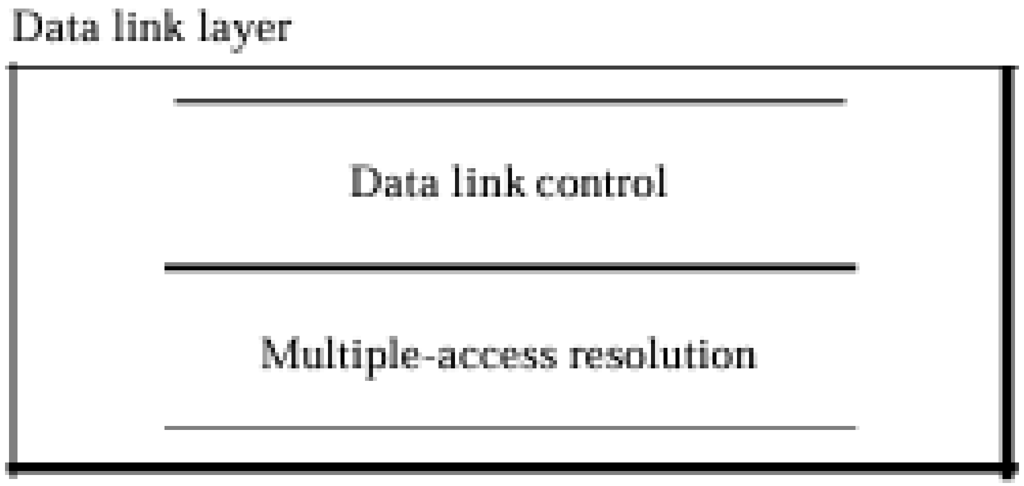
Data Communication & Networks

Chapter 4: Medium Access Control Sublayer (MAC)

