MAC Sublayer

Prepared and compiled by
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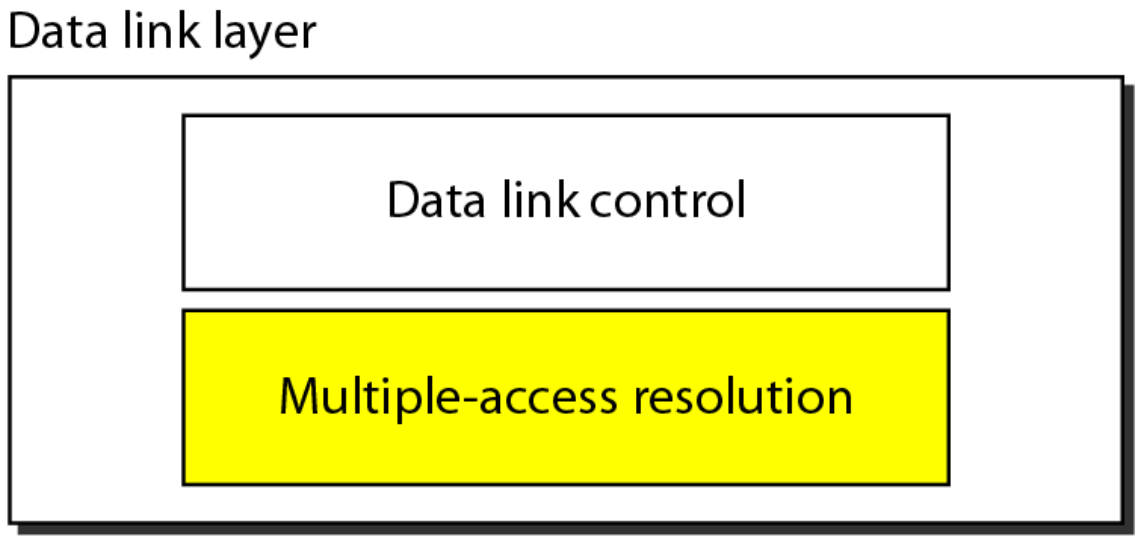
Outlines:

- **MAC Sublayer-**
  - Static and Dynamic Chanel Allocation in LAN

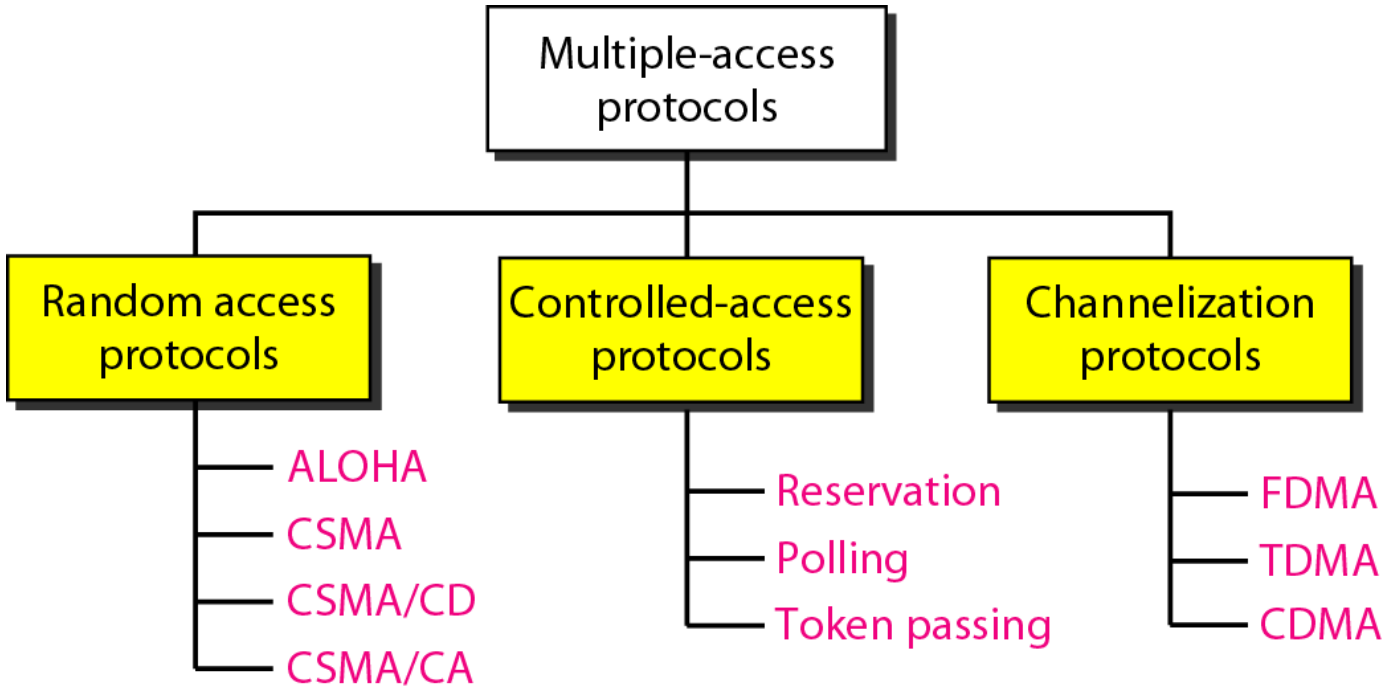
- **MAC protocols-**
  - ALOHA and Slotted ALOHA,
  - CSMA, CSMA/CD, CSMA/CA
  - Collision Free protocols
  - Limited Contention Protocols
  - Channelization Methods

- **Ethernet-**
  - Ethernet Cabling, Frame Format
  - Binary Exponential Back-off Algorithm
  - Ethernet Performance, Fast and Gigabit Ethernet
  - MAC address

Data link layer divided into two functionality-oriented sublayers



Taxonomy of multiple-access protocols discussed in this chapter



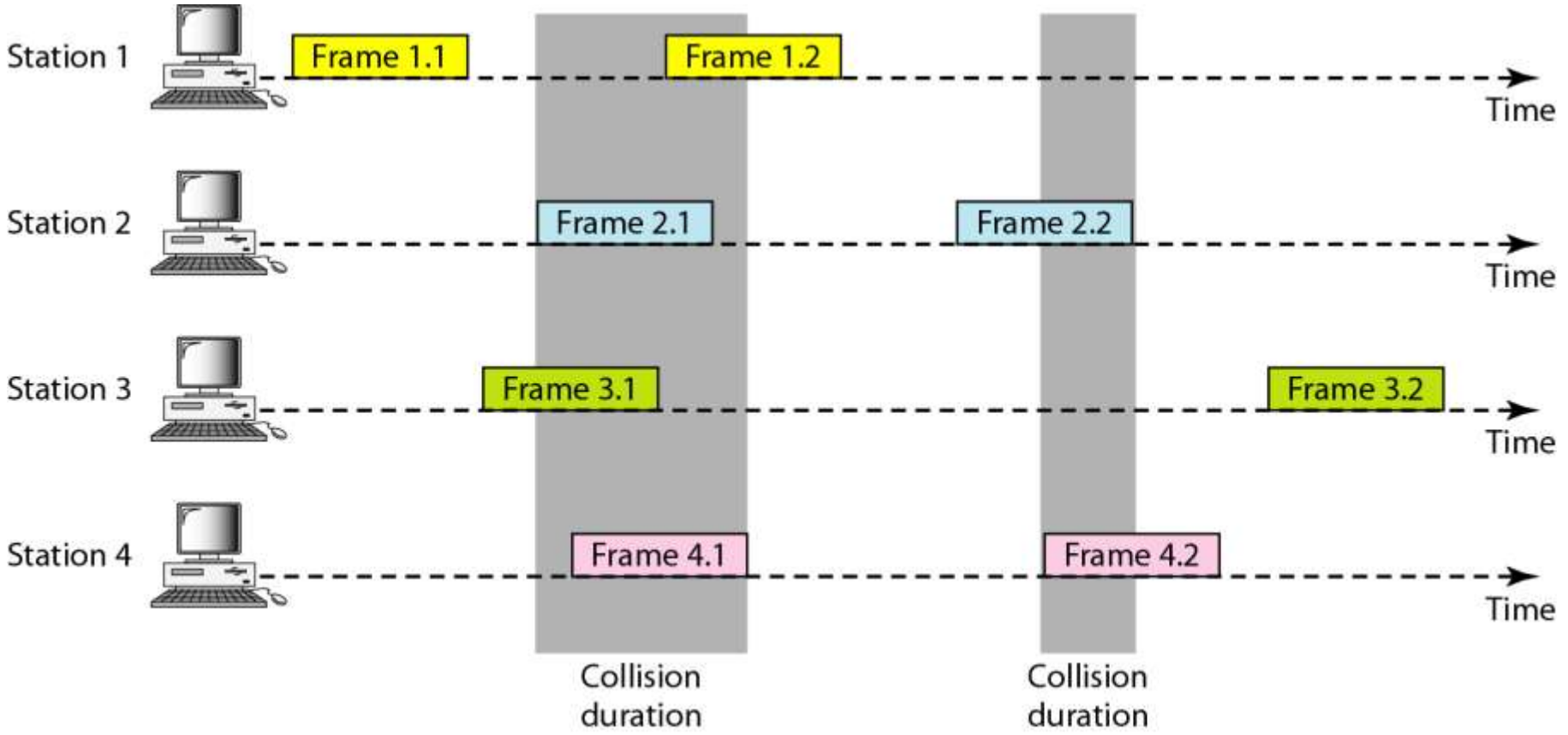
RANDOM ACCESS

In random access or contention methods, no station is superior to another station and none is assigned the control over another.

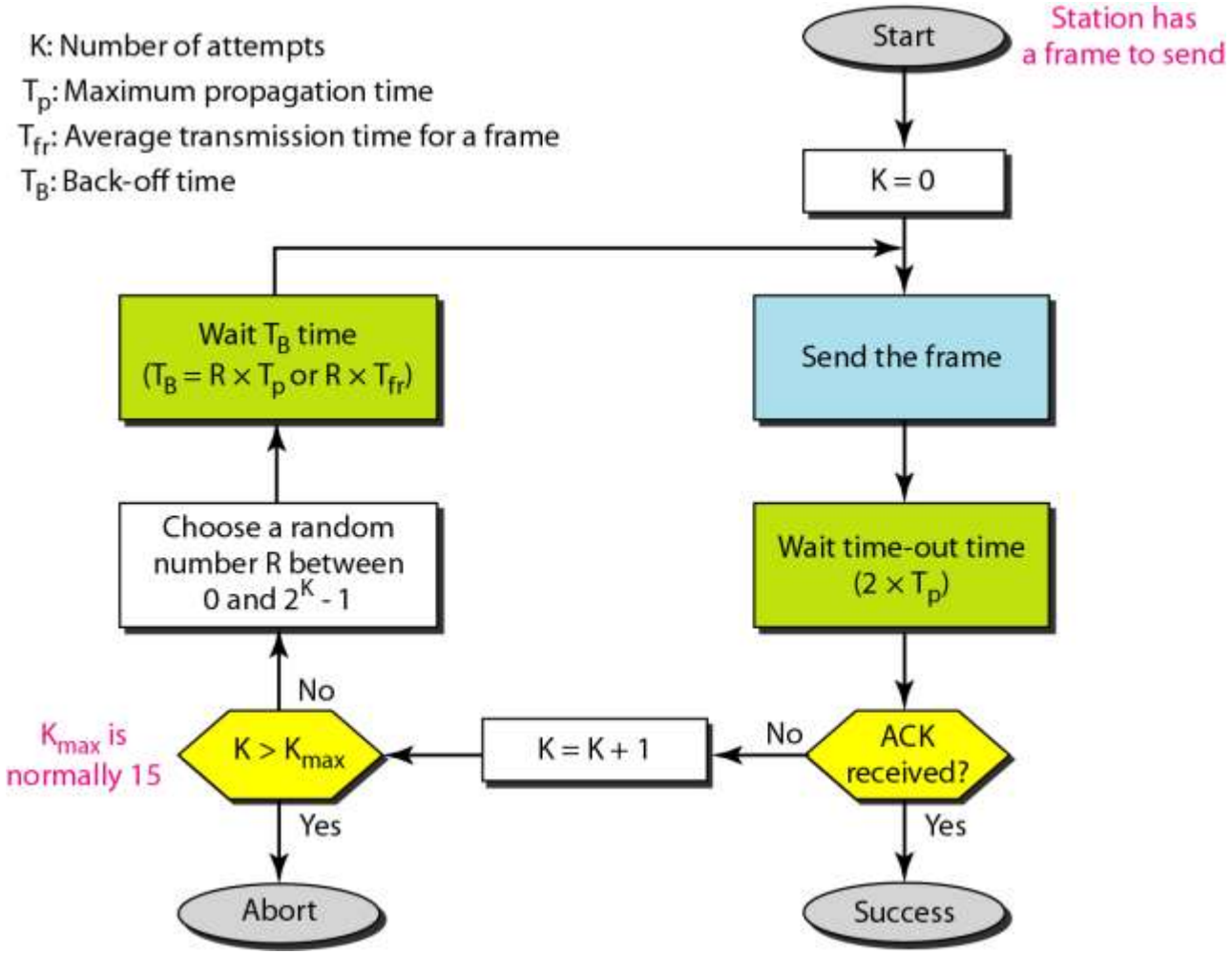
No station permits, or does not permit, another station to send.

At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.

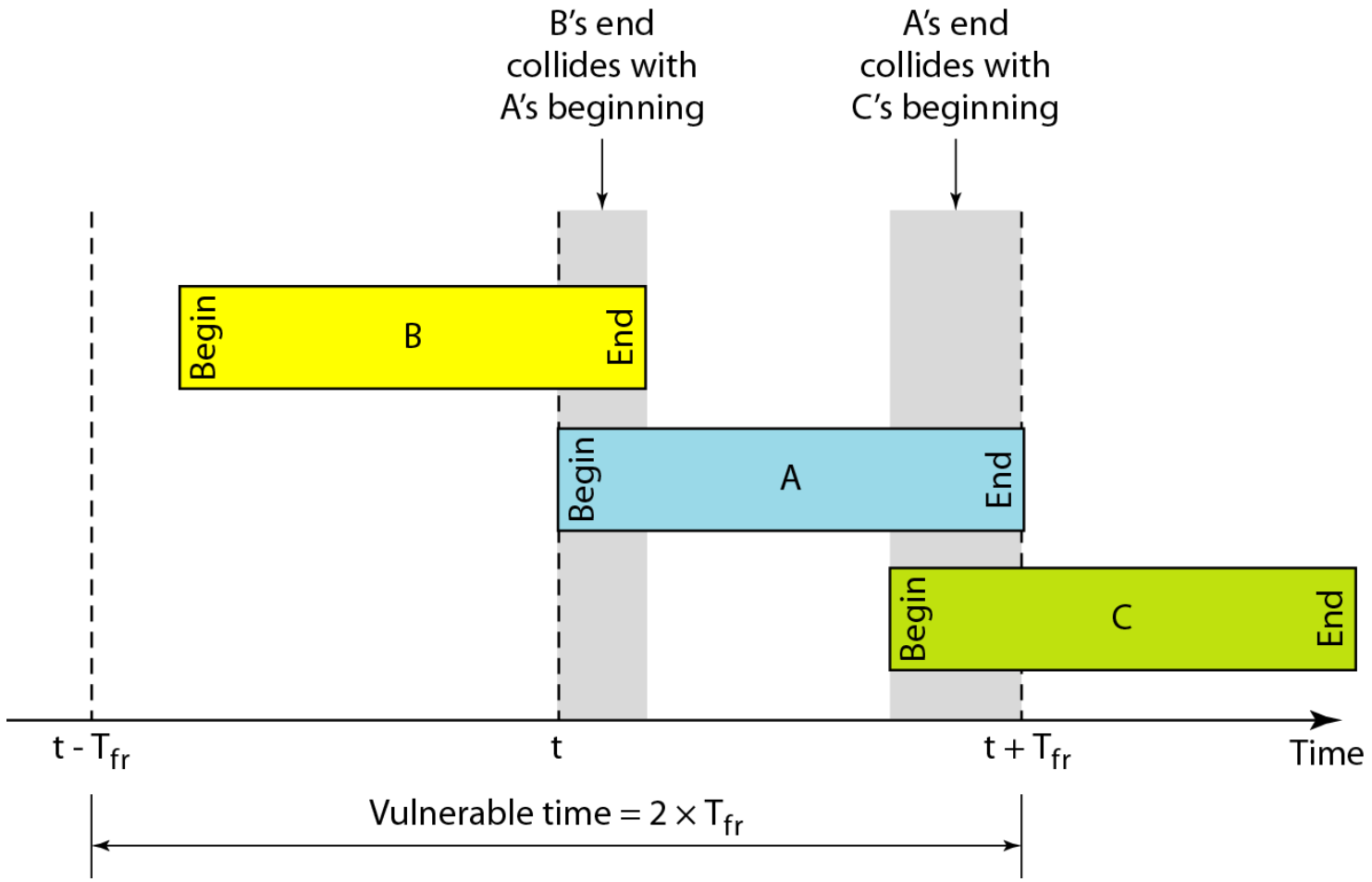
Frames in a pure ALOHA network



Procedure for pure ALOHA protocol



Vulnerable time for pure ALOHA protocol



- It is assumed that all the pkts are of same length. and each needs t_p time for transx.
- In figure, pkt A is starting from t_0 + t_p & ending at $t_0 + 2t_p$.
- If pkt B is started bet t_0 & $t_0 + t_p$ then end of pkt B will collide with start of A.
- Similar, if pkt C is transmitted bet $t_0 + t_p$ and $t_0 + 2t_p$ then again it will collide with A.
- Therefore, if two pkts overlap by even the slightest amount in the vulnerable period of length $2t_p$, both pkts will be corrupted & will require to retransx.

