lecture 6 Data Link Layer - Medium Access Control

Segment name

1h 30m 50s

Total

Segment	Start time	End time	Duration
Segment 1	25-03-20 15:15:55	25-03-20 16:46:45	1h 30m 50s

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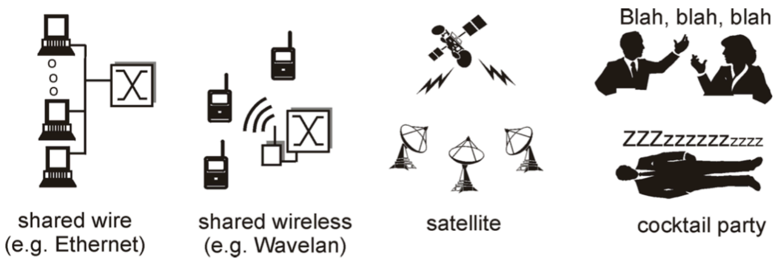
Medium Access Control

Contexts for the multiple Access Problem

- **Shared (Broadcast)** transmission medium
    - Message from any transmitter is received by all receivers
    - Two or more simultaneous transmissions by nodes: interference 干扰
    - Collision if a node receives two or more signals at the same time
    - Colliding messages are garbled 碰撞消息乱码

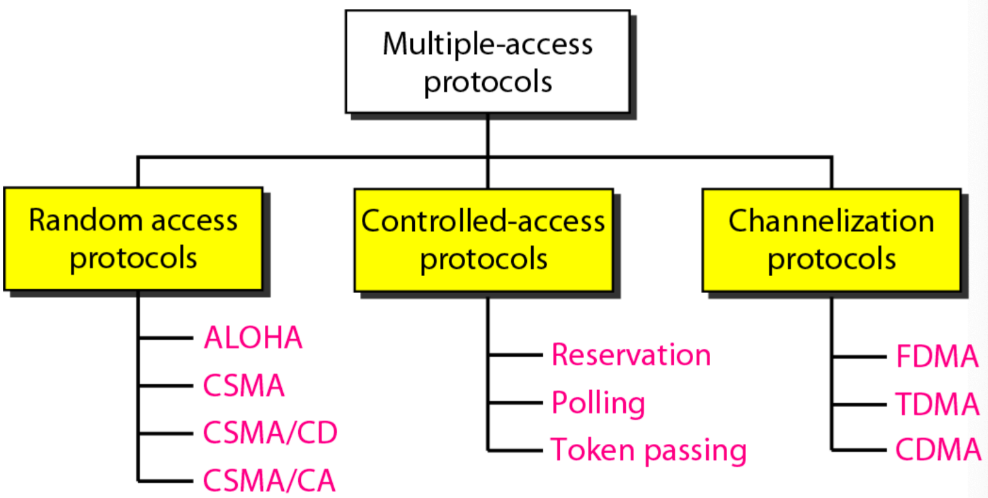


Multiple Access Protocols

- To determine how nodes share a channel, *determine when a node can transmit*
- Communication about channel sharing must use the channel itself
- Goal
  - maximize message throughput
  - minimize mean waiting time

Three broad classes

- **Random Access**
  - The channel is not divided, allow collisions
  - "Recover" from collisions
- **Control Access**
  - Nodes *take turns*, but nodes with more to send can take longer turns
- **Channel Partitioning**
  - Divide the channel into *smaller "pieces"* (time, frequency, code)
  - Allocate a piece to each node for *exclusive use*



Random Access Protocols

- When a node has packets to send
  - transmit at **full channel data rate R**
  - *no a prioriy coordination* among nodes
- collision
- **Random access MAC protocol** specifies:
  - *detect*

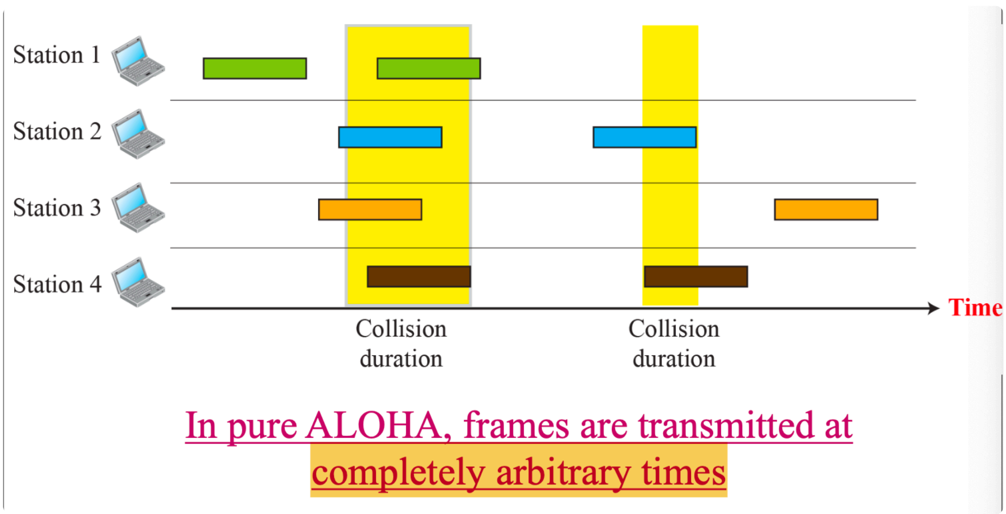
- *recover* (e.g. delayed retransmissions)

1. ALOHA Protocols

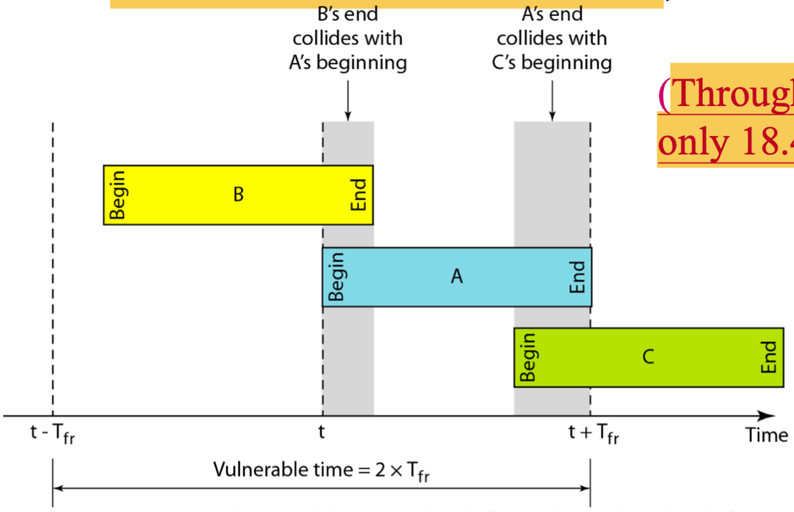
- Advocates of Linus Open-source Hawaii Association
- University of Hawaii
- basic idea: *applicable to any system* in which uncoordinated user are competing for the use of *a single shared channel*
- Pure and Slotted ALOHA

