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Data Communication and Computer Networks

Chapter 06:

6.0 SWITCHING AND MULTIPLEXING

5.1 Switching Concept and Types

- A network is a set of connected device.
- Whenever we have multiple devices, we have the problem of how to connect them to make one to one communication possible.
- One possible solution is to make a point to point connection between each pair of devices or between a central device and every other device.
- These methods however are impractical and wasteful when applied to a very large networks.
- The number and length of links require too much infrastructure to be cost efficient, the majority of those links would be idle most of the time.

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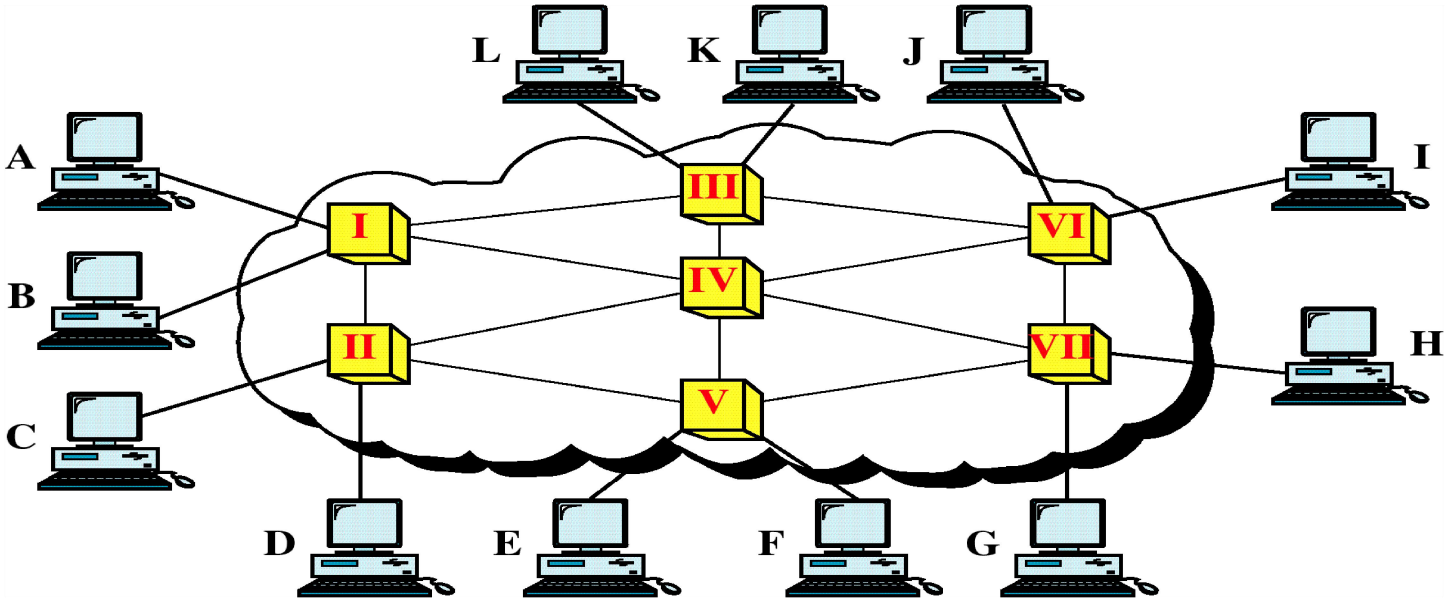
- A better solution is switching.
- A switch network consists of a series of interlinked nodes called switches.
- Switches are devices capable of creating temporary connections between two or more devices linked to the switch.



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Traditionally there are three methods of switching

- Circuit switching
- Packet switching and
- Message switching

1. Circuit Switched Networks

- A circuit switched network consists a set of switched connected by physical links.
- A connection between the two stations is a dedicated path made of one or more links.
- However, each connection uses only one dedicated channel in each link.
- Each link is normally divided into n channels by using FDM or TDM.

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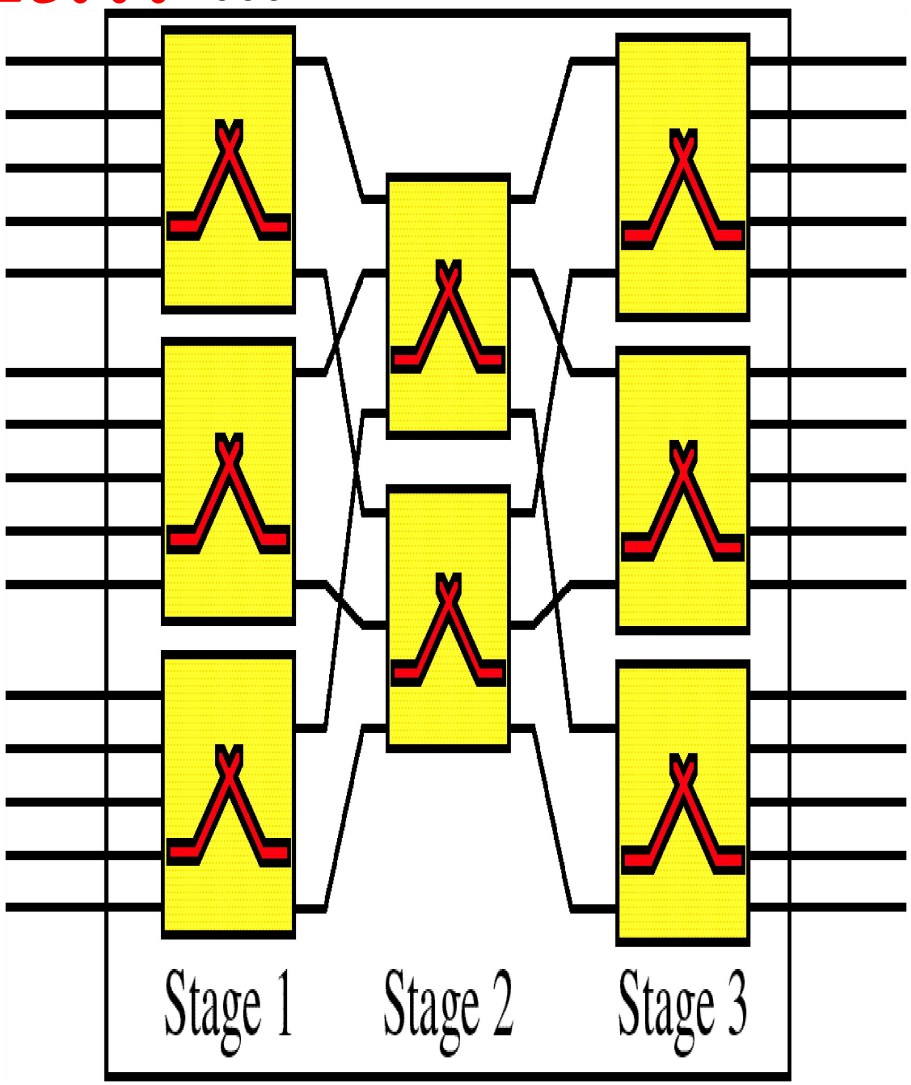
- Circuit switching takes place at the physical layer

The actual communication in circuit switch network required three phases:

- ✓ **Connection setup,**
- ✓ **Data transfer , and**
- ✓ **Connection teardown.**



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Setup Phase

- Before the two parties or multiple parties can communicate , a dedicated circuit needs to be established.
- The end systems are normally connected through dedicated lines to the switches, so connection set up means creating a dedicated channel.

