Chapter 12

Multiple Access

Multiple-access protocols

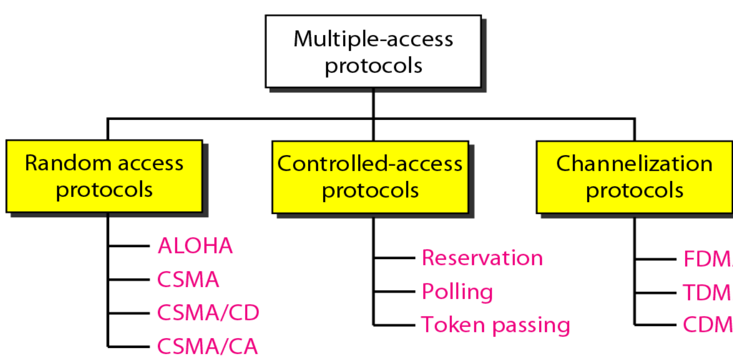
- *When more than two nodes send at the same time , the transmitted frames collide.*
- *All collide frames are lost and the bandwidth of the broadcast channel will be wasted.*
- We need multiple –access protocol to coordinate access to multipoint or broadcast link (Nodes or stations are connected to or use a common link)
- *Multiple access protocols are needed in wire and wireless LANs and satellite networks*

Multiple-access protocols

Problem of controlling the access to the medium is similar to the rules of speaking in an assembly :

- **Given everyone a chance to speak**
- **Don't speak until you are spoken to**
- **Don't monopolize the conversation**
- **Raise your hand if you have a question**
- **Don't interrupt when someone speaking**

Multiple-access protocols



1- 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. This decision depends on the state of the medium(idle or busy)

Random Access Methods:

- **ALOHA**
- **Carrier Sense Multiple Access ; CSMA**
- **Carrier Sense Multiple Access with Collision Detection (CSMA/CD)**
- **Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)**

1-RANDOM ACCESS

- **Each station has the right to the medium without being controlled by any other station.**
- **Two features gives the method its name:**
  - **There is no schedule time for a station to transmit:**

  → **transmission is random among stations**
  - **Stations compete with one another to access the medium**

  → **Contention method.**
- **Collision: an access conflict occurs when more than one station tries to send, as a result the frame will be either destroyed or modified.**

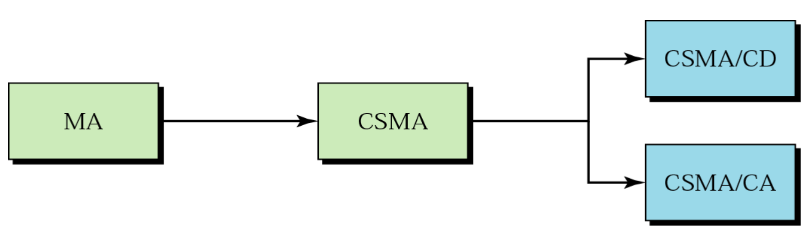
RANDOM ACCESS

Each station follows a procedure that answer the following questions to avoid collision:

- **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 (collision)?**

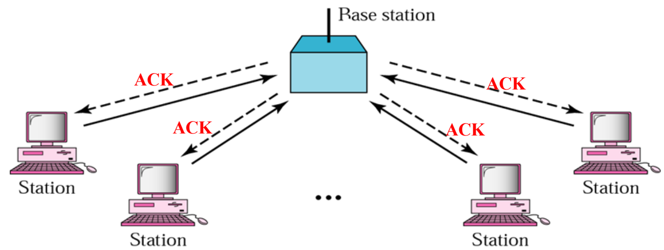
Evolution of random-access methods

- ***ALOHA* : *uses MA* (Multiple Access) No carrier sense**
- ***CSMA* : Carrier Sense Multiple Access**
- ***CSMA/CD* : Collision Detection**
- ***CSMA/CA* Collision Avoidance**

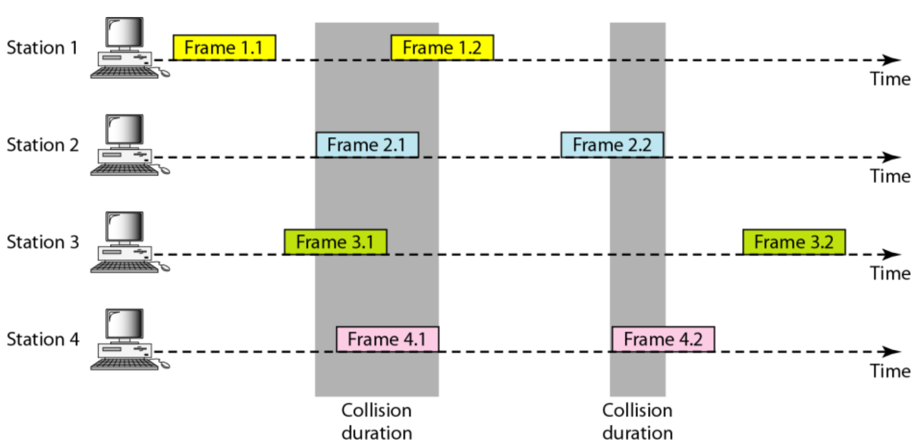


Pure ALOHA

- The earliest random access method developed at the Univ. of Hawaii in the early 1970s
- Designed for a radio (wireless) LAN
- Simple method. Each station sends a frame whenever it has a frame to send.
- Since there is only one channel to share, there is the possibility of collision between frames from different stations.



