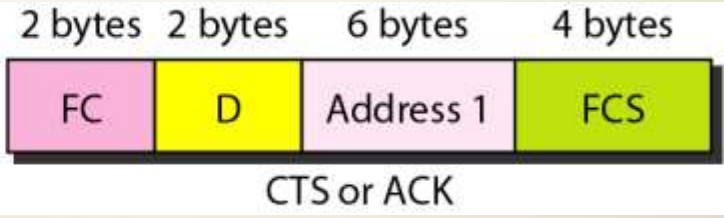
Frame Types

- IEEE 802.11 has three categories of frames:
  - management frames:

    used for the initial communication between stations and access points.
  - control frames.

    used for accessing the channel and acknowledging frames





  - data frames.

    Data frames are used for carrying data and control information.

Frame Types

Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 14.2)
To DS	Defined later
From DS	Defined later
More flag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

Addressing Mechanism

- IEEE 802.11 addressing mechanism specifies four cases defined by the value of the two flags in the FC field, *To DS and From DS.*

Addressing Mechanism

- Case 1: 00, To DS = 0 and From DS = 0
  - This means that the frame is not going to a distribution system and is not coming from a distribution system.
  - The ACK frame should be sent to the original sender.

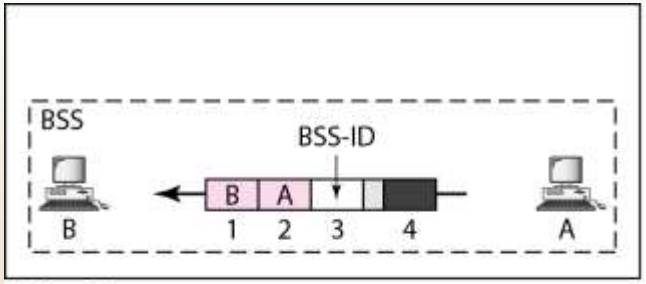
- Case 2: 01, In this case, To DS = 0 and From DS = 1.
  - This means that the frame is coming from a distribution system (coming from an AP).
  - The ACK should be sent to the AP. The addresses are as address 3 contains the original sender of the frame (in another BSS).

Addressing Mechanism

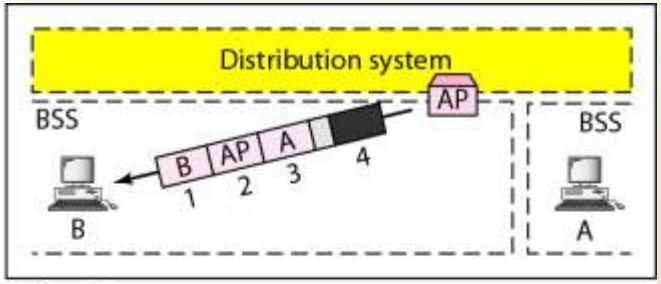
- Case 3: 10, To DS =1 and From DS =O.
  - This means that the frame is going to a distribution system (frame is going from a station to an AP)
  - The ACK is sent to the original station. address 3 contains the final destination of the frame (in another BSS).
- o Case 4:11, To DS =1 and From DS =1.
  - This is the case in which the distribution the frame is going from one AP to another AP in a wireless distribution system.
  - We do not need to define addresses if the distribution system is a wired LAN because the frame in these cases has the format of a wired LAN frame (Ethernet, for example).
  - Here, we need four addresses to define the original sender, the final destination, and two intermediate APs.

Addressing Mechanism

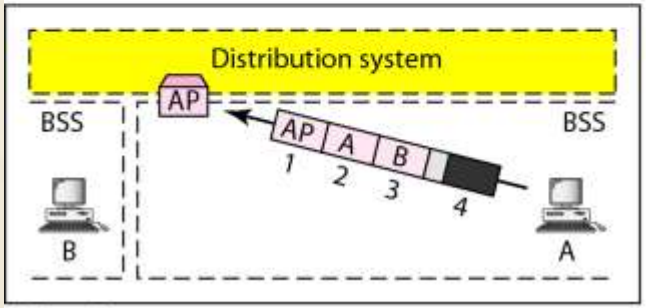
To DS	*From DS*	*Address 1*	*Address 2*	*Address 3*	*Address 4*
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source