Throughput ⇒

Let, S = channel throughput.

↓

(i.e. the avg no. of successful transmission per time period t_p)

G = Total traffic entering the channel from an infinite population of users

↓

(i.e. G represents the no. of pkts transmission which are attempted in time period t_p.

Means total load assigned to channel in time t_p.)

P_K = Probability of k transmission attempts. For

Probability P_K can be given as,

$$P_K = \frac{G^K \cdot e^{-G}}{K!} \longrightarrow (i)$$

- If transmission is successful then $K = 0$ i.e. in first attempt pkt is transmitted successfully.
- So the throughput S is just the offered load G times the probability of a successful trans.

i.e. $S = G \cdot P_0 \longrightarrow (ii)$

Where P_0 = probability that a pkt doesn't suffer a collision.

i.e. P_0 is the probability that no other traffic is produced in the duration of vulnerable time.

So by eq.(i) $P_0 = e^{-2G}$

So by eq.(i) $P_0 = e^{-2G}$

If the interval is two frame time long, the mean no. of frames generated is $2G$

So probability that no other frame is transmitted during vulnerable period is,

$$P_0 = e^{-2G}$$

So Throughput is $\boxed{S = G.e^{-2G}}$ → (iii)

Now Max. Throughput for Pure Aloha ⇒

differentiate eq. (iii) and put it equal to zero.

$$\frac{dS}{dG} = \frac{d(G * e^{-2G})}{dG} = 0$$

$$\Rightarrow e^{-2G} + [G \cdot (-2) e^{-2G}] = 0$$

$$\Rightarrow e^{-2G} - 2Ge^{-2G} = 0$$

$$\Rightarrow e^{-2G} [1 - 2G] = 0$$

$$\Rightarrow 1 - 2G = 0$$

$$\Rightarrow G = 1/2$$

It means when $G = 0.5$ (i.e. 50%) then maximum throughput will occur for Pure ALOHA.

i.e. $S = \frac{1}{2} * e^{-2 * \frac{1}{2}}$

$= \frac{1}{2} * e^{-1}$

$= \frac{0.3678}{2}$

$\boxed{S = 0.184}$

So best channel utilization is on 18.4%. in Pure ALOHA.

Means when $S = \frac{1}{2e}$ then max. throughput will occur at $G = 0.5$

Note

The throughput for pure ALOHA is

$$S = G \times e^{-2G} .$$

The maximum throughput

$$S_{max} = 0.184$$ **when G= (1/2).**

Slotted ALOHA ⇒

- To overcome disadvantages of pure ALOHA, Robert published a method for doubling the channel capacity.
- In this method, time is divided into discrete intervals, and each interval is correspond to one frame.
- Time is divided into slots & stations are forced to send at the beginning of slots.

Frames in a slotted ALOHA network

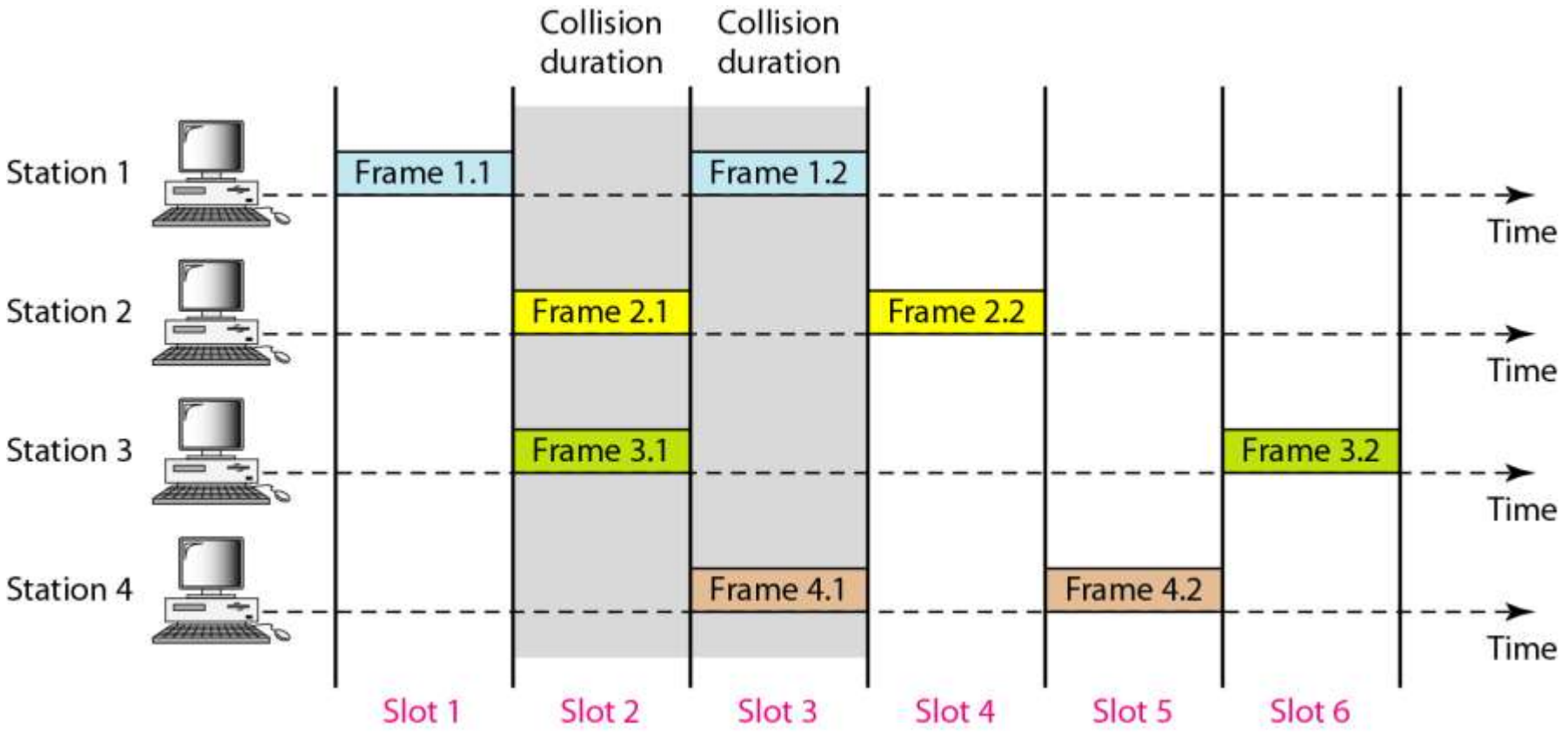
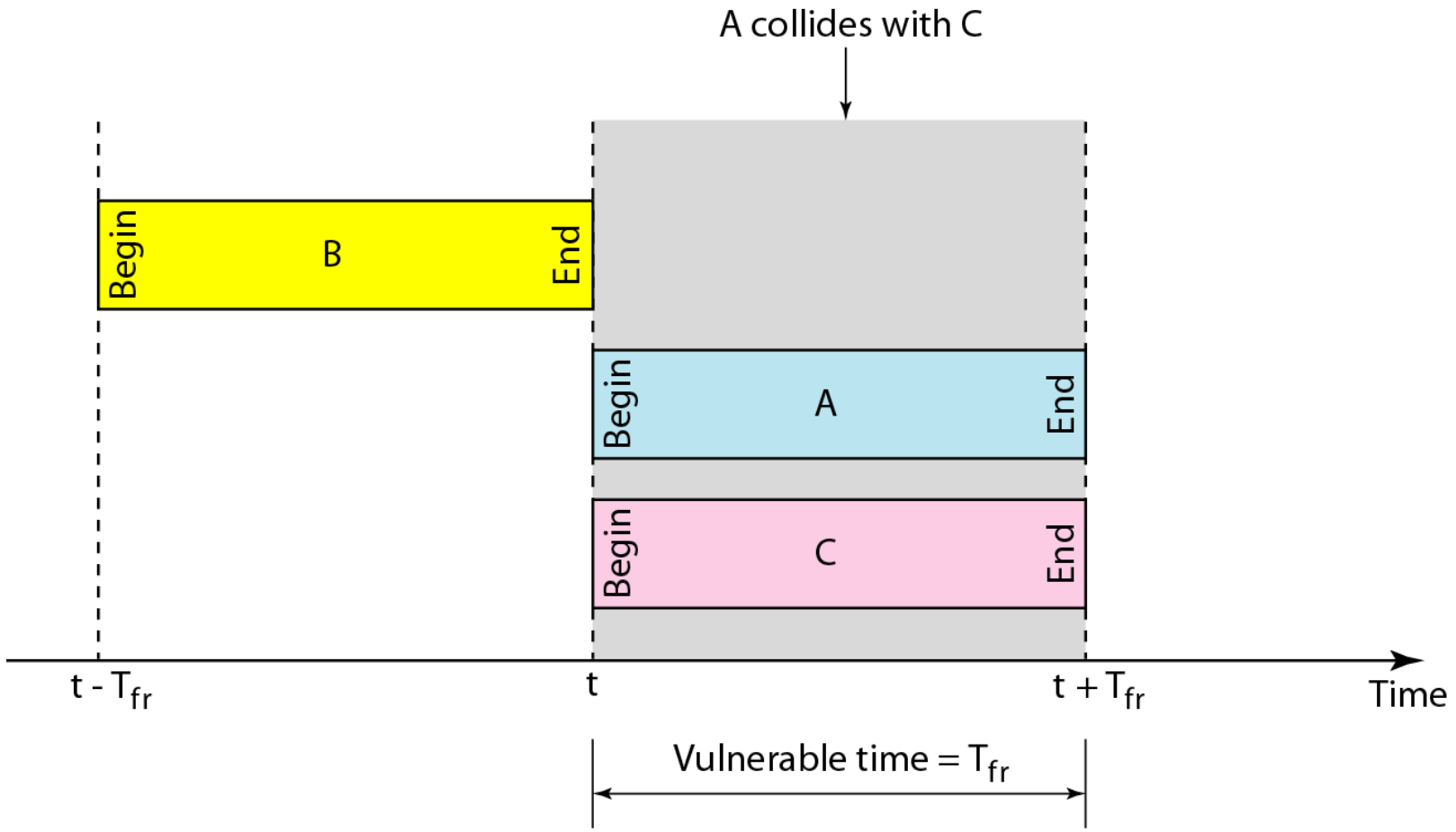


Figure 12.7 *Vulnerable time for slotted ALOHA protocol*



- If station 1 is missed to send the frame at t_0 then it must have to wait for next slot
- Still there is a possibility of collision, if two stations send the frame in the same slot.
- But vulnerable time is significantly reduced in slotted aloha as compare to Pure Aloha as half.
- So throughput for slotted ALOHA is

$$S = Ge^{-G}$$

S_{max} at $G=1$ and $K=0$ i.e. $S = 0.368 = 37\%$.

Note

The throughput for slotted ALOHA is

$$S = G \times e^{-G} .$$

The maximum throughput

$$S_{max} = 0.368 \text{ when } G = 1.$$

Differences bet pure ALOHA & slotted ALOHA ⇒

Pure ALOHA	Slotted ALOHA.
1. Frames are transmitted at arbitrary times	1. Since time is divided into slots, the frames are sent at the start of a slot.
2. Performance is given by $S = Ge^{-2G}$	2. Performance is $S = Ge^{-G}$
3. Maximum utilization is = 18%.	3. Max. utilization = 37%.
4. Doesn't require global time	4. Requires global time synchronization, coz of discrete slots.
5. It can't be used for Satellites coz of low utilization.	5. Can be used for the broadcast satellites

Q.1. Measurements of a slotted ALOHA channel with an infinite no of users. show that 10% of slots are idle –

(a) channel load
(b) Throughput
(c) Is channel overloaded or underloaded.

(a) channel load :

For slotted ALOHA,

$$P_0 = e^{-G}$$

given $P_0 = 10\%$ i.e. 0.1

$\therefore \quad 0.1 = e^{-G}$

$\therefore \quad -2.3 = -G$

$\therefore \quad G = 2.3$

(b) Throughput :

$$S = Ge^{-G}$$
$$= 2.3\, e^{-2.3}$$
$$= 0.23$$

(c) Since G is beyond 1, so channel is overloaded.

Ques 2 :- Measurement of slotted ALOHA with an infinite no. of users show that 20% slots are idle

(a) Channel load.
(b) Throughput
(c) Channel overload or underload

Here, $P_0 = 20\%$, i.e. 0.2

$P_0 = e^{-G}$

$\therefore 0.2 = e^{-G} \Rightarrow G = 1.6094$.

(b) Throughput $\Rightarrow S = Ge^{-G} \Rightarrow 1.6094\, e^{-1.6094}$

$\Rightarrow 0.3218$

(c) Since $G > 1$, so channel is overloaded.

Ques :- An ALOHA network uses 19.2 kbps channel for sending message pkts of 100 bit long size. Calculate the max. throughput of Pure ALOHA.

Sol^n Rate of Transmission = 19.2 kbps
= 19200 bps

Frame length = 100 bits

So No. of frames per second = $\frac{19200}{100}$ = 192 frames/s.

Now Max. Throughput for Pure ALOHA = 0.184

∴ Throughput is = 0.184 x No. of frames/s.
= 0.184 x 192
= 35.328 frames/s.

Ques: ALOHA protocol uses to share 56 kbps satellite channel. If each pkt is 1000 bits long then find the max. Throughput in pkts/sec.

Sol^ Rate of Tranx. = 56 kbps
= 56000 bps

Frame length = 1000 bits

No of frames/sec = 56000 = 56 frames/sec

⇒ Throughput for pure ALOHA =

= 0.184 * 56
= 10.304 frames/sec.

⇒ Throughput for slotted ALOHA =

= 0.368 * 56
= 20.608 frames/sec.

CSMA

- CSMA/CD
- CSMA/CA

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CSMA (Carrier Sense Multiple Access).

- It operates on the principle of carrier sensing.
- In this, a station listens to see the presence of transmission on the cable & decides to act accordingly.