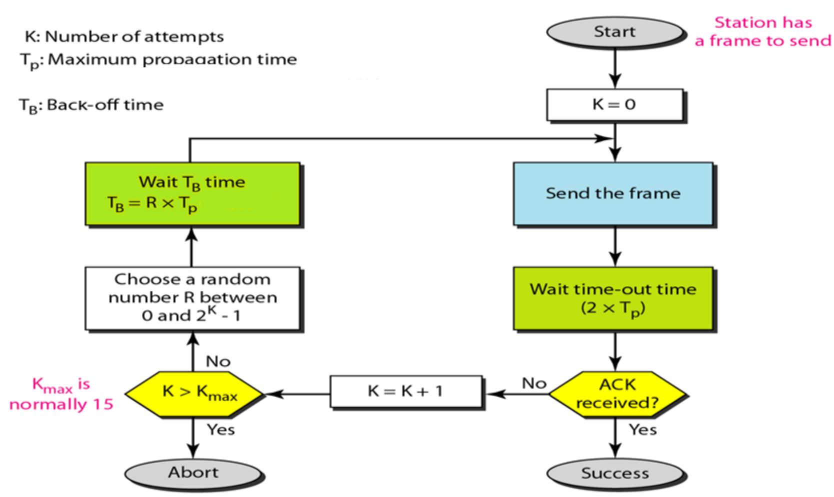
Frames in a pure ALOHA network



Pure ALOHA

- Each station sends a frame whenever it has a frame to send.
- It relies on acknowledgments from the receiver.
- If the ACK dose not arrive after a time-out period, the station resend the frame.
- time-out is equal the max possible round trip time = 2 x Tp
- Tp(max propagation time) time required to send a frame between the most widely separated station
- To minimize collisions, each station waits a random amount of time (back-off time T_B) before resending its frame.
- T_B is a random value that depend on K (the number of attempted unsuccessful transmission) .
- The formula of T_B is the binary exponential back-off.
- After a max number of retransmission attempts K_{max}, a station must give up and try later to prevent congestion.

Procedure for pure ALOHA protocol



Note: *R range from 0 to 2^k -1*

Example 1

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

$$T_p = (600 \times 10^3) / (3 \times 10^8) = 2 \text{ ms.}$$

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

a. For $K = 1$, the range R is {0, 1}. The station needs to generate a random number with a value of 0 or 1. This means that T_B is either 0 ms (0×2) or 2 ms (1×2), based on the outcome of the random variable.

Example 1 (continued)

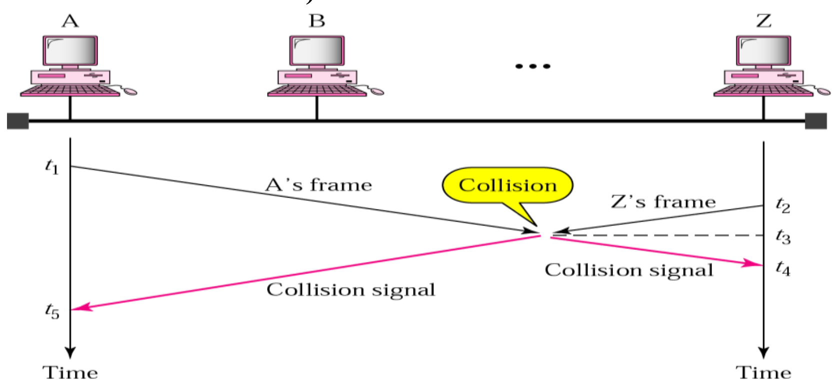
b. For $K = 2$, the range is {0, 1, 2, 3}. This means that T_B can be 0, 2, 4, or 6 ms, based on the outcome of the random variable.

c. For $K = 3$, the range is {0, 1, 2, 3, 4, 5, 6, 7}. This means that T_B can be 0, 2, 4, . . . , 14 ms, based on the outcome of the random variable.

d. We need to mention that if $K > 10$, it is normally set to 10.