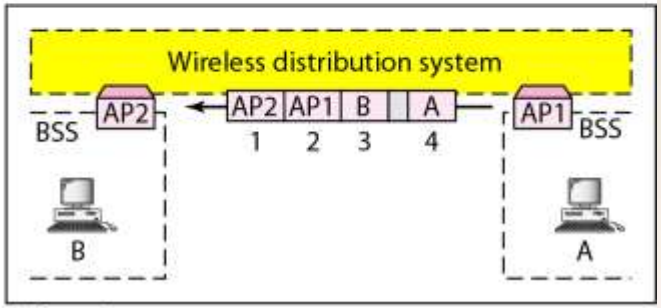
a. Case 1



b. Case 2

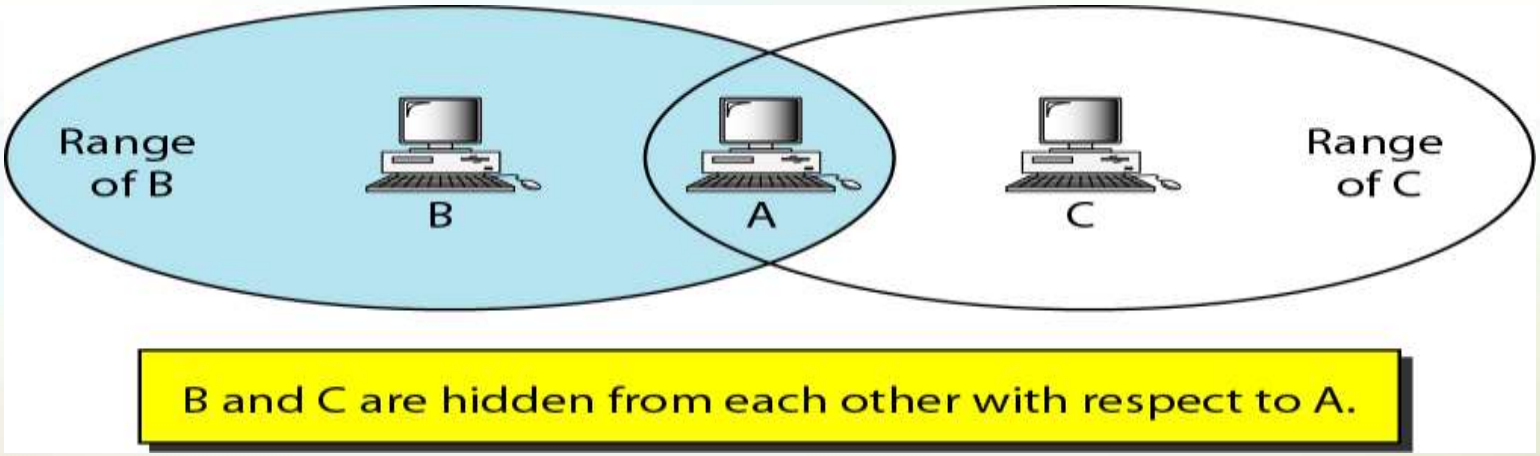


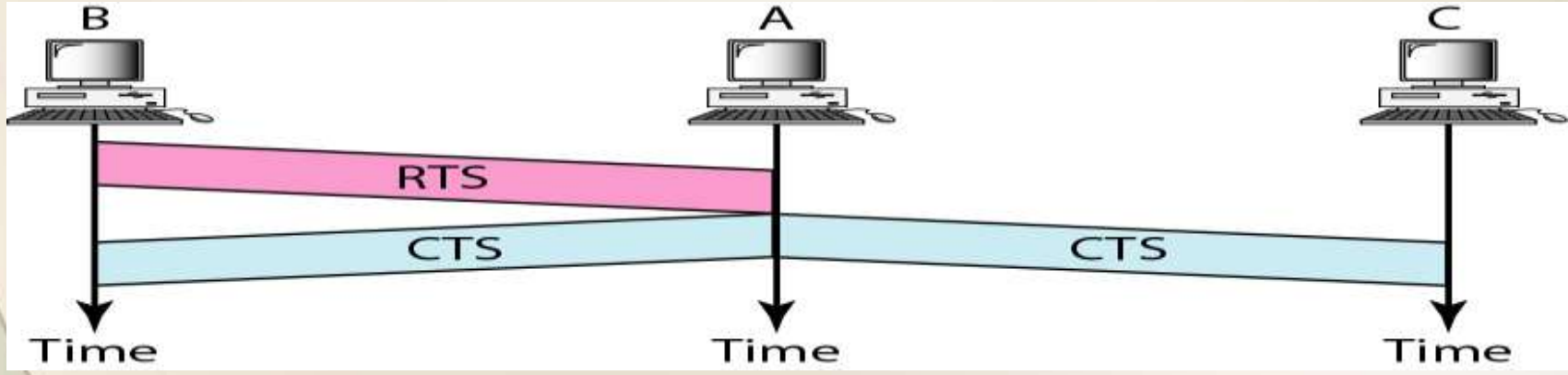
c. Case 3



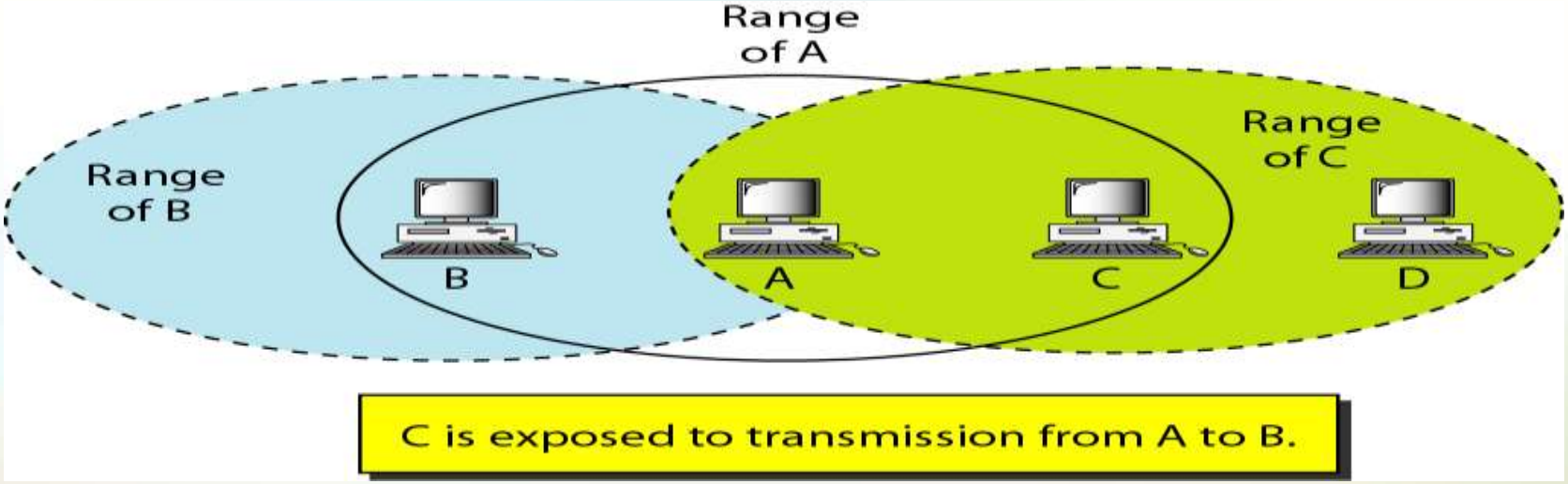
d. Case 4

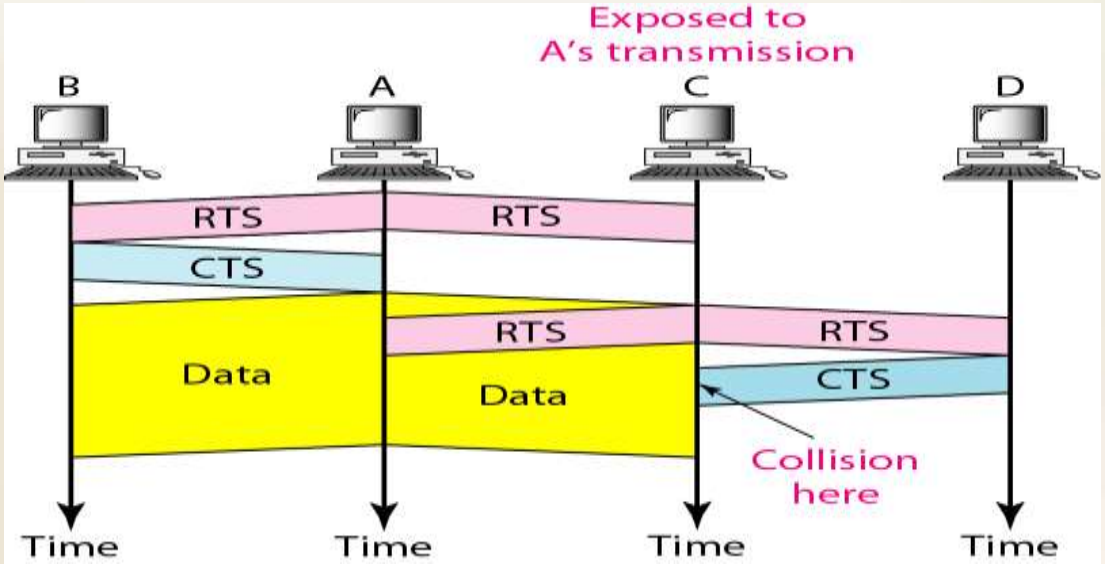
Hidden Station Problem





Exposed Station Problems



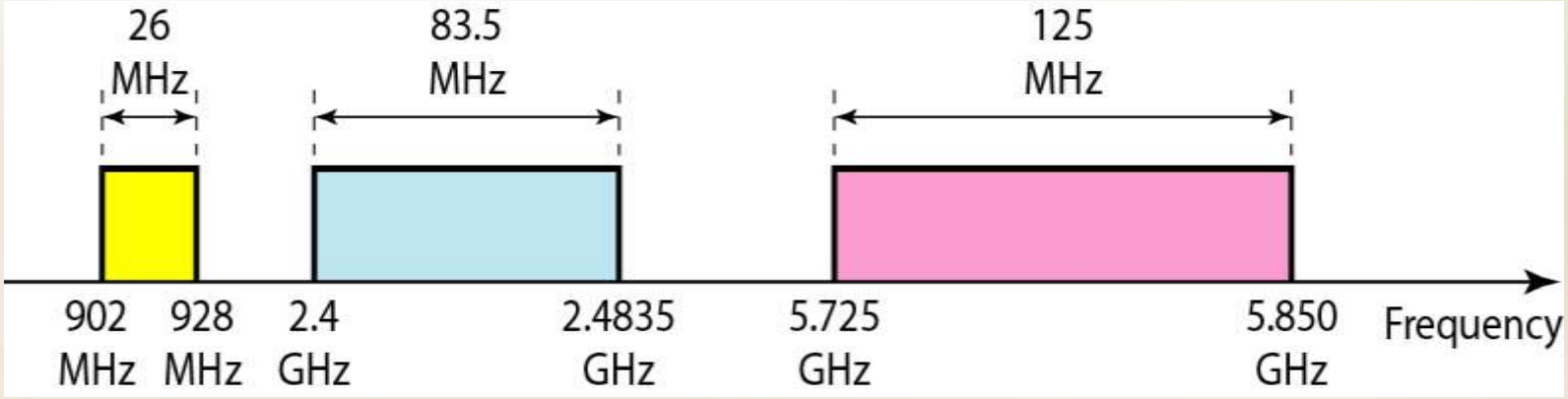


Physical Media Defined by Original 802.11 Standard

IEEE	*Technique*	*Band*	*Modulation*	*Rate (Mbps)*
802.11	FHSS	2.4 GHz	FSK	1 and 2
	DSSS	2.4 GHz	PSK	1 and 2
		Infrared	PPM	1 and 2
802.11a	OFDM	5.725 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.4 GHz	PSK	5.5 and 11
802.11g	OFDM	2.4 GHz	Different	22 and 54