So the principle of CSMA is = 'sense before transmit'
or 'listen before talk'

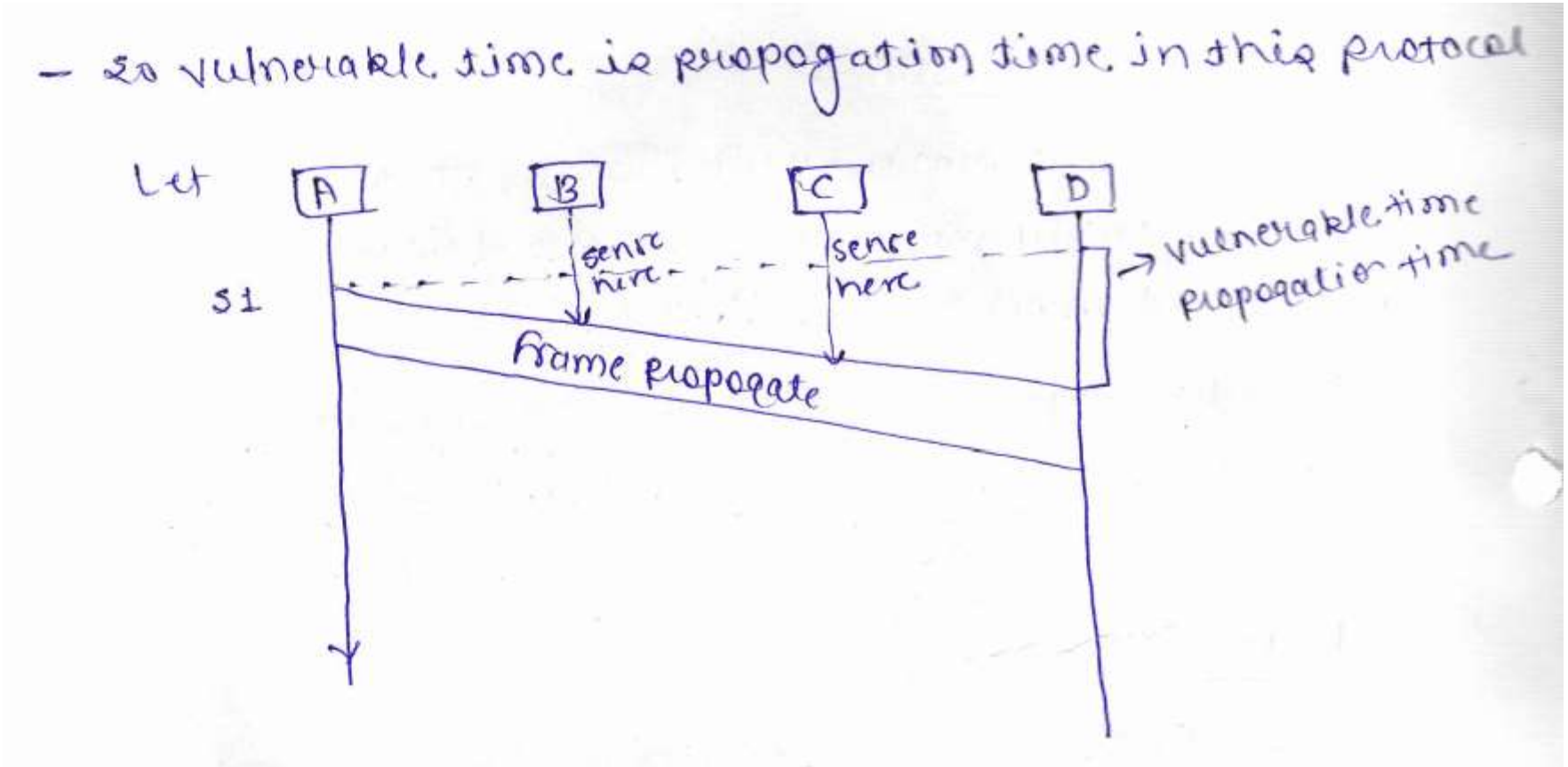
But there is also a possibility of collision due to propagation time.

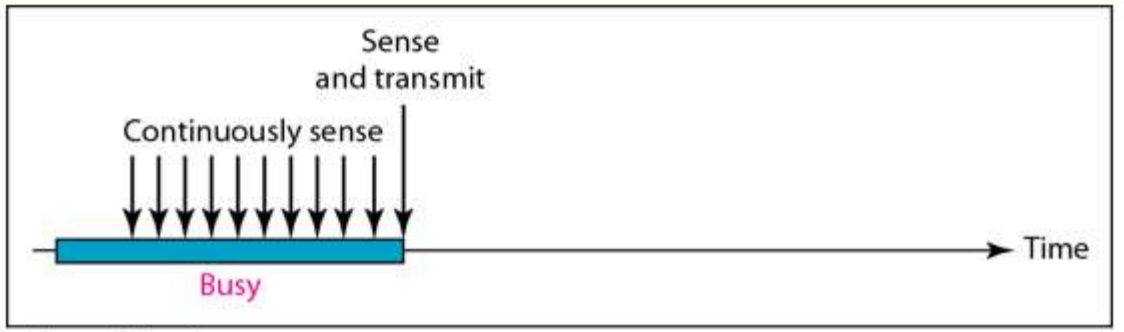
eg.

① Let st 1 sending the data

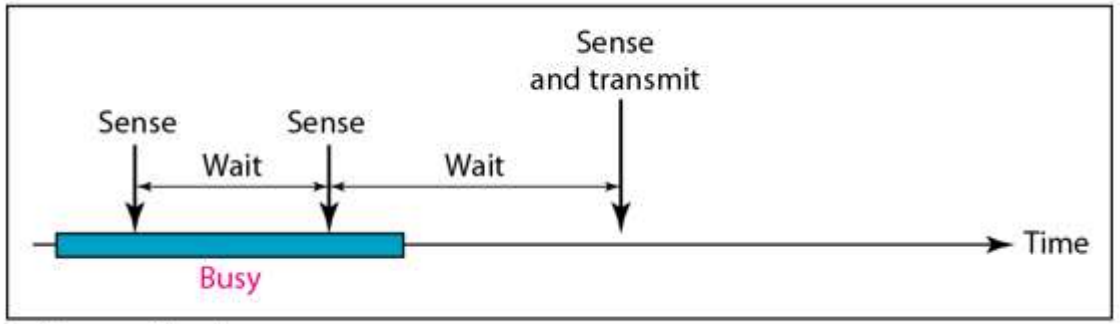
② at that time st n also assume channel is idle as 1's data hasn't reached to n. so n will transmit data

– So vulnerable time is propagation time in this protocol

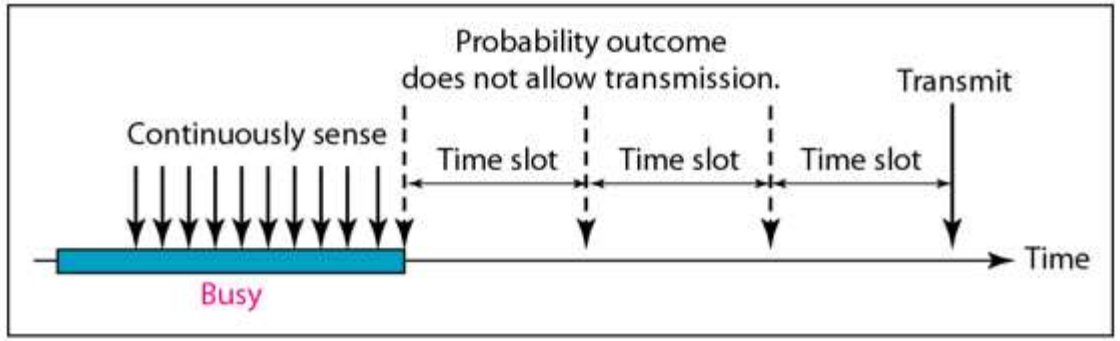




a. 1-persistent

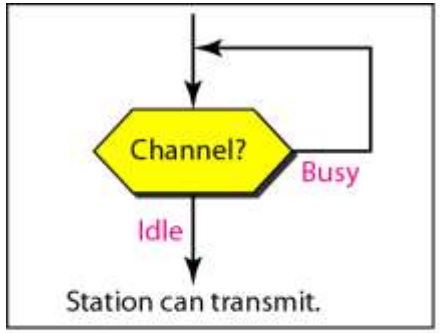


b. Nonpersistent

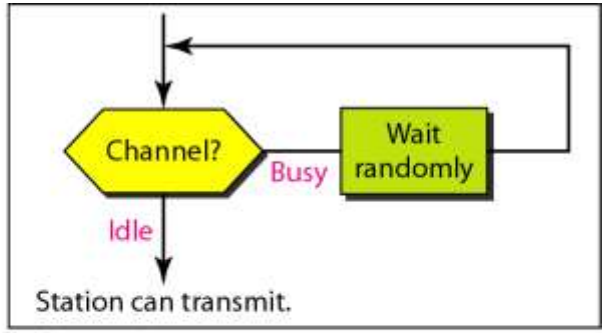


c. p-persistent

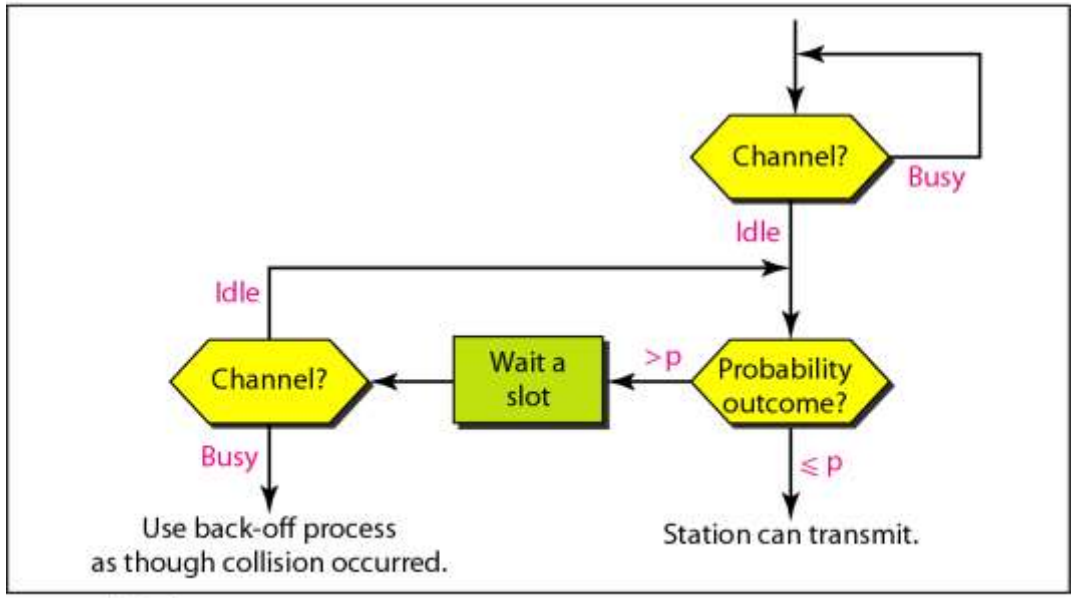
Flow diagram for three persistence methods



a. 1-persistent

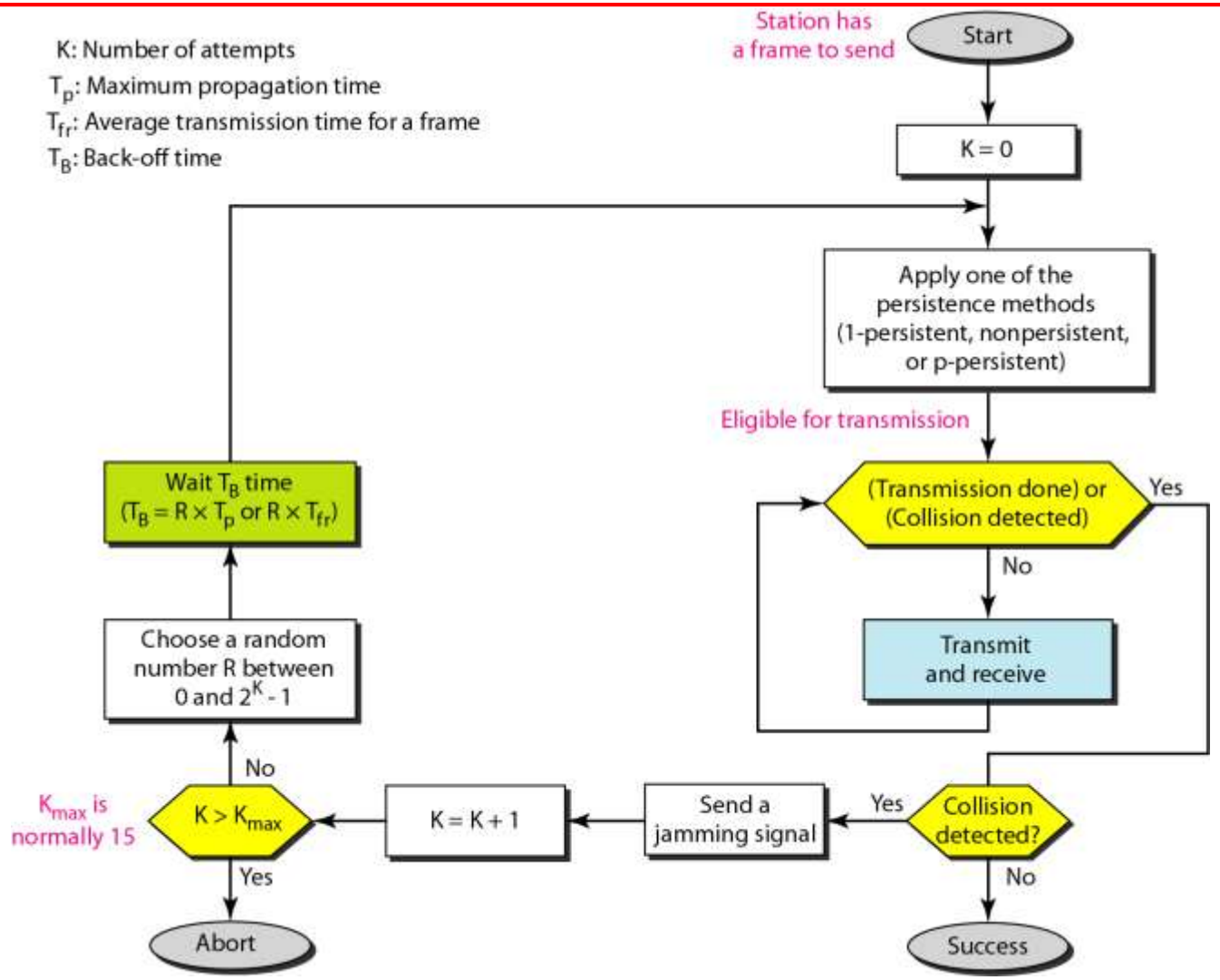


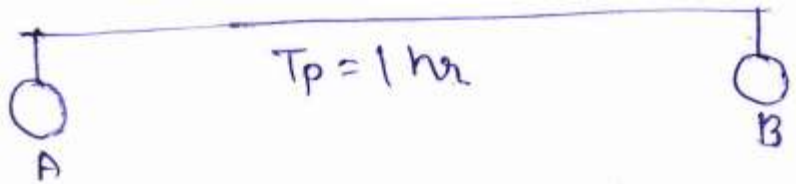
b. Nonpersistent



c. p-persistent

Flow diagram for the CSMA/CD





at t = 10:00, A & B starts transmitting.

at t = 10:30, there will be collision.

t = 11:00, both A & B will see collision signal

Means after tp, A & B will get collision signal.

If $T_t > T_p$

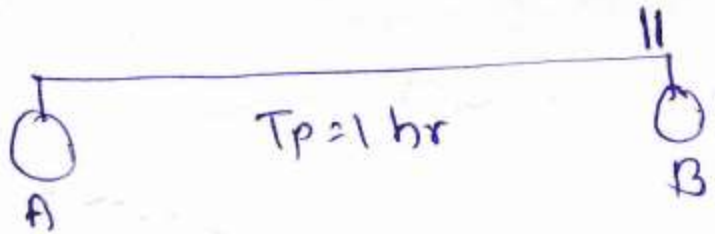
transmitting time

It means if you are still transmitting data then you will recieve collision signal & will sure that its my own data involved in collision

so $T_t > T_p$.

In worst case,

if A starts transmitting at 10:00
after what time A will get collision.



at 10:00 = A starts

at 10:59:59 → 1st bit of A will be at the end of channel
→ and B start transmitting.

so there will be collision at 11:00

& after 1 hr. means at 12:00, A will get collision

$T_t \geq 2 * T_p$

for detecting collision, T_t should be greater than $2 T_p$.

Q If I have to transmit $T_t \geq 2 * T_p$ then how much data should i sent to detect the collision.

$$T_t \geq 2 * T_p$$

$$\frac{L}{B} \geq 2 * T_p$$

$$L \geq B * 2 * T_p$$

This is the minimum pkt size in order to detect the collision.

Q. Let $T_p = 1$ ms & BW = 1 mbps, then what is length of pkt in order to detect the collision in CSMA/CD.

$\therefore L \geq 2 * T_p * B$

$\Rightarrow L \geq 2 * 10^{-3} * 10^6$

$\Rightarrow L \geq 2000$ bits

↑ pkt should be of 2000 bits in length in order to find the collision.

If pkts size is smaller than this size then we can use padding to make it upto 2000 bits.

Que: consider building a CSMA/CD NIW running at 1 Gbps over a 1km. cable with no repeaters. The signal speed in the cable is 200000 km/sec, what is minimum frame size?

Sol

∵ frame size / Length of frame = $\boxed{2 * T_p * B.}$

We have, B = 1 Gbps.

= $1 * 10^9$ bps.

Now, T_p = ?

∵ $T_p = \frac{\text{distance}}{\text{speed}}$

distance = 1 km. = 1000 m.

Speed = 200000 km/s = $2 * 10^8$ m/s.

