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Multiple Access

Module 2

Data Link Layer

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Multiple Access

Outline:

- Multiple access mechanisms
- Random access
- Controlled access
- Channelization

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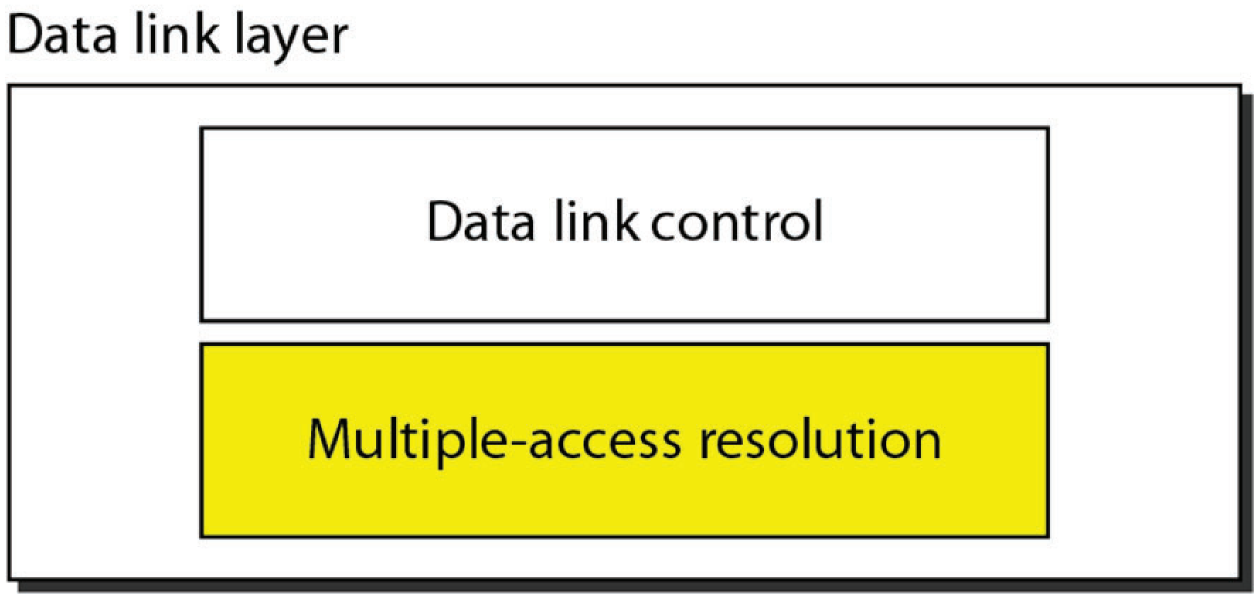
Sublayers of Data Link Layer

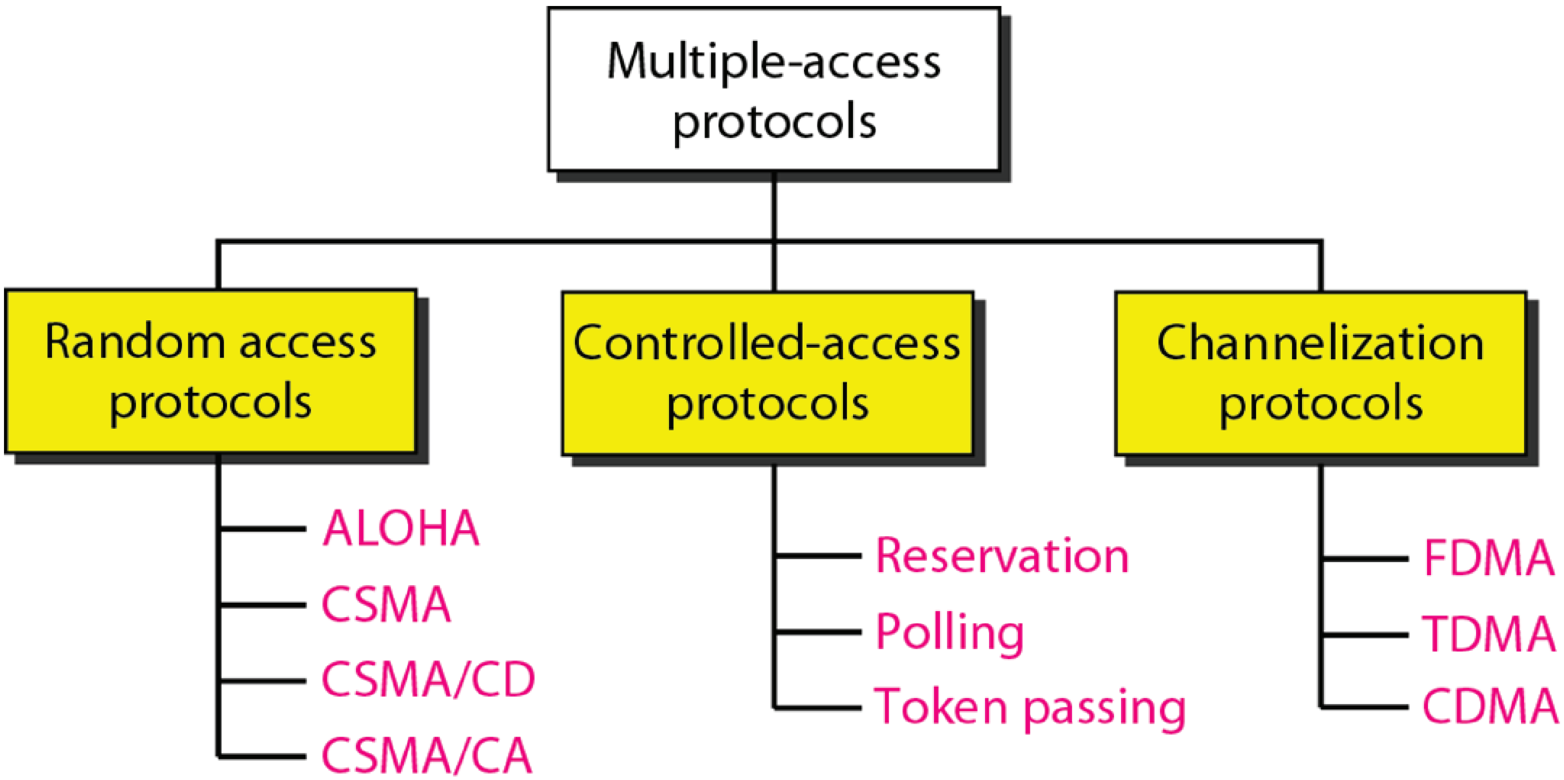


Sublayers of Data Link Layer

- The upper sub layer that is responsible for flow and error control is called the **logical link control (LLC) layer.**

- Lower sub layer that is mostly responsible for multiple access resolution is called the **media access control (MAC) layer.**

Multiple Access Mechanisms



Random Access

- Also called *contention-based access*
- No station is assigned to control another
- 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.

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Random Access

- Transmission is random among the stations - *random access.*
- Stations compete with one another to access the medium - *contention methods*.
- each station has the right to the medium without being controlled by any other station
  - more than one station tries to send
  - access conflict-collision - and the frames destroyed or modified.

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ALOHA Network

When a station sends data, another station may attempt to do so at the same time. The data from the two stations collide and become garbled.

- ✓ Pure Aloha
- ✓ Slotted Aloha

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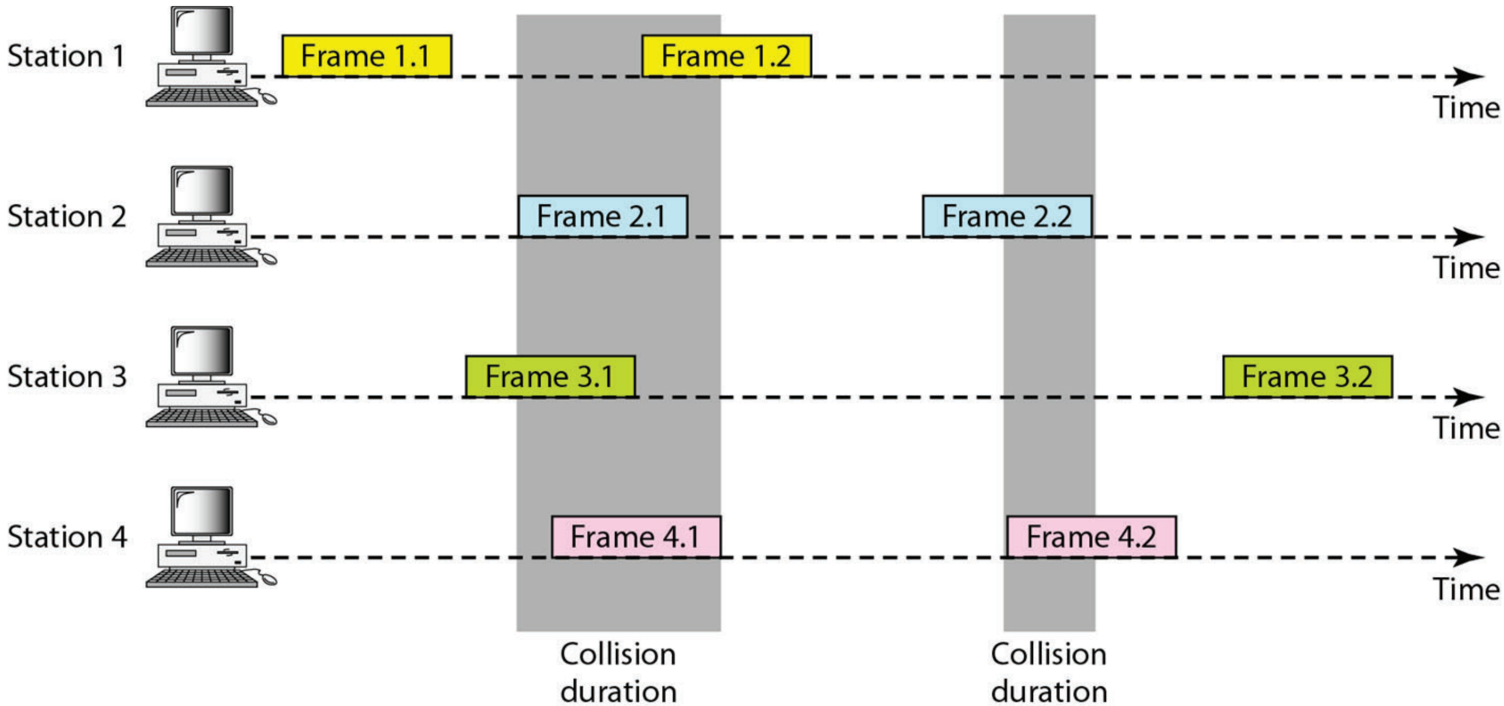
Pure ALOHA

- The idea is that 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.
- Even if one bit of a frame coexists on the channel with one bit from another frame, there is a collision, and both will be destroyed.

Frames in Pure ALOHA



Pure ALOHA

- Resend the frames that have been destroyed during transmission - acknowledgments from the receiver.
- Timeout – resend the frame
- Pure ALOHA - when the time-out period passes, each station waits a random amount of time before resending its frame.

