Chapter 6

High-Speed LANs

Introduction

- Fast Ethernet and Gigabit Ethernet
- High-speed Wireless LANs

Emergence of High-Speed LANs

- 2 Significant trends
  - Computing power of PCs continues to grow rapidly
  - Network computing
- Examples of requirements
  - Centralized server farms
  - Power workgroups
  - High-speed local backbone

Classical Ethernet

- Bus topology LAN
- 10 Mbps
- CSMA/CD medium access control protocol
- 2 problems:
  - A transmission from any station can be received by all stations
  - How to regulate transmission

Solution to First Problem

- Data transmitted in blocks called frames:
  - User data
  - Frame header containing unique address of destination station

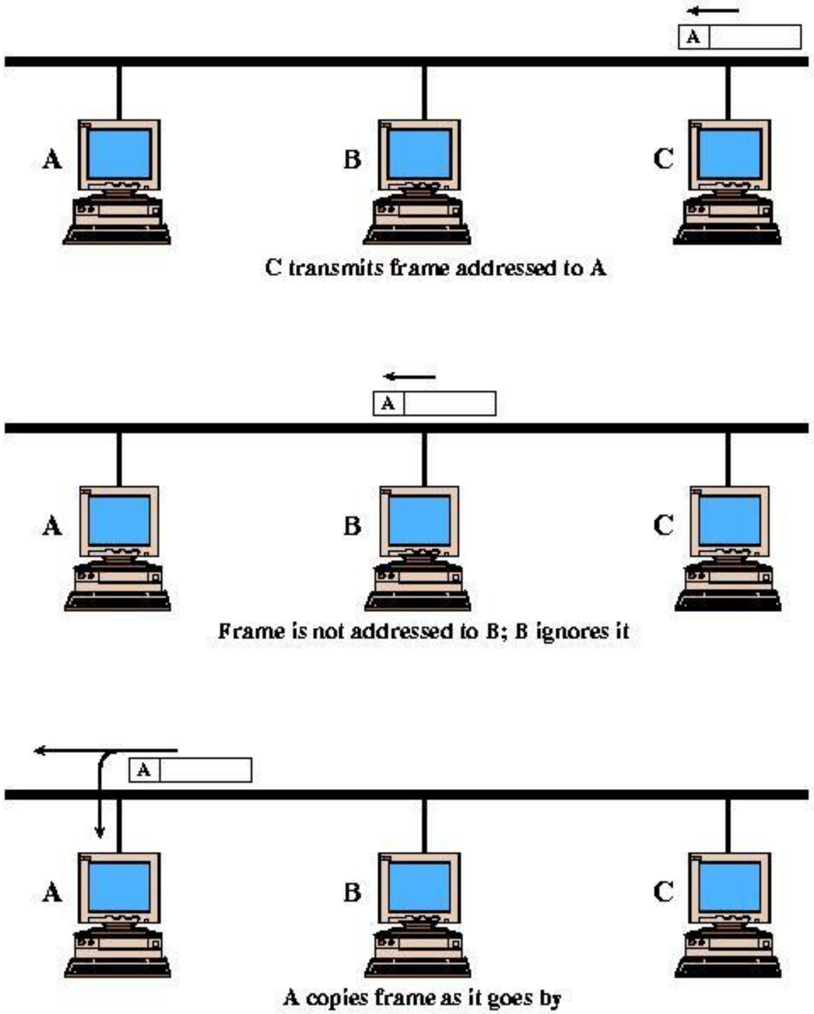


Figure 6.1 Frame Transmission on a Bus LAN

CSMA/CD

Carrier Sense Multiple Access/ Carrier Detection

1. If the medium is idle, transmit.
2. If the medium is busy, continue to listen until the channel is idle, then transmit immediately.
3. If a collision is detected during transmission, immediately cease transmitting.
4. After a collision, wait a random amount of time, then attempt to transmit again (repeat from step 1).

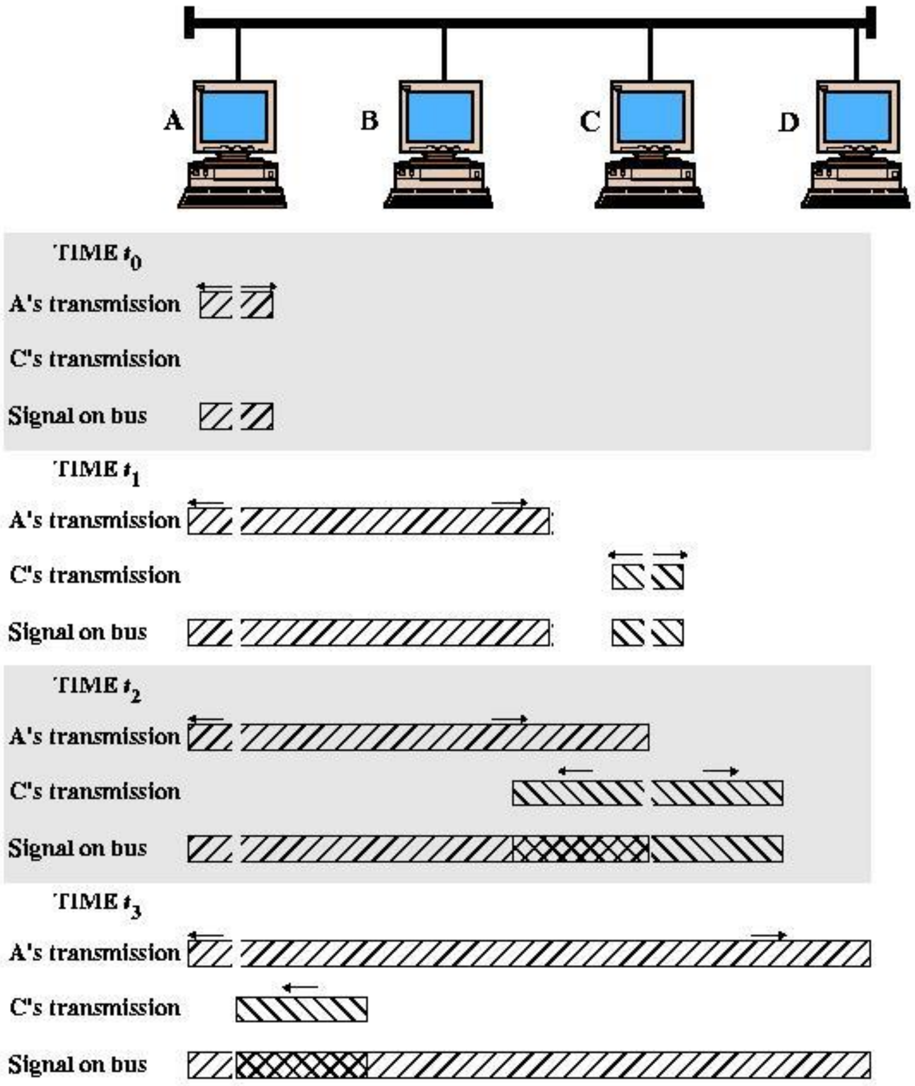


Figure 6.2 CSMA/CD Operation

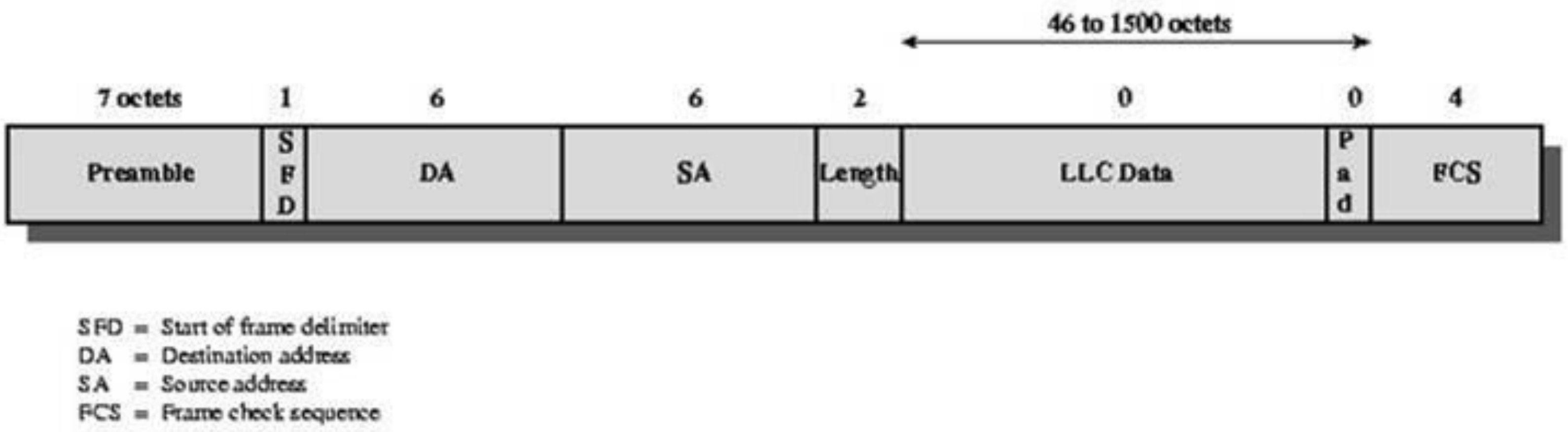


Figure 6.3 IEEE 802.3 Frame Format

Medium Options at 10Mbps

- <data rate> <signaling method> <max length>
- 10Base5
  - 10 Mbps
  - 50-ohm coaxial cable bus
  - Maximum segment length 500 meters
- 10Base-T
  - Twisted pair, maximum length 100 meters
  - Star topology (hub or multipoint repeater at central point)