1.1 Pure ALOHA

- Simple idea: **let user transmit whenever they have data to send**
- collided frames are destroyed
- relies on *ack from the receiver*. If ack does not arrive after a time-out period, the station assumes the frame is destroyed and *resends after waiting a random amount of time*
- **Randomness** will help avoid more collisions, **The backoff time** T_B
- time-out period = *maximum possible round-trip propagation delay*
- prevent congesting the channel with retransmitted frames. After **a maximum number of retransmission attempts** K_{max}, a station must give up and try later
- T_B is a random value depends on K
- T_B common formula is the **binary exponential backoff**
- for each retransmission, a multiplier $R = 0 \to 2^K - 1$ is randomly chosen and multiplied by T_p (maximum propagation time) or T_{fr} (the average time required to send out a frame) to find T_B
- the, range of the random numbers *increases* after each collision, the value of Kmax is usually chosen as 15

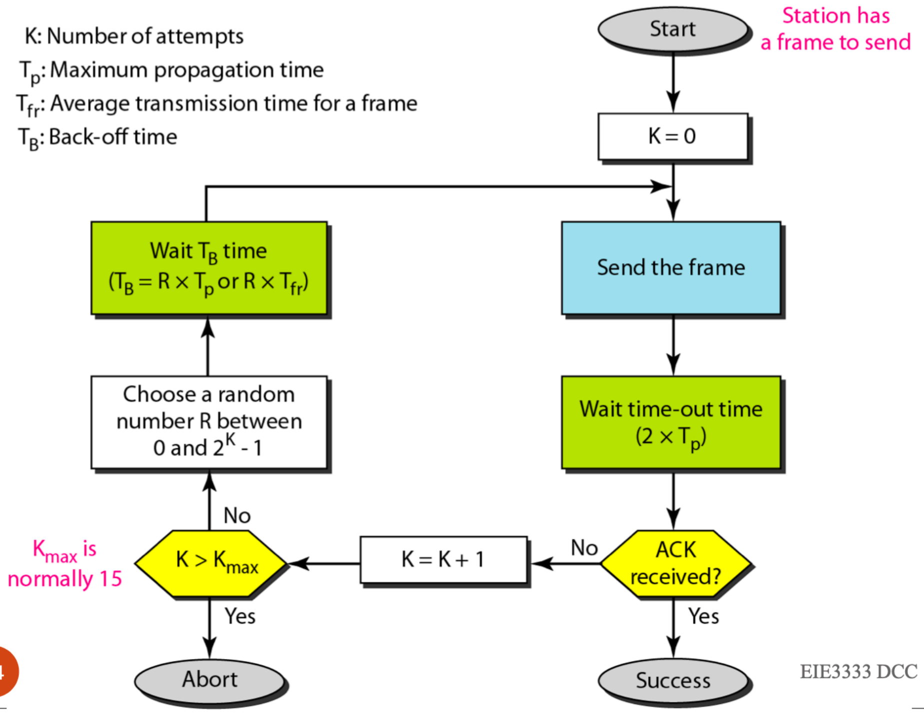


- A frame will not suffer a collision if no other frames are sent within one frame time of its start, as shown below:



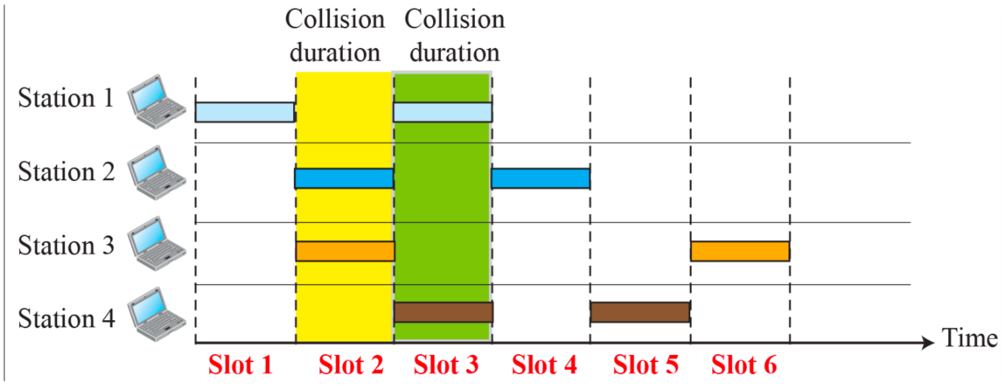
(Throughput is only 18.4%)

Vulnerable period for the shaded frame



1.2 Slotted ALOHA

- frame *same size*
- *equal-size time slots*
- transmit only at the *beginning* of slots
- synchronized
- transmits in the next slot
- retransmits in each random subsequent slot until success

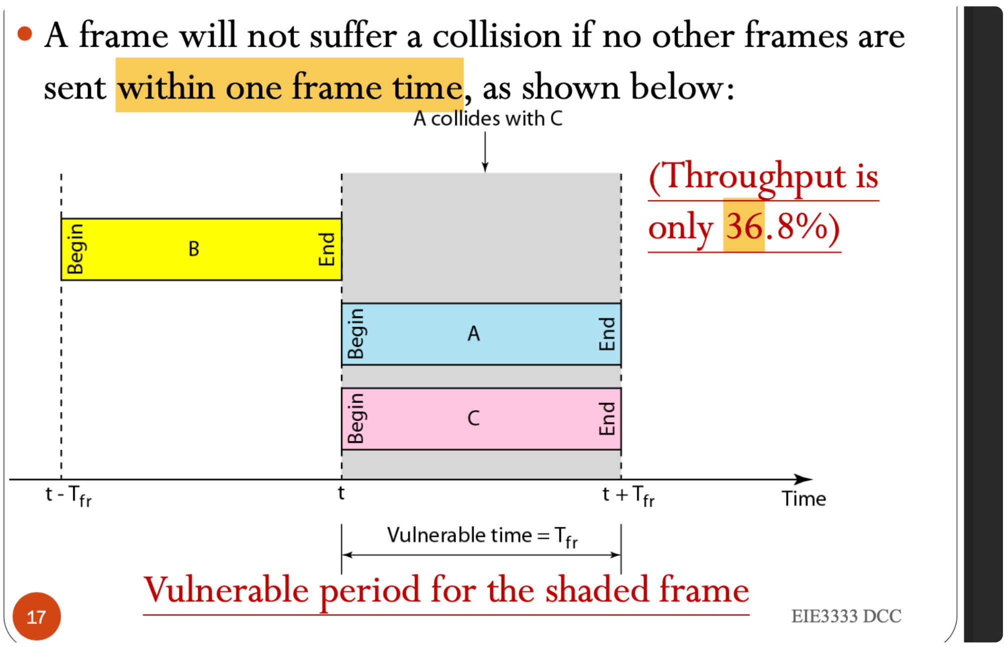


Pros

- at full rate of channel
- decentralized: only requires sync slot
- simple

Cons

- wasting slot
- idle slots
- clock synchronization



1.3 Analyze Through in Infinite Population Model

- frames all the same length
- infinite frames generators -> Poisson distribution with mean *G frames per frame time*