Industrial-Scientific-Medical (ISM) band

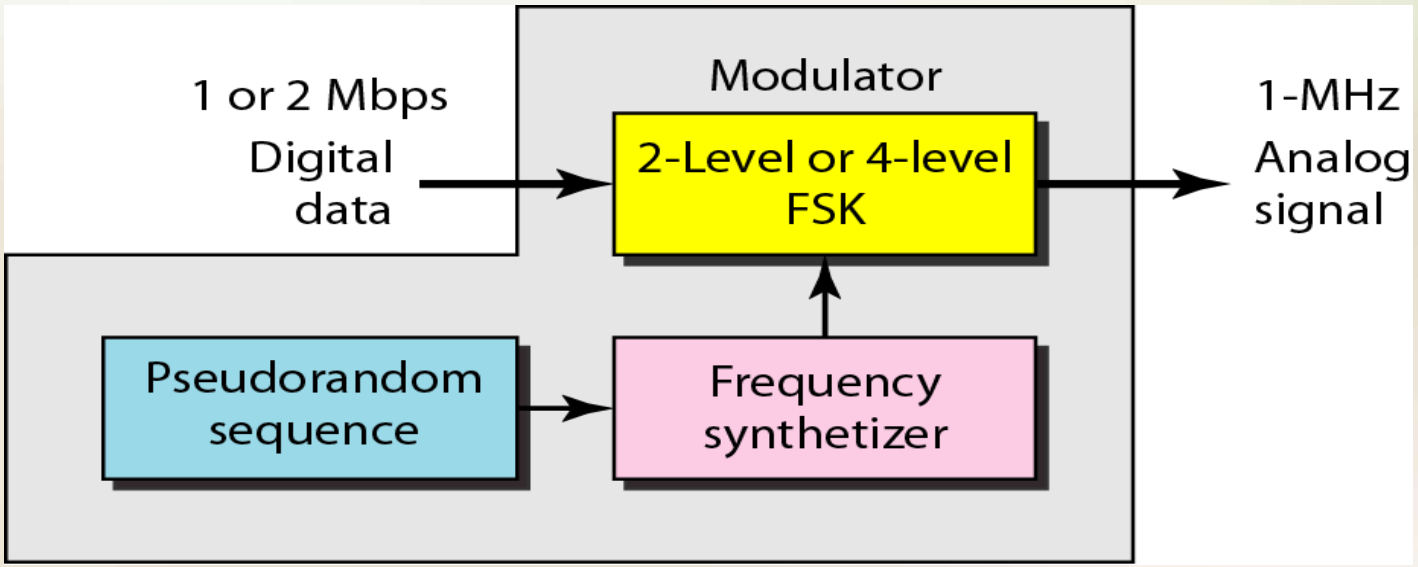
- The 2.4GHz ISM band is divided into 79 bands of 1MHz



Physical layer of IEEE 802.11 FHSS

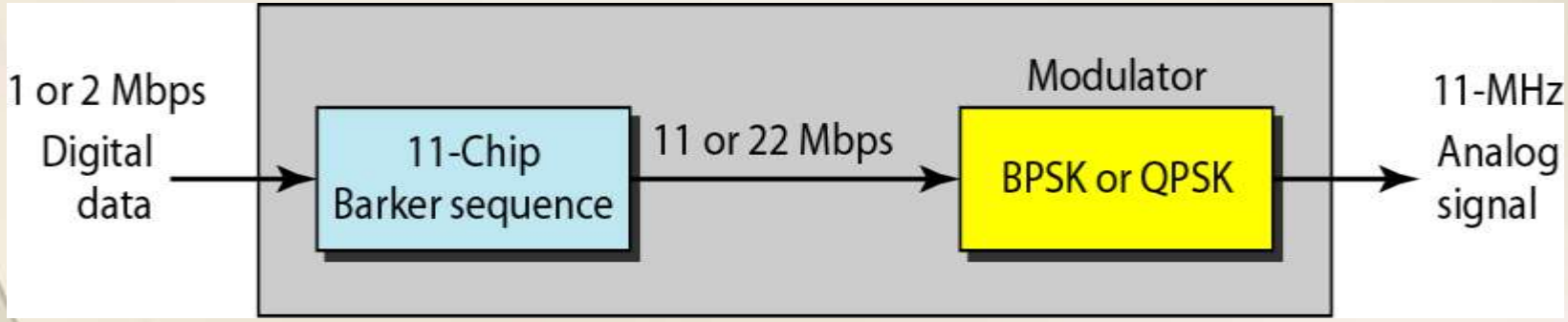
- In Frequency Hopping Spread Spectrum (FHSS) the sender sends on one carrier frequency for a short amount of time, then hops to another carrier frequency for the same amount of time, and so on. After N hop-pings, the cycle is repeated.