Chapter 12 of Reference Book

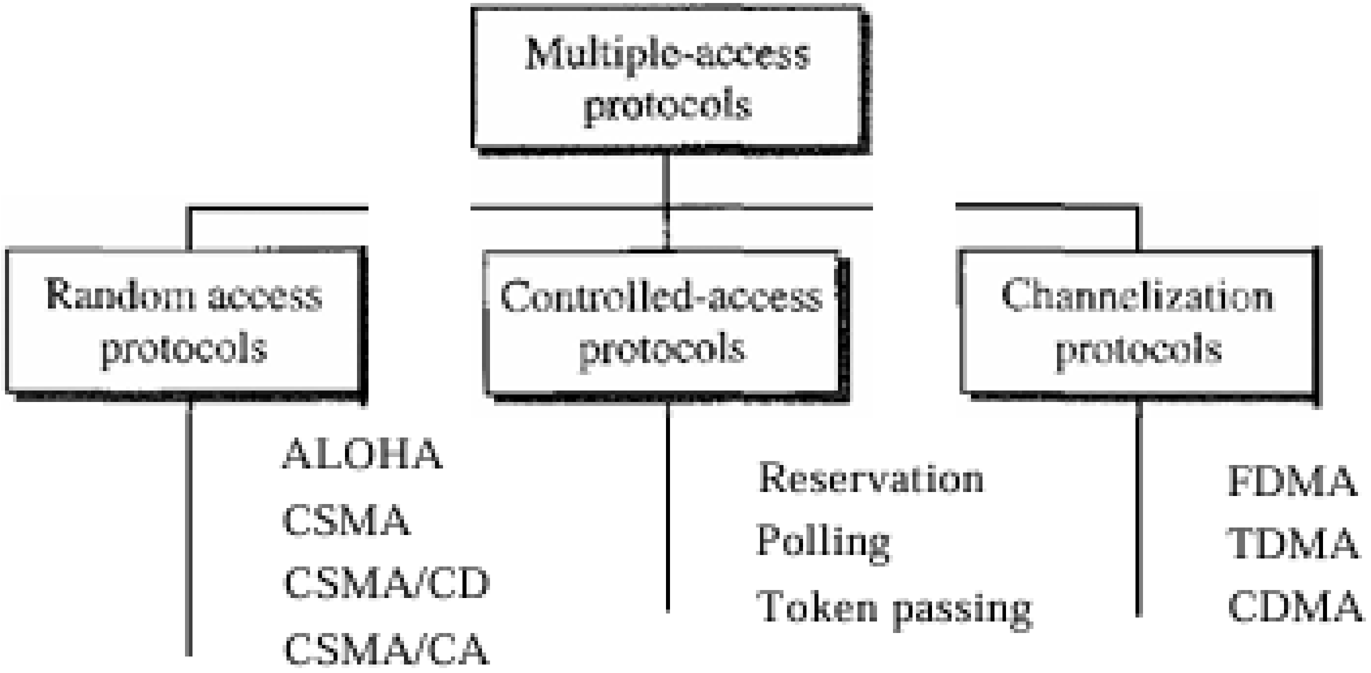
Data Link Layer

Figure 12.1 *Data link layer divided into two functionality-oriented sublayers*

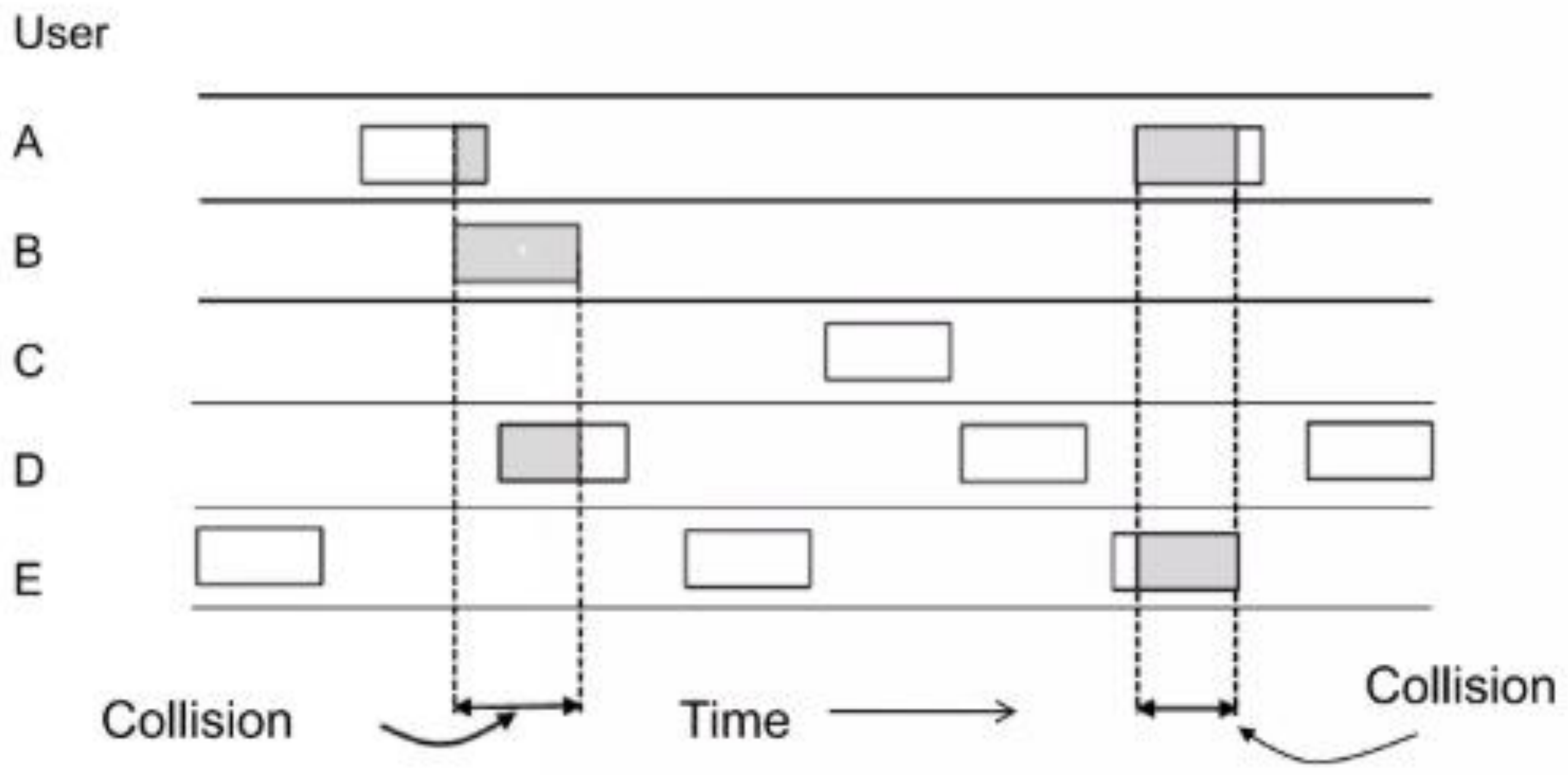


Multiple Access Protocol

Figure 12.2 *Taxonomy ofmultiple-access protocols discussed in this chapter*



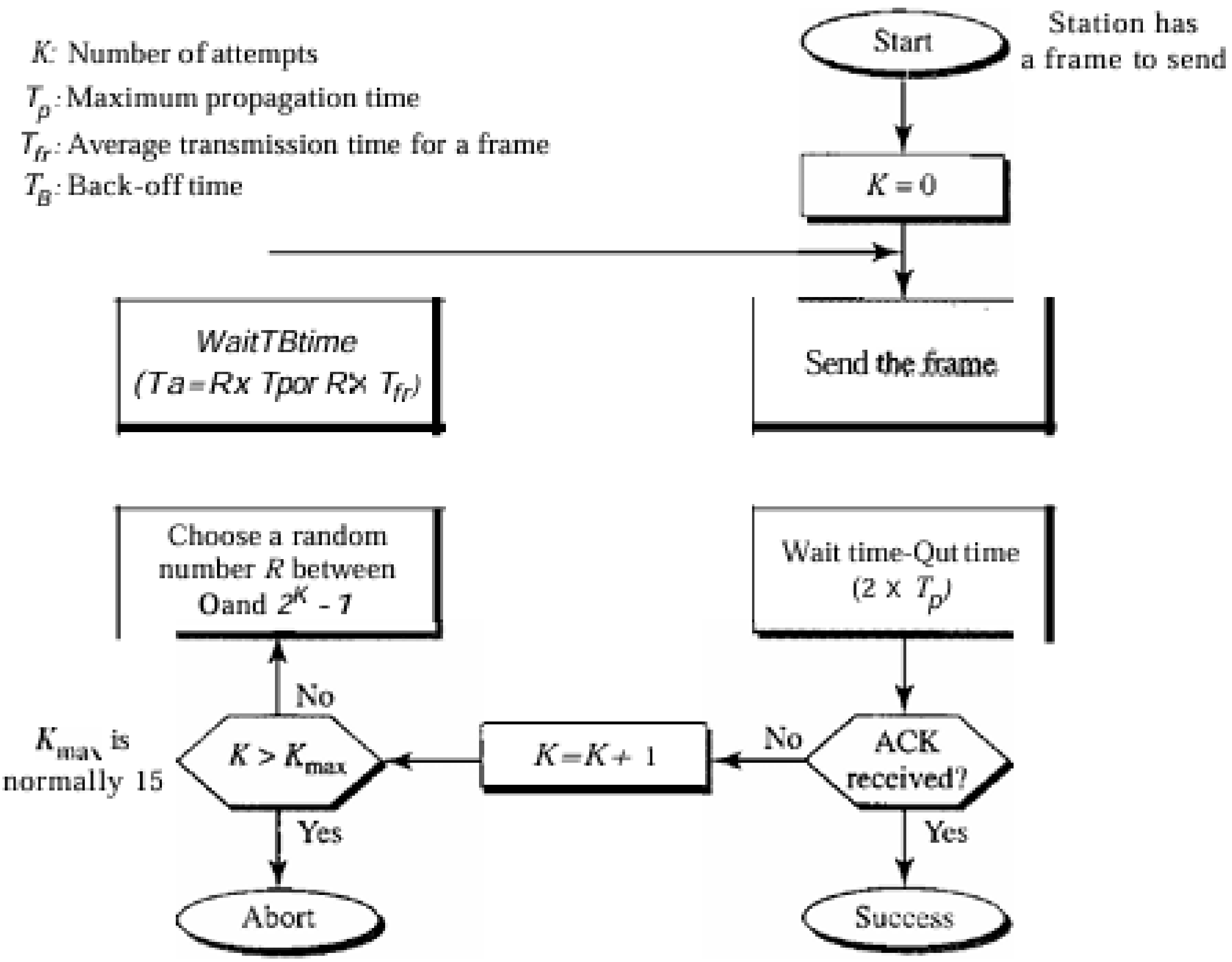
ALOHA



In pure ALOHA, frames are transmitted at completely arbitrary times

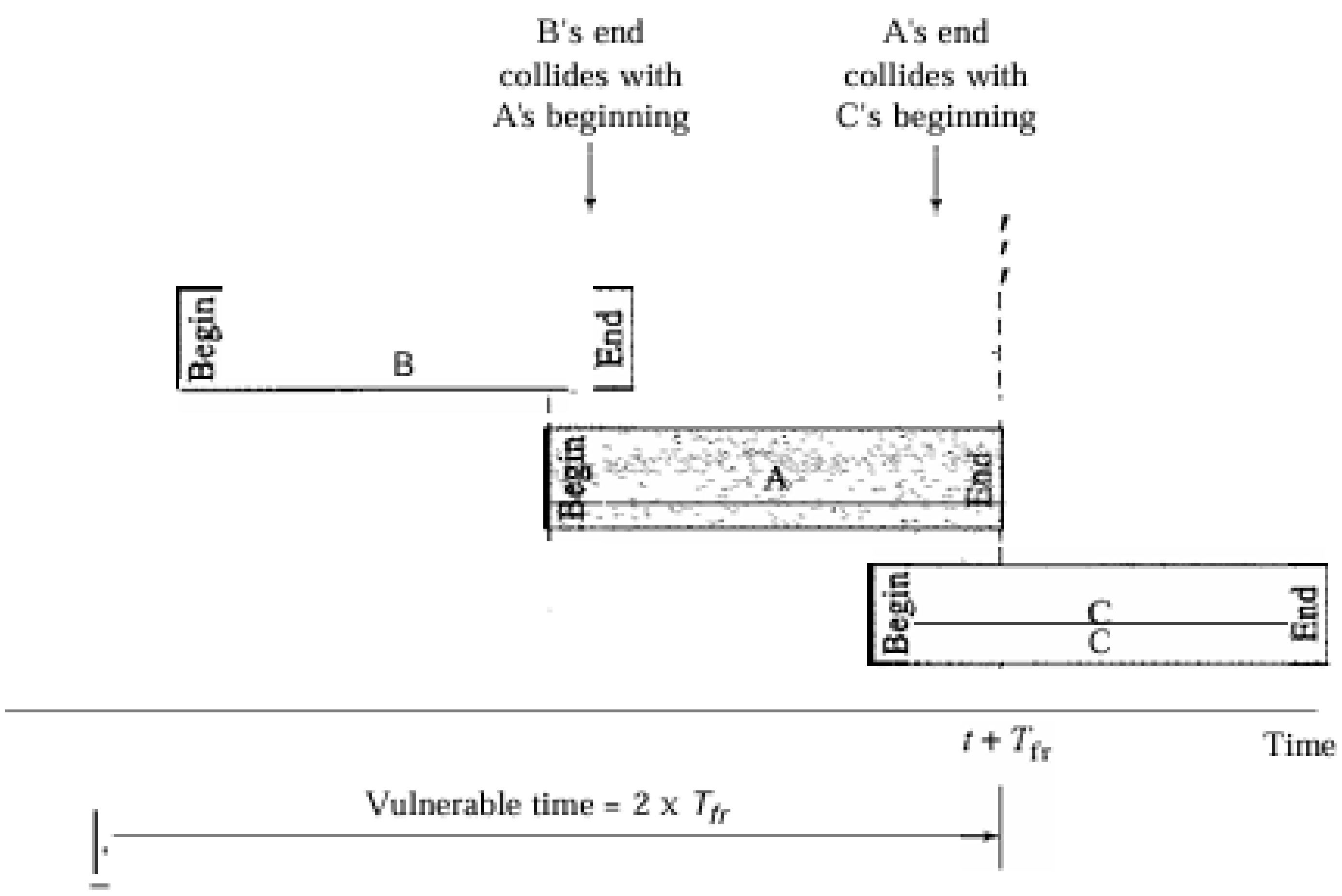
ALOHA

Figure 12.4 *Procedure for pure ALOHA protocol*



ALOHA

Figure 12.5 *Vulnerable time for pure ALOHA protocol*



ALOHA

The throughput for pure ALOHA is $S = G \times e^{-2G}$.

The maximum throughput $S_{max} = 0.184$ when $G = (1/2)$.

Throughput Let us call G the average number of frames generated by the system during one frame transmission time. Then it can be proved that the average number of successful transmissions for pure ALOHA is $S = G \times e^{-2G}$. The maximum throughput S_{max} is 0.184, for $G = \frac{1}{2}$.

ALOHA

The throughput for pure ALOHA is $S = G \times e^{-2G}$.

The maximum throughput $S_{max} = 0.184$ when $G = (1/2)$.

Example 12.3

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces

a. 1000 frames per second

b. 500 frames per second

c. 250 frames per second

Solution

The frame transmission time is *2001200* kbps or 1 ms.

a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

Carrier Sense Multiple Access (CSMA)

- When a station has data to send, it first listens to the channel to see if anyone else is transmitting at that moment. If the channel is idle, the stations sends its data. Otherwise, if the channel is busy, the station just waits until it becomes idle. Then, the station transmits a frame.
- If a collision occurs, the station waits a random amount of time and starts all over again.
- The protocol is called 1-persistent CSMA because the station transmits with a probability of 1 when it finds the channel idle.