Pure ALOHA

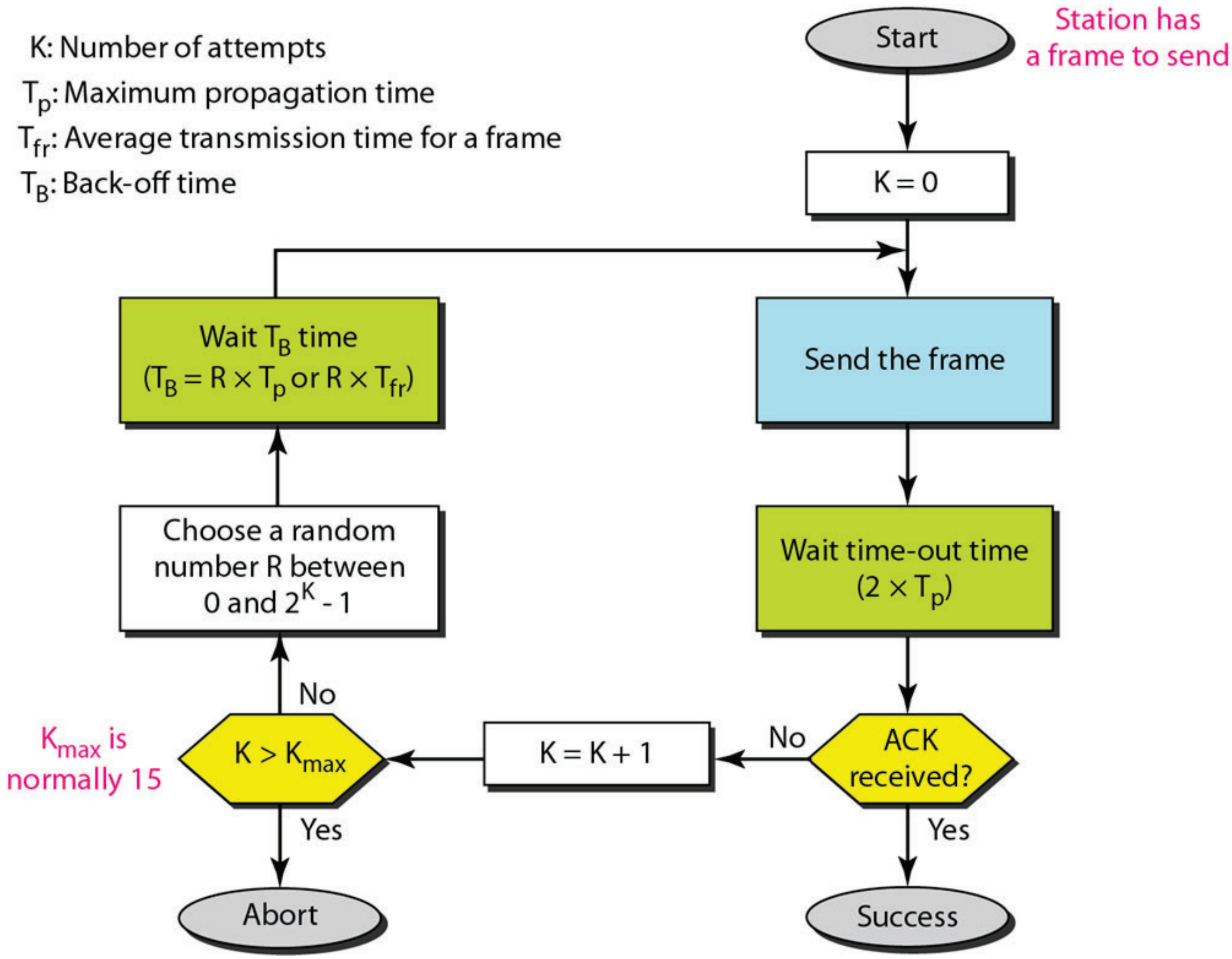
- The randomness will help avoid more collisions.
- *Random time – Back off time T_B*
- Second method to prevent congesting the channel with retransmitted frames.
- Maximum number of retransmission, K_{max} , after that give up and try later.

K: Number of attempts

T_p: Maximum propagation time

T_{fr}: Average transmission time for a frame

T_B: Back-off time



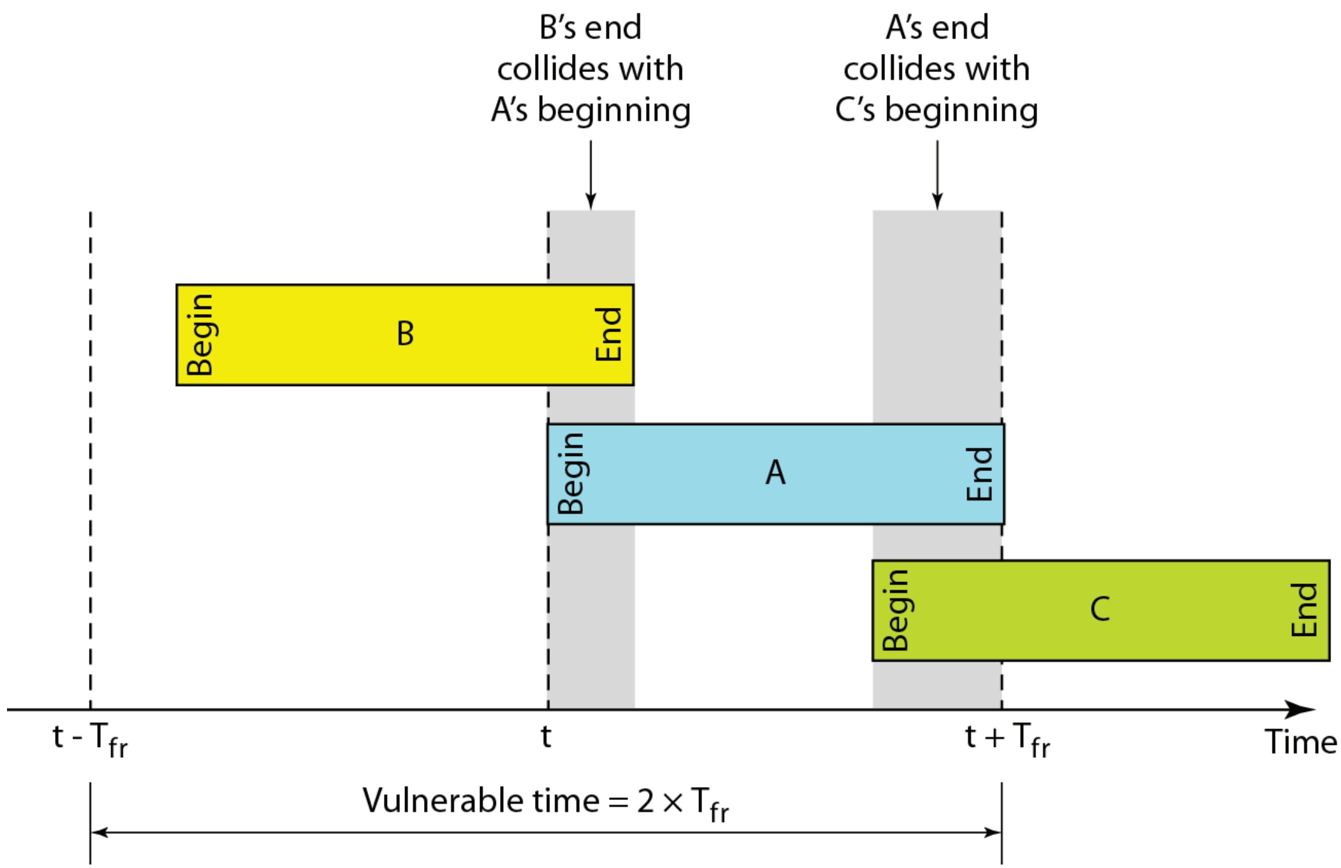
Example

Calculate possible values of T_B when stations on an ALOHA network are a maximum of 600 km apart; signal propagates at 3×10^8 m/s.

$$T_p = (600 \times 103) / (3 \times 10^8) = 2 \text{ ms}$$

When K=1, $T_B \in \{0 \text{ ms}, 2 \text{ ms}\}$
When K=2, $T_B \in \{0 \text{ ms}, 2 \text{ ms}, 4 \text{ ms}, 6\text{ms}\}$

ALOHA: Vulnerable Time



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ALOHA: Throughput

- Assume number of stations trying to transmit follow *Poisson Distribution*

- The throughput for pure ALOHA is:

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

where G is the *average number of frames requested/generated by the system per frame-time*

- The maximum throughput

$$S_{max} = 0.184 \text{ when } G= 1/2$$

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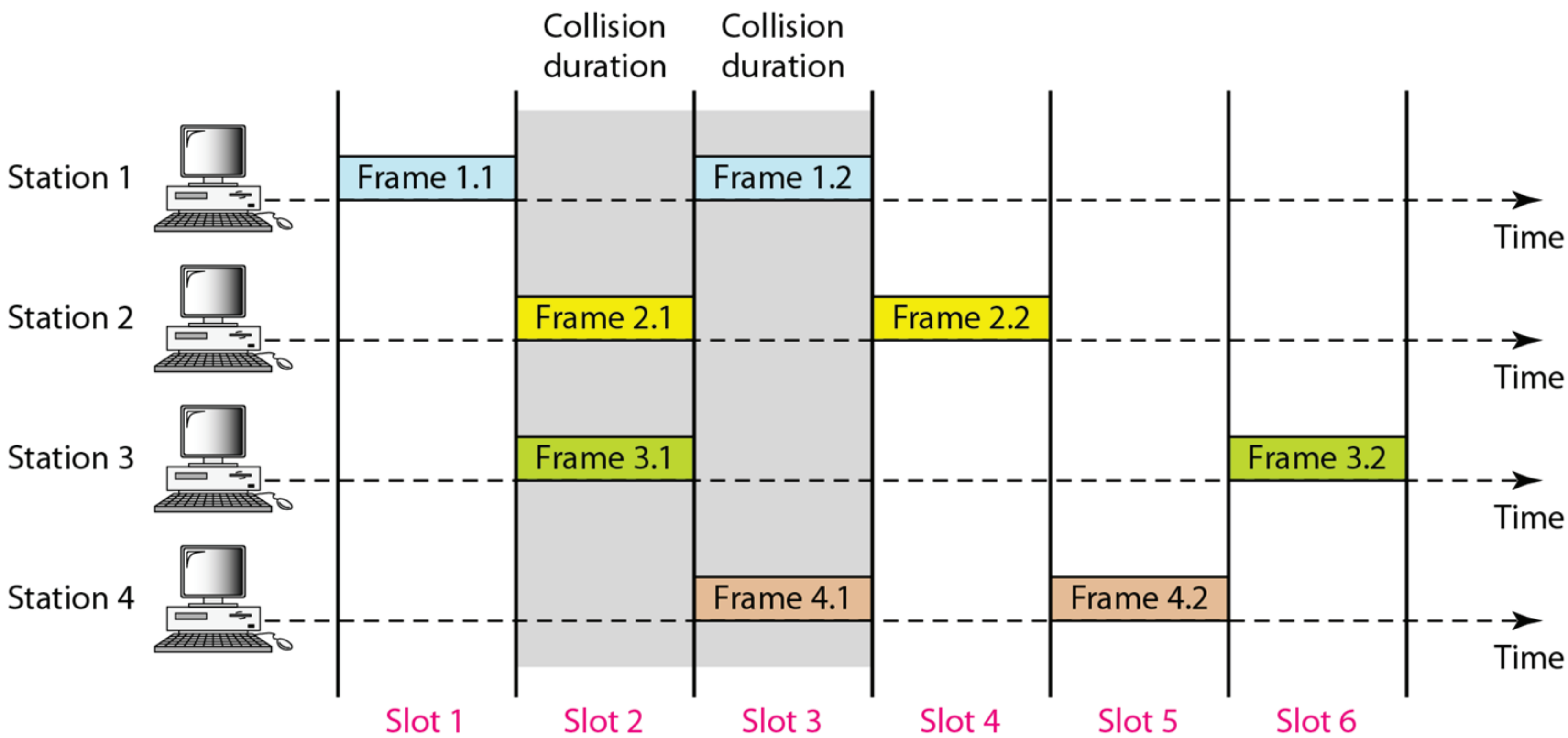
Slotted ALOHA



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Slotted ALOHA

- Pure ALOHA has a vulnerable time of $2 \times T_{fr}$ - no rule that defines when the station can send.
- Slotted ALOHA was invented to *improve the efficiency* of pure ALOHA.
- Slotted ALOHA divide time into slots of T_{fr} and force the station to send only at the beginning of the time slot.