Carrier Sense Multiple Access (CSMA)

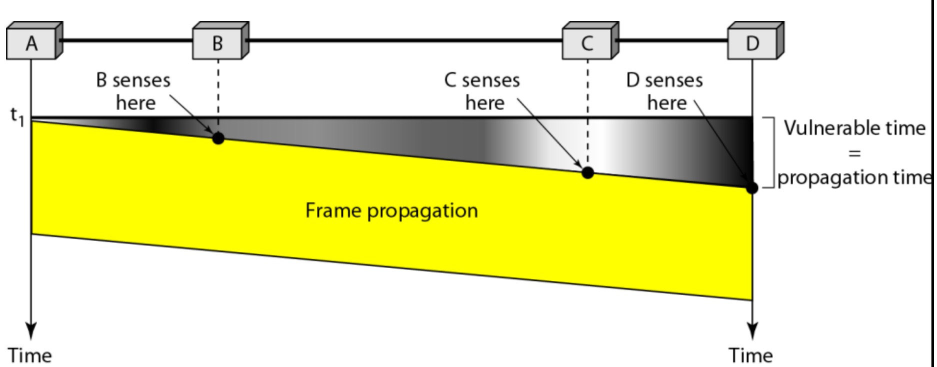
- **Sense the carrier before transmit :** ***"listen before you talk"***
- **CSMA can reduce the possibility of collision, but it can not eliminate it because of the propagation delay (a station may sense the medium and find it idle, only because the first bit of a frame sent by another station has not been received)**



Vulnerable time in CSMA

Vulnerable time : time in which there is a possibility of collision

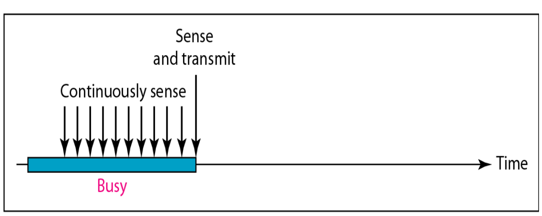
- Vulnerable time for CSMA is the **max propagation time Tp** needed for a signal to propagate from one end of the medium to the other



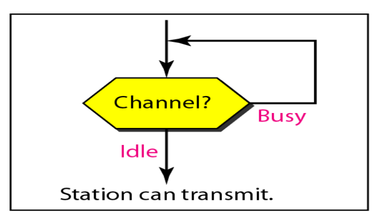
persistence methods

- *What should a station do if the channel is busy?*
- *What should a station do if the channel is idle?*

1-persistence methods



a. 1-persistent

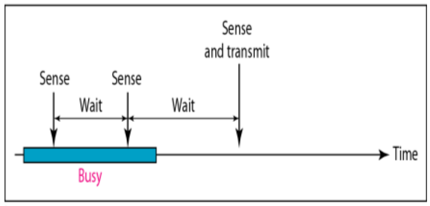


a. 1-persistent

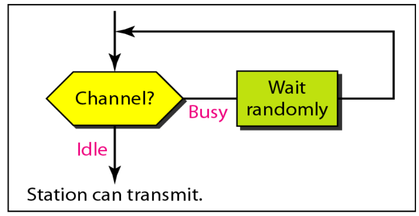
- **When the sender (station) is ready to transmit data, it checks if the medium is busy. If so, it senses the medium continually until it becomes idle**
- **If line is idle, sends the frame immediately (with probability of 1).**

Chances of collision is high.

non-persistence methods



b. Nonpersistent



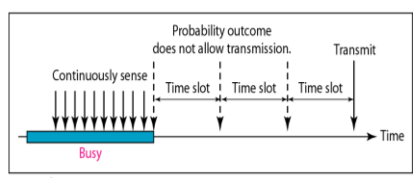
b. Nonpersistent

- If a station has a frame to send, it senses the line.
- If line is idle, the station sends the frame immediately.
- If line is not idle, the station **waits a random period of time** and then senses the line again.
  - **Chances of collision is reduced**
  - **Reduces efficiency of the network (because the medium remain idle when there may be stations with frames to send**

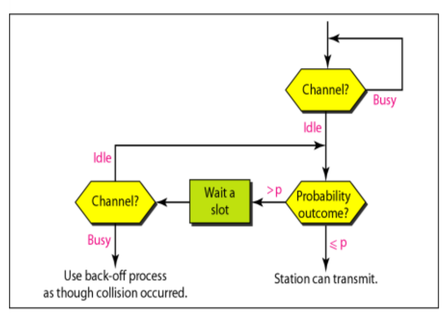
P- Persistence

- **It used if the channel has time slots with a slot duration equal to or grater than the maximum propagation time.**
- **When the sender (station) is ready to transmit data, it checks if the medium is busy. If so, it senses the medium continually until it becomes idle.**
- **If line is idle it may or may not send. It sends with probability p.**

  - **Reduces the chance of collision and improves the efficiency by combining the other two strategies**