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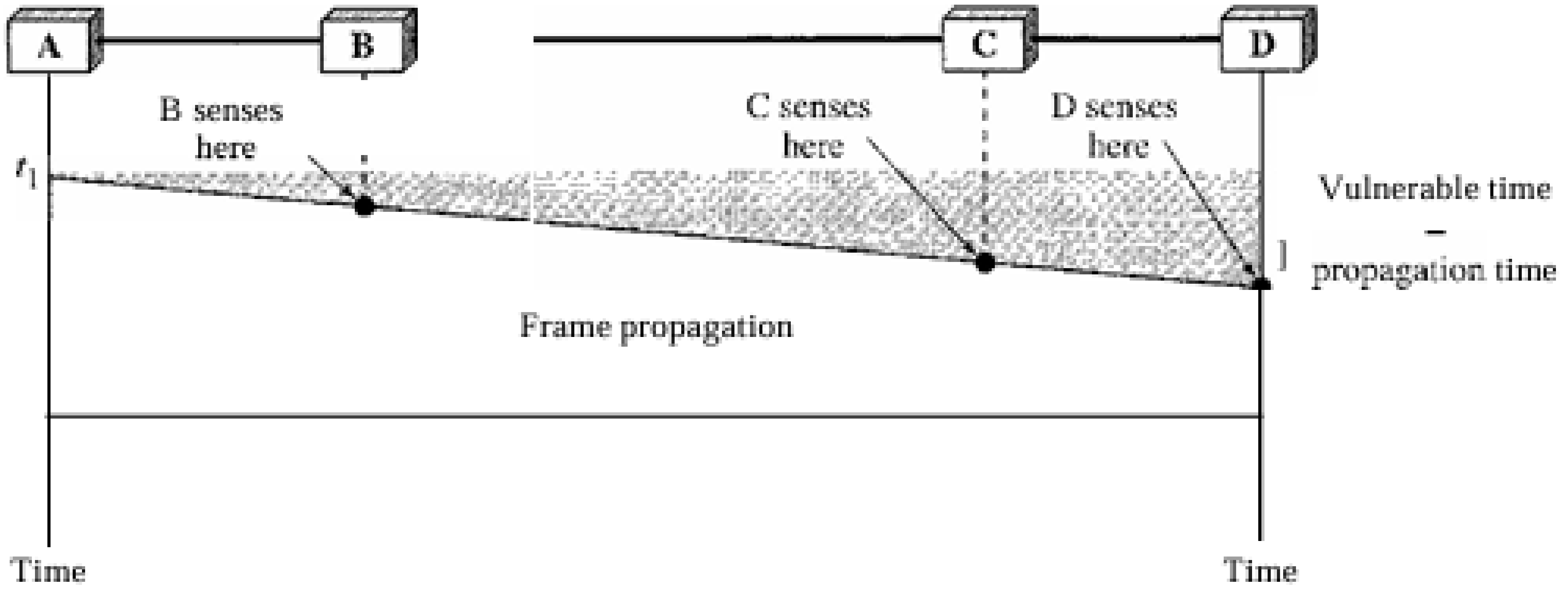
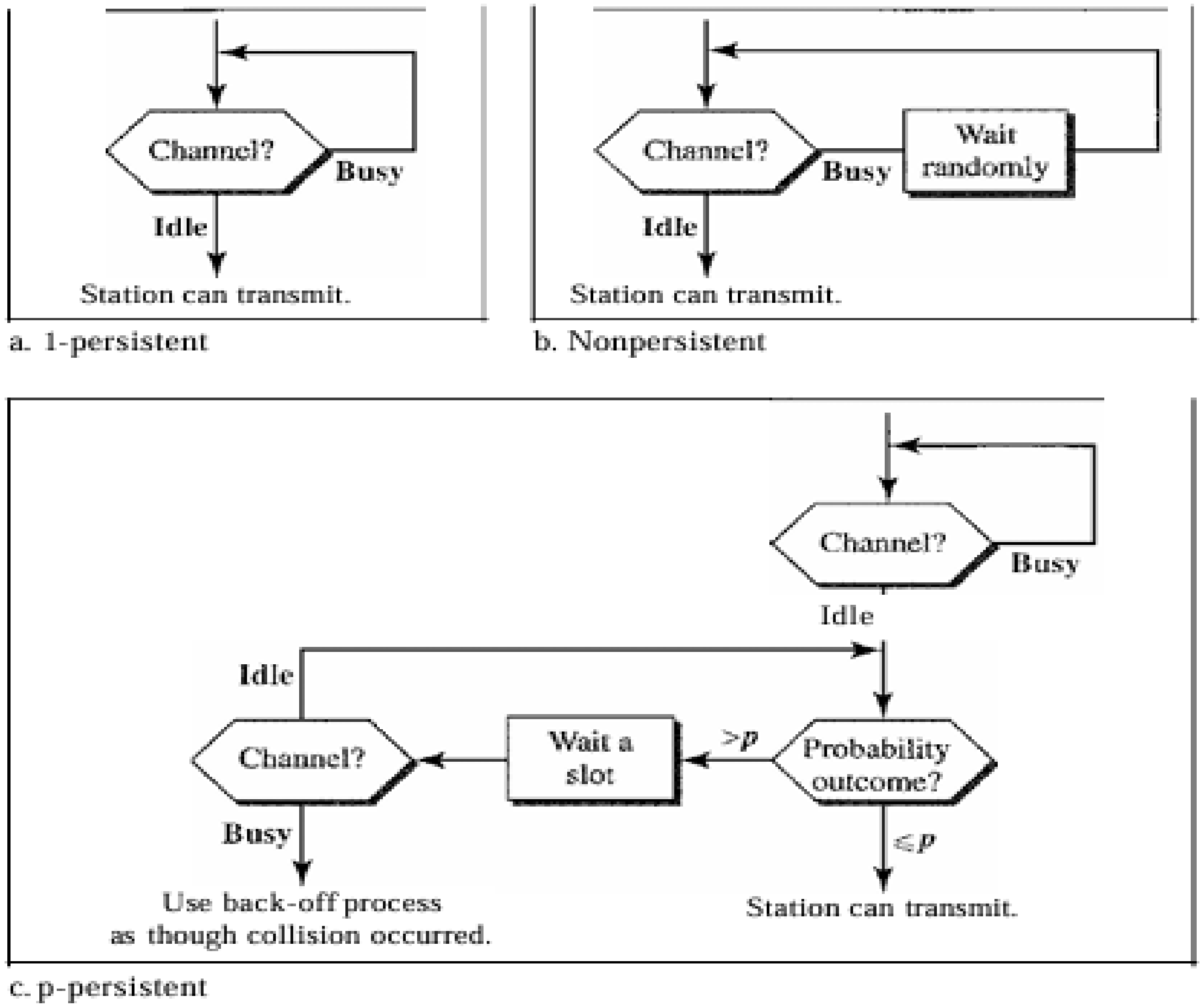
Carrier Sense Multiple Access (CSMA)

Figure 12.9 *Vulnerable time in CSMA*



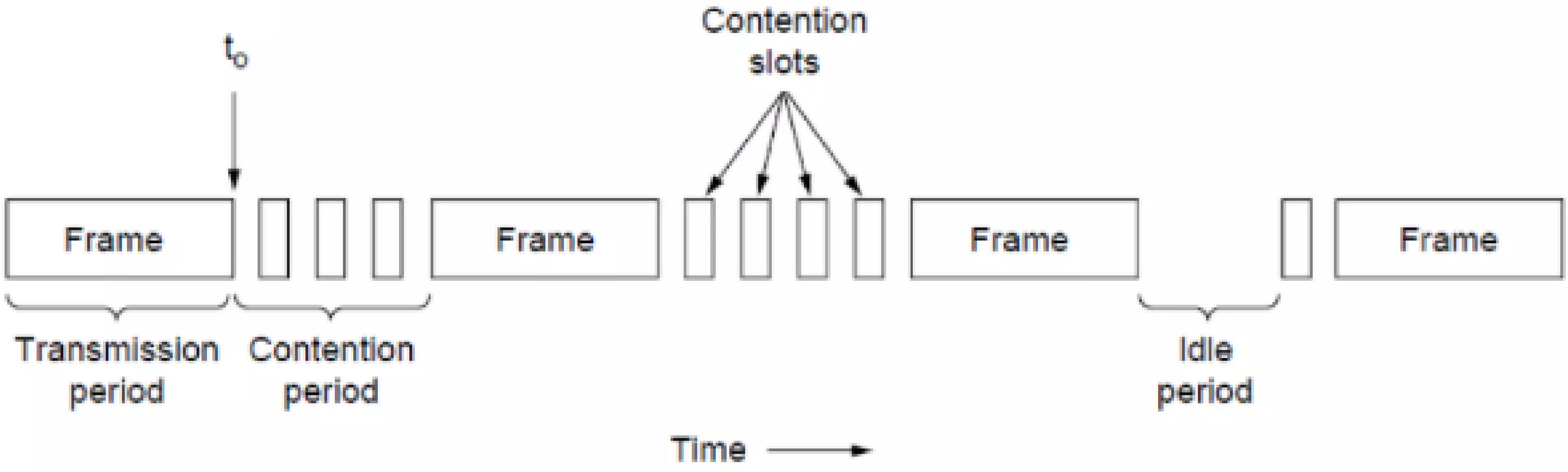
Carrier Sense Multiple Access (CSMA)

Figure 12.11 *Flow diagram for three persistence methods*



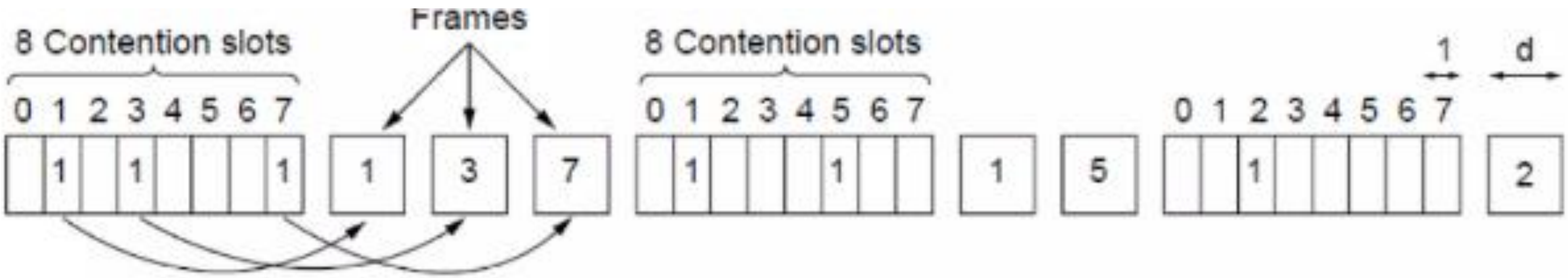
Carrier Sense Multiple Access (CSMA/CD)

CSMA with Collision Detection



- When collision is detected, nodes stop sending their frames.
- station must wait 2T to know if it has seized the channel or not.
- for a 1 km cable T= 5 μsec
- CSMA/CD can be in one of three states: contention, transmission, or idle.