- G is **offered load**
- *throughput* is offered load * the probability of successful

$$S = GP_0$$

- The probability that *k frames are generated* during a given frame time

$$P_r(k) = (G^k/k!)e^{-G}$$

- The probability of *zero frame* is just e^{-G}

Two-frame time

- generated is 2G
- no other traffic being initiated during the period is $p_0 = p_r(0) = e^{-2G}$
- throughput S is

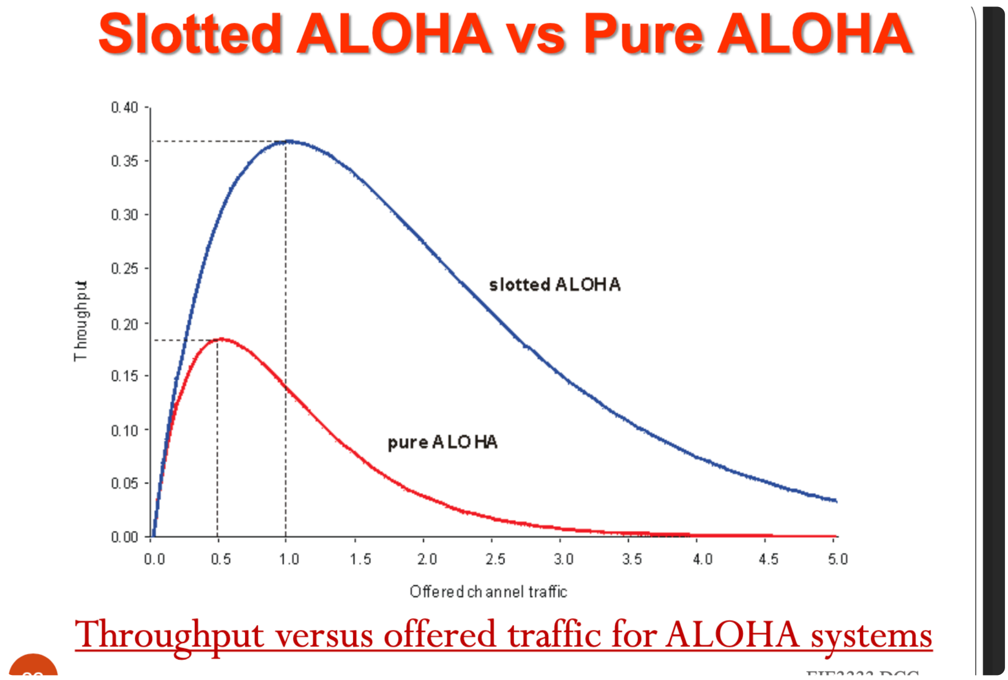
$$S = GP_0 = Ge^{-2G} \qquad \text{(A-4)}$$

  - The maximum throughput occurs at G=0.5, with S_{max} = 1/2e, which is about 0.184.
  - In other words, the best we can hope for is a channel utilization of 18 percent.
-

Slotted ALOHA

> - As vulnerable period reduces to one frame time, hence
>
> $$P_0 = P_r(0) = e^{-G} \Rightarrow S = Ge^{-G} \qquad \text{(A-5)}$$
>
> - So maximum throughput occurs at G=1, with a throughput of S = 1/e or about 0.368, twice that of pure ALOHA.

1.4 slotted vs. Pure



2.1 Carrier Sense Multiple Access(CSMA) Protocols

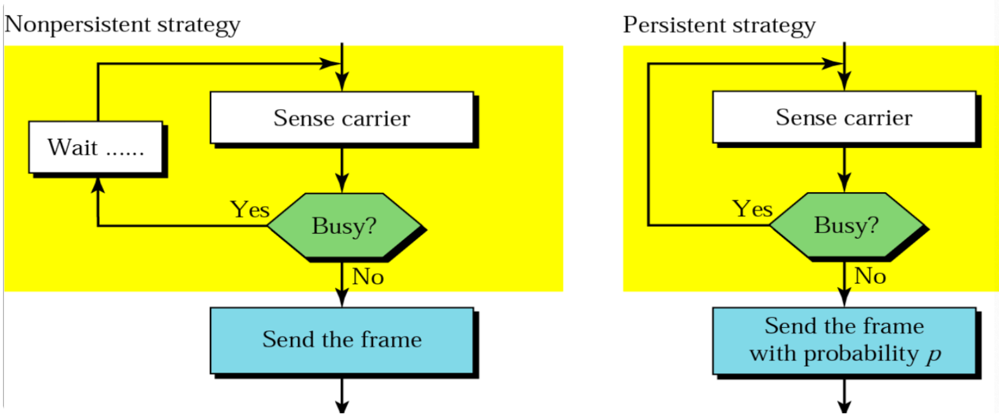
- first listening to the medium to determine if another transmission is in progress
- three approaches
  - non-persistent CSMA
  - p-persistent
  - 1-persistent

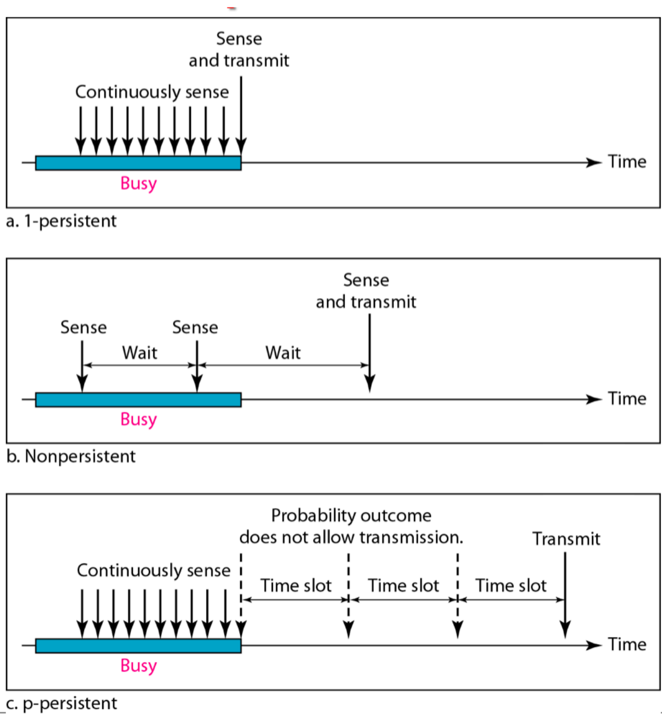
Non-persistent CSMA

- idle, transmit
- if busy, wait *random amount* of time and re-sense the channel