Data transfer phase

- After the establishment of the dedicated circuit(channel), the two parties can transfer data.

Teardown Phase

- When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

Cont…

Efficiency

- Circuit switch network is not as efficient as the other two types of network because resources are allocated during the entire duration of the connection
- These resources are unavailable to other connections
- Allowing resources to be dedicated means that other connections are deprived

Delay

- Although circuit switched network normally has low efficiency, the delay in this type of network is minimal.

Cont…

- During data transfer the data aren't delayed at each switch; the resources are allocated for the duration of the connection.
- There is no waiting time at each switch.
- The total delay is due to the time needed to create the connection , transfer data, and disconnect the circuit.

2. Packet Switch Network

- In data communication, we need to send messages from one end system to another.
- If the message is going to pass through a packet switched network, it needs to be divided into packets of fixed or variable size.
- The size of the packet is determined by the network and the governing protocols.
- In packet switching,
  - There is no resource allocation for a packet
  - There is no reserved bandwidth on the links, and
  - There is no scheduled processing time for each packet.
  - Resources are allocated on demand

- The allocation is done on the first come first served basis.
- The packet switch networks are sometimes referred to as connectionless network
- The term connectionless here means that the switch (packet switch) doesn't keep information about the connection state
- There is no setup or teardown phases
- Each packet is treated the same by a switch regardless of its source or destination

Cont…

Routing Table

- If there are no setup or tear down phases, the packets are routed to their destination by the routing table at the Switch or router.
- The destination address and the corresponding forwarding output ports are recorded in the routing tables

Efficiency

- The efficiency of packet switch network is better than that of circuit switched network; resources are allocated only when there are packets to be transferred.

Delay

- There may be greater delay in packet switch network that the circuit switch network
- Although there are no setup and teardown phase, each packet may experience a wait at a switch before it is forwarded

Cont…

Message switching

- Message (block data) is stored in a switching node and then forwarded later one hop at a time
- Message received in its entirety , inspected for error, and then forwarded
- Need “LARGE” storage space to store data in each node

Ex. Telegraph, military applications

6.2 Multiplexing Concepts and Types

- Multiplexing is the name given to techniques, which allow more than one message to be transferred via the same communication channel.
- The channel in this context could be a transmission line, *e.g.* a twisted pair or co-axial cable, a radio system or a fibre optic system *etc*.
- The technique of transmitting multiple signals over a single medium is ***multiplexing.***
- ***Multiplexing*** is the transmission of multiple signals on one medium.
- A **channel** is an assigned set of frequencies that is used to transmit the user's signal
- A channel will offer a specified bandwidth, which is available for a time t, where t may $\rightarrow \infty$.
- Thus, with reference to the channel there are 2 'degrees of freedom', i.e. bandwidth or frequency and time.

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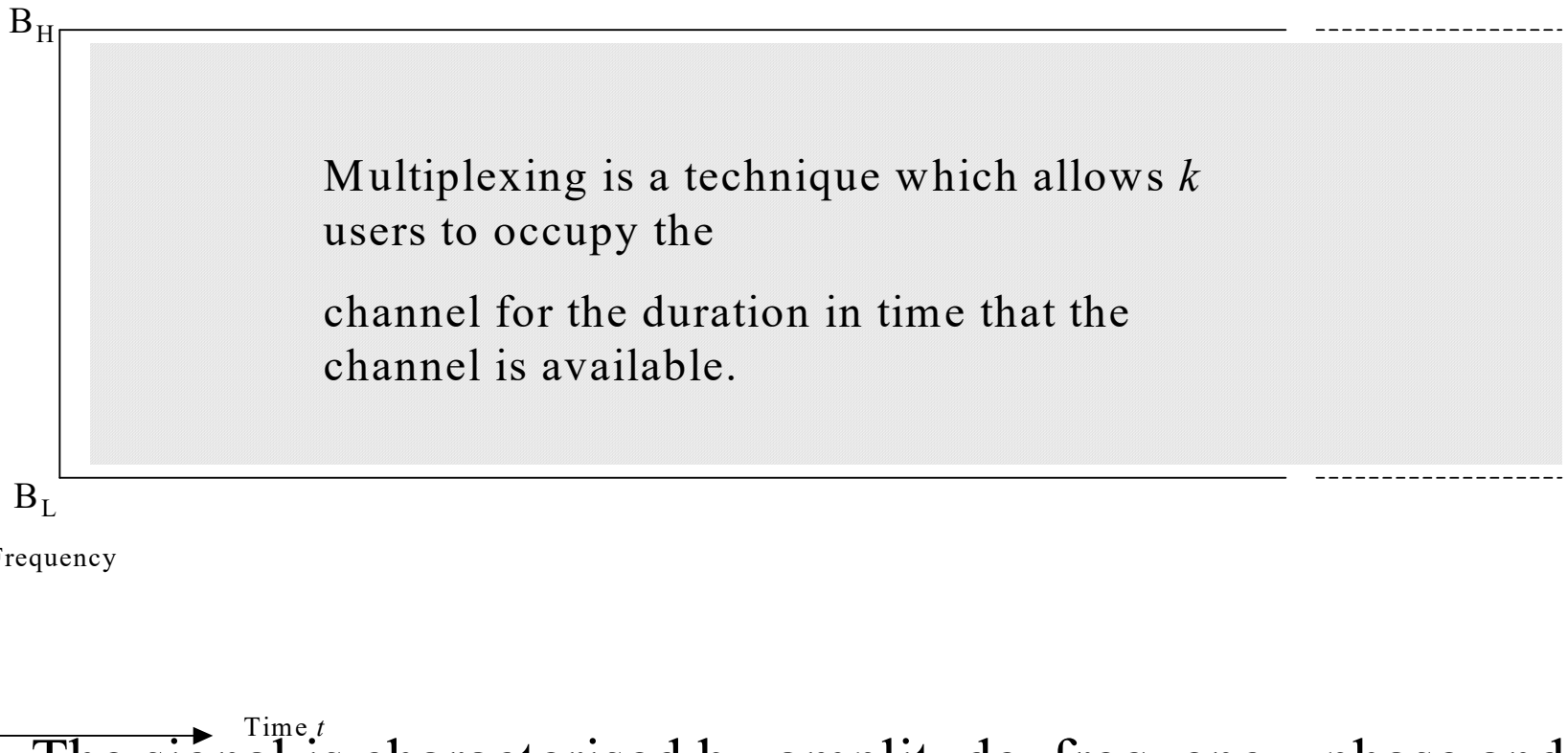

The signal is characterised by amplitude, frequency, phase and time.