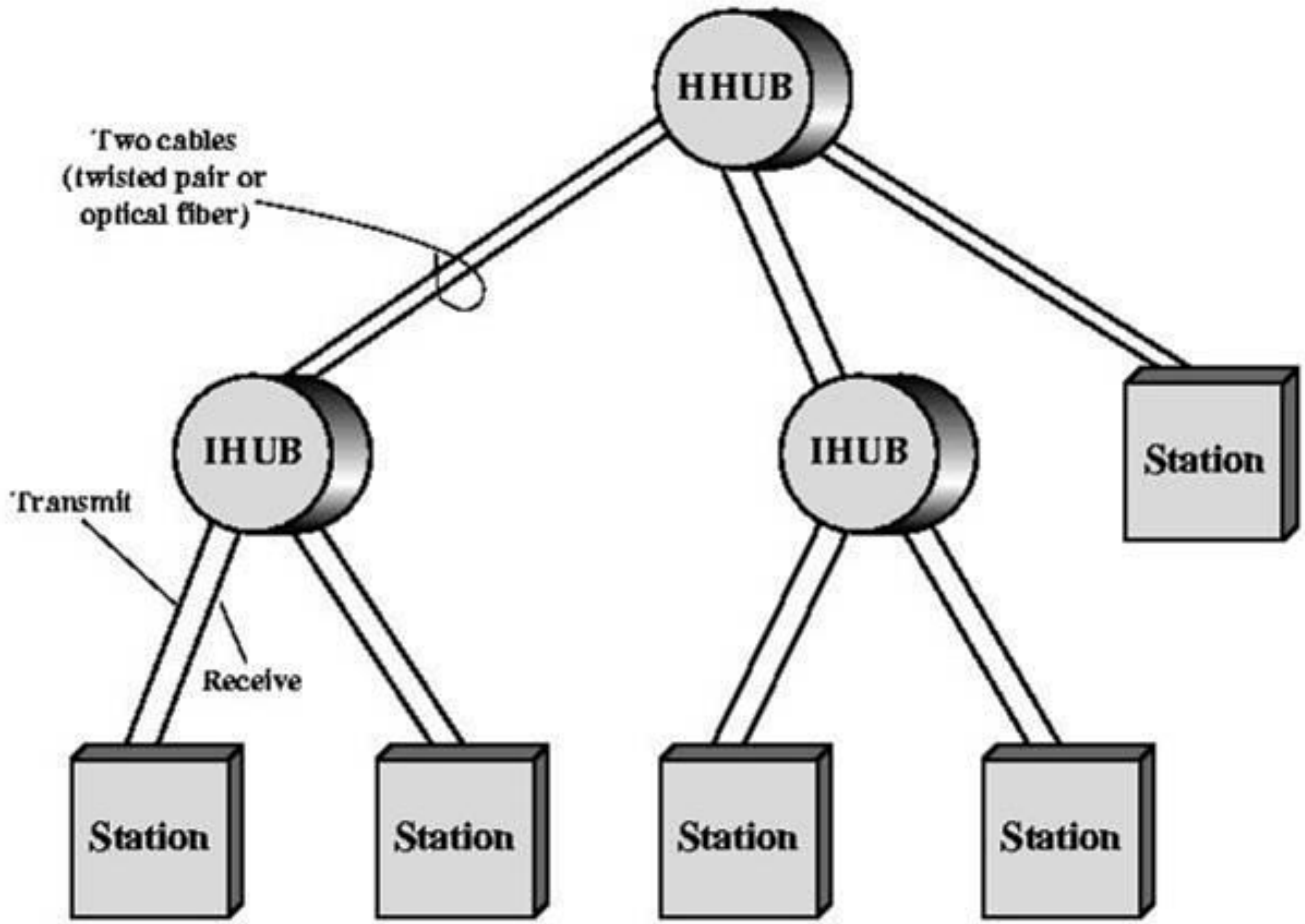


Figure 6.4 Two-Level Star Topology

Hubs and Switches

Hub

- Transmission from a station received by central hub and retransmitted on all outgoing lines
- Only one transmission at a time

Layer 2 Switch

- Incoming frame switched to one outgoing line
- Many transmissions at same time

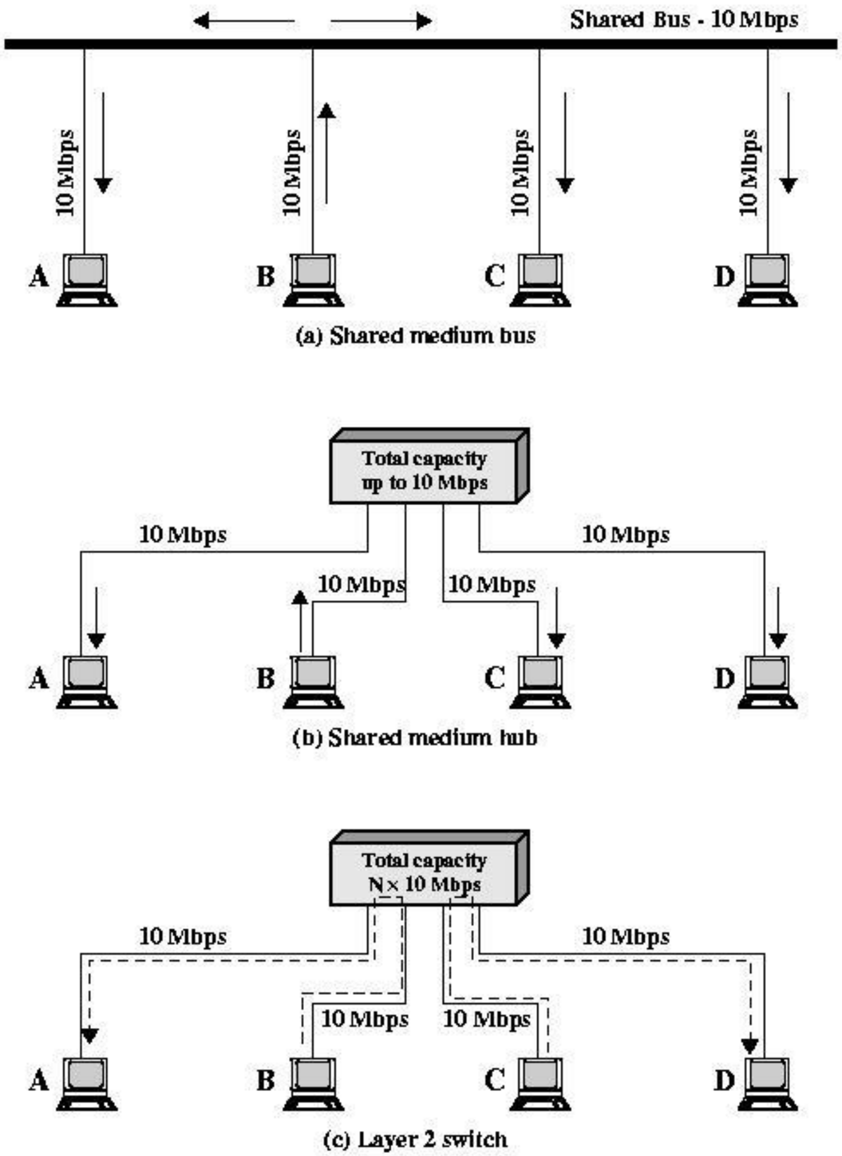


Figure 6.5 LAN Hubs and Switches

Bridge

- Frame handling done in software
- Analyze and forward one frame at a time
- Store-and-forward

Layer 2 Switch

- Frame handling done in hardware
- Multiple data paths and can handle multiple frames at a time
- Can do cut-through

Layer 2 Switches

- Flat address space
- Broadcast storm
- Only one path between any 2 devices

- Solution 1: subnetworks connected by routers
- Solution 2: layer 3 switching, packet-forwarding logic in hardware

