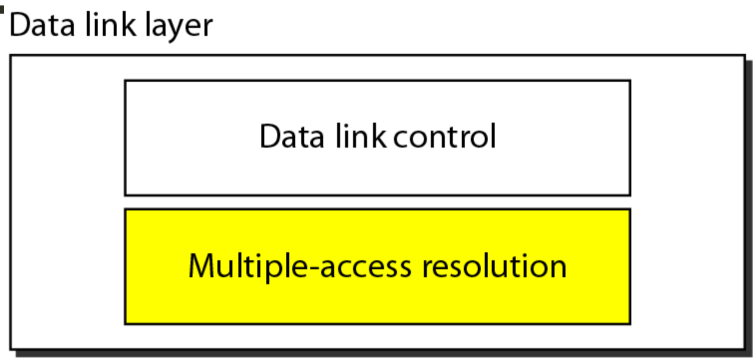
Data Communication & Computer Networks

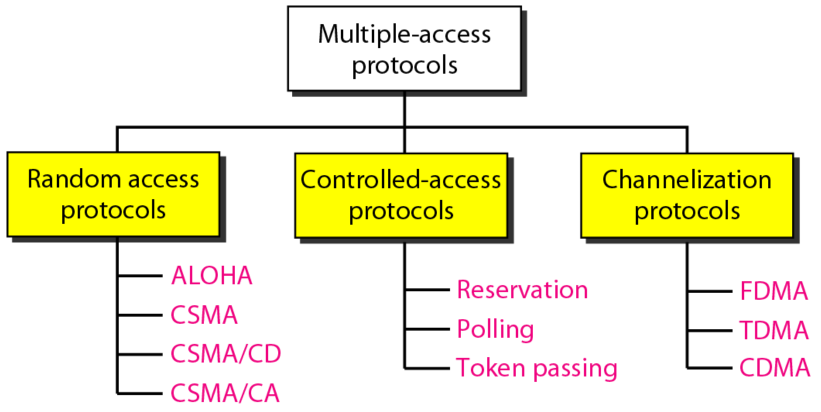
4. Multiple Access

Data link layer functionality divided into two sublayers



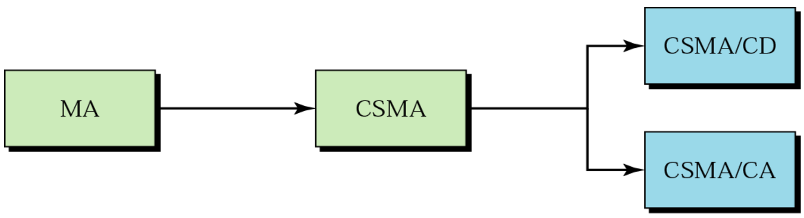
In IEEE standards, the upper sublayer is called the Logical Link Control (LLC) layer and the lower sublayer is called the Media Access Control (MAC) layer.

Multiple-access protocols



Random Access

- Each station has a right to the medium without being controlled by another station
- Chances of access conflict (collision)

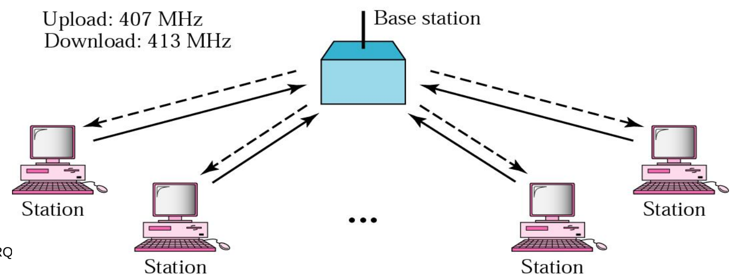


Random Access

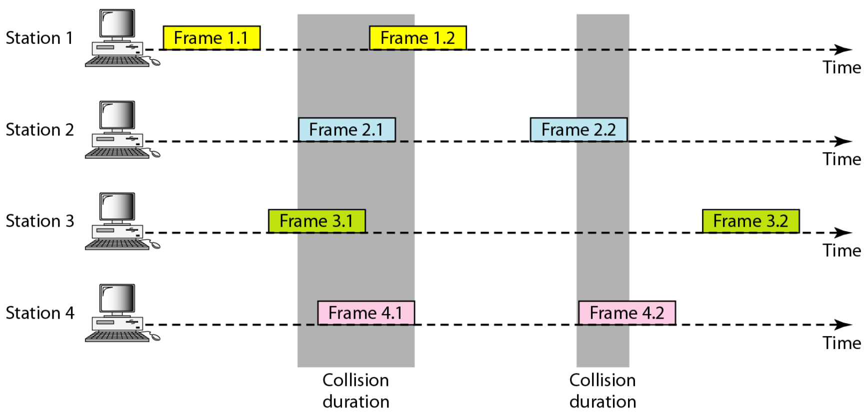
- To address access conflict, each station follows a procedure that answers the following questions:
  - When can the station access the medium?
  - What can the station do if the medium is busy?
  - How can the station determine the success or failure of the transmission?
  - What can the station do if there is an access conflict?

