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Chapter 5

LAN & MAC

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Contents

- Channel allocation Methods
  - Channel partitioning
  - Random Access
  - Taking Turning
- Ethernet

Local Area Network

Local Area Network

Network Classification by diameter

Diameter	Host Location	Network Type
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Local Area Network

LAN characteristics

- One channel shared by all hosts
- Using broadcast transmission technique
- Not require a witching unit such as routers or switches in simple LAN

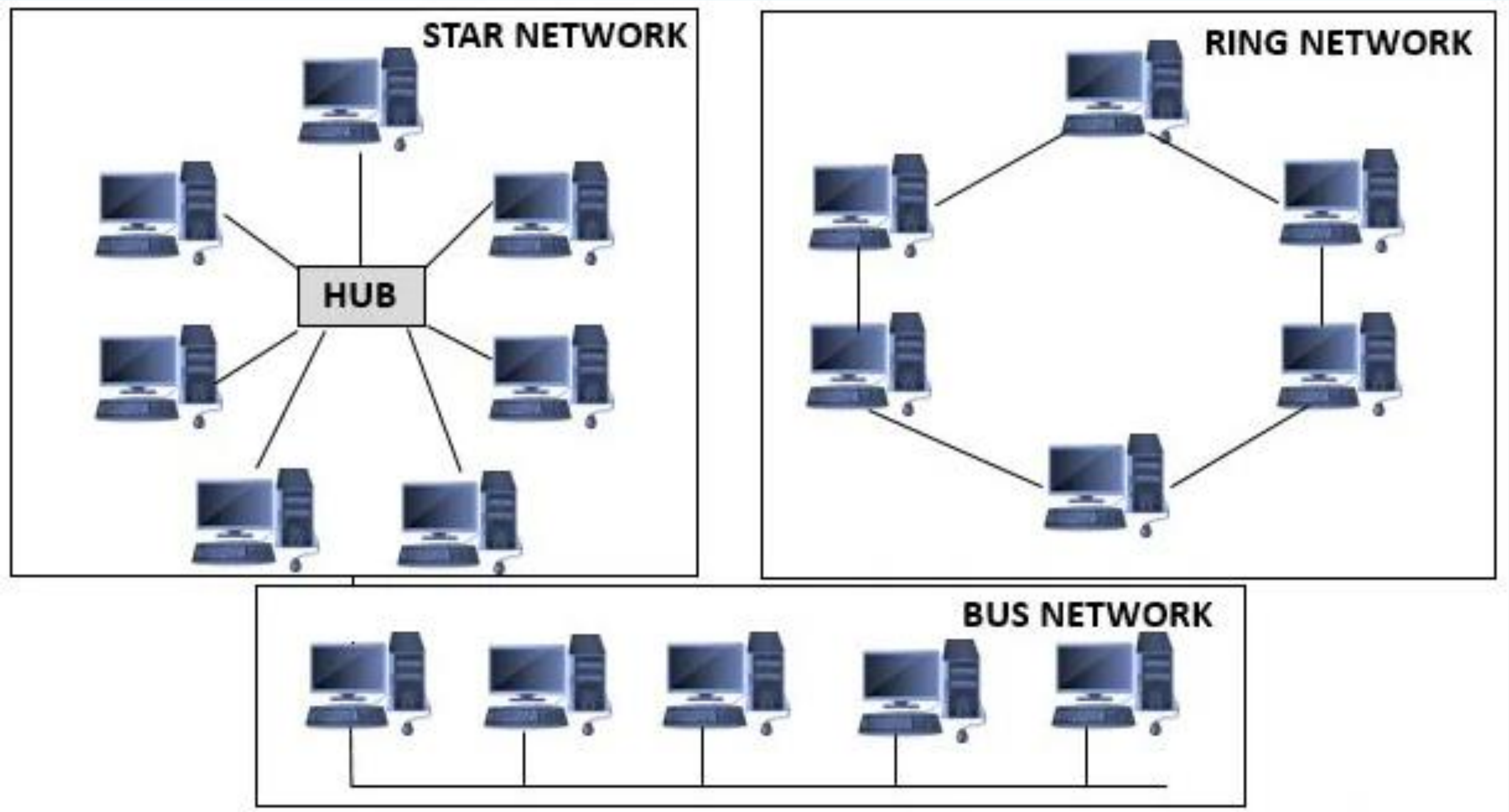
Local Area Network

LAN parameters

- Topology: specify the connection schema of hosts in a LAN
- Shared channel: specify the type of the channel used to connect hosts in a LAN (Coaxial cable, Twisted pair cable, fiber optical cable)
- Protocol of medium access control (MAC – Protocol): Specify the way/method used by hosts to share a common channel in a LAN
- MAC Protocol controls access of hosts to a channel of a LAN and is the base for identifying characteristics of a LAN