Collision Free Protocol (Bitmap Protocol)



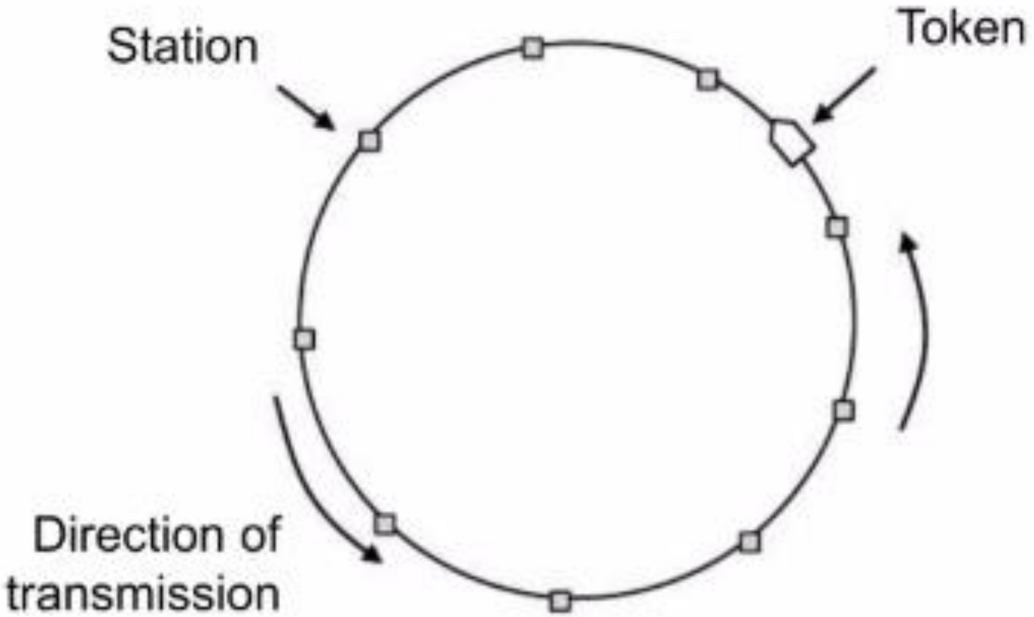
a) low-numbered stations must wait on average 1.5*N slots and high-numbered stations must wait* 0.5*N slots.*

b) *the mean for all stations is N slots.*

c) Channel efficiency = *d /(d + N)* if each frame contains d bits.

Collision Free Protocol (Token Ring)

Collision-Free Protocols (Token Ring)



IEEE802.5, 802.17

The efficiency is same as bitmap protocol.

Important Examples

- Do examples 12.1, 12.2, 12.3, and 12.4 from the reference book by Behrouze Ferozan

Ethernet

Ethernet (IEEE 802.3)

a) **Classic Ethernet**

- Shared medium

  Thick Ethernet : 500 m, 100 users

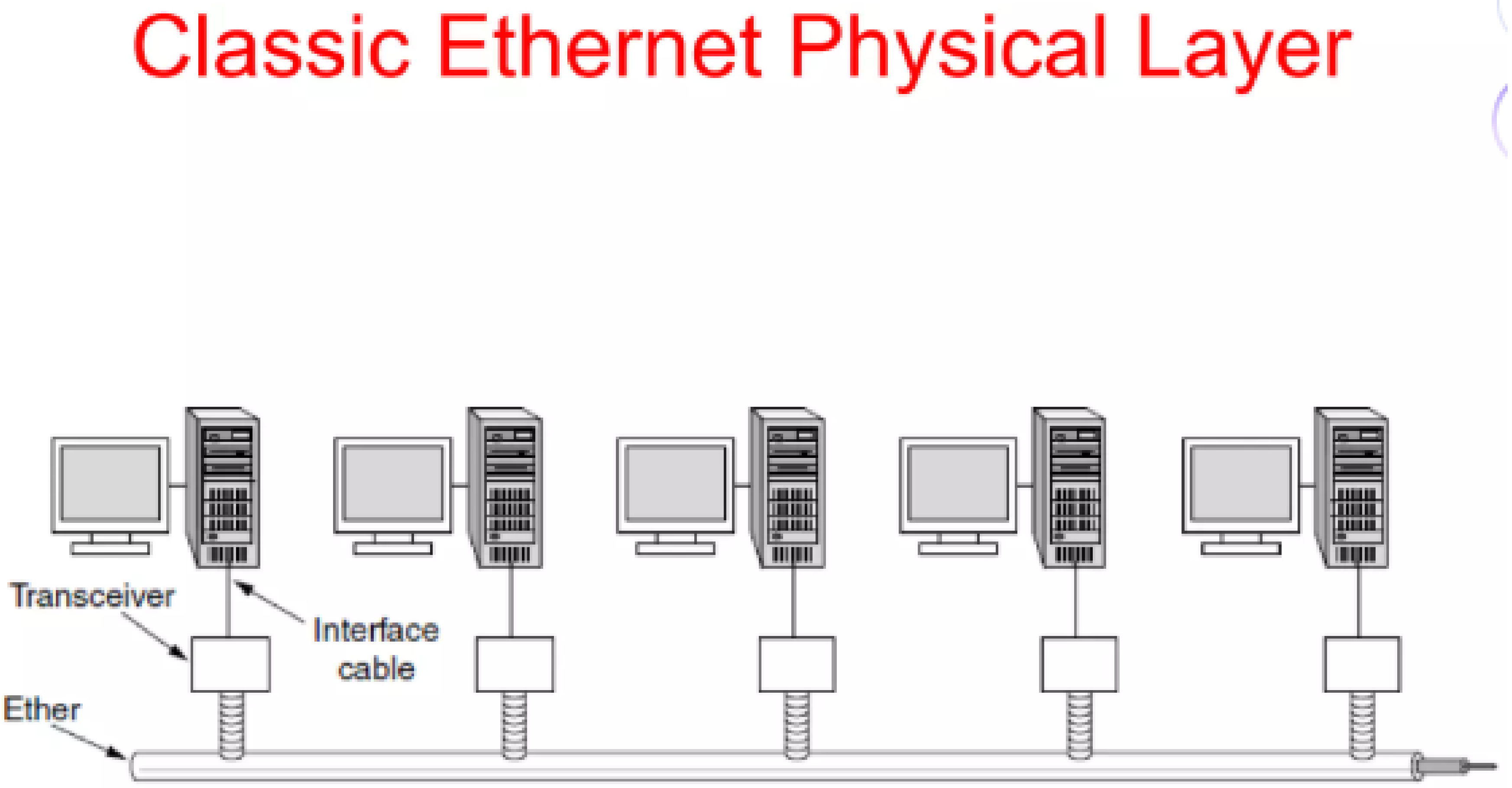
  Thin Ethernet: 185 m, 30 users

- 2.5 km max + 4 repeaters

b) **switched Ethernet**

- Fast Ethernet : 100 Mbps
- Gigabit Ethernet
- 10 Gigabit Ethernet

Ethernet


Classic Ethernet Physical Layer
Transceiver
Interface cable
Ether

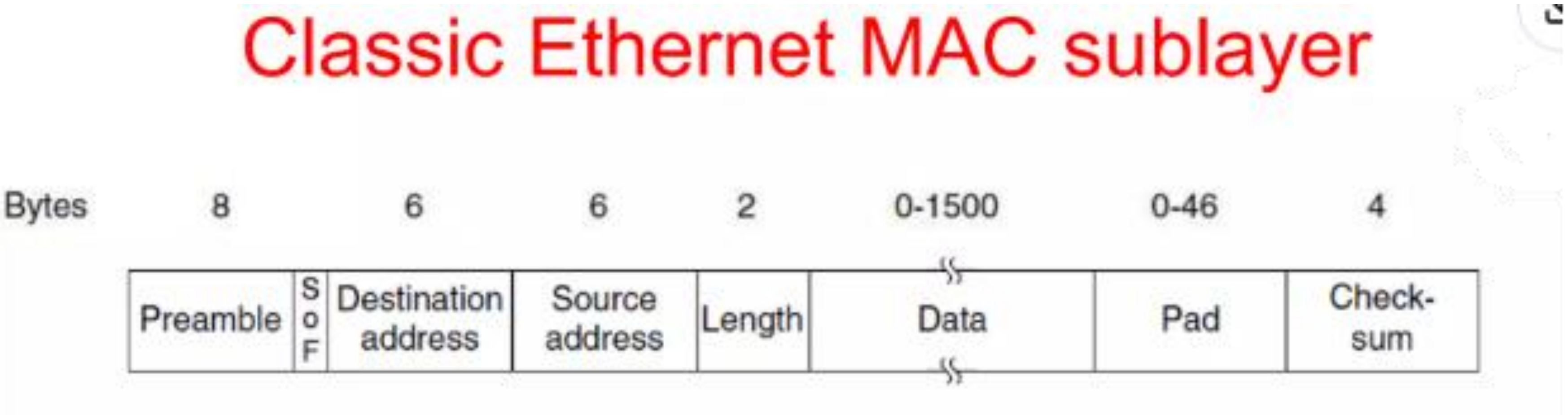
Ethernet

Classic Ethernet MAC sublayer

Bytes	8		6	6	2	0-1500	0-46	4
	Preamble	SoF	Destination address	Source address	Length	Data	Pad	Check-sum