Cont…

Various multiplexing methods are possible in terms of the channel bandwidth and time, and the signal, in particular the frequency, phase or time. The two basic methods are:

1. Frequency Division Multiplexing (FDM)

- When the carrier is frequency, FDM is used.
- FDM is an analog technology.
- FDM divides the spectrum or carrier bandwidth in logical channels and allocates one user to each channel.
- Each user can use the channel frequency independently and has exclusive access of it.
- All channels are divided in such a way that they do not overlap with each other.
- Channels are separated by guard bands. Guard band is a frequency which is not used by either channel.

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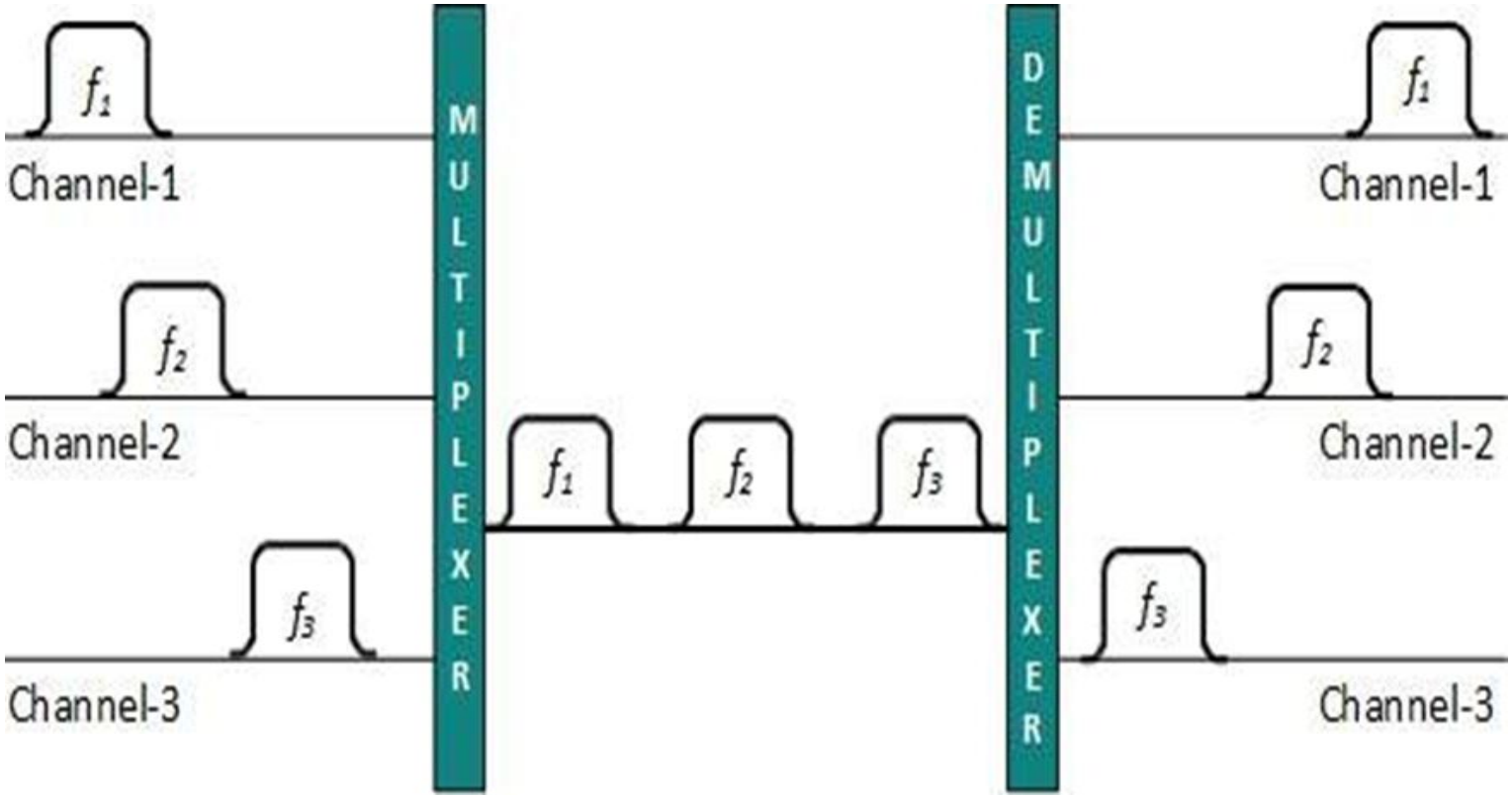
f_1
Channel-1
f_2
Channel-2
f_3
Channel-3
MULTIPLEXER
f_1
f_2
f_3
DEMULTIPLEXER
f_1
Channel-1
f_2
Channel-2
f_3
Channel-3

Cont…

2. Time Division Multiplexing (TDM)

- TDM is applied primarily on digital signals but can be applied on analog signals as well.
- In TDM the shared channel is divided among its user by means of time slot. Each user can transmit data within the provided time slot only.
- Digital signals are divided in frames, equivalent to time slot i.e. frame of an optimal size which can be transmitted in given time slot.
- TDM works in synchronized mode. Both ends, i.e. Multiplexer and De-multiplexer are timely synchronized and both switch to next channel simultaneously.

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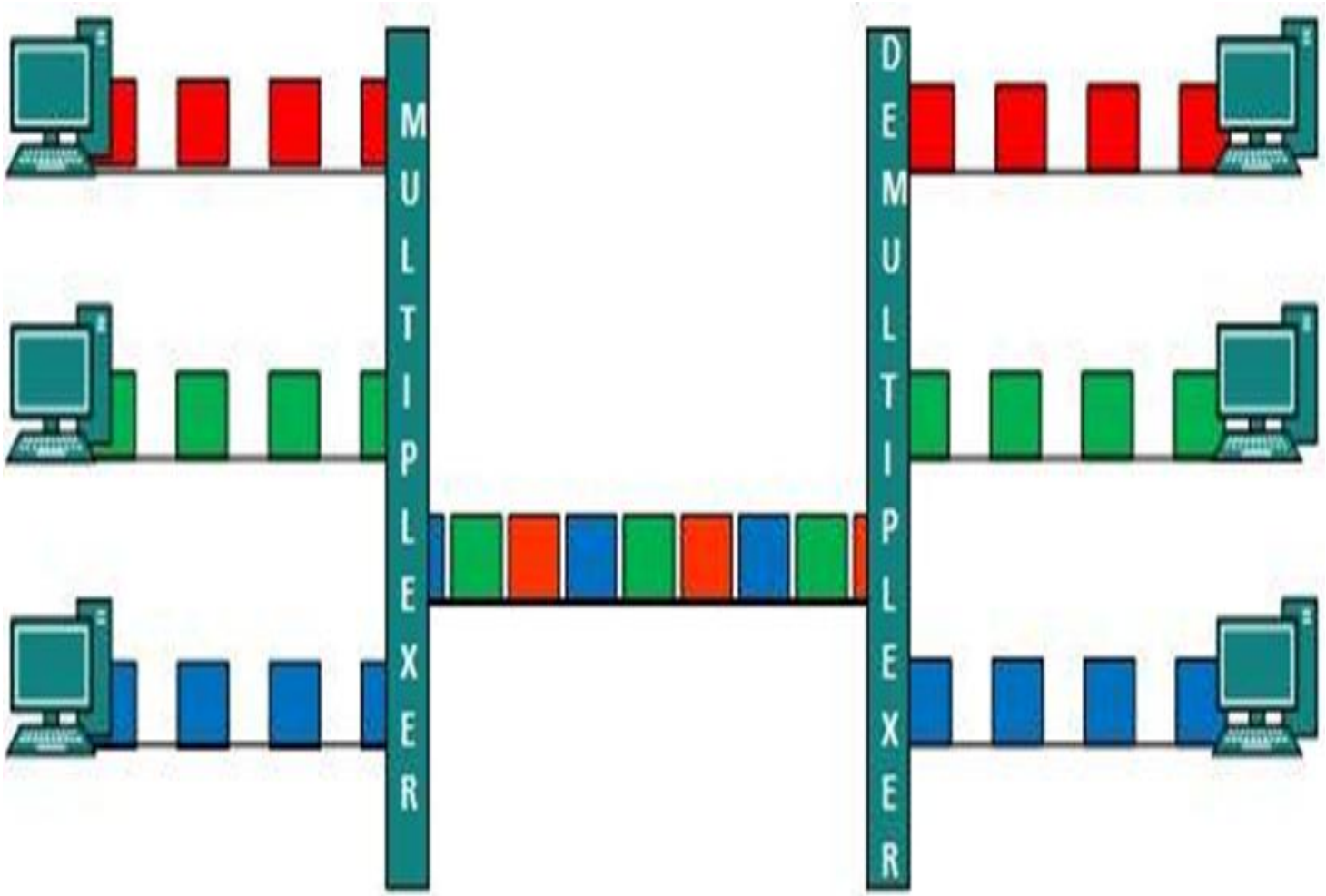


