

# Unit-3

## ETHERNET

# IEEE 802

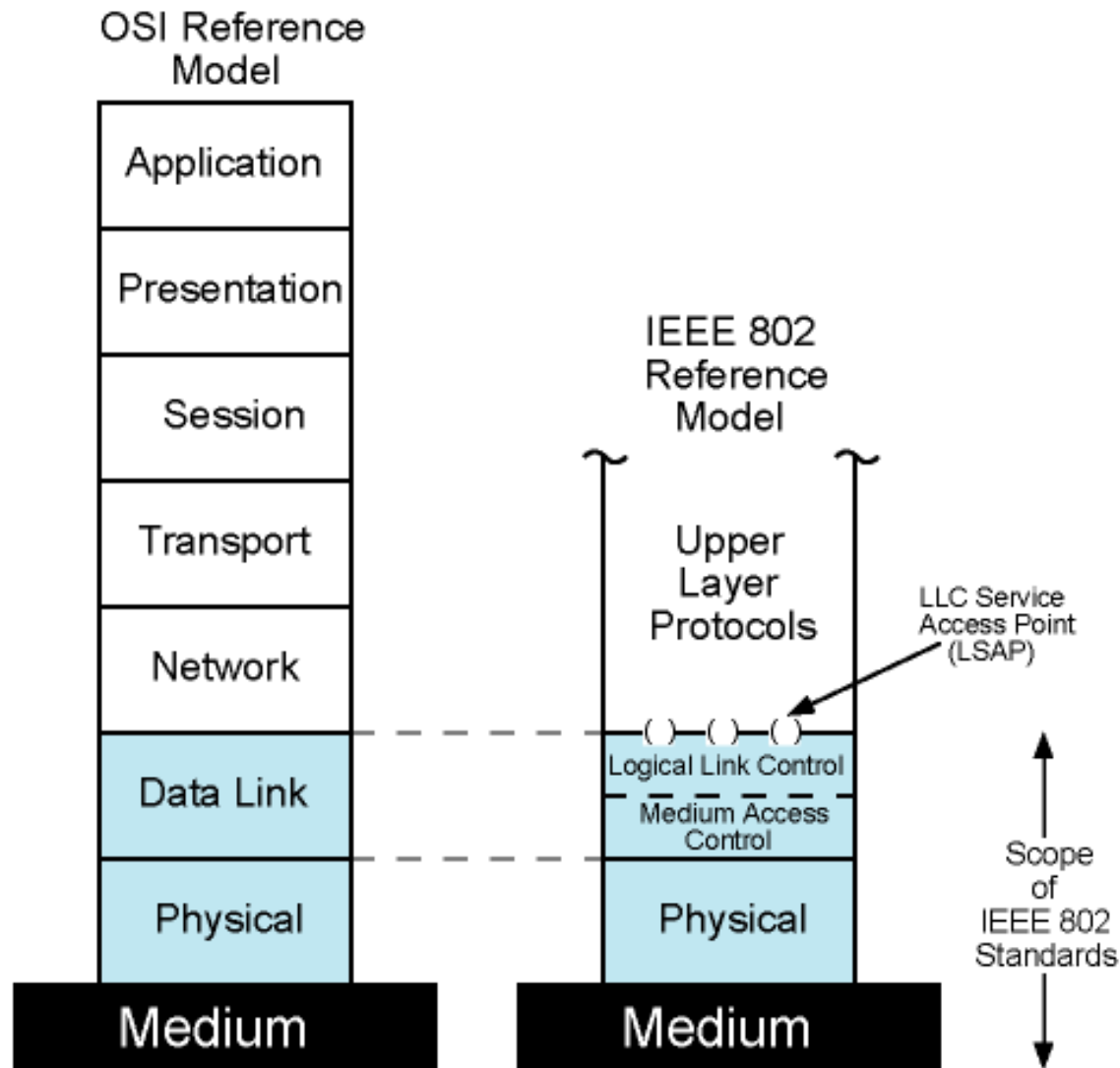
IEEE 802.1 Higher layer LAN protocols  
IEEE 802.2 Logical link control  
**IEEE 802.3 Ethernet**  
IEEE 802.4 Token bus  
IEEE 802.5 Token Ring  
IEEE 802.6 Metropolitan Area Networks  
IEEE 802.7 Broadband LAN using Coaxial Cable  
IEEE 802.8 Fiber Optic TAG  
IEEE 802.9 Integrated Services LAN  
IEEE 802.10 Interoperable LAN Security  
**IEEE 802.11 Wireless LAN (Wi-Fi)**  
IEEE 802.12 demand priority  
IEEE 802.14 Cable modems

**IEEE 802.15 Wireless PAN**  
IEEE 802.15.1 (Bluetooth)  
IEEE 802.15.4 (ZigBee)  
**IEEE 802.16 Broadband Wireless Access (WiMAX)**  
**IEEE 802.16e (Mobile) Broadband Wireless Access**  
IEEE 802.17 Resilient packet ring  
IEEE 802.18 Radio Regulatory TAG  
IEEE 802.19 Coexistence TAG  
IEEE 802.20 Mobile Broadband Wireless Access  
IEEE 802.21 Media Independent Handoff  
IEEE 802.22 Wireless Regional Area Network

# 1 5.2 LAN Protocol Architecture

- ▶ Lower layers of OSI model
- ▶ IEEE 802 reference model
  - Physical
  - Logical link control (LLC)
  - Medium access control (MAC)

# Figure 15.1 IEEE 802 Protocol Layers Compared to OSI Model



# 802 Layers – Physical


- ▶ Encoding/decoding
- ▶ Preamble generation/removal (for sync.)
- ▶ Bit transmission/reception
- ▶ Transmission medium
- ▶ Topology

# 802 Layers – Medium Access Control

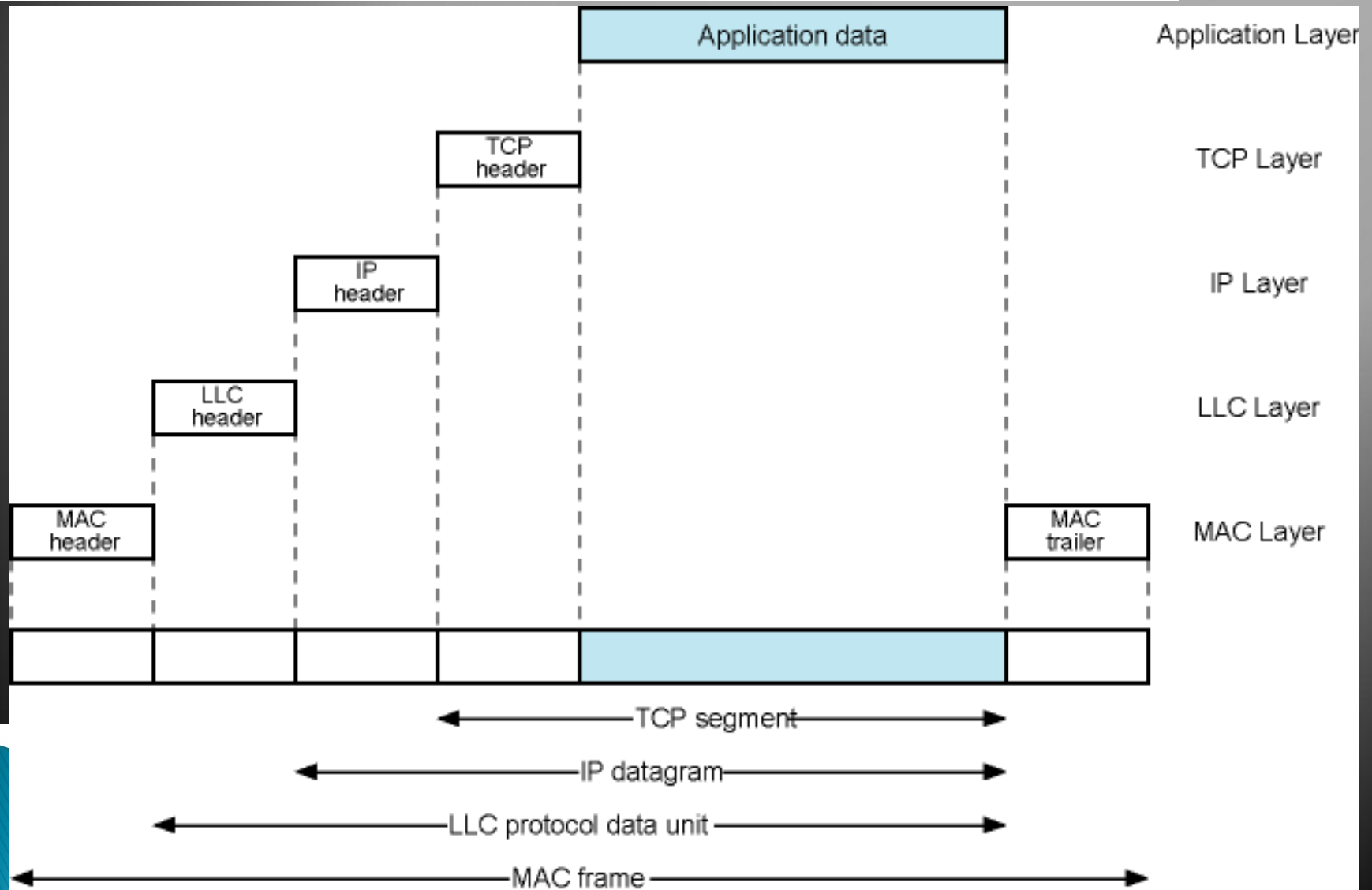
- Assemble data into frame
- Disassemble frame, and perform address recognition and error detection
- Govern access to the LAN transmission medium

## 802 Layers - Logical Link Control

---

- ▶ Interface to higher levels
  - ▶ Flow and error control
- 

# Figure 15.2 LAN Protocols in Context



# Logical Link Control


- ▶ Transmission of link level PDUs between two stations
- ▶ Must support multiaccess, shared medium
- ▶ Relieved of some link access details by MAC layer
- ▶ Addressing involves specifying source and destination LLC users
  - Referred to as service access points (SAP)
  - Typically higher level protocol



# LLC Services

- ▶ Based on HDLC
- ▶ Three services
  - Unacknowledged connectionless service
  - Connection mode service
  - Acknowledged connectionless service

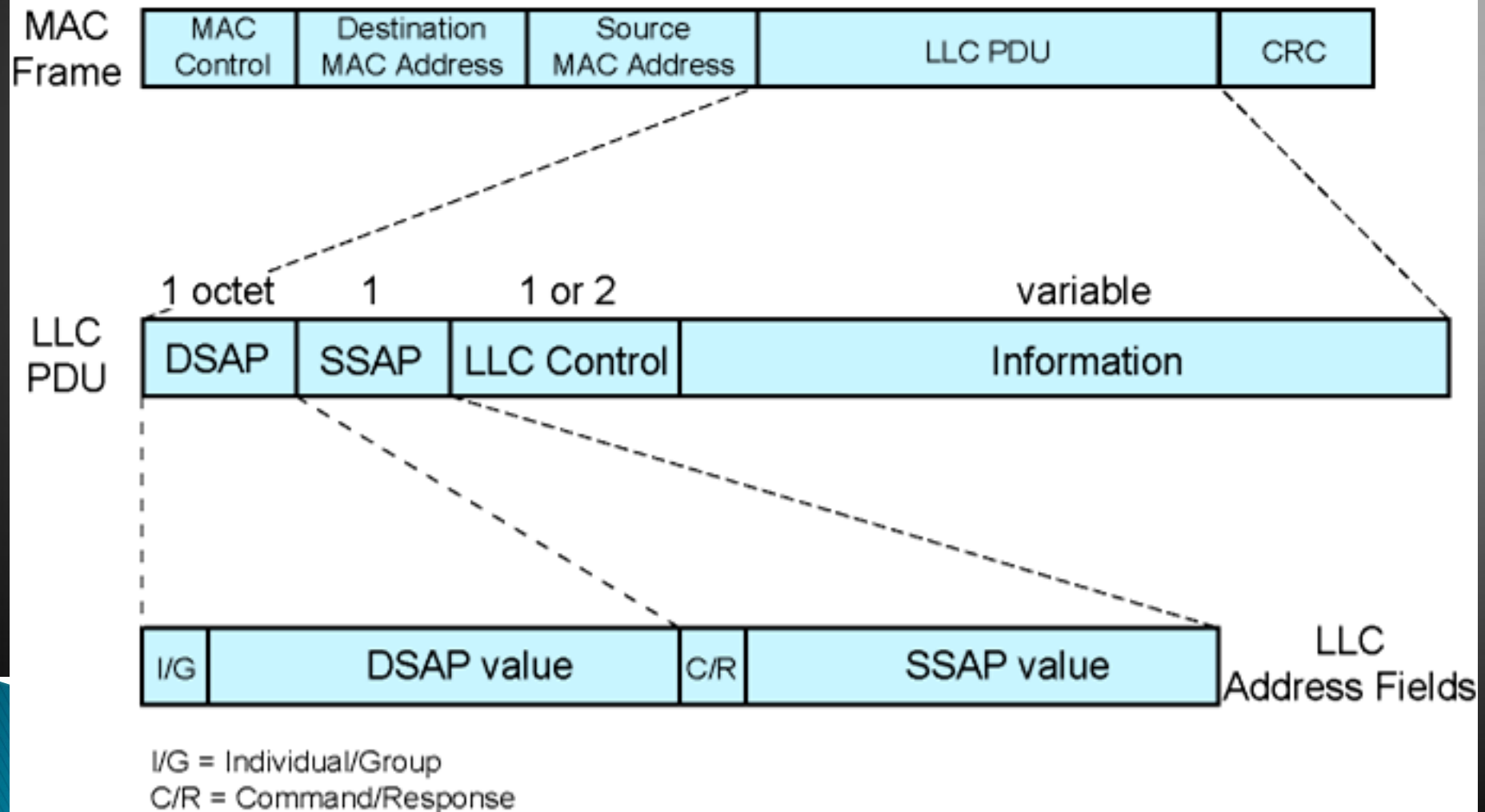
# Medium Access Control

- ▶ Multiple devices shares the network's transmission capacity/medium
  - ▶ Means of controlling access to the transmission medium
  - ▶ MAC layer receives data from LLC layer
  - ▶ LLC PDU is enclosed in a MAC frame
- 