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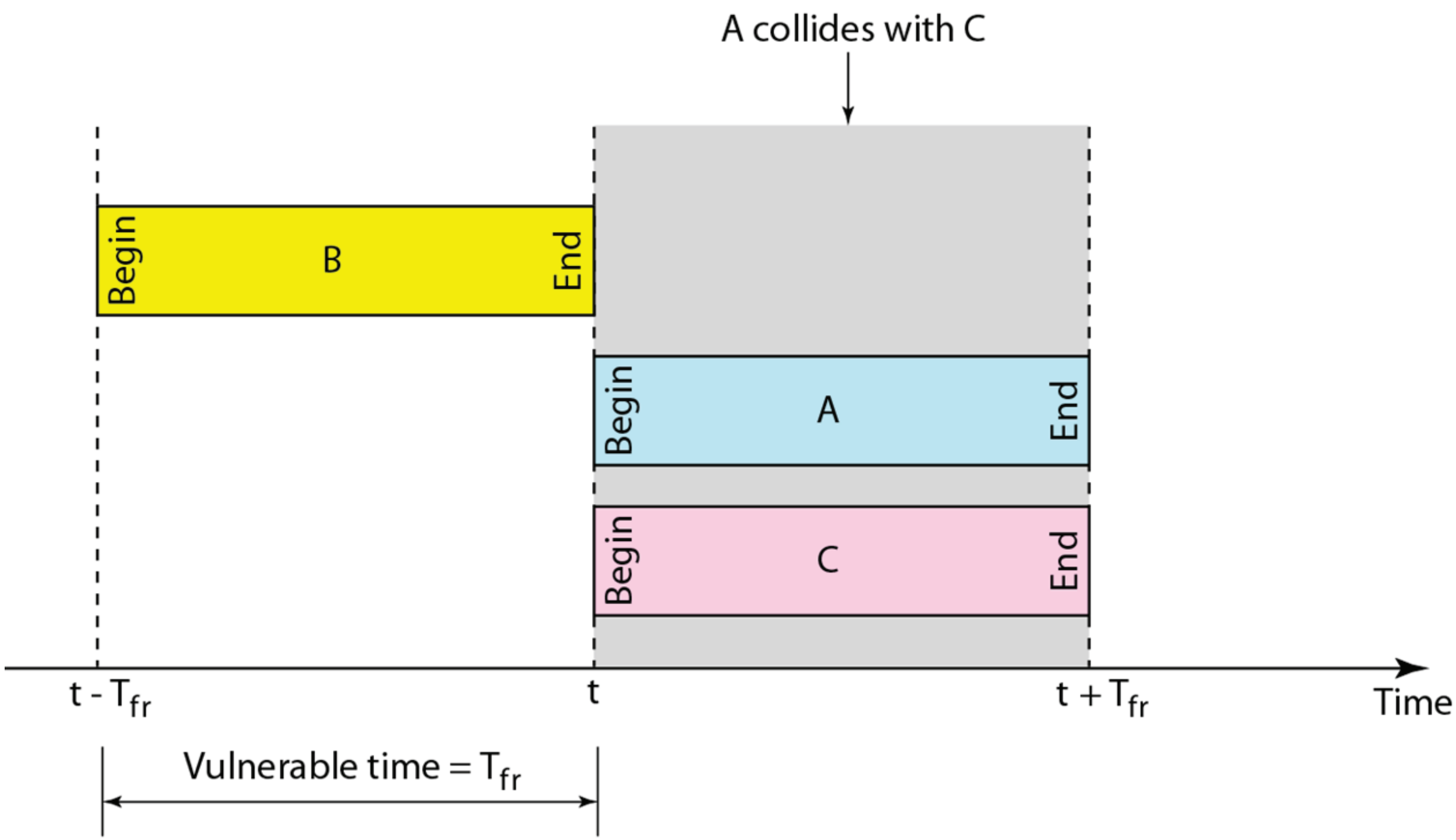
Slotted ALOHA: Vulnerable Time



Slotted ALOHA: Throughput

- The throughput for Slotted ALOHA is

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

where G is the average number of frames requested per frame-time

- The maximum throughput

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

CSMA

- **C**arrier **S**ense **M**ultiple **A**ccess

  "Listen before talk“

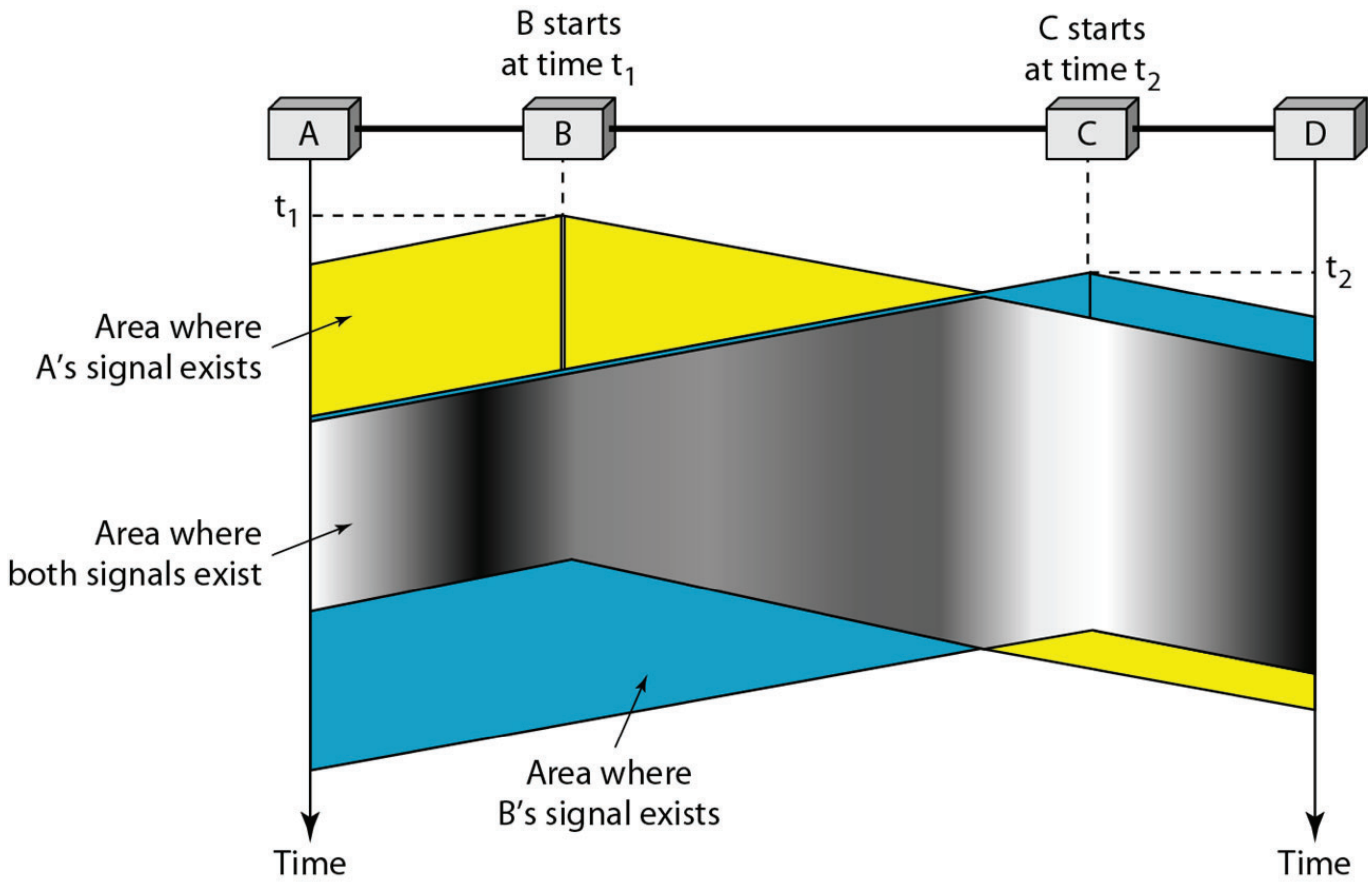
- Reduce the possibility of collision, but *cannot completely eliminate* it

- Carrier sense multiple access (CSMA) requires that each station first check the state of the medium before sending.

CSMA

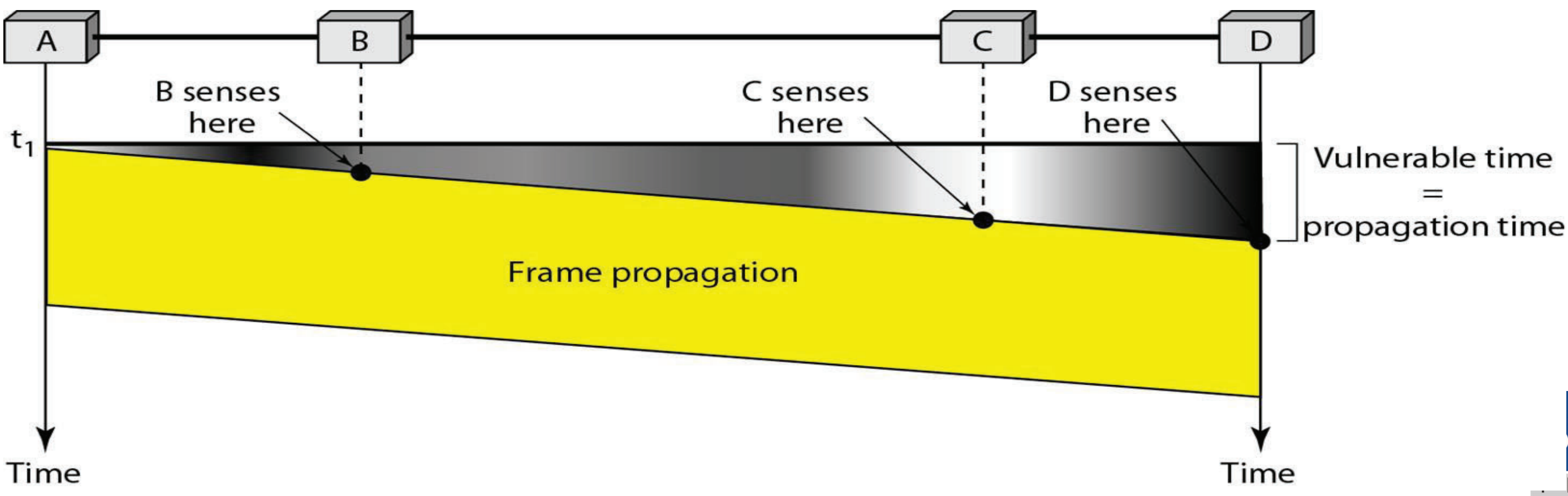
- The possibility of collision still exists because of propagation delay when a station sends a frame, it still takes time (although very short) for the first bit to reach every station and sense it.