Local Area Network

LAN topologies

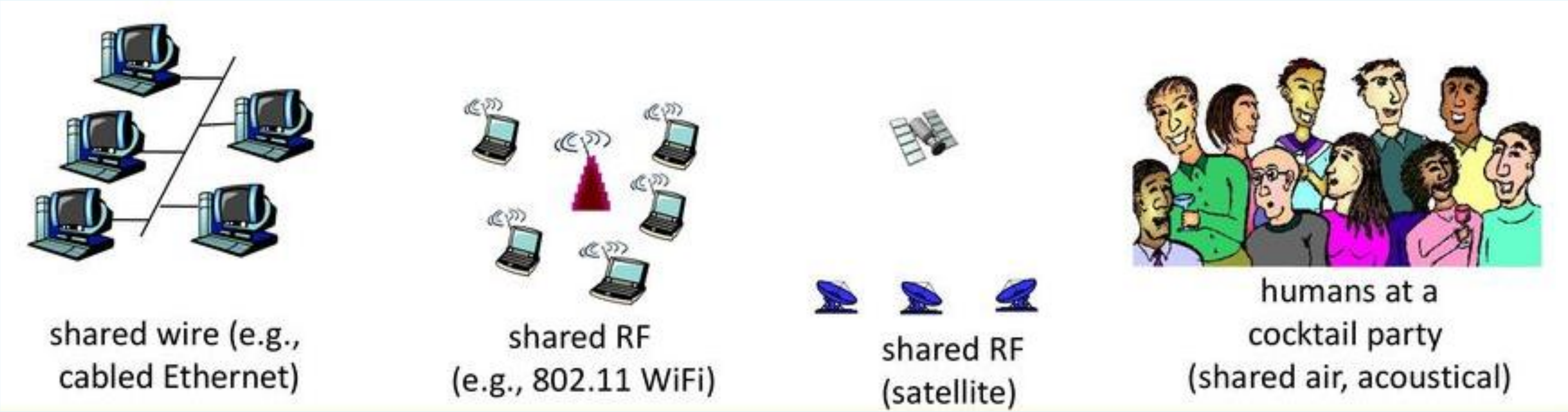


Local Area Network

Multiple access links

3 types of channels

1) Point – to – point (single wire, e.g. PPP, SLIP)
2) Broadcast (shared wire or medium; e.g, Ethernet, etc)
3) Switched (switched Ethernet, ATM)