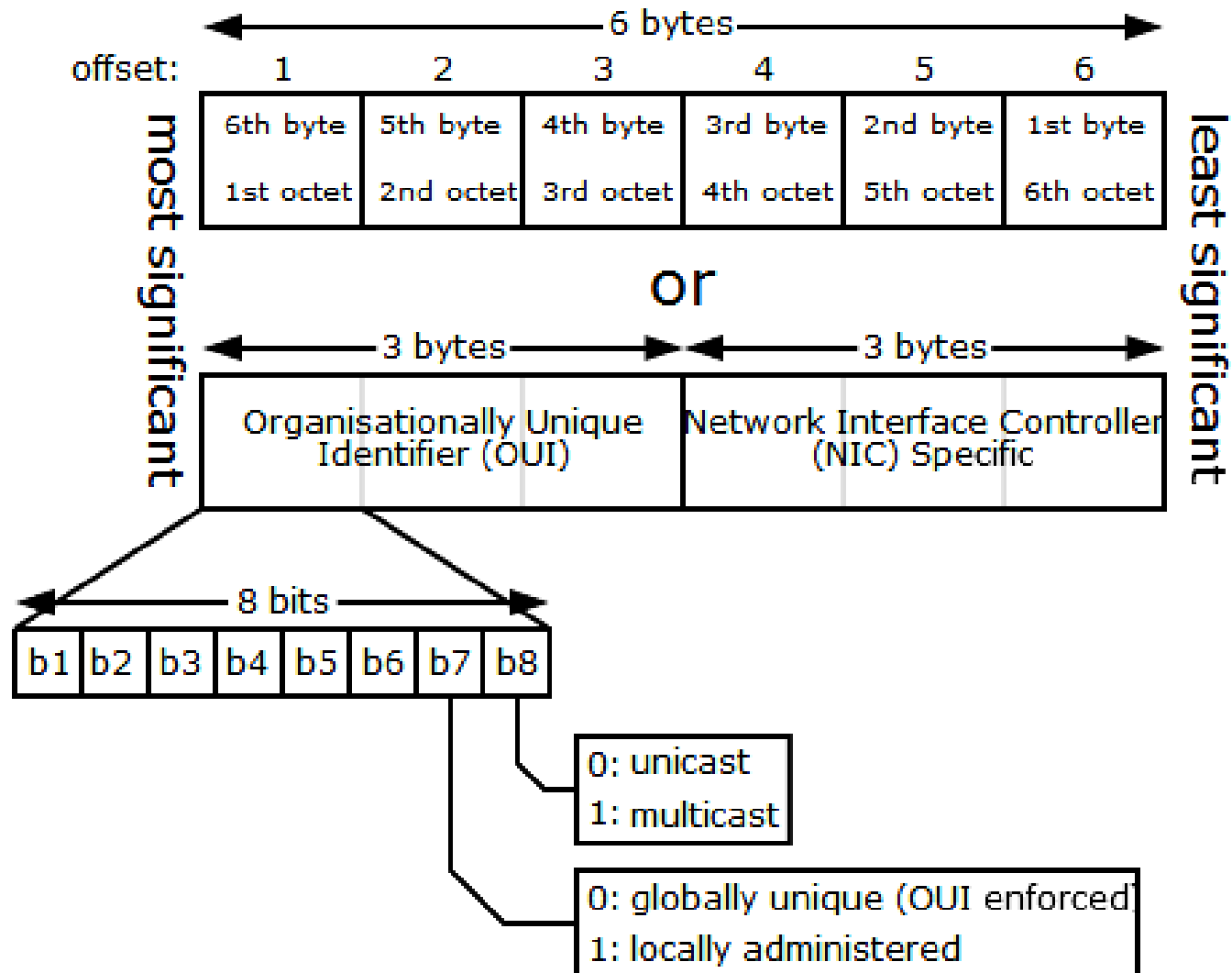
# MAC Frame Format

- ▶ The fields of MAC frame:
  - MAC Control – any protocol control info., e.g. priority
  - Destination MAC address
  - Source MAC address
  - LLC PDU – data from next layer up
  - CRC (Cyclic Redundancy Code) – error detection
- ▶ MAC layer detects errors and discards frames
- ▶ LLC optionally retransmits unsuccessful frames

# Figure 15.3 LLC PDU in a Generic MAC Frame Format



# MAC Address



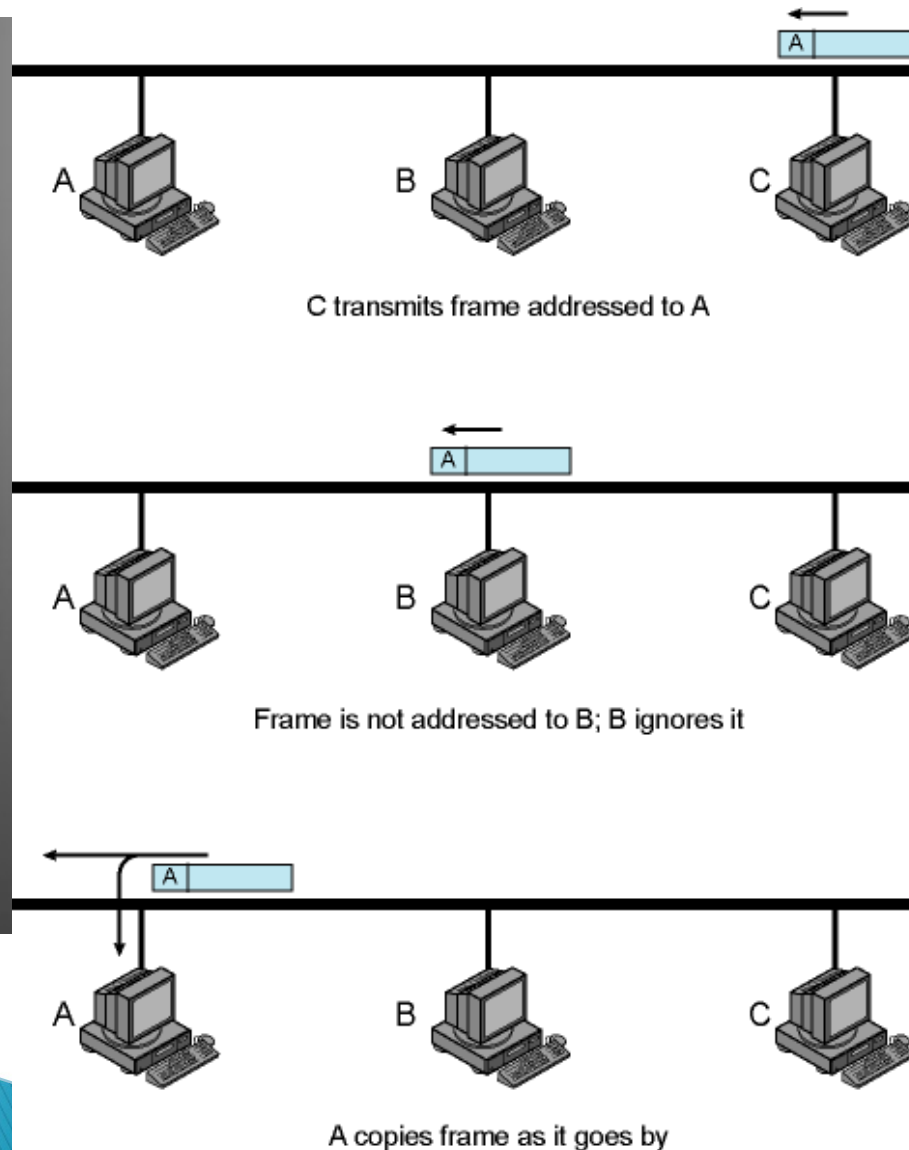
# 1 5.3 Ethernet

- ▶ Developed by Xerox
- ▶ IEEE 802.3
- ▶ Classical Ethernet
  - 10 Mbps
  - Bus topology
  - MAC: CSMA/CD (carrier sense multiple access with collision detection)
- ▶ <http://en.wikipedia.org/wiki/Category:Ethernet>

# Bus Topology

- ▶ Stations attach to linear transmission medium (bus), via a tap
- ▶ Full-duplex between station and tap
- ▶ Transmission propagates length of medium in both directions
- ▶ Received by all other stations
- ▶ At each end of bus: terminator, to absorb signal
- ▶ Need to indicate for whom transmission is intended
- ▶ Need to regulate transmission
  - If two stations attempt to transmit at same time, signals will overlap and become garbled
  - If one station transmits continuously access blocked for others
- ▶ Transmit data in small blocks (frames)
- ▶ Each station assigned unique address
  - Destination address included in frame header

# Figure 15.4 Frame Transmission on a Bus LAN





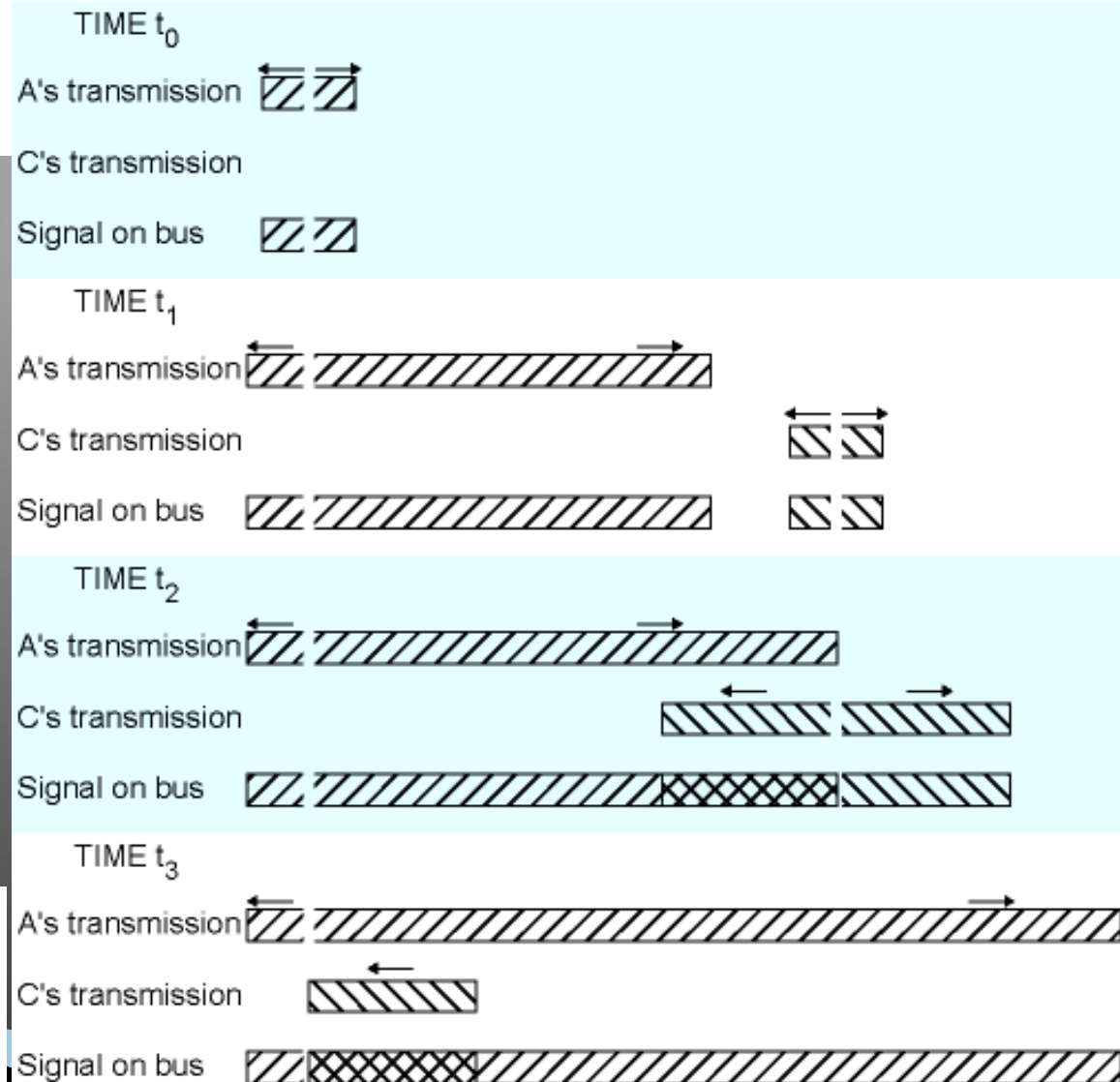
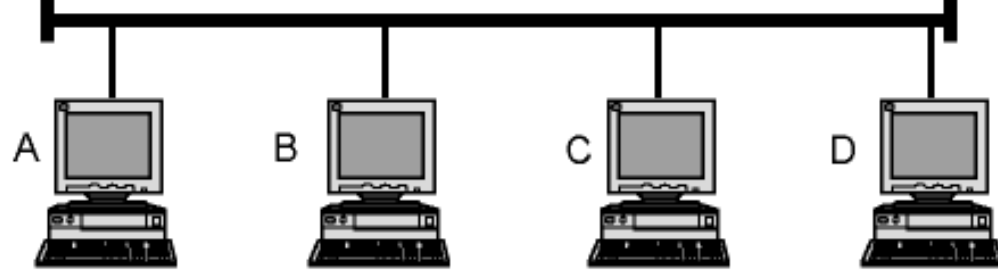
# CSMA/CD

- ▶ With CSMA, collision occupies medium for duration of transmission
- ▶ Stations listen whilst transmitting

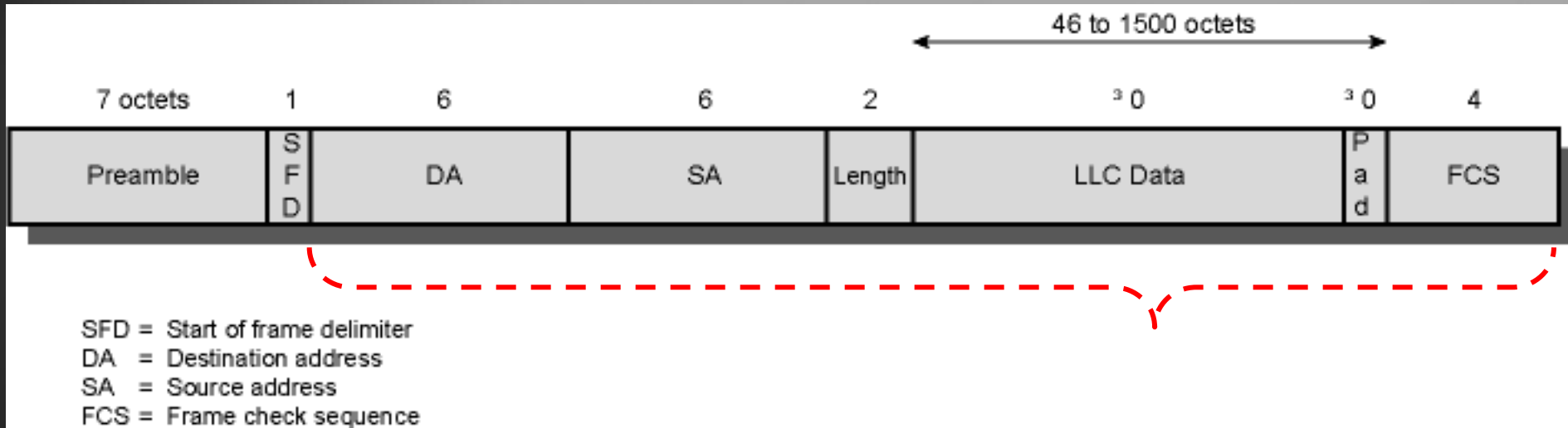
1. If medium idle, transmit, otherwise, step 2
2. If busy, listen for idle, then transmit
3. If collision detected, send a jamming signal and then cease transmission
4. After jam, wait random time (**backoff**) then start from step 1

- ▶ *Binary exponential backoff*
  - Random delay is doubled (the first 10 retransmission)
  - After 16 unsuccessful attempts, give up