Collision in CSMA

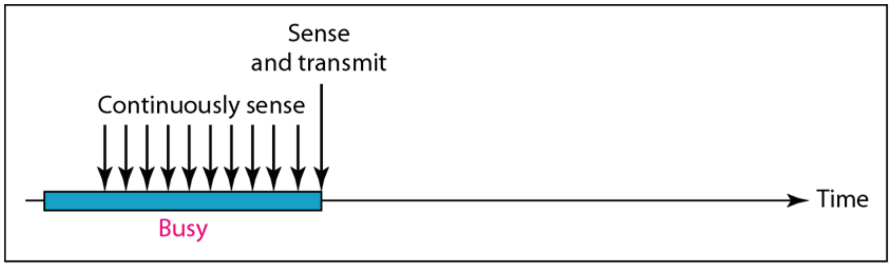


Collision in CSMA

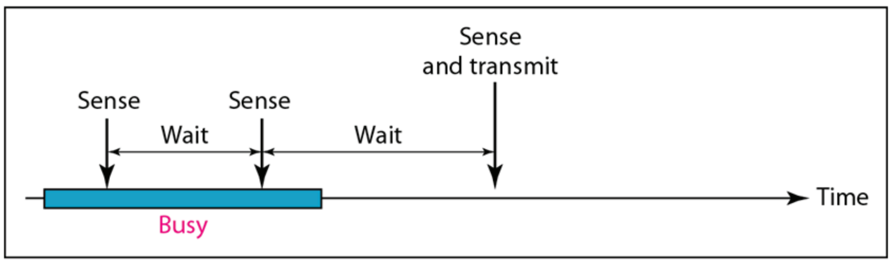
The vulnerable time for CSMA is the propagation time Tp



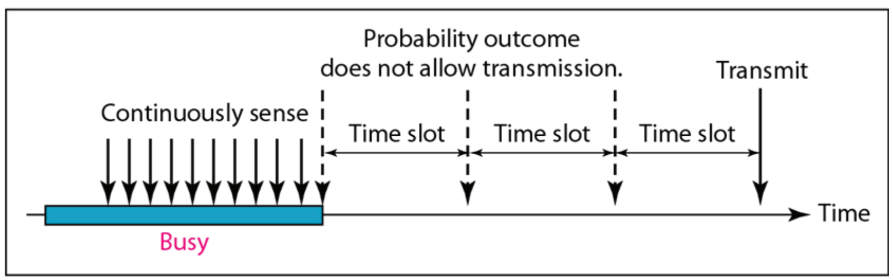
Persistence Methods



a. 1-persistent



b. Nonpersistent

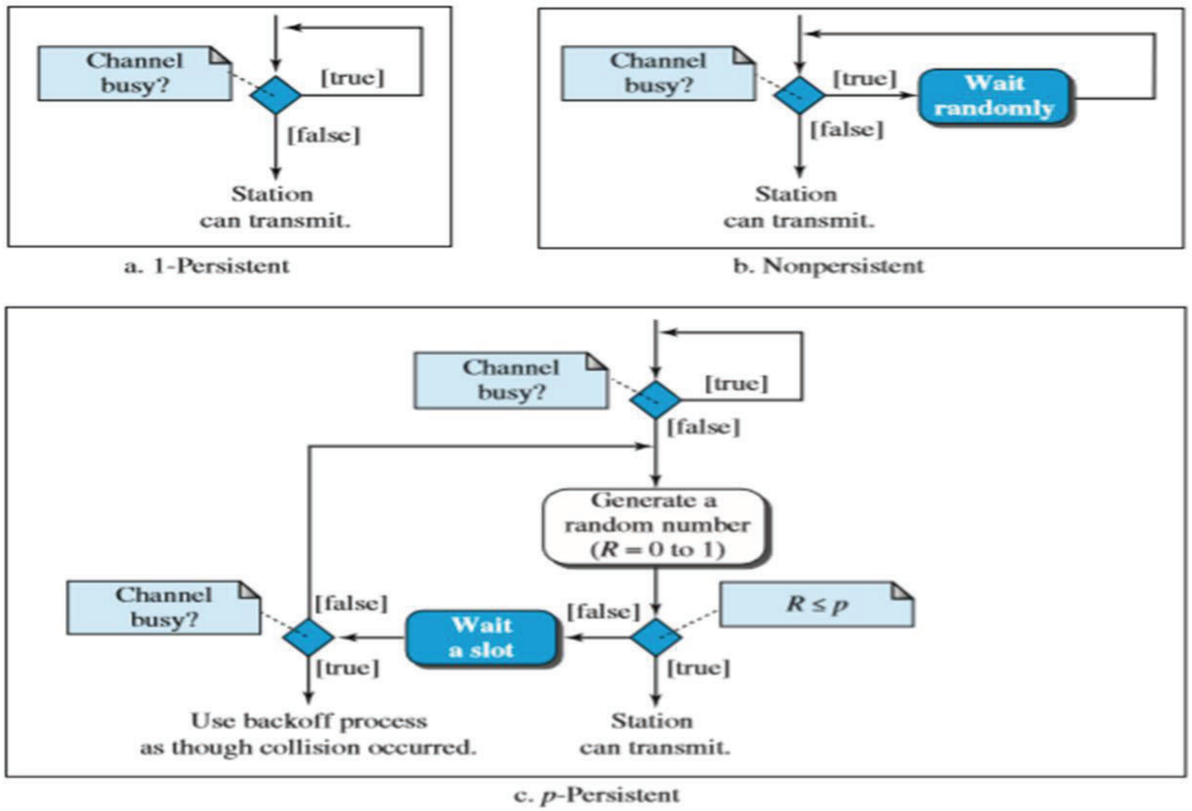


c. p-persistent

What a station does when channel is idle or busy

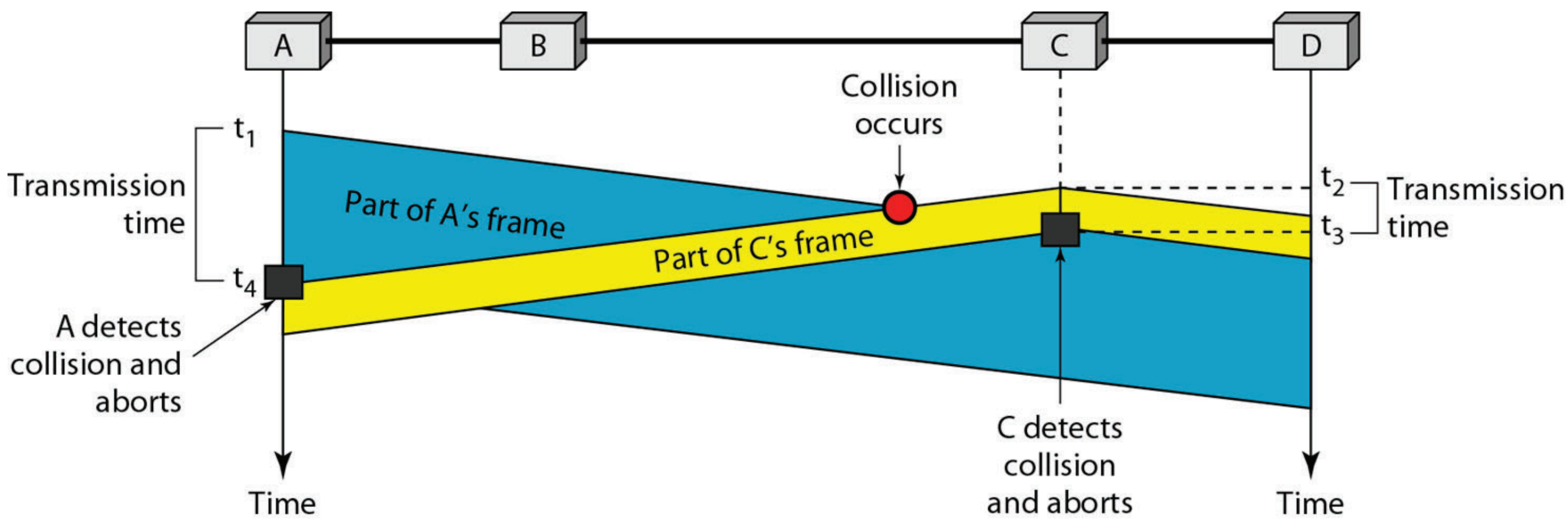
Persistence Methods

Figure 12.10 *Flow diagram for three persistence methods*



CSMA/CD

- **C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **D**etection
- Station monitors channel while sending a frame.



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CSMA/CD

- (CSMA/CD) augments the algorithm to handle the collision.
- a station monitors the medium after it sends a frame to see if the transmission was successful.
- For CSMA/CD to work, we need a restriction on the frame size.

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CSMA/CD

- Before sending last bit, station must detect a collision because once entire frame is sent, station does not keep copy of frame.

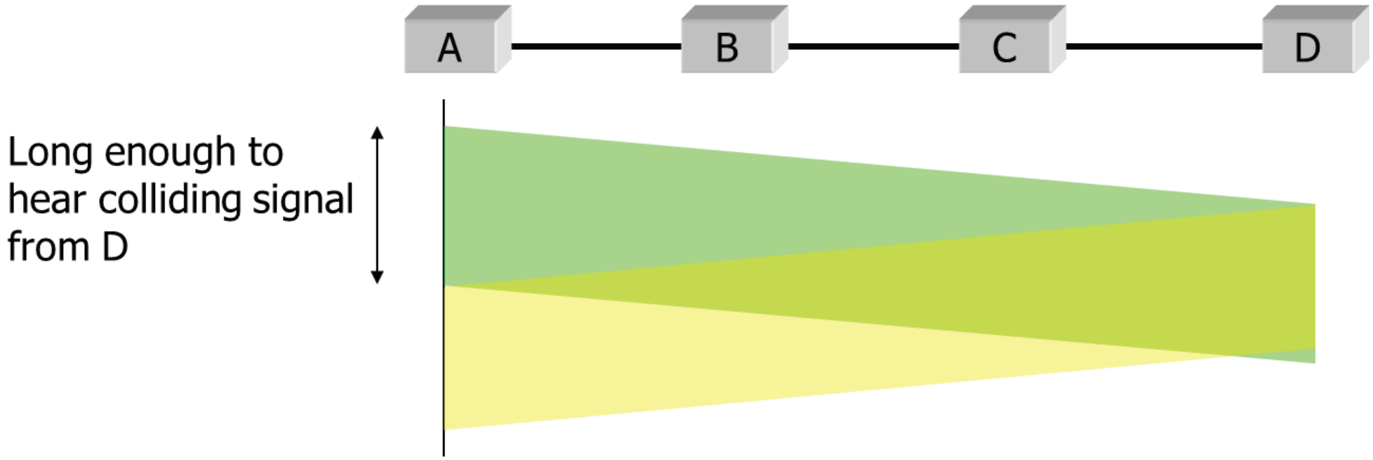
- Frame Transmission time T_{fr} must be atleast