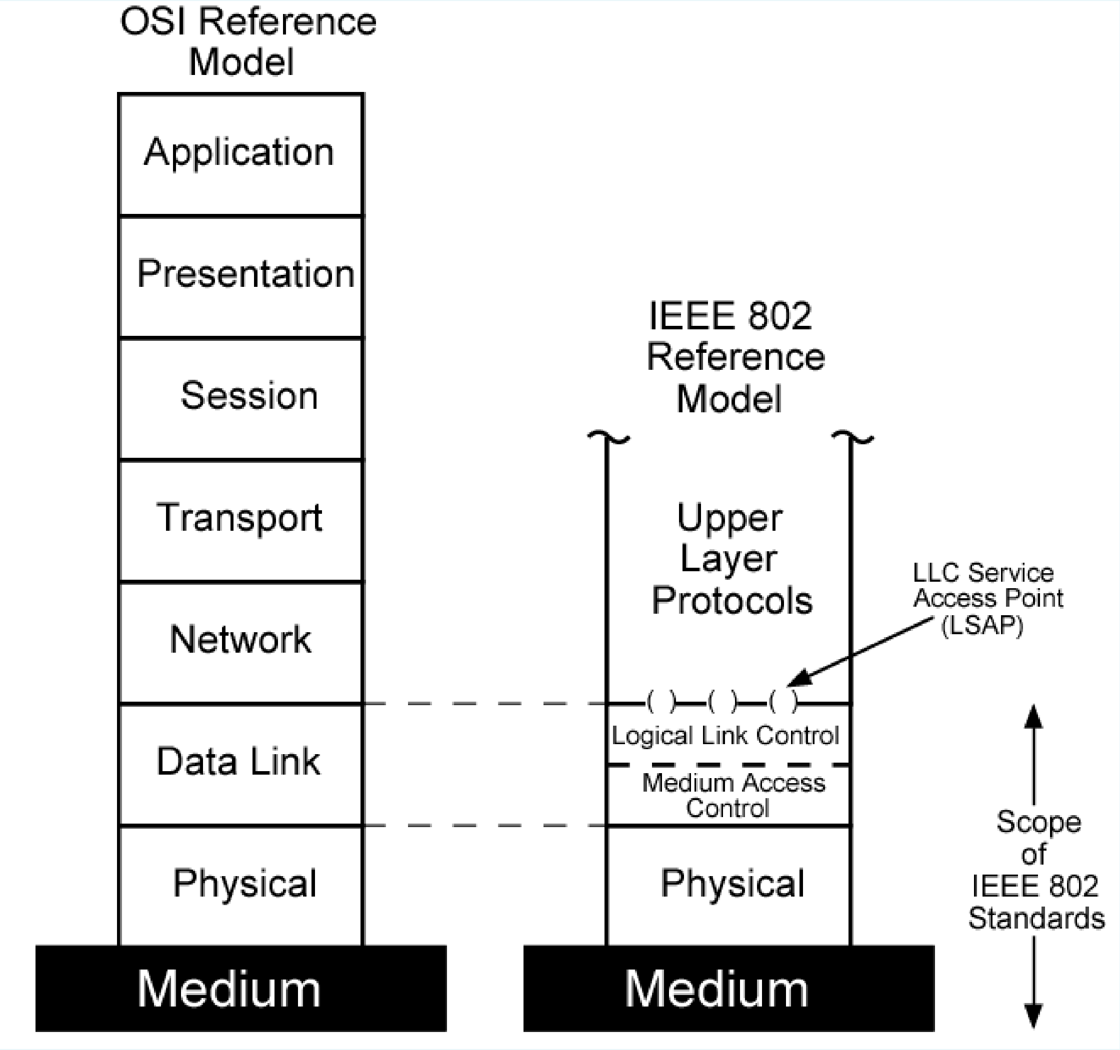
Local Area Network

Medium Access Control Protocol

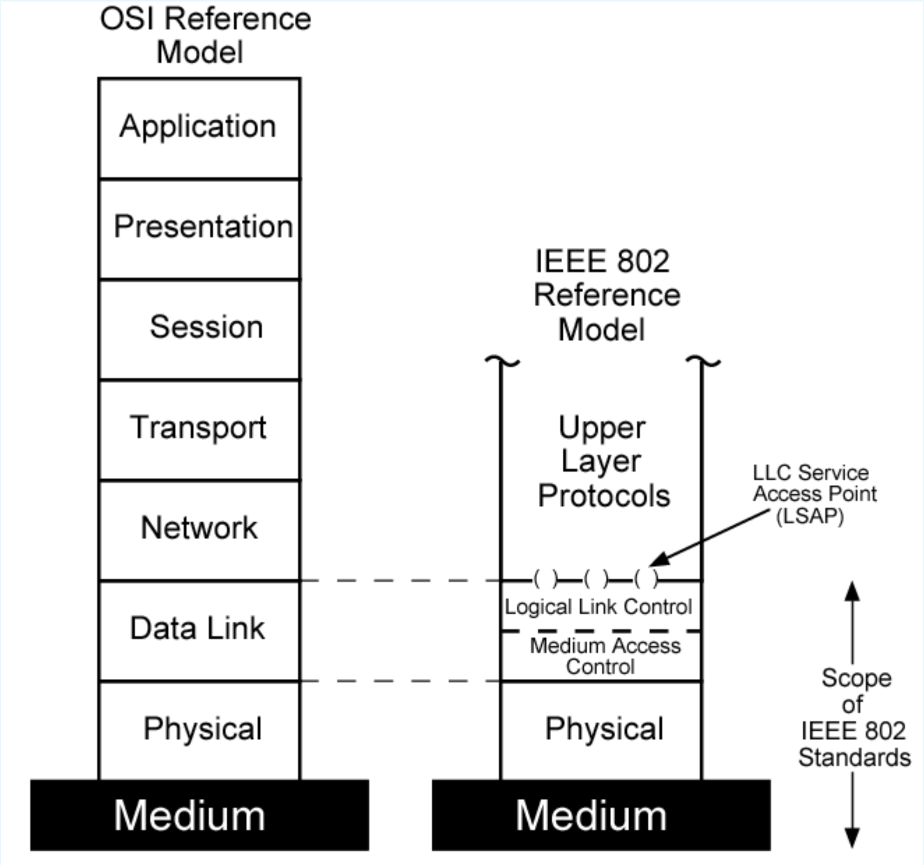
- LAN: One channel shared for all hosts
- Two hosts transmitting data at the same time will cause signal overlap → transmission error status
- Only one host is permitted to send data at a point of time
- Need a protocol to control the sharing of channel between hosts → Medium Access Control Protocol (MAC Protocol)