- Spreading makes it difficult for unauthorized persons to make sense of the transmitted data



Physical layer of IEEE 802.11 DSSS

- In Direct Sequence Spread Spectrum (DSSS) each bit sent by the sender is replaced by a sequence of bits called a chip code.
- To avoid buffering, the time needed to send one chip code must be the same as the time needed to send one original bit.
- DSSS is implemented at the physical layer and uses a 2.4GHz ISM band



Physical layer of IEEE 802.11a OFDM

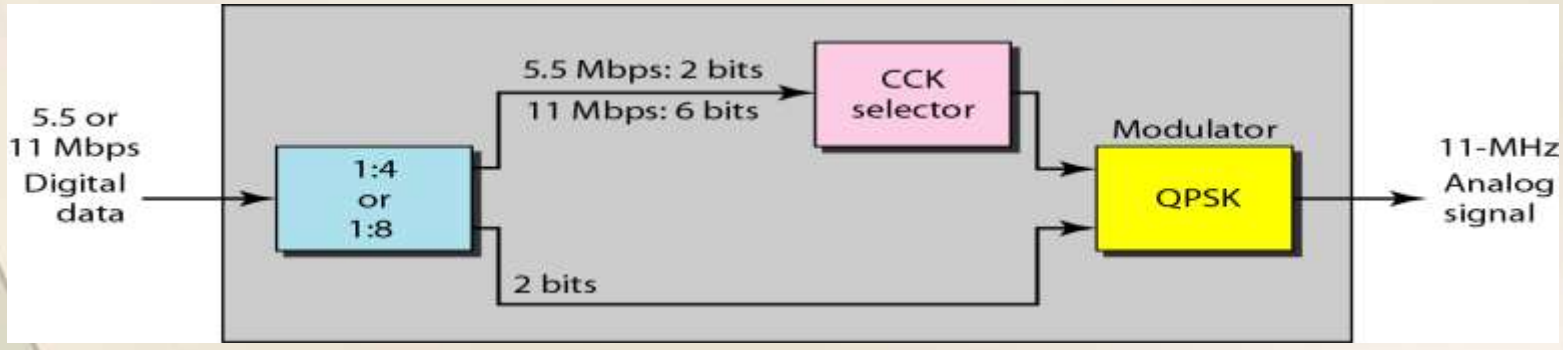
- IEEE 802.11a describes the orthogonal frequency-division multiplexing (OFDM) method for signal generation in the 5GHz ISM band

- OFDM is the same as FDM with one major difference:
  - All the subbands are used by one source at a given time
  - Sources conend with one another at the data link layer for access

- OFDM uses PSK (18Mbps) and QAM (54Mbps) for modulation

Physical layer of IEEE 802.11b

- IEEE 802.11b describes the high-rate DSSS method for signal generation at 2.4GHz ISM band.
- This is similar to DSSS except for the encoding method, which is called **complementary code keying (CCK)**
- CCK encodes 4 or 8 bits to one CCK symbol



Physical Media Defined by Original 802.11 Standard

- IEEE 802.11 FHSS(Frequency-hopping spread spectrum)
  - Operating in 2.4 GHz ISM band
  - Lower cost, power consumption
  - Most tolerant to signal interference
- IEEE 802.11 DSSS (Direct-sequence spread spectrum)
  - Operating in 2.4 GHz ISM band
  - Supports higher data rates
  - More range than FH or IR physical layers
- IEEE 802.11 Infrared
  - Lowest cost
  - Lowest range compared to spread spectrum
  - Doesn’t penetrate walls, so no eavesdropping

IEEE 802.11a , IEEE 802.11b and IEEE 802.11g

- IEEE 802.11a
  - Makes use of 5-GHz band
  - Provides rates of 6, 9 , 12, 18, 24, 36, 48, 54 Mbps
  - Uses orthogonal frequency division multiplexing (OFDM)
- IEEE 802.11b
  - 802.11b operates in 2.4 GHz band
  - Provides data rates of 5.5 and 11 Mbps
  - Complementary code keying (CCK) modulation scheme
- IEEE 802.11g
  - 802.11g operates in 2.4 GHz band
  - Provides data rates of 22 and 54 Mbps
  - Uses orthogonal frequency division multiplexing (OFDM)

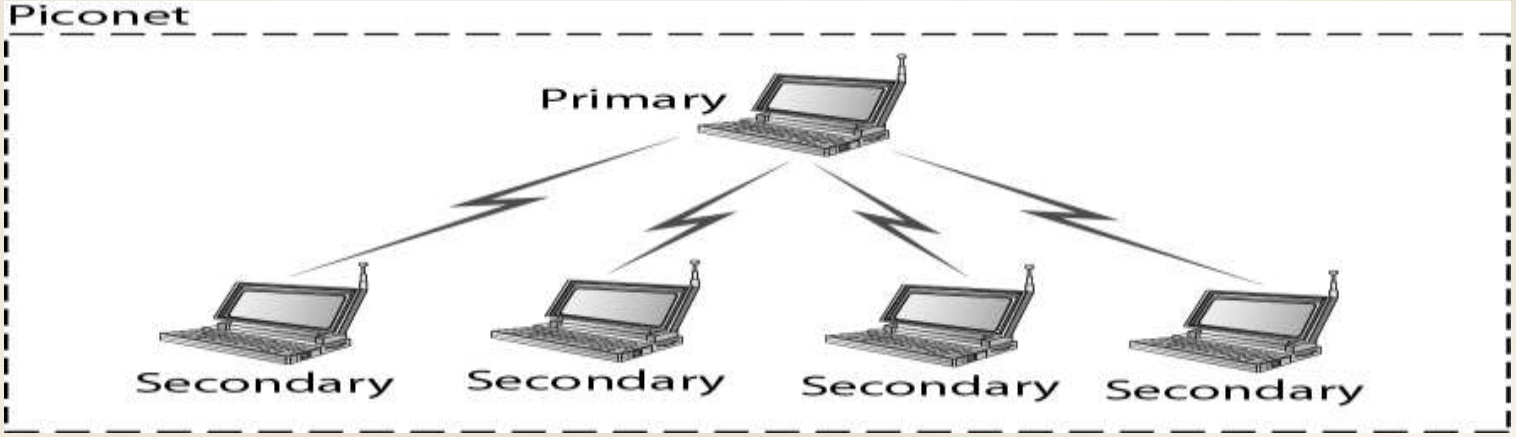
BLUETOOTH

- Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers, cameras, printers, coffee makers, and so on. A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously.