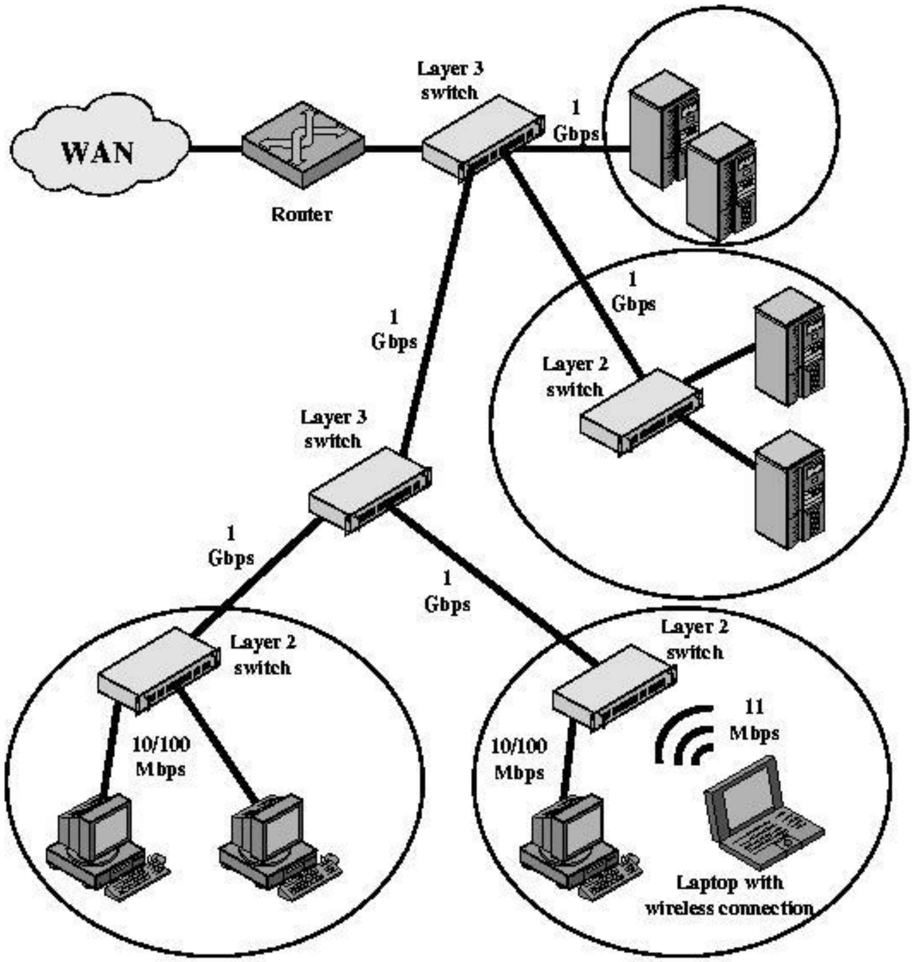


Figure 6.6 Typical Premises Network Configuration

Fast Ethernet

- Drops bus topology – keep only the star topology
- Half duplex or full duplex
- Two and four wires

Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	Cat 5 UTP or STP	Fiber	Cat 4 UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m
Block encoding	4B/5B	4B/5B	
Line encoding	MLT-3	NRZ-I	8B/6T