Local Area Network
Medium Access Control Protocol

- Data link layer divided into two sub-layers
  - Logical Link Control layer (LLC layer)
  - Medium Access Control layer (MAC layer)
- LLC Layer:
  - Communicates with network layer
  - Responsible for error control and flow control
  - Provides services for network layer
    - ✓ Unacknowledged connectionless service
    - ✓ Acknowledged connectionless service
    - ✓ Connection oriented service

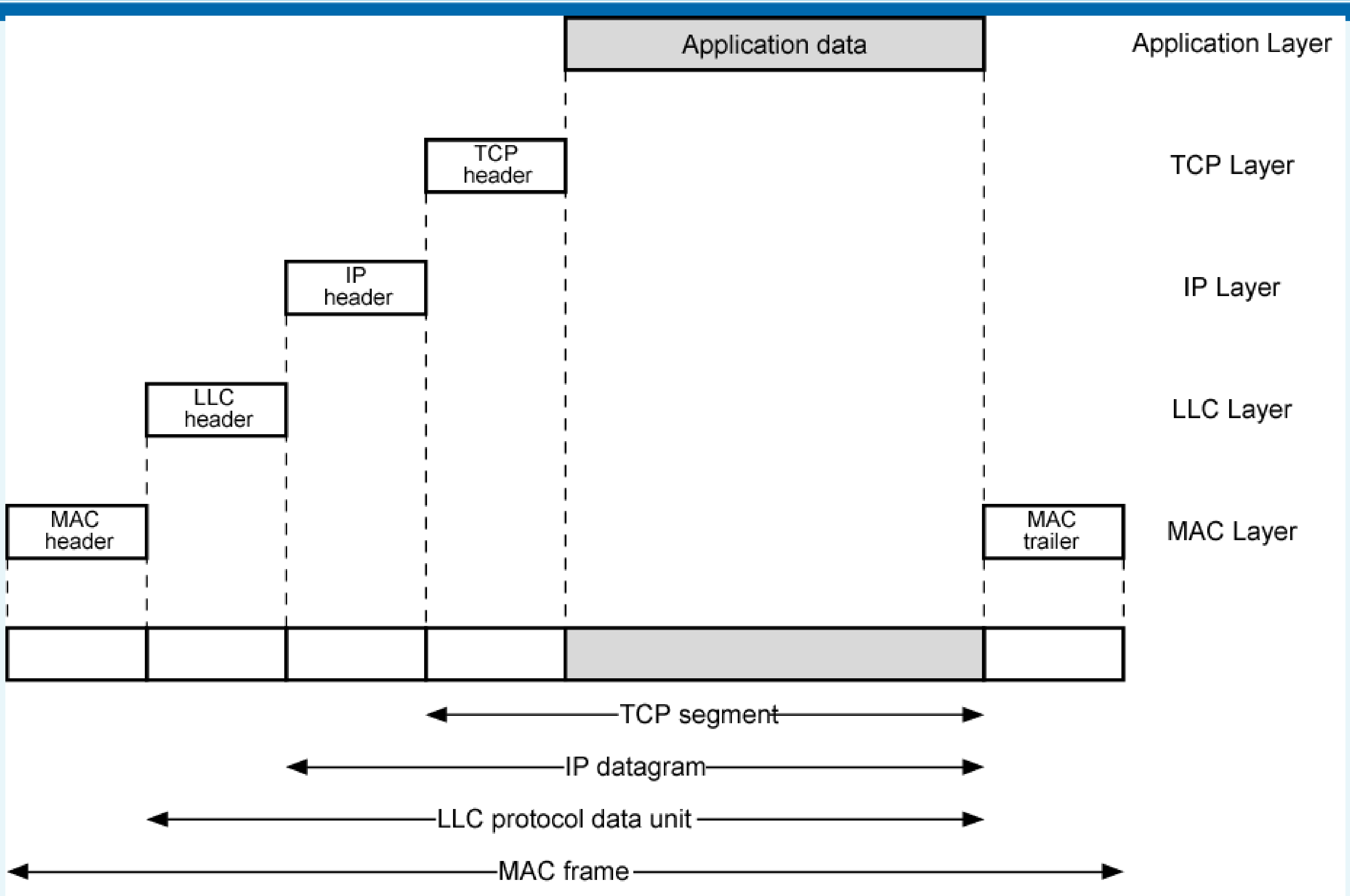


- MAC layer:
  - Creates frames including a header (sender address, receiver address), data and checksum
  - Receives frame, extracts sender address and receiver address, data, and detects frame error