# Figure 15.5 CSMA/CD Operation



# Figure 15.6 IEEE 802.3 Frame Format

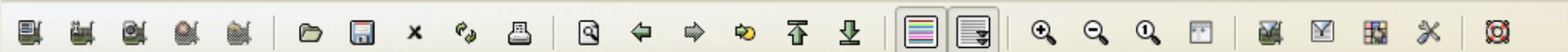


$$1518 = 18 + 1500$$

Preamble: 10101010...10101010

SFD: 10101011

File Edit View Go Capture Analyze Statistics Help

Filter:  Expression... Clear Apply

No.	Time	Source	Destination	Protocol	Info
5	1.246609	D-Link_b4:22:51	Spanning-tree-(for-br STP	Conf.	Root = 32768/00:0d:88:b4:22:51 Cost = 0 Port = 0x8032

+ Frame 5 (64 bytes on wire (8 bytes captured) on interface eth0)

## IEEE 802.3 Ethernet

- Destination: Spanning-tree-(for-bridges)\_00 (01:80:c2:00:00:00)  
Address: Spanning-tree-(for-bridges)\_00 (01:80:c2:00:00:00)  
.... 1 = IG bit: Group address (multicast/broadcast)  
.... 0 = LG bit: Globally unique address (factory default)
- Source: D-Link\_b4:22:51 (00:0d:88:b4:22:51)  
Address: D-Link\_b4:22:51 (00:0d:88:b4:22:51)  
.... 0 = IG bit: Individual address (unicast)  
.... 0 = LG bit: Globally unique address (factory default)
- Length: 38  
Trailer: 00000000806B22DC  
Frame check sequence: 0x806b22e8 [incorrect, should be 0xa90754bf]

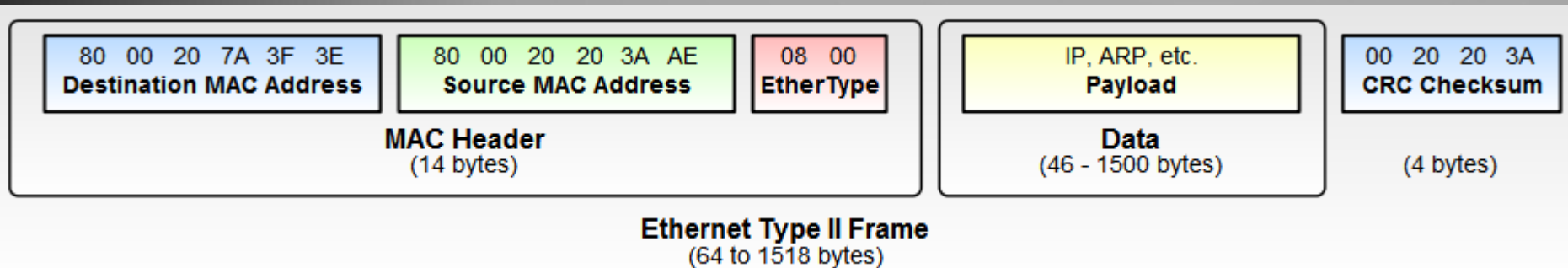
## Logical-Link Control

- DSAP: Spanning Tree BPDU (0x42)  
IG Bit: Individual  
SSAP: Spanning Tree BPDU (0x42)  
CR Bit: Command
- Control field: U, func=UI (0x03)  
000. 00.. = Command: Unnumbered Information (0x00)  
.... 11 = Frame type: Unnumbered frame (0x03)

## + Spanning Tree Protocol

0000	01 80 c2 00 00 00 0d 88 b4 22 51 00 26 42 42	..... "Q, &BB
0010	03 00 00 00 00 00 80 00 00 0d 88 b4 22 51 00 00	..... "Q..
0020	00 00 80 00 00 00 0d 88 b4 22 51 80 32 00 00 14 00	..... "Q.2....
0030	02 00 0f 00 00 00 00 00 80 6b 22 dc 80 6b 22 e8	..... .k"..k".

# Ethernet II

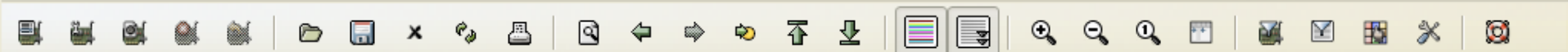


- *How to distinguish between 802.3 and Ethernet II frames?*

802.3: Length ( $\leq 05\ DC$ )

Ethernet II: EtherType ( $\geq 06\ 00$ )

<http://en.wikipedia.org/wiki/Ethertype>

Filter:  Expression... Clear Apply

No.	Time	Source	Destination	Protocol	Info
2	0.000740	163.22.2.3	10.10.13.137	ICMP	Destination unreachable (Port unreachable)

+ Frame 2 (70 bytes on wire (70 bytes captured))

- Ethernet II, Src: Cisco\_74:e4:00 (00:1a:30:74:e4:00), Dst: AsustekC\_ec:4a:50 (00:15:f2:ec:4a:50)

- Destination: AsustekC\_ec:4a:50 (00:15:f2:ec:4a:50)

Address: AsustekC\_ec:4a:50 (00:15:f2:ec:4a:50)

.... 0 .... = IG bit: Individual address (unicast)

.... 0 .... = LG bit: Globally unique address (factory default)

- Source: Cisco\_74:e4:00 (00:1a:30:74:e4:00)

Address: Cisco\_74:e4:00 (00:1a:30:74:e4:00)

.... 0 .... = IG bit: Individual address (unicast)

.... 0 .... = LG bit: Globally unique address (factory default)

Type: IP (0x0800)

+ Internet Protocol, Src: 163.22.2.3 (163.22.2.3), Dst: 10.10.13.137 (10.10.13.137)

+ Internet Control Message Protocol

0000	00 15 f2 ec 4a 50 00 1a 30 74 e4 00 08 00 45 00	....JP.. 0t...E.
0010	00 38 6f c2 00 00 3e 01 50 57 a3 16 02 03 0a 0a	.8o...>. PW.....
0020	0d 89 03 03 b3 55 00 00 00 00 45 00 00 ea 6f c2	.....U.. ..E...o.
0030	00 00 7e 11 0f 95 0a 0a 0d 89 a3 16 02 03 00 8a	..~.....
0040	00 8a 00 d6 47 bd	....G.

# 10Mbps Specification (Ethernet)

<data rate> <Signaling method> <Max segment length>  
(hundreds of meters)

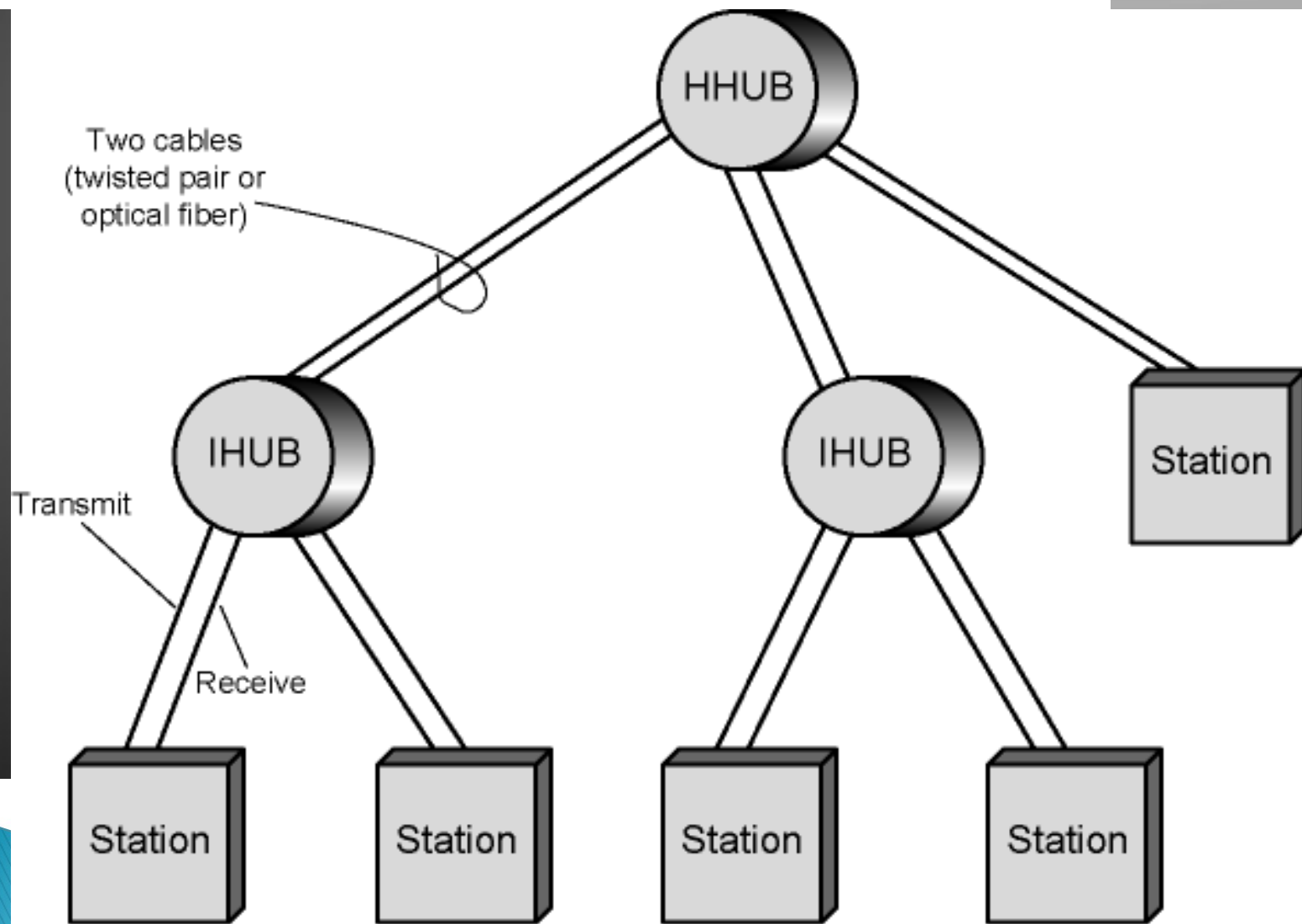
	10Base5	10Base2	10Base-T <sup>(100m)</sup>
▶ Medium	Coaxial	Coaxial	UTP
▶ Signaling	Baseband	Baseband	Baseband
▶	Manchester	Manchester	Manchester
▶ Topology	Bus	Bus	Star
▶ Nodes	100	30	–

# 10BASE-T

- ▶ Unshielded twisted pair (UTP) medium
  - Also used for telephone
- ▶ Star-shaped topology
  - Stations connected to central point, (multiport repeater)
  - Two twisted pairs (transmit and receive)
  - Repeater accepts input on any one line and repeats it on all other lines
- ▶ Link limited to 100 m on UTP
  - Optical fiber 500 m
- ▶ Central element of star is active element (hub)
- ▶ Physical star, logical bus
- ▶ Multiple levels of hubs can be cascaded



# Figure 15.7 Two-Level Star Topology



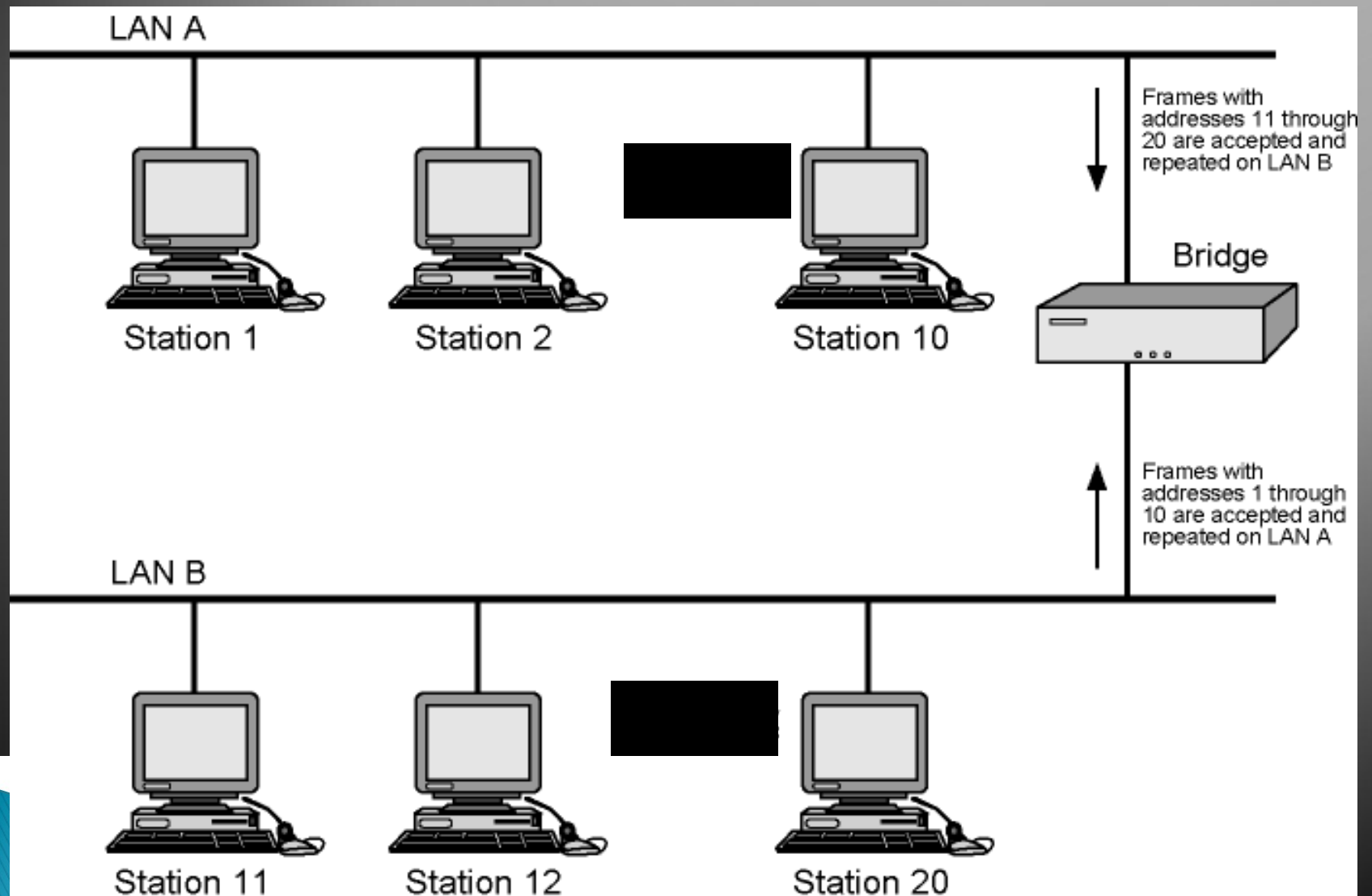
# 1 5.4 Bridges, Hubs, and Switches

- ▶ Ability to expand beyond single LAN
- ▶ Provide interconnection to other LANs/WANs
- ▶ Use Bridge or router
- ▶ Bridge is simpler
  - Connects similar LANs
  - Identical protocols for physical and link layers
  - Minimal processing
- ▶ Router more general purpose
  - Interconnect various LANs and WANs
  - see later