- Bluetooth defines two types of networks: piconet and scatternet.

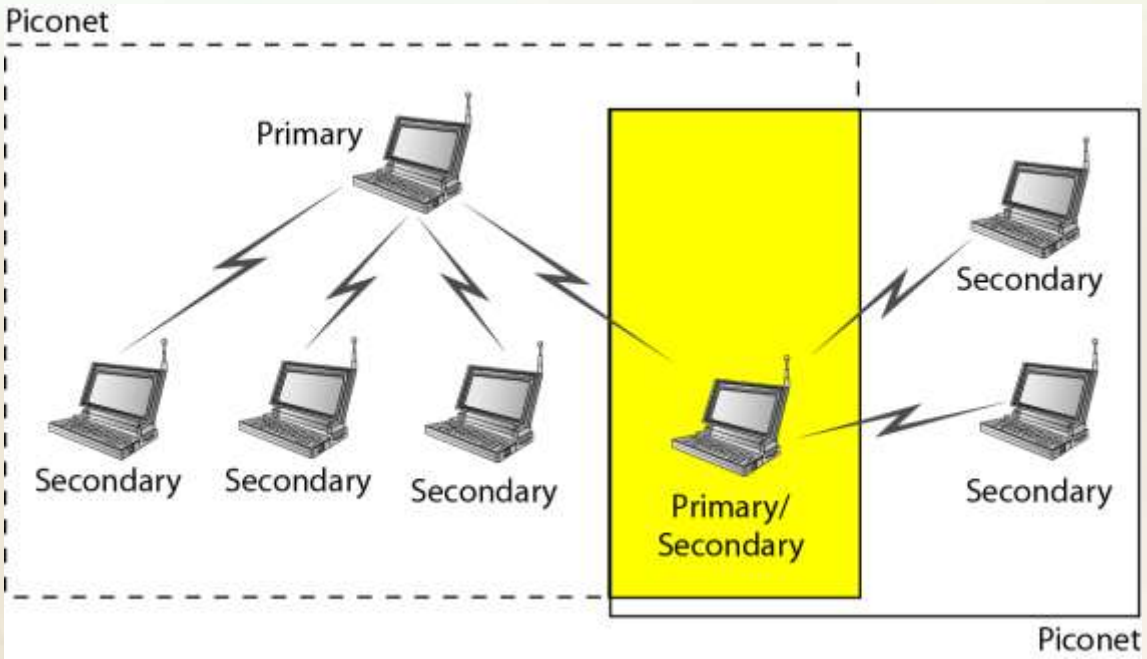
Piconet

- A Bluetooth network is called a piconet, or a small net.
- It can have up to eight stations, one of which is called the master; the rest are called slaves.
- Maximum of seven slaves. Only one master.
- Slaves synchronize their clocks and hopping sequence with the master.
- But an additional eight slaves can stay in parked state, which means they can be synchronized with the master but cannot take part in communication until it is moved from the parked state.