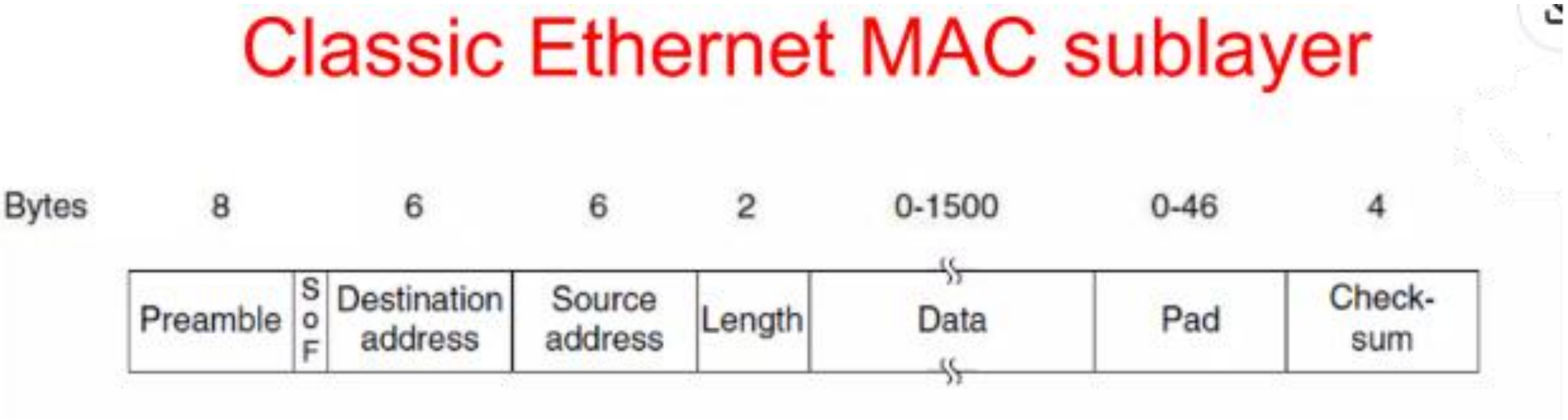
- Preamble: 10101010 → 10 MHz square wave 6.4 μsec
- Start of frame: 10101011
- D_addr: 0… : unicast, 1… : multicast, 11…1 : broadcast
- S_addr: globally unique for each NIC. First 3 bytes are for manufacturers assigned by IEEE, the last 3 byte is assigned by manufacturer to each produced NIC.

Ethernet



- The purpose of the length field in an Ethernet frame is to indicate the number of bytes in the frame's payload (data). In IEEE 802.3 Ethernet, this 2-byte field is used to specify the data's size, which is crucial for the receiver to know how much data to read. If the value in this field is 1,500 or less, it is interpreted as the length of the data payload.

Ethernet



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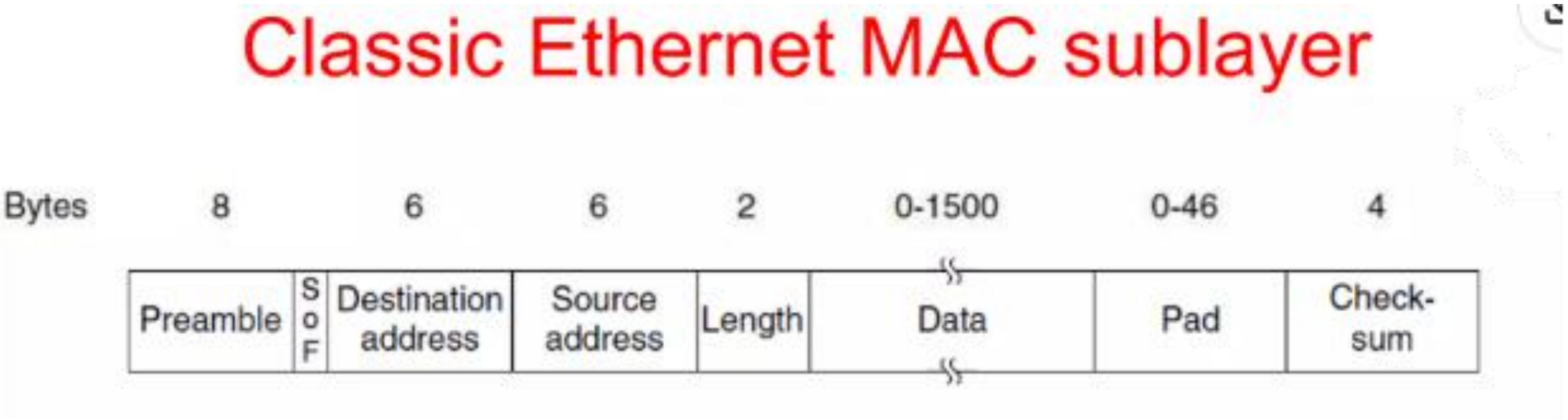
Ethernet



- The purpose of padding in an Ethernet frame is to ensure the data portion (payload) meets the minimum length requirement of 46 bytes

Ethernet

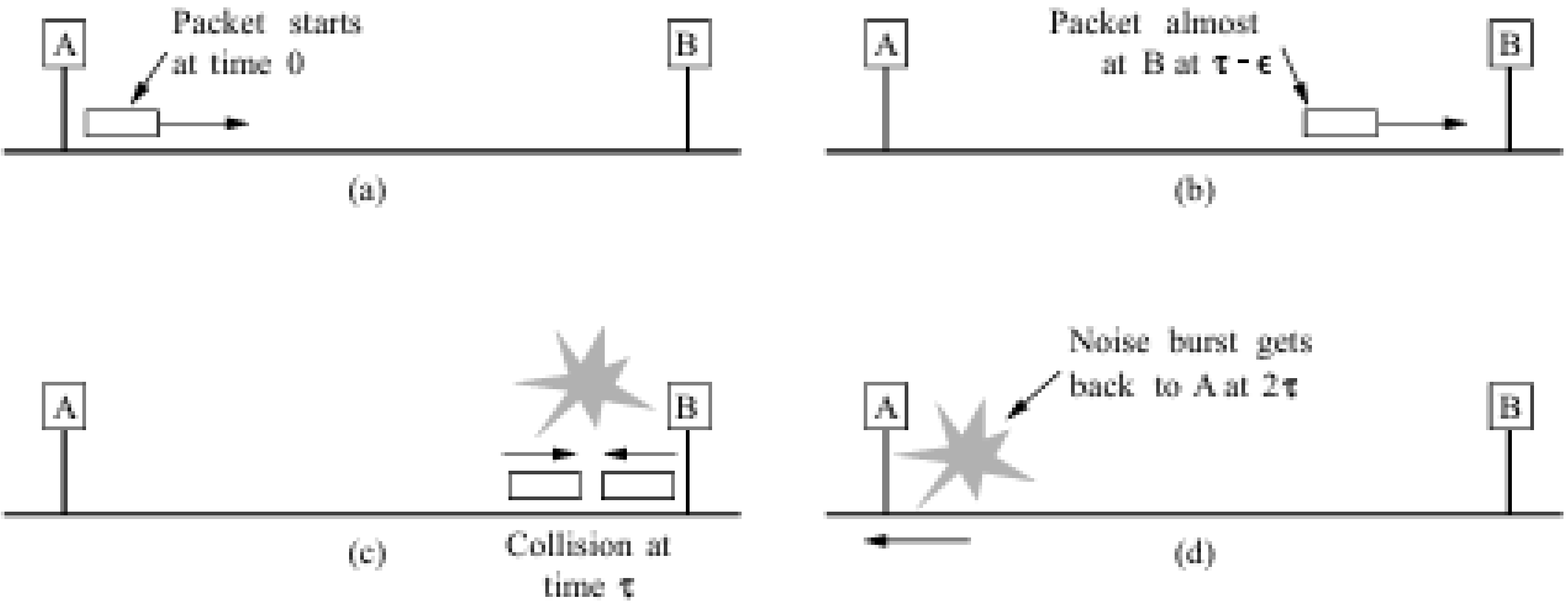


Figure 4-15. Collision detection can take as long as 2τ.

Ethernet

Another (and more important) reason for having a minimum length frame is to prevent a station from completing the transmission of a short frame before the first bit has even reached the far end of the cable, where it may collide with another frame. This problem is illustrated in Fig. 4-15. At time 0, station A, at one end of the network, sends off a frame. Let us call the propagation time for this frame to reach the other end τ. Just before the frame gets to the other end (i.e., at time $\tau - \varepsilon$), the most distant station, B, starts transmitting. When B detects that it is receiving more power than it is putting out, it knows that a collision has occurred, so it aborts its transmission and generates a 48-bit noise burst to warn all other stations. In other words, it jams the ether to make sure the sender does not miss the collision. At about time 2τ, the sender sees the noise burst and aborts its transmission, too. It then waits a random time before trying again.