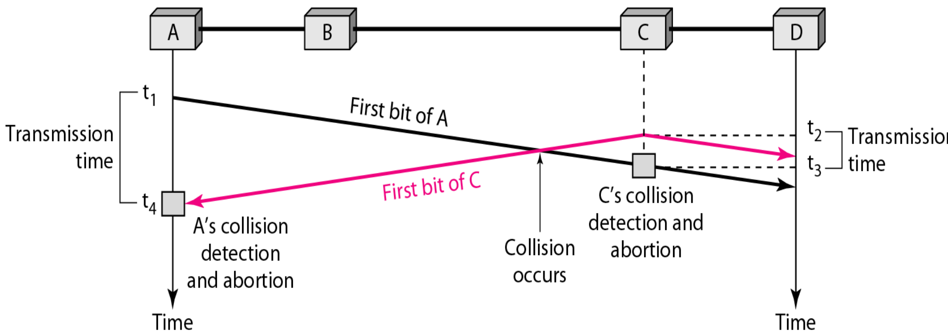
c. p-persistent



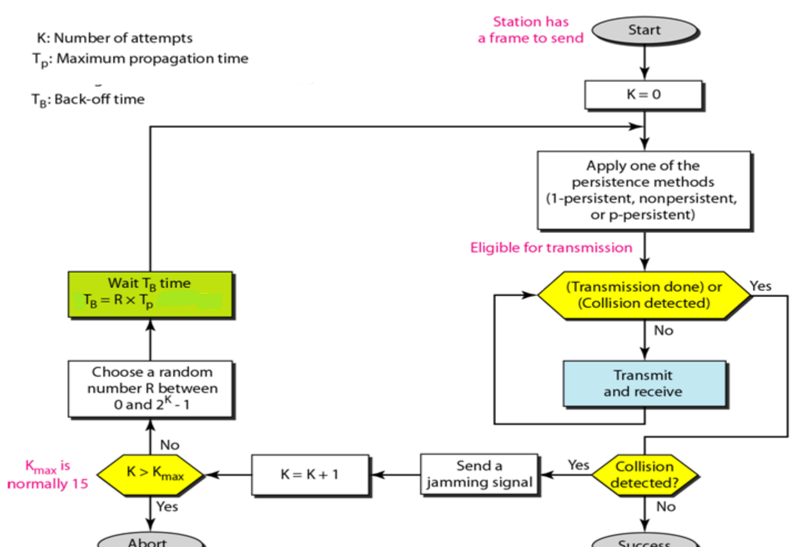
c. p-persistent

Carrier Sense Multiple Access collision detection CSMA/CD

"***Listen-while-talk***" **protocol. A host listens even while it is transmitting, and if a collision is detected, stops transmitting**



Flow diagram for the CSMA/CD

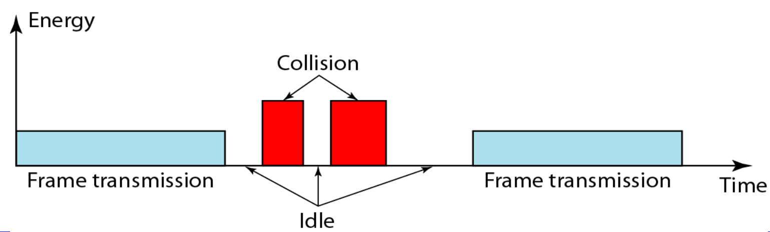


Collision Detection

How the station detects a collision?

- **Detecting voltage level on the line**
- **Detecting energy level .**

- **Energy in channel can have three values: zero, normal, and abnormal.**
- **at zero level, the channel is idle**
- **At the normal level, a station has successfully captured the channel and is sending its frame.**
- **At the abnormal level, there is a collision and the level of the energy twice the normal level.**



Minimum frame size

- ***For CSMA/CD to work correctly we need to restrict the minimum frame size.***
- ***Before sending the last bit of a frame , the sending station must detect a collision and abort the transmission.***
- ***This is so because the station, once the entire frame is sent does not keep a copy of the frame and does not monitor the line of collision detection.***
- ***For the worst case scenario; if the two stations involved in a collision are the max distance apart***

$$\textit{transmission time} >= 2 \ x \ \ \textit{max. propagation time}$$

$$T_{fr} >= 2 \ X \ \ T_p$$

$$(\textit{MinFrame size})/B\text{-}W = 2 \ X \ Tp$$

Example 2:

A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal) is 25.6 μs, what is the minimum size of the frame?

Solution

The frame transmission time is $T_{fr} = 2 \times T_p = 51.2$ μs. This means, in the worst case, a station needs to transmit for a period of 51.2 μs to detect the collision.

The minimum size of the frame = 10 Mbps × 51.2 μs
= 512 bits or 64 bytes.

This is actually the minimum size of the frame for Standard Ethernet.