ALOHA

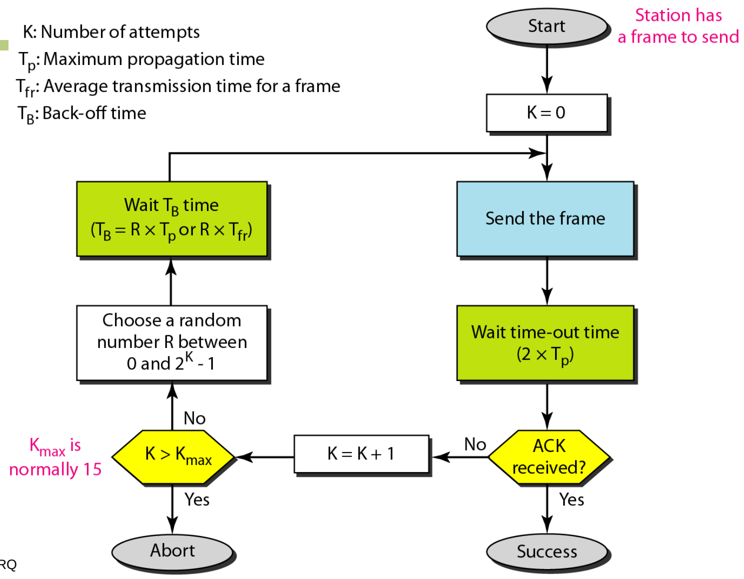
- ALOHA was designed for wireless LANs in 1970s (data rate = 9600 bps)
- A base station is the central controller
- Based on Multiple Access and ACKs



Frames in pure Aloha



Procedure for pure ALOHA



Example

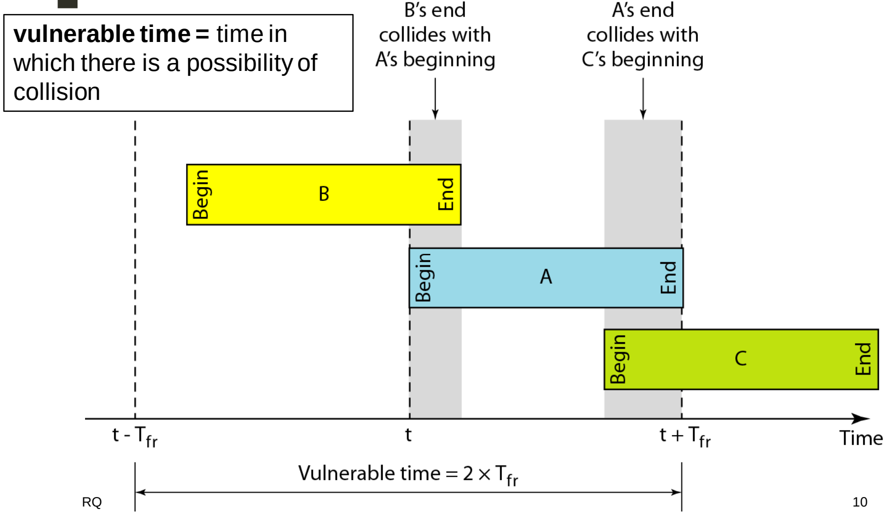
The stations on a wireless ALOHA network are a maximum of 600 km apart. If we assume that signals propagate at 3×10^8 m/s, we find

$$T_p = (6 \times 10^5) / (3 \times 10^8) = 2 \text{ ms}.$$

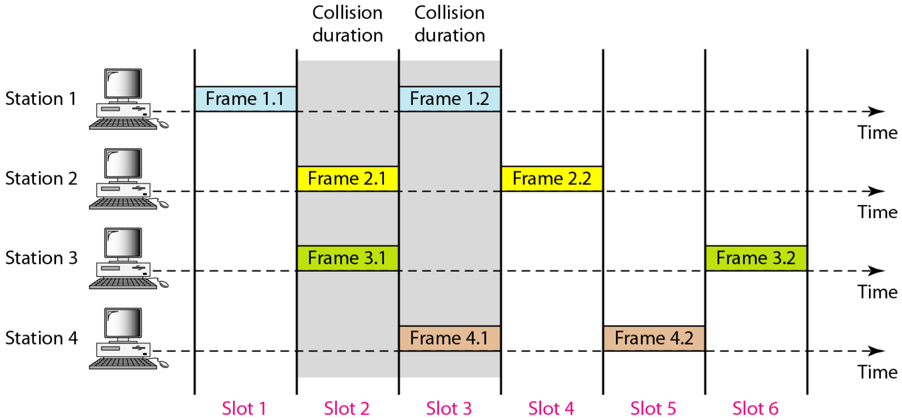
Now we can find the value of T_B for different values of K .