Ethernet

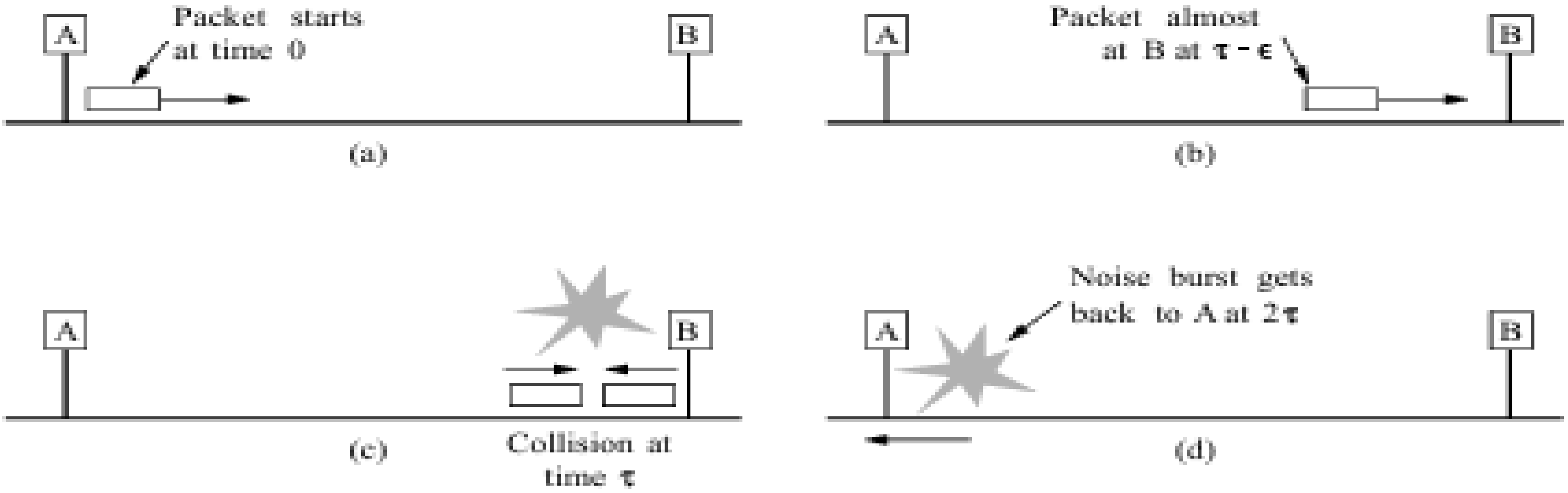


Figure 4-15. Collision detection can take as long as 2τ.

- Collision detection can take as long as 2τ so a minimum frame length is required.
- For a 2500 m cable: RTT = 50 μsec RTT is a Round-trip Time
- For 10 Mbps BW = min frame size = 500 bit or 64 bytes.

Ethernet

CSMA/CD with Binary Exponential Backoff

a) After i'th consecutive collision, the sender nodes wait a random number of time slots between 0 and $2^i - 1$.

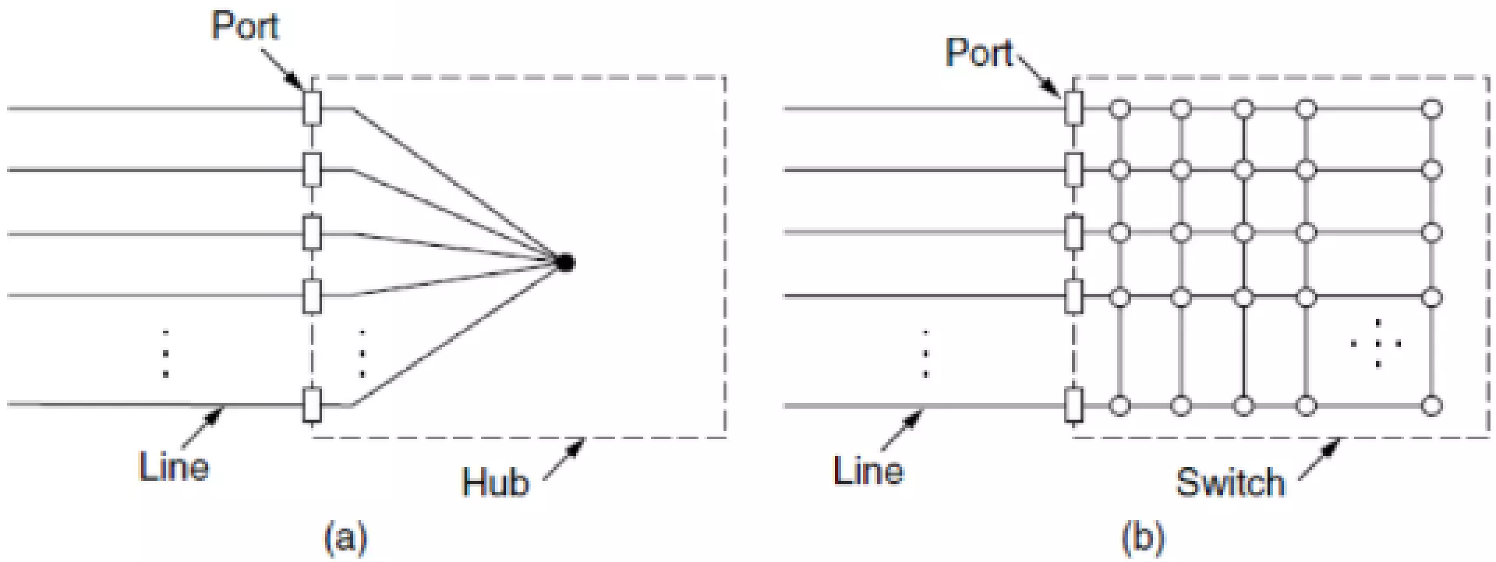
b) Each Time slot = 51.2 µsec = 512 bit times

c) after 10 collisions, the interval is frozen at maximum 1023 slots.

d) After 16 collisions, the controller reports failure back

Ethernet

Switched Ethernet (1)



(a) Hub. (b) Switch.

Ethernet

Fast Ethernet

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps (Cat 5 UTP)
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

- 100B-T4: uses 4 twisted pairs with 25 MHz BW. 1 to the switch, 1 from the switch and other 2 are interchangeable. Using 3 voltage levels for symbols. Manchester encoding.

- 100B-TX: 4B/5B encoding. 125 MHz BW results 100 Mbps. 2 pairs of cable required.

- 100B-FX: only works with switches because the maximum cable length should be less than 250 m for CD to work.

Ethernet

Gigabit Ethernet

a) Two ways to enhance cable length to 200 m when using hubs:
   - Hardware **carrier extension** to 512 bytes.
   - **frame bursting**

b) 8B/10B encoding is used to maintain synchronization.

c) In UTP cables all 4 pairs are used in simultaneous full-duplex mode!
   With 5 voltage levels

d) Pause frames are defined to cease the communication speed.

Ethernet

10 Gigabit Ethernet

- Fiber cables use 64B/66B coding is used.
- CX cables use 8B/10B coding and 3.125 Gsymbol/sec on each pair.
- T cabling requires 16 voltage levels. LDPC (Low Density Parity Check) is used.
- 40Gbps and 100Gbps Ethernet standards are in the way.

Wireless LANS

Wireless LANS

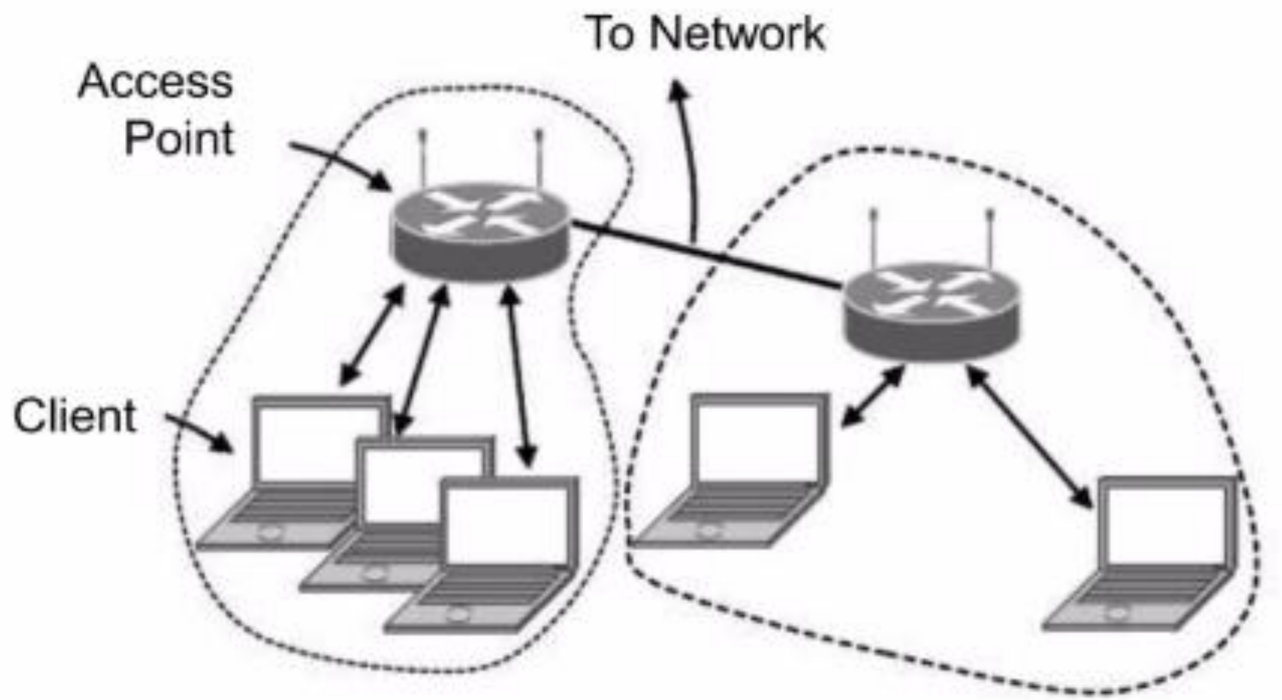
Wireless LANS

Wireless Lans

- 802.11 architecture and protocol stack
- 802.11 physical layer
- 802.11 MAC sublayer protocol
- 802.11 frame structure
- Services