2 - CONTROLLED ACCESS

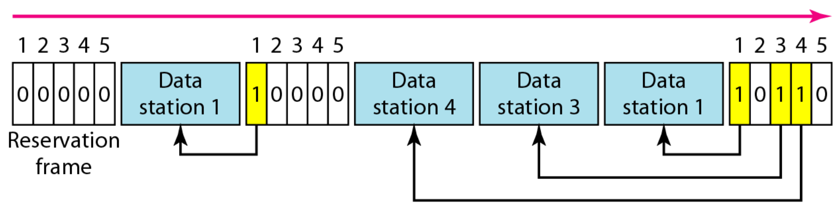
In controlled access, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations. We discuss three popular controlled-access methods.

Controlled Access merhods

Reservation
Polling
Token Passing

Reservation access method

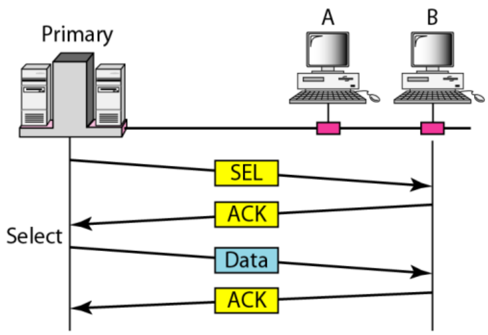
- A station needs to make a reservation before sending data.
- Time is divided into intervals
  - A reservation frame proceeds each time interval
  - Number of stations and number of mini-slots in the reservation frame are equal
  - Each time slot belongs to a particular station
  - If there are N stations in the system, there are exactly N reservation mini-slots in the reservation frame



Polling access method

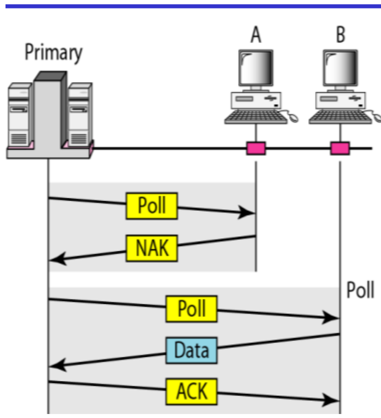
- Devices are designated as a **Primary station** and **secondary station.**
- All data exchange must go through the primary station
- **Primary** station controls the link and **initiates** the session; the secondary station follow its instructions.
- Two functions: **polls** and **select**
  - **Poll** : If the primary wants to **receive data**, it asks the secondary if they have anything to send.
  - **Select:** if the primary wants to **send data**, it tells the secondary to get ready to receive data

Select function



- The select function is used when the primary has frames to send.
- The primary creates and transmits a select (SEL) frame.
- SEL alerts the secondary to the upcoming transmission
- The primary waits for ACK to send the data

Poll function



- When the primary is ready to receive data, it must ask (Poll) each device in turn if it has anything to send.
- When the first secondary is approached, it responds either with a NAK frame if it has nothing to send or with data if it does.
- If the response is NAK, the primary polls the next secondary.
- If it receives data, it sends ACK frame.

Token Passing

- In the token-passing, the stations are organized in a **logical ring.**
- For each station there is a predecessor and a successor
- predecessor is the station which is logically before the station in the ring
- The successor is the station which is logically after the station in the ring
- The current station is the one that accessing the channel now.

How is The right to access channel passed from one station to another?

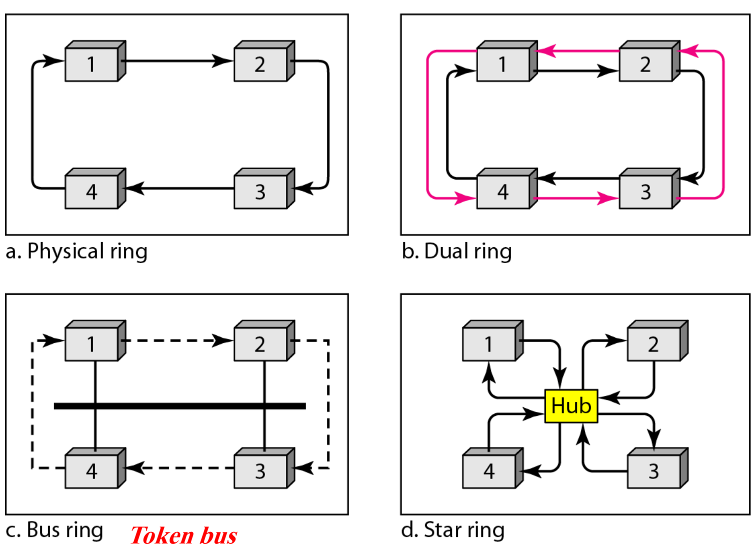
Token Passing

- Station is authorized to send data when it receives a special frame called a **token**
- Stations are arranged around a ring.
- When no data are being sent, a token circulates the ring.
- If a station needs to send data, it waits for the token.
- The station captures the token and sends one or more frames (as long as it has frames to send or the allocated time has not expired), and finally it releases the token to be used by next station (successor).
- The maximum time any station can hold the token is limited.
- Since there is only one token, only one station transmits at a time, and **collisions never occur.**