# Why Bridge?

- ▶ Reliability
- ▶ Performance
- ▶ Security
- ▶ Geography

# Figure 15.8 Bridge Operation



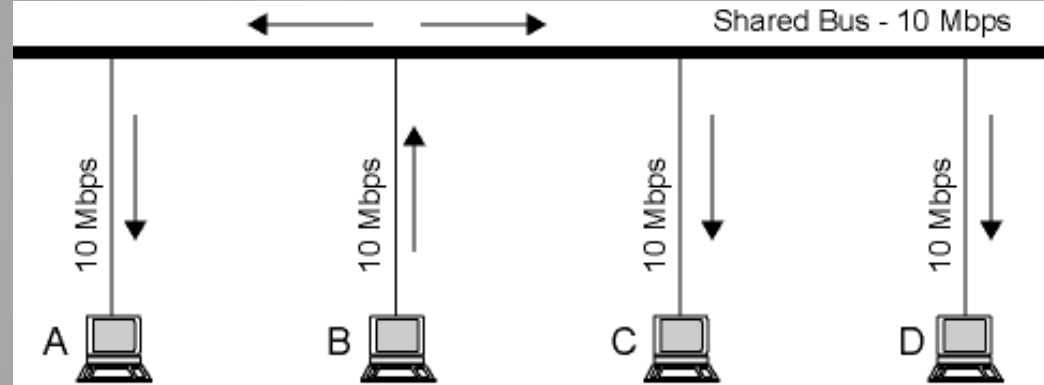
# Functions of a Bridge

- ▶ Read all frames transmitted on one LAN and accept those address to any station on the other LAN
  - ▶ Using MAC protocol for second LAN, retransmit each frame
  - ▶ Do the same the other way round
- 

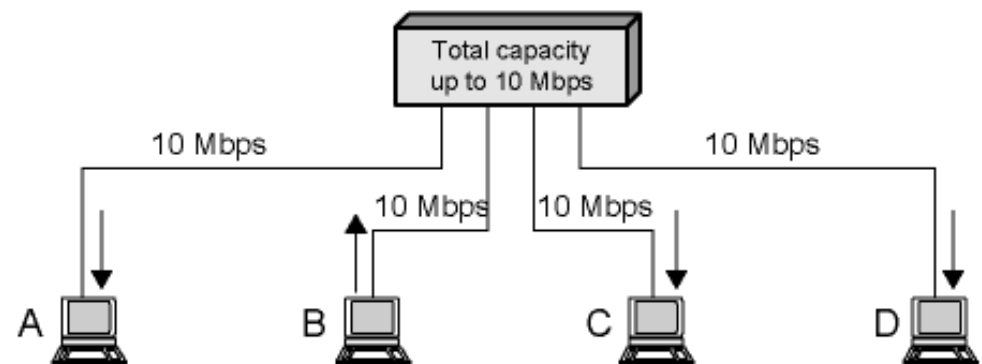
# Bridge Design Aspects

- ▶ No modification to content or format of frame
- ▶ No encapsulation
- ▶ Exact bitwise copy of frame
- ▶ Minimal buffering to meet peak demand
- ▶ Contains routing and address intelligence
  - Must be able to tell which frames to pass
  - May be more than one bridge to cross
- ▶ May connect more than two LANs
- ▶ Bridging is transparent to stations
  - Appears to all stations on multiple LANs as if they are on one single LAN

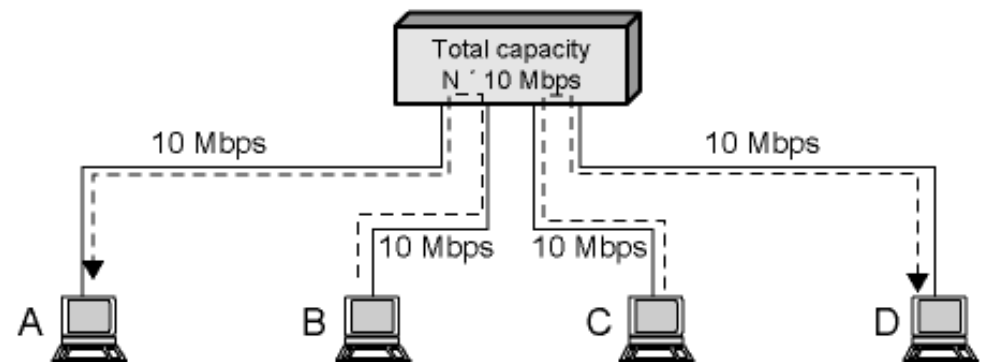
# Figure 15.9 LAN Hubs and Switches



(a) Shared medium bus




(b) Shared medium hub



(c) Layer 2 switch

# Layer 2 Switches

- ▶ Central hub acts as switch
  - ▶ Incoming frame from particular station switched to appropriate output line
  - ▶ Unused lines can switch other traffic
  - ▶ More than one station transmitting at a time
  - ▶ Multiplying capacity of LAN
- 



# Layer 2 Switch Benefits

- ▶ No change to attached devices to convert bus LAN or hub LAN to switched LAN
- ▶ For Ethernet LAN, each device uses Ethernet MAC protocol
- ▶ Device has dedicated capacity equal to original LAN
  - Assuming switch has sufficient capacity to keep up with all devices
  - For example if switch can sustain throughput of 20 Mbps, each device appears to have dedicated capacity for either input or output of 10 Mbps
- ▶ Layer 2 switch scales easily
  - Additional devices attached to switch by increasing capacity of layer 2

# Types of Layer 2 Switch

- ▶ Store-and-forward switch
  - Accepts frame on input line
  - Buffers it briefly,
  - Then routes it to appropriate output line
  - Delay between sender and receiver
  - Boosts integrity of network
- ▶ Cut-through switch
  - Takes advantage of destination address appearing at beginning of frame
  - Switch begins repeating frame onto output line as soon as it recognizes destination address
  - Highest possible throughput
  - Risk of propagating bad frames
    - Switch unable to check CRC prior to retransmission

# Layer 2 Switch v Bridge

- ▶ Layer 2 switch can be viewed as full-duplex hub
- ▶ Can incorporate logic to function as multiport bridge
- ▶ Bridge frame handling done in software
- ▶ Switch performs address recognition and frame forwarding in hardware
- ▶ Bridge only analyzes and forwards one frame at a time
- ▶ Switch has multiple parallel data paths
  - Can handle multiple frames at a time
- ▶ Bridge uses store-and-forward operation
- ▶ Switch can have cut-through operation
- ▶ Bridge suffered commercially
  - New installations typically include layer 2 switches with bridge functionality rather than bridges

# Problems with Layer 2 Switches (1)

- ▶ As number of devices in building grows, layer 2 switches reveal some inadequacies
- ▶ Broadcast overload
- ▶ Lack of multiple links
- ▶ Set of devices and LANs connected by layer 2 switches have flat address space
  - All users share common MAC broadcast address
  - If any device issues broadcast frame, that frame is delivered to all devices attached to network connected by layer 2 switches and/or bridges
  - In large network, broadcast frames can create big overhead
  - Malfunctioning device can create broadcast storm
    - Numerous broadcast frames clog network

# Problems with Layer 2 Switches (2)

- ▶ Current standards for bridge protocols dictate no closed loops
  - Only one path between any two devices
  - Impossible in standards-based implementation to provide multiple paths through multiple switches between devices
    - Limits both performance and reliability.
- ▶ Solution: break up network into subnetworks connected by routers
- ▶ MAC broadcast frame limited to devices and switches contained in single subnetwork
- ▶ IP-based routers employ sophisticated routing algorithms
  - Allow use of multiple paths between subnetworks going through different routers

# Problems with Routers

- ▶ Routers do all IP-level processing in software
  - High-speed LANs and high-performance layer 2 switches pump millions of packets per second
  - Software-based router only able to handle well under a million packets per second
- ▶ Solution: **layer 3 switches**
  - Implement packet-forwarding logic of router in hardware
- ▶ Two categories of Layer 3 switches
  - Packet by packet
  - Flow based

# Packet by Packet or Flow Based

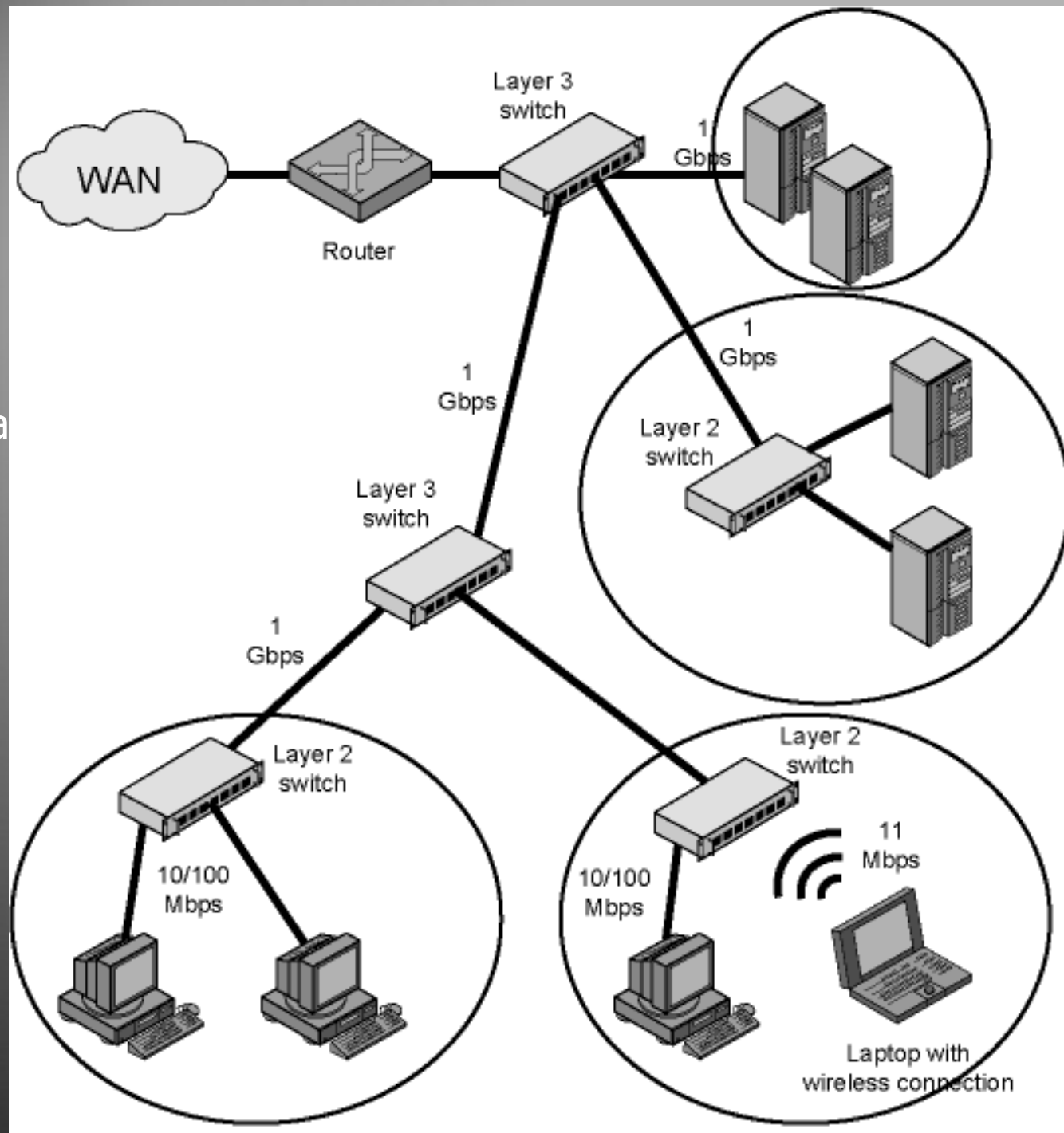
- ▶ Packet-by-packet
  - Operates in same way as traditional router
  - Hardware-based layer 3 switch can achieve better performance than software-based router
- ▶ Flow-based switch tries to enhance performance by identifying flows of IP packets
  - Same source and destination
  - Done by observing ongoing traffic or using a special flow label in packet header (IPv6)
  - Once flow is identified, predefined route can be established

# Typical Large LAN Organization

- ▶ Thousands to tens of thousands of devices
- ▶ Desktop systems links 10 Mbps to 100 Mbps
  - Into layer 2 switch
- ▶ Wireless LAN connectivity available for mobile users
- ▶ Layer 3 switches at local network's core
  - Form local backbone
  - Interconnected at 1 Gbps
  - Connect to layer 2 switches at 100 Mbps to 1 Gbps
- ▶ Servers connect directly to layer 2 or layer 3 switches at 1 Gbps
- ▶ Lower-cost software-based router provides WAN connection
- ▶ MAC broadcast frame limited to own subnetwork



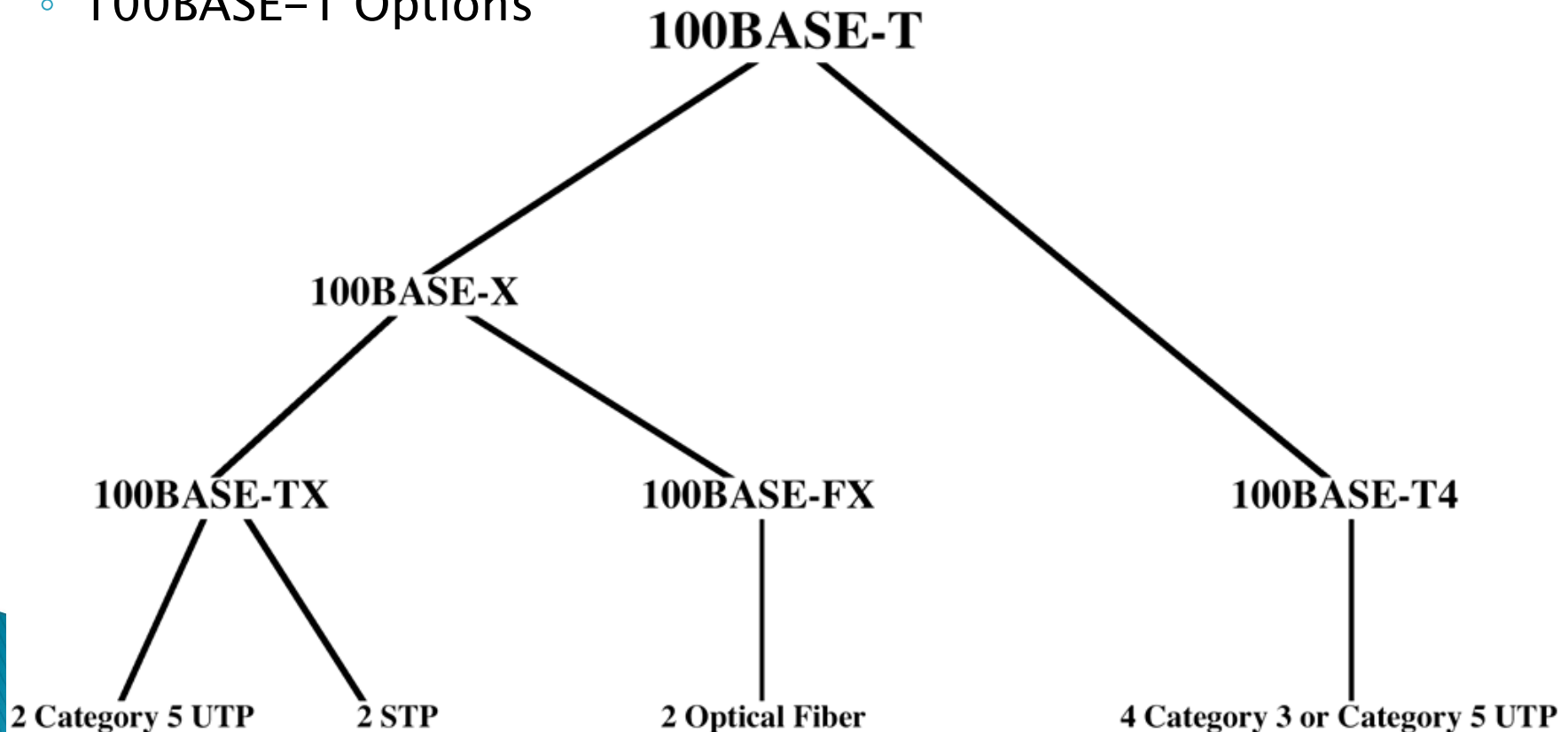
\* Circles identify separate subnetworks.