For example:
For K = 2, the range is {0, 1, 2, 3}. This means that T_B can be 0, 2, 4, or 6 ms, based on the outcome of the random variable.

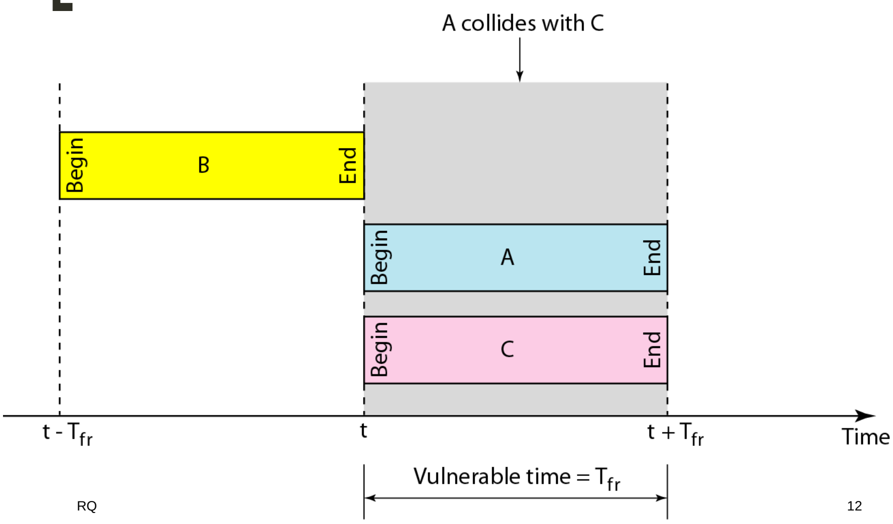
Vulnerable time for pure ALOHA



Frames in slotted Aloha



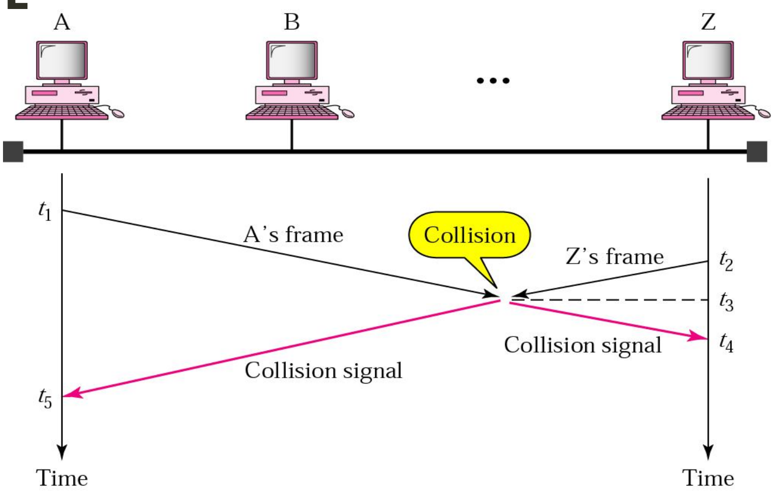
Vulnerable time for slotted ALOHA



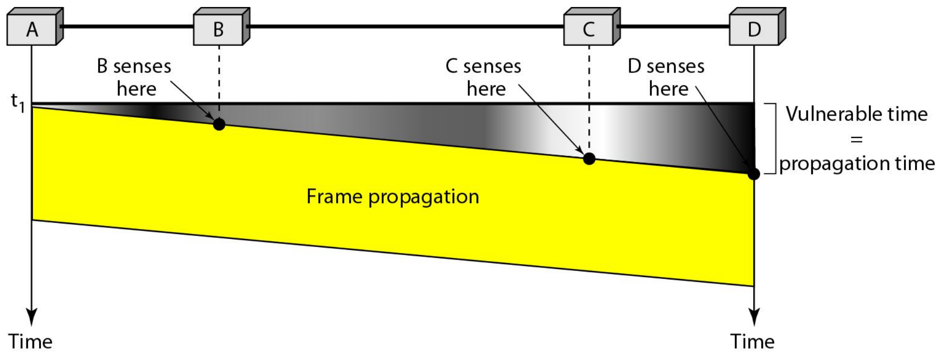
CSMA

- Carrier Sense Multiple Access
- CSMA is based on the principle “sense before transmit” or “listen before talk”.
- Chances of collision reduced by sensing the medium before transmitting
- Propagation delay hinders the elimination of collision

Collision in CSMA



Vulnerable time in CSMA

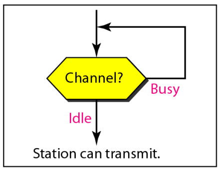


Persistence strategies

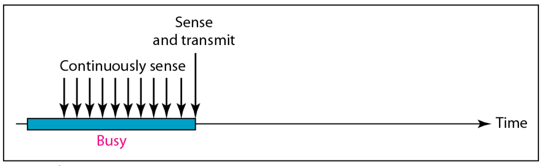
- What should a station do if the channel is busy?
- What should a station do if the channel is idle?
- Three methods have been devised to answer these questions:
  - 1-persistent method
  - Non-persistent method
  - p-persistent method

1-Persistent method

- In this method, after the station finds the line idle, it sends its frame immediately (with probability 1).
- This method has the highest chance of collision because two or more stations may find the line idle and send their frames immediately.