6.3 Introduction to Ethernet & Wireless Networks

- **Ethernet** is a predominant **LAN technology** in the world.
- Internet Engineering Task Force (**IETF**) maintains the functional protocols and services for the TCP/IP protocol suite in the **upper layers**.
- However, the functional protocols and services at the OSI *Data Link layer and Physical layer* are described by various engineering organizations (**IEEE, ANSI, ITU**) or by private companies (proprietary protocols).
- The foundation for Ethernet technology was first established in 1970 with a program called Alohanet.
- Alohanet was a digital radio network designed to transmit information over a shared radio frequency between the Hawaiian Islands

Cont…

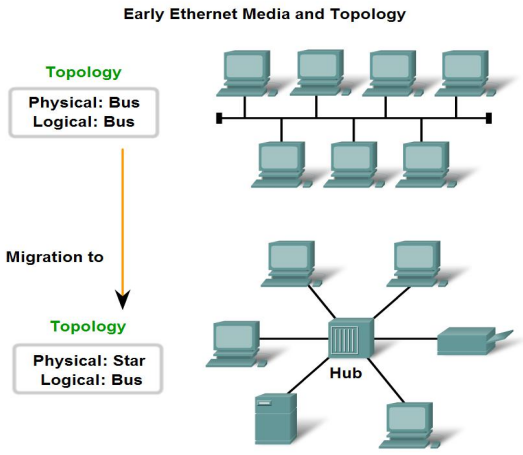
- Alohanet required all stations to follow a protocol in which an unacknowledged transmission required re-transmitting after a short period of waiting
- The techniques for using a shared medium in this way were later applied to wired technology in the form of Ethernet
- The first version of Ethernet incorporated a media access method known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).
- CSMA/CD is a type of contention protocol that defines how to respond when a collision is detected, or when two devices attempt to transmit packages simultaneously.
- CSMA/CD managed the problems that result when multiple devices attempt to communicate over a shared physical medium.

Cont…

- **Characteristics of Ethernet in its early years**
- The first versions of Ethernet used coaxial cable to connect computers in a bus topology. Each computer was directly connected to the backbone.
- These early versions of Ethernet were known as:
- **Thicknet(10BASE5):** cabling distances of up to 500 meters before the signal required a repeater
- **Thinnet(10BASE2):** was smaller in diameter and more flexible than Thicknet and allowed for cabling distances of 185 meters.

The evolved once are:

- cable(coaxial-to-UTP)
- Media Access(CSMA-to-CSMA/CD)
- Physical Topology(Bus-to-Star)



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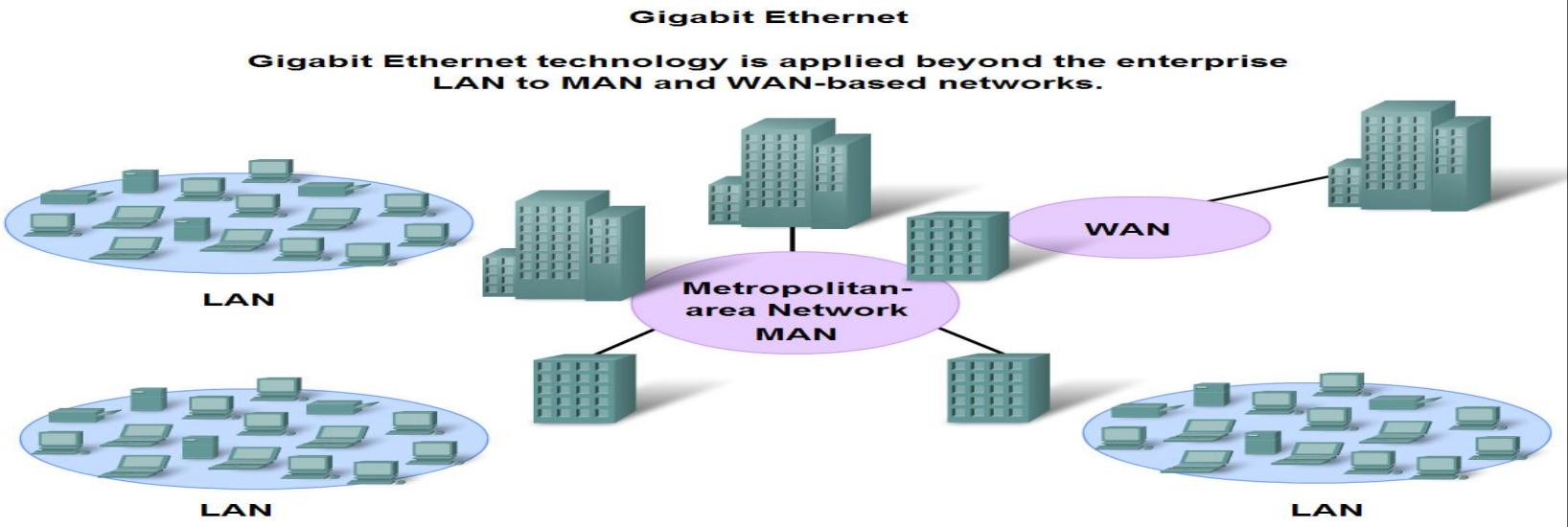
- Ethernet Beyond the LAN:
- The increased cabling distances enabled by the use of ***fiber-optic cable*** in Ethernet-based networks has resulted in a ***blurring*** of the distinction between LANs and WANs.
- Ethernet was initially limited to LAN cable systems within single buildings, and then extended to between buildings.
- It can now be applied across a city in what is known as a Metropolitan Area Network (MAN)