# 15.5 High-Speed Ethernet

## ▶ 100Mbps Fast Ethernet

- Use IEEE 802.3 MAC protocol and frame format
- Star-wire topology (Similar to 10BASE-T)
- 100BASE-T Options



# 100BASE-X, 100BASE-T4

- ▶ Unidirectional data rate 100 Mbps over single link
- ▶ 100BASE-TX uses STP or Cat. 5 UTP
- ▶ 100BASE-FX uses optical fiber
- ▶ 100BASE-T4 can use Cat. 3, voice-grade UTP
  - Uses four twisted-pair lines between nodes
  - Data transmission uses three pairs in one direction at a time

# 100BASE-X Media

- ▶ 100BASE-X refers to a set of options using two physical links between nodes
  - Transmission and reception
- ▶ 100BASE-TX
  - Two pairs of twisted-pair cable
  - One pair for transmission and one for reception
  - STP and Category 5 UTP allowed
- ▶ 100BASE-FX
  - Two optical fiber cables
  - One for transmission and one for reception

# 100BASE-T4

- ▶ Can not get 100 Mbps on single twisted pair
  - Data stream split into three separate streams
    - Each with an effective data rate of 33.33 Mbps
  - Four twisted pairs used (Cat. 3)
  - Data transmitted and received using three pairs
  - Two pairs configured for bidirectional transmission

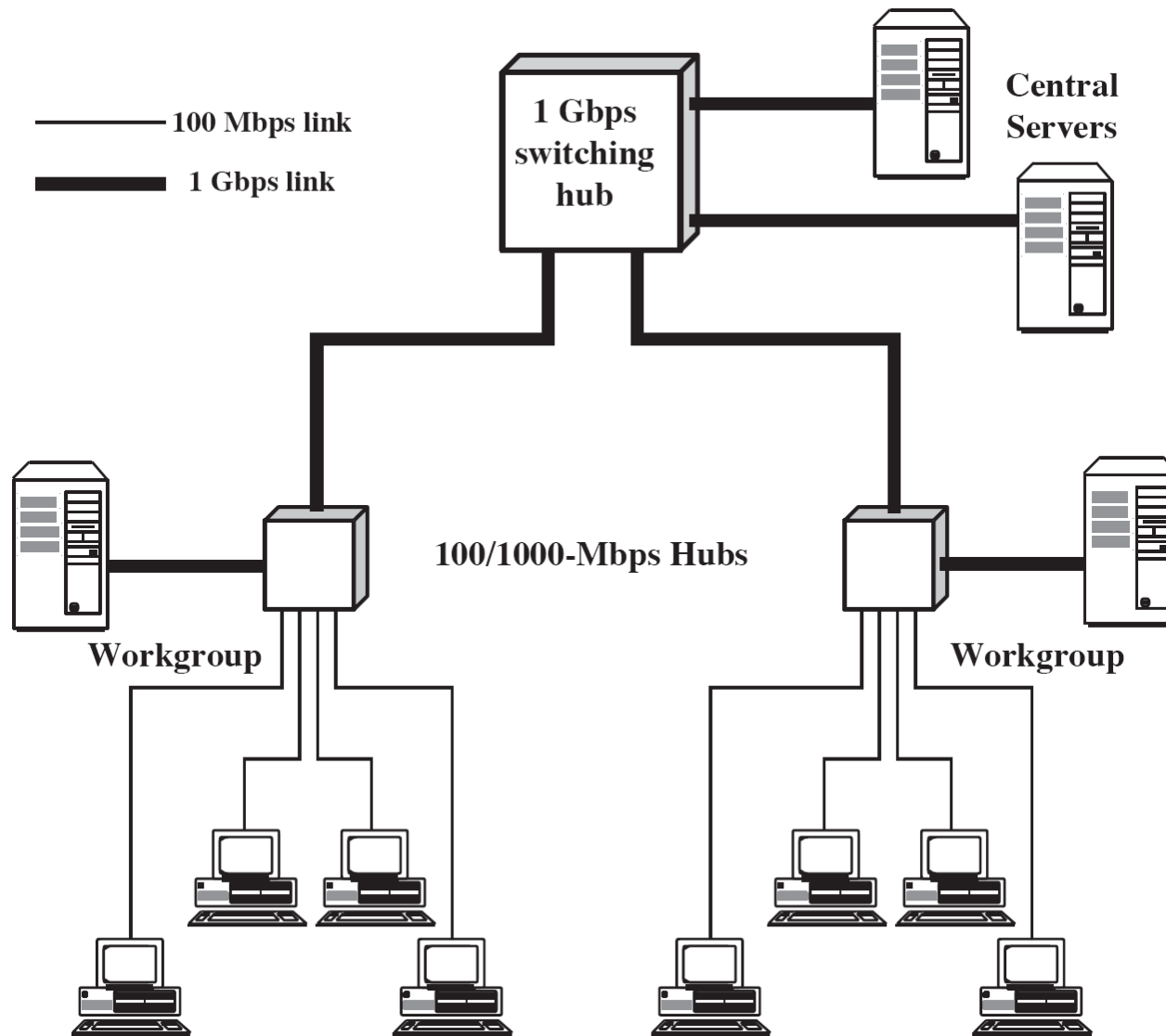
# Full Duplex Operation

- ▶ Traditional Ethernet half duplex
  - Either transmit or receive but not both simultaneously
- ▶ With full-duplex, station can transmit and receive simultaneously
- ▶ 100-Mbps Ethernet in full-duplex mode, theoretical transfer rate 200 Mbps
- ▶ Attached stations must have full-duplex adapter cards
- ▶ Must use switching hub
  - Each station constitutes separate collision domain
  - In fact, no collisions
  - CSMA/CD algorithm no longer needed
  - 802.3 MAC frame format used
  - Attached stations can continue CSMA/CD

# Gigabit Ethernet

- ▶ Strategy same as Fast Ethernet
- ▶ New medium and transmission specification
- ▶ Retains CSMA/CD protocol and frame format
- ▶ Compatible with 100BASE-T and 10BASE-T
  - Migration path

# Figure 15.12 Example Gigabit Ethernet Configuration

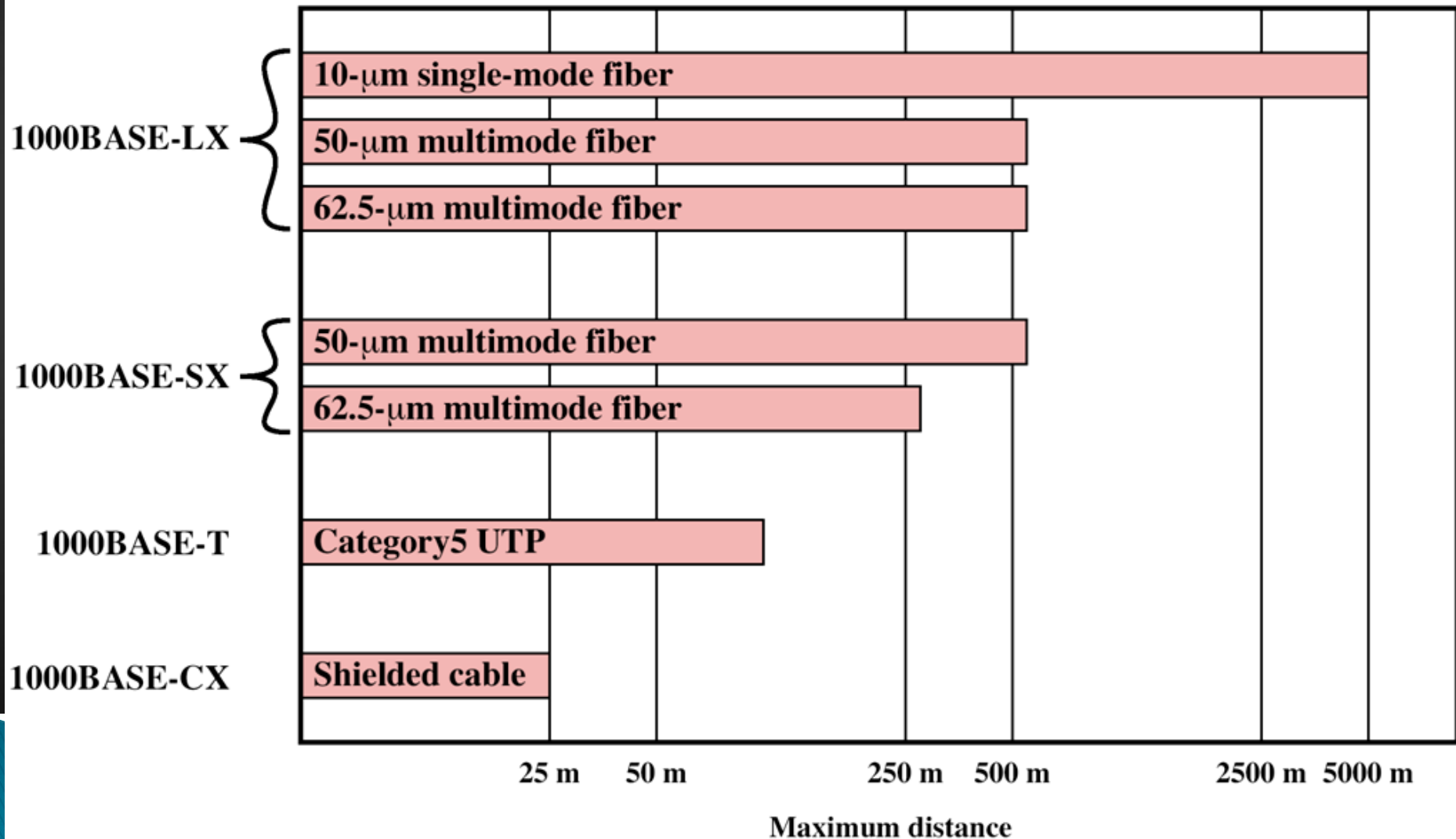




# Gigabit Ethernet – Physical

- ▶ 1000Base-SX
  - Short wavelength, multimode fiber
- ▶ 1000Base-LX
  - Long wavelength, Multi or single mode fiber
- ▶ 1000Base-CX
  - Copper jumpers <25m, shielded twisted pair
- ▶ 1000Base-T
  - 4 pairs, cat 5 UTP


# Figure 15.13 Gigabit Ethernet Medium Options (Log Scale)



# 10Gbps Ethernet – Uses

- ▶ High-speed, local backbone interconnection between large-capacity switches
- ▶ Server farm
- ▶ Campus wide connectivity
- ▶ Enables Internet service providers (ISPs) and network service providers (NSPs) to create very high-speed links at very low cost
- ▶ Allows construction of (MANs) and WANs
  - Connect geographically dispersed LANs between campuses or points of presence (PoPs)
- ▶ Ethernet competes with ATM and other WAN technologies
- ▶ 10-Gbps Ethernet provides substantial value over ATM

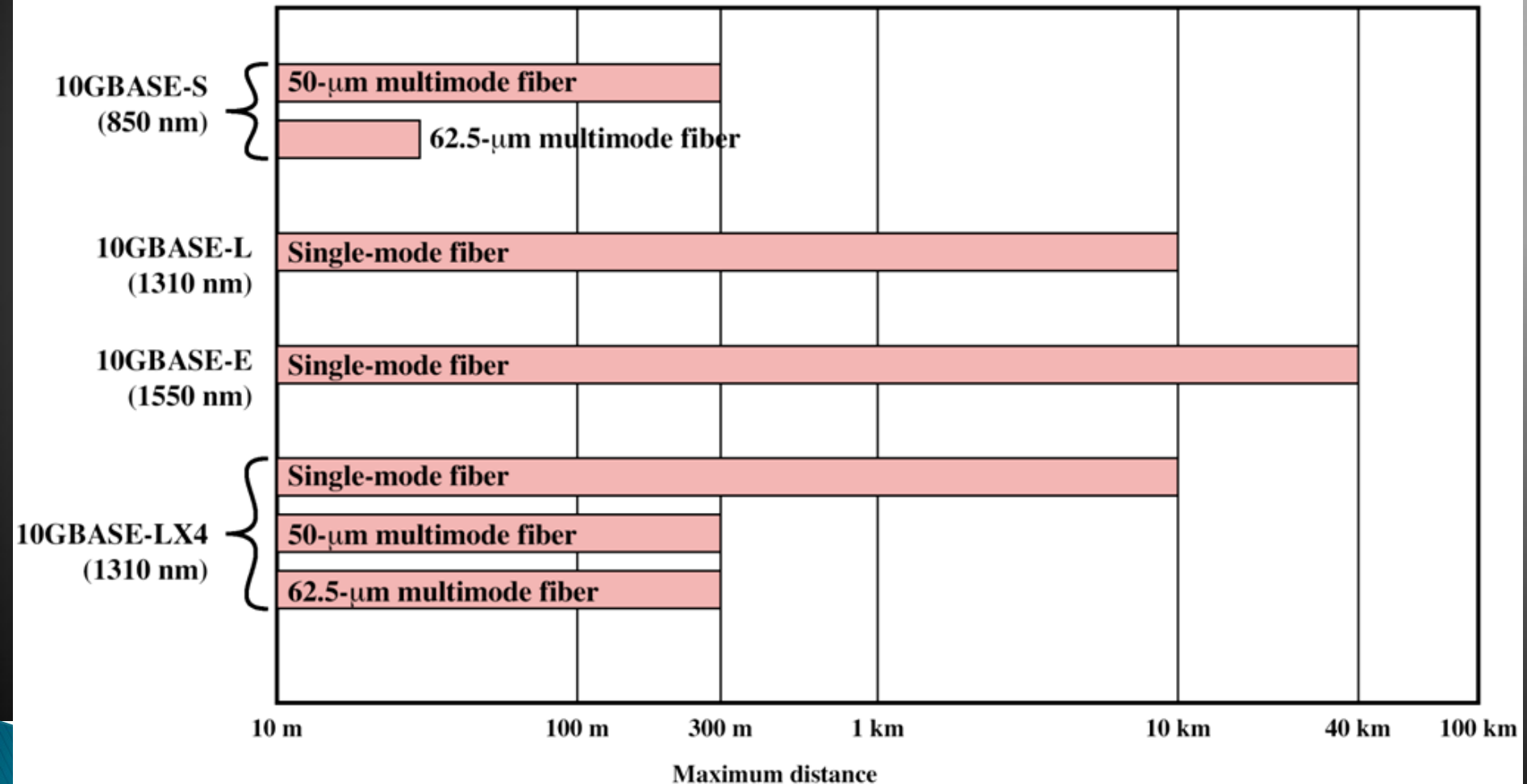
# 10Gbps Ethernet – Advantages

- ▶ No expensive, bandwidth-consuming conversion between Ethernet packets and ATM cells
  - ▶ Network is Ethernet, end to end
  - ▶ IP and Ethernet together offers QoS and traffic policing as ATM
  - ▶ Advanced traffic engineering technologies available to users and providers
  - ▶ Variety of standard optical interfaces (wavelengths and link distances) specified for 10 Gb Ethernet
  - ▶ Optimizing operation and cost for LAN, MAN, or WAN
- 