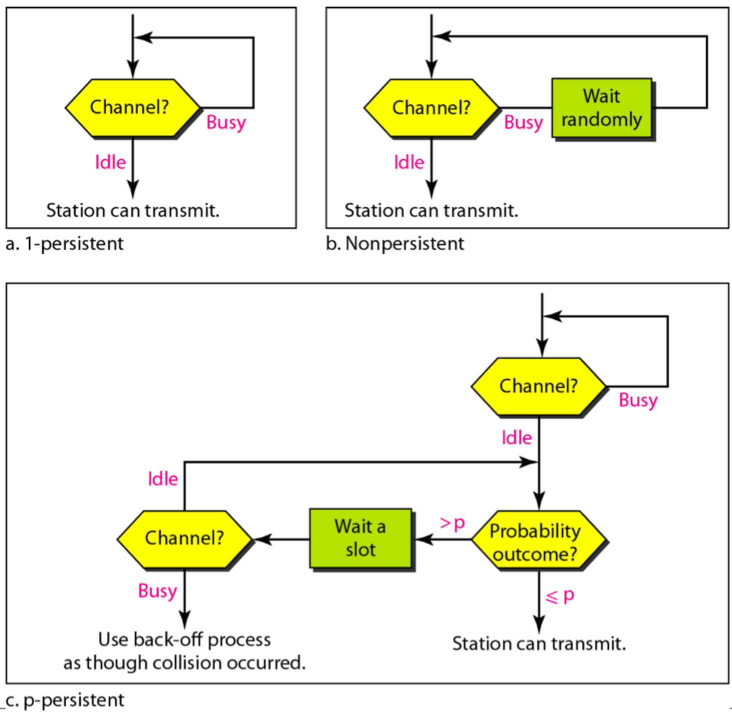
p-persistent CSMA

- idle, transmit with probability p, with $q = 1 - p$, deter until the next *slot*
- busy, continue listening until idle





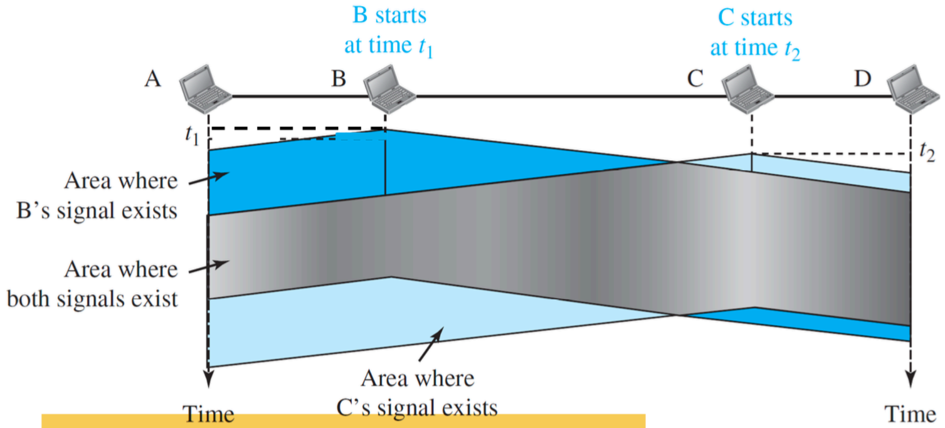
Flow diagram for three persistence methods



2.2 CSMA Collisions

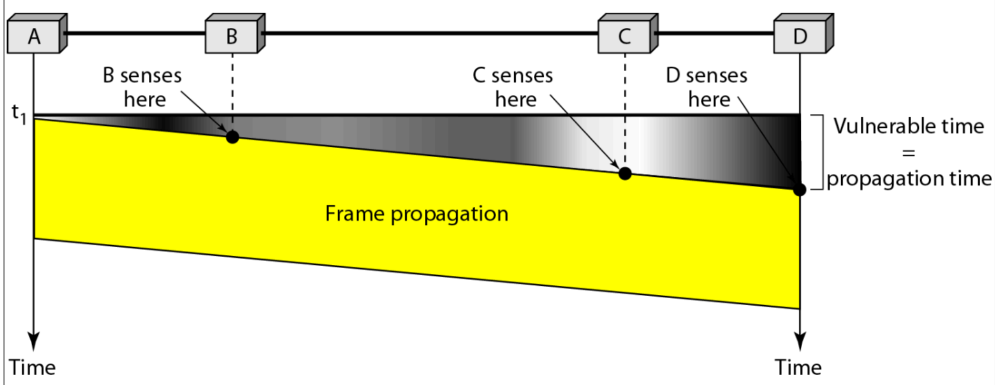
- **Collisions can still occur**: propagation delay, and Role of distance in determining collision probability