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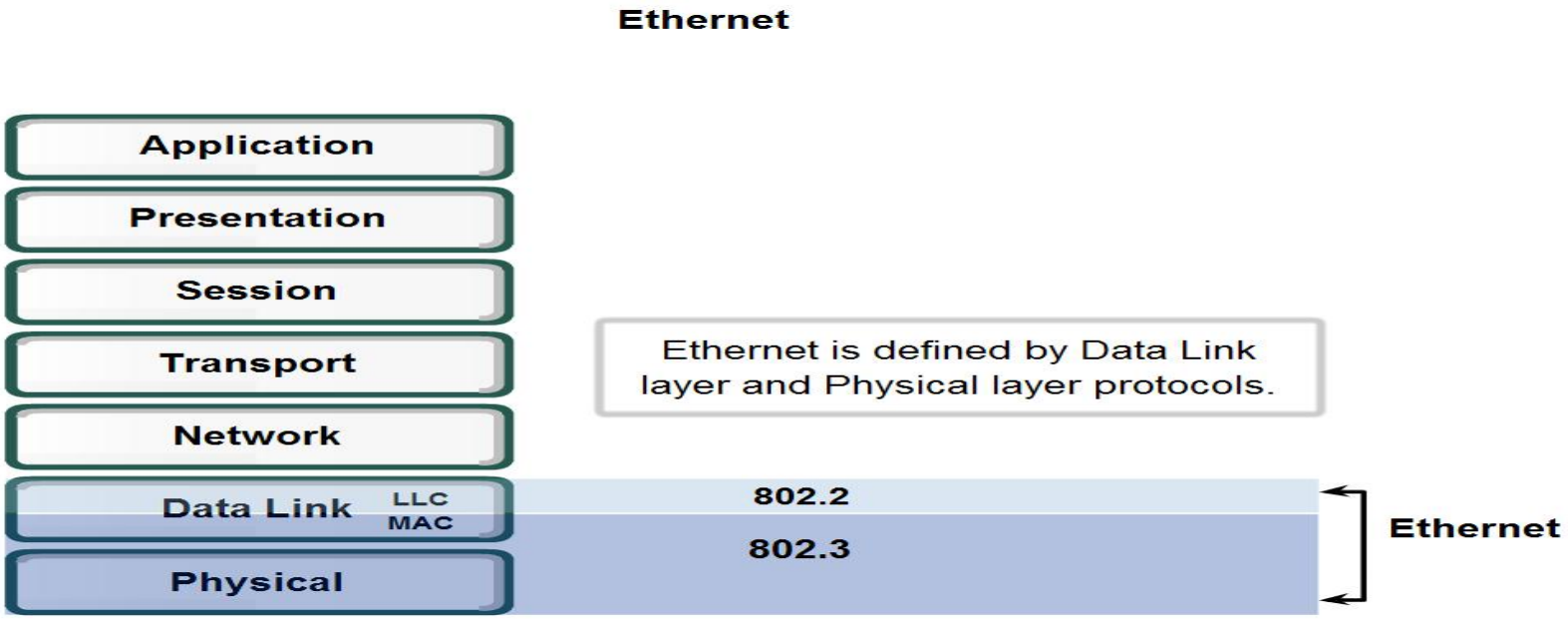
- **Physical and Data Link Features of Ethernet:**
- **Standards and Implementation**
  - In 1985, the Institute of Electrical and Electronics Engineers (IEEE) standards committee for Local and Metropolitan Networks published standards for LANs. These standards start with the number 802. The standard for **Ethernet is 802.3**.



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- **Physical and Data Link Features of Ethernet:**
- Standards and Implementation
- Ethernet operates in the lower two layers of the OSI model (L1 & L2)
- Ethernet L1 performs a key role in the communication that takes place between devices, but each of its functions has limitations.
- Ethernet at Layer 2 addresses these limitations

Layer 1 Limitations	Layer 2 Functions
Cannot communicate with upper layers	Connects to upper layers via Logical Link Control (LLC)
Cannot identify devices	Uses addressing schemes to identify devices
Only recognizes streams of bits	Uses frames to organize bits into groups
Cannot determine the source of a transmission when multiple devices are transmitting	Uses Media Access Control (MAC) to identify transmission sources

Cont…

Physical and Data Link Features of Ethernet:

Logical Link Control-Connecting to upper layers

- Ethernet separates the functions of the Data Link layer into two distinct sub-layers: the Logical Link Control (LLC) sub-layer and the Media Access Control (MAC) sub-layer
- The use of these sub-layers contributes significantly to compatibility between diverse end devices
- LLC is implemented in software, and its implementation is independent of the physical equipment
- In a computer, the LLC can be considered the driver software for the Network Interface Card (NIC). The NIC driver is a program that interacts directly with the hardware on the NIC to pass the data between the media and the Media Access Control sub-layer
- The IEEE 802.2 standard

describes the

LLC sub-layer functions

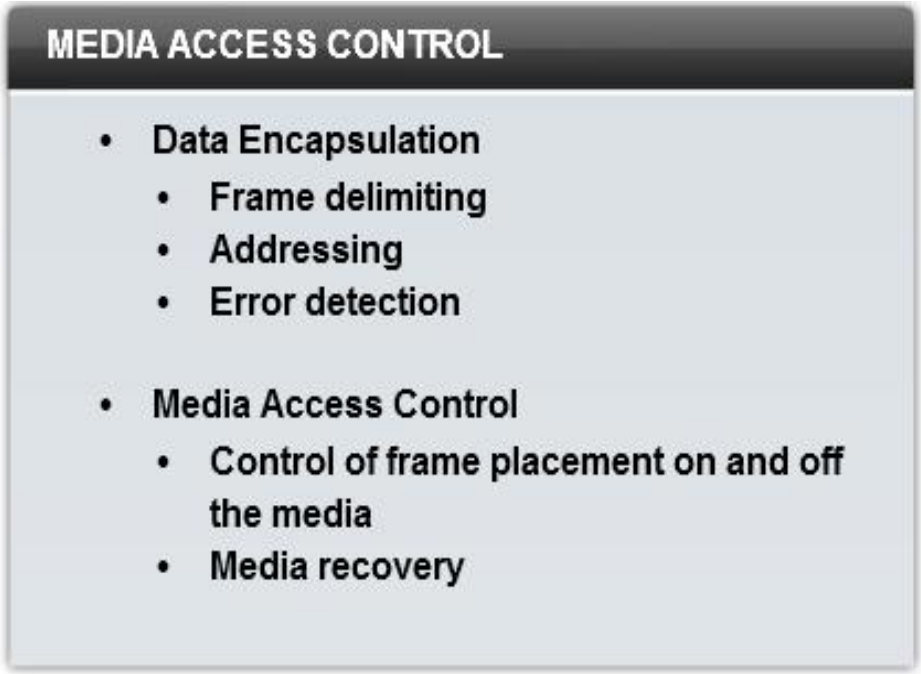
- Makes the connection with the upper layers
- Frames the Network layer packet
- Identifies the Network layer protocol
- Remains relatively independent of the physical equipment

