DATA LINK LAYER

HDLC

***High-level Data Link Control (HDLC)* is a *bit-oriented* protocol for communication over point-to-point and multipoint links. It implements the ARQ mechanisms**

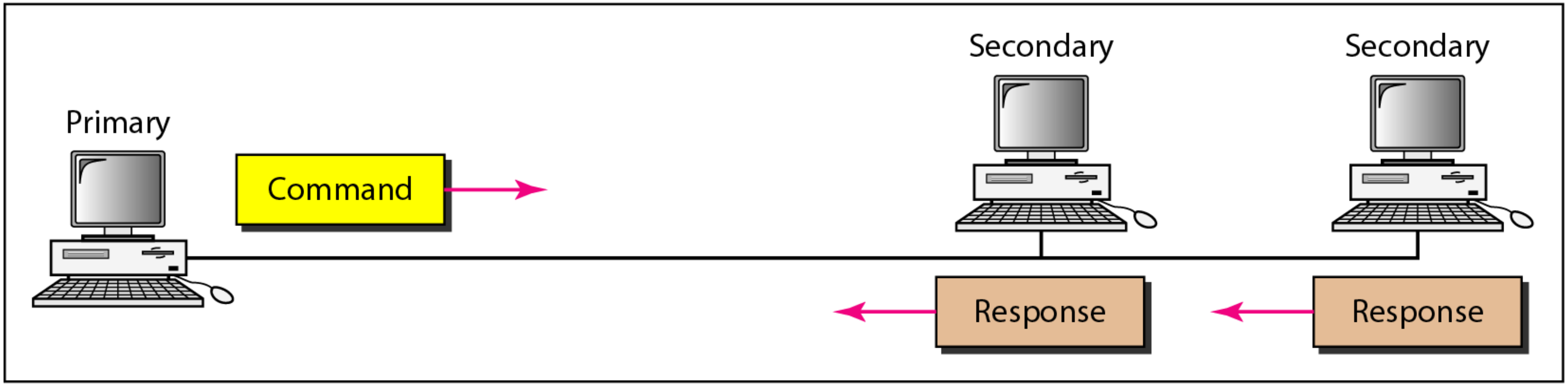
Topics discussed in this section:

Configurations and Transfer Modes
Frames
Control Field

HDLC

Normal response mode

a. Point-to-point



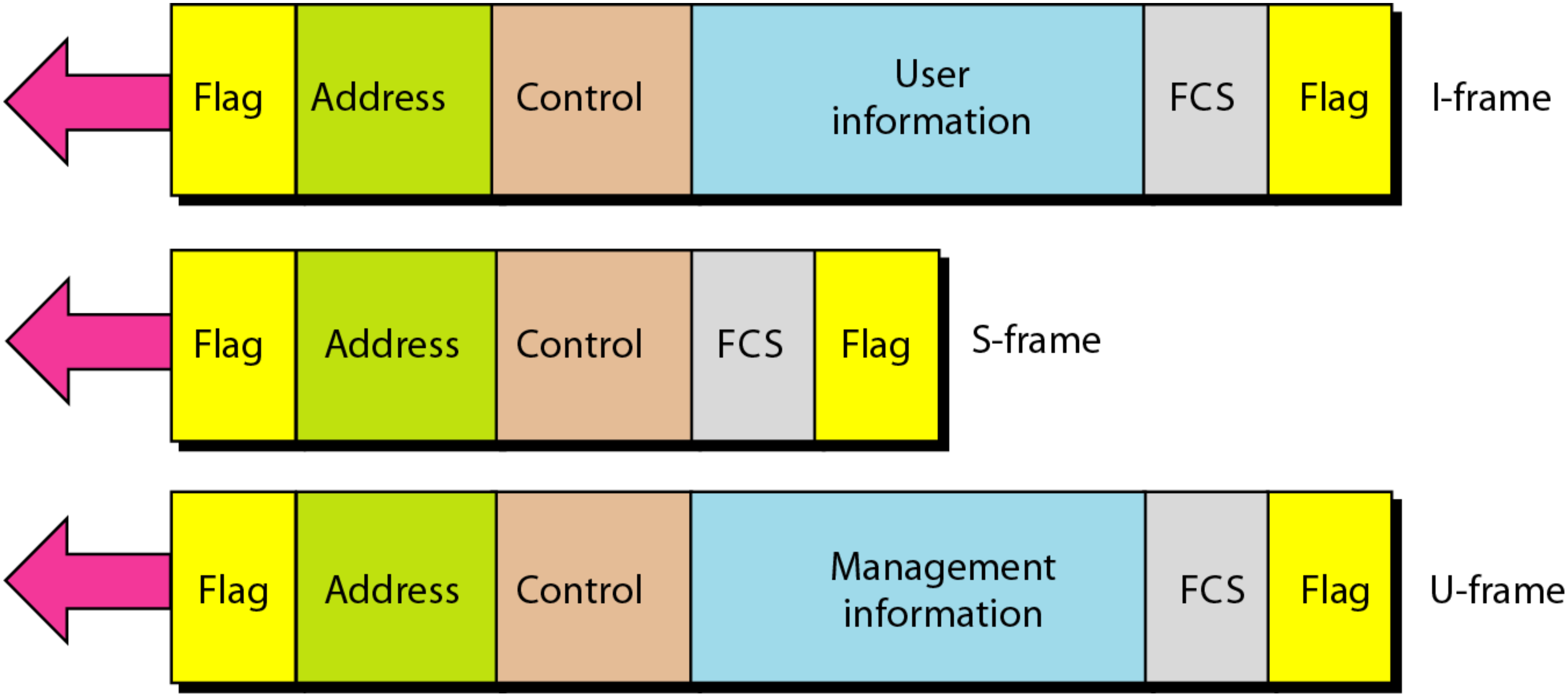
b. Multipoint

HDLC

Asynchronous balanced mode

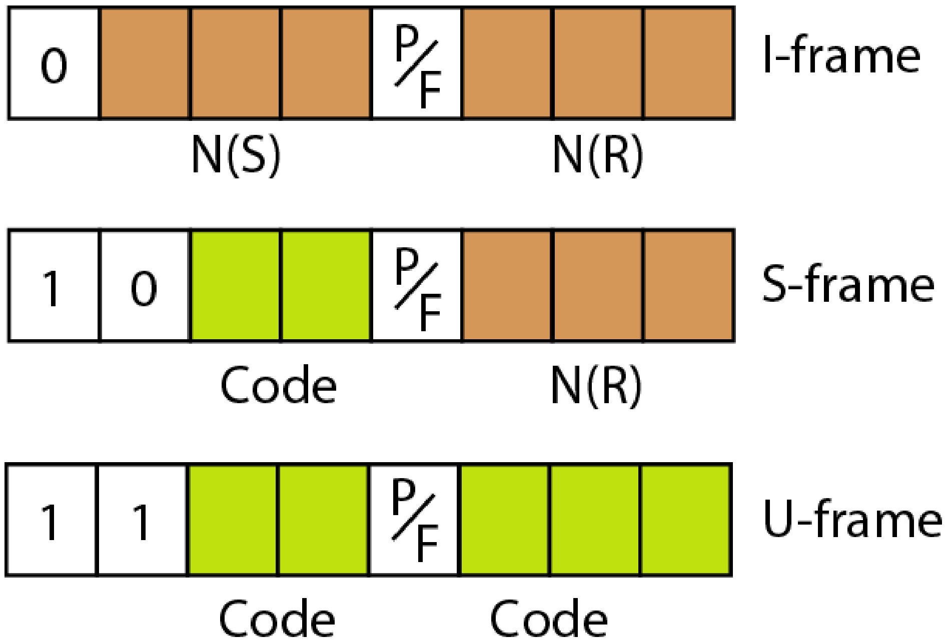
HDLC

HDLC frames



HDLC

Control field format for the different frame types



HDLC

U-frame control command and response

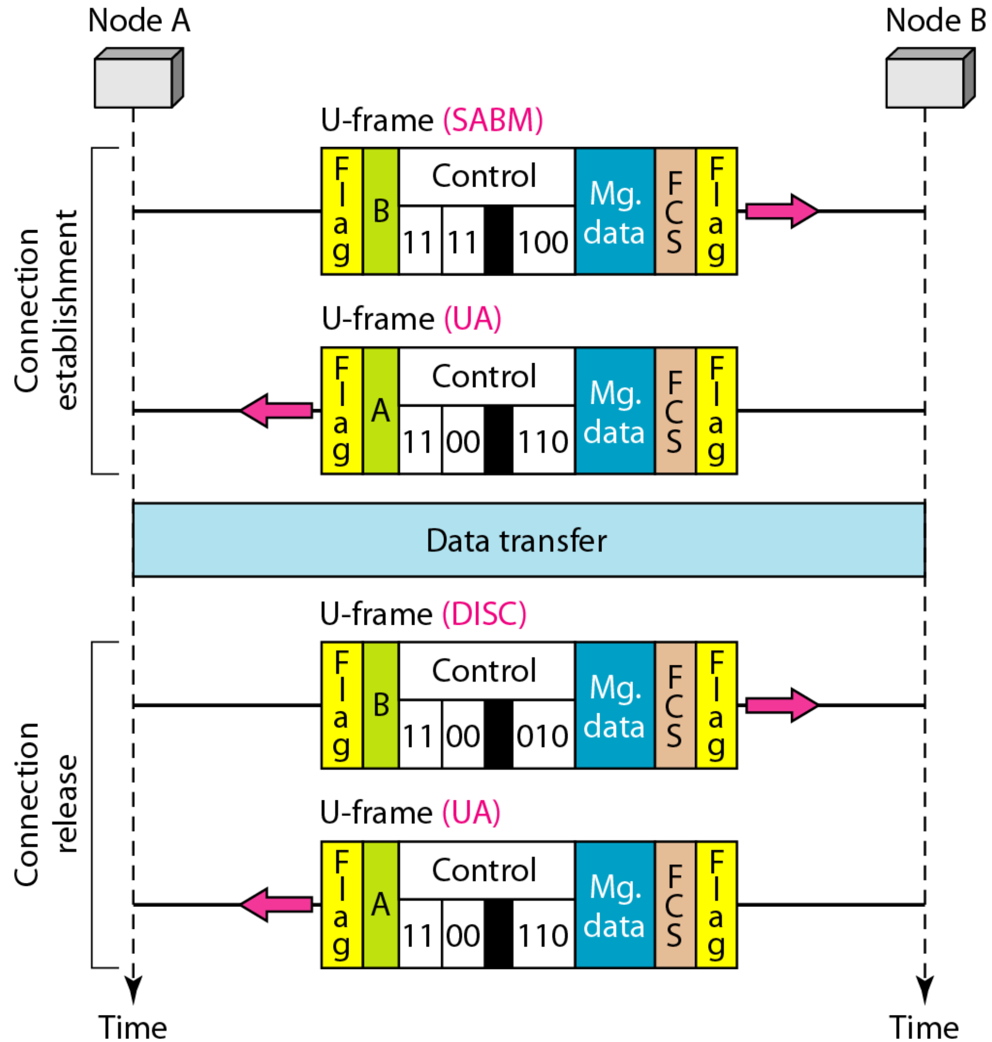
Code	*Command*	*Response*	*Meaning*
00 001	SNRM		Set normal response mode
11 011	SNRME		Set normal response mode, extended
11 100	SABM	**DM**	Set asynchronous balanced mode or **disconnect mode**
11 110	SABME		Set asynchronous balanced mode, extended
00 000	UI	**UI**	Unnumbered information
00 110		**UA**	**Unnumbered acknowledgment**
00 010	DISC	**RD**	Disconnect or **request disconnect**
10 000	SIM	**RIM**	Set initialization mode or **request information mode**
00 100	UP		Unnumbered poll
11 001	RSET		Reset
11 101	XID	**XID**	Exchange ID
10 001	FRMR	**FRMR**	Frame reject

HDLC

Figure shows how U-frames can be used for connection establishment and connection release. Node A asks for a connection with a set asynchronous balanced mode (SABM) frame; node B gives a positive response with an unnumbered acknowledgment (UA) frame. After these two exchanges, data can be transferred between the two nodes (not shown in the figure). After data transfer, node A sends a DISC (disconnect) frame to release the connection; it is confirmed by node B responding with a UA (unnumbered acknowledgment).