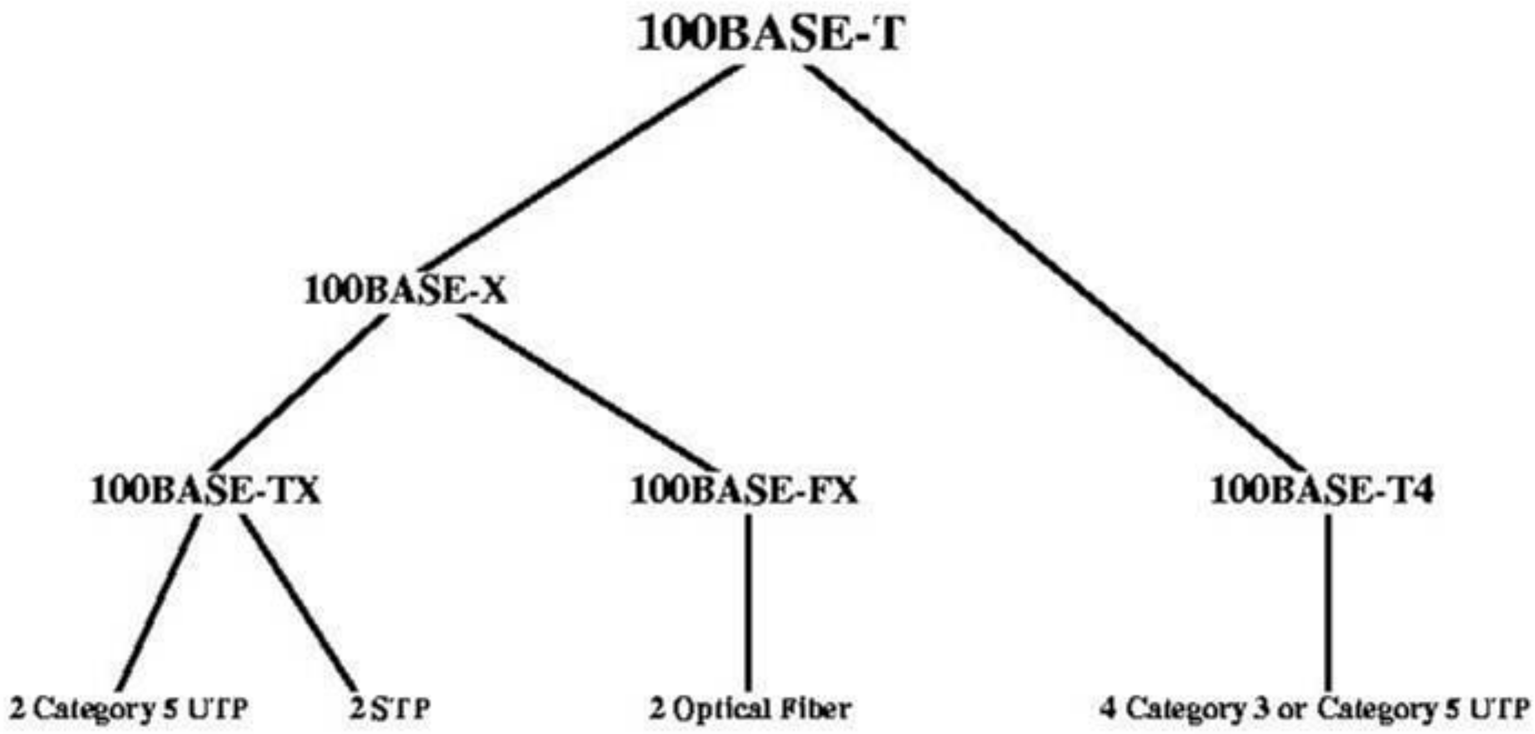


Figure 6.7 IEEE 802.3 100BASE-T Options

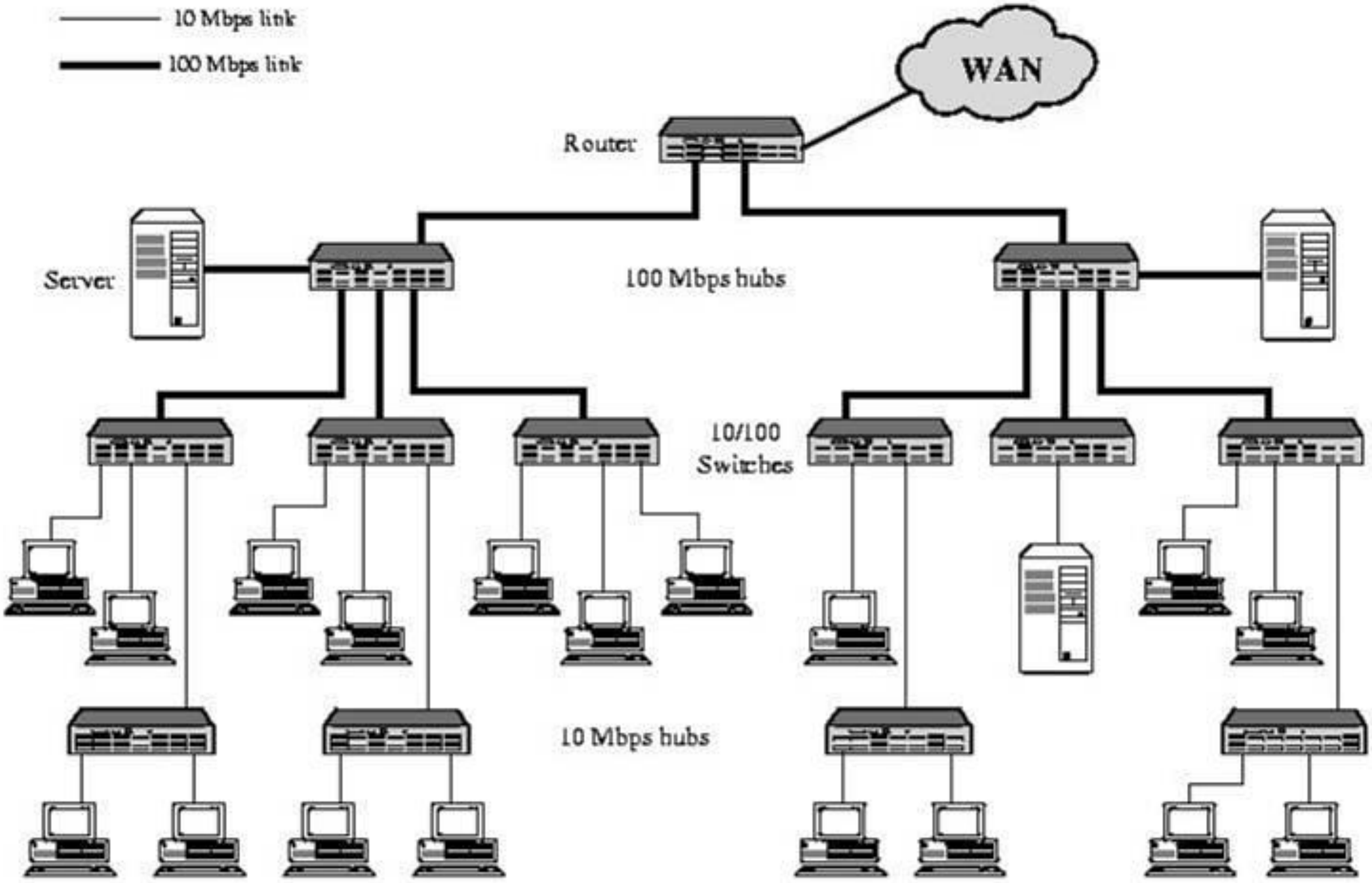


Figure 6.8 Example 100-Mbps Ethernet Backbone Strategy

Gigabit Ethernet

- Medium access approaches
  - Half duplex
    - A central hub, CSMA/CD
    - The maximum length dependent on the minimum frame size
  - Full duplex (most common)
    - A central switch, no collision
    - The maximum length of a cable is determined by the signal attenuation

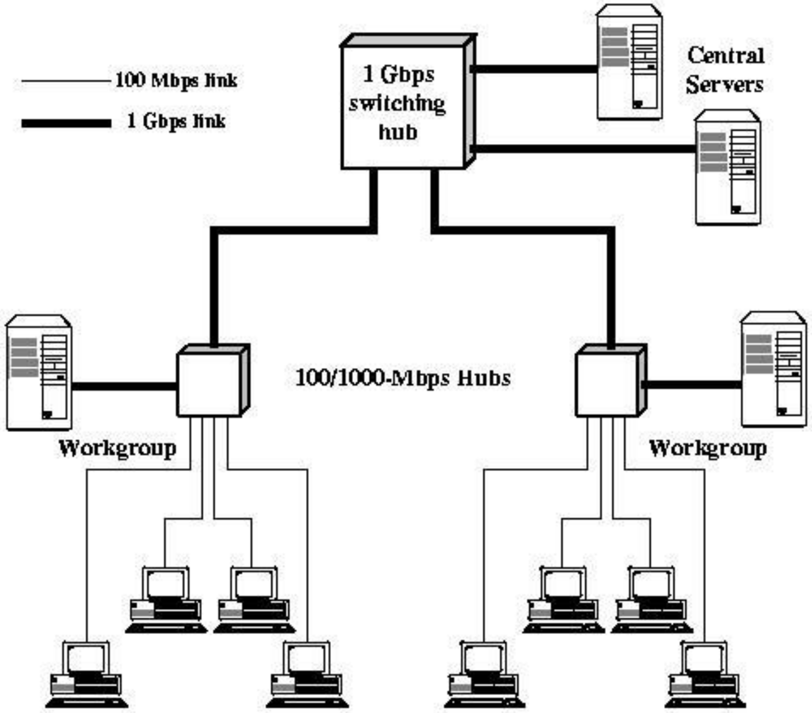


Figure 6.9 Example Gigabit Ethernet Configuration

Ten Gigabit Ethernet

- Operates only in full duplex mode – no contention
- Physical layer – use fiber optic cable over long distance

Characteristics	*10GBase-S*	*10GBase-L*	*10GBase-E*
Media	Short-wave 850-nm multimode	Long-wave 1310-nm single mode	Extended 1550-mm single mode
Maximum length	300 m	10 km	40 km

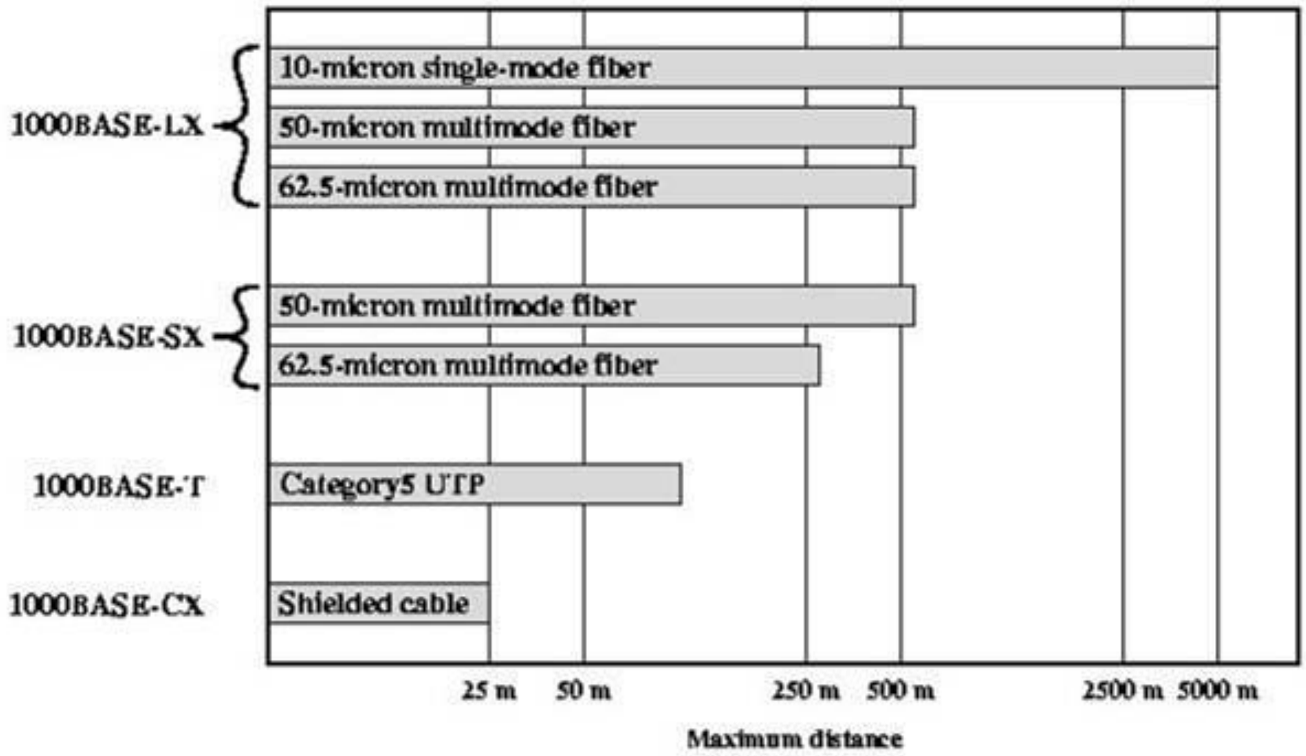


Figure 6.10 Gigabit Ethernet Medium Options (log scale)