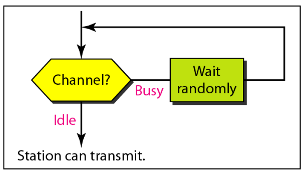
a. 1-persistent



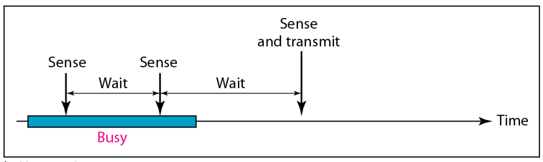
a. 1-persistent

Non-persistent 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.
- Reduces the chance of collision as it is unlikely that two stations will wait the same amount of time and retry to send simultaneously.
- Reduces the efficiency of the network as well because the medium remains idle when there may be stations with frames to send.



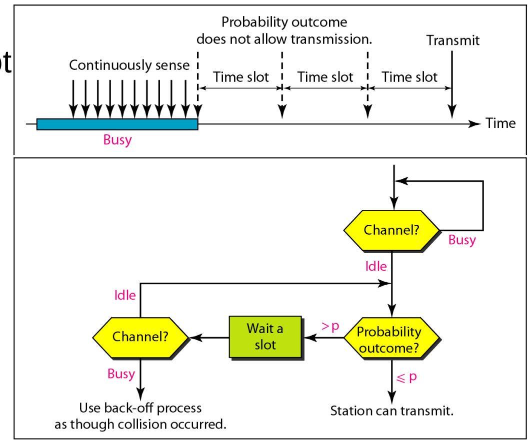
b. Nonpersistent



b. Nonpersistent

P-Persistence method

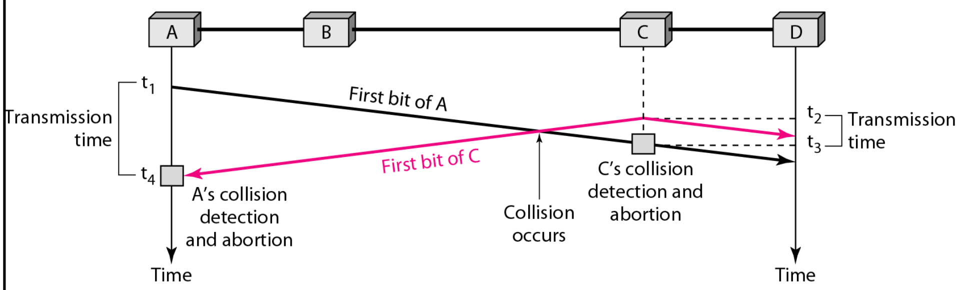
- It is used if the channel has time slots with a slot duration equal to or greater than the max propagation time.
- Combines the advantages of the other two strategies.
  - reduces the chance of collision
  - improves efficiency



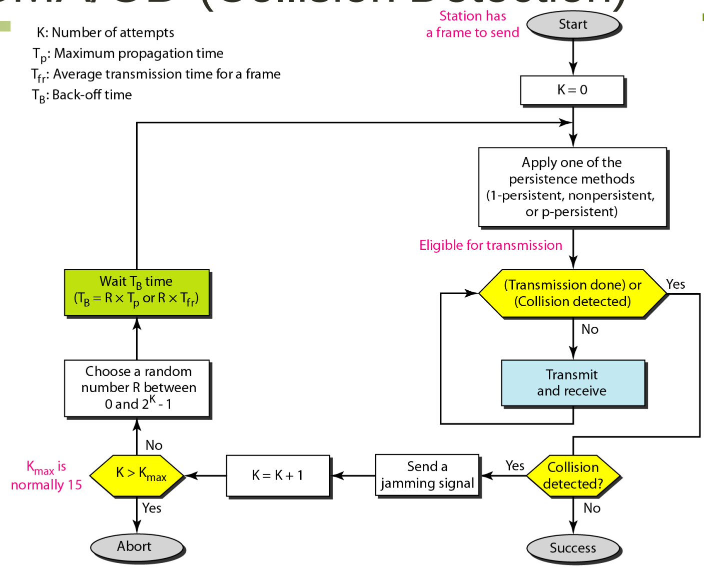
c. p-persistent

CSMA/CD (Collision Detection)