Wireless LANS

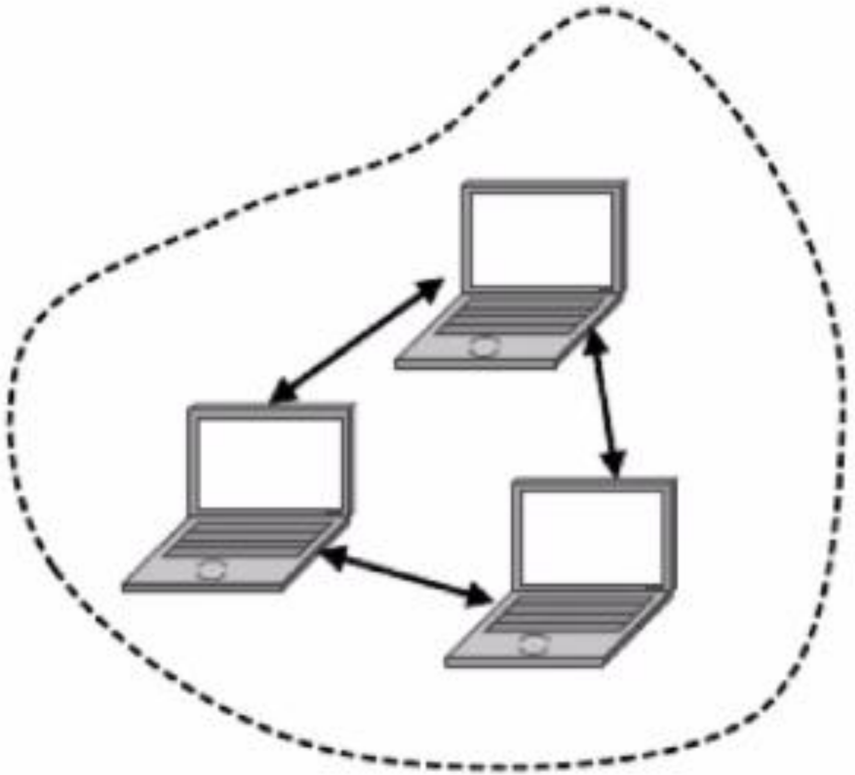
802.11 Architecture and Protocol Stack



802.11 architecture – infrastructure mode

Wireless LANS

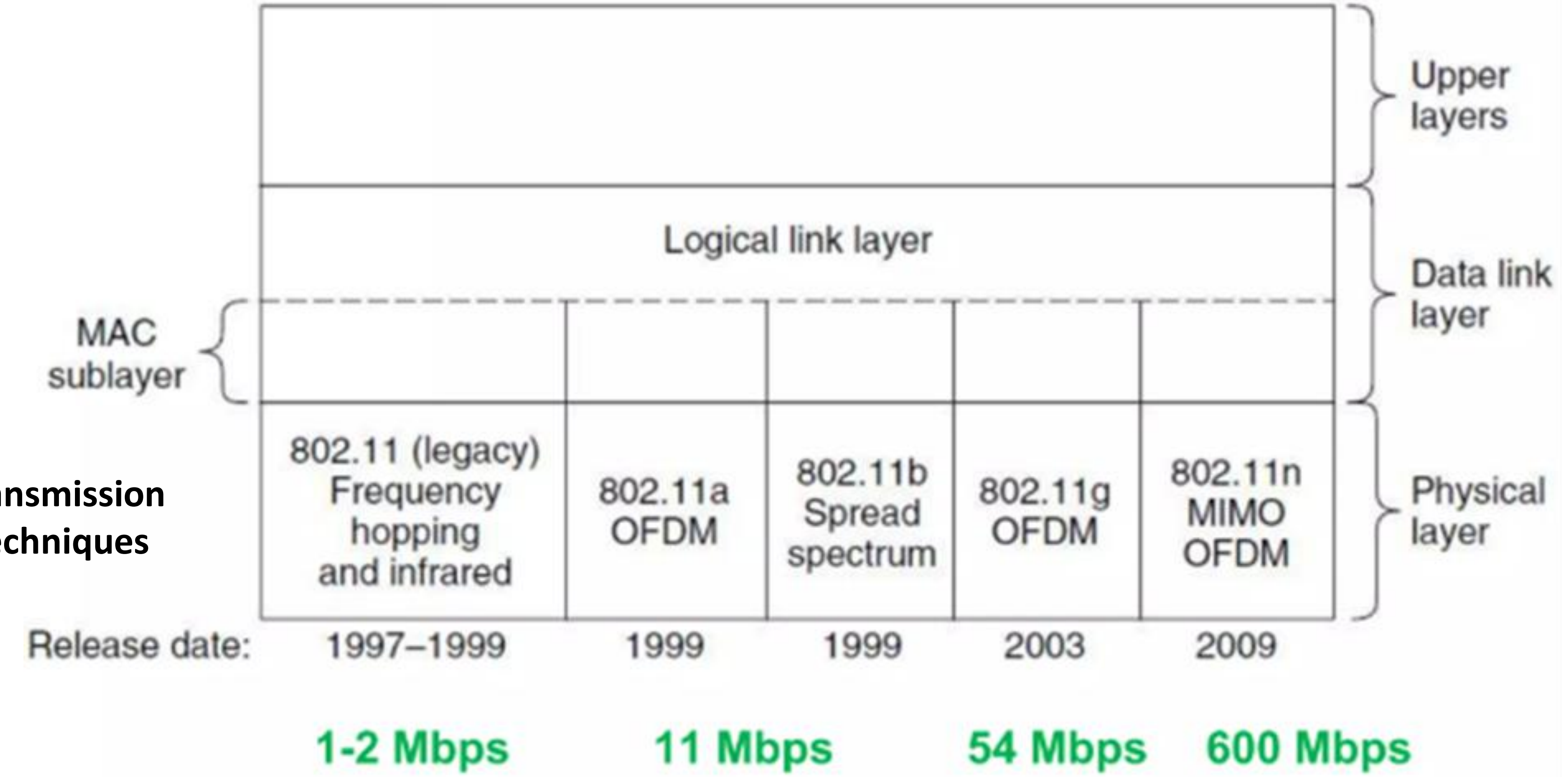
802.11 Architecture and Protocol Stack



802.11 architecture – ad-hoc mode-

Wireless LANS

802.11 Protocol Stack



- **Transmission techniques**

Wireless LANS

802.11b PHY Layer

a) 1 Mbps : 11 chip barker code to spread the signal with BPSK to send 1 bit per 11 chip. The chip rate is 11 Mchips/sec.

b) 2 Mbps : QPSK (*Quadrature Phase Shift Keying*) to send 2 bits per 11 chip.

c) 5.5 Mbps: CCK (*Complementary Code Keying*) with 4 bits per 8 chips.

d) 11 Mbps: CCK with 8 bits per 8 chips.

Wireless LANS

802.11a, g, n PHY Layer

a) Works in 5GHz band.

b) Uses OFDM (*Orthogonal frequency-division multiplexing*) with 52 subcarriers 48 for data and 4 for sync.

c) Each symbol lasts 4μs and sends 1, 2, 4, or 6 bits.

d) Supports 8 data rates from 6 up to 54Mbps.

e) Communication range is 1/7 802.11b because of freq. band.

f) 802.11 g uses OFDM in 2.4GHz band.

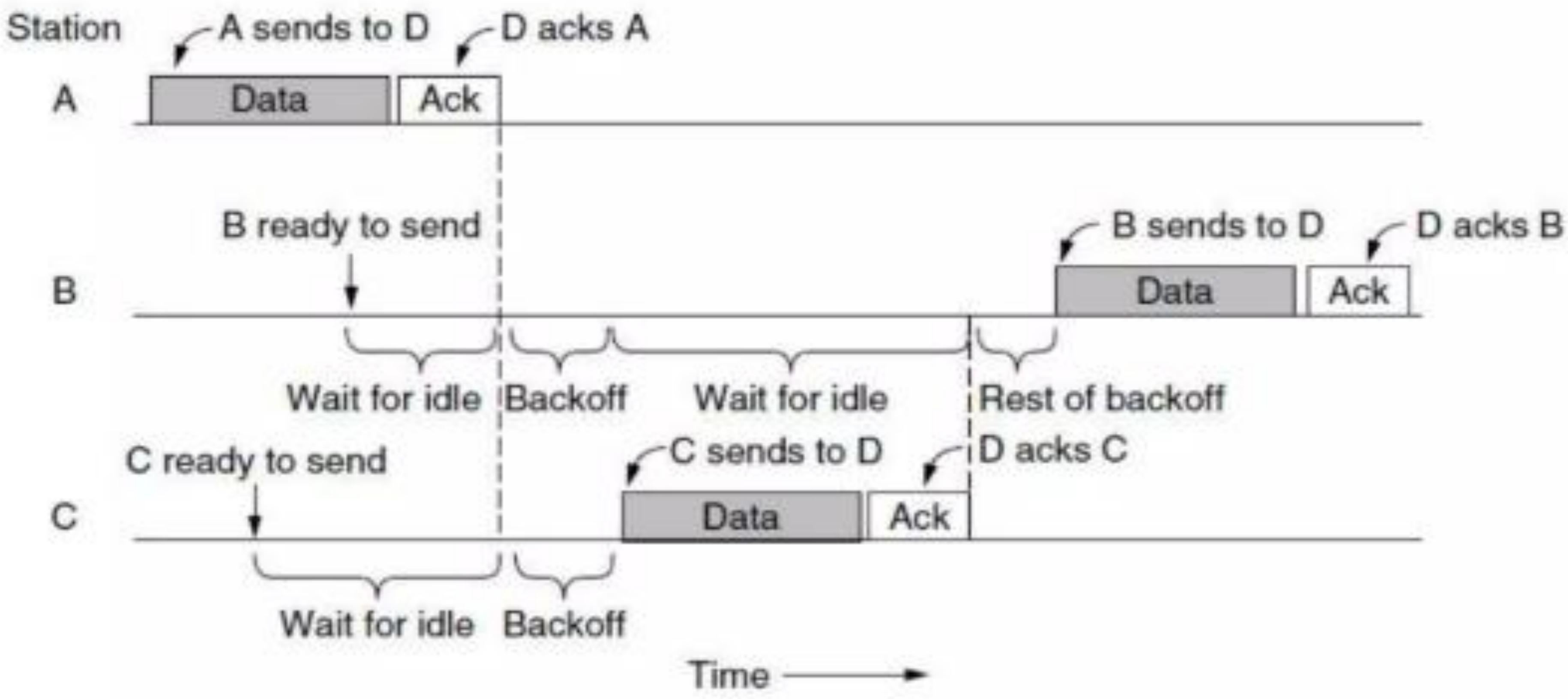
g) Supports same rates of 802.11a with same range of 802.11b