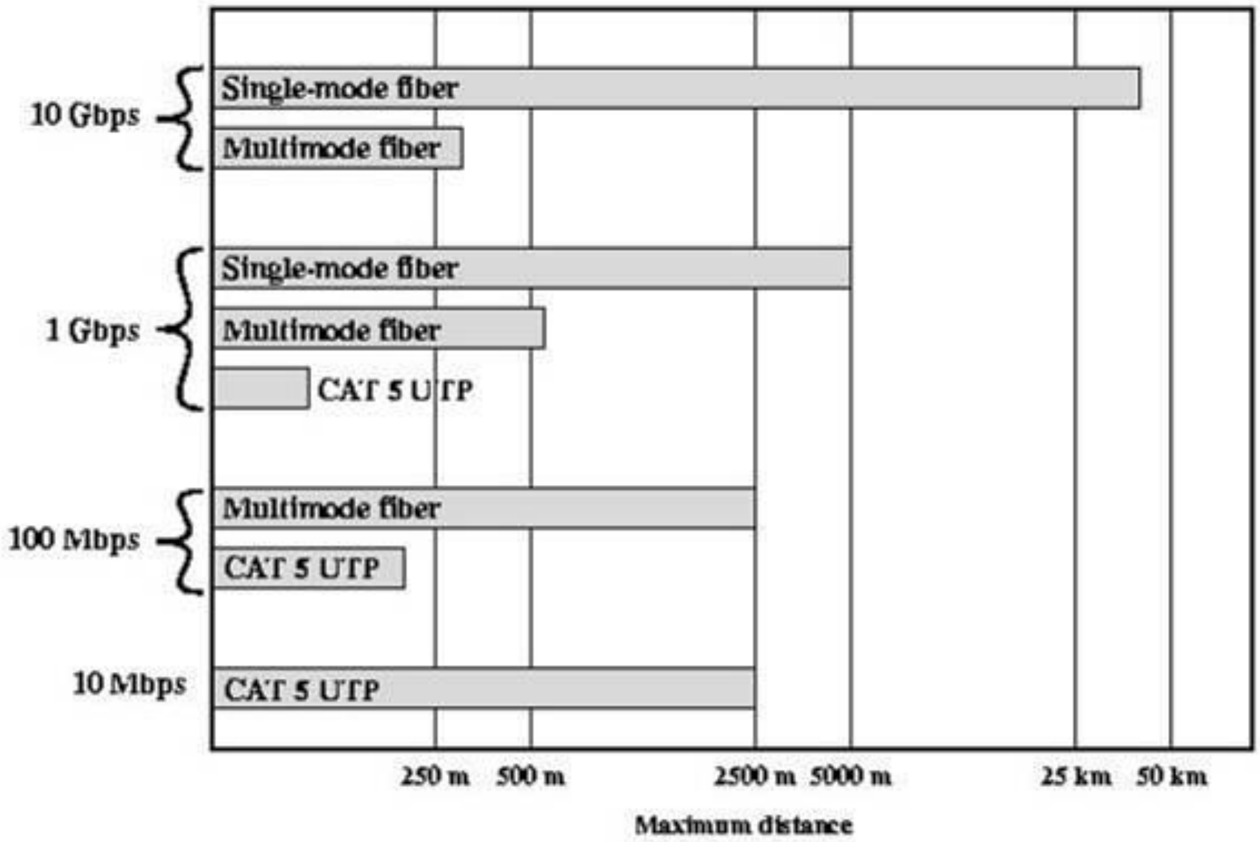


Figure 6.11 Ethernet Data Rate and Distance Options (log scale)

Benefits of 10 Gbps Ethernet over ATM

- No expensive, bandwidth consuming conversion between Ethernet packets and ATM cells
- Network is Ethernet, end to end
- IP plus Ethernet offers QoS and traffic policing capabilities approach that of ATM
- Wide variety of standard optical interfaces for 10 Gbps Ethernet

Wireless LAN

Wireless LAN Requirements

- Throughput
- Number of nodes
- Connection to backbone
- Service area
- Battery power consumption
- Transmission robustness and security
- Collocated network operation
- License-free operation
- Handoff/roaming
- Dynamic configuration

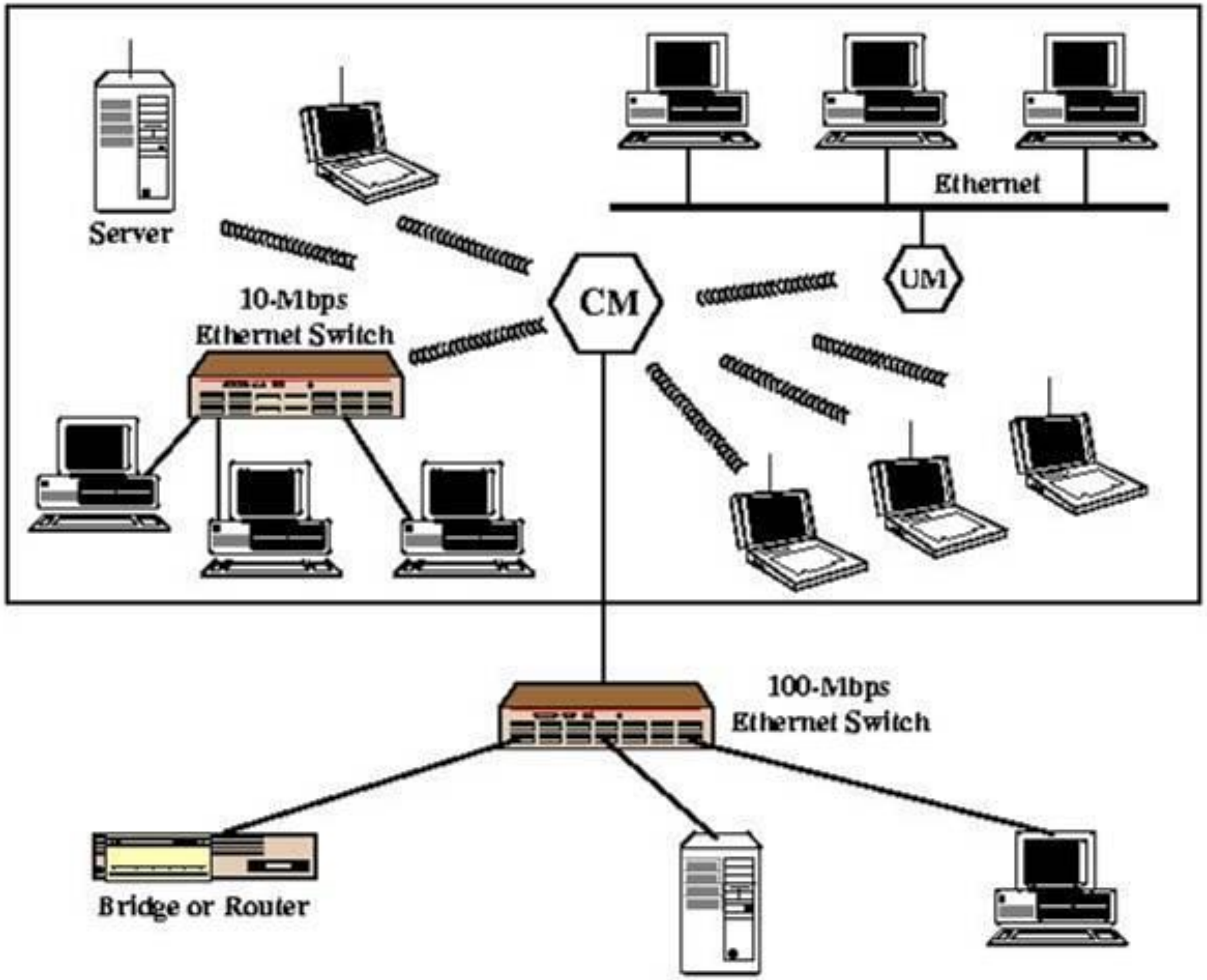
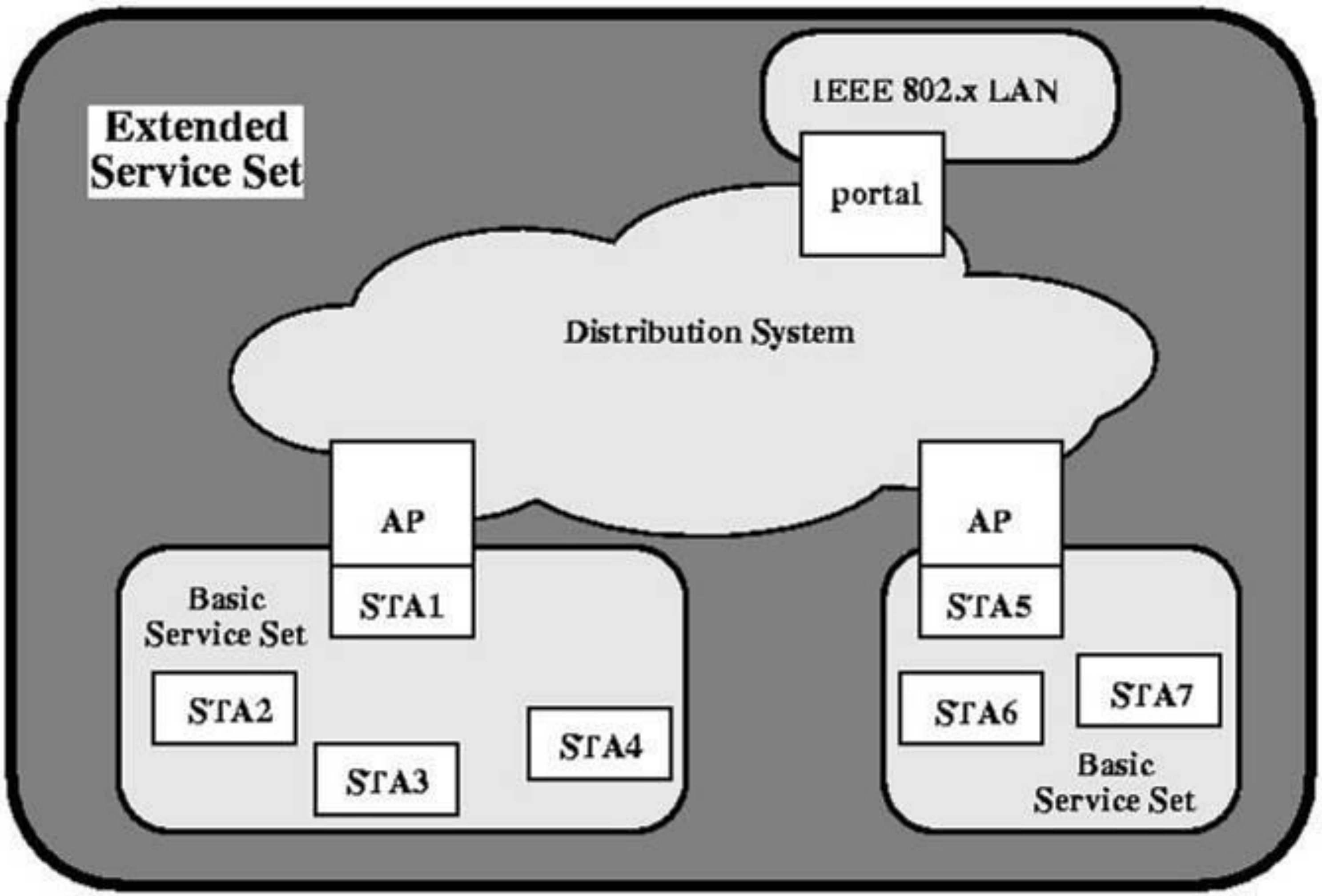