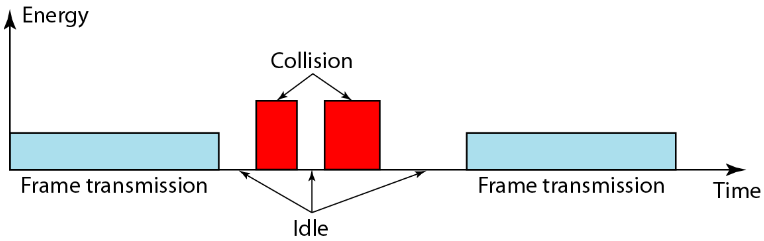
- Collision of the first bit in CSMA/CD



CSMA/CD (Collision Detection)



Energy levels

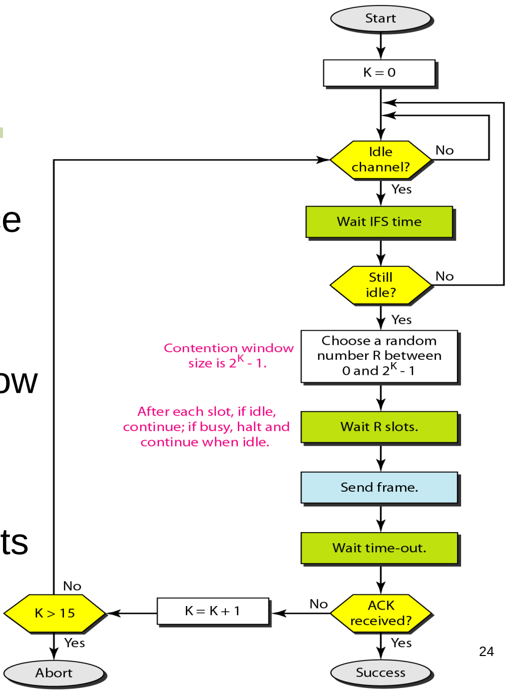


CSMA/CA (Collision Avoidance)

- In a wireless network, much of the sent energy is lost in transmission, hence collision detection is difficult.
- Collisions are avoided through the use of CSMA/CA's three strategies:
  - the inter-frame space
  - the contention window
  - acknowledgments

CSMA/CA

- inter-frame space
- contention window
- acknowledgments

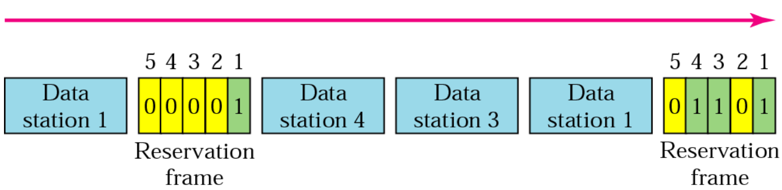


Controlled Access

- Stations consult one another to find who should transmit
- A station can not transmits until authorized by others
- Three popular methods
  - Reservation
  - Polling
  - Token Passing

Reservation

- A station needs to make a reservation before sending data
- With N stations in a system, there are N minislots in the reservation frames

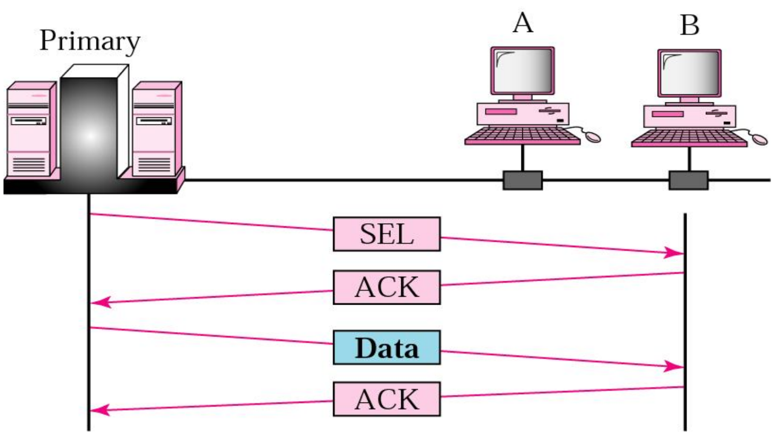


Polling

- Works with topologies having 1 primary and N secondary stations
- The primary device controls the link
- If primary device wants to send data, it *selects*
- If primary device wants to receive data, it *polls*