Spatial layout of nodes



Role of distance & propagation delay in determining collision probability

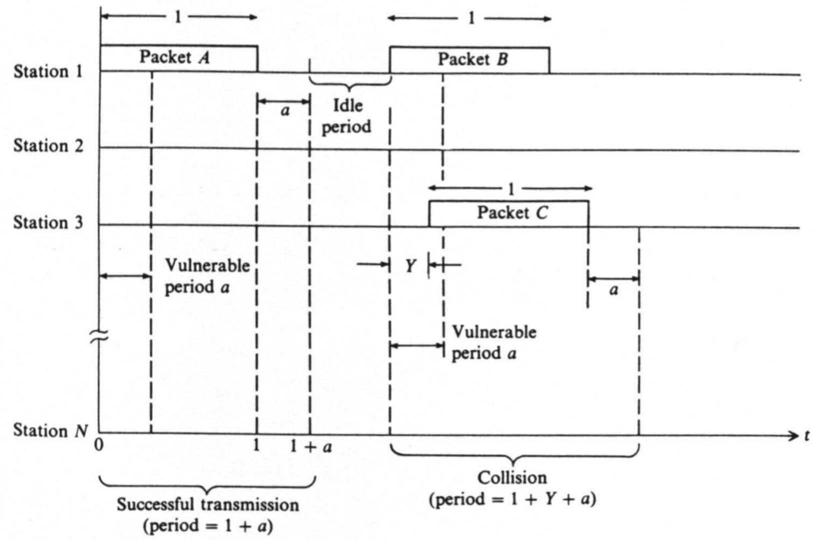
31



Vulnerable time in CSMA

Non-persistent CSMA

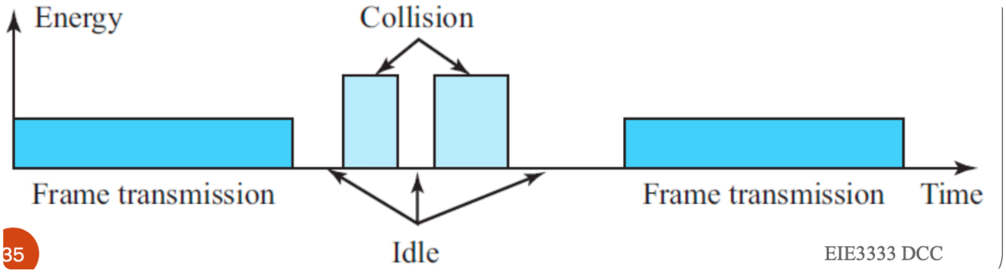
Successful and unsuccessful transmission attempts for nonpersistent CSMA. Time is measured in units of frame transmission time t_f



33

2.3 CSMA/CD Collision Detection

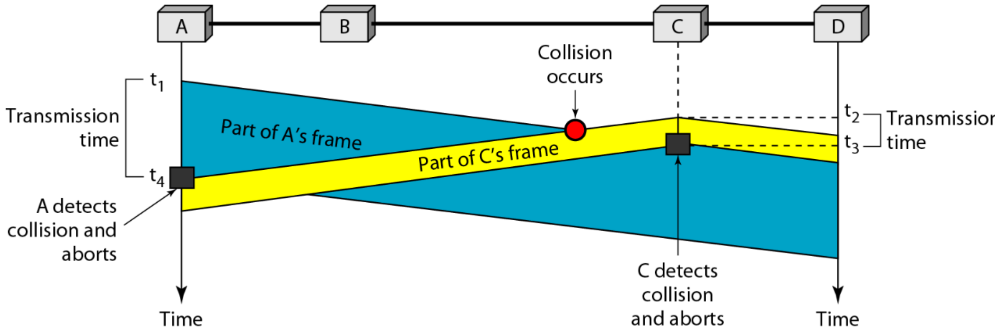
- handle collision
- **monitor the medium after it sends a frame to see if transmission is successful**
- abort
- three approaches
- CD: the level of energy, zero, normal and abnormal (twice the normal)
- A station needs to monitor the energy level



35

EIE3333 DCC

Example

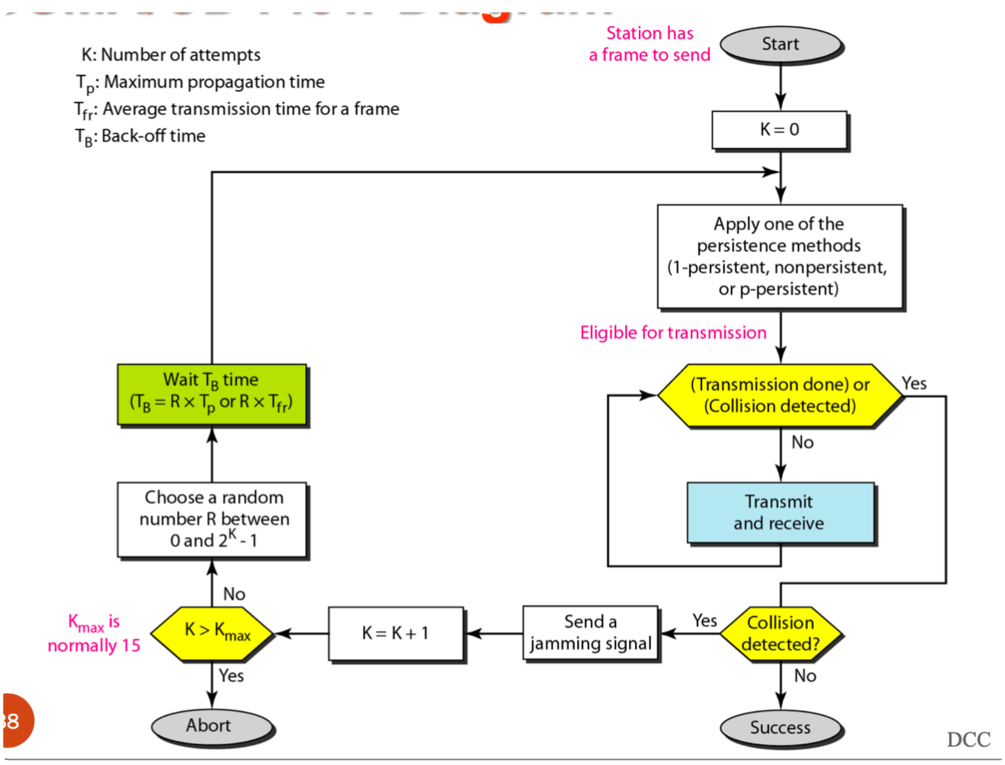


At time t_1, station A has executed its persistence procedure and starts sending the bits of its frame. At time t_2, station C has not yet sensed the first bit sent by A. Station C executes its persistence procedure and starts sending the bits in its frame, which propagate both to the left and to the right. The collision occurs sometime after time t_2. Station C detects a collision at time t_3 when it receives the first bit of A's frame. Station C immediately (or after a short time, but we assume immediately) aborts transmission. Station A detects collision at time t_4 when it receives the first bit of C's frame; it also immediately aborts transmission. Looking at the figure, we see that A transmits for the duration $t_4 - t_1$; C transmits for the duration $t_3 - t_2$.