Token Passing

- **Token management is needed for this access method:**
  - **Stations must be limited in the time they can have possession of the token**
  - **the token must be monitored to ensure it has not been lost or destroyed(if the station that is holding the token fails, the token will disappear from the network)**
  - **Assign priorities to the stations , to make low-priority stations release the token to high priority stations.**
- **Stations do not have to be physically connected in a ring ; the ring can be logical one**

Logical ring and physical topology in token-passing access method



3. CHANNELIZATION

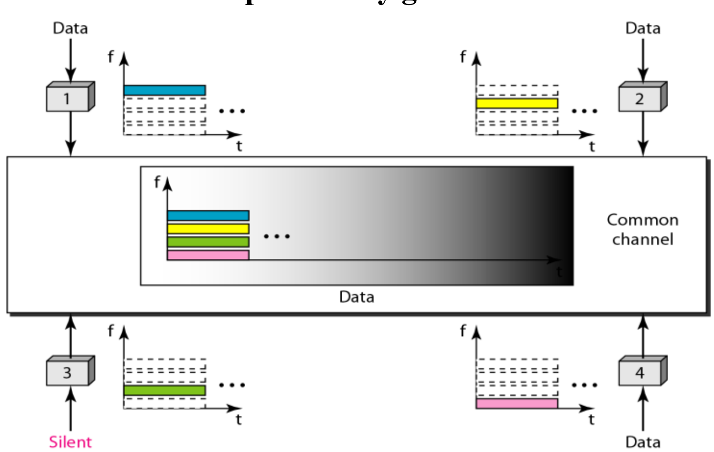
***Channelization* is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.**

Channelization methods:

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

Frequency-division multiple access (FDMA)

Available bandwidth of the common channel is divided into bands that are separated by guard bands

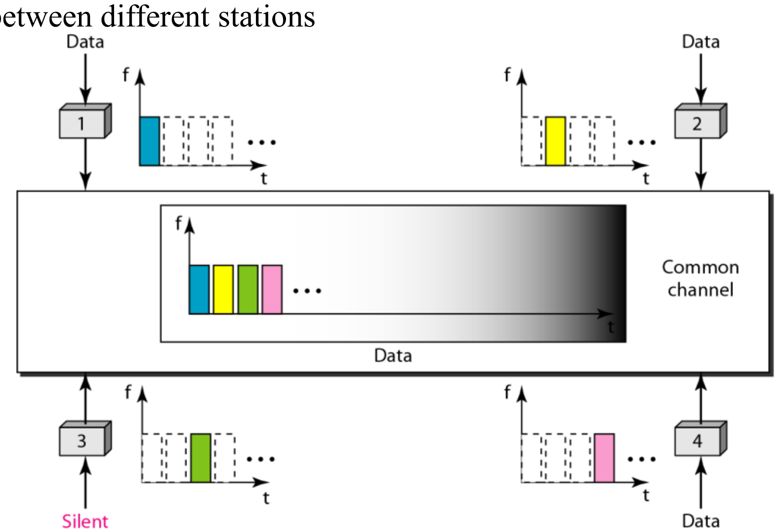


Note

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

Time-division multiple access (TDMA)

The bandwidth is just one channel that is timeshared between different stations



Note

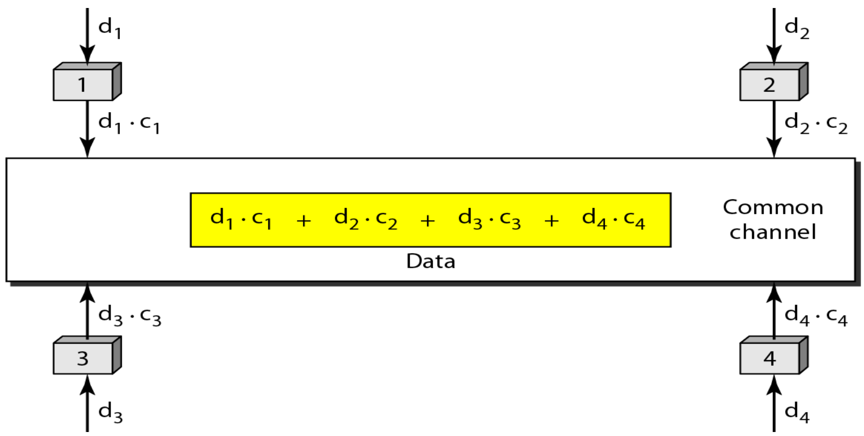
In TDMA, the bandwidth is just one channel that is timeshared between different stations.

Code Division Multiple Access: CDMA

Note

In CDMA, one channel carries all transmissions simultaneously.