$= \frac{10^3}{2 * 10^8}$ sec.

$= 0.5 * 10^{-5}$ sec.

$= 5 * 10^{-6}$ sec.

A 2 km long broadcast LAN has 10^7 bps bandwidth and uses CSMA/CD. The signal travels along the wire at 2×10^8 m/s. What is the minimum packet size that can be used on this network?

(a) 50 bytes
(b) 100 bytes
(c) 200 bytes
(d) None of these

Distance = 2 km
Bandwidth = 10^7 bps
Speed = 2×10^8 m/s
Minimum packet size ?
Propagation time = 0.00001 sec
Transmission time = 0.00002 sec

So Length = Tt x Bandwidth = 0.00002×10^7 = 200bits = 200/8 bytes = 25 bytes

(d) None of these

The minimum frame size required for a CSMA/CD based computer network running at 1Gbps on a 200m cable with a link speed of 2×10^8 m/sec is:

(a) 125 bytes
(b) 250 bytes
(c) 500 bytes
(d) None of the above

Bandwidth = 1 gbps = 10^9 bps
Distance = 200 m
Speed = 2×10^8 m/sec
Propagation Time = 0.000001 sec
Transmission time Tt = 0.000002 sec

So Length = Tt x Bandwidth = 0.000002 x 10^9 = 2000 bits

2000 bits = 2000/8 bytes = 250 bytes

(b) 250 bytes

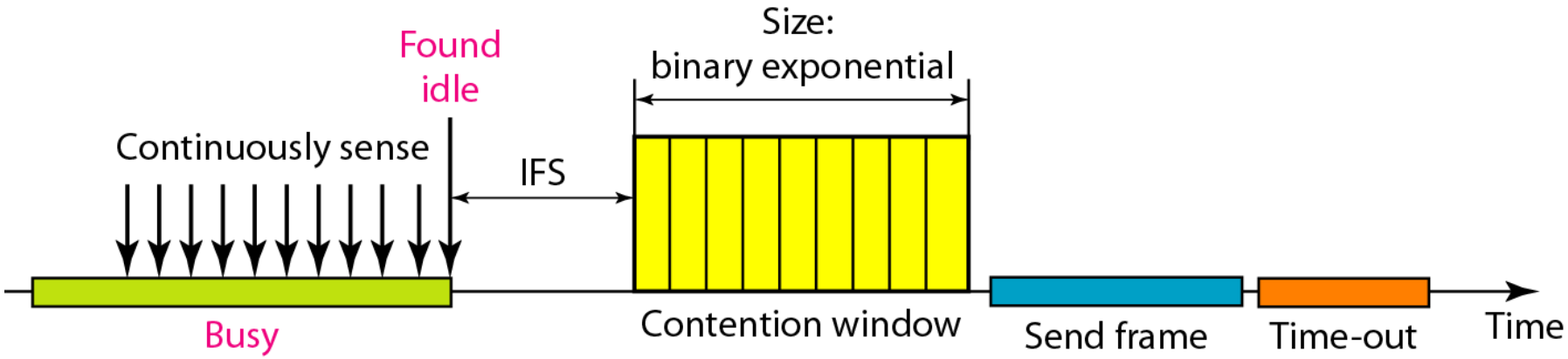
CSMA|CA ⇒

↳ Basically used for wireless channel.
Since in wireless medium, energy level of signals are very low coz lots of energy is wasted in wireless trans so collision detection is difficult, in CSMA|CA (wireless) so a mechanism to avoid the collision is used in CSMA|CA.

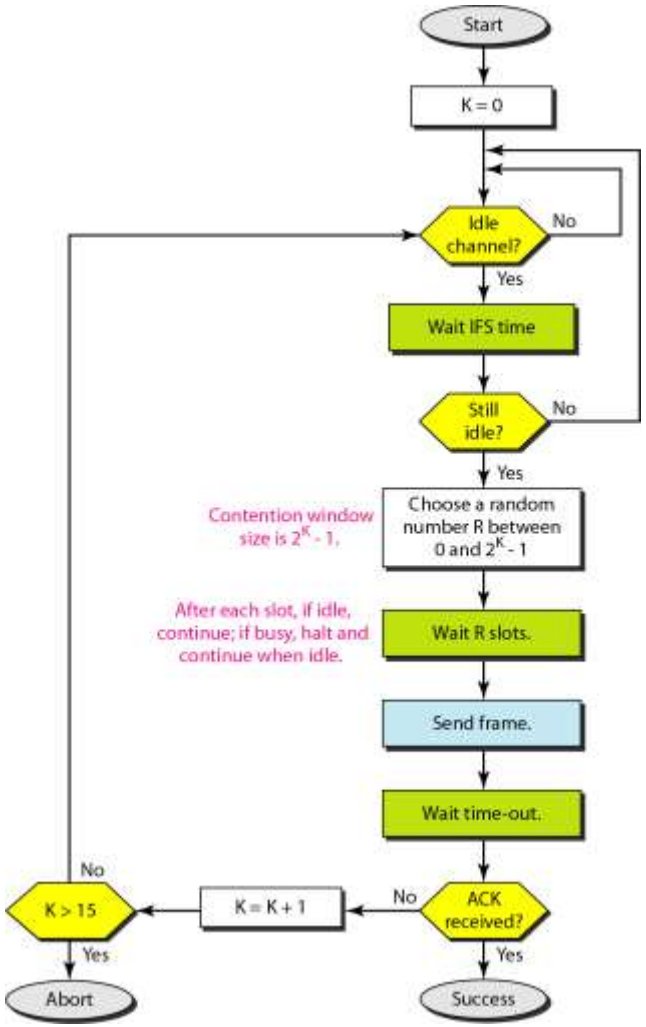
- This collision avoidance is achieved by the increasing waiting time since channel is idle. So there may be less possibility of collision.

- collisions are avoid through foll. strategies -

Timing in CSMA/CA



Flow diagram for CSMA/CA



Note

In CSMA/CA, if the station finds the channel busy, it does not restart the timer of the contention window;
it stops the timer and restarts it when the channel becomes idle.

S.NO	CSMA/CD	CSMA/CA
1.	CSMA / CD is effective after a collision.	Whereas CSMA / CA is effective before a collision.
2.	CSMA / CD is used in wired networks.	Whereas CSMA / CA is commonly used in wireless networks.
3.	It only reduces the recovery time.	Whereas CSMA/ CA minimizes the possibility of collision.
4.	CSMA / CD resend the data frame whenever a conflict occurs.	Whereas CSMA / CA will first transmit the intent to send for data transmission.
5.	CSMA / CD is used in 802.3 standard.	While CSMA / CA is used in 802.11 standard.
6.	It is more efficient than simple CSMA(Carrier Sense Multiple Access).	While it is similar to simple CSMA(Carrier Sense Multiple Access).

Collision Free Protocols

1. **Bitmap Protocol**
2. **Broadcast Recognition with Alternating Priorities**
3. **Binary Countdown**

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Collision Free Protocols :-

- We have seen that almost collision can be avoided in CSMA/CD, they can still occur collision during contention Period.
- This collision during contention period, affects the system performance, this happens when the cable is long & length of pkt is short. This is serious problem when fiber optic n/w is used.
- Here, there are some protocols that resolve the collision during contention period.
- In these protocols, we assume that there are N stations having unique addresses from 0 to N-1.

(i) * Bit-Map protocol :-

- In this, total contention period is first divided into many no. of slots equal to no. of stations.

- Thus every station is having a number & aware about its position.

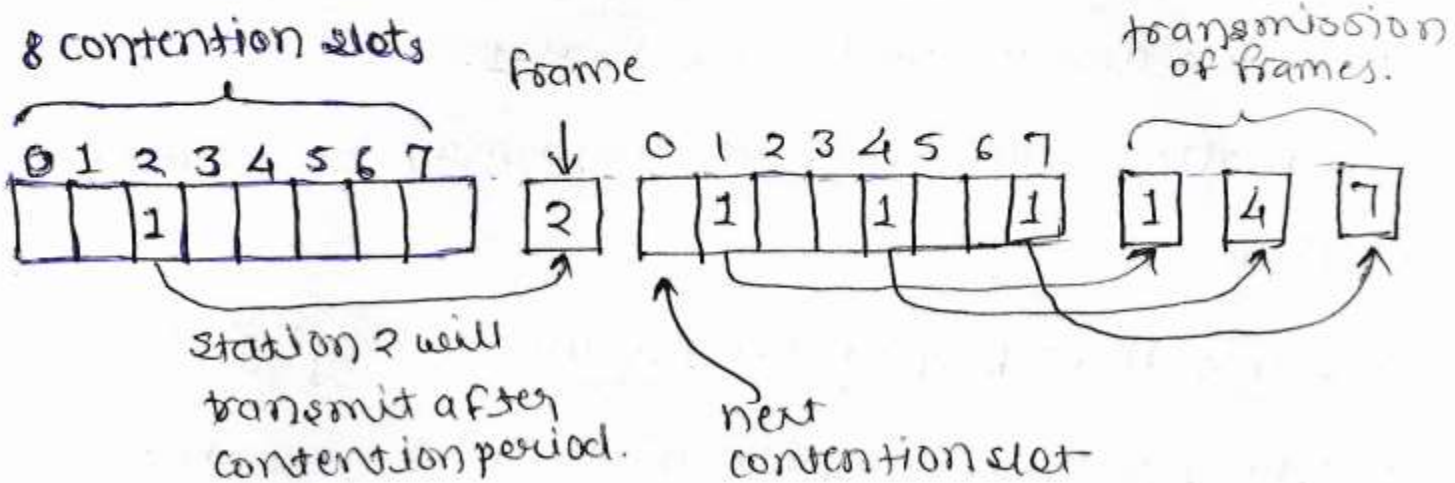
- When a station wants to transmit, then it transmits a bit in its respective slot period.

- For eg. if station 2 has a frame to send, then it transmits 1 bit in second slot.

- In general station 2 may announce the fact that it has a frame to send by inserting 1 bit into slot 2.

- In this way each station has complete knowledge of which station want to transmit. So there will be no collision.

- This type of protocol, in which desire to transmit is broadcast before the actual transmission are called reservation protocols.



(ii) BRAP (Broadcast Recognition with Alternating priorities)

Basic bit map protocol has some drawbacks

(a) Higher numbered stations get better service than lower numbered

(b) In low load condition, a station must wait for the current scan of contention slot.

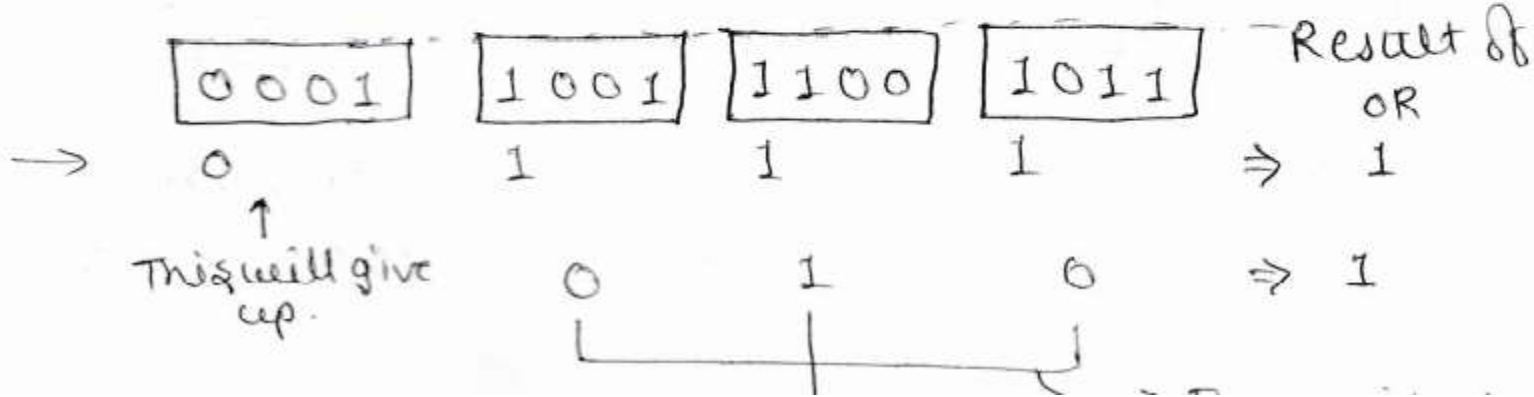
BRAP eliminates these 2 drawbacks ⇒

- This is similar to the basic bit map protocol, only difference is as,
  - when a station reserves a slot (means wants to transmit), it gets a chance to send msg immediately

(iii) Binary countdown :-

- Binary countdown is used to overcome the overhead 1 bit per station.
- In this, binary addresses for stations are used.
- All the addresses are of same length.
- A station that wish to transmit, will broadcast its address as a binary bit string, starting with the most significant bit.
- Lets see an eg. In this addresses of stations are OR ed together to decide the priority of transmitting

- Let four stations addresses → 0001, 1001, 1100, 1011 all are trying to use channel. All stations will first broadcast their most significant bit i.e. 0, 1, 1 & 1 respectively.
- Now MSB will be 'OR'ed together. O/P will be = 1 of OR operation. then station 0001 will see that there are other stations having higher number, so it will give up for current round.
- other three stations 1001, 1100, 1011 will broadcast their second most significant bit and same process will continue..
- Station 1100 will get the chance to send frame.



Limited contention protocols:-

- Performance of these protocols is based on 2 parameters delay and efficiency.

- If the load of channel increases, then contention protocols are not effective because overheads are there.
  Means if load is low in contention protocols then delay is low.

- In other hand, in collision free protcals, if load is high then channel efficiency improves.

  Thus in contention protocol ⇒ if load ↓ then delay ↓
  and in collision free —"— ⇒ if load ↑ then efficiency ↑

⇒ So Limited contention protocols are the combination of both characteristics.

i.e. combination of contention & collision free protocols.
because contention protocols provides low delay at low load & collision free protocols provide good η at high load.

CONTROLLED ACCESS

In controlled access, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations. We discuss three popular controlled-access methods.

Topics discussed in this section:

Reservation
Polling
Token Passing

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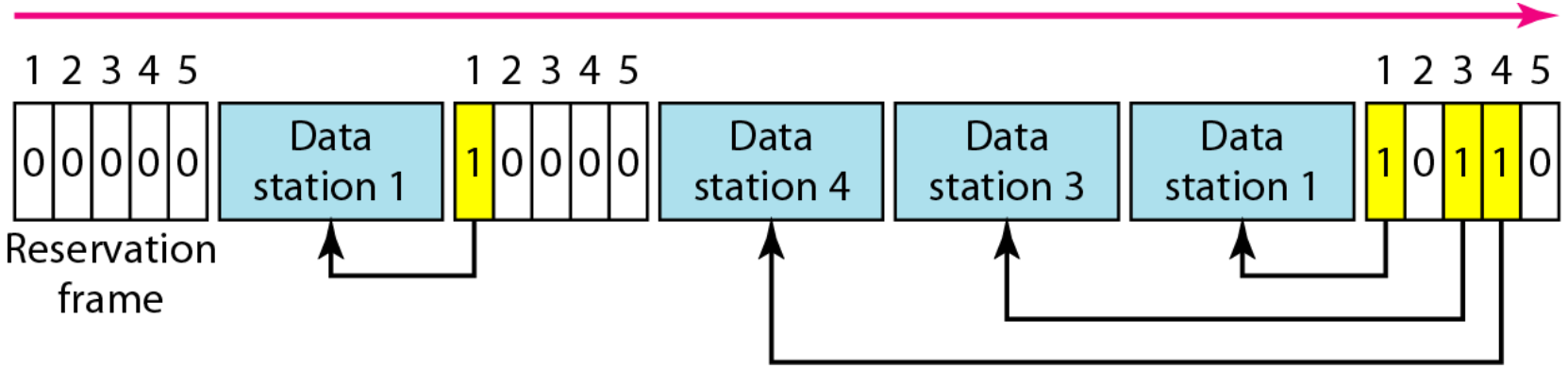
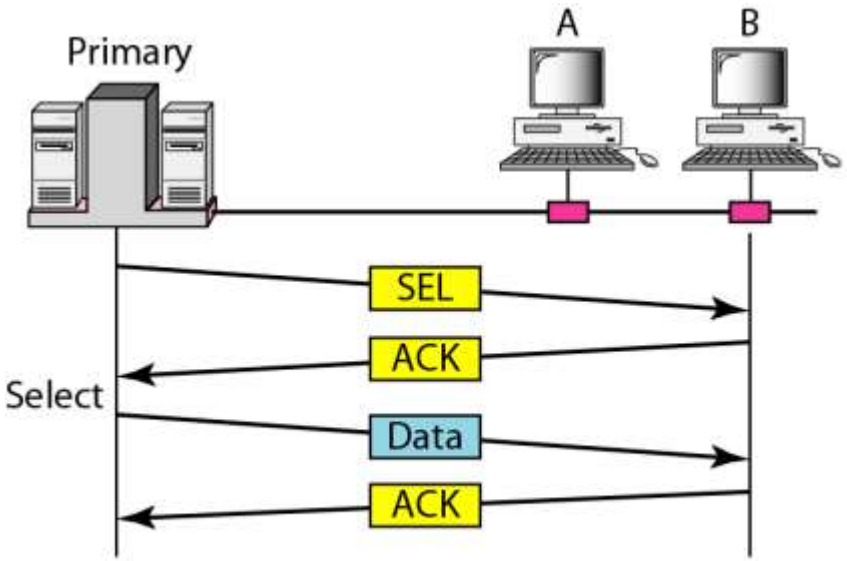
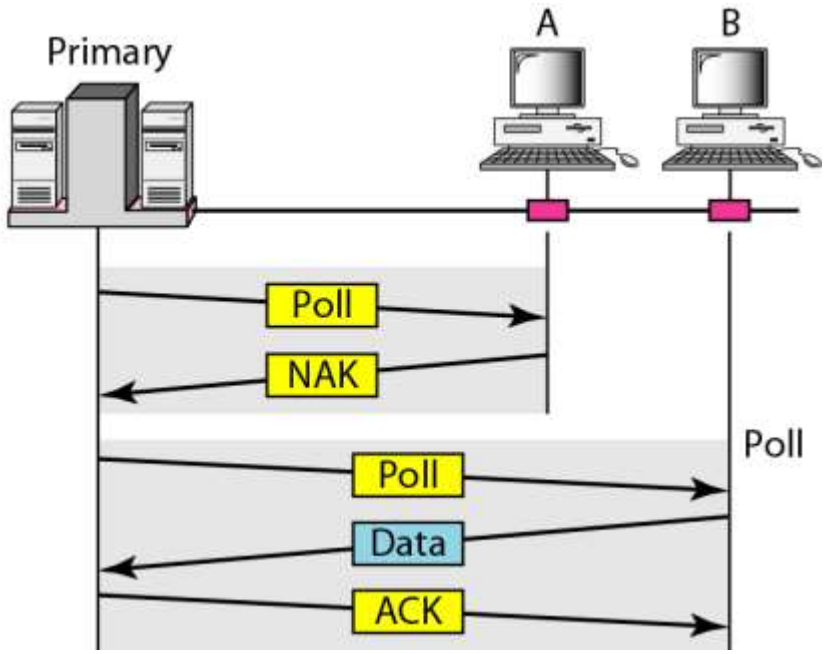
Reservation access method

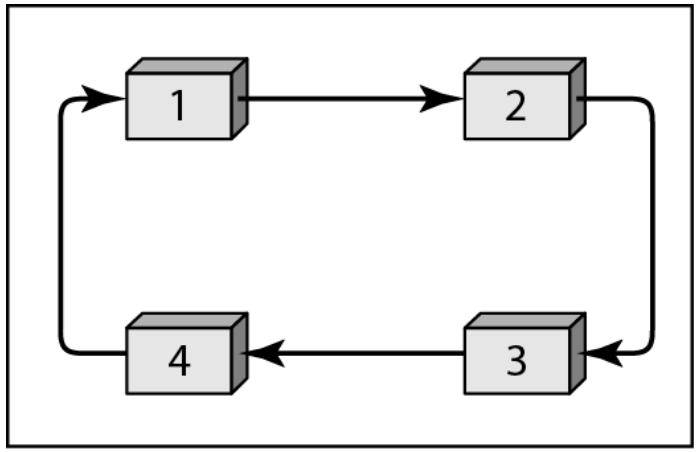


Select and poll functions in polling access method

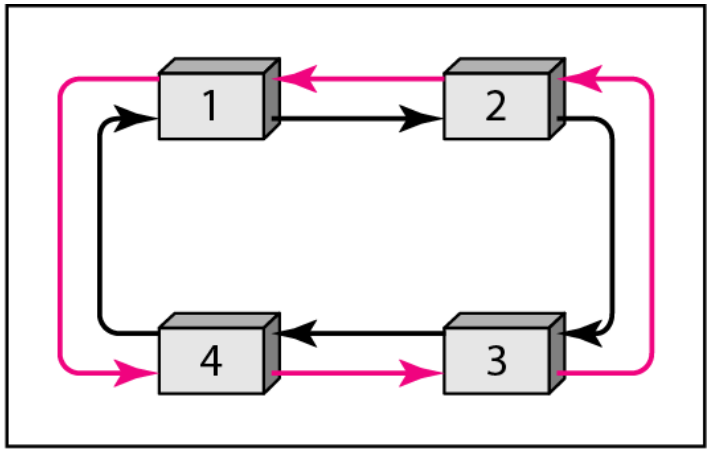




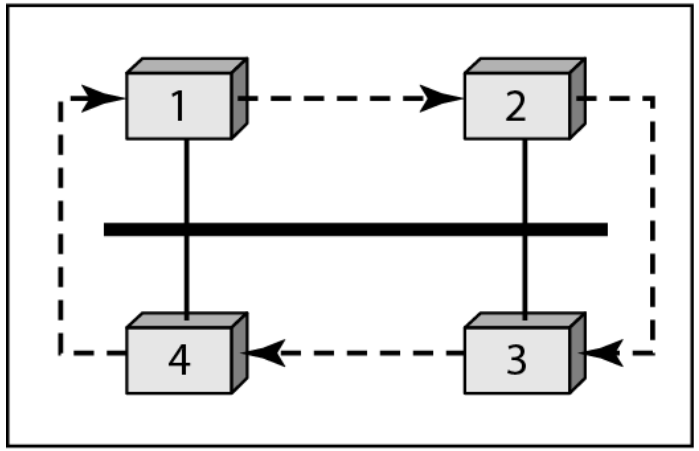
Logical ring and physical topology in token-passing access method



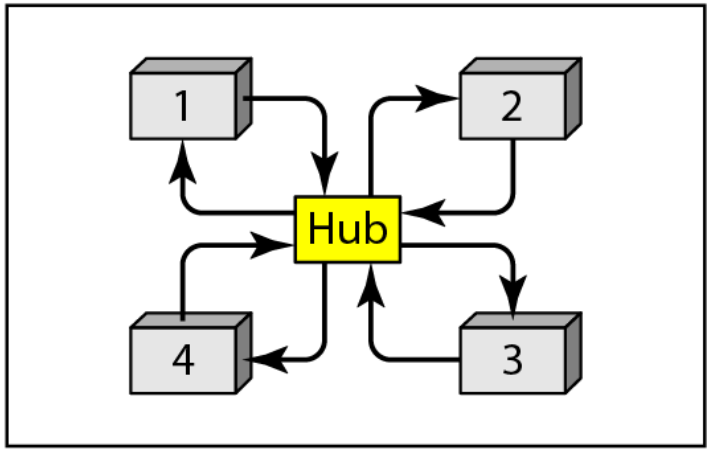
a. Physical ring



b. Dual ring



c. Bus ring



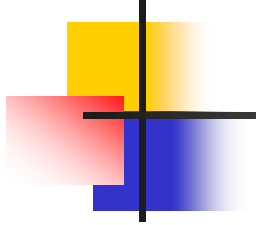
d. Star ring

CHANNELIZATION

Channelization ***is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.***

Topics discussed in this section:

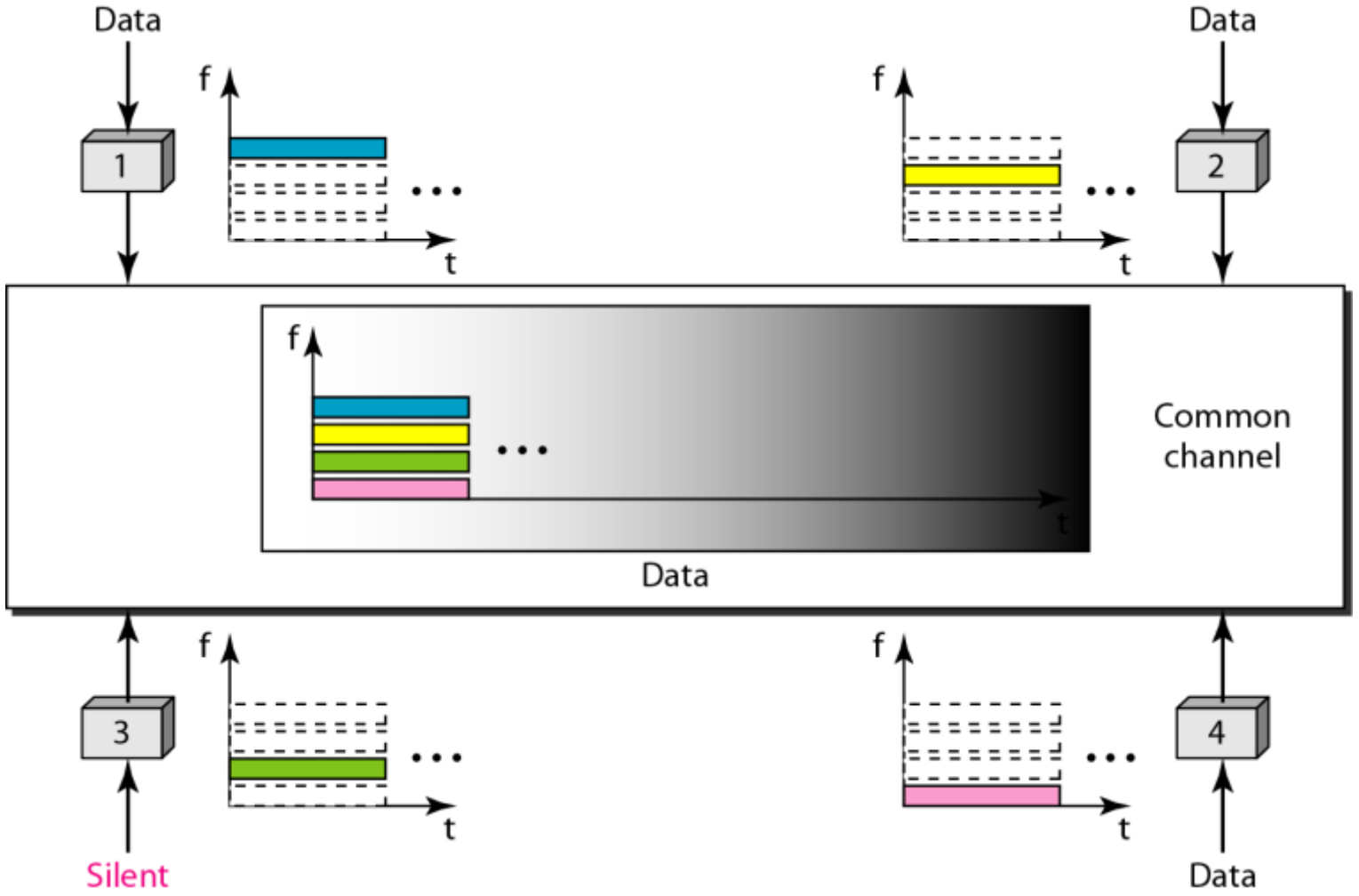
Frequency-Division Multiple Access (FDMA)
Time-Division Multiple Access (TDMA)
Code-Division Multiple Access (CDMA)



Note

We see the application of all these methods in Chapter 16 when we discuss cellular phone systems.

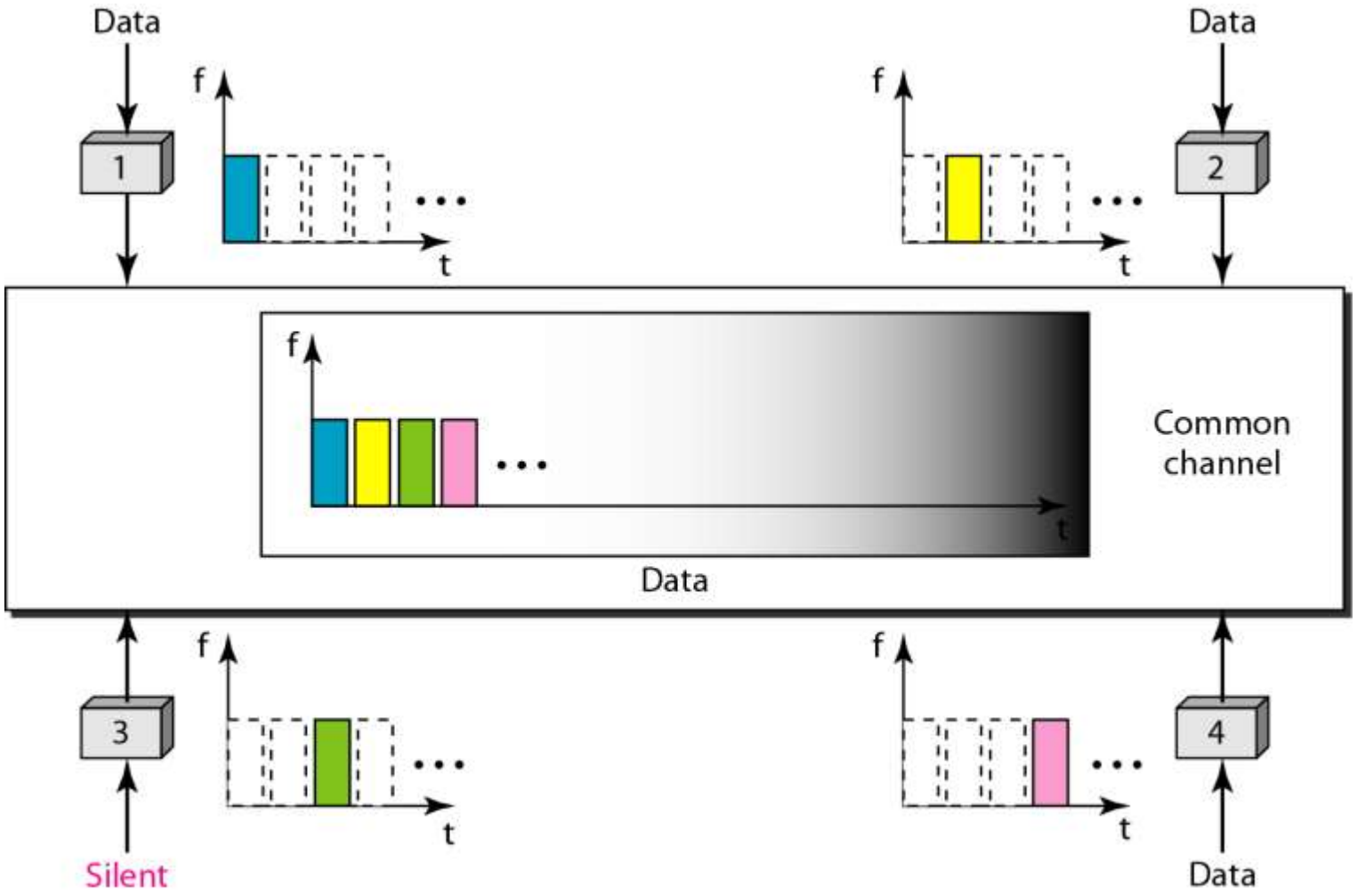
Frequency-division multiple access (FDMA)



Note

In FDMA, the available bandwidth of the common channel is divided into bands that are separated by guard bands.