# 10Gbps Ethernet – Advantages

- ▶ Maximum link distances cover 300 m to 40 km
- ▶ Full-duplex mode only
- ▶ 10GBASE-S (short):
  - 850 nm on multimode fiber
  - Up to 300 m
- ▶ 10GBASE-L (long)
  - 1310 nm on single-mode fiber
  - Up to 10 km
- ▶ 10GBASE-E (extended)
  - 1550 nm on single-mode fiber
  - Up to 40 km
- ▶ 10GBASE-LX4:
  - 1310 nm on single-mode or multimode fiber
  - Up to 10 km
  - Wavelength-division multiplexing (WDM) bit stream across four light waves

# Figure 15.14 10-Gbps Ethernet Data Rate and Distance Options (Log Scale)



# 1 5.6 Wireless LANs

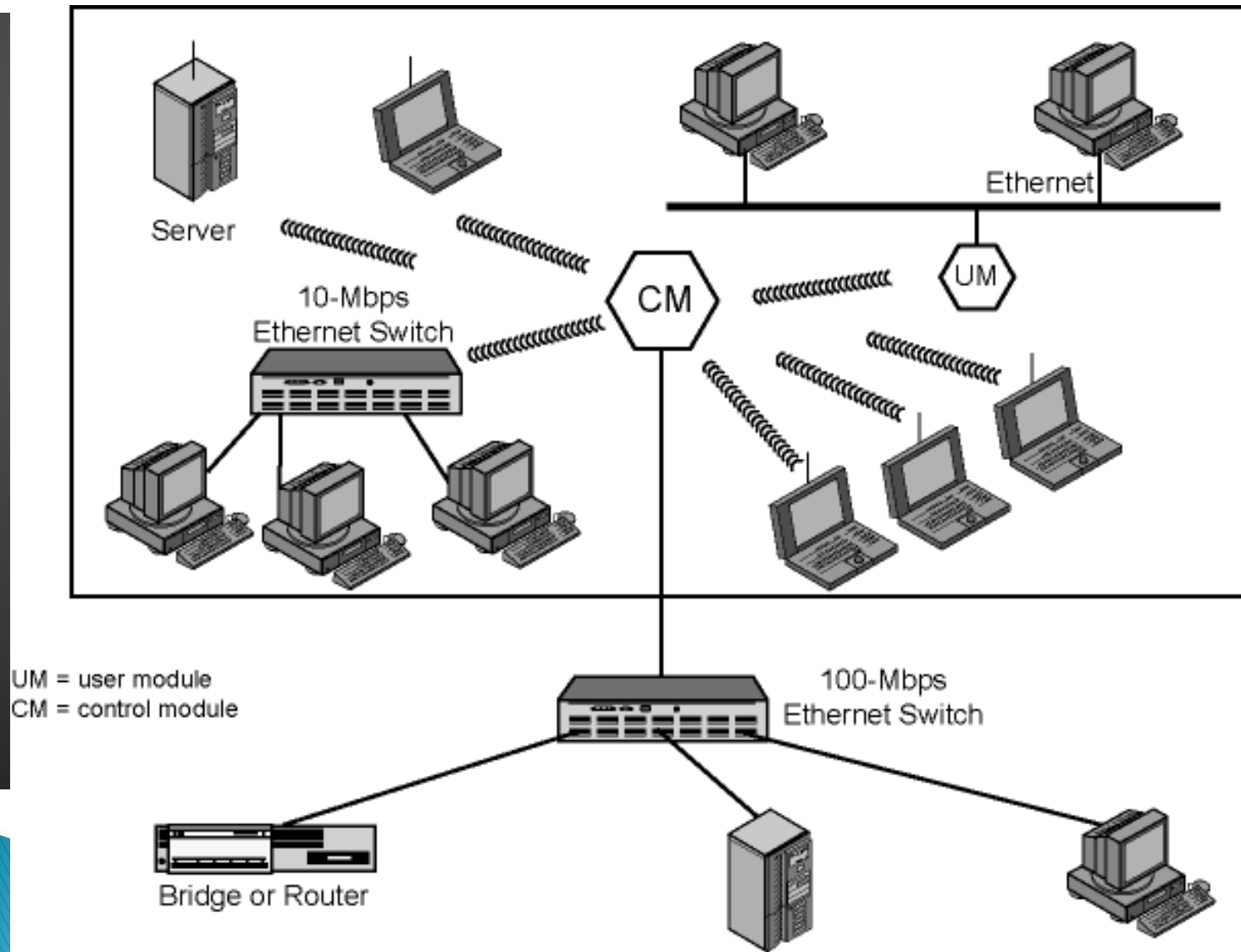
- ▶ A wireless LAN uses wireless transmission medium
- ▶ To satisfy requirements for
  - mobility
  - relocation
  - ad hoc networking
  - coverage of locations difficult to wire
- ▶ WLANs were little used for their high prices, low data rates, occupational safety concerns, and licensing requirements.
- ▶ As the above problems have been addressed, popularity of wireless LANs has grown rapidly.

# Applications – LAN Extension

- ▶ Saves installation of LAN cabling
- ▶ Eases relocation and other modifications to network structure
- ▶ However, increasing reliance on twisted pair cabling for LANs
  - Most older buildings already wired with Cat 3 cable
  - Newer buildings are prewired with Cat 5
- ▶ Wireless LAN to replace wired LANs has not happened
- ▶ In some environments, role for the wireless LAN
  - Buildings with large open areas
    - Manufacturing plants, stock exchange trading floors, warehouses
    - Historical buildings
    - Small offices where wired LANs not economical
- ▶ May also have wired LAN
  - Servers and stationary workstations



# Figure 15.15 Example Single-Cell Wireless LAN Configuration




# Applications – Cross-Building Interconnect

- ▶ Connect LANs in nearby buildings
- ▶ Point-to-point wireless link
- ▶ Connect bridges or routers
- ▶ Not a LAN by itself
  - Usual to include this application under heading of wireless LAN

# Applications – Nomadic Access

- ▶ Link between LAN hub and mobile data terminal
  - Laptop or notepad computer
  - Enable employee returning from trip to transfer data from portable computer to server
- ▶ Also useful in extended environment such as campus or cluster of buildings
  - Users move around with portable computers
  - May wish access to servers on wired LAN


# Applications – Ad Hoc Networking

- ▶ Peer-to-peer network
  - ▶ Set up temporarily to meet some immediate need
  - ▶ E.g. group of employees, each with laptop or palmtop, in business or classroom meeting
  - ▶ Network for duration of meeting
- 

# Wireless LAN Requirements (1)

- ▶ Same as any LAN
  - High capacity, short distances, full connectivity, broadcast capability
- ▶ Throughput:
  - efficient use wireless medium
- ▶ Number of nodes:
  - Hundreds of nodes across multiple cells
- ▶ Connection to backbone LAN:
  - Use control modules to connect to both types of LANs
- ▶ Service area: 100 to 300 m
- ▶ Low power consumption:
  - Need long battery life on mobile stations
  - Must not require nodes to monitor access points or frequent handshakes

# Wireless LAN Requirements (2)

- ▶ Transmission robustness and security:
    - WLANs may be interference prone and easily eavesdropped
  - ▶ Collocated network operation:
    - Two or more wireless LANs in same area
  - ▶ License-free operation
  - ▶ Handoff/roaming:
    - Move from one cell to another
  - ▶ Dynamic configuration:
    - Addition, deletion, and relocation of end systems without disruption to users
- 

# IEEE 802.11 Architecture

- ▶ MAC protocol and physical medium specification for wireless LANs
- ▶ Smallest building block is basic service set (BSS)
  - Number of stations
  - Same MAC protocol
  - Competing for access to same shared wireless medium
- ▶ May be isolated or connect to backbone distribution system (DS) through access point (AP)
  - AP functions as bridge
- ▶ MAC protocol may be distributed or controlled by central coordination function in AP
- ▶ BSS generally corresponds to cell
- ▶ DS can be switch, wired network, or wireless network

# BSS Configuration

- ▶ Simplest: each station belongs to single BSS
  - Within range only of other stations within BSS
- ▶ Can have two BSSs overlap
  - Station could participate in more than one BSS
- ▶ Association between station and BSS is dynamic
  - Stations may turn off, come within range, and go out of range



# Extended Service Set (ESS)

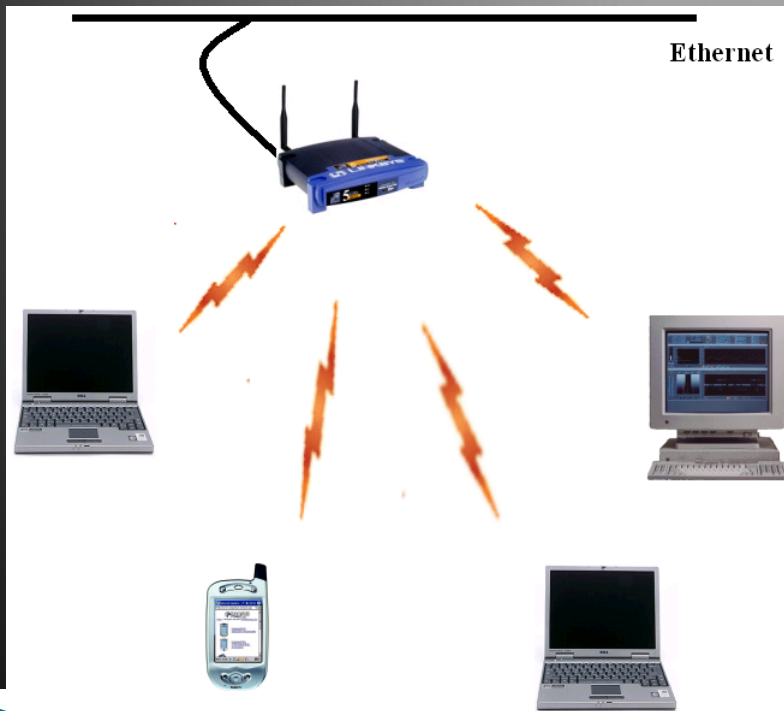
- ▶ Two or more BSS interconnected by DS
  - Typically, DS is wired backbone but can be any network
- ▶ Appears as single logical LAN to LLC

# SSID

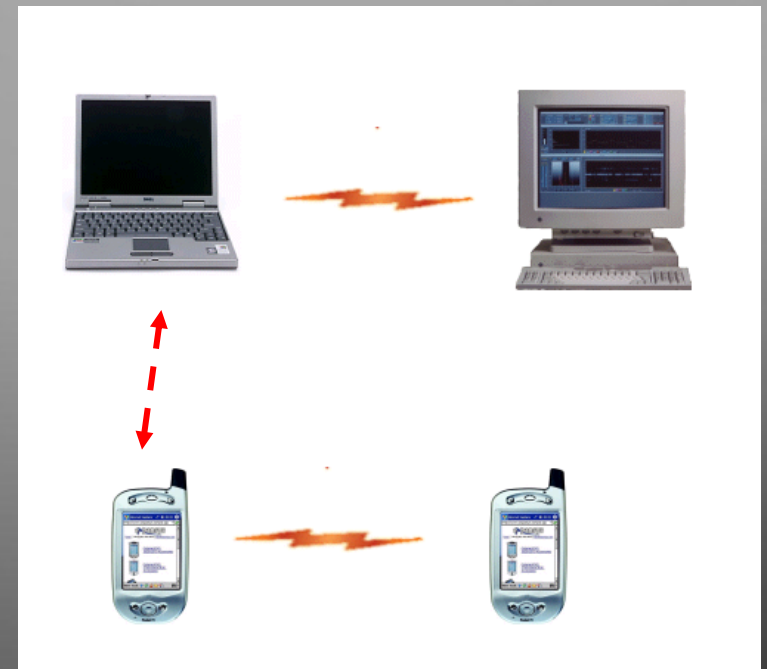
- ▶ SSID (Service Set Identifier)
  - Service Set識別碼
- ▶ 用來區分不同的網路服務集，無線網卡設定不同的SSID，進入不同的網路。
- ▶ SSID廣播
  - AP週期性廣播SSID，讓無線用戶端得知無線區域網路服務。
  - 可禁止AP廣播SSID，提高WLAN安全性