2.4 Minimum Frame Size

- Before sending the last bit of the frame, the sending station must detect a collision
- Once the entire frame is sent, does not keep a copy of the frame and does not monitor the line for collision detection
- T_{fr} must be at least two times the maximum propagation time T_p

2.5 Diagram

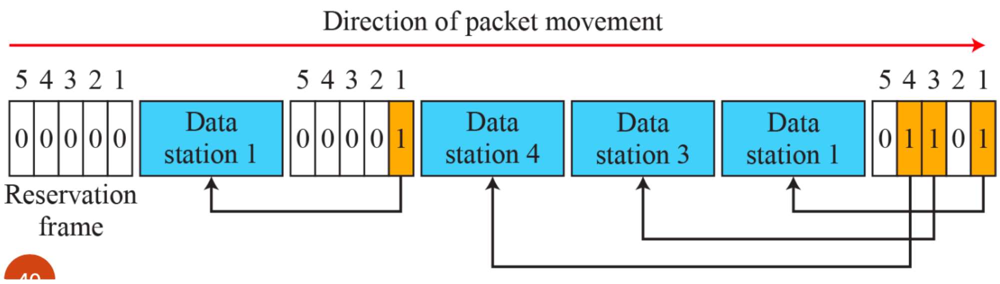


Controlled Access MAC Protocols

- the station *consult one another* to find which station has the right to send
- a station cannot send unless it has been *authorized by other stations*
- Three methods
  - **Reservation**
  - **Polling**
  - **Token Passing**

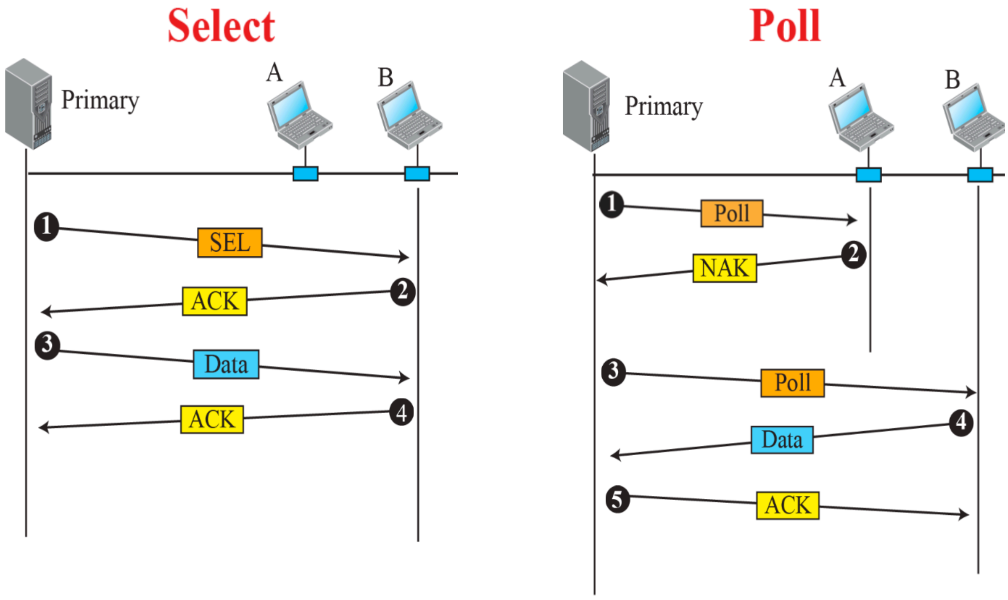
1.1 Reservation

- a station needs to *make a reservation* before sending data,
- Time is *divided into intervals*
- In each interval, a reservation frame *precedes* the data frames sent in that interval
- N station, N reservation mini-slot, each belongs to a station
- When a station needs to send, it makes a reservation in its own mini-slot
- The station that made reservations can send their data frames after the reservation frame



1.2 Polling

- topologies
- primary and secondary stations
- All data through the primary device
- primary controls the links, the secondary follows its instructions

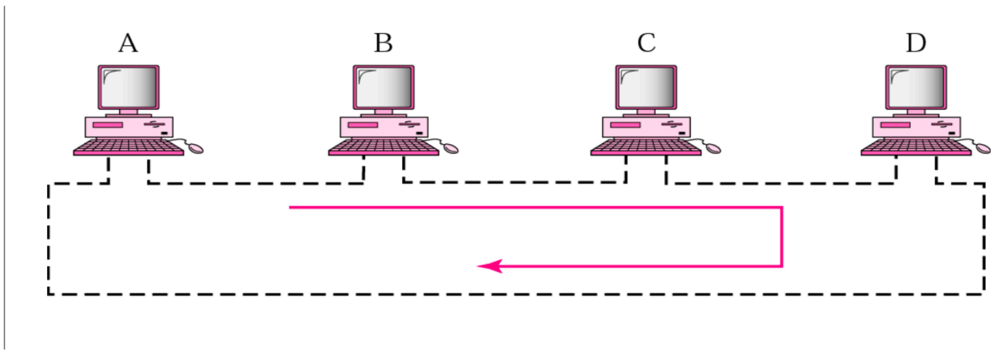


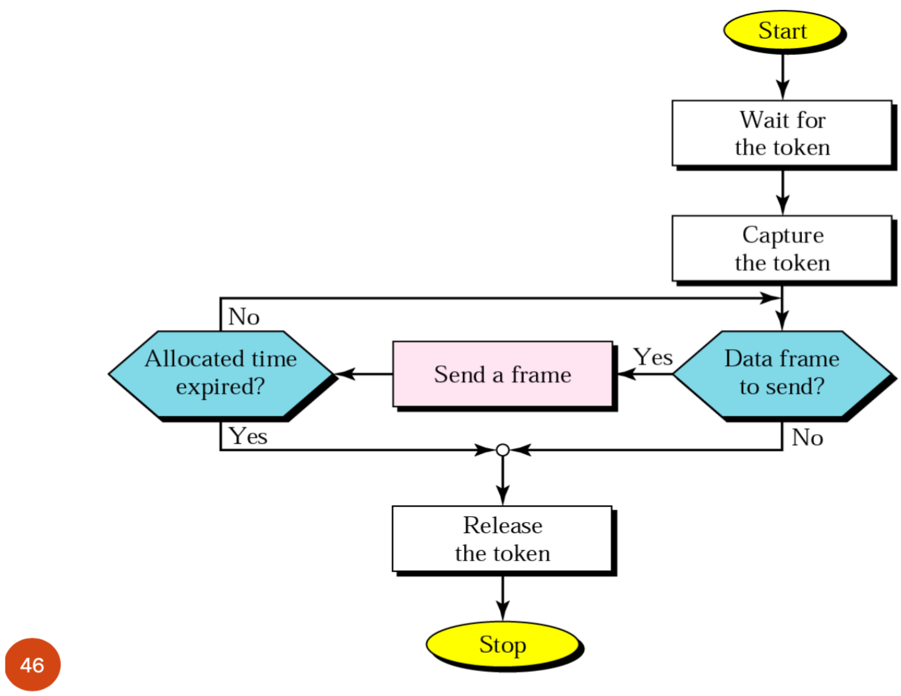
1.3 Token Controlled Technique

- Tokens are *special bit patterns or packets*, several bits in length
- Token *circulates* from node to node when no message traffic
- When a station wants to send
  - remove the token from line and hold it
  - then has exclusive access to network for transmitting
- Other station continuously monitoring the messages pass by
- All stations are responsible for *identifying and accepting* messages addressed to them, or pass on messages to other
- finish, *puts the token back* into circulation
- *ring or bus* topologies