Time-division multiple access (TDMA)



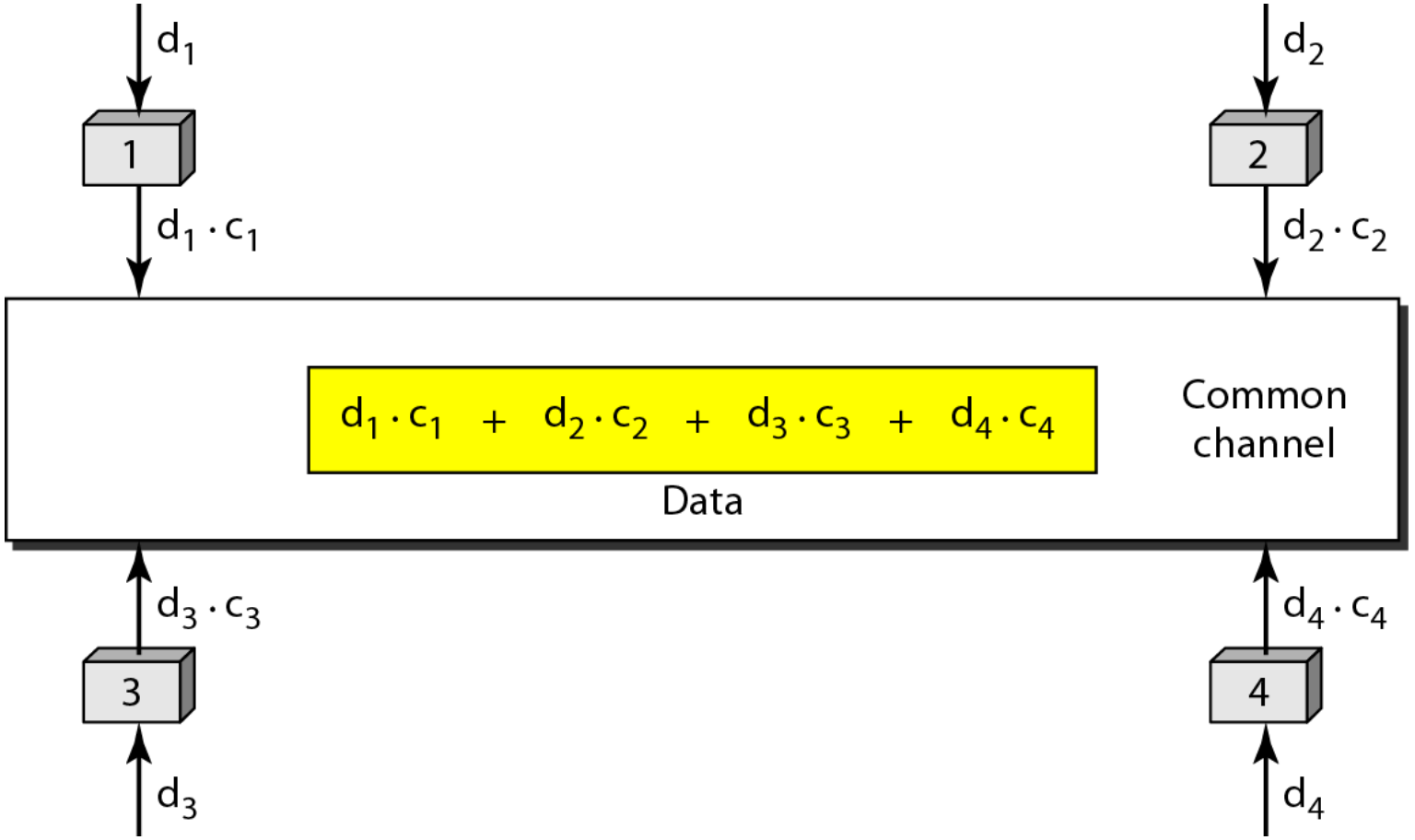
Note

In TDMA, the bandwidth is just one channel that is timeshared between different stations.

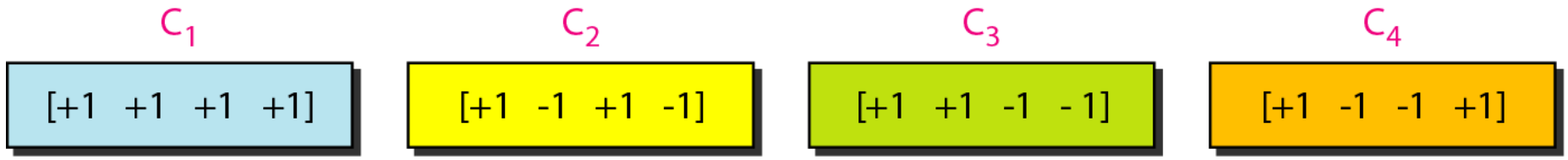
Note

In CDMA, one channel carries all transmissions simultaneously.

Simple idea of communication with code

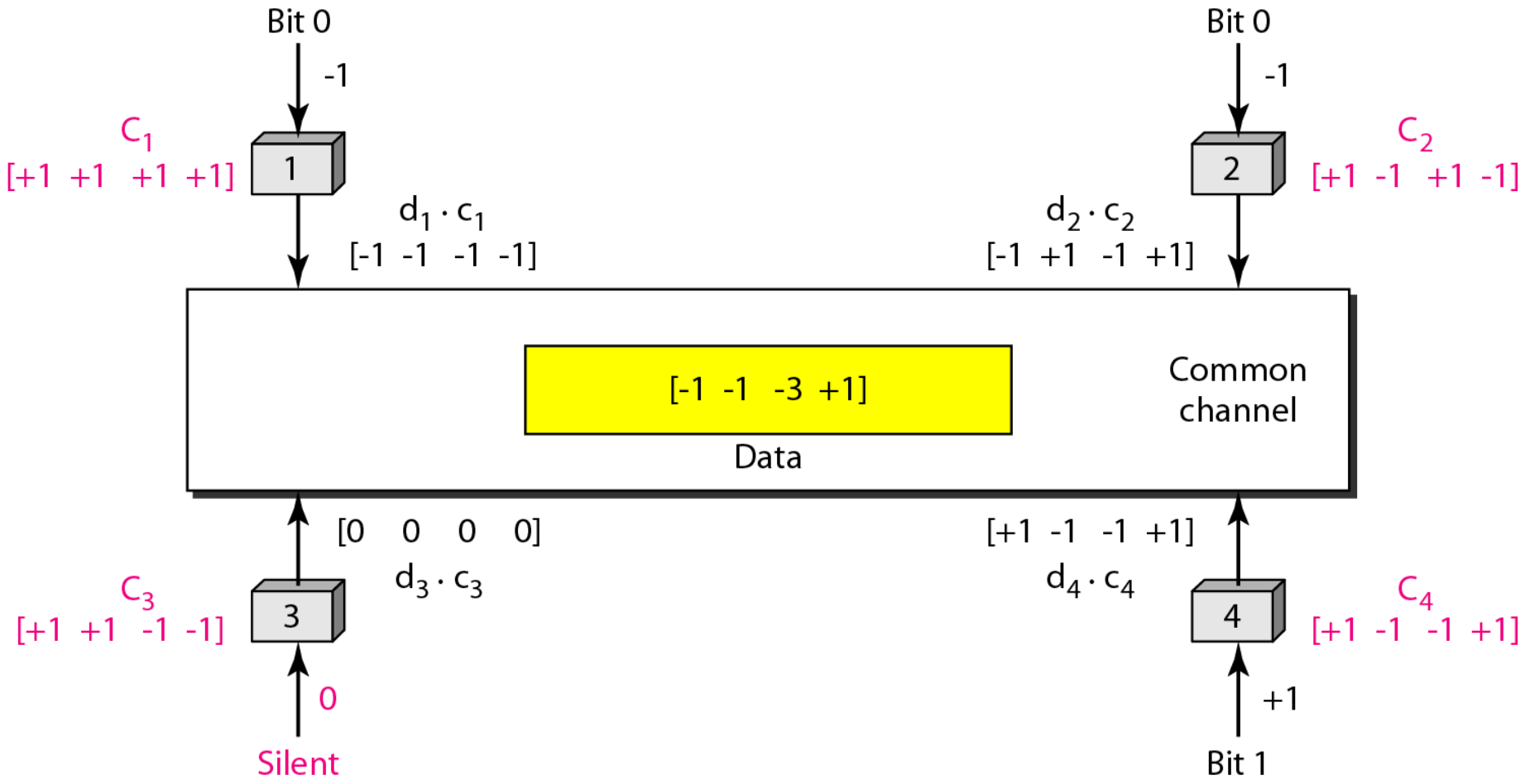


Chip sequences

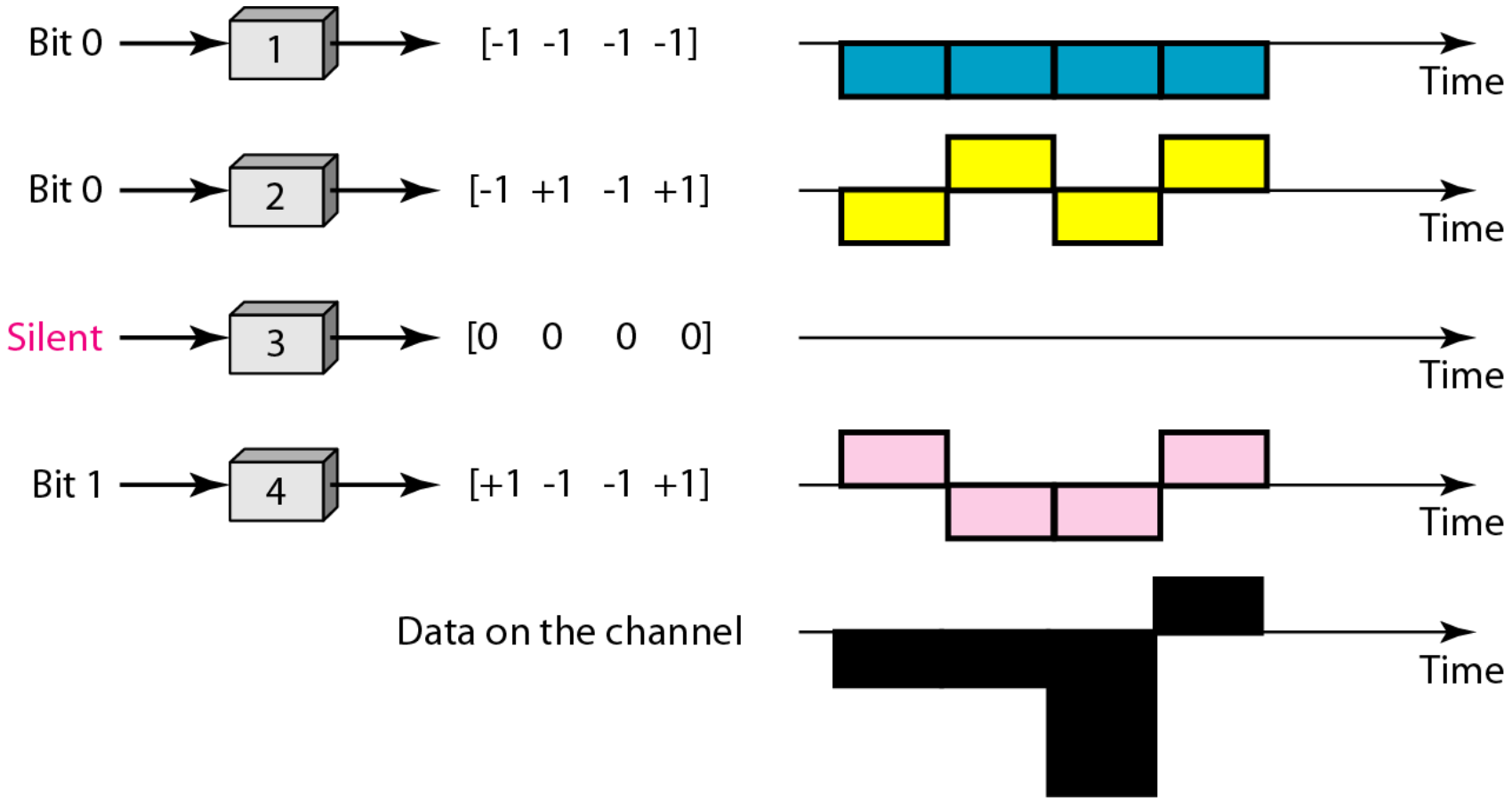


Data representation in CDMA

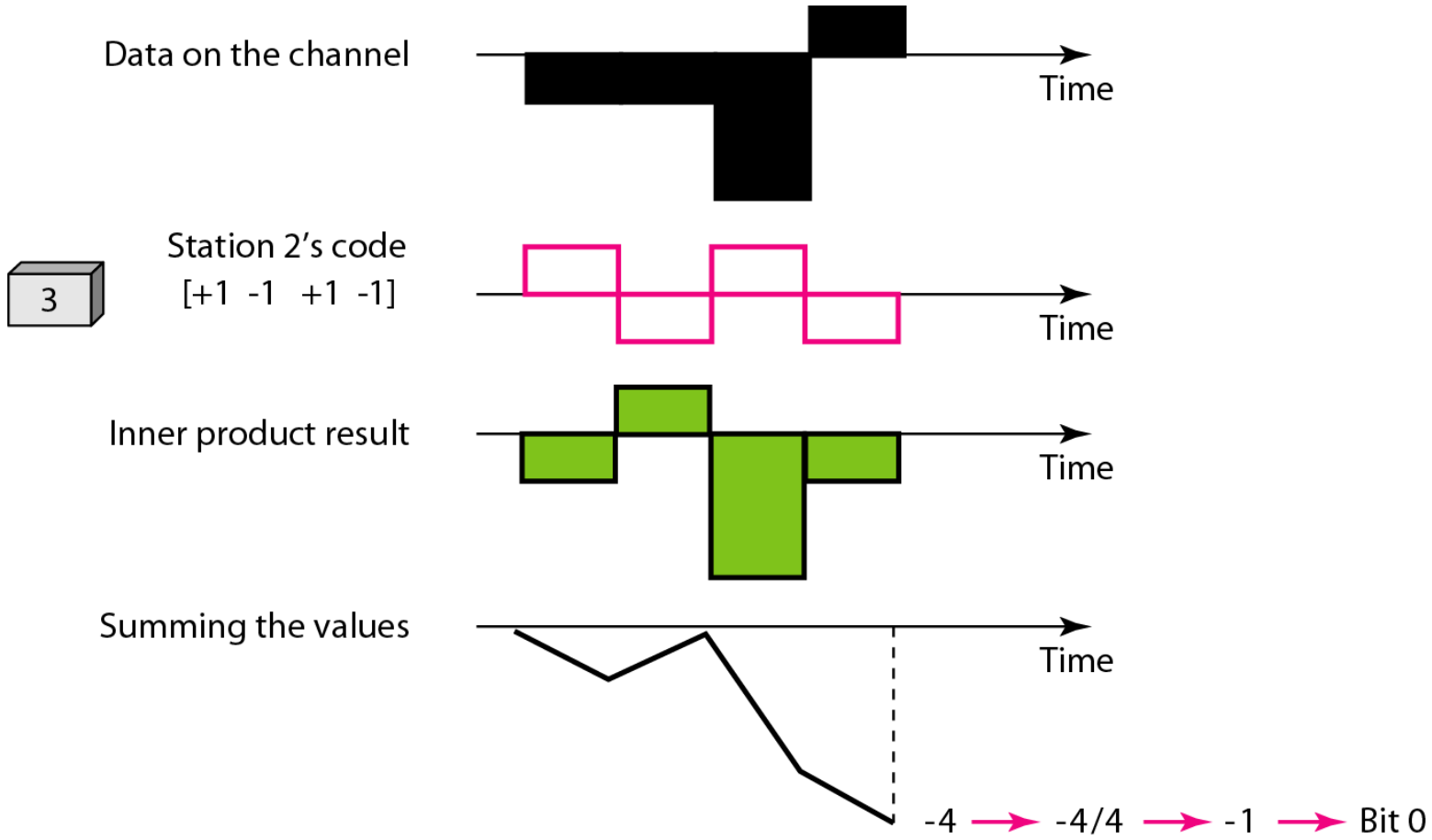
Figure 12.26 *Sharing channel in CDMA*



Digital signal created by four stations in CDMA



Decoding of the composite signal for one in CDMA

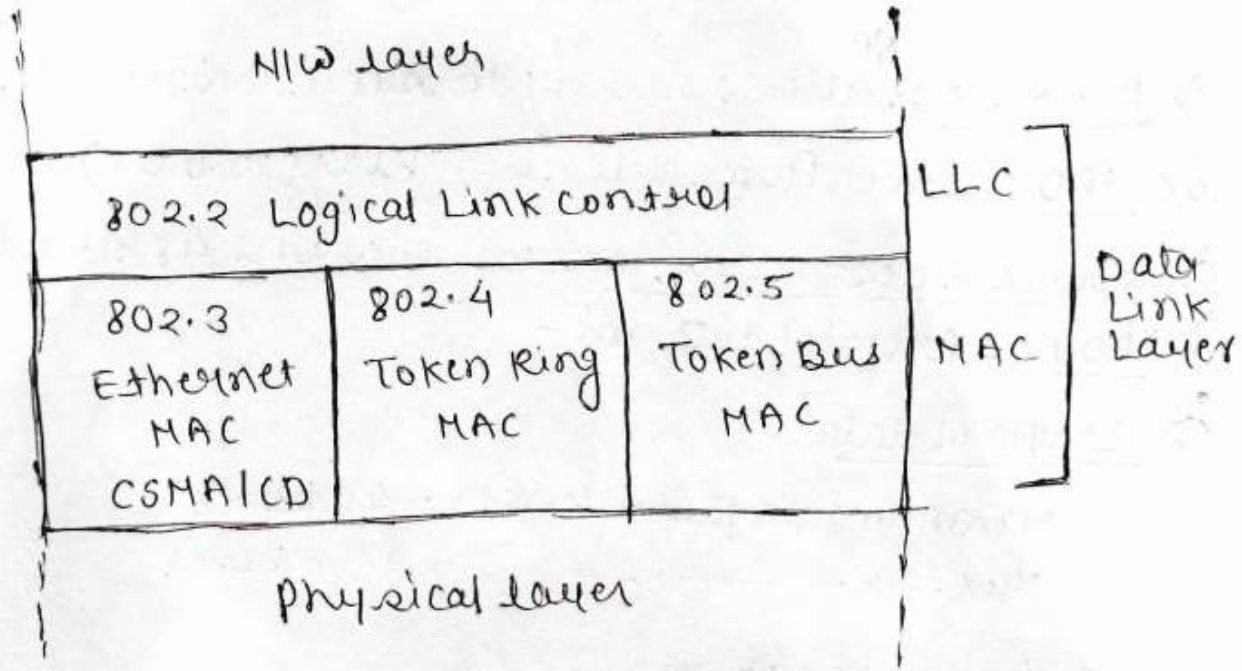


Ethernet

Prepared and compiled by
Bhupendra Panchal, Asst. Professor, CSE

IEEE standards :-

- IEEE (The institution of Electrical & Electronics Engineers) has developed the layered architecture and other standards of LAN, under their project 802 set up in 1980.
- Project 802 is a way of specifying functions of the physical layer & data link layer of major LAN protocols.