  - Controls access to medium
    - ✓ This function is not included in traditional data link layer
  - One LLC layer can have many types of MAC layer



Local Area Network

Data units



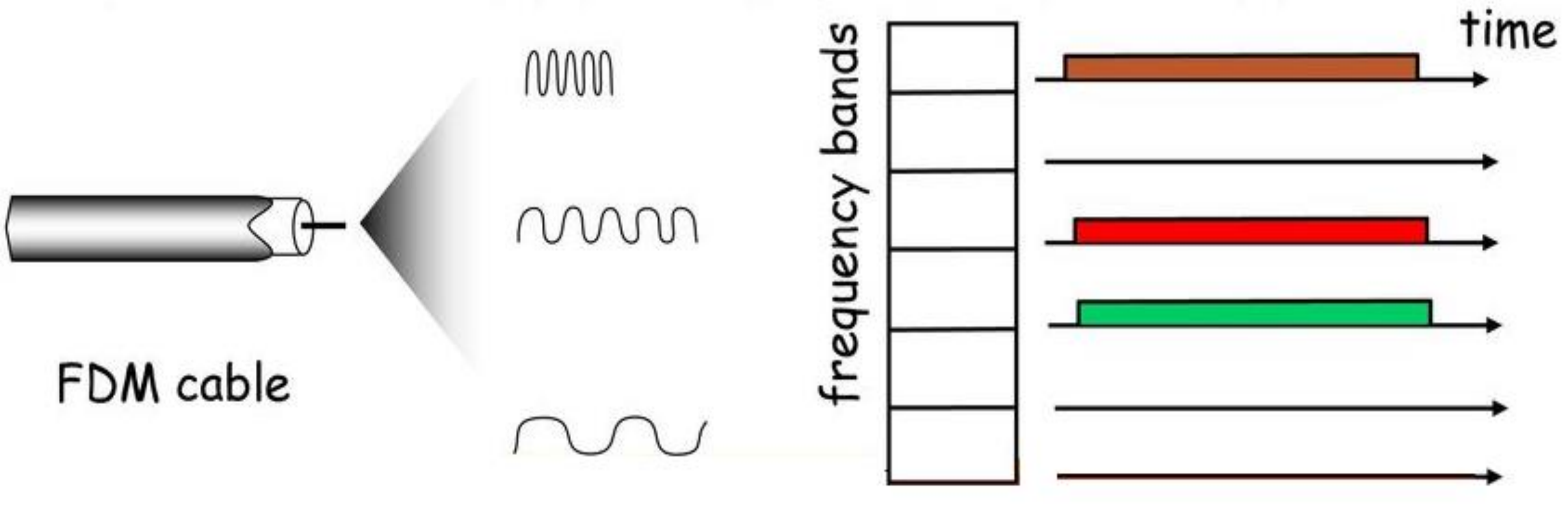
- Channel partitioning protocols
  - ✓ Partition the channel into many parts (time slots, frequency, code)
  - ✓ Allocate each part to a host for using in an exclusive way
- Random access protocols
  - ✓ Allow the collision between hosts in using a channel
  - ✓ Redo after collision
- Taking turn protocol
  - ✓ Cooperation between hosts in using the channel to avoid the collision