1.4 Token Passing Network

- in a token ring the stations are connected logically in a ring with each station transmitting to the next sequentially





1.5 Polling and Token Passing

Polling

- polling overhead
- latency
- single point of failure (master)

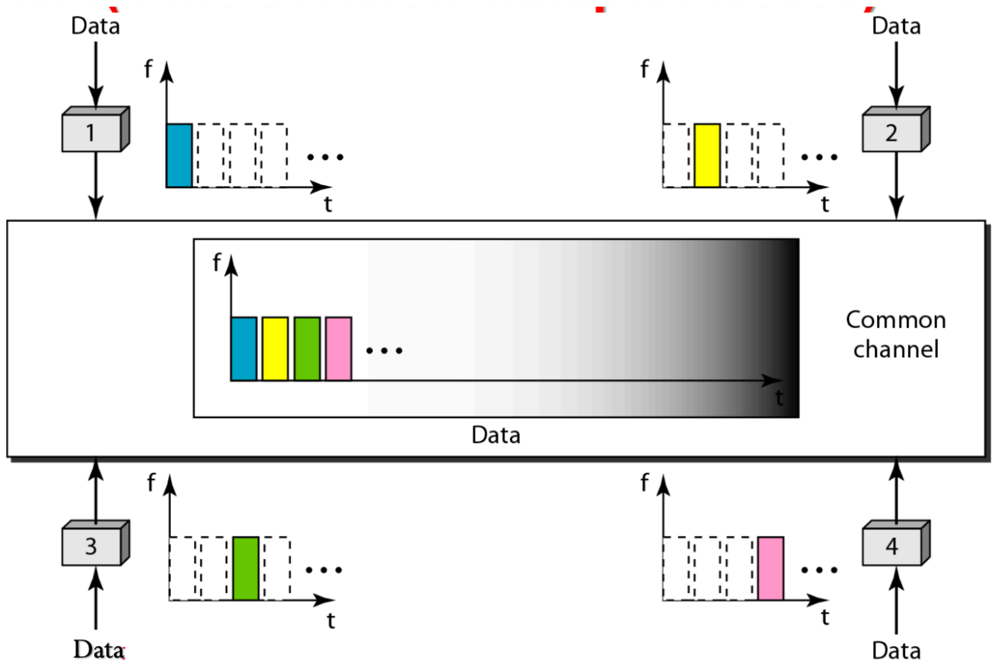
Token passing

- token overhead
- latency
- single point of failure (token)

Channel Partitioning MAC Protocols

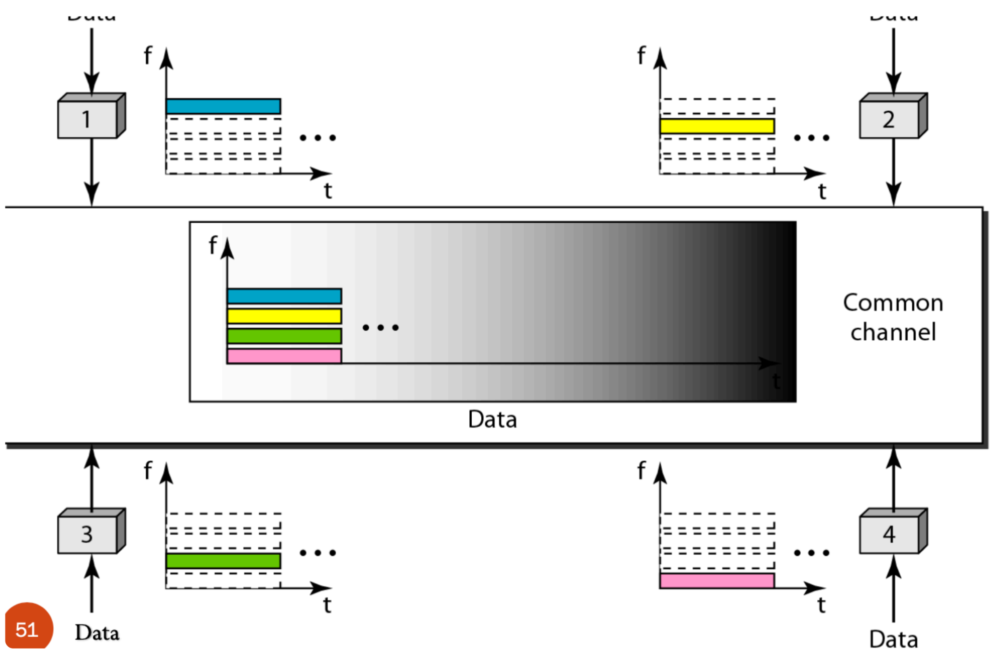
- TDM (Time Division Multiplexing)
  - N time slots
  - Inefficient with low duty cycle user and at light load
- FDM (Frequency Division Multiplexing)
  - Frequency subdivided

1.1 TDMA



- access to channel *in rounds*
- fix length slot (length = packet transmission time) in each round
- idle unused slot