Simple idea of communication with CDMA



Simple idea of communication with CDMA

- **One channel carries all transmissions simultaneously**
- **Two properties that the assigned cods have:**
  - **If we multiply each code by another, we get 0.**
  - **If we multiply each code by itself, we get number of channel**
- **Each station wants to receive data from one of other stations multiplies the common data on the channel by the code of the sender**

Example 3

Prove that a receiving station can get the data sent by a specific sender if it multiplies the entire data on the channel by the sender's chip code and then divides it by the number of stations.

Solution

Let us prove this for the first station, using our previous four-station example. We can say that the data on the channel

$D = (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4).$

The receiver which wants to get the data sent by station 1 multiplies these data by c_1.

Example 3 (continued)

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

When we divide the result by N, we get d_1.

Chip sequences

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

Orthogonal sequences have the following properties:

- Each sequence is made of N elements, where N is the number of stations
- If we multiply a sequence by a number, every element in the sequence is multiplied by that element (scalar multiplication)
- If we multiply two equal sequence, element by element, and add the results, we get **inner product = N**
- If we multiply two different sequence, element by element, and add the results, we get **inner product = 0**
- Adding two sequence means adding the corresponding elements. The result is another sequence

General rule and examples of creating Walsh tables

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

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

Note

The number of sequences in a Walsh table needs to be $N = 2^m$.

Example 4

Find the chips for a network with
a. Two stations ***b. Four stations***

Solution
We can use the rows of W_2 and W_4 in Figure slide 46
a. For a two-station network, we have

[+1 +1] and [+1 −1].

b. For a four-station network we have

[+1 +1 +1 +1], [+1 −1 +1 −1],
[+1 +1 −1 −1], *and* [+1 −1 −1 +1].

Example 5

What is the number of sequences if we have 90 stations in our network?

Solution

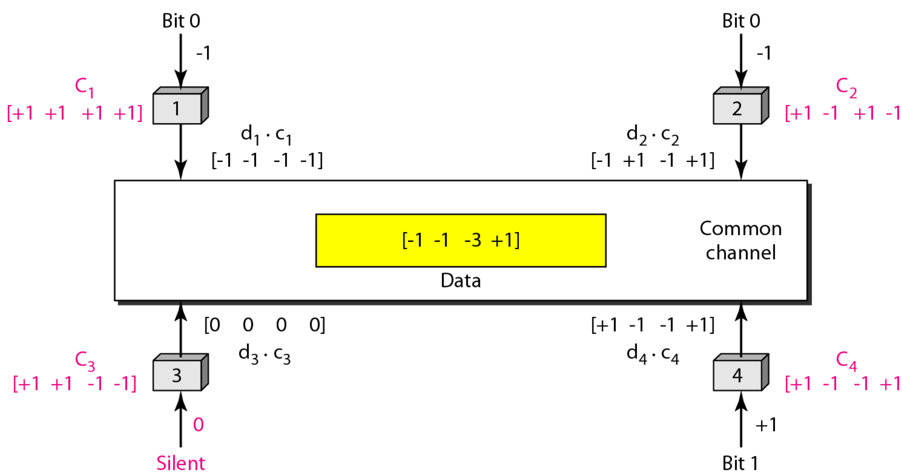
The number of sequences needs to be 2^m. We need to choose $m = 7$ and Number of sequences = 2^7 or 128.
We can then use 90 of the sequences as the chips.

Data representation in CDMA

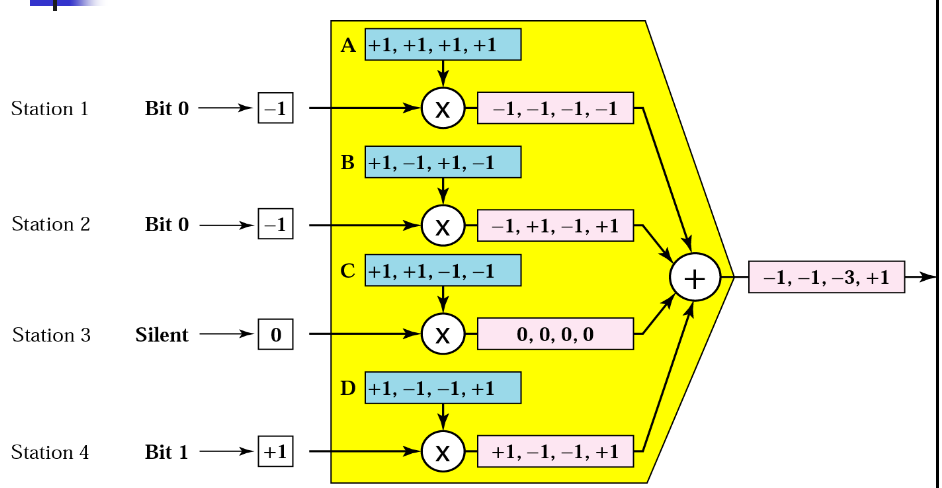
Data bit 0 → -1	Data bit 1 → +1	Silence → 0