Figure 6.14 Example Single-Cell Wireless LAN Configuration

IEEE 802.11 Services

- Association
- Reassociation
- Disassociation
- Authentication
- Privacy



STA = station

Figure 6.15 IEEE 802.11 Architecture

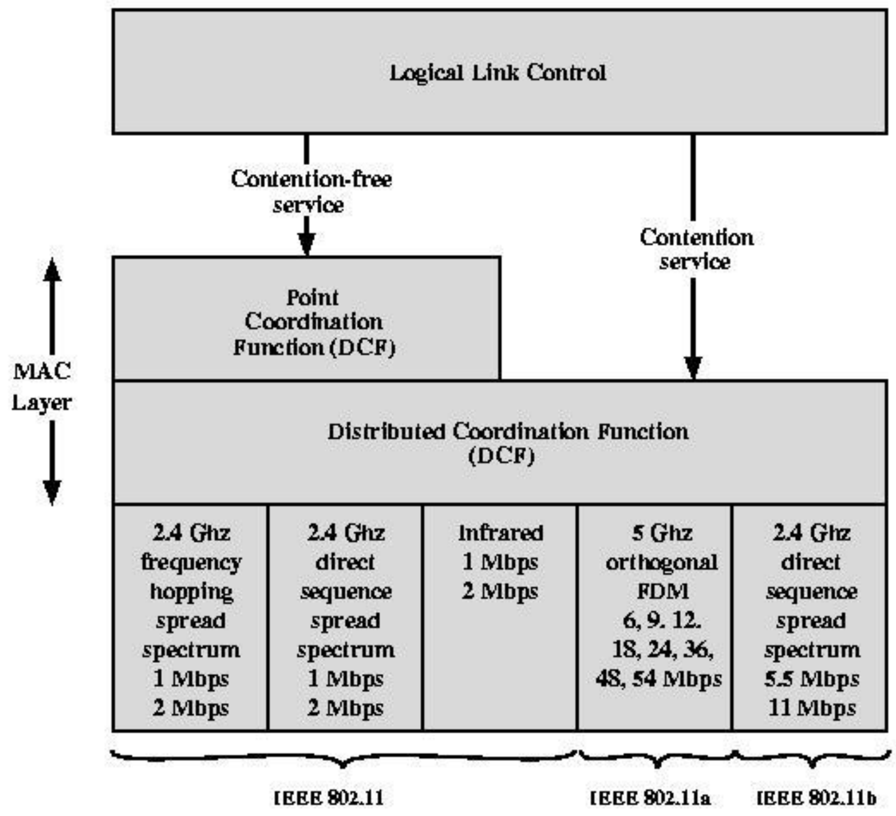
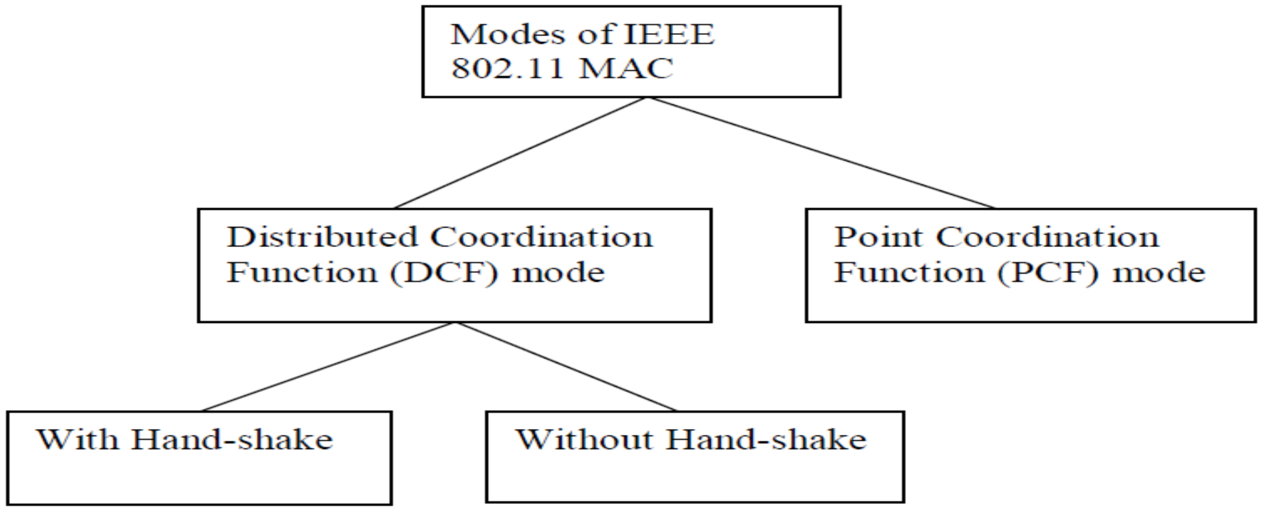


Figure 6.16 IEEE 802.11 Protocol Architecture

Important Assumption

- For CSMA/CD protocol to work in a wired LAN, the ff assumption must work.
  - *Signal from any computer in a ntk must reach all computers in the network. The CD mechanism won't work without this assumption.*
- However, in WLAN, the above assumption may not hold. Hence at the MAC level, we do not go for CD
- Another consequence of signal not reaching all the computers in a network is that computers in a network may not be able to communicate directly.
- For two computers to be able to communicate, service of another computer in the network or a fixed infrastructure, namely, an Access Point (AP), is used.

Different modes of operation of IEEE 802.11 MAC protocol



1: Different modes of operation of MAC protocol in a WLAN

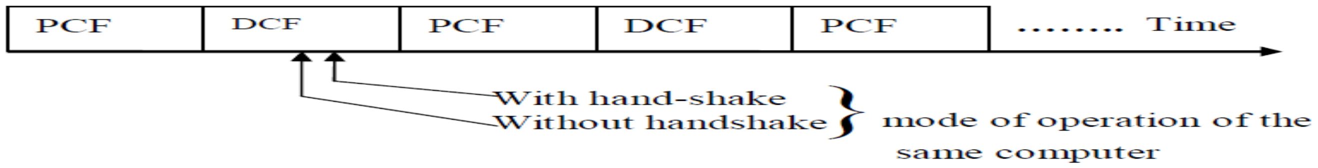


Figure W3: Alternative use of PCF and DCF modes and consecutive appearances of "with hand-shake" and "without hand-shake" modes in the same DCF period.

Cont'd

- The IEEE 802.11 standard says that implementation of the PCF mode of operation is *optional*.
- The DCF mode of operation is not suitable for real-time traffic. Rather, data delivery is made on a *best effort basis—the network* makes an effort to deliver data across the wireless medium, but there is no guarantee of bandwidth or bound on delay.
- The IEEE 802.11 standard says that implementation of the DCF mode of operation is *mandatory*, *that is*, *the DCF mode of* operation must be supported by a network card claiming to implement IEEE 802.11.

Important Note

- The two modes of DCF operation, namely with hand-shake and without handshake, are not mutually exclusive. Rather, both coexist, and the two modes can be selected on a packet basis. For example, the *dotRTSThreshold* variable in the MAC management database can be used to choose a certain mode of operation. The *dotRTSThreshold* variable is initialized with an integer value representing a threshold packet length in bytes.
- If the length of a data packet is equal to or greater than the *dotRTSThreshold* value, then the MAC layer chooses the "with hand-shake" mode. On the other hand, if the packet length is smaller than the *dotRTSThreshold* value, then the "without hand-shake" mode is chosen to transmit the data packet.