2* TP

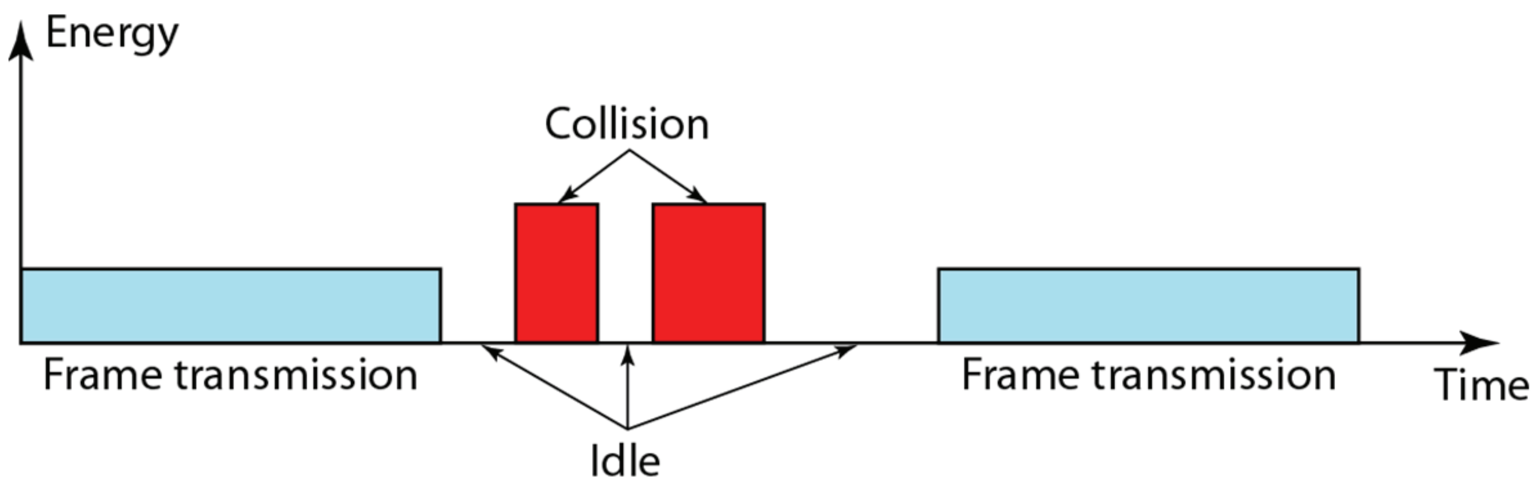
i.e. twice the maximum Propagation time.

CSMA/CD: Minimum Frame Size

- Each frame must be large enough for a sender to detect a collision.
- Worst case scenario:
  "A" is transmitting
  "D" starts transmitting just before A's signal arrives



CSMA/CD: Energy Levels



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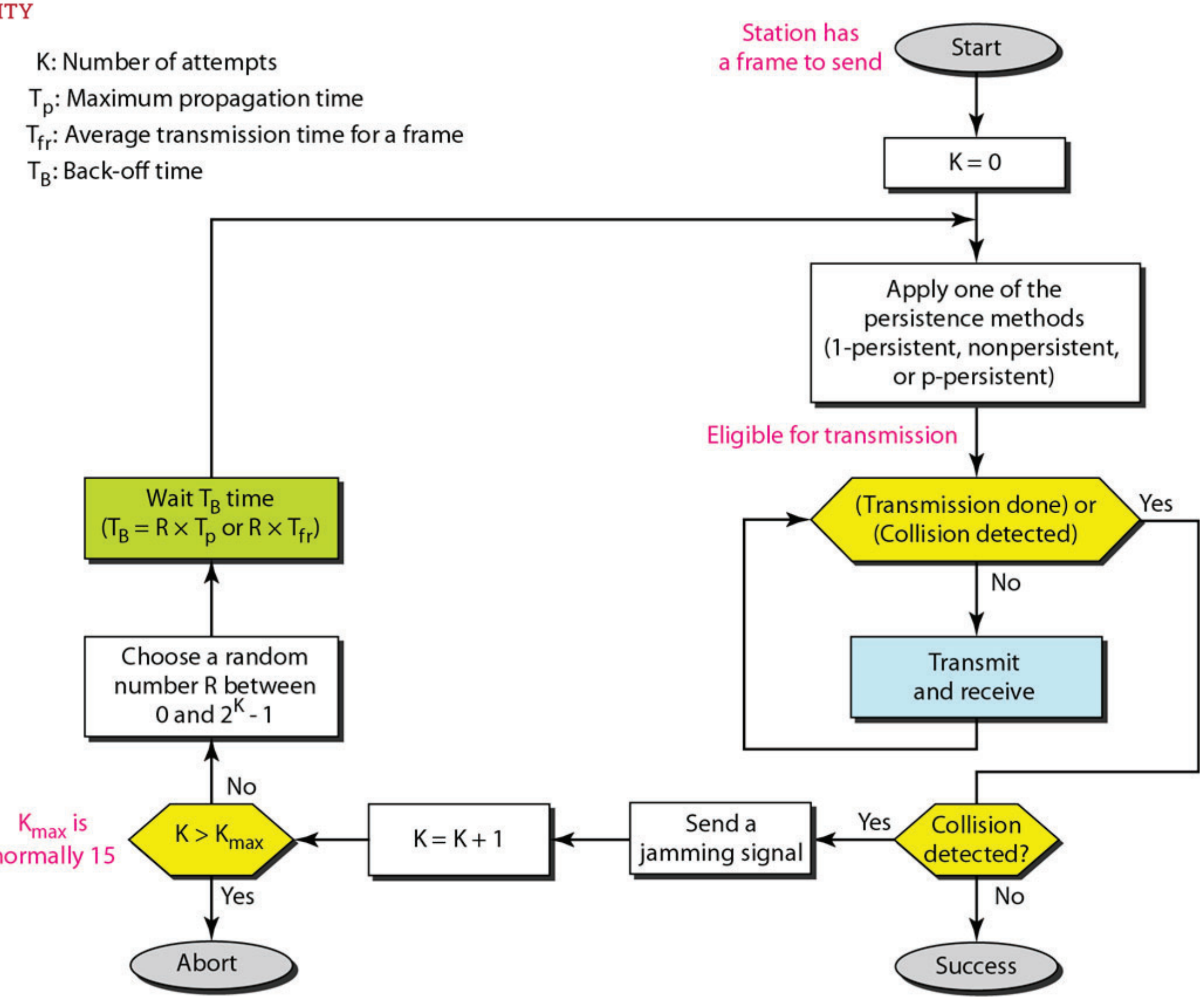


Difference ALOHA and CSMA/CD

- first difference is the addition of the persistence process (for sensing the medium).

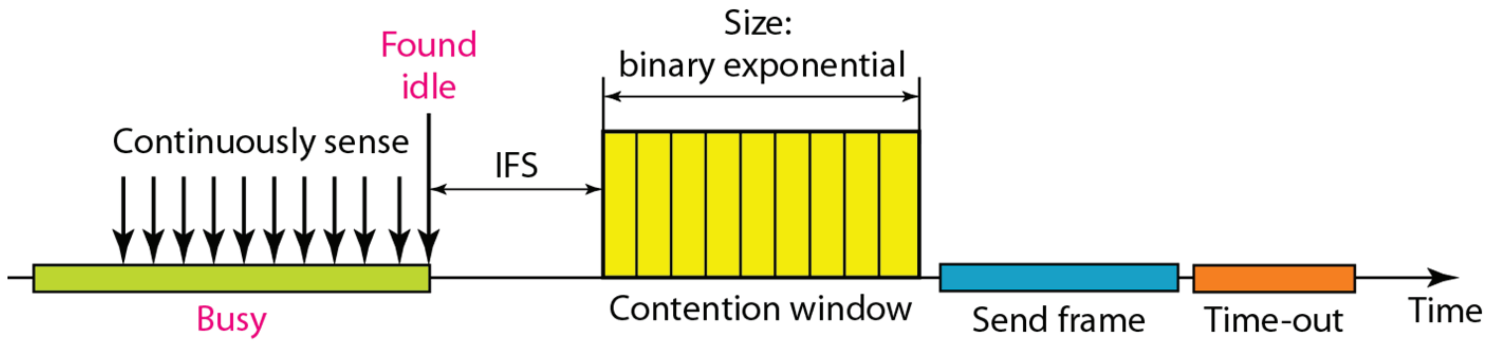
- second difference is the frame transmission.
  - In ALOHA, *first transmit the entire frame and then wait for an acknowledgment*.
  - In CSMA/CD, *transmission and collision detection is a continuous process.*

- The third difference is the sending of a short jamming signal that enforces the collision in case other stations have not yet sensed the collision.

CSMA/CA

- **C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **A**voidance

- Used in a network where collision cannot be detected.
  - E.g., wireless LAN



IFS – Interframe Space

CSMA/CA

- need to avoid collisions on wireless networks because they cannot be detected.

- Collisions are avoided through the use of CSMA/CA's three strategies:
    - Inter-frame space
    - contention window
    - acknowledgments

CSMA/CA

Interframe Space (IFS)

- collisions are avoided by deferring transmission even if the channel is found idle.

- idle channel is found - does not send immediately – waits for period of time called IFS.

- The IFS variable can also be used to prioritize stations or frame types. For example, a station that is assigned a shorter IFS has a higher priority.

CSMA/CA

Contention Window

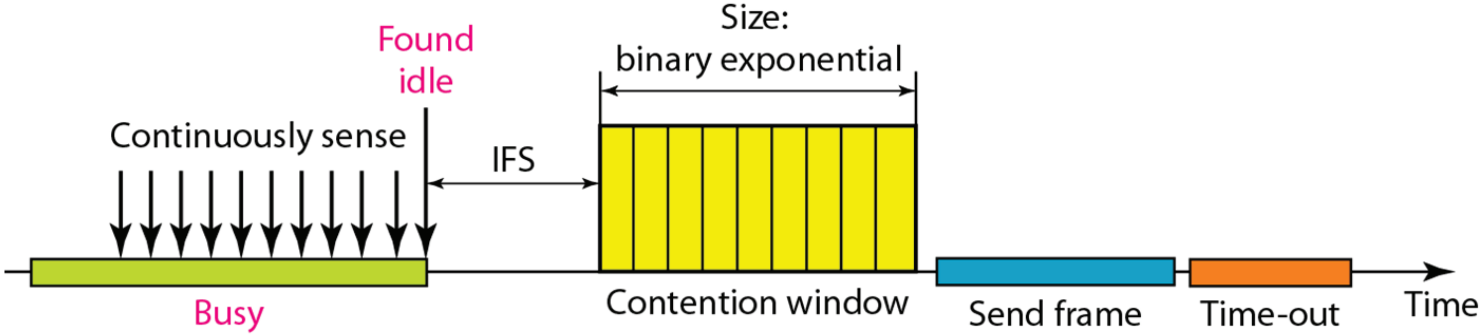
- The contention window is an amount of time divided into slots.
- A station that is ready to send chooses a random number of slots as its wait time.
- No. of slots in window changes according to binary exponential back-off strategy.
- Channel set to one slot the first time and then doubles each time the station cannot detect an idle channel after the IFS time.