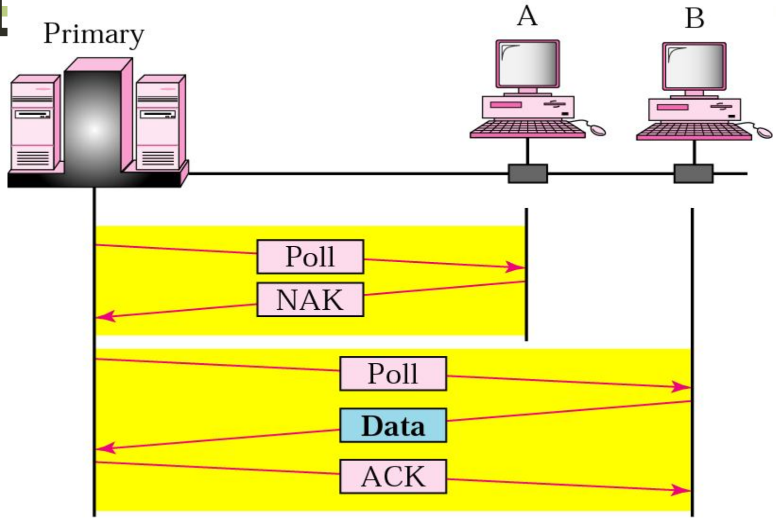
RQ 27

Select



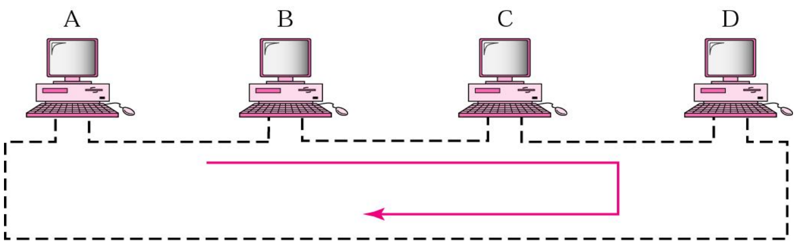
RQ 28

Poll

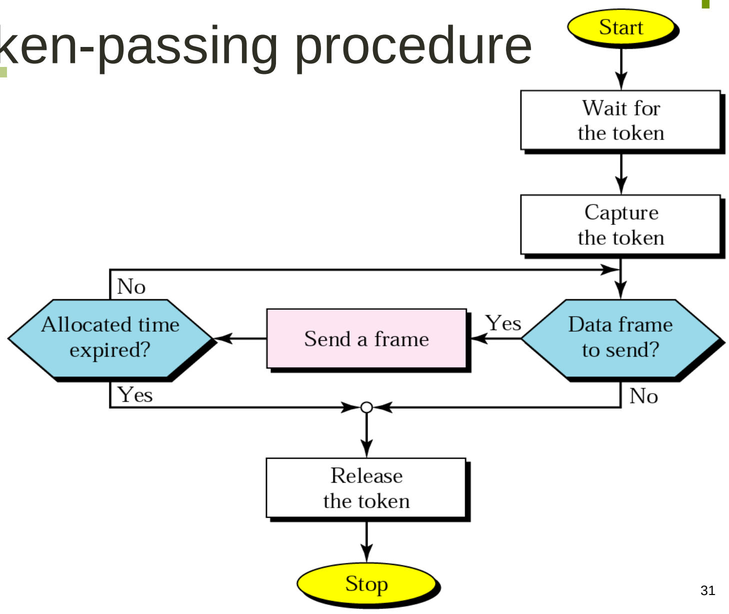


Token Passing

- A station can transmit only when it has the token



Token-passing procedure



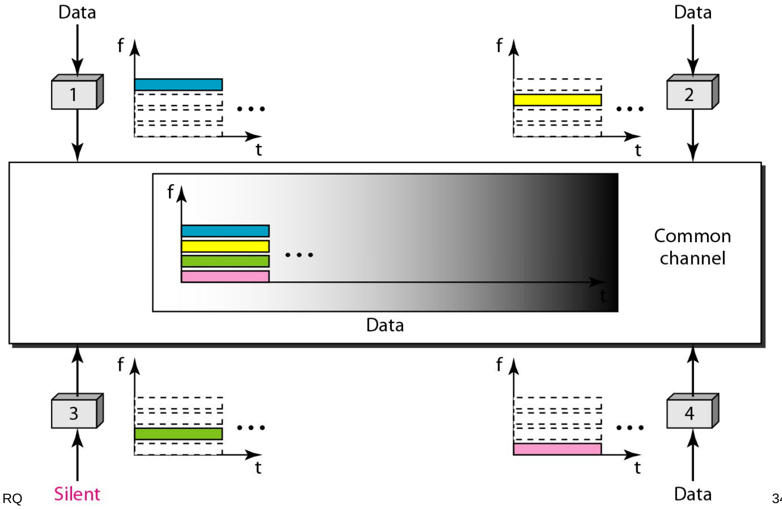
Channelization

- Available bandwidth of a link is shared in frequency, time or through code
- FDMA
- TDMA
- CDMA

FDMA

- Frequency-division multiple access
- In FDMA, the bandwidth is divided into channels.
- FDMA is a data link layer protocol that uses FDM at the physical layer