Cont…

Physical and Data Link Features of Ethernet:

MAC-Getting Data to the Media

- MAC is the lower Ethernet sublayer of L2. MAC is implemented by hardware, typically in the computer Network Interface Card (NIC).
- The Ethernet MAC sublayer has two primary responsibilities:
  - Data Encapsulation
  - Media Access Control



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Physical and Data Link Features of Ethernet:

Physical Implementation of Ethernet:

- Ethernet specifies and implements encoding and decoding schemes that enable frame bits to be carried as signals across the media.
- Ethernet devices make use of a broad range of cable and connector specifications
- UTP copper cables and optical fiber to interconnect network devices via intermediary devices such as hubs and switches. With all of the various media types that Ethernet supports
- The introduction of **Gigabit Ethernet** has extended the original LAN technology to distances that make Ethernet a MAN and WAN standard.
- Today, the same protocol that transported data at **3 Mbps** can carry data at **10 Gbps**
- **The success of Ethernet is due to the following factors:**
  - Simplicity and ease of maintenance
  - Ability to incorporate new technologies
  - Reliability
  - Low cost of installation and upgrade

Ethernet

MAC in Ethernet: Functions & Characteristics

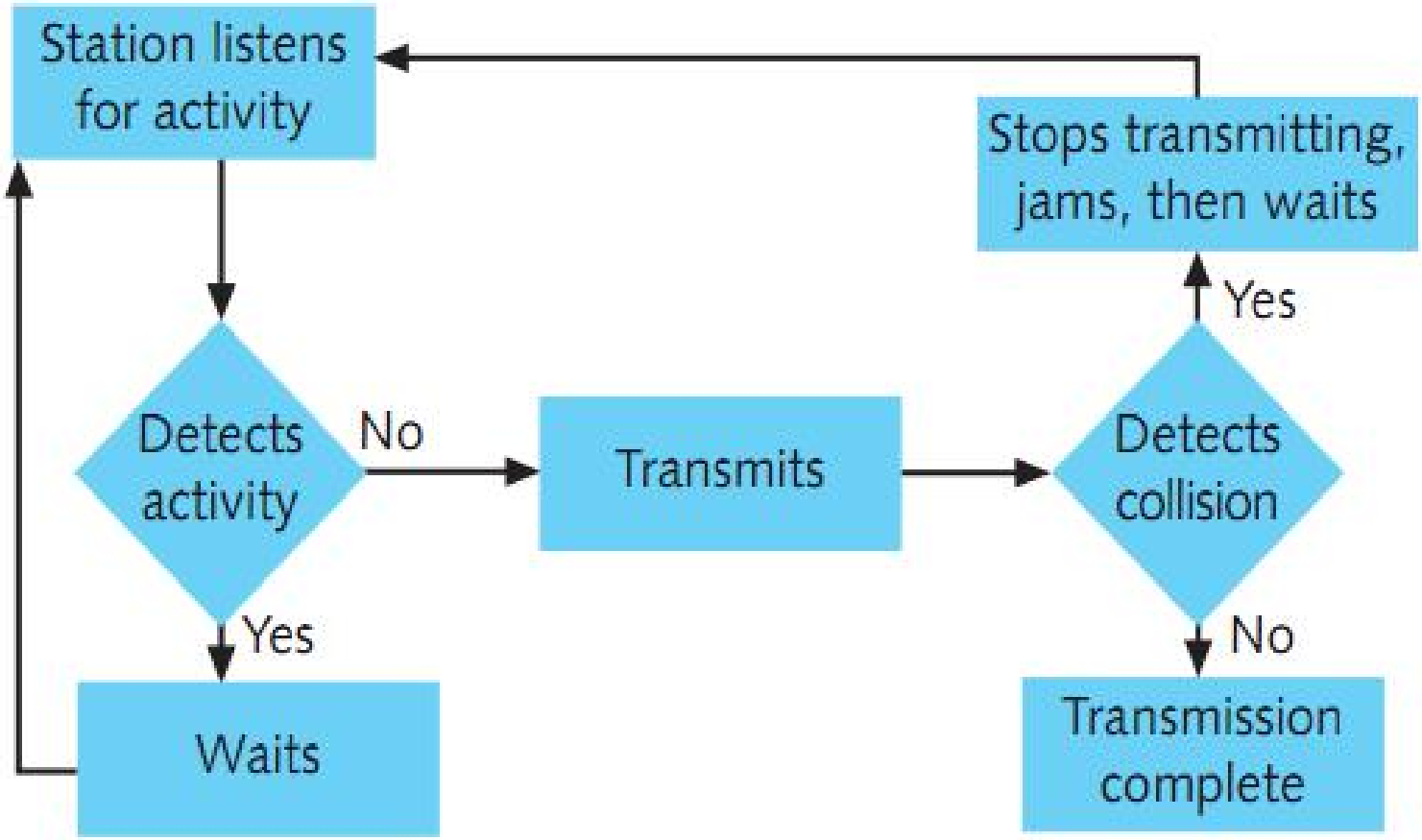
- Ethernet uses **CSMA/CD** to detect and handle collisions and manage the resumption of communications

The Process:

- **Carrier Sense:** Listen before transmitting
  - If a device detects a signal from another device, it will wait for a specified amount of time before attempting to transmit.
- **Multi-access** :several Ethernet nodes can monitor traffic, or access the media, simultaneously.
- **Collision Detection:** refers to the way nodes respond to a collision
- **Jam Signal and Random Backoff**
  - This jamming signal is used to notify the other devices of a collision, so that they will invoke a backoff algorithm
  - Backoff algorithm causes all devices to stop transmitting for a random amount of time, which allows the collision signals to subside

After the delay has expired on a device, the device goes back into the "listening before transmit" mode

CSMA/CD process



Ethernet

Ethernet Physical Layer: 10/100/1000Mbps & Future Options

- The differences between standard Ethernet, Fast Ethernet, Gigabit Ethernet, and 10 Gigabit Ethernet occur at the Physical layer

- Currently Four data rates are defined by IEEE 802.3 for operation over optical fiber and twisted-pair cables:
  - 10 Mbps - 10Base-T Ethernet
  - 100 Mbps - Fast Ethernet
  - 1000 Mbps - Gigabit Ethernet
  - 10 Gbps - 10 Gigabit Ethernet

Ethernet

Ethernet Physical Layer: 10/100/1000Mbps & Future Options

Types of Ethernet

Ethernet Type	Bandwidth	Cable Type	Duplex	Maximum Distance
10Base-5	10 Mbps	Thicknet Coaxial	Half	500 m
10Base-2	10 Mbps	Thinnet Coaxial	Half	185 m
10Base-T	10 Mbps	Cat3/Cat5 UTP	Half	100 m
100Base-TX	100 Mbps	Cat5 UTP	Half	100 m
100Base-TX	200 Mbps	Cat5 UTP	Full	100 m
100Base-FX	100 Mbps	Multimode Fiber	Half	400 m
100Base-FX	200 Mbps	Multimode Fiber	Full	2 km
1000Base-T	1 Gbps	Cat5e UTP	Full	100 m
1000Base-TX	1 Gbps	Cat6 UTP	Full	100 m
1000Base-SX	1 Gbps	Multimode Fiber	Full	550 m
1000Base-LX	1 Gbps	Single-Mode Fiber	Full	2 km
10GBase-CX4	10 Gbps	Twin-axial	Full	100 m
10GBase-T	10 Gbps	Cat6a/Cat7 UTP	Full	100 m
10GBase-LX4	10 Gbps	Multimode Fiber	Full	300 m
10GBase-LX4	10 Gbps	Single-Mode Fiber	Full	10 km

Wireless Network

- What is a wireless network?
  - A technology that enables two or more entities to communicate without network cabling
- Any application currently used on a traditional wired network can be used on a wireless network.
- New applications may be available or can be developed to take advantage of wireless, such as Wireless PDA access to a card catalog.