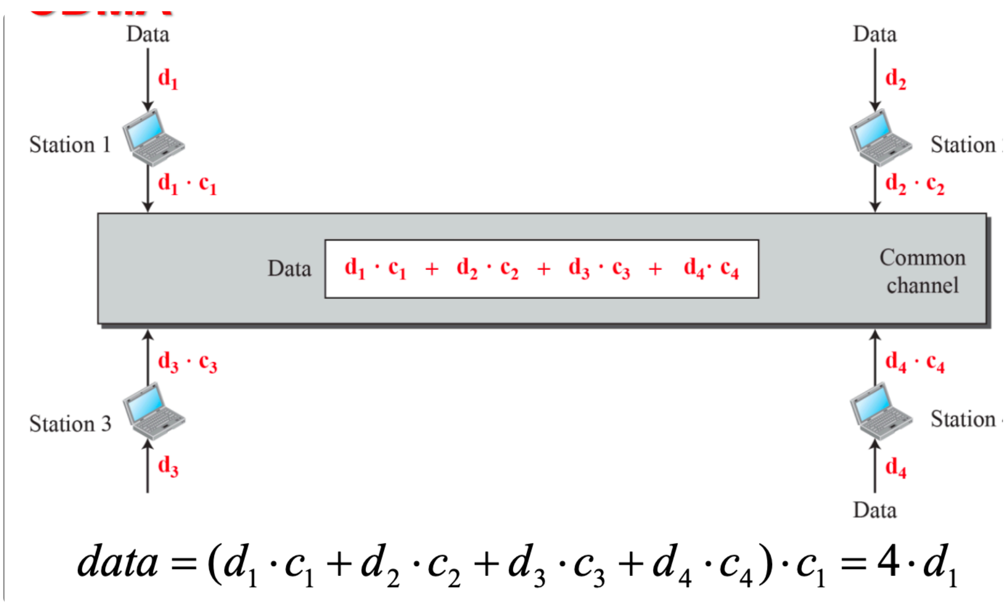
1.2 FDMA



- frequency bands
- fixed frequency band
- unused - idle

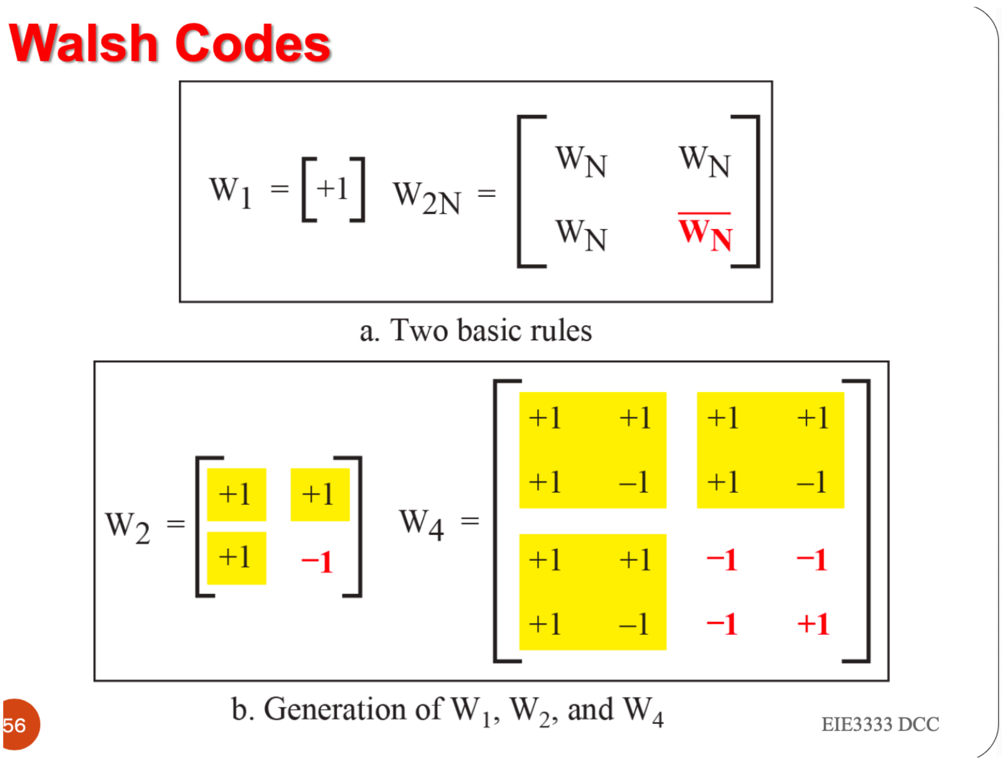
1.3.1 CDMA

- only one channel occupies the *entire bandwidth*
- all stations send *simultaneously*, no timesharing
- carries all transmissions simultaneously
- different code



1.3.2 Chips

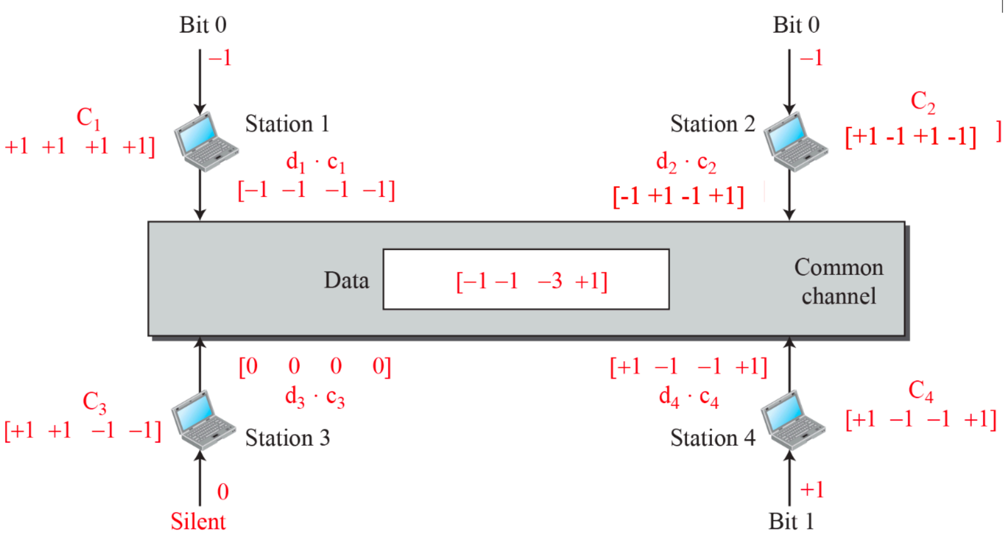
- coding theory
- each station is assigned a code, which is a sequence numbers called *chips*
- N element
- Walsh codes



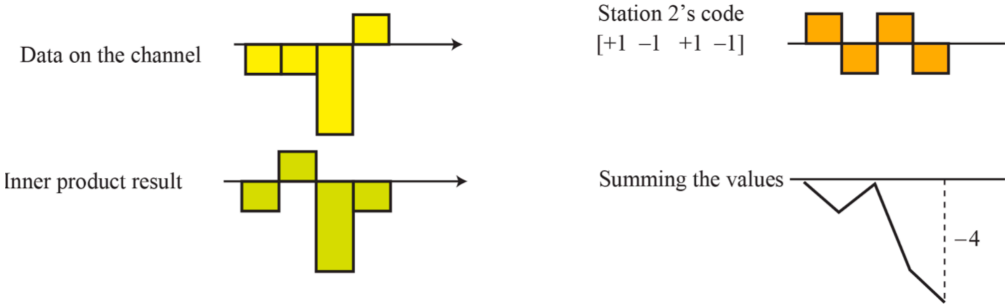
Data bit 0 → −1

Data bit 1 → +1

Silence → 0



Decoding of the composite signal for one in CDMA



−4 → −4/4 → −1 → Bit 0