HDLC

Example of connection and disconnection

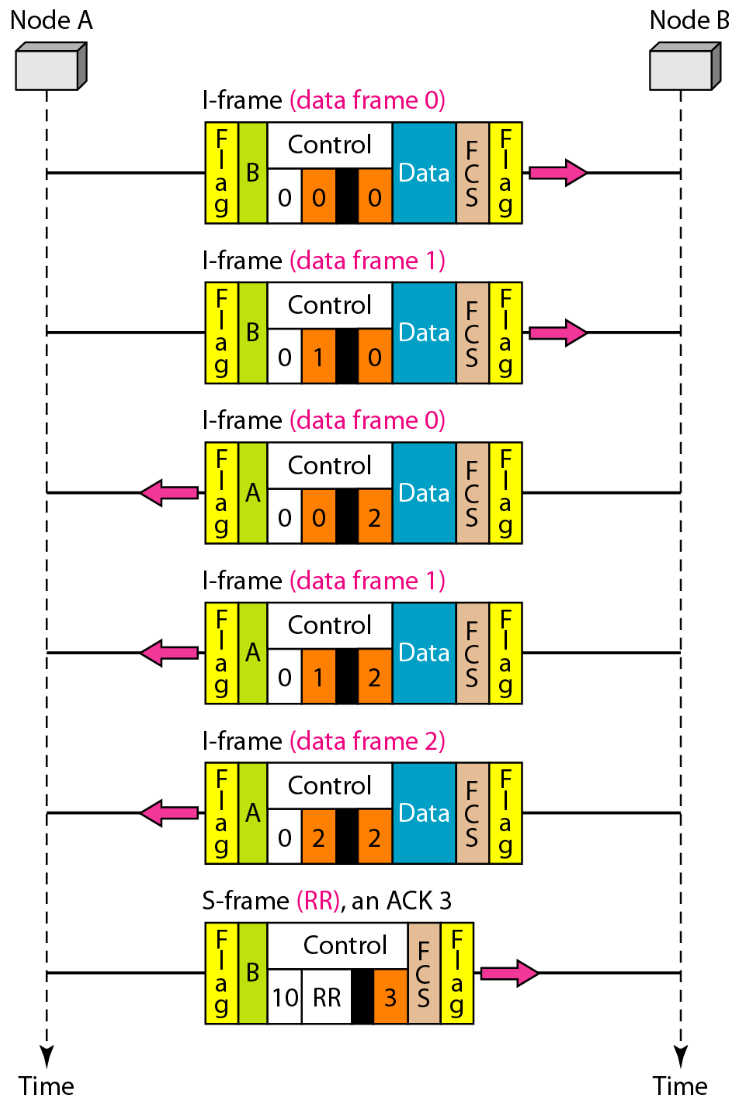


HDLC

Figure shows an exchange using piggybacking. Node A begins the exchange of information with an I-frame numbered 0 followed by another I-frame numbered 1. Node B piggybacks its acknowledgment of both frames onto an I-frame of its own. Node B's first I-frame is also numbered 0 [N(S) field] and contains a 2 in its N(R) field, acknowledging the receipt of A's frames 1 and 0 and indicating that it expects frame 2 to arrive next. Node B transmits its second and third I-frames (numbered 1 and 2) before accepting further frames from node A.

HDLC

Example of piggybacking without error



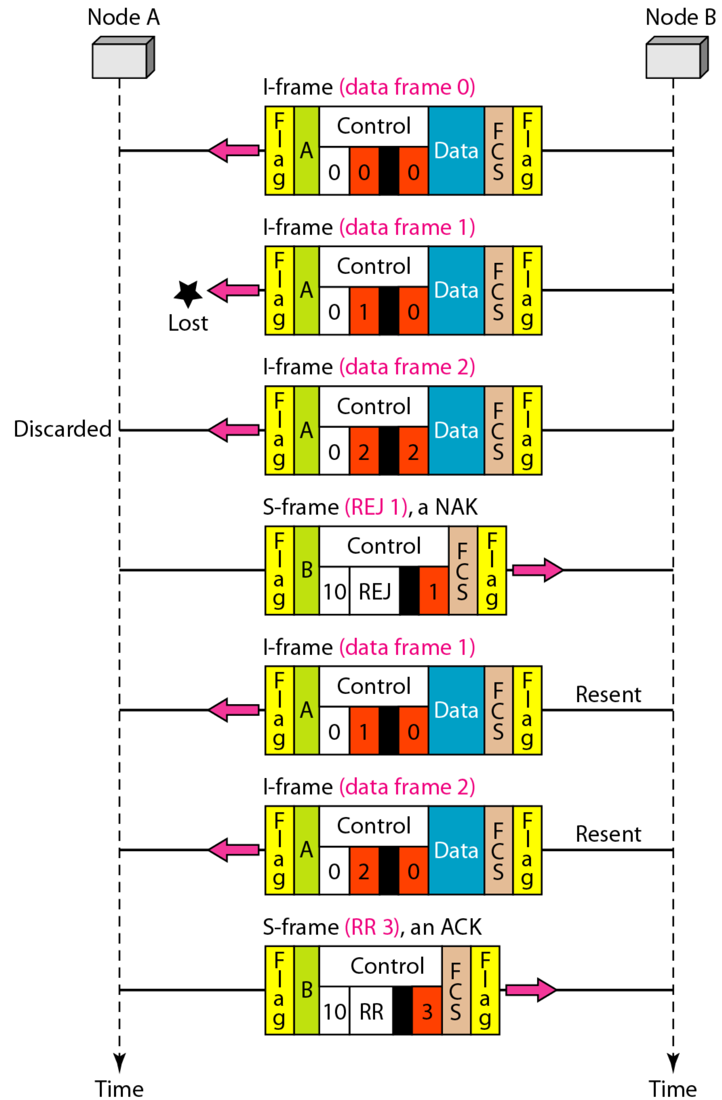
Its N(R) information, therefore, has not changed: B frames 1 and 2 indicate that node B is still expecting A's frame 2 to arrive next. Node A has sent all its data. Therefore, it cannot piggyback an acknowledgment onto an I-frame and sends an S-frame instead. The RR code indicates that A is still ready to receive. The number 3 in the N(R) field tells B that frames 0, 1, and 2 have all been accepted and that A is now expecting frame number 3.

HDLC

Figure shows an exchange in which a frame is lost. Node B sends three data frames (0, 1, and 2), but frame 1 is lost. When node A receives frame 2, it discards it and sends a REJ frame for frame 1. Note that the protocol being used is Go-Back-N with the special use of an REJ frame as a NAK frame. The NAK frame does two things here: It confirms the receipt of frame 0 and declares that frame 1 and any following frames must be resent. Node B, after receiving the REJ frame, resends frames 1 and 2. Node A acknowledges the receipt by sending an RR frame (ACK) with acknowledgment number 3.

HDLC

Example of piggybacking with error



DLL-MAC

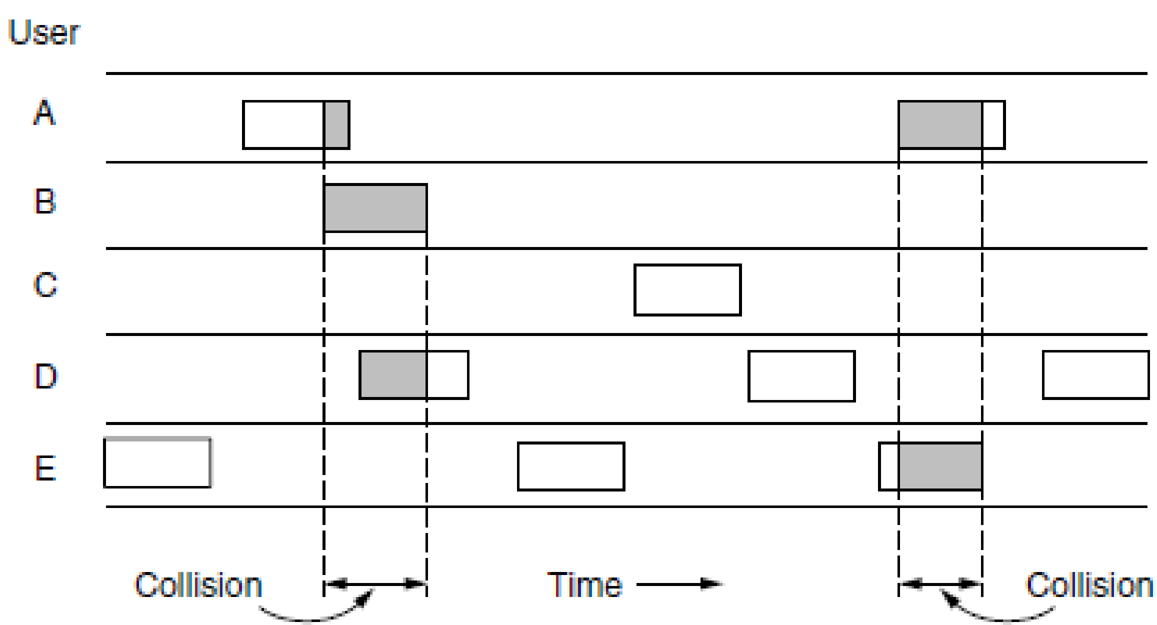
THE CHANNEL ALLOCATION

- **Static Channel Allocation-** Fixed channel allocation uses FDM or TDM
- **Dynamic Channel Allocation-** Channel allocation on dynamic basis
    - Independent Traffic
    - Single Channel
    - Observable collisions
    - Continuous or slotted time
    - Carrier sense or no carrier sense

DLL-MAC

ALOHA- used short-range radios, with each user terminal sharing the same upstream frequency to send frames to the central computer

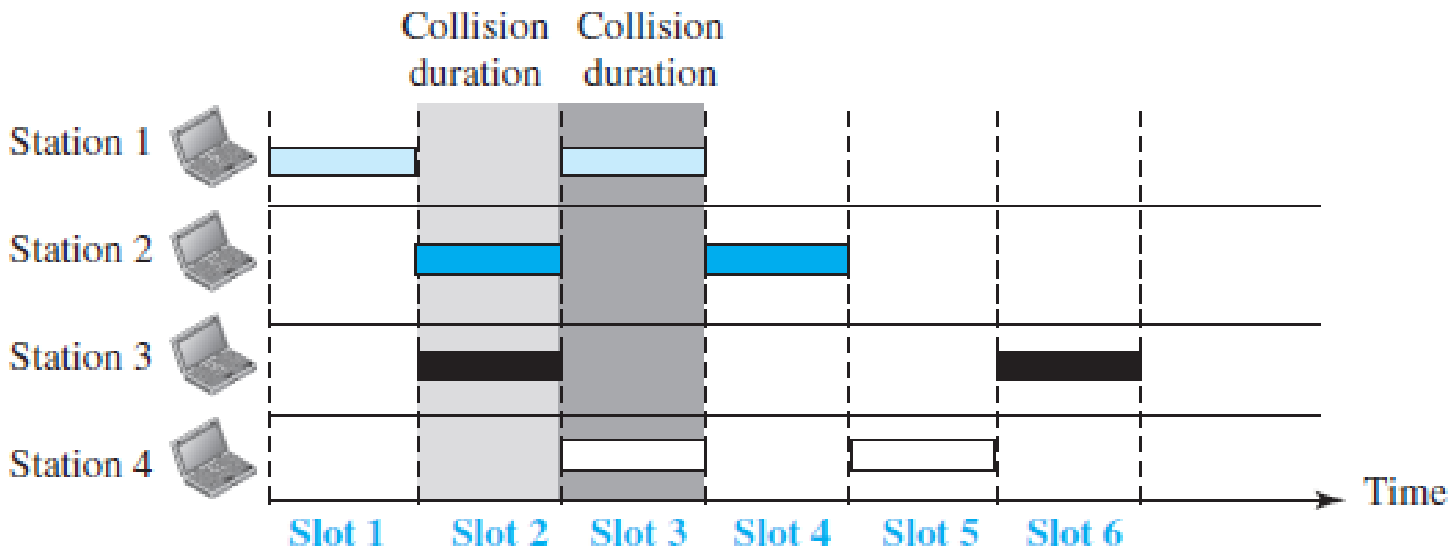
- Pure ALOHA- Users transmit whenever they have data to sent (contention System) and there will be collision as well as frame damage



DLL-MAC

ALOHA

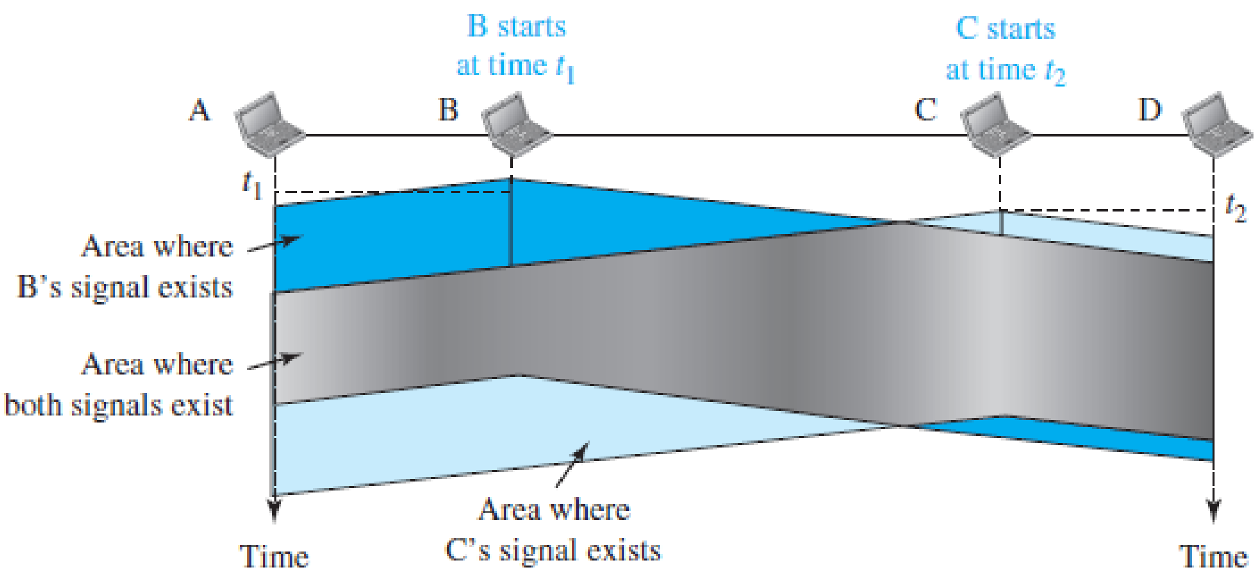
Slotted Aloha- Transmission during slot times (force the station to send only at the beginning of the time slot)



DLL-MAC

Carrier Sense Multiple Access Protocols

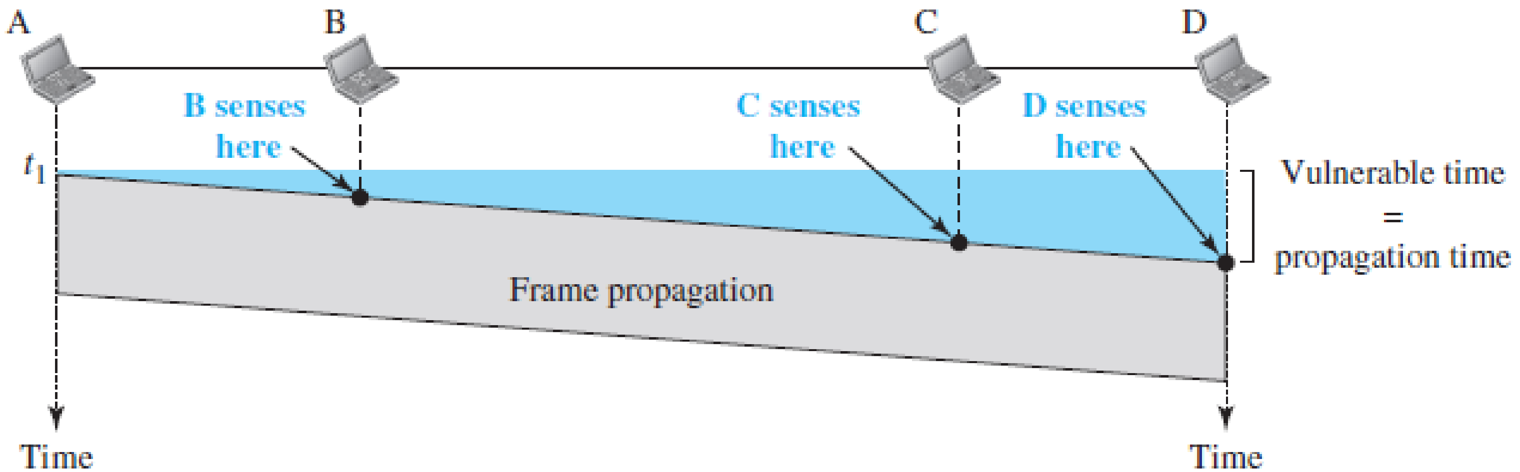
- CSMA is based on the principle “sense before transmit” or “listen before talk.”
- Collision will take place based on propagation delay
- Station may sense the medium and find it idle, only because the first bit sent by another station has not yet been received.



DLL-MAC

Carrier Sense Multiple Access Protocols

The vulnerable time for CSMA is the ***propagation time*** *Tp*
The leftmost station, A, sends a frame at time $t1$, which reaches the rightmost station, D, at time $t1 + Tp$. The gray area shows the vulnerable area in time and space.



DLL-MAC

Carrier Sense Multiple Access Protocols

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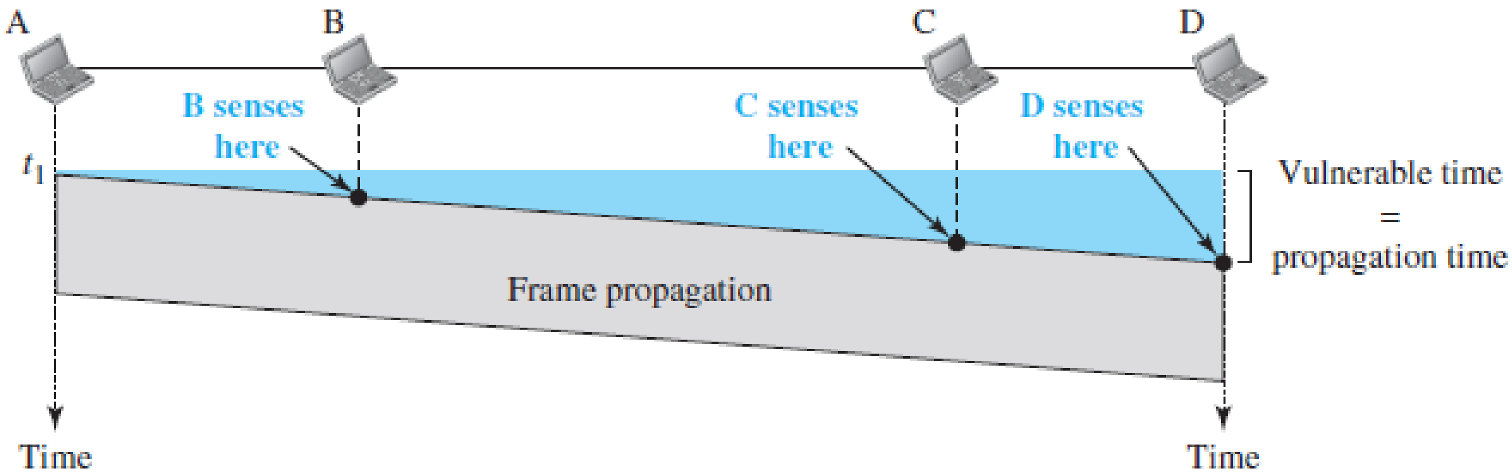
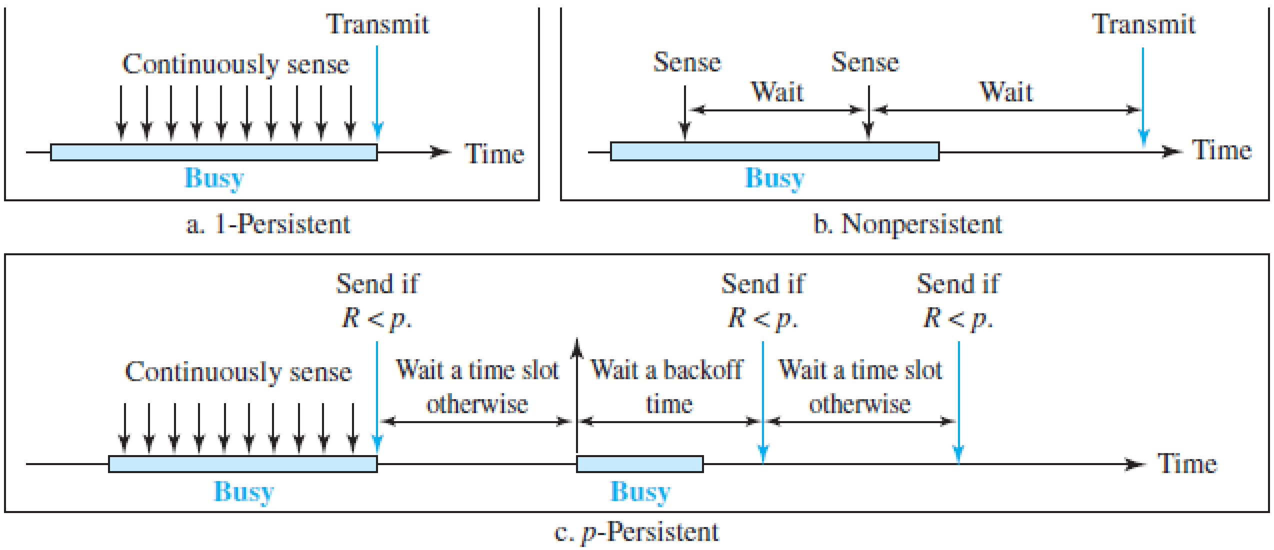


DLL-MAC

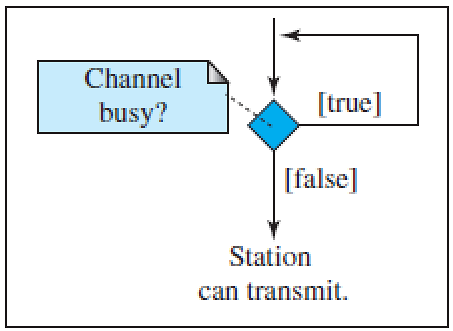
Carrier Sense Multiple Access Protocols

- ***1-Persistent*-** When the station finds the line idle, it sends its frame immediately (with probability 1)
- **N*onpersistent method-*** a station that has a frame to send senses the line. If the line is idle, it sends immediately. If the line is not idle, it waits a random amount of time and then senses the line again.
- **p-*Persistent*-** used if the channel has time slots with a slot duration equal to or greater than the maximum propagation time.

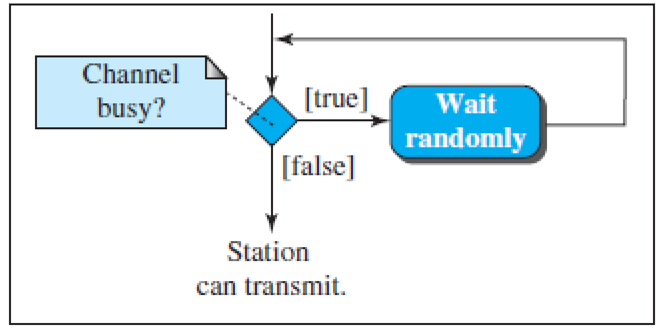


DLL-MAC

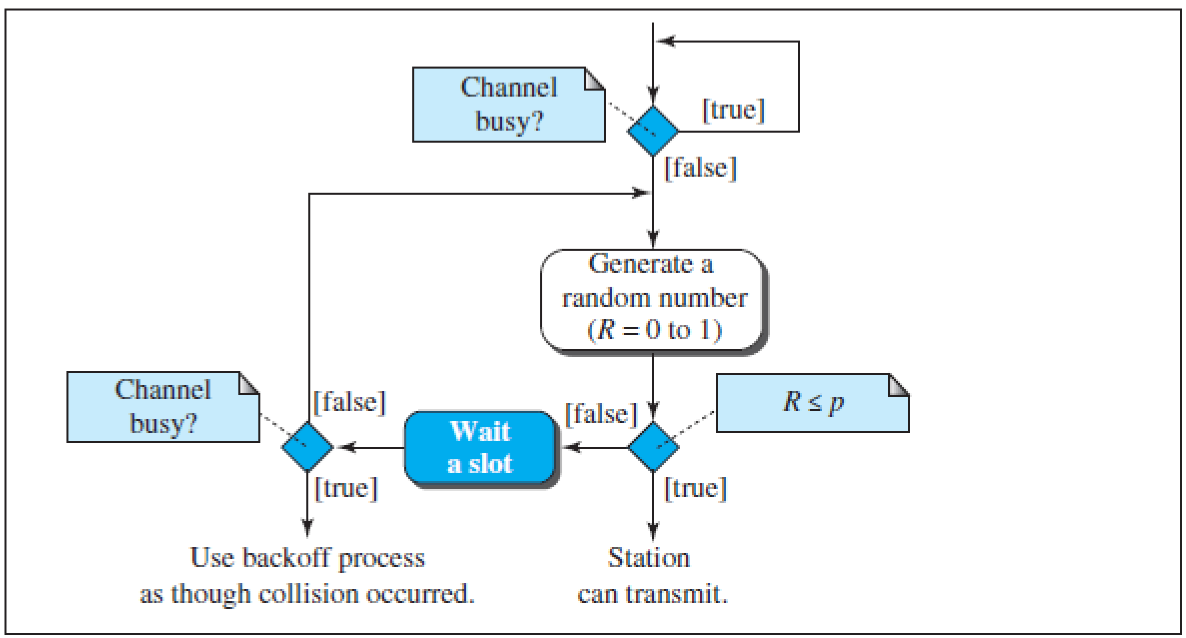
Carrier Sense Multiple Access Protocols



a. 1-Persistent



b. Nonpersistent

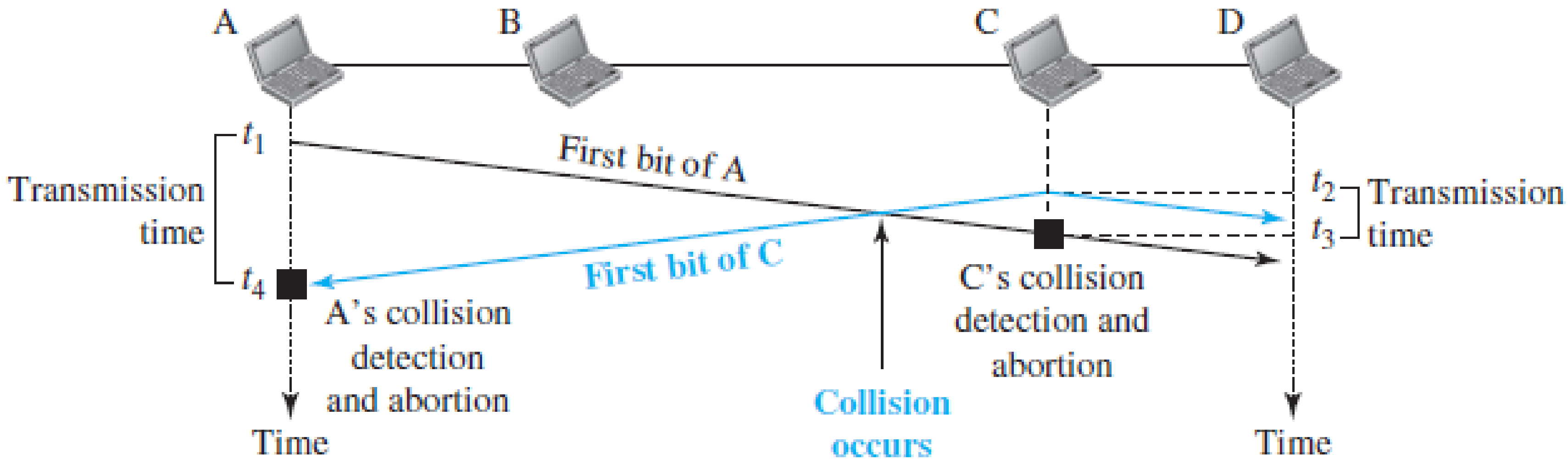


c. p-Persistent

DLL-MAC

Carrier Sense Multiple Access with Collision Detection(CSMA/CD)

Algorithm used to manage collisions



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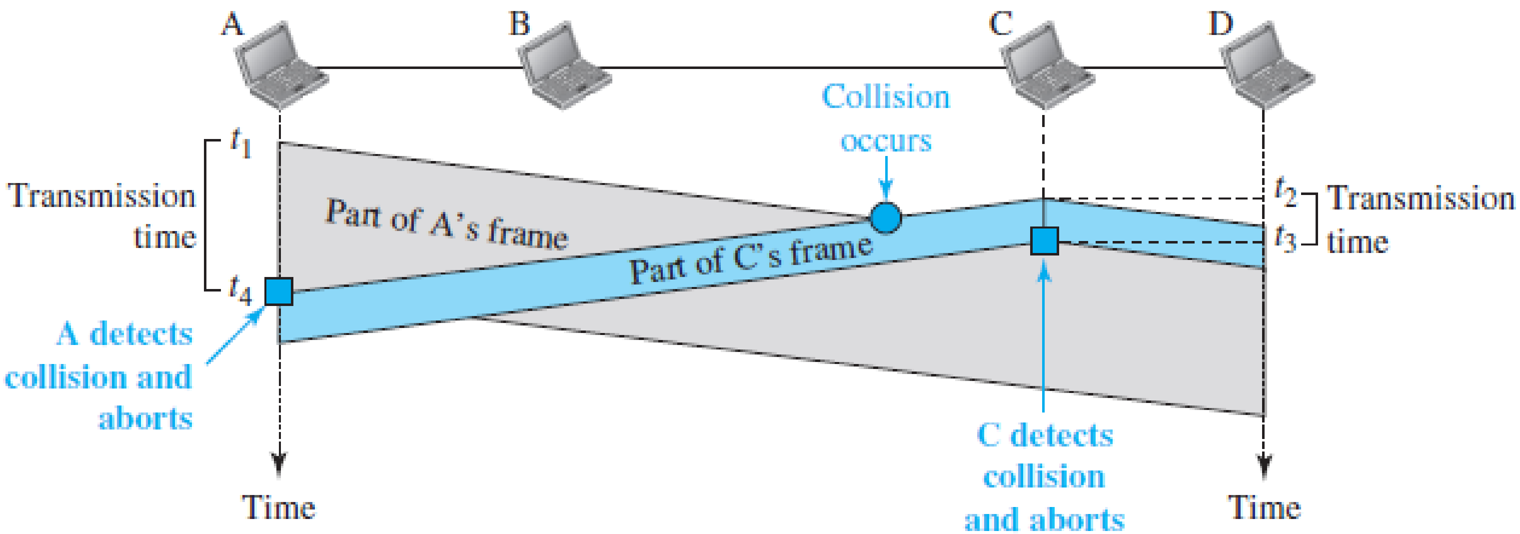

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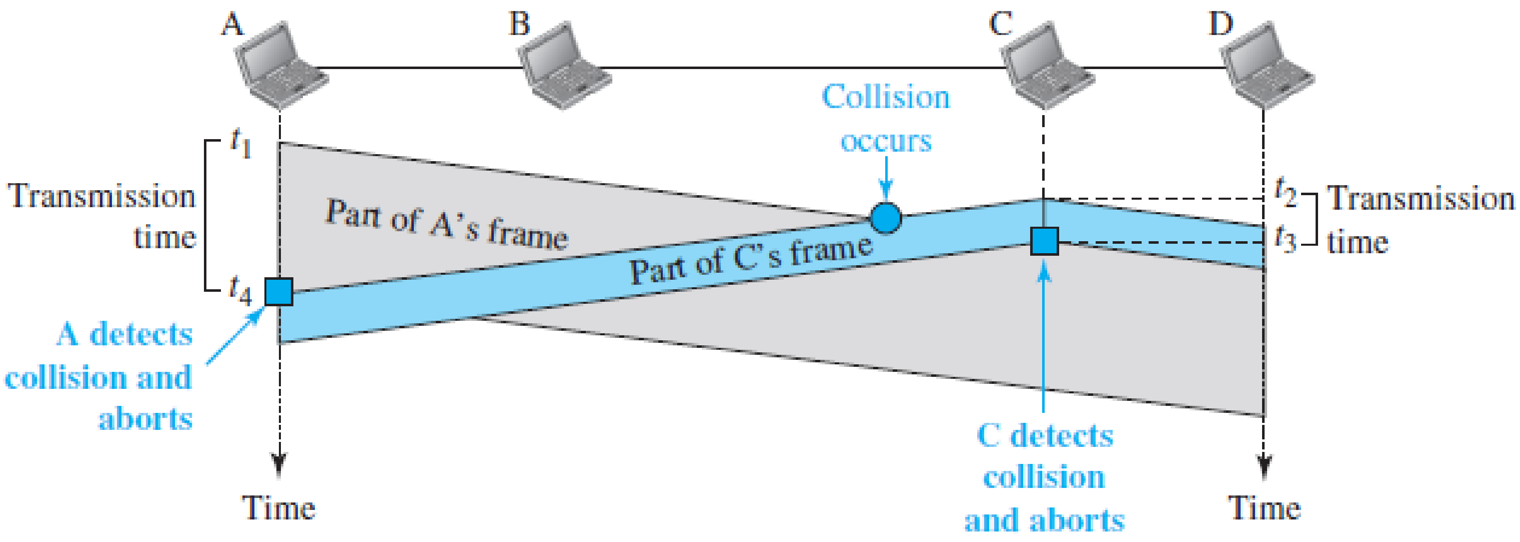
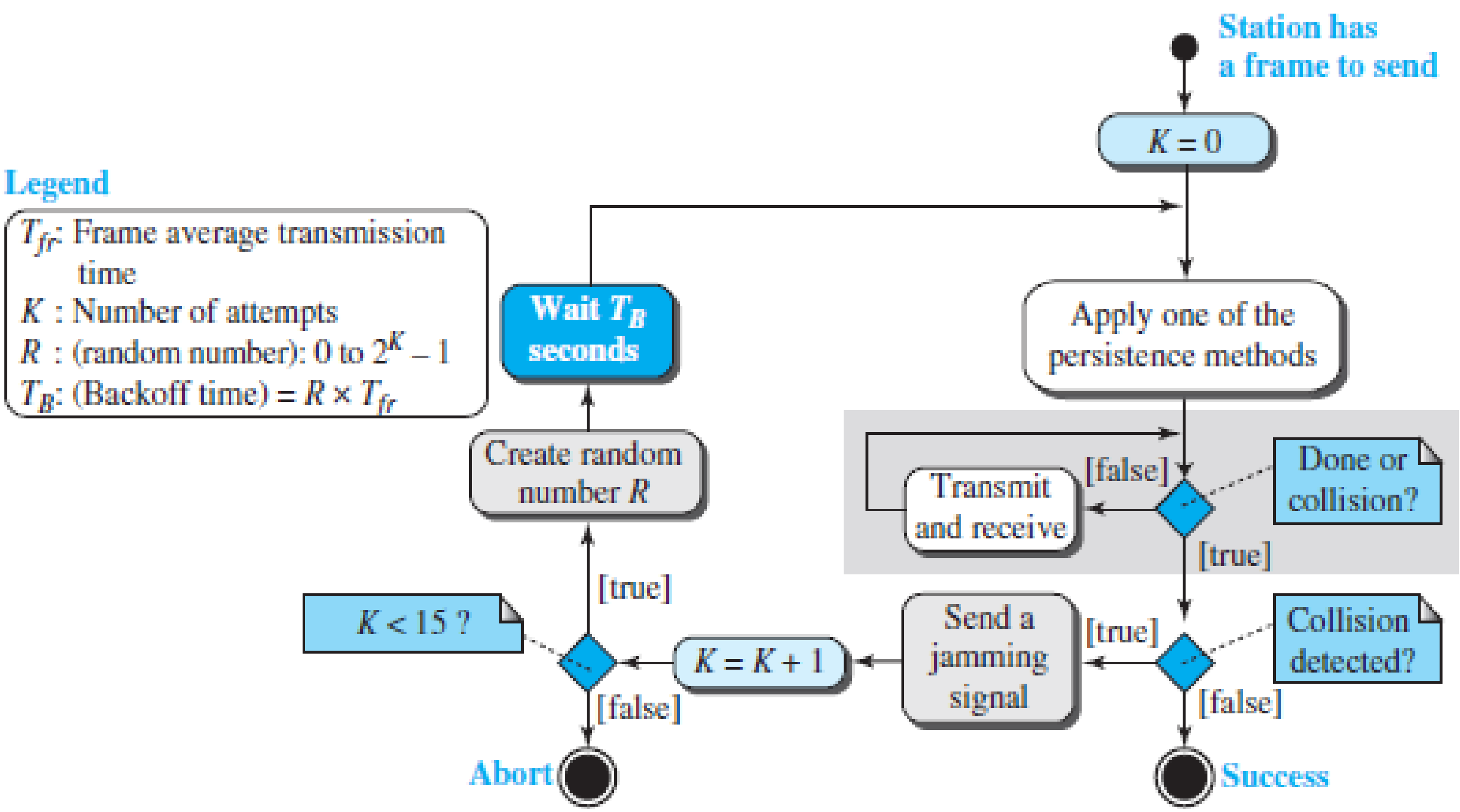
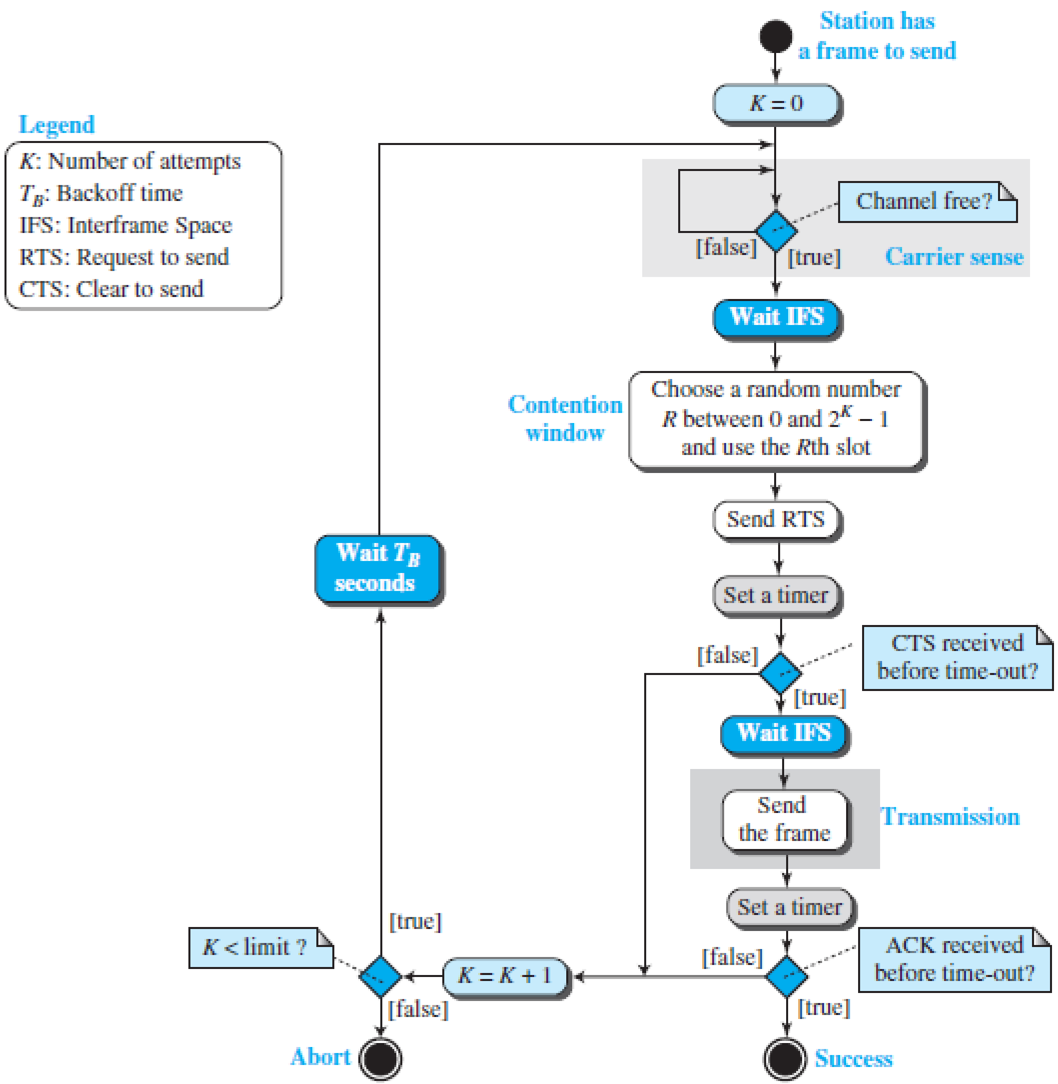


Carrier Sense Multiple Access with Collision Detection(CSMA/CD)



DLL-MAC

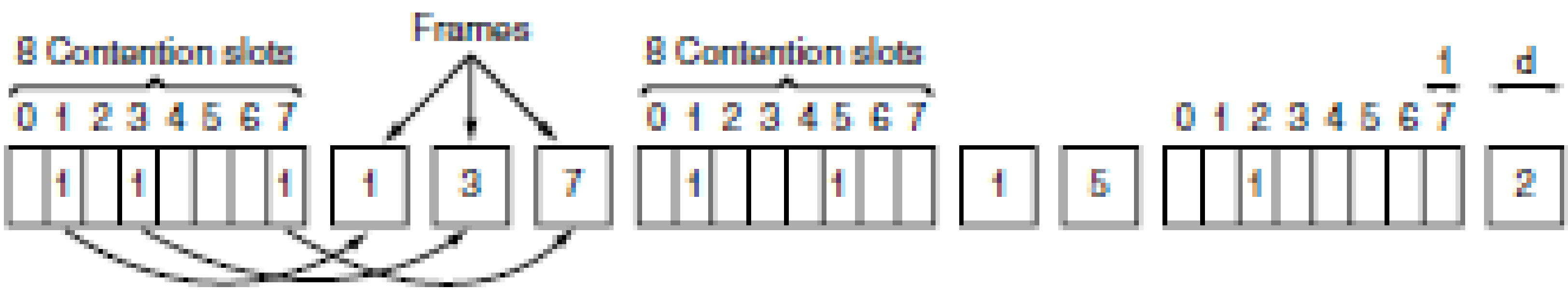
Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

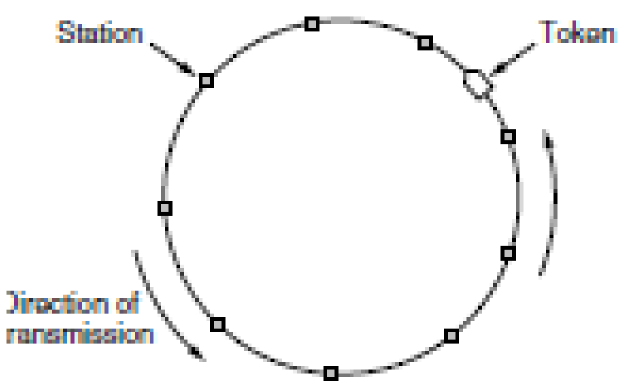


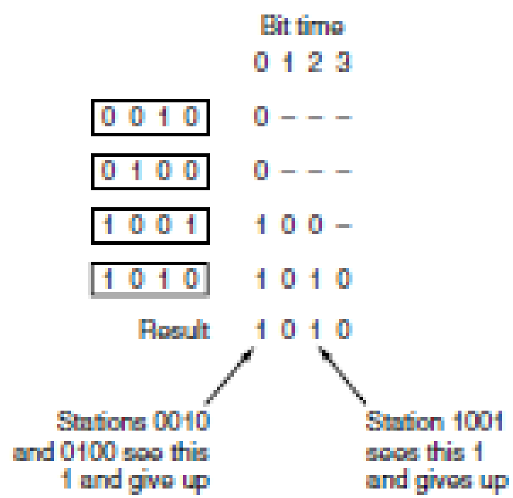
DLL-MAC

BIT MAP PROTOCOL

Also called reservation protocol.
Contention slots are reserved for frame transmission
Token based and binary count down are other alternatives

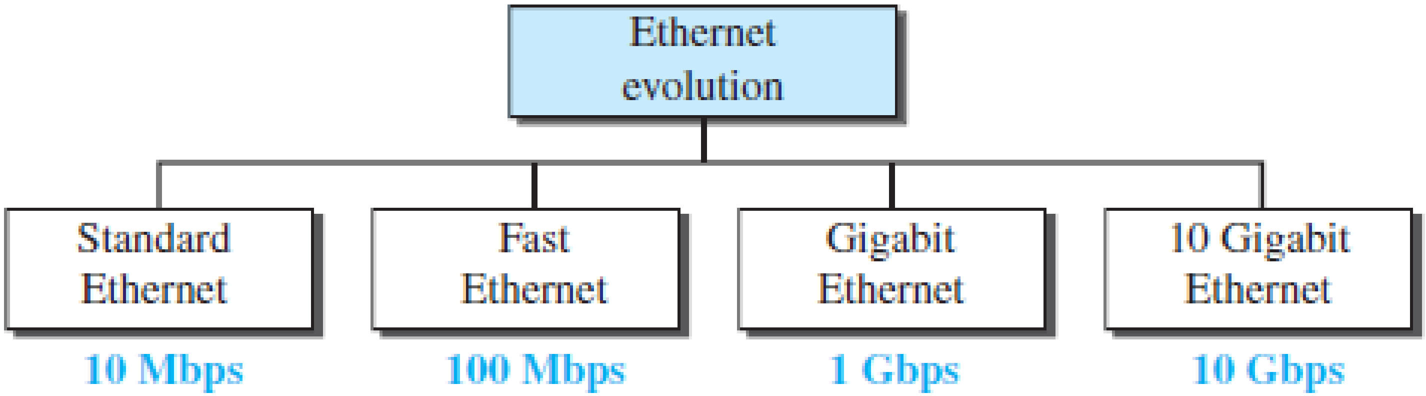


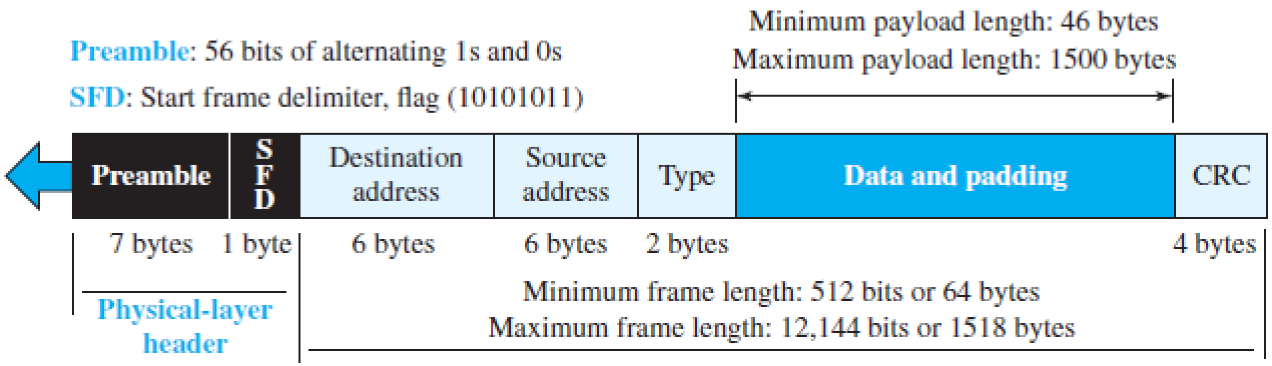




IEEE 802

IEEE 802.3(Ethernet)

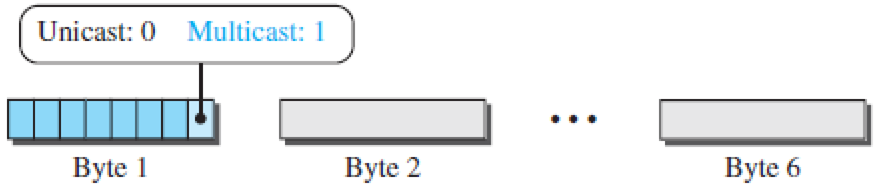




IEEE 802

IEEE 802.3(Ethernet)

A source address is always a *unicast address*—the frame comes from only one station. The destination address, however, can be *unicast*, *multicast*, or *broadcast*



To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are Fs, the address is broadcast.

Define the type of the following destination addresses:

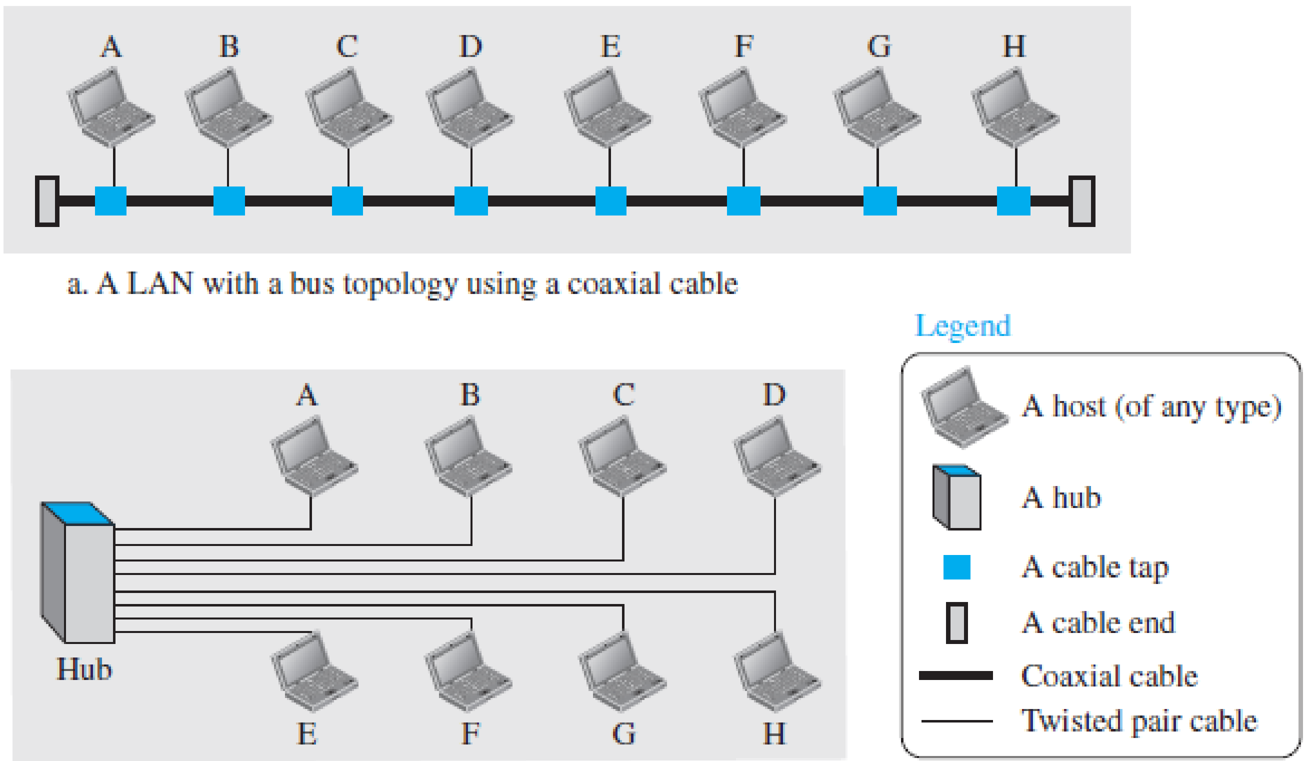
a. **4A:30:10:21:10:1A**

b. **47:20:1B:2E:08:EE**

c. **FF:FF:FF:FF:FF:FF**

IEEE 802

IEEE 802.3(Ethernet)



a. A LAN with a bus topology using a coaxial cable

b. A LAN with a star topology using a hub

IEEE 802

IEEE 802.3(Ethernet)

Categories of standard Ethernet

Implementation	*Medium*	*Medium Length*	*Encoding*
10Base5	Thick coax	500 m	Manchester
10Base2	Thin coax	185 m	Manchester
10Base-T	2 UTP	100 m	Manchester
10Base-F	2 Fiber	2000 m	Manchester

Efficiency of standard Ethernet

$$\text{Efficiency} = 1 / (1 + 6.4 \times a)$$

$\boldsymbol{a}$ = (propagation delay)/(transmission delay)

In the Standard Ethernet with the transmission rate of 10 Mbps, we assume that the length of the medium is 2500 m and the size of the frame is 512 bits. The propagation speed of a signal in a cable is normally 2×10^8 m/s.

IEEE 802

IEEE 802.3(Ethernet)

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Propagation delay = $2500/(2 \times 10^8) = 12.5\ \mu s$	Transmission delay = $512/(10^7) = 51.2\ \mu s$
$a = 12.5/51.2 = 0.24$	Efficiency = 39%

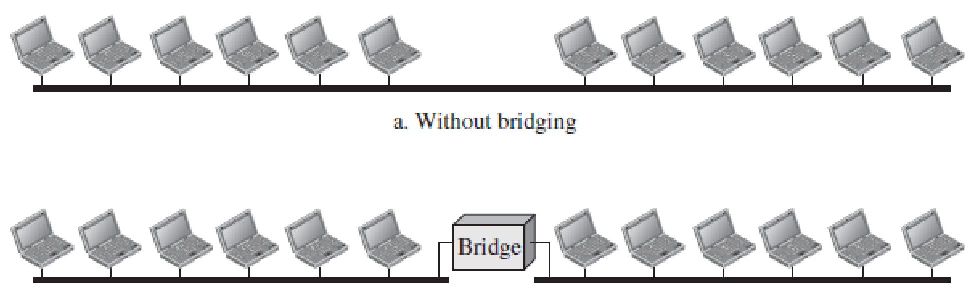
IEEE 802

Bridged Ethernet

Bridges raise the bandwidth, and separate collision domains

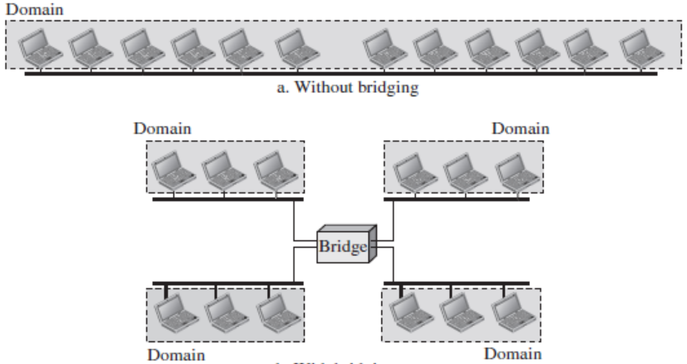
A bridge divides the network into two or more networks and raising the bandwidth

In fig(a) total capacity is shared by 12 systems where as in fig(b) two network each getting the capacity of the single network



a. Without bridging

b. With bridging



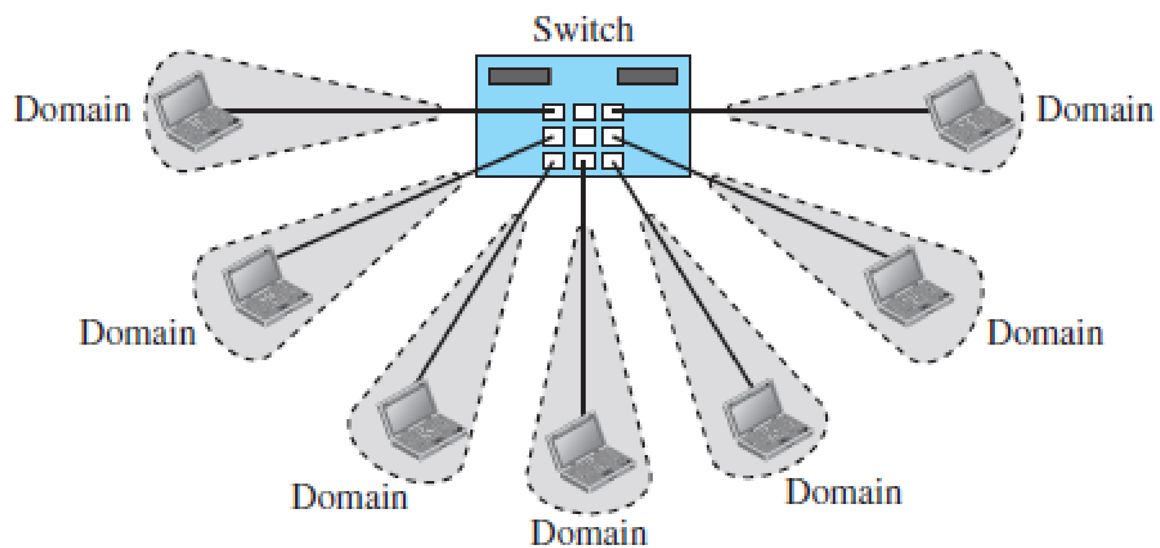
a. Without bridging

b. With bridging

IEEE 802

Switched Ethernet

- Instead of having two to four networks, we can have *N* networks, where *N* is the number of stations on the LAN
- The bandwidth is shared only between the station and the switch
- The collision domain is divided into *N* domains.



IEEE 802

FAST ETHERNET (100 MBPS)

Main Goals

- Upgrade the data rate to 100 Mbps.
- Make it compatible with Standard Ethernet.
- Keep the same 48-bit address.
- Keep the same frame format

Solutions

- Totally drop the bus topology and use a passive hub and star topology and make the max length of the network 250m (Standard Ethernet -2500 m)
- Use link-layer switch with a buffer to store frames and a full-duplex connection to each host to make the transmission medium private for each host.
- Autonegotiation (incompatible device communication)

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
100Base-TX	UTP or STP	100 m	2	4B5B + MLT-3
100Base-FX	Fiber	185 m	2	4B5B + NRZ-I
100Base-T4	UTP	100 m	4	Two 8B/6T

IEEE 802

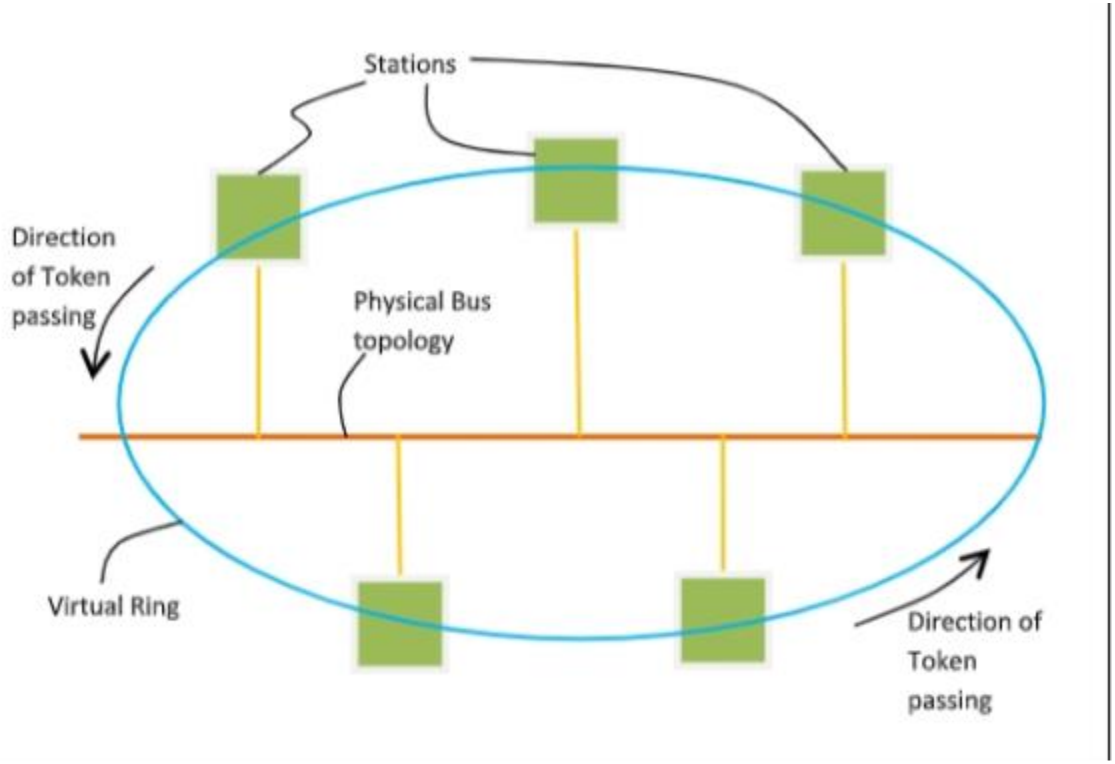
GIGABIT ETHERNET (1000 MBPS)

- In the full-duplex mode of Gigabit Ethernet, there is no collision
- The maximum length of the cable is determined by the signal attenuation in the cable.
- Gigabit Ethernet can also be used in half-duplex mode, with hub uses CSMA/CD
- Uses carrier extension by increasing the minimum frame length
- Uses frame bursting by sending multiple frames at a time

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
1000Base-SX	Fiber S-W	550 m	2	8B/10B + NRZ
1000Base-LX	Fiber L-W	5000 m	2	8B/10B + NRZ
1000Base-CX	STP	25 m	2	8B/10B + NRZ
1000Base-T4	UTP	100 m	4	4D-PAM5

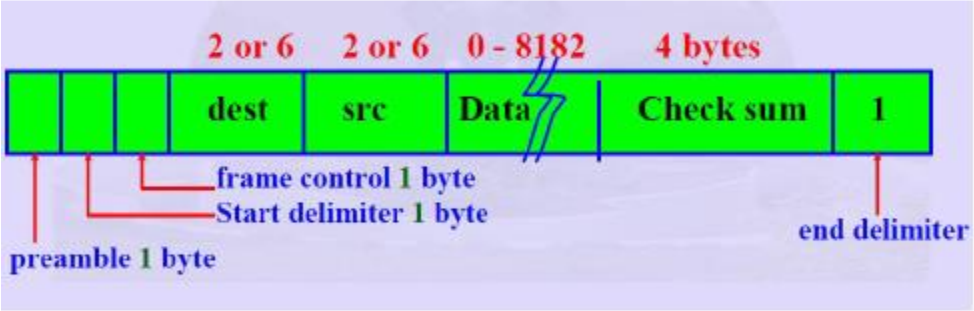
IEEE 802

IEEE 802.4



IEEE 802

IEEE 802.4



Frame control indicates the type of frame it holds. Frame can hold various values including:

•0 – claim token; doing at the initialization stage

•1 – solicit successor one; used when you are adding a node to the ring

•2 – solicit successor two; again add node to ring

•3 – who follows; used in case of lost token

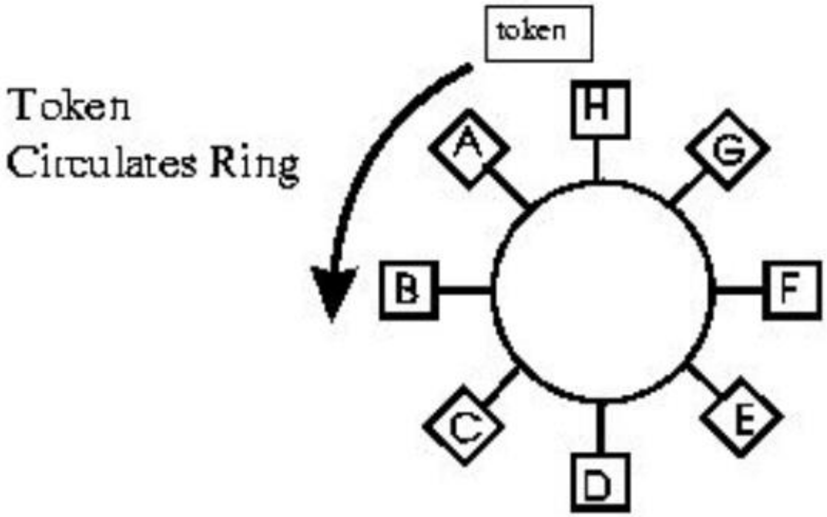
•4 – for resolving contention in case of multiple station addition

•8 – used to pass the token

•12 – for setting the successor, mostly used when deletion of node from a ring

IEEE 802

IEEE 802. 5



- When a station wishes to transmit, it must wait for the token to pass by and seize the token.
- Each station interrogates passing frame.
- If destined for station, it copies the frame into local buffer.
- As bits have propagated around the ring & they come back, they are removed from the ring by the sender.

IEEE 802

IEEE 802. 5 Frame format

SF	AC	FC	SA	DA	DATA	FCS	FS	EF
1B	1B	1B	6B	6B	4500B	4B	1B	1B

- Starting delimiter(SF) and ending delimiter(EF) mark the beginning & ending of the frame.
- Access control(AC) consist of token bit, monitor bit,priority bit.
- Destination address(DA) & source address(SA) fields gives the address.
- Checksum(FCS) field is used to detect transmission errors
- Frame control(FC) has a set of codes which is used to control the frame which is in transmission
- Frame status(FS)

IEEE 802

IEEE 802. 11

Two modes- Infrastructure and Adhoc

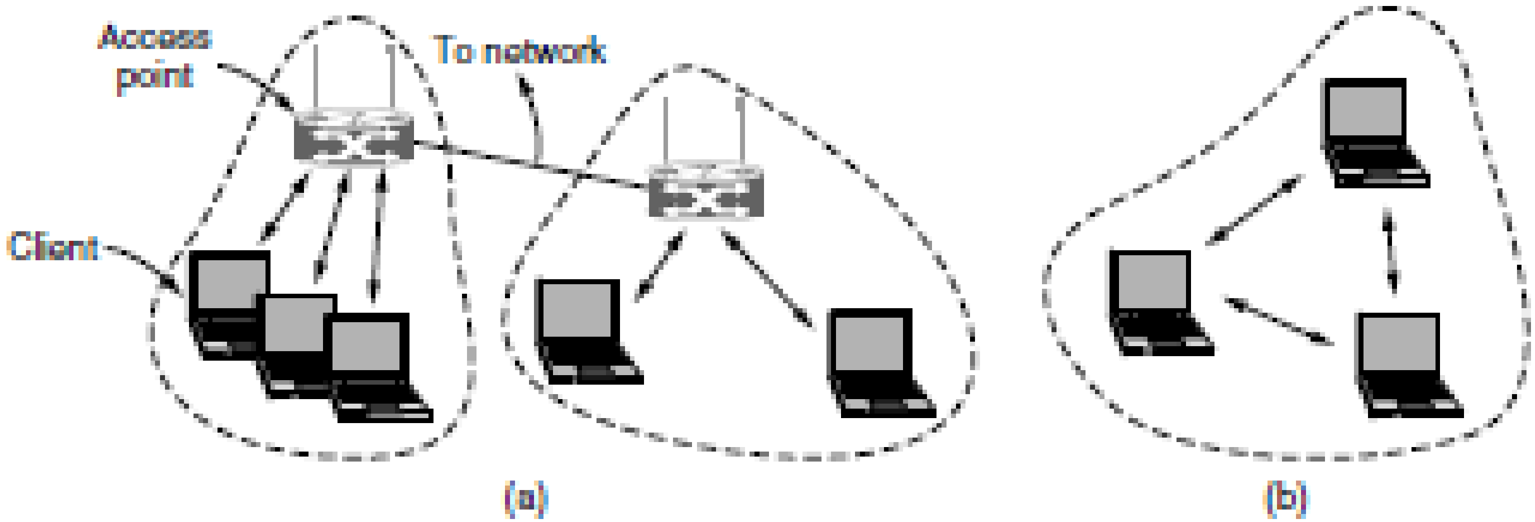


Figure 4-23. 802.11 architecture. (a) Infrastructure mode. (b) Ad-hoc mode.

DLL-MAC

HIDDEN AND EXPOSED TERMINAL PROBLRM

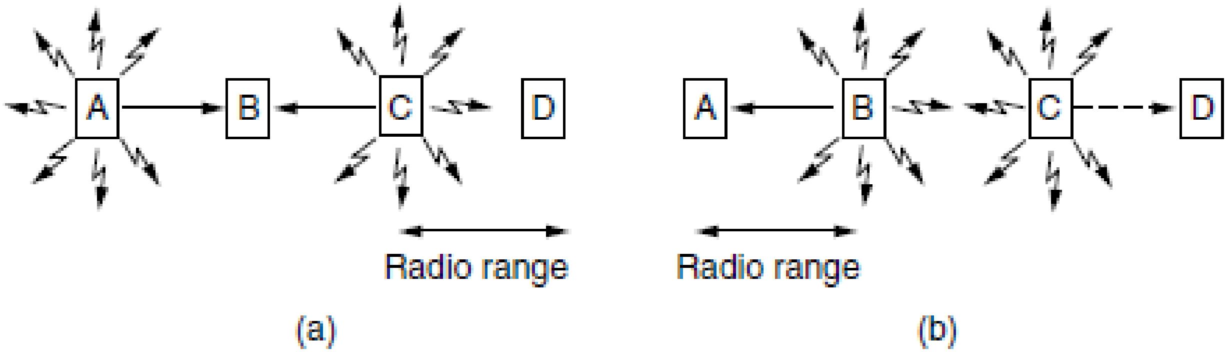


Figure 4-11. A wireless LAN. (a) *A* and *C* are hidden terminals when transmitting to *B*. (b) *B* and *C* are exposed terminals when transmitting to *A* and *D*.

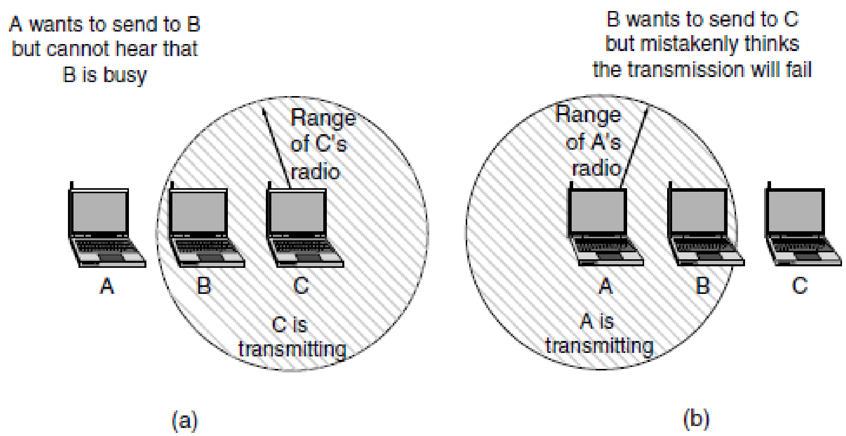


Figure 4-26. (a) The hidden terminal problem. (b) The exposed terminal problem.

DLL-MAC

HIDDEN AND EXPOSED TERMINAL PROBLRM

MACA-Multiple Access with Collision Avoidance

RTS-Ready to Send CTS –Clear to Send

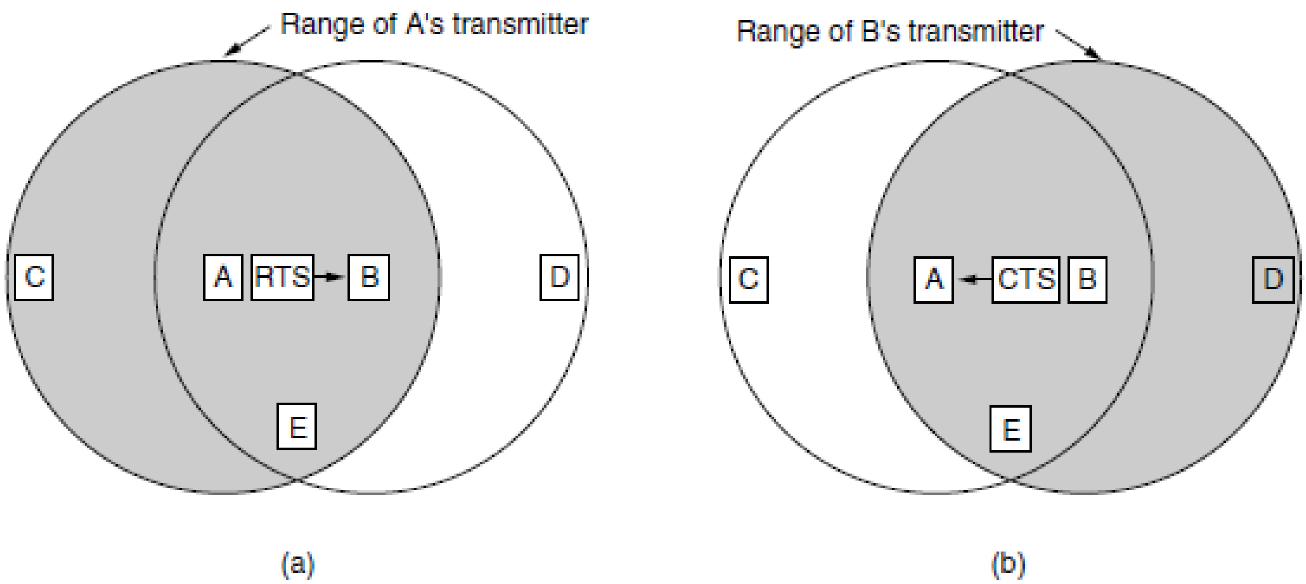
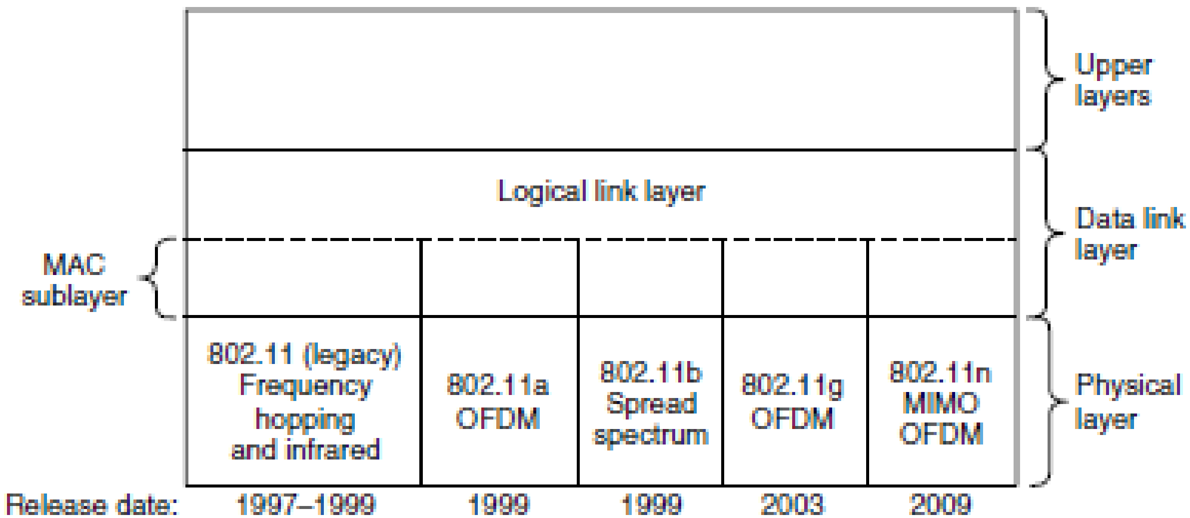
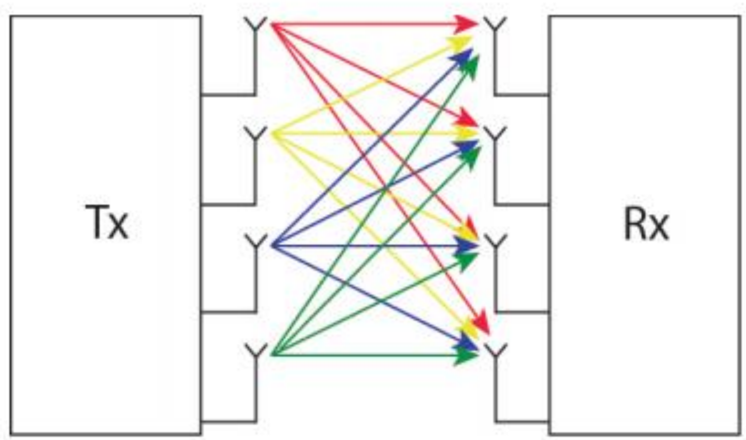


Figure 4-12. The MACA protocol. (a) *A* sending an RTS to *B*. (b) *B* responding with a CTS to *A*.

IEEE 802

IEEE 802. 11-protocol Stack





IEEE 802

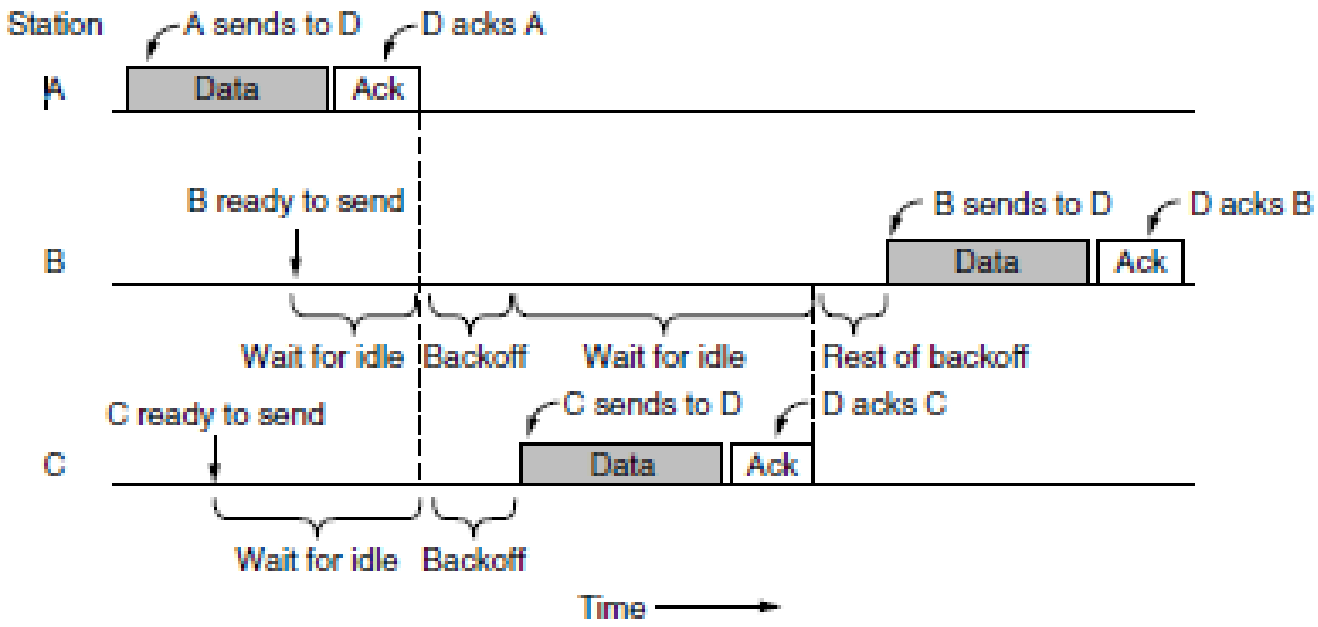
IEEE 802. 11-Physical Layer

- Rate Adaptation
- 802.11b(Data rate up to 11Mbps 2.4 GHz ISM band)
- 802.11a(Data rate up to 54Mbps uses OFDM resists to multipath 5GHz ISM band)
- 802.11g(same features of 802.11a 2.4 GHz ISM band)
- 802.11n((Data rate up to 100Mbps and 5GHz ISM band)

IEEE	*Technique*	*Band*	*Modulation*	*Rate (Mbps)*
802.11	FHSS	2.400–4.835 GHz	FSK	1 and 2
	DSSS	2.400–4.835 GHz	PSK	1 and 2
	None	Infrared	PPM	1 and 2
802.11a	OFDM	5.725–5.850 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.400–4.835 GHz	PSK	5.5 and 11
802.11g	OFDM	2.400–4.835 GHz	Different	22 and 54
802.11n	OFDM	5.725–5.850 GHz	Different	600

IEEE 802

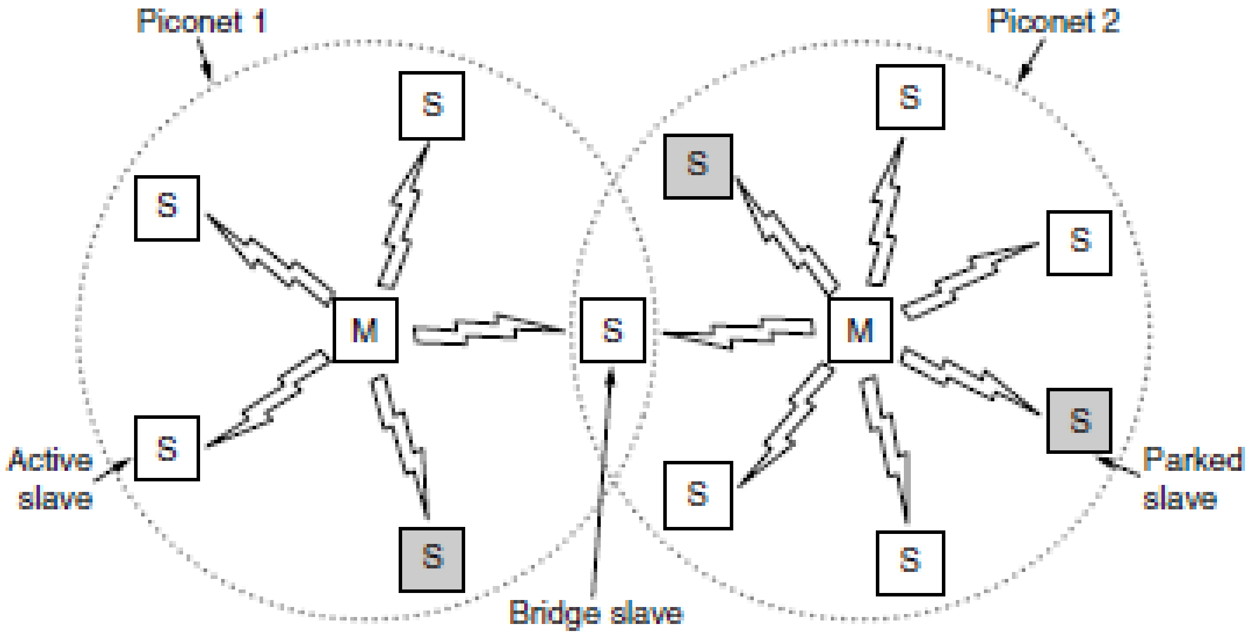
IEEE 802. 11-MAC –CSMA/CA



IEEE 802

IEEE 802. 15 BLUETOOTH

Two piconets form a Scatternet

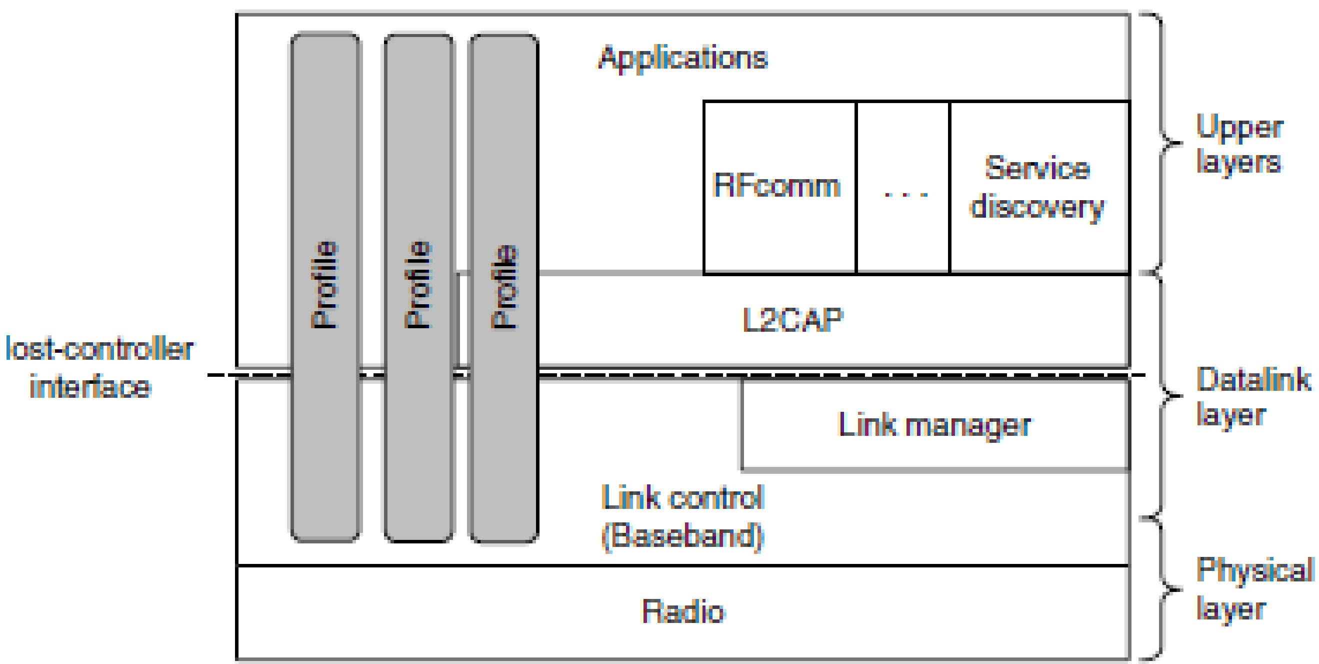


IEEE 802

IEEE 802. 15 BLUETOOTH

Protocol Stack

- The link manager handles the establishment of logical channels between devices, including power management, pairing and encryption, and quality of service
- The protocols below the Host Controller line implemented on a Bluetooth chip and the protocols above the line will be implemented on the Bluetooth device that hosts the chip.
- **L2CAP** (**Logical Link Control Adaptation Protocol**) perform message formatting and profile helps in writing applications



IEEE 802

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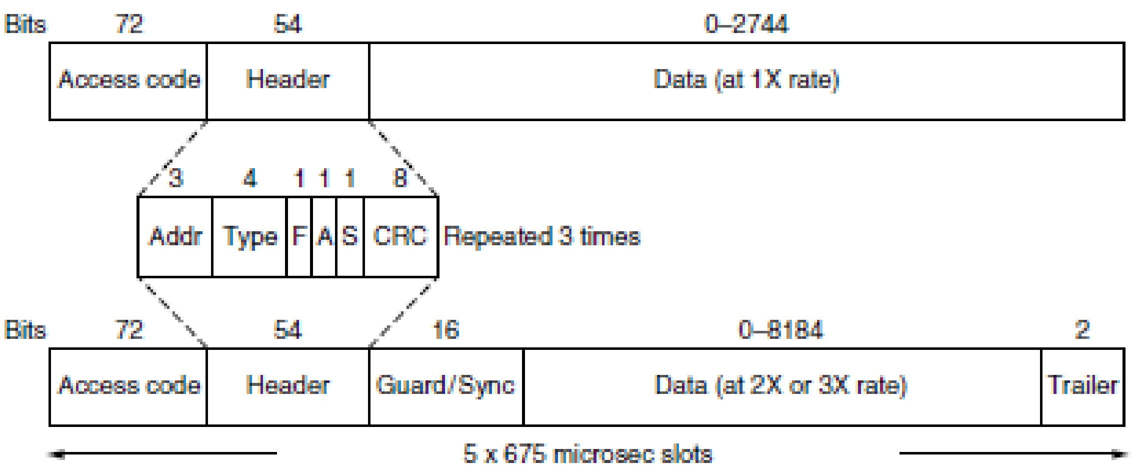
Radio Layer

- 10m range 2.4GHz band with FHSS (adaptive)

Link Layer

- Device pairing (PIN / passkey)
- Link establishment
    - SCO
    - ACL

Frame Format (Flow, Ack, Sequence)



(a) Basic rate data frame, top (b) Enhanced rate data frame, bottom