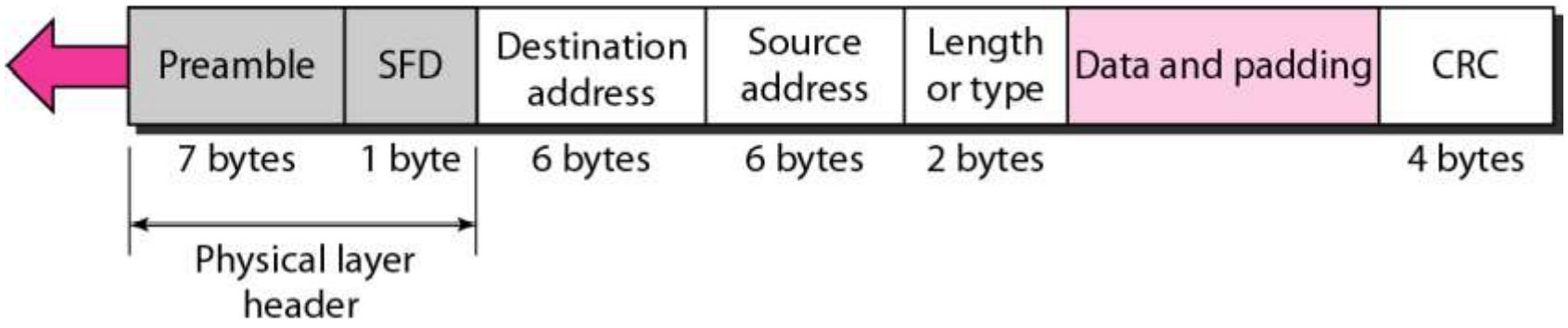


"IEEE LAN & Related standards"

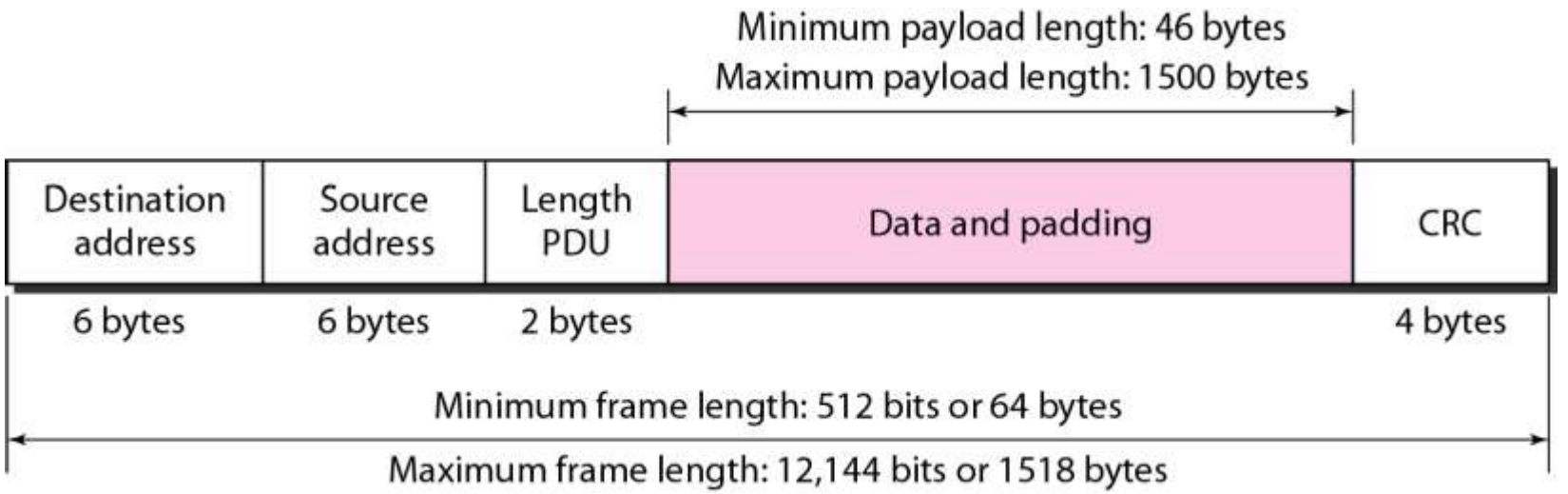
802.3 MAC frame

Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)



Minimum and maximum lengths



Note

Frame length:

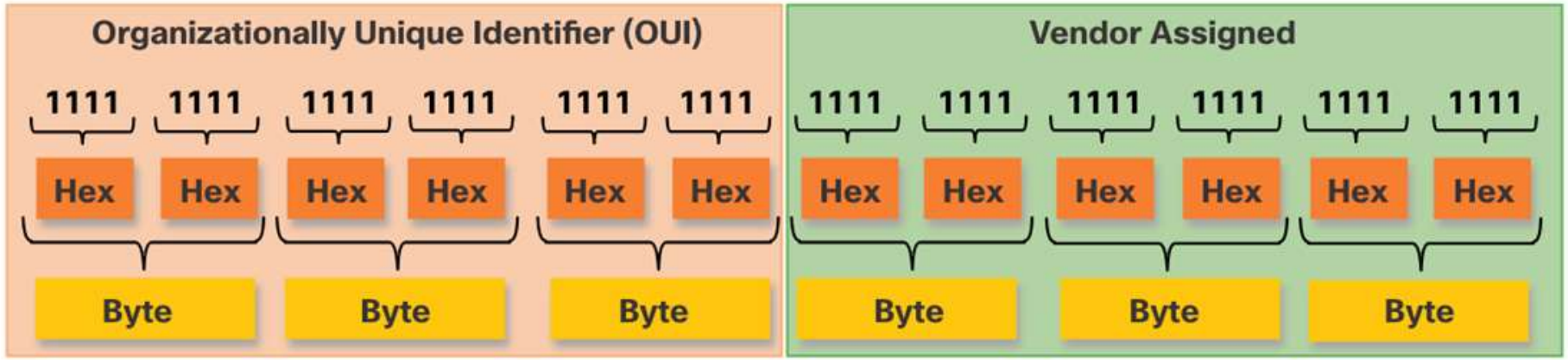
Minimum: 64 bytes (512 bits)

Maximum: 1518 bytes (12,144 bits)

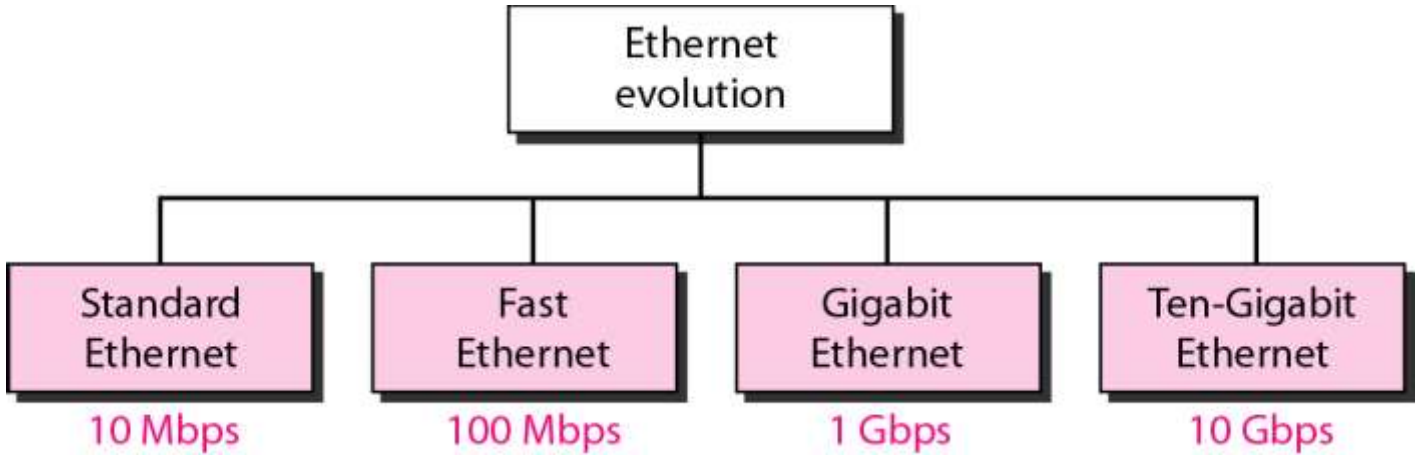
Example of an Ethernet address in hexadecimal notation

MAC Address

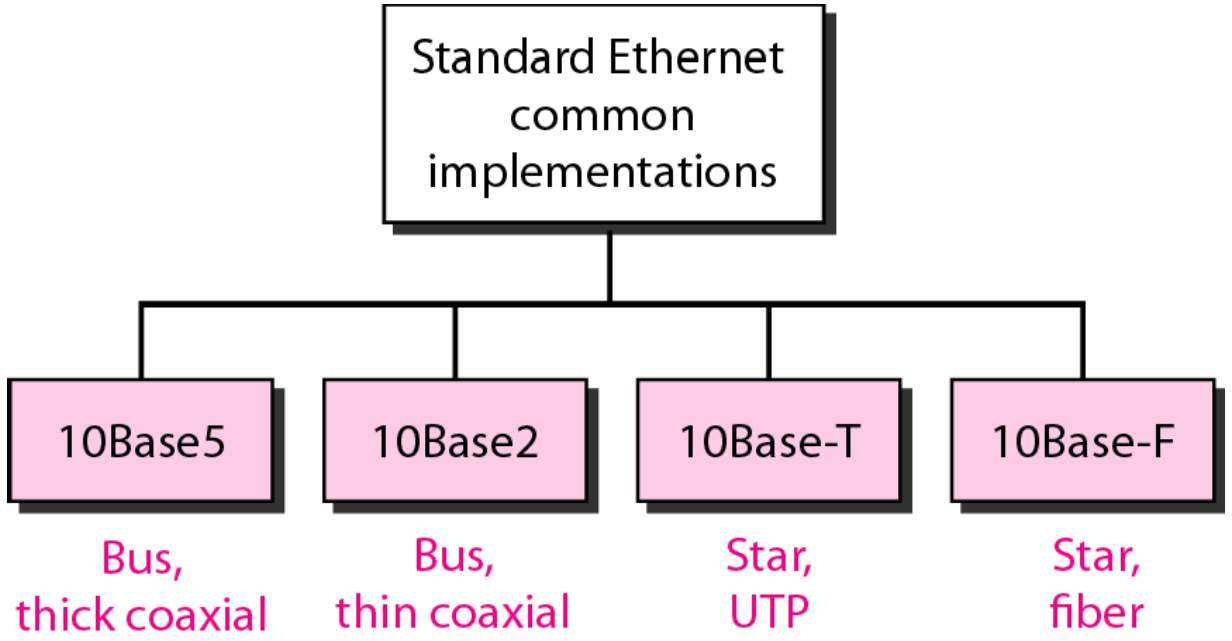
- An Ethernet MAC address is a 48-bit address expressed using 12 hexadecimal digits. Because a byte equals 8 bits, we can also say that a MAC address is 6 bytes in length.
- All MAC addresses must be unique to the Ethernet device or Ethernet interface. To ensure this, all vendors that sell Ethernet devices must register with the IEEE to obtain a unique 6 hexadecimal (i.e., 24-bit or 3-byte) code called the organizationally unique identifier (OUI).
- An Ethernet MAC address consists of a 6 hexadecimal vendor OUI code followed by a 6 hexadecimal vendor-assigned value.



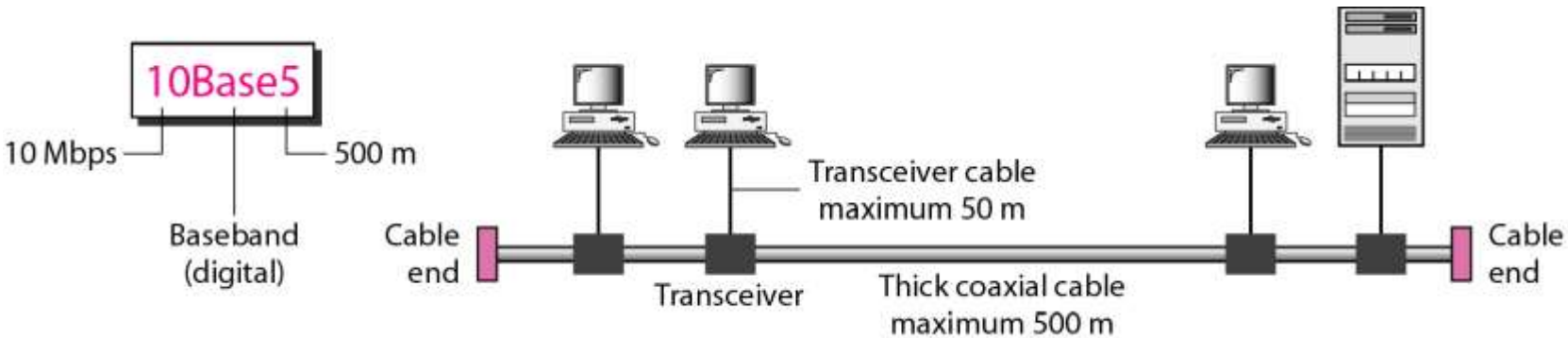
Ethernet evolution through four generations