# Ad Hoc模式

## Infrastructure Mode



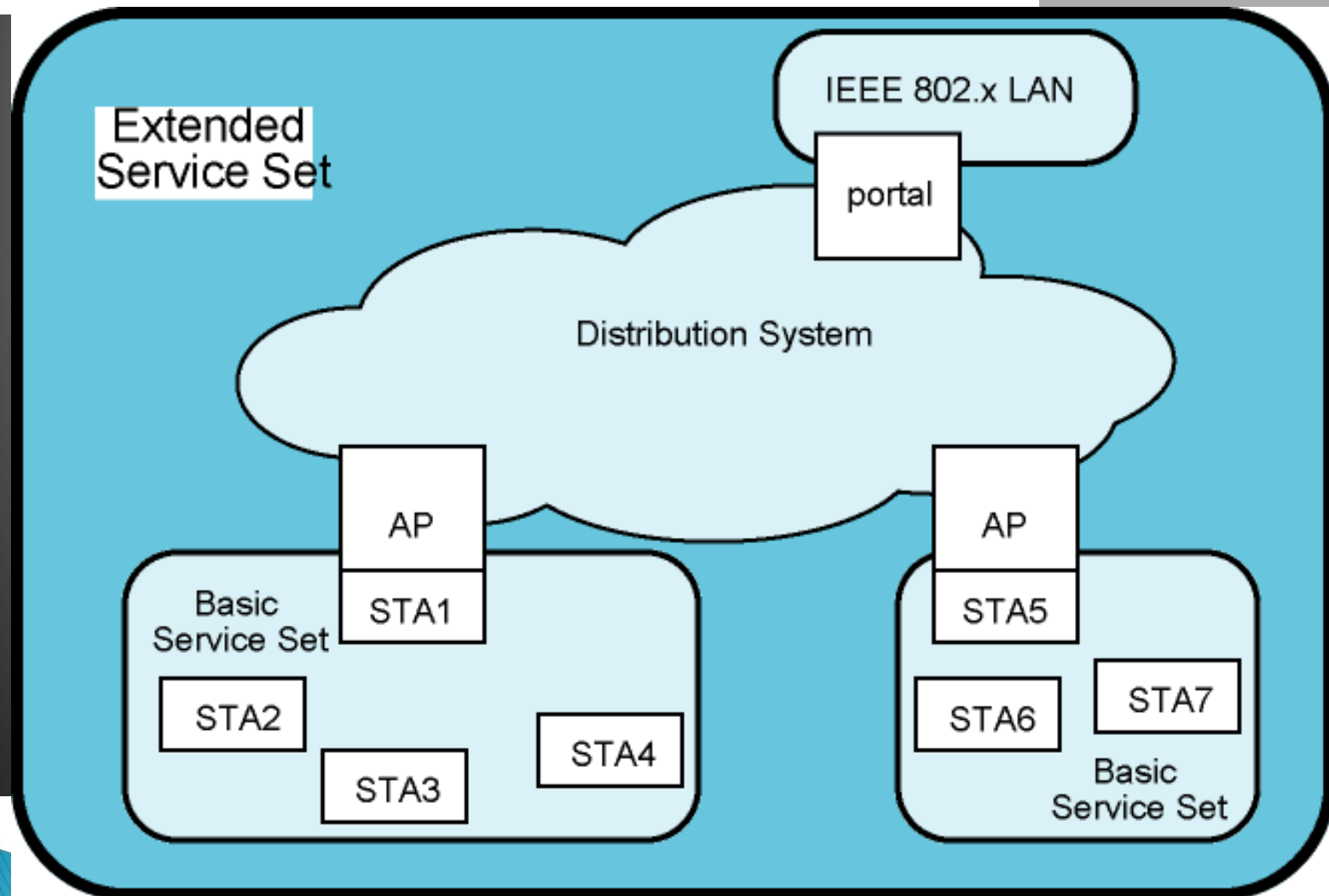
## Ad Hoc Mode



# Access Point (AP)

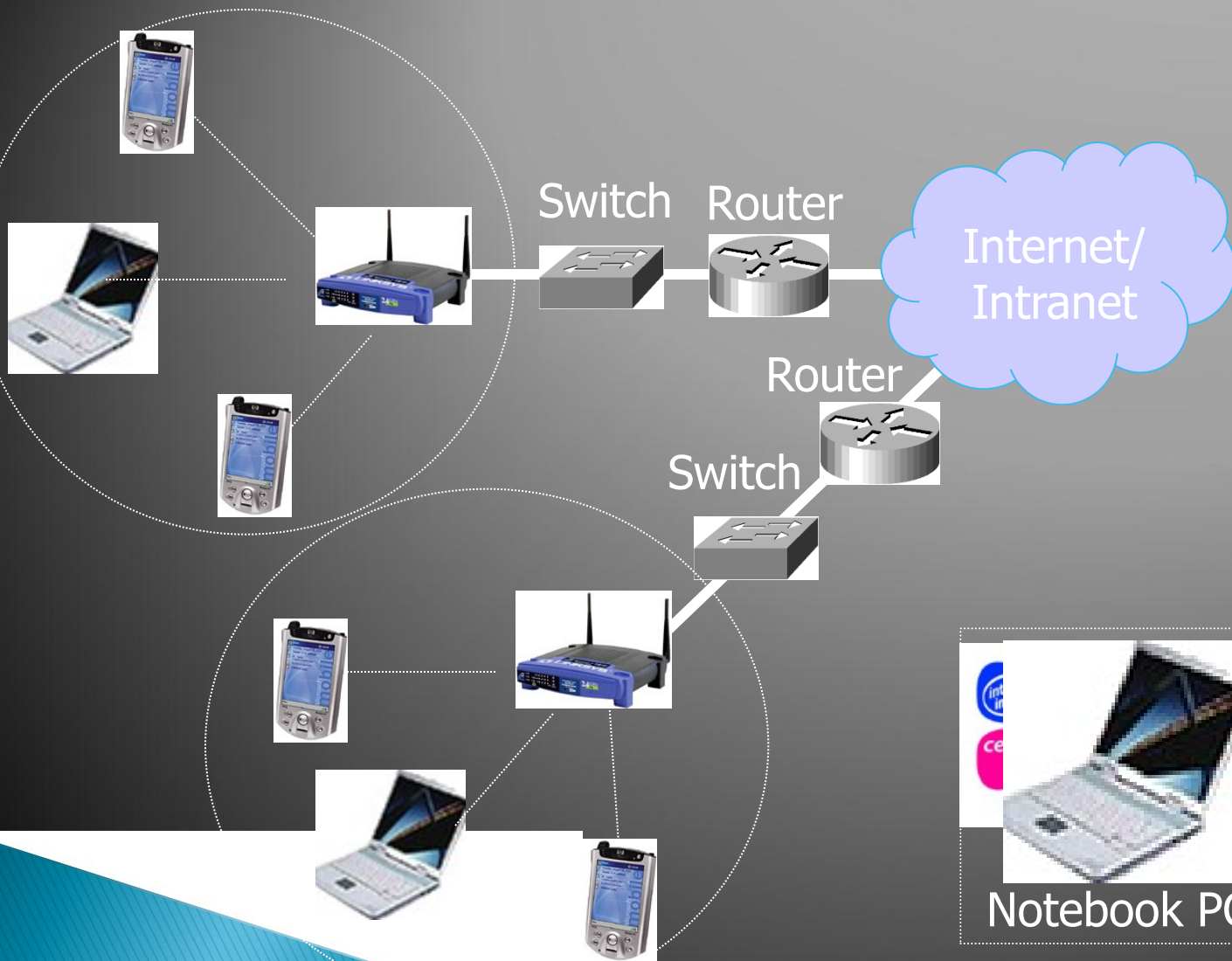
- ▶ Logic within station that provides access to DS
  - Provides DS services in addition to acting as station
- ▶ To integrate IEEE 802.11 architecture with wired LAN, a portal is used.
- ▶ Portal logic implemented in device that is part of wired LAN and attached to DS
  - E.g. Bridge or router

# Figure 15.16 IEEE 802.11 Architecture



STA = station  
AP = access point

# Typical Wireless LAN Configuration



Access Point

WLAN  
Adapter



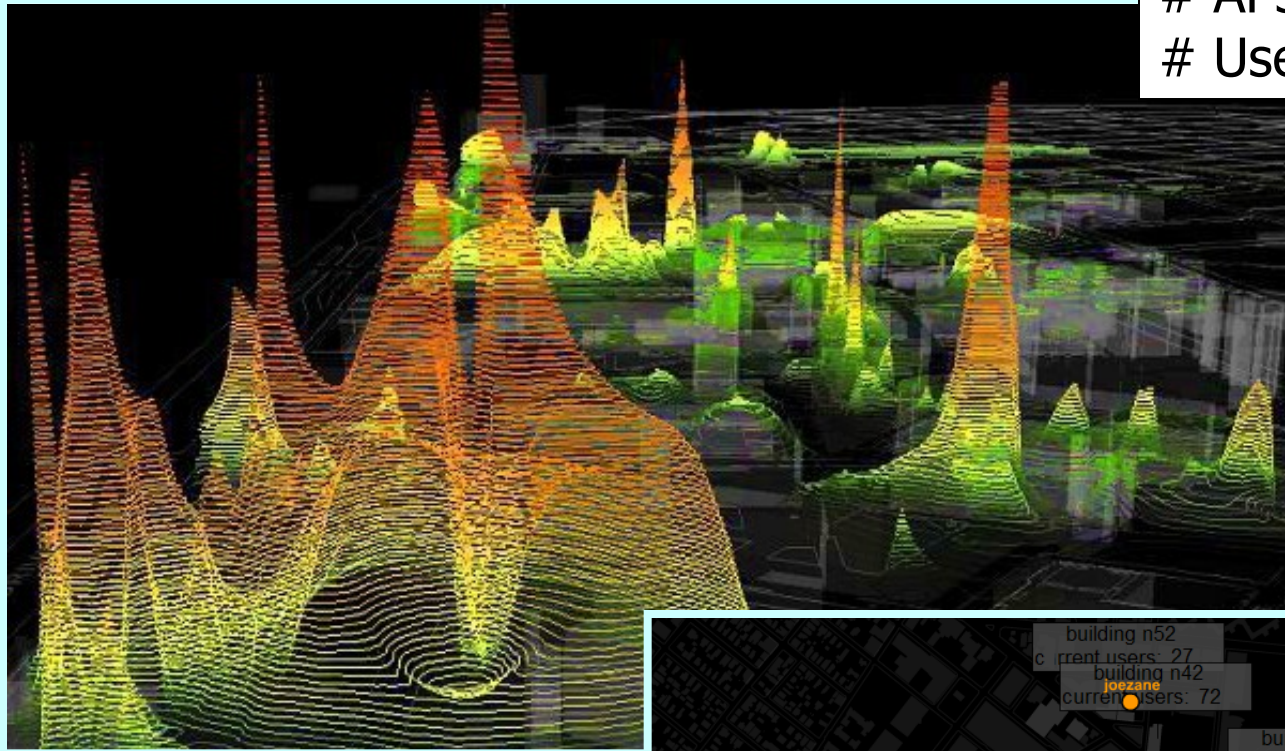
PDA



# MIT iSPOTS – <http://ispots.mit.edu/ispots/>

# APs : ~ 2800

# Users per 15 min: ~1000

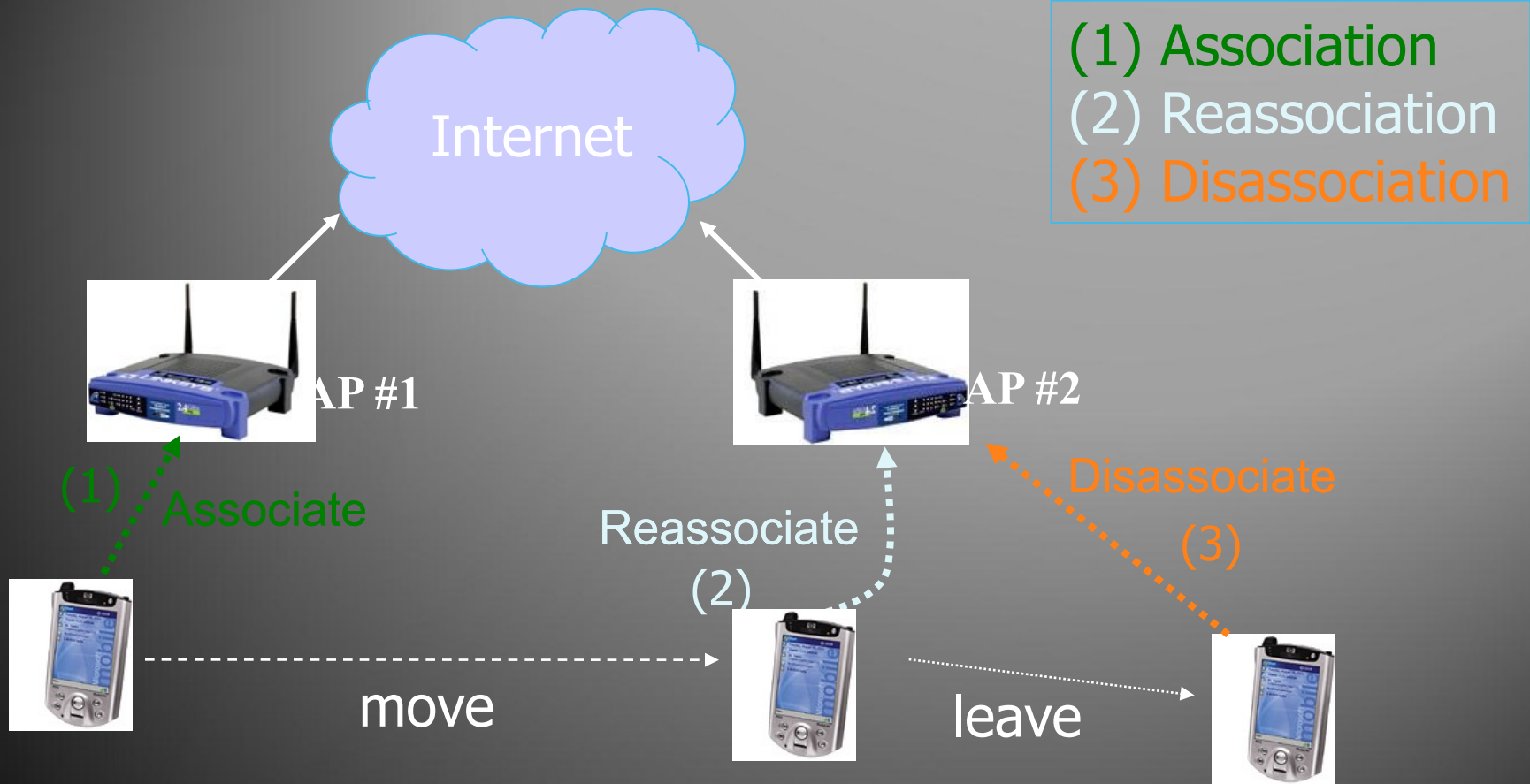


# IEEE 802.11 Services

- ▶ **Association:**
  - Establish an initial association between a station and an AP
- ▶ **Reassociation:**
  - Enables an established association to be transferred from one AP to another
- ▶ **Disassociation:**
  - Terminate an existing association
- ▶ **Authentication:**
  - Establish the identity of stations to each other
- ▶ **Privacy:**
  - Prevent eavesdropping



# A Scenario



# Medium Access Control

- ▶ MAC layer covers three functional areas
- ▶ Reliable data delivery
- ▶ Access control
- ▶ Security
  - Beyond our scope

# Reliable Data Delivery

- ▶ 802.11 physical and MAC layers subject to unreliability
  - ▶ Noise, interference, and other propagation effects result in loss of frames
  - ▶ Even with error-correction codes, frames may not successfully be received
  - ▶ Can be dealt with at a higher layer, such as TCP
    - However, retransmission timers at higher layers typically order of seconds
    - More efficient to deal with errors at the MAC level
  - ▶ 802.11 includes frame exchange protocol
    - Station receiving frame returns acknowledgment (ACK) frame
    - Exchange treated as atomic unit
      - Not interrupted by any other station
- If noACK within short period of time, retransmit