Example 6

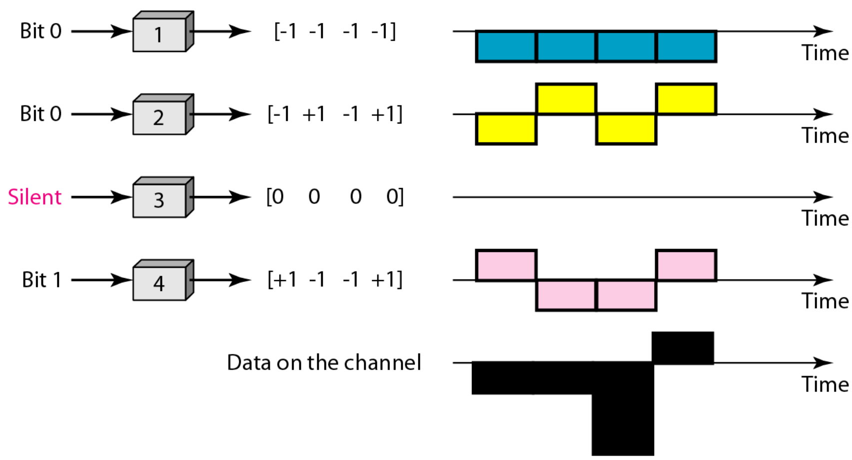
Show how four stations share the link during a 1-bit interval?



CDMA Multiplexer



Digital signal created by four stations in CDMA



Decoding of the composite signal for one in CDMA

Any station can detect the data sent for example by station 2 by using the code of station 2 as follow:

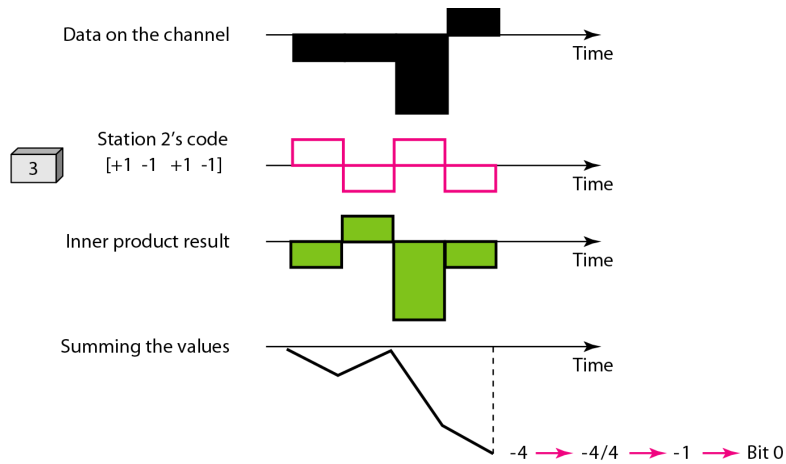
[-1 -1 -3 +1] x [+1 -1 +1 -1] = [-1 +1 -3 -1]

= - 4 /4(no of stations)

= -1

-1 means bit 0

Decoding of the composite signal for one in CDMA



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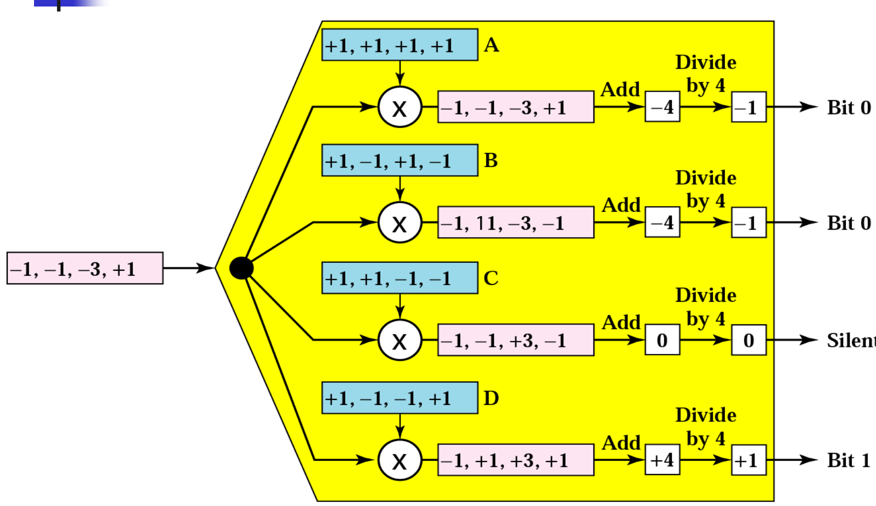
CDMA demultiplexer



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