CSMA/CA

Contention Window

- station needs to sense the channel after each time slot.

- 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.

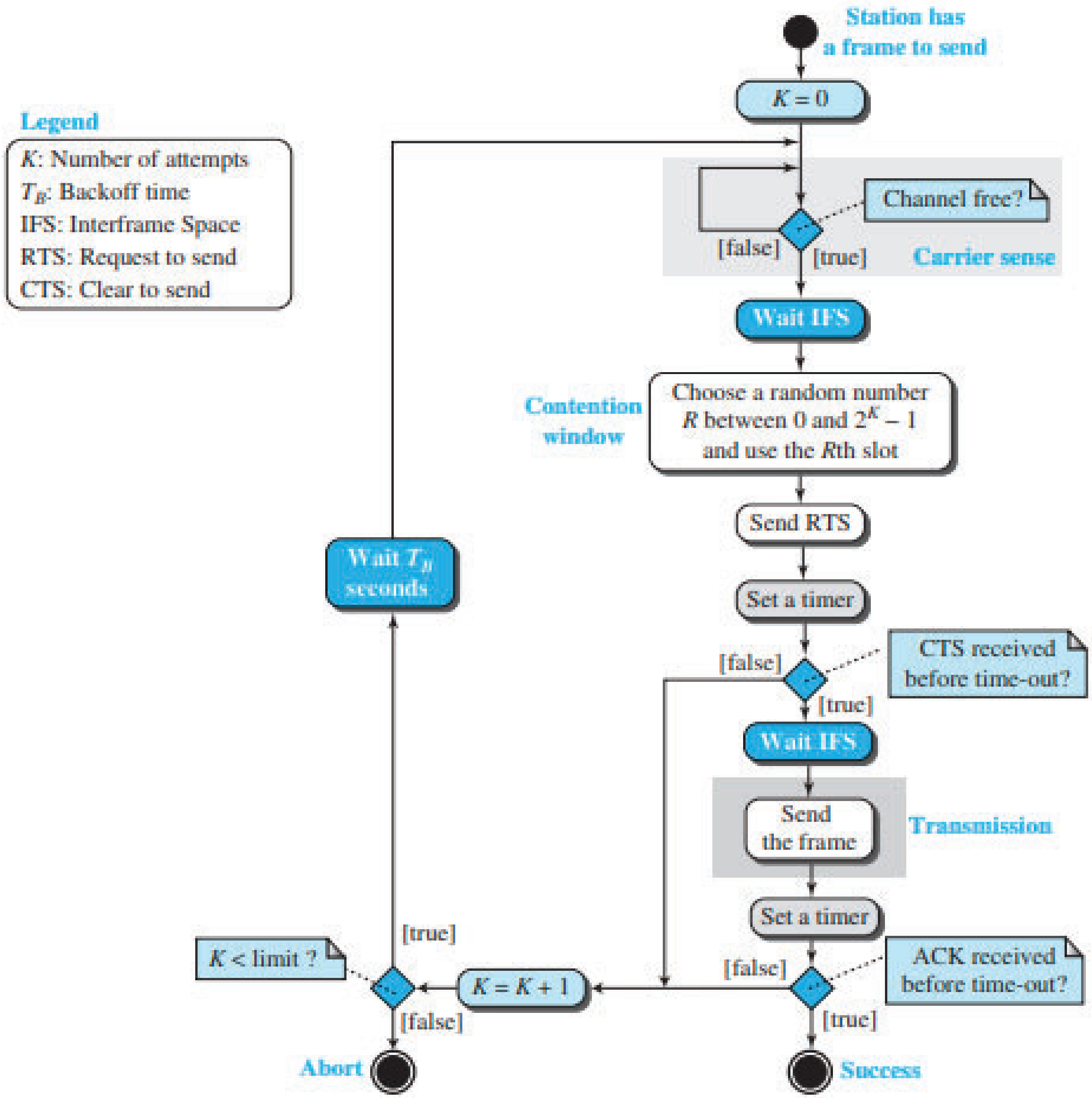


IFS – Interframe Space

CSMA/CA

Acknowledgment

- there still may be a collision resulting in destroyed data.
- the data may be corrupted during the transmission.
- The positive acknowledgment and the time-out timer can help guarantee that the receiver has received the frame.



Legend
K: Number of attempts
T_B: Backoff time
IFS: Interframe Space
RTS: Request to send
CTS: Clear to send
Station has a frame to send
K = 0
Channel free?
[false]
[true]
Carrier sense
Wait IFS
Contention window
Choose a random number R between 0 and $2^K - 1$ and use the Rth slot
Send RTS
Set a timer
CTS received before time-out?
[false]
[true]
Wait IFS
Send the frame
Transmission
Set a timer
ACK received before time-out?
[false]
[true]
Success
K = K + 1
K < limit ?
[true]
[false]
Wait T_B seconds
Abort

Controlled Access

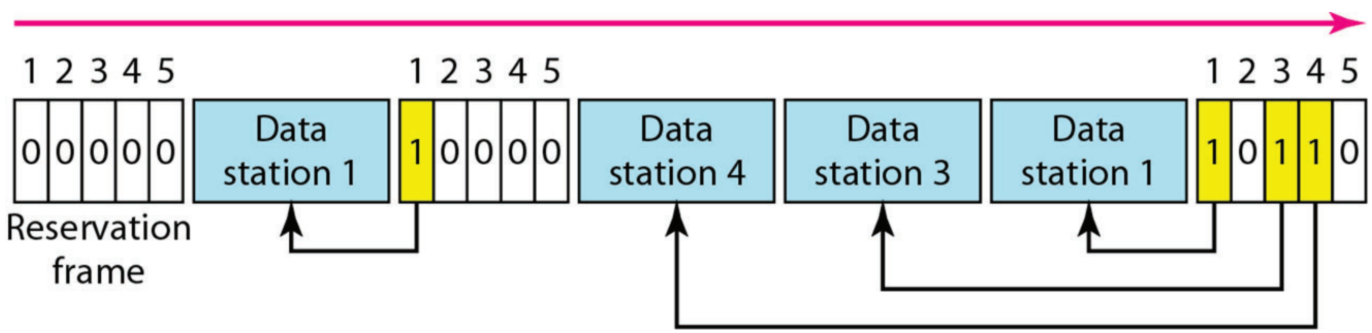
In controlled access, the stations consult one another to find which station has the right to send.

- A station must be authorized by someone (e.g., other stations) before transmitting
- Three common methods:
    - Reservation
    - Polling
    - Token passing

Reservation

- a station needs to make a reservation before sending data.
- Time is divided into intervals.
- a reservation frame precedes the data frames sent in that interval.
- N stations in the system, there are exactly N reservation mini-slots

Reservation Method



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Polling Method

- Polling works with topologies in which one device is designated as a primary station and the other devices are secondary stations.

- All data exchanges must be made through the primary device.

- It is up to the primary device to determine which device is allowed to use the channel

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Polling Method

- primary device - always the initiator of a session
- The select function is used whenever the primary device has something to send.
- The poll function is used by the primary device to solicit transmissions from the secondary devices.

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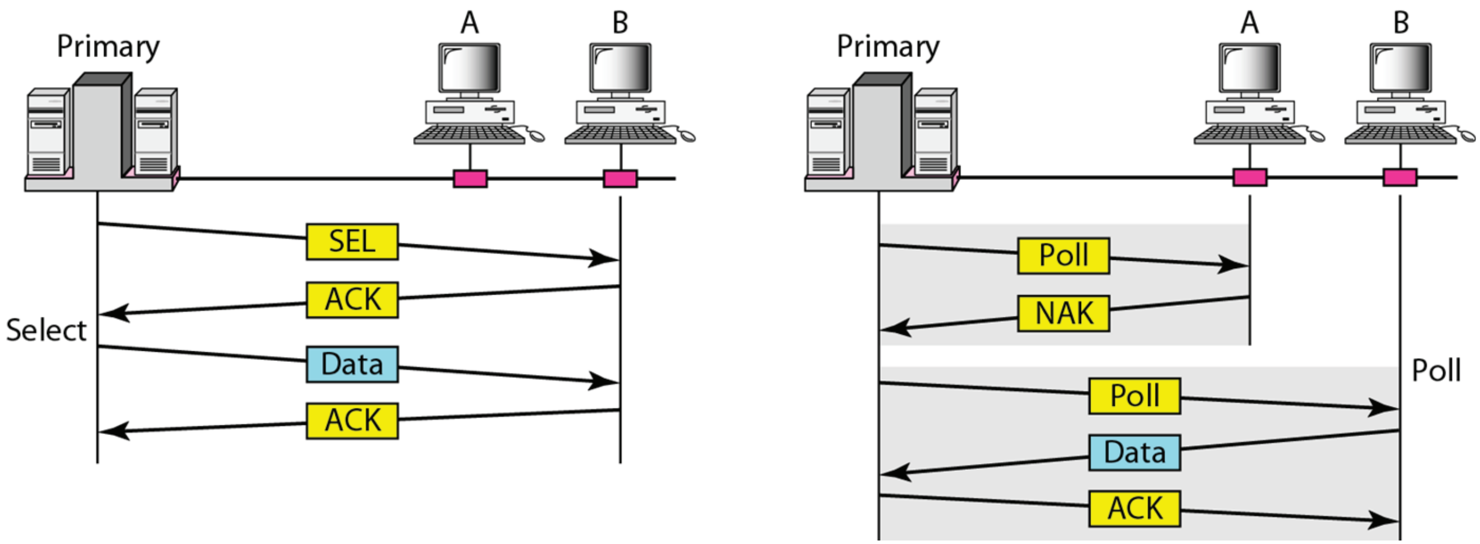
Polling Method



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Token Passing

- the stations in a network are organized in a logical ring.
- for each station, there is a predecessor and a successor.
- current station is the one that is accessing the channel now.
- right to this access has been passed from the predecessor to the current station.

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Token Passing

- right will be passed to the successor when the current station has no more data to send.

- a special packet called a token circulates through the ring.

- Token management is needed for this access method.

- Stations must be limited in the time they can have possession of the token.

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Token Passing

- token must be monitored to ensure it has not been lost or destroyed.
- assign priorities to the stations and to the types of data being transmitted.
- make low-priority stations release the token to high priority stations.