Why Wireless

- **Mobility:** Wireless LAN systems can provide LAN users with access to real-time information anywhere in their organization. This mobility supports productivity and service opportunities not possible with wired networks.

Why Wireless?

- **Installation Speed and Simplicity:** Installing a wireless LAN system can be fast and easy and can eliminate the need to pull cable through walls and ceilings.
- **Reduced Cost-of-Ownership**: While the initial investment required for wireless LAN hardware can be higher than the cost of wired LAN hardware, overall installation expenses and life-cycle costs can be significantly lower.
- **Scalability:** Wireless LAN systems can be configured in a variety of topologies to meet the needs of specific applications and installations. Configurations are easily changed and range from peer-to-peer networks suitable for a small number of users to full infrastructure networks of thousands of users that enable roaming over a broad area.

Wireless Networks

Comparing WLAN to a LAN:

- WLANs connect clients to the network through a **wireless access point** (AP) instead of an **Ethernet switch**.
- WLANs connect mobile devices that are often **battery powered**, as opposed to **plugged-in LAN devices**. Wireless network interface cards (NICs) tend to reduce the battery life of a mobile device.
- WLANs support hosts that contend for access on the **RF** media (frequency bands). 802.11 prescribes **collision-avoidance** instead of **collision-detection** for media access to proactively **avoid collisions within the media.**
- **WLANs** use a different frame format than wired Ethernet LANs. WLANs require additional information in the Layer 2 header of the frame.
- WLANs raise more privacy issues because radio frequencies can reach outside the facility.

Comparing a WLAN to a LAN

Characteristic	802.11 Wireless LAN	802.3 Ethernet LANs
Physical Layer	Radio Frequency (RF)	Cable
Media Access	Collision Avoidance	Collision Detection
Availability	Anyone with a radio NIC in range of an access point	Cable connection required
Signal Interference	Yes	Inconsequential
Regulation	Additional regulation by local authorities	IEEE standard dictates

Wireless Networks

WLAN Standards: the 802.11 wireless standards

- 802.11 wireless LAN is an IEEE standard that defines how radio frequency (RF) in the unlicensed industrial, scientific, and medical (ISM) frequency bands is used for the physical layer and the MAC sub-layer of wireless links
- When 802.11 was first released, it prescribed **1 - 2 Mb/s data rates** in the 2.4 GHz band. At that time, **wired LANs** were operating at 10 Mb/s so the new wireless technology was not enthusiastically adopted
- Since then, wireless LAN standards have continuously improved with the release of **IEEE 802.11a**, **IEEE 802.11b**, **IEEE 802.11g**, and draft 802.11n.

✓**802.11** -- applies to wireless LANs and provides 1 or 2 Mbps transmission in the 2.4 GHz band.

✓**802.11a** -- an extension to 802.11 that applies to wireless LANs and provides up to 54 Mbps in the 5GHz band.

✓**802.11b** (also referred to as *802.11 High Rate* or *Wi-Fi*) -- an extension to 802.11 that applies to wireless LANS and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz band.

✓**802.11g** -- applies to wireless LANs and provides 20+ Mbps in the 2.4 GHz band.

Wireless Network Components

- **Access Points**
- **NICs – Network Interface Cards**
  - PCMCIA(***P****ersonal* ***C****omputer* ***M****emory* ***C****ard* ***I****nternatio nal* ***A****ssociation*)
  - USB
  - PCI(Peripheral Component Interconnect)
  - CompactFlash
- **Other Wireless Devices**
  - Bridges and Routers
  - Print Servers
- **PCs, Laptops, PDAs**

Wireless(802.11) Infrastructure Components:

Access Point: connects wireless clients (or stations) to the wired LAN.

- an access point converts the TCP/IP data packets from their **802.11 frame** encapsulation format in the air to the **802.3 Ethernet** frame format on the wired Ethernet network.
- An access point is a **Layer 2** device that functions like an 802.3 Ethernet hub.
- RF is a shared medium and access points hear all radio traffic. Just as with 802.3 Ethernet, the devices that want to use the medium contend for it. Unlike Ethernet NICs, though, it is expensive to make wireless NICs that can transmit and receive at the same time,
- so **radio devices** do not detect collisions. Instead, WLAN devices are designed to avoid them.

- Access points oversee a distributed coordination function (DCF) called **Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)**.
- This simply means that devices on a WLAN must sense the medium for energy (RF stimulation above a certain threshold) and wait until the medium is free before sending.
- Because all devices are required to do this, the function of coordinating access to the medium is distributed.
- If an access point receives data from a client station, it sends an acknowledgement to the client that the data has been received.
- This acknowledgement keeps the client from assuming that a collision occurred and prevents a data retransmission by the client.

Wireless Operating Mode

The IEEE 802.11 standards specify two operating modes: **infrastructure mode** and **ad hoc mode**.

- **Infrastructure mode** is used to connect computers with wireless network adapters, also known as wireless clients, to an existing wired network with the help from wireless router or access point.
- **Ad hoc mode** is used to connect wireless clients directly together, without the need for a wireless router or access point. An ad hoc network consists of up to 9 wireless clients, which send their data directly to each other.

Wireless Networks

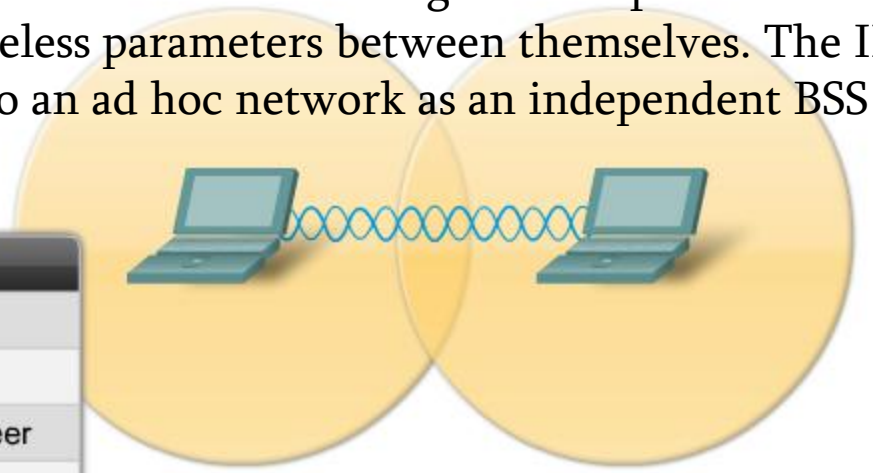
Wireless Operations : 802.11 Topologies

- Wireless LANs can accommodate various network topologies. When describing these topologies, the fundamental building block of the IEEE 802.11 WLAN architecture is the basic service set (BSS). The standard defines a BSS as a group of stations that communicate with each other.