FDMA

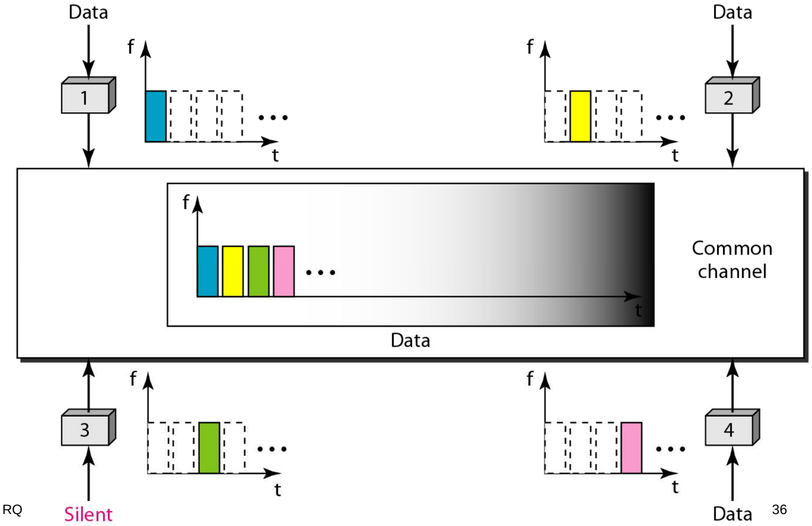


TDMA

- Time-division multiple access
- In TDMA, the bandwidth is just one channel that is timeshared
- TDMA is a data link layer protocol that uses TDM at the physical layer

RQ 35

TDMA



RQ 36

CDMA

- Code-division multiple access
- In CDMA, one channel carries all transmissions simultaneously
- It differs form FDMA and TDMA because only one channel occupies the entire bandwidth and all stations can send data simultaneously
- It is defined in International standard IS-95

CDMA basics

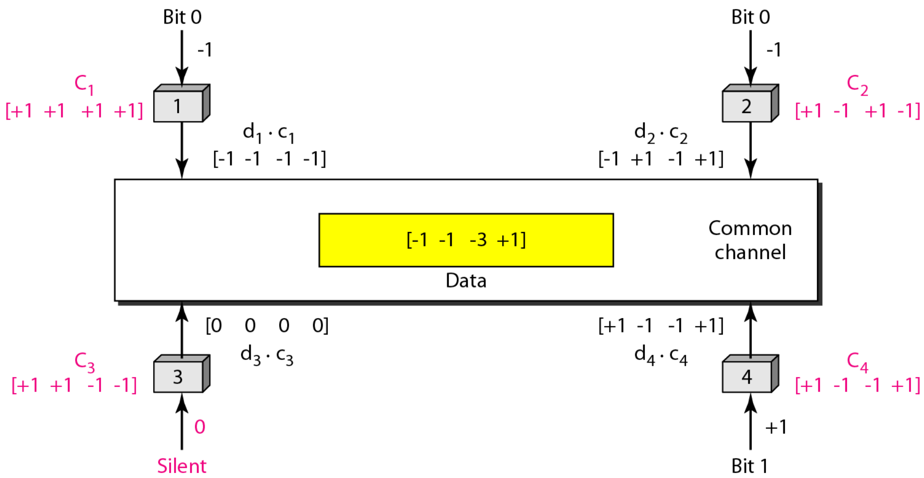
- Each bit time is subdivided into *N* short intervals called *chips*
- Typically there are 64 or 128 chips per bit
- Each station is assigned a unique *N*-bit code called a *chip sequence*

C_1	C_2	C_3	C_4
[+1 +1 +1 +1]	[+1 -1 +1 -1]	[+1 +1 -1 - 1]	[+1 -1 -1 +1]

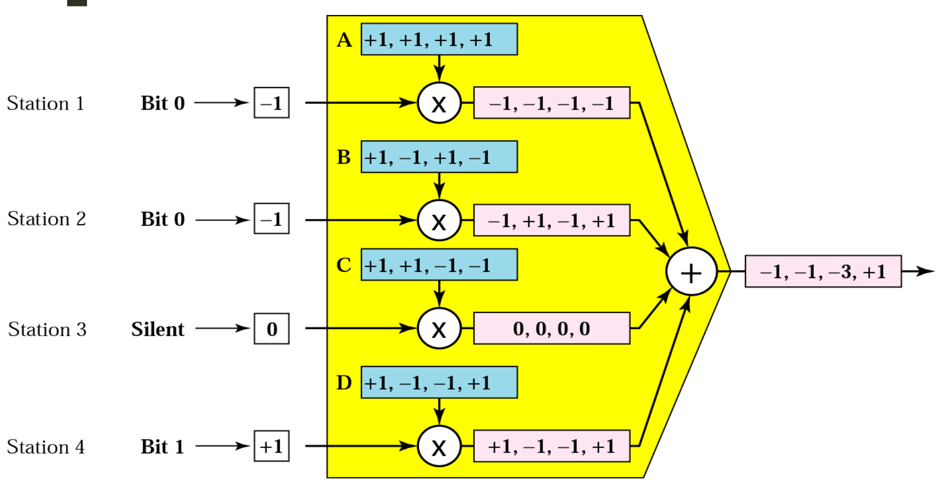
- Encoding Rule:

Data bit 0 $\rightarrow$ **−1** **Data bit 1** $\rightarrow$ **+1** **Silence** $\rightarrow$ **0**

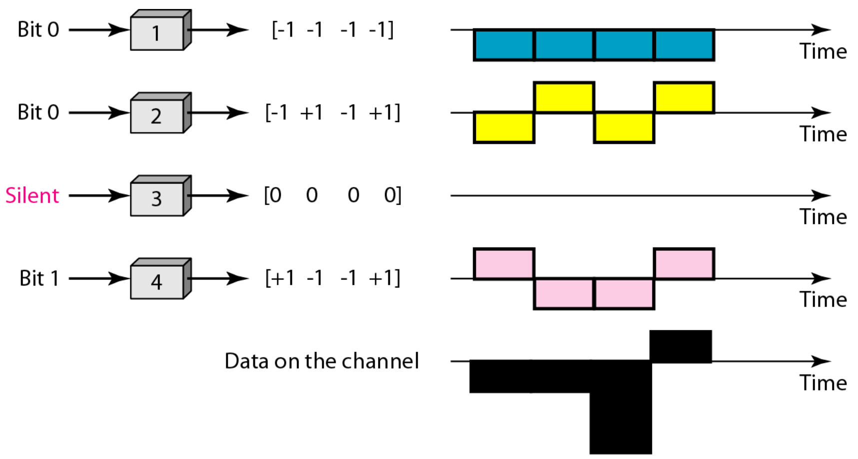
Sharing channel in CDMA



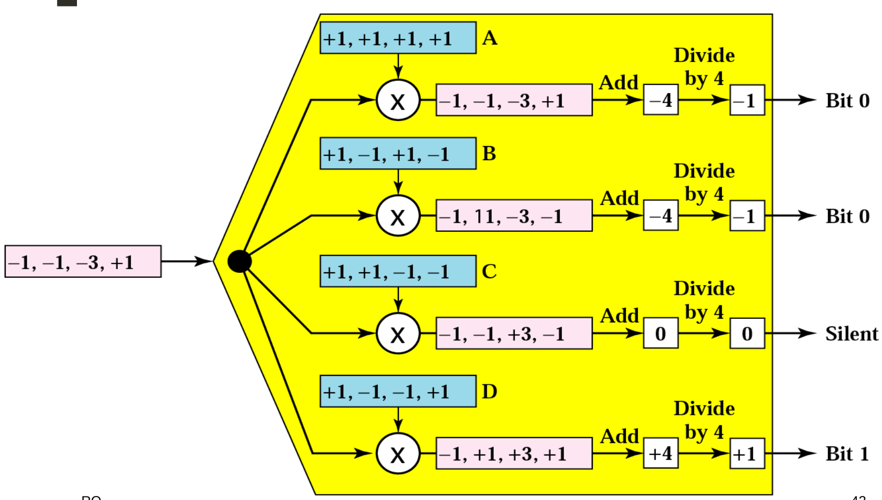
CDMA Multiplexer



Digital signal created by four stations in CDMA



CDMA Demultiplexer



Chip sequence properties

- Let us use symbol **S** (or A, B etc) for *N*-chip sequence and $\overline{\mathbf{S}}$ for its negation
- If S · T = 0, then S & T are orthogonal
  - S · T is the inner product of any two distinct chip sequences S and T
- If S · T = 0, then S · $\overline{\mathrm{T}}$ is also 0
- S · S = *N* and S · $\overline{\mathrm{S}}$ = -*N*

RQ 43

CDMA data

We can say that the data on the channel

D = (d1 · c1 + d2 · c2 + d3 · c3 + d4 · c4).

The receiver which wants to get the data sent by station 1 multiplies these data by c1.

$$\begin{aligned} D \cdot c_1 &= (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4) \cdot c_1 \\ &= d_1 \cdot c_1 \cdot c_1 + d_2 \cdot c_2 \cdot c_1 + d_3 \cdot c_3 \cdot c_1 + d_4 \cdot c_4 \cdot c_1 \\ &= d_1 \times N + d_2 \times 0 + d_3 \times 0 + d_4 \times 0 \\ &= d_1 \times N \end{aligned}$$

When we divide the result by N, we get d1 .

RQ 44

Sequence Generation – Walsh Table

- According to Walsh, if we know the table for *N* sequences W_N we can create the table for *2N* sequences W_{2N}
- The number of sequences in a Walsh table needs to be $N = 2^m$.

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \qquad W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_1, W_2, and W_4