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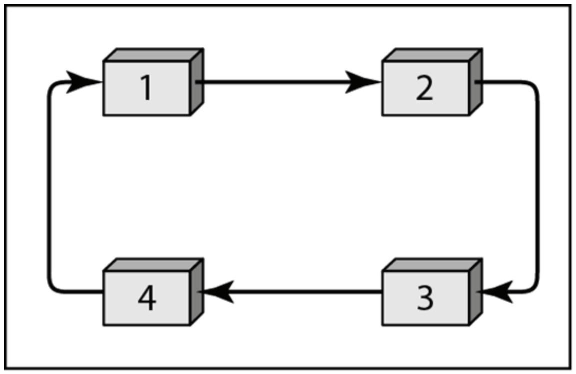
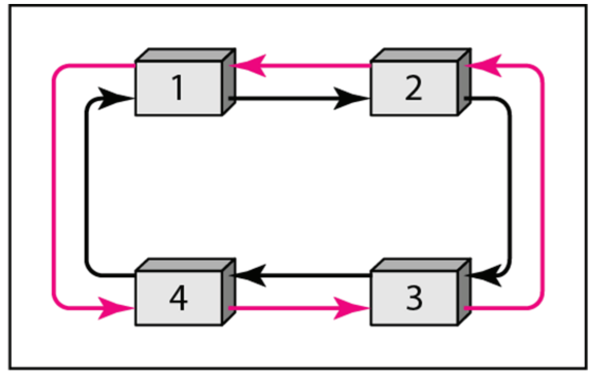
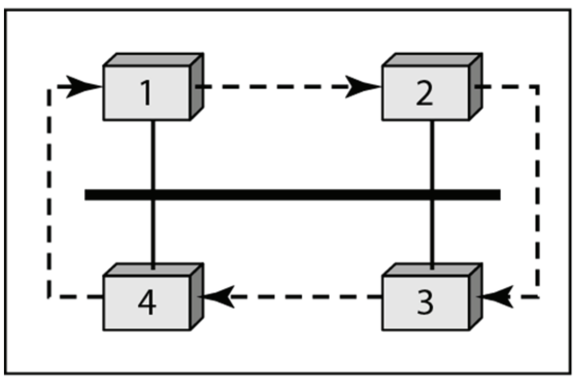
Token Passing



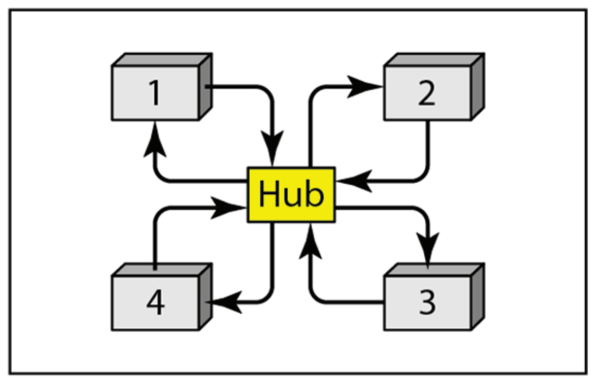
a. Physical ring



b. Dual ring



c. Bus ring



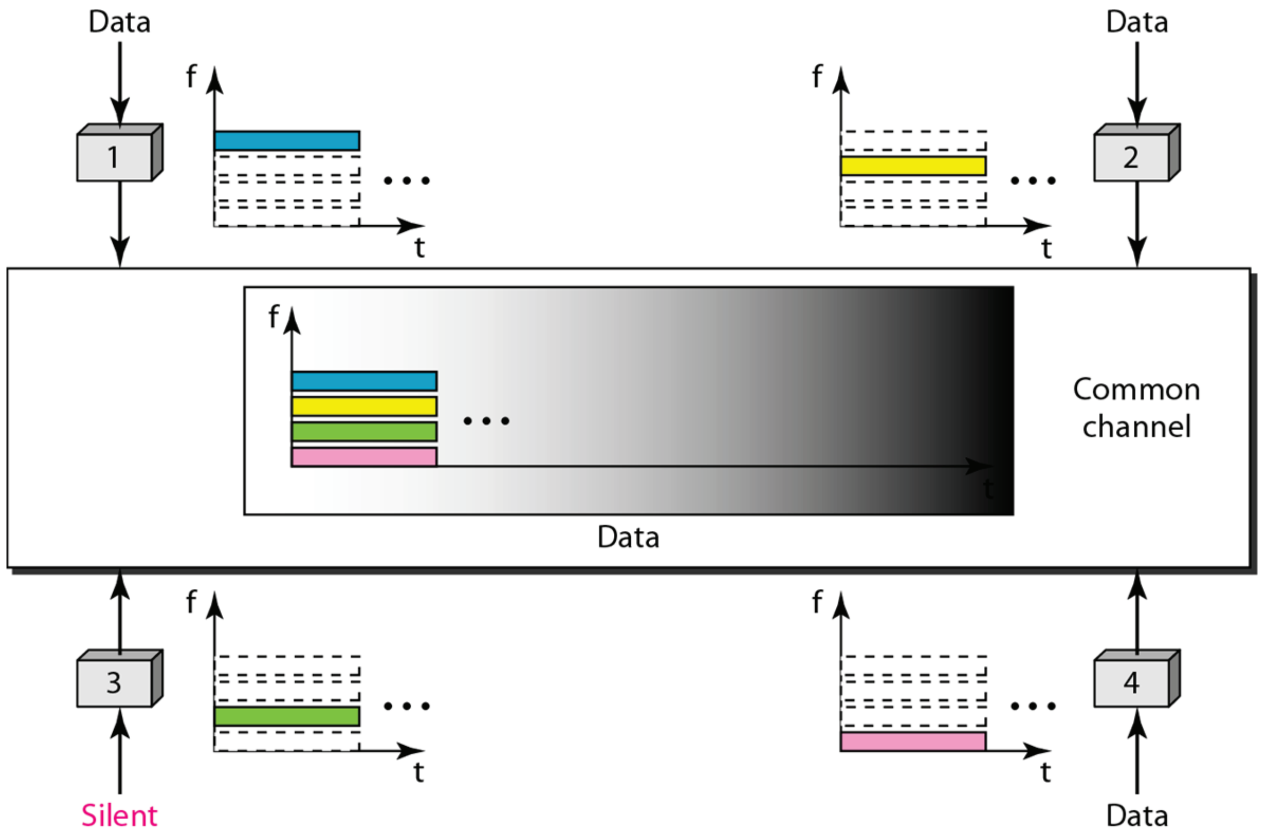
d. Star ring

Channelization

- Similar to multiplexing

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

FDMA



FDMA and FDM

- FDM is a physical layer multiplexing technique, while FDMA is a data link layer access method.
- Using FDM to allow multiple users to utilize the same bandwidth is called FDMA.
- FDM uses a physical multiplexer, while FDMA does not.

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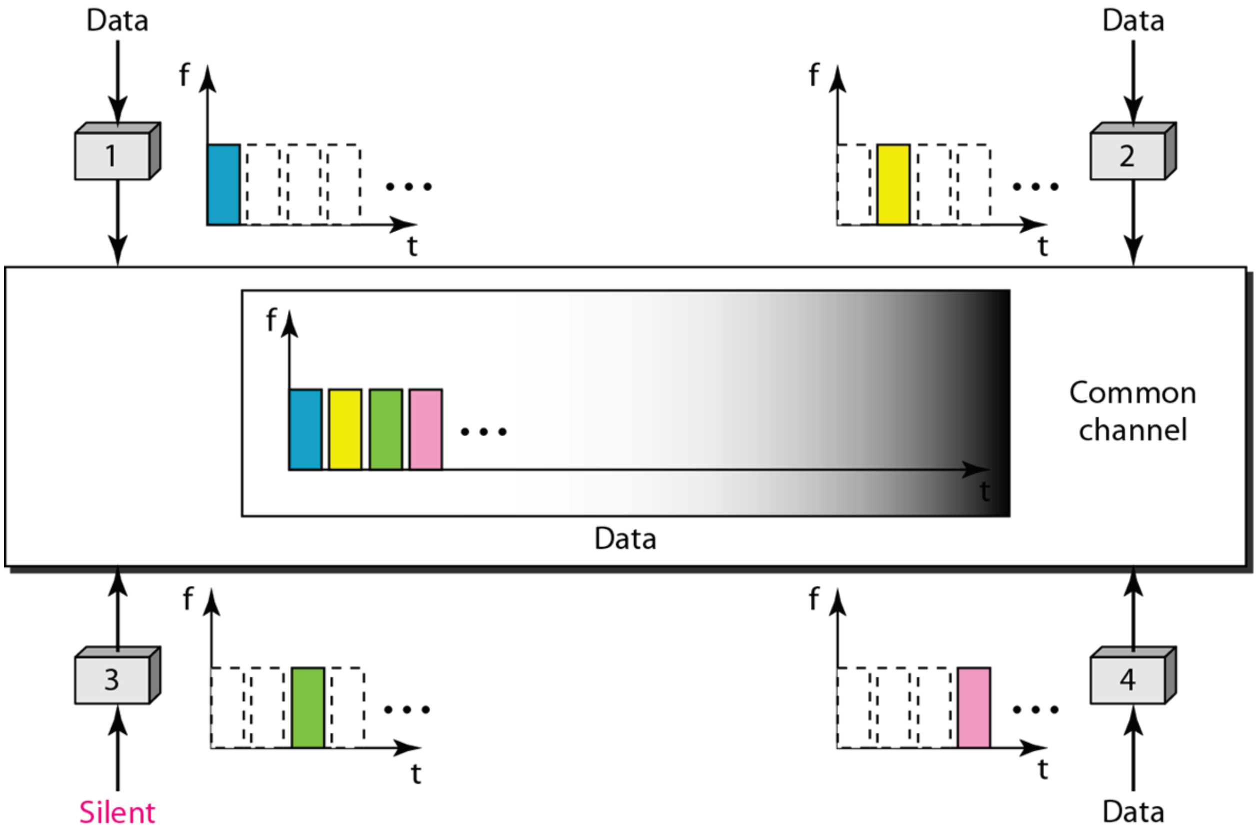
TDMA



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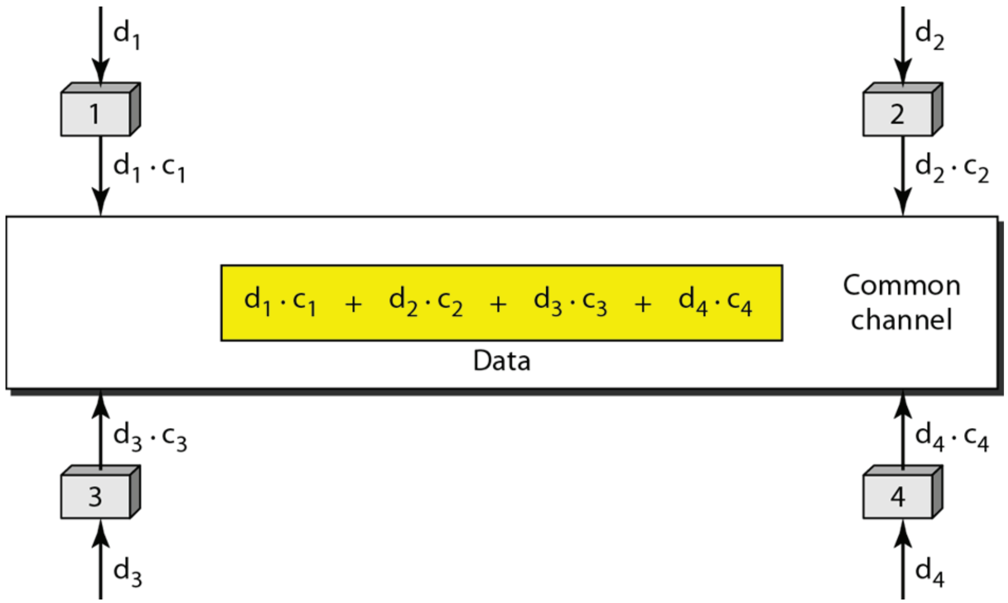
CDMA

- One channel carries all transmissions at the same time
- Each channel is separated by code.