Ad hoc Networks

- Wireless networks can operate without access points; this is called an **ad hoc topology**. Client stations which are configured to operate in ad hoc mode configure the wireless parameters between themselves. The IEEE 802.11 standard refers to an ad hoc network as an independent BSS (IBSS).

APs	None
Topology	IBSS
Connection	Peer-to-Peer
Mode	Ad hoc
Coverage	Basic Service Area (BSA)



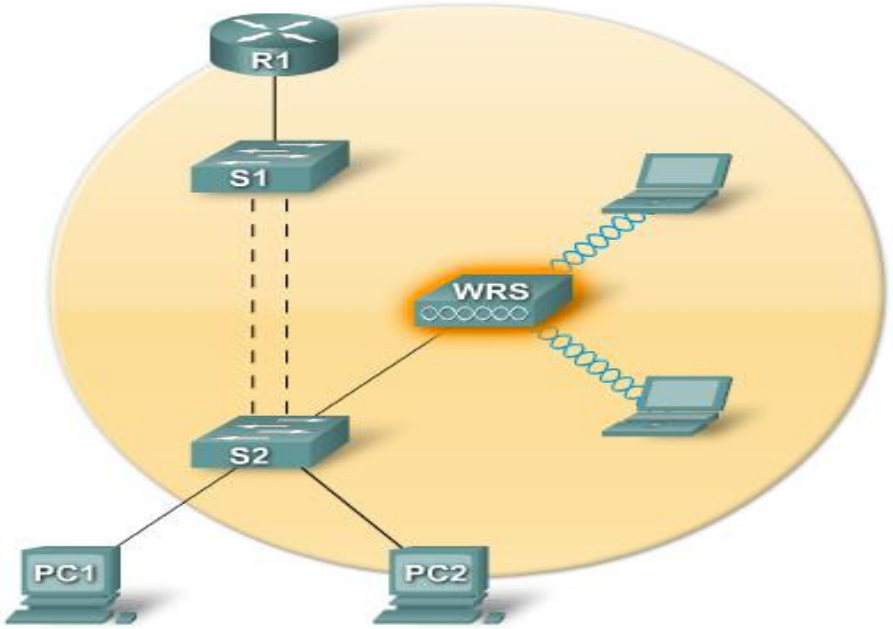
Wireless Networks

Wireless Operations: 802.11 Topologies

Basic Service Sets

- Access points provide an infrastructure that adds services and improves the range for clients. A single access point in infrastructure mode manages the wireless parameters and the topology is simply a BSS. The coverage area for both an IBSS and a BSS is the basic service area (B

APs	One
Topology	BSS
Connection	Client to AP
Mode	Infrastructure
Coverage	Basic Service Area (BSA)

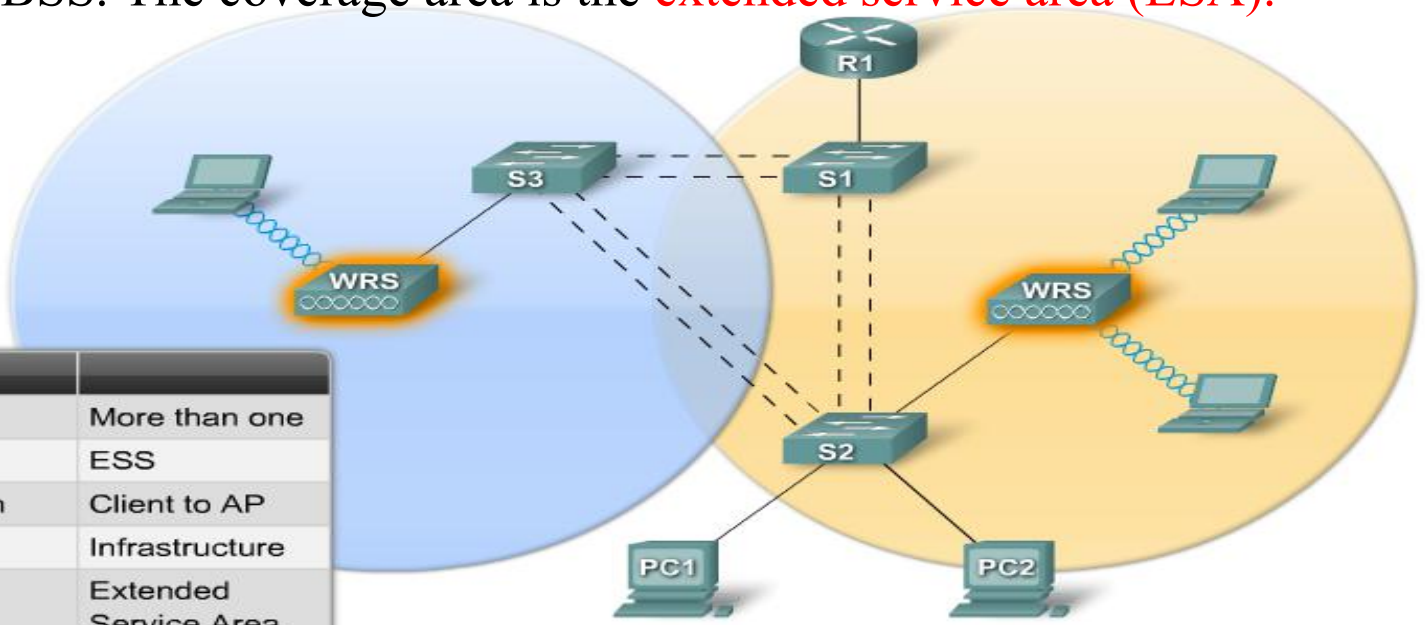


Wireless Networks

Wireless Operations: 802.11 Topologies

Extended Service Sets

- When a single BSS provides insufficient RF coverage, one or more can be joined through a common distribution system into an extended service set (ESS). In an ESS, one BSS is differentiated from another by the BSS identifier (BSSID), which is the MAC address of the access point serving the BSS. The coverage area is the extended service area (ESA).



APs	More than one
Topology	ESS
Connection	Client to AP
Mode	Infrastructure
Coverage	Extended Service Area (ESA)

Wireless Networks

Wireless Operations: 802.11 Topologies

Summary of WLAN Topologies

Wireless Devices	Topology Mode	Topology Building Block	Coverage Area
No access points	Ad Hoc	Independent Basic Service Set (IBSS)	Basic Service Area (BSA)
One access point	Infrastructure	Basic Service Set (BSS)	Basic Service Area (BSA)
More than one access point	Infrastructure	Extended Service Set (ESS)	Extended Service Area (ESA)