Scatternet

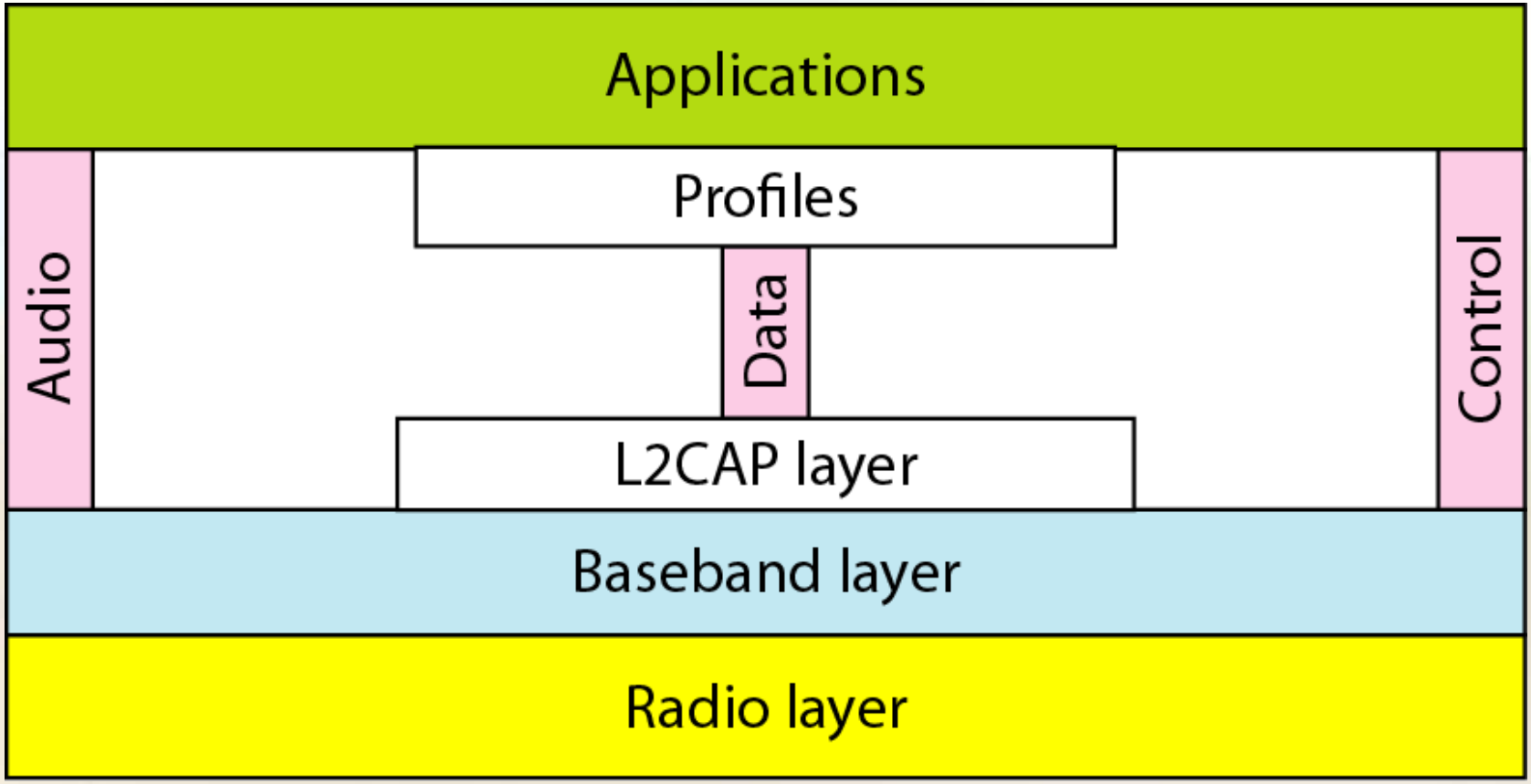
- Piconets can be combined to form what is called a scatternet.
- A slave station in one piconet can become the master in another piconet.
- Bluetooth devices has a built-in short-range radio transmitter.



Bluetooth layers

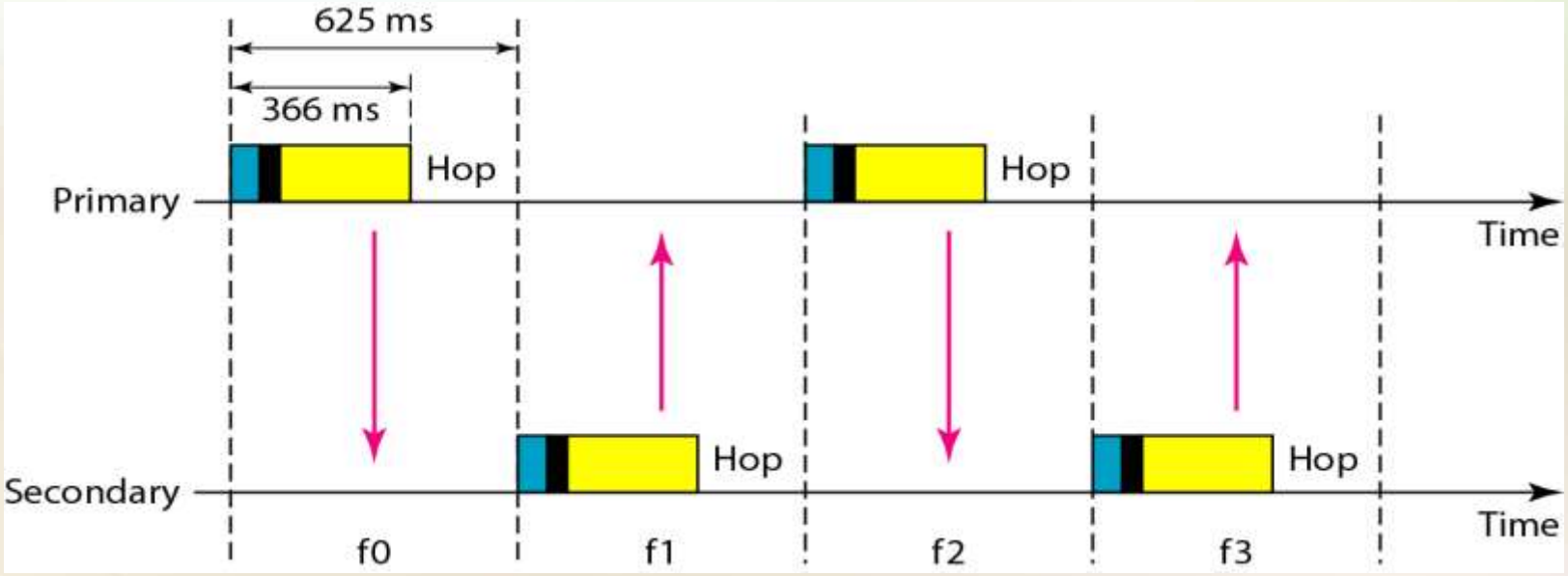
- Radio Layer: Roughly equivalent to physical layer of the Internet model. Physical links can be synchronous or asynchronous.
  - Uses Frequency-hopping spread spectrum [Changing frequency of usage]. Changes it modulation frequency 1600 times per second.
  - Uses frequency shift keying (FSK)with Gaussian bandwidth filtering to transform bits to a signal.
- Baseband layer: Roughly equivalent to MAC sublayer in LANs. Access is using Time Division (Time slots).
  - Length of time slot = dwell time = 625 microsec. So, during one frequency, a sender sends a frame to a slave, or a slave sends a frame to the master.
- Time division duplexing TDMA (TDD-TDMA) is a kind of half-duplex communication in which the slave and receiver send and receive data, but not at the same time (half-duplex). However, the communication for each direction uses different hops, like walkie-talkies.