# CSMA/CA+ACK

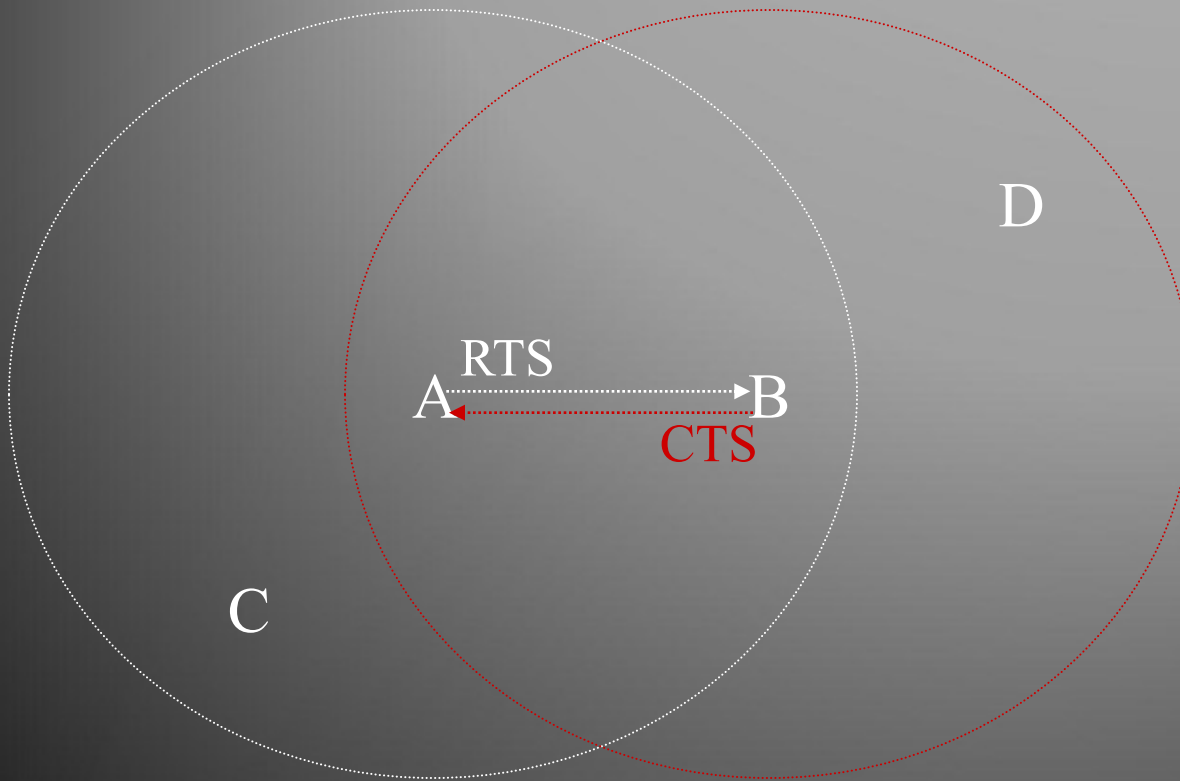
- ▶ CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)
  - If there has been no traffic for a sufficiently long time, station or access point may send immediately.
  - If there is current traffic or collision,
    - the station sets a random timer
    - If there is no traffic when the timer finishes, may send
  - Receiver immediately sends back an acknowledgement(ACK) when it receives a frame.

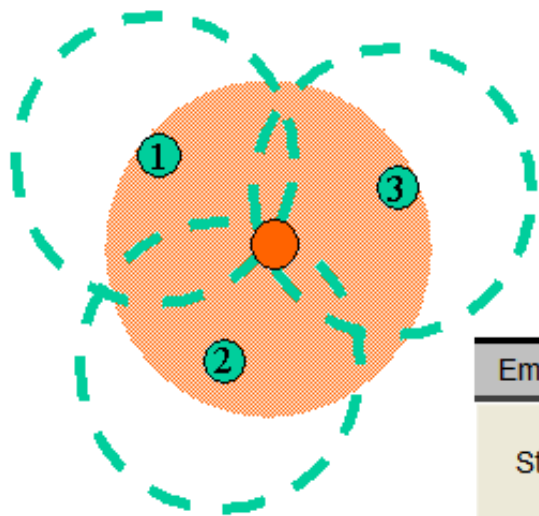
# Four Frame Exchange

- ▶ Basic data transfer involves exchange of two frames
- ▶ To further enhance reliability, four-frame exchange may be used
  - Source issues a Request to Send (RTS) frame to destination
  - Destination responds with Clear to Send (CTS)
  - After receiving CTS, source transmits data
  - Destination responds with ACK
- ▶ RTS alerts all stations within range of source that exchange is under way
- ▶ CTS alerts all stations within range of destination
- ▶ Stations refrain from transmission to avoid collision
- ▶ RTS/CTS exchange is required function of MAC but may be disabled

# RTS/CTS

CSMA/CA



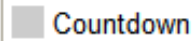
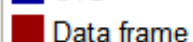


● Access Point  
● Mobile Station

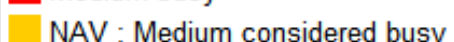
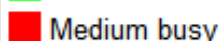
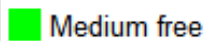
Emit Frame		Queue	BackOff
Station 1		0	0
Station 2		0	0
Station 3		0	0
Access Point			

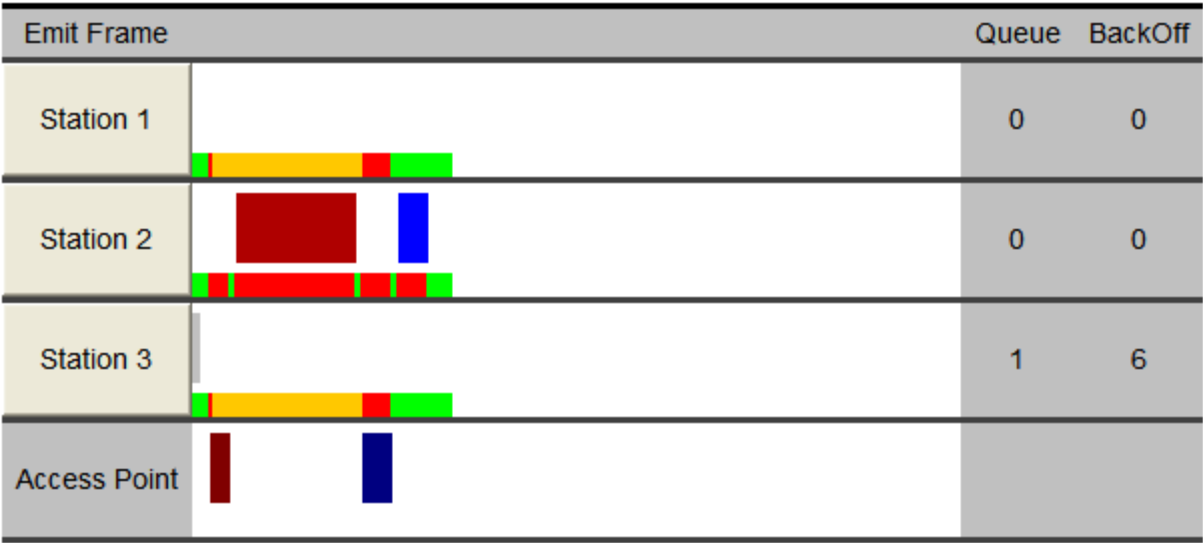
#### Legend

##### Frame type



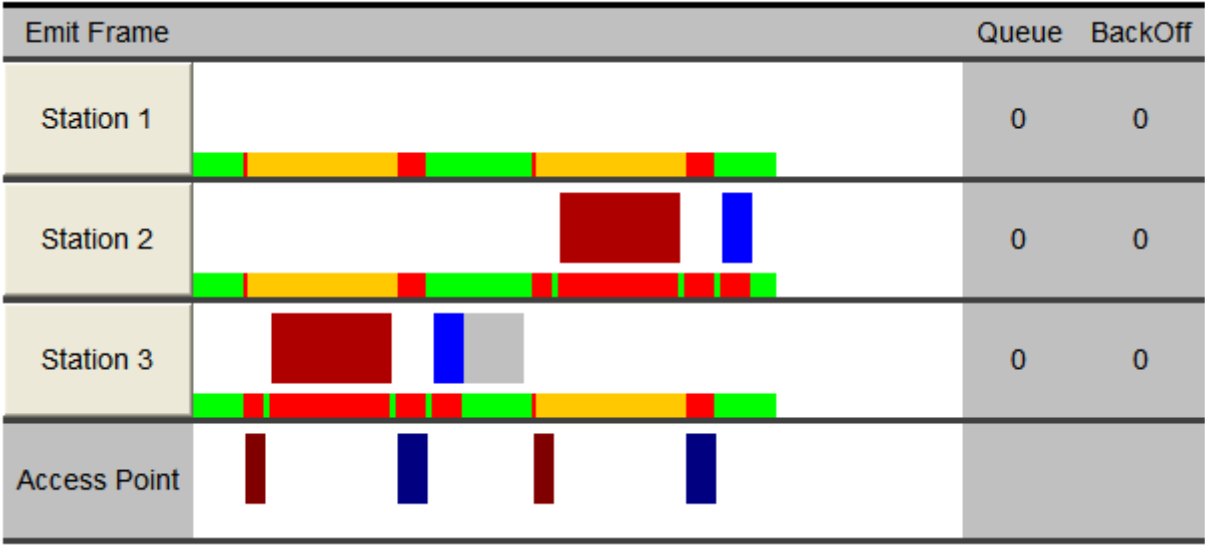
##### Carrier sensing





**Legend**

Frame type	Carrier sensing
RTS	Medium free
CTS	Medium busy
Data frame	NAV : Medium considered busy
ACK	
Countdown	

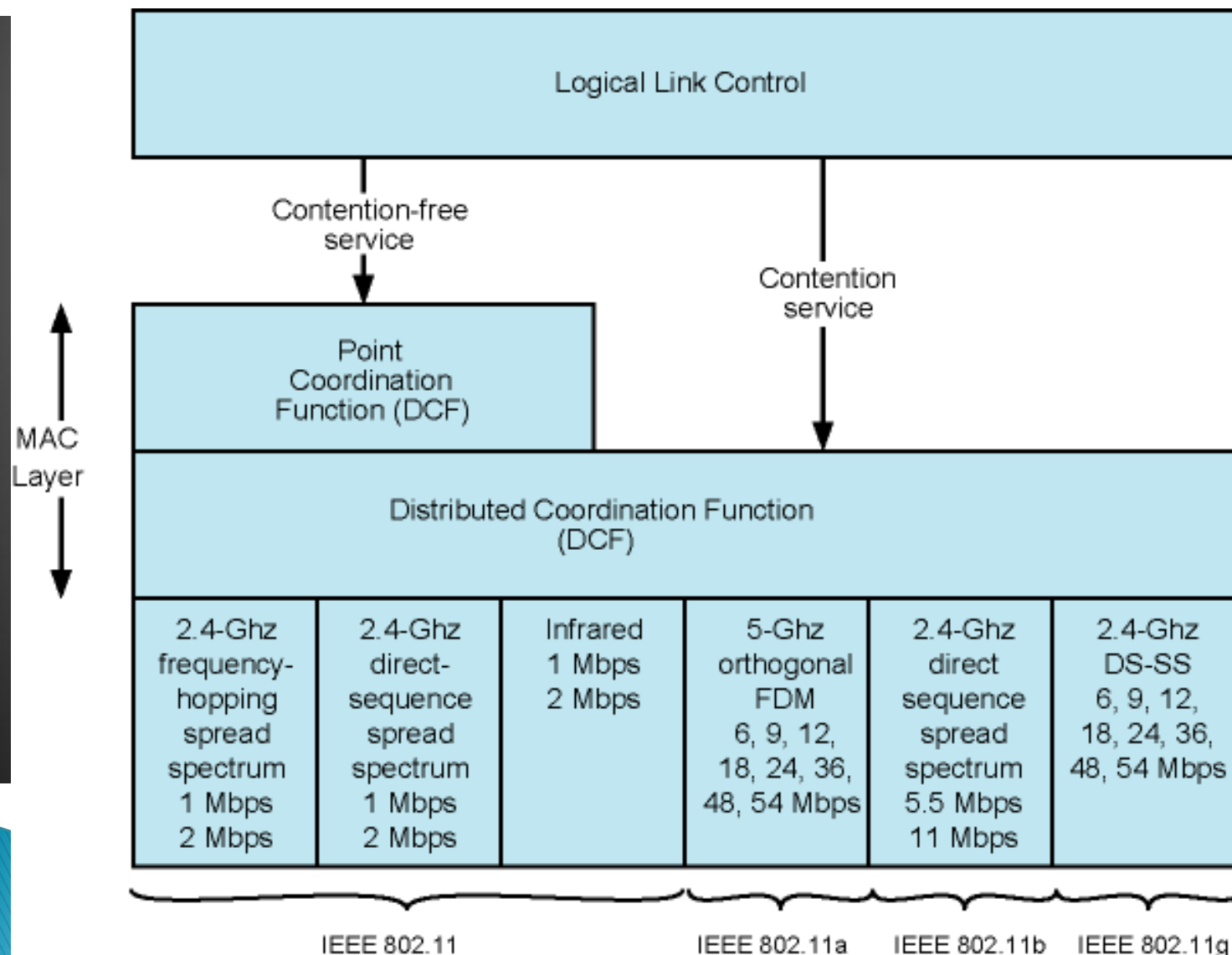




# Medium Access Control

- ▶ Distributed wireless foundation MAC (DWFMAC)
  - Distributed access control mechanism
  - Optional centralized control on top
- ▶ Lower sublayer is distributed coordination function (DCF)
  - Contention algorithm to provide access to all traffic
  - Asynchronous traffic
- ▶ Point coordination function (PCF)
  - Centralized MAC algorithm
  - Contention free
  - Built on top of DCF

# Figure 15.17 IEEE 802.11 Protocol Architecture



# 802.11 Physical Layer

- ▶ Issued in four stages
- ▶ First part in 1997
  - IEEE 802.11
  - Includes MAC layer and three physical layer specifications
  - Two in 2.4-GHz band and one infrared
  - All operating at 1 and 2 Mbps
- ▶ Two additional parts in 1999
  - IEEE 802.11a
    - 5-GHz band up to 54 Mbps
  - IEEE 802.11b
    - 2.4-GHz band at 5.5 and 11 Mbps
- ▶ Most recent in 2002
  - IEEE 802.g extends IEEE 802.11b to higher data rates

# 802.11 Summary

- Data Rate -

Protocol	Release Date	Op. Frequency (Unlicensed Band)	Typ	Max	# of Non-Overlapping Channels	Range (Indoor)
Legacy	1997	2.4-2.5 GHz	1 Mbps	2 Mbps	3	?
802.11a	1999	5.15-5.35 / 5.47-5.725 / 5.725-5.875 GHz	25 Mbps	54 Mbps	24	~30 m
802.11b	1999	2.4-2.5 GHz	6.5 Mbps	11 Mbps	3	~50 m
802.11g	2003	2.4-2.5 GHz	25 Mbps	54 Mbps	3	~30 m
802.11n	2006 draft	2.4 GHz or 5 GHz bands	200 Mbps	540 Mbps	3 / 24	~50 m

Channel	Nominal Frequency (MHz)	Minimum (MHz)	Maximum (MHz)
<b>1</b>	2412	2401	2423
2	2417	2405	2428
3	2422	2411	2433
4	2427	2416	2438
5	2432	2421	2443
<b>6</b>	2437	2426	2448
7	2442	2431	2453
8	2447	2436	2458
9	2452	2441	2463
10	2457	2446	2468
<b>11</b>	2462	2451	2473