Problems in a Wireless LAN

- There are three problems in a wireless LAN, which are not found in wired LANs. These problems are as follows:
  - Hidden terminal problem
  - Exposed terminal problem
  - Inability to detect collision.

Hidden Terminal Problem

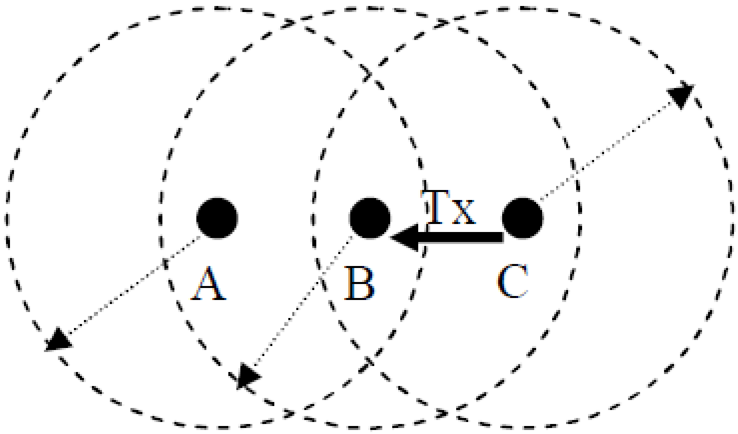
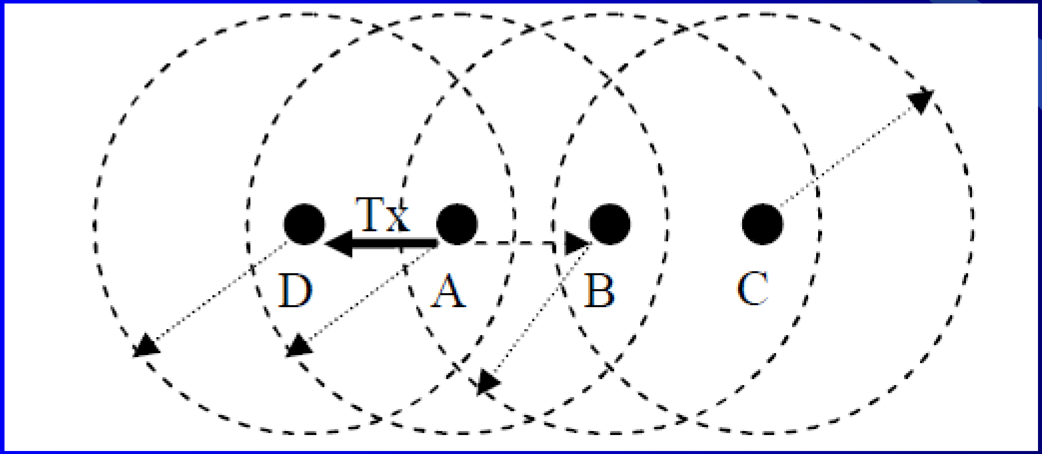


Figure W4: Illustration of the hidden terminal problem

Exposed Terminal Problem



: Illustration of the exposed terminal problem

Inability to Detect Collision

- Ideally, a sender should detect collision at a receiver, because it is the collision at the receiver that matters.
- In a wired LAN, collision is detected at the sender's end by assuming that signals from all computers can reach all other computers.
- However, this assumption does not hold in a wireless LAN as it has been explained in the context of the hidden terminal problem.
- Another reason for the difficulty in not being able to detect collision is that many wireless devices use half duplex transceivers to simplify transceiver design. That is, a half-duplex wireless device turns on its transmitter and receiver in an alternating manner.

Transmit condition and virtual carrier sensing

- Because of inability to detect collision and sensing media by PHY is not enough to avoid problems like the hidden terminal problem – So we need another sensing mechanism
- Before a computer can transmit anything—data or control packets—it is essential to detect idleness of the medium.
- In a wired LAN, it was sufficient to detect idleness by sensing the physical medium.
- However, in a wireless LAN, because of the hidden terminal problem, it is not enough to sense the medium to know whether or not the medium is idle. In addition to carrier sensing at the PHY level, the WLAN MAC protocol uses the concept of virtual carrier sensing to tackle the hidden terminal problem.

Cont'd

- In virtual carrier sensing, a computer monitors the transmission of all control packets that it can receive, utilizes the duration information contained in those packets, and infers whether or not the medium is idle at its intended receiver.
- Thus, the medium is said to be idle if the PHY level carrier sensing mechanism detects no carrier and it is inferred from the virtual carrier sensing mechanism that the intended receiver within its radio range is not receiving data.

Cont'd

- Virtual carrier sensing is implemented by using two concepts as listed below:
  - Control frames (or, packets)
    - Request-To-Send (RTS) frame
    - Clear-To-Send (CTS) frame
- Network Allocation Vector (NAV): This is a scalar, integer variable held by each computer.

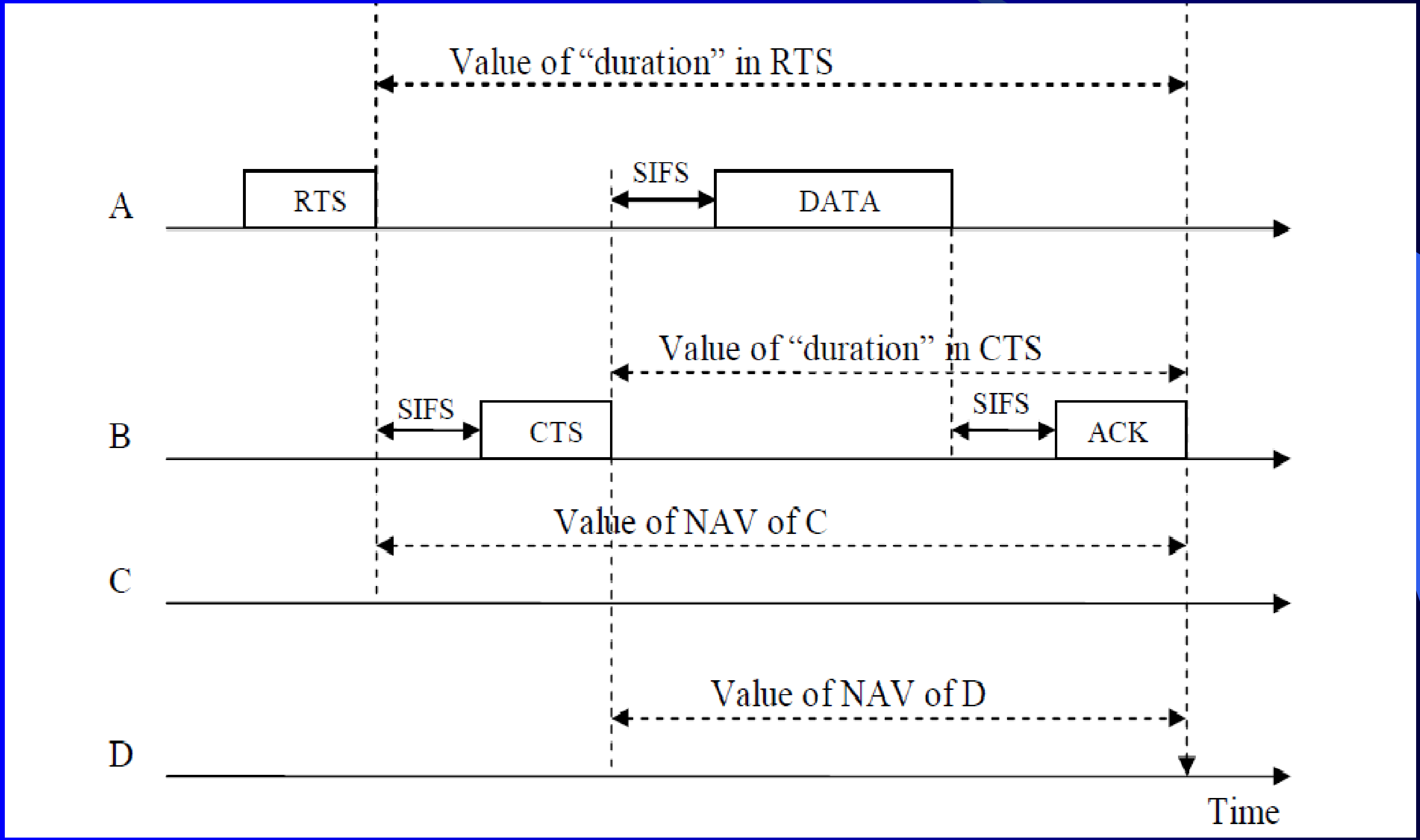
Cont'd

- Computers update and interpret their NAV variables as follows.
  - Each computer has its own NAV with an initial value of 0.
  - NAV represents for how long the medium is likely to remain busy.
  - The unit of time information in NAV is *microseconds.*
  - NAV is decremented by 1 with the elapse of each microsecond of real time.
  - When NAV = 0, it is no more decremented.
  - NAV is updated using the duration field in a received control frame as follows:
    - NAV = Max(NAV, *duration value received in a control frame)*
  - NAV = 0 means no pre-announced transmission is going on in the vicinity.
  - Idle medium is defined as **absence of carrier AND NAV = 0.**

Timing Relationship between RTS and CTS

- The hand-shake mechanism using RTS and CTS control frames has been illustrated in the figure next. In the figure we assume that computer A wants to send a data frame to computer B, C is a computer within the radio range of A, and D is a computer within the radio range of B. We also assume that D is out of range of A, and C is out of range of B.
- The four frames, namely RTS, CTS, DATA, and ACK, are separated by a time interval known as Short Inter Frame Space (SIFS).
- The idea behind this spacing is to maintain a logical association between these frames. Because of propagation delay and the delay involved in computing a response to a frame, there is a need to have an allowed time gap between logically related frames.