Bluetooth layers



Single-secondary communication

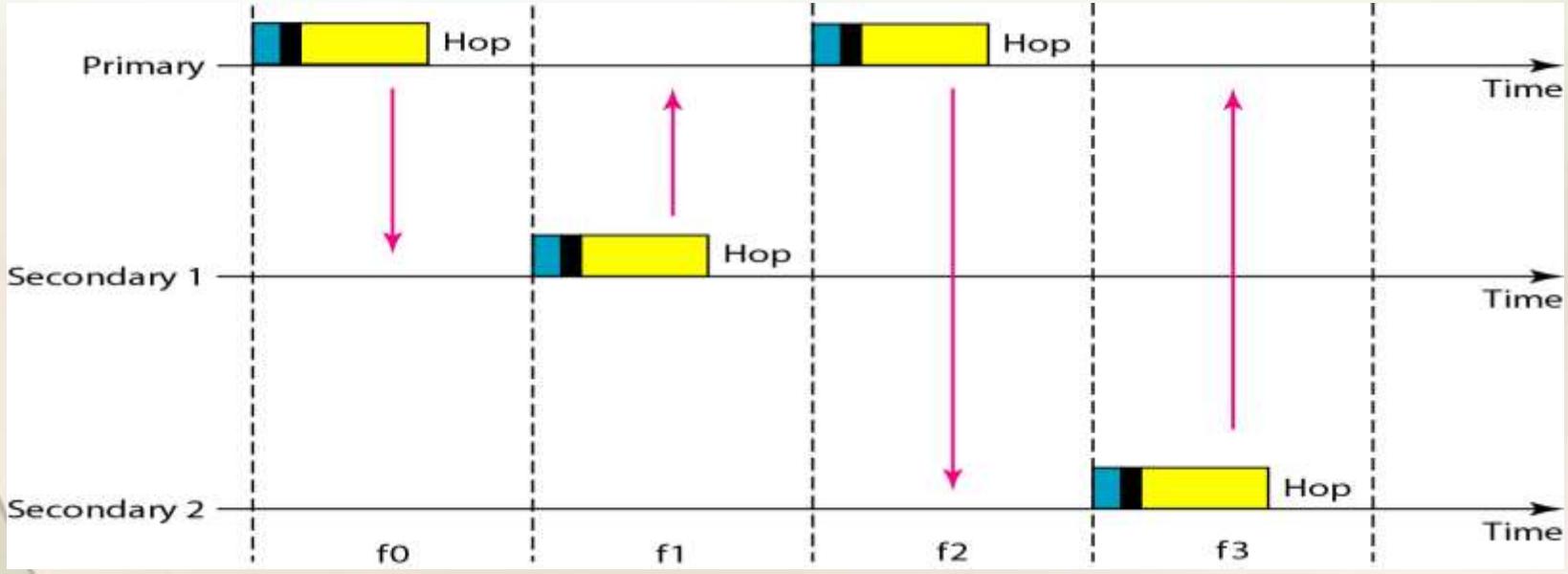
- **Also called Single-slave communication**
  - Master uses even-numbered slots
  - Slave uses odd-numbered slots



Multiple-secondary communication

Also called Multiple-slave communication

- Master uses even-numbered slots
- Slave sends in the next odd-numbered slot if the packet in the previous slot was addressed to it.



Physical Links

- Synchronous connection-oriented (SCO)
  - Latency is important than integrity.
  - Transmission using slots.
  - No retransmission.
- Asynchronous connectionless link (ACL)
  - Integrity is important than latency.
  - Does like multiple-slave communication.
  - Retransmission is done.
- L2CAP (Logical Link Control and Adaptation Protocol)
  - Equivalent to LLC sublayer in LANs.
  - Used for data exchange on ACL Link. SCO channels do not use L2CAP.
  - Frame format has 16-bit length [Size of data coming from upper layer in bytes], channel ID, data and control.
  - Can do Multiplexing, segmentation and Reassembly, QoS [with no QoS, best-effort delivery is provided] and Group mangement [Can do like multicast group, using some kind of logical addresses].

L2CAP data packet format

SUMMARY

- The wireless LAN access method is CSMA/CA.
- The network allocation vector (NAV) is a timer for collision avoidance.
- The MAC layer frame has nine fields. The addressing mechanism can include up to four addresses.
- Wireless LANs use management frames, control frames, and data frames.
- Bluetooth is a wireless LAN technology that connects devices (called gadgets) in a small area.
- A Bluetooth network is called a piconet. Multiple piconets form a network called a scatternet.
- The Bluetooth radio layer performs functions similar to those in the Internet model's physcial layer.
- The Bluetooth baseband layer performs functions similar to those in the Internet model's MAC sublayer.
- A Bluetooth network consists of one master device and up to seven slave devices.
- •A Bluetooth frame consists of data as well as hopping and control mechanisms. A frame is one, three, or five slots in length with each slot equal to 625 μs.