- Partition the channel into many parts
- Allocate each part to a host for using
- Three principle methods
  - ✓ FDMA (Frequency Division Multiple Access)
  - ✓ TDMA (Time Division Multiple Access)
  - ✓ CDMA (Code Division Multiple Access)

Frequency Division Multiple Access

- Channel spectrum divided into frequency bands
- Each station assigned a fixed frequency band
- Unused transmission time in frequency bands go idle

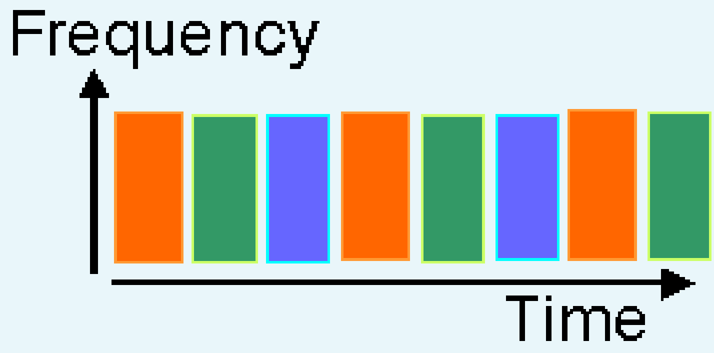
Example: 6-station LAN;
1, 3 and 4 have data;
frequency bands 2,5,6 idle



- Frequency Division Multiple Acces
  - Advantages
    - ✓ No collision between hosts
    - ✓ Efficient in systems with small and stable number of users; each user always have data to send
  - Disadvantages
    - ✓ Waste of channel if the number of users smaller than the number of frequency bands
    - ✓ User request denied if the number of users larger than the number of frequency bands
    - ✓ Not exploit the maximum capacity of the channel

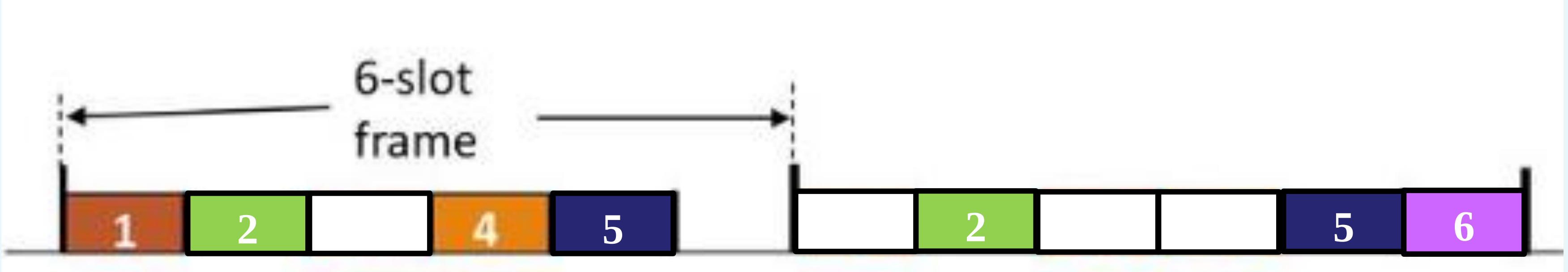
TDMA (Time Division Multiple Access)

- A set of *N* users share the same radio channel, but each user only uses the channel during predetermined slots
- Each station will be assigned a time slot that is long enough to send a frame
- When a station is in turn and assigned a time slot but it has no data to transmit, it still occupies the time slot.
  - ✓ The slot is considered in idle state