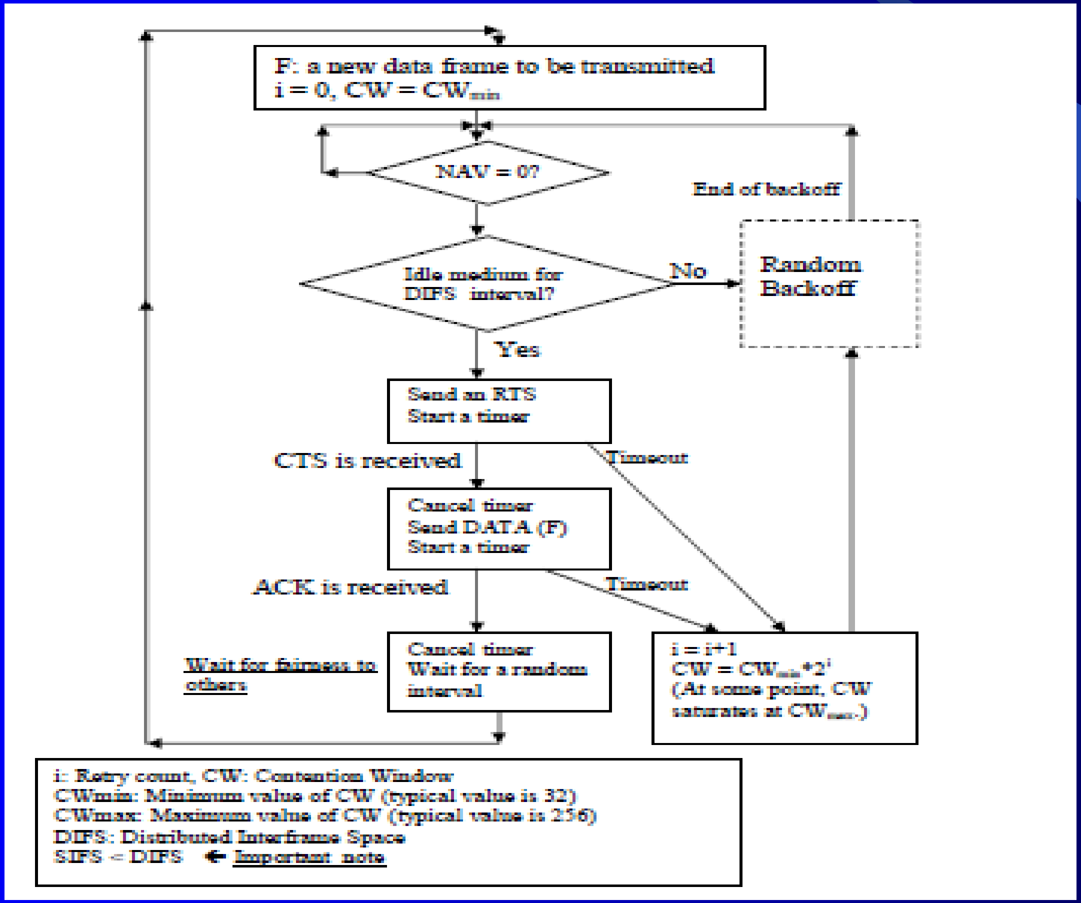
Timing Relationship between RTS and CTS



Why do we need the ACK frame?

- There is no ACK frame in Ethernet, or CSMA/CD.
- In Ethernet Upper layer protocols deal with lost frames and re-transmit. Why not here in the wireless case?
- Consider the BER in wired and wireless media – the prob. Of bit error. Consider also bothering upper layer protocols that have significant delay for retransmission.

Hand-Shake mode of DCF Operation – Sender's Behavior



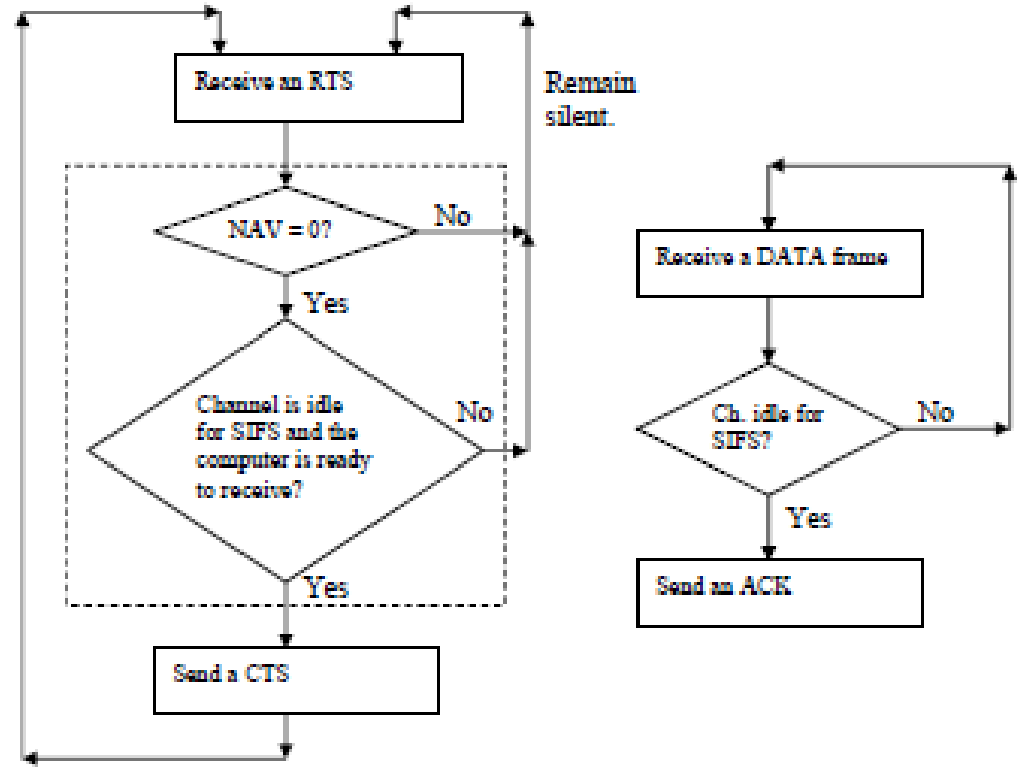
The Random Backoff Protocol

- The backoff mechanism in the WLAN protocol works differently from the backoff mechanism in CSMA/CD protocol for Ethernet as follows.
  - Choose a random number in the range [0, CW]. A variable, called Backoff Time Counter (BTC) is initialized with the chosen random number. The unit of time represented by the BTC variable is denoted by aSlotTime, where aSlotTime accounts for propagation time and transceiver switching time (switching time between transmitter and receiver and vice versa.)
  - BTC is decremented by 1 if the channel is idle for aSlotTime.
  - Stop decrementing the BTC if the medium is busy.
  - Resume decrementing the BTC after finding the channel to be idle for DIFS interval. Thus, whenever the channel is found to be busy, decrementing of BTC is done after finding the channel to be idle for DIFS interval immediately after the busy period ends. Once the channel is idle for at least DIFS interval, subsequent decrement is done for each idle period of aSlotTime interval
  - BTC = 0 means that the backoff process has finished.

Important Note

- Note the important relationship between SIFS and DIFS in the form of SIFS < DIFS.
- In the DCF mode, a computer senses the medium to be idle for at least a DIFS period.
- Thus, even if the computer finds the medium to be idle for SIFS period between frames in the sequence {RTS, CTS, DATA, ACK}, it does not initiate a transmission in order to not disturb an ongoing communication.
- Thus, the relationship SIFS < DIFS is very important.
- A recommended equality relationship between SIFS and DIFS is: DIFS = SIFS + 2*aSlotTime

Hand-shake mode of DCF Operation (Receiver's Behavior



Note: The above two fragments of flow-charts can be easily merged.