h) 802.11n doubles the channel width from 20 to 40MHz.

i) Uses multiple antennas and MIMO techniques to increase BW.

Wireless LANS

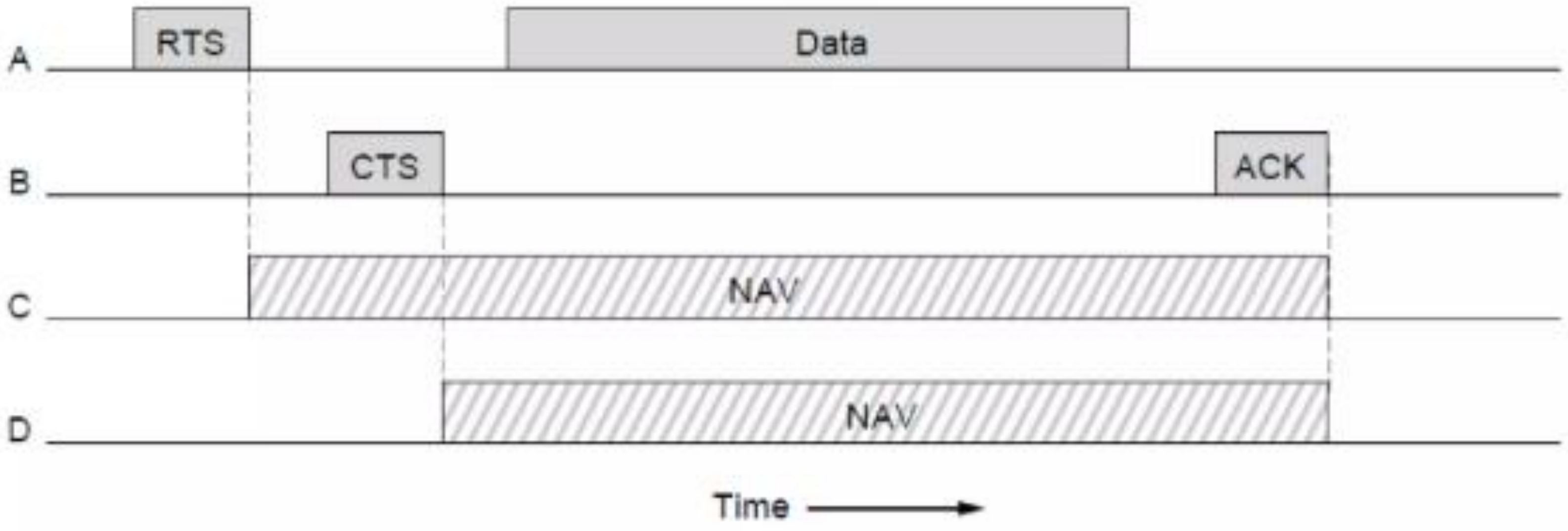
The 802.11 MAC Sublayer Protocol



Sending a frame with CSMA/CA.

Wireless LANS

Collision Avoidance mechanism



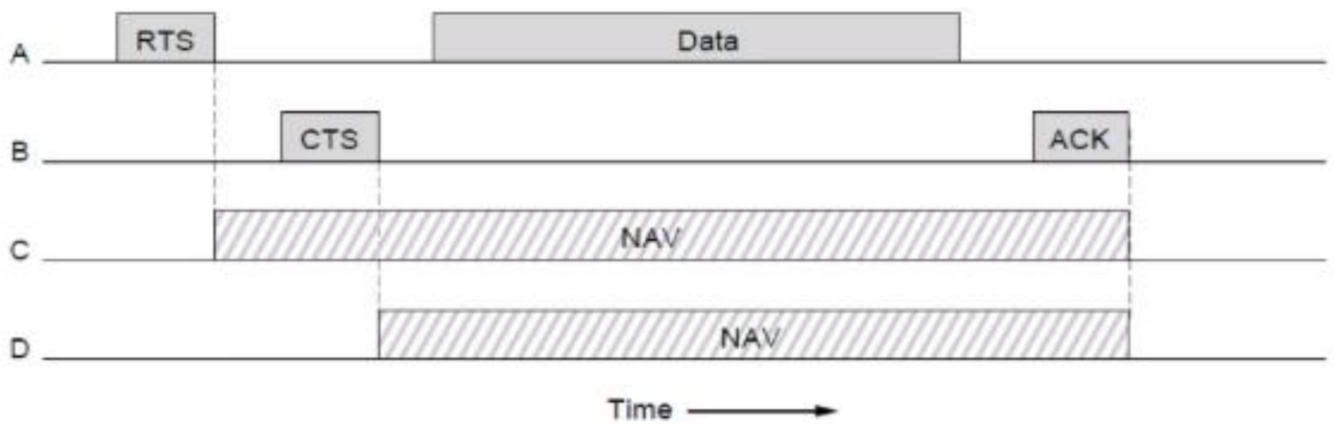
The use of virtual channel sensing using CSMA/CA.

NAV (Network Allocation Vector)

RTS/CTS: request to send/ clear to send

Wireless LANS

Collision Avoidance mechanism



The use of virtual channel sensing using CSMA/CA.

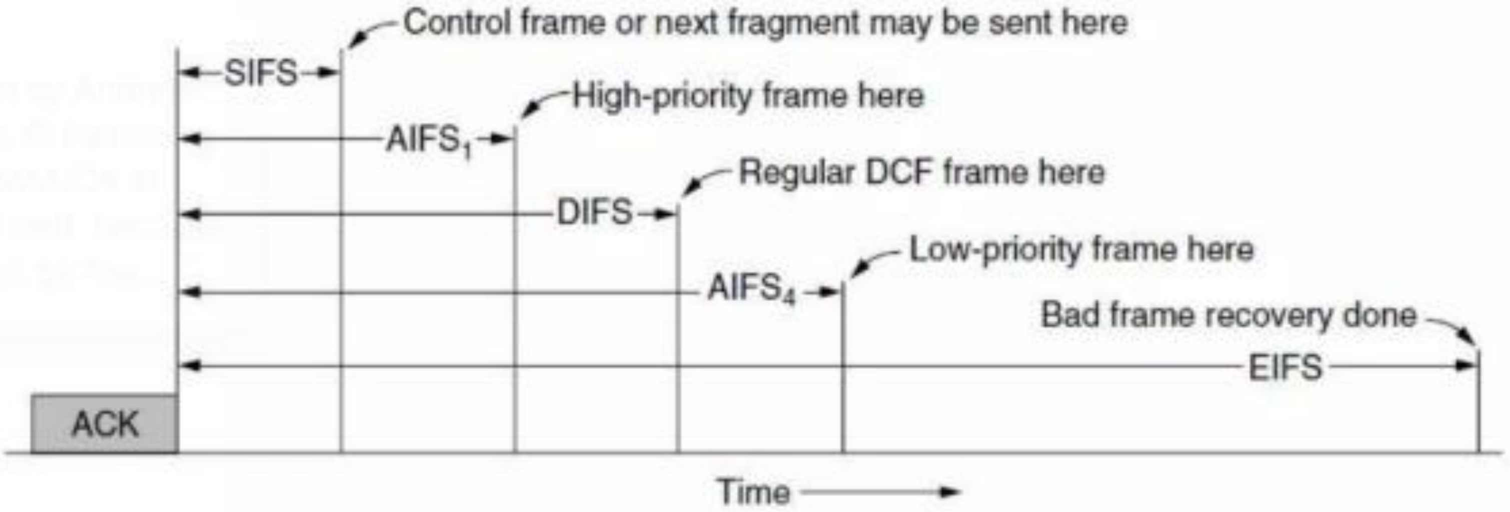
NAV (Network Allocation Vector)

RTS/CTS: request to send/ clear to send

- Physical sensing simply checks the medium to see if there is a valid signal (Signal strength)
- With virtual sensing, each station keeps a logical record of when the channel is in use by tracking the NAV (Network Allocation Vector).

Wireless LANS

Interframe timing for QoS purposes



a) SIFS (Short InterFrame Spacing)
b) DIFS (Distributed Coordination Function InterFrame Spacing)
c) AIFS (Arbitration InterFrame Space)
d) EIFS (Extended InterFrame Spacing)