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CDMA: Chip Sequences

- Each station is assigned a unique 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]

- Chip sequences are *orthogonal vectors*
  - Inner product of any pair must be zero
- With N stations, sequences must have the following properties:
  - They are of length N
  - Their self inner product is always N

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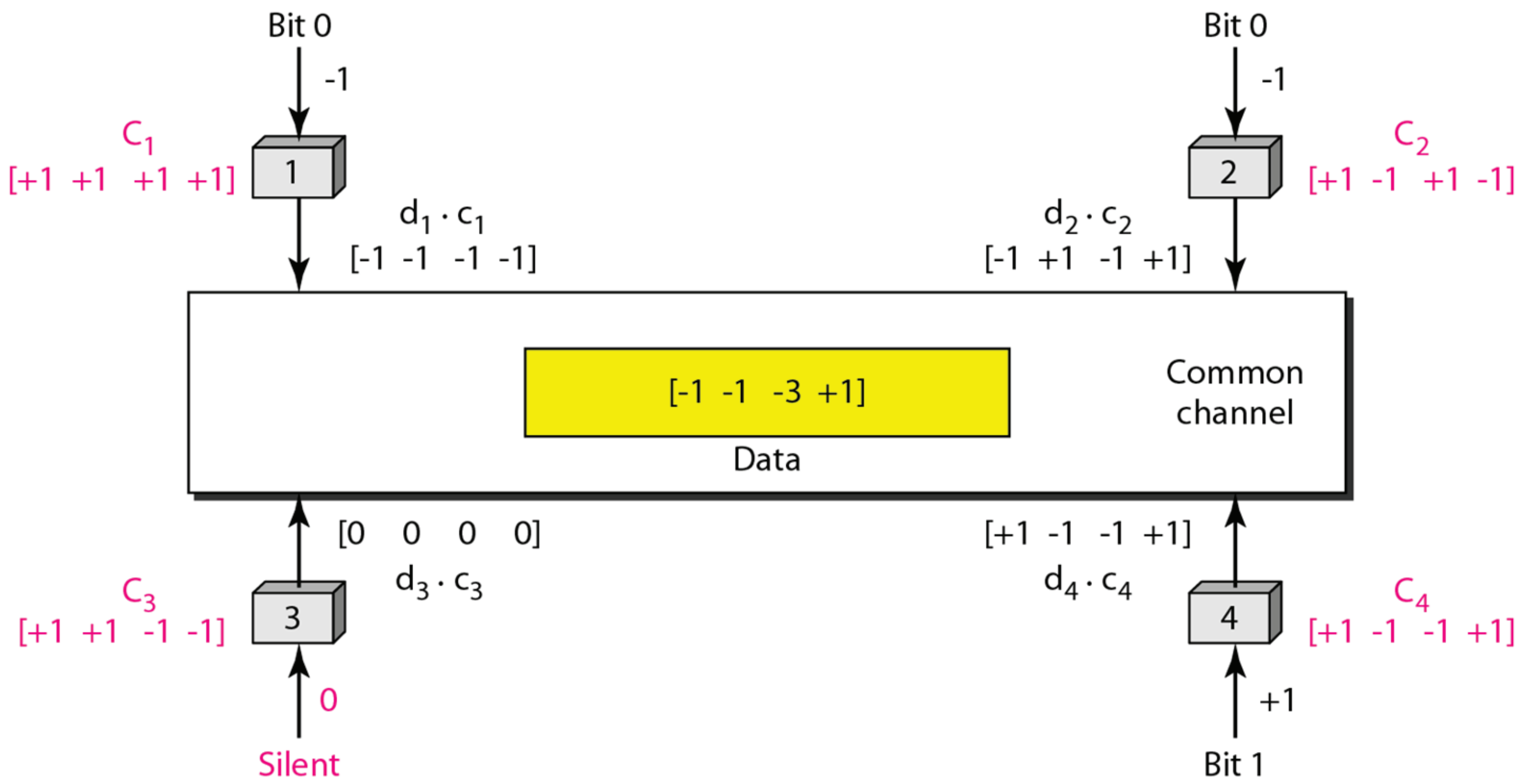
CDMA: Bit Representation

Data bit 0 → -1

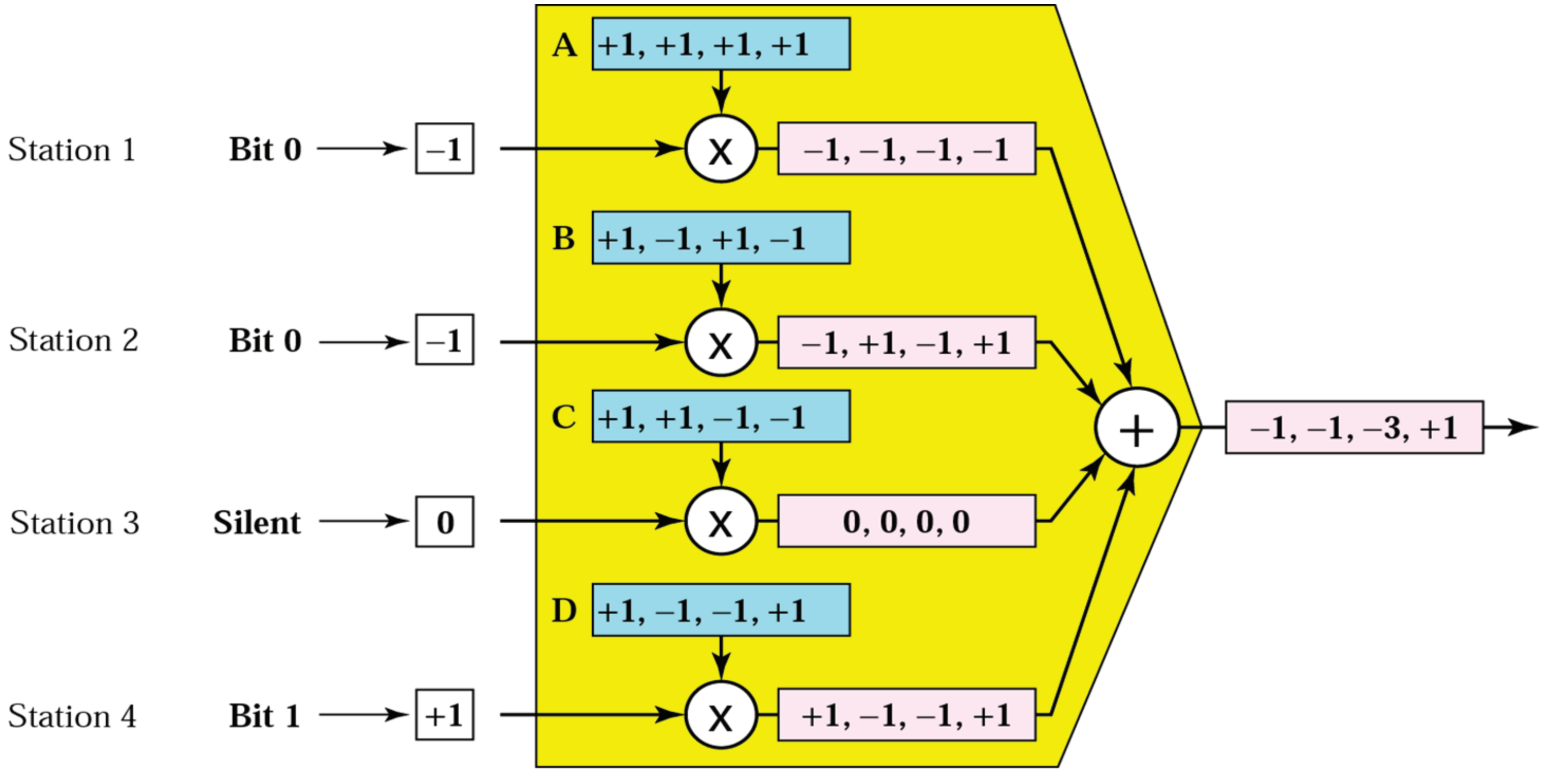
Data bit 1 → +1

Silence → 0

Transmission in CDMA



CDMA Encoding



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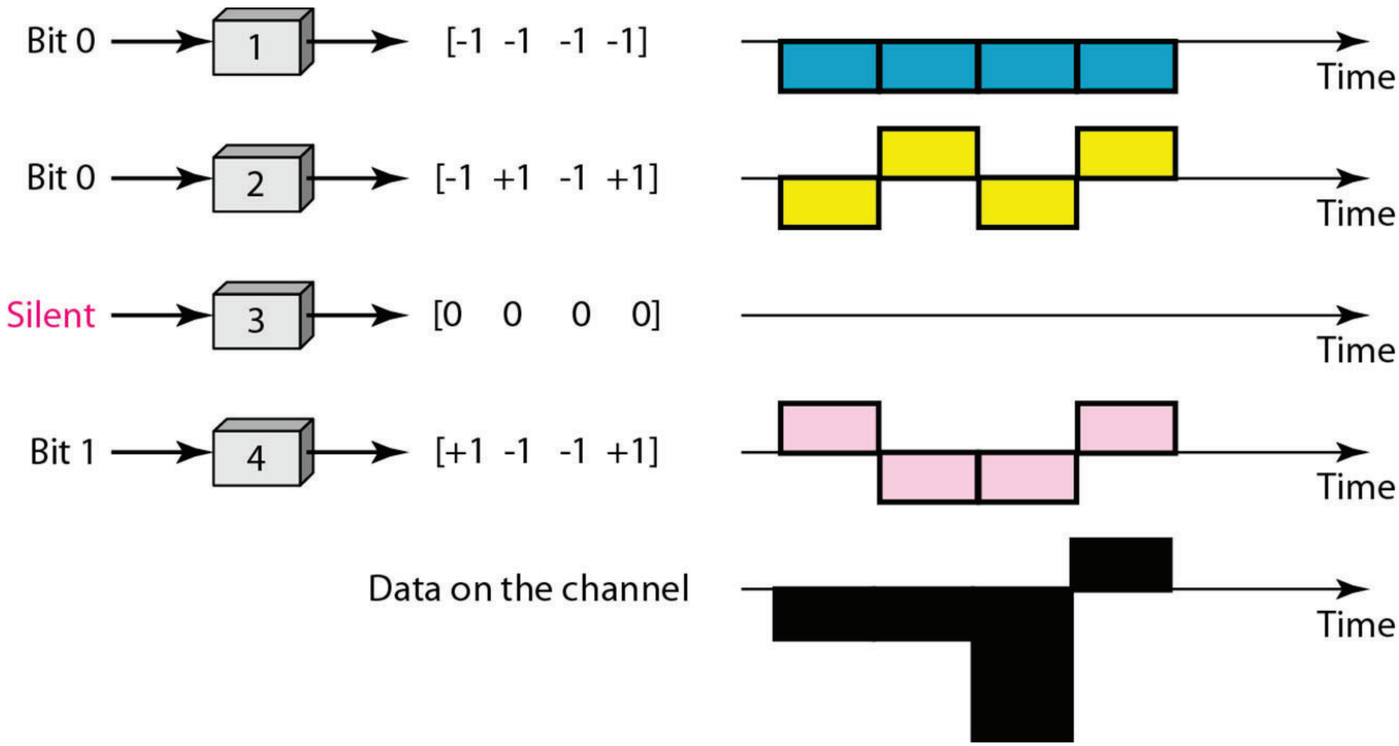
Signal Created by CDMA



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CDMA Decoding