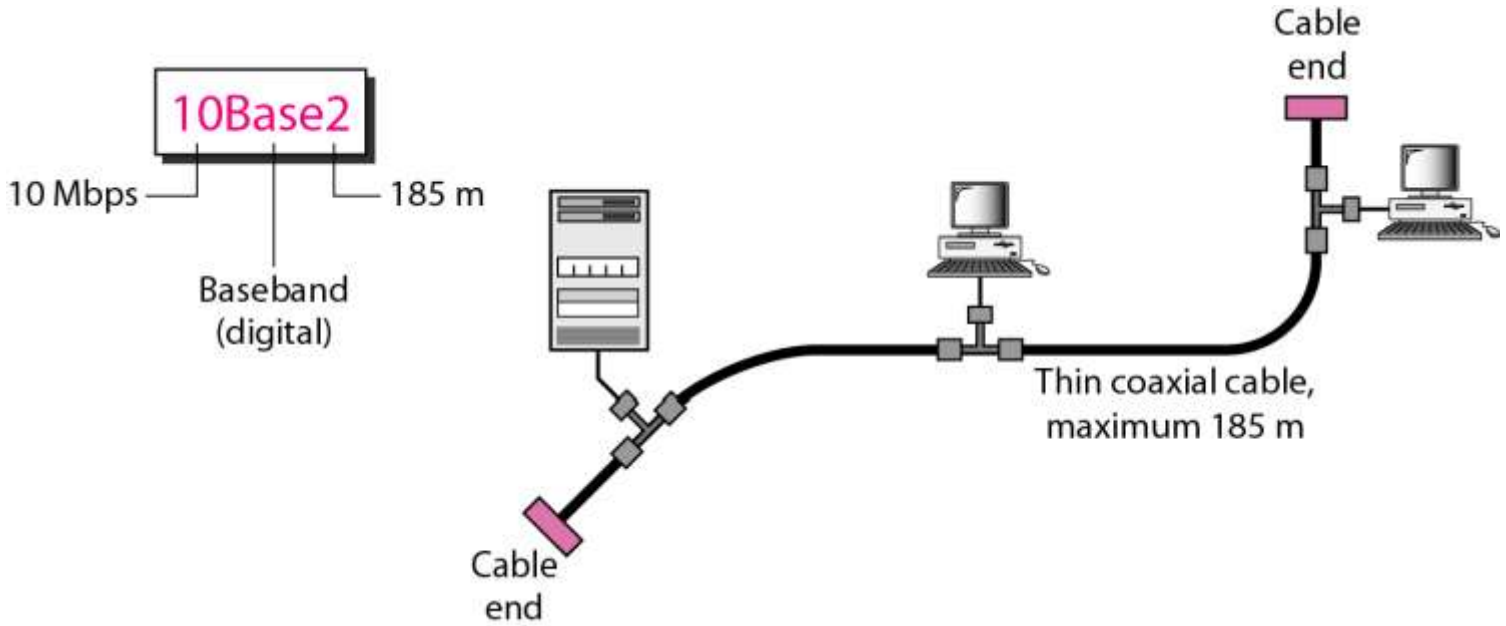
Categories of Standard Ethernet



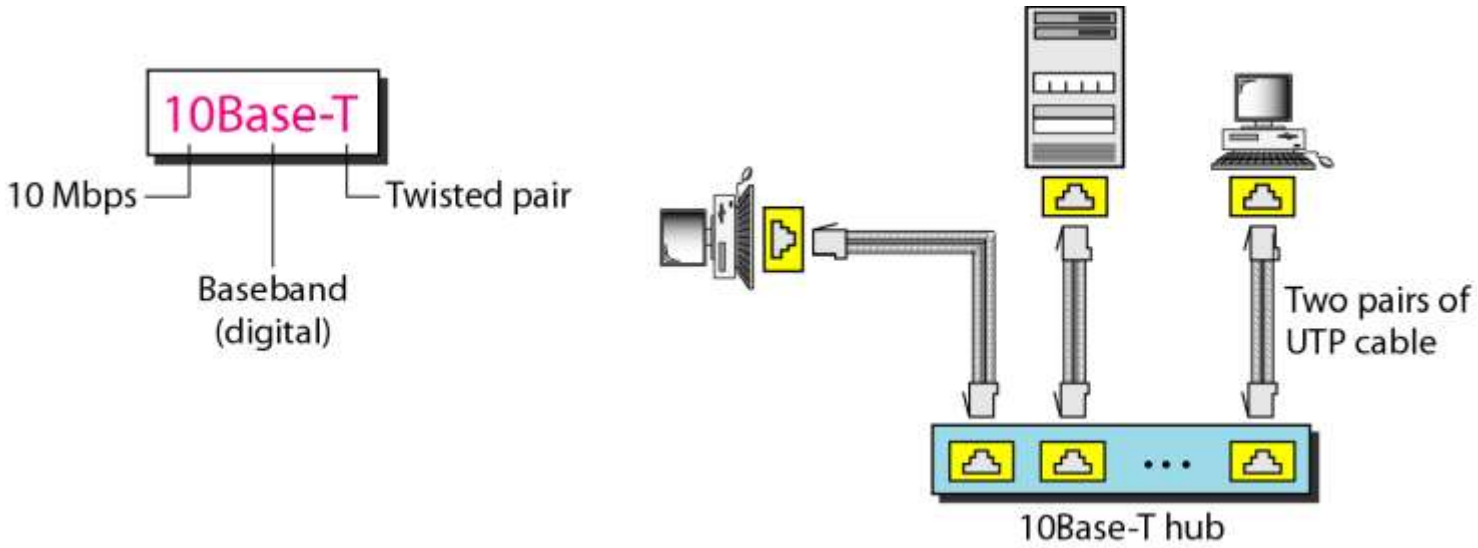
10Base5 implementation



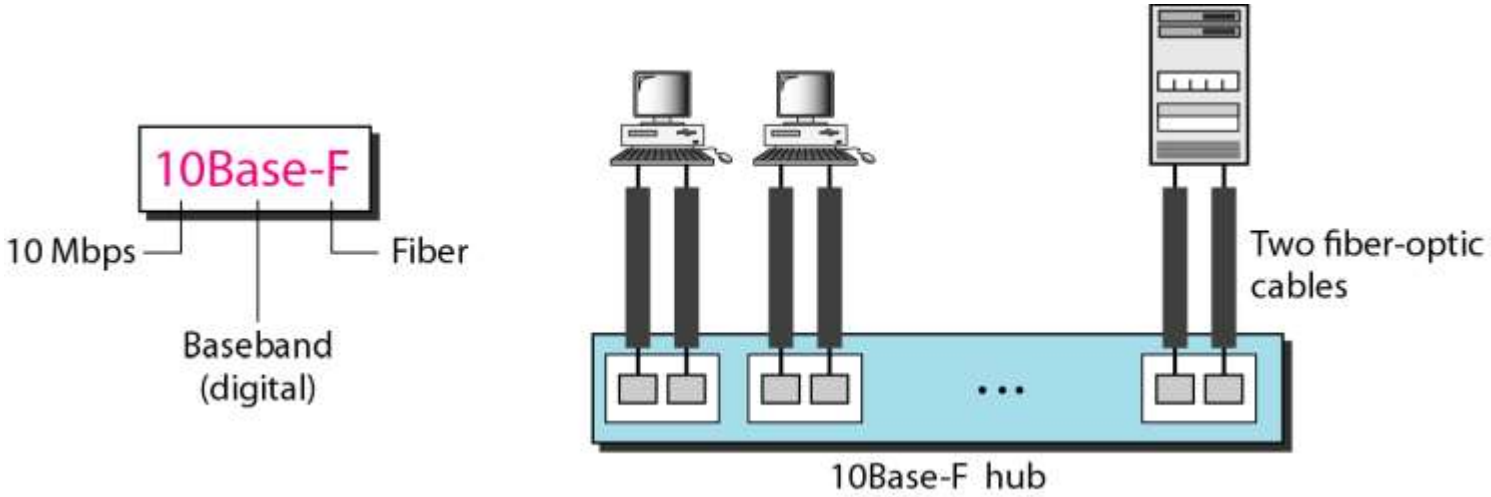
10Base2 implementation



10Base-T implementation



10Base-F implementation



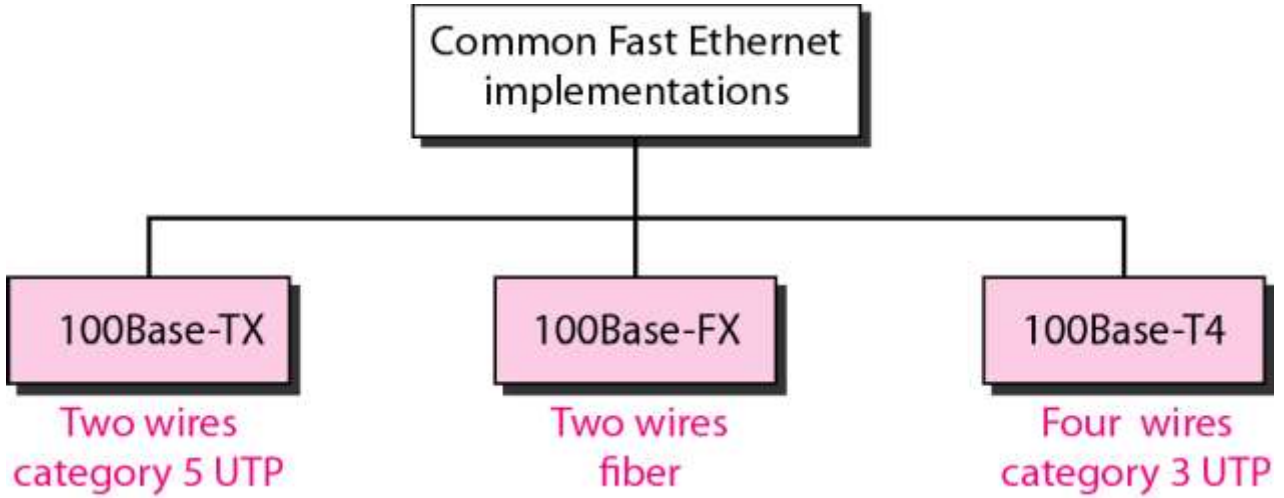
Summary of Standard Ethernet implementations

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m

13-44 FAST ETHERNET

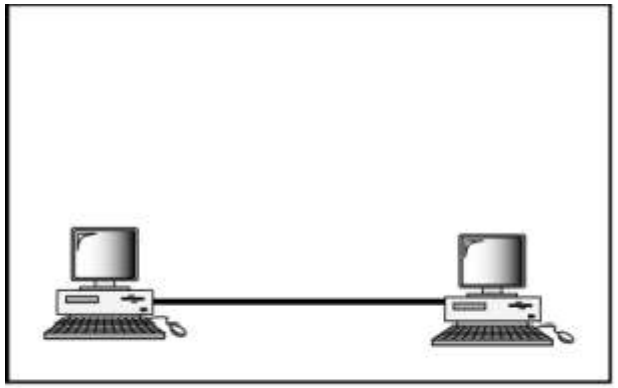
- is a protocol designed to work upto 100 Mbps.
- Traditional Ethernet can operate upto 10 Mbps.
- was designed to compete with LAN protocols such as FDDI or fiber channel.
- IEEE created Fast Ethernet under the name 802.3u.
- It can transmit data 10 times better than std. Ethernet.

Fast Ethernet implementations

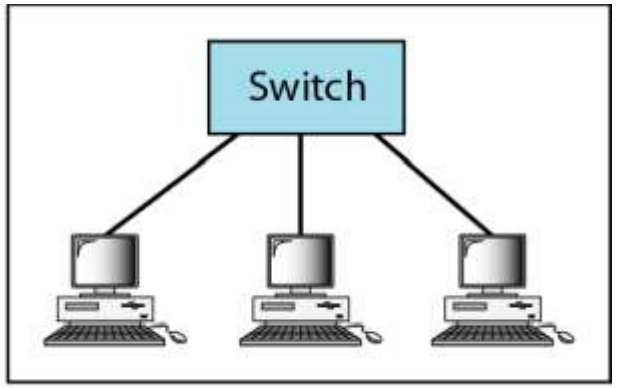


Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	Cat 5 UTP or STP	Fiber	Cat 4 UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m

Fast Ethernet topology



a. Point-to-point

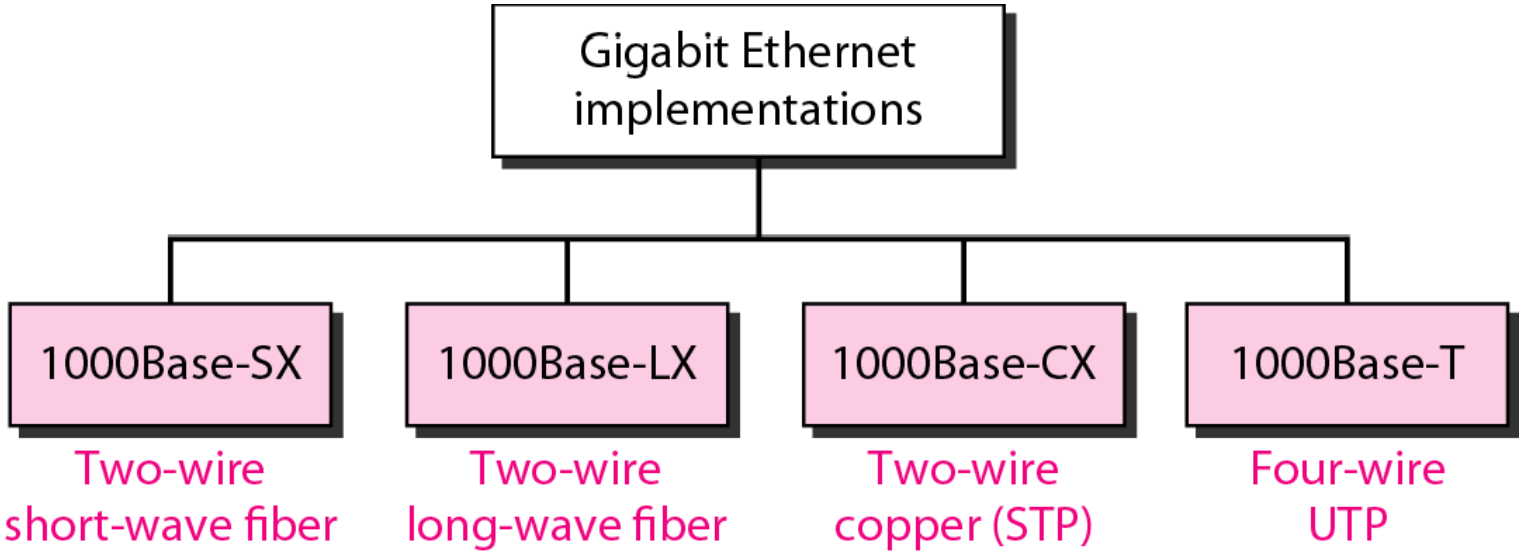


b. Star

GIGABIT ETHERNET

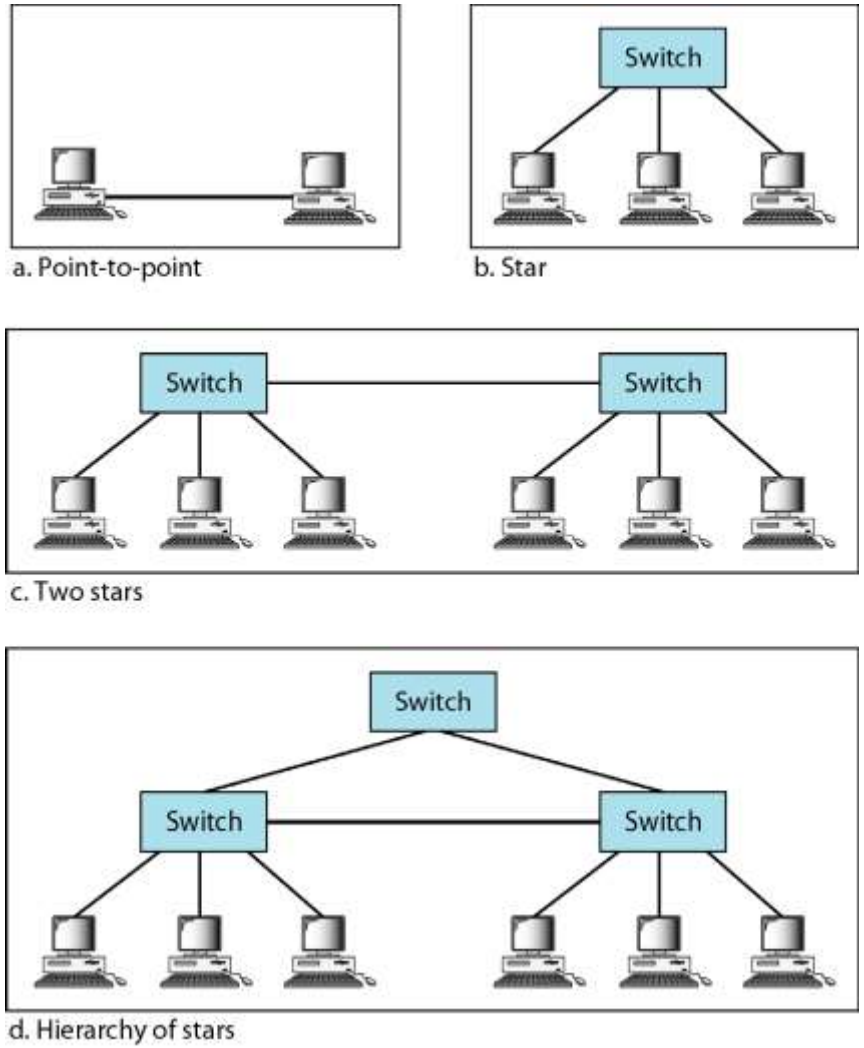
- Designed for the high data rate upto 1000 Mbps / 1Gbps
- IEEE called is 802.3z

Gigabit Ethernet implementations



Characteristics	*1000Base-SX*	*1000Base-LX*	*1000Base-CX*	*1000Base-T*
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550 m	5000 m	25 m	100 m

Topologies of Gigabit Ethernet



a. Point-to-point

b. Star

c. Two stars

d. Hierarchy of stars

End of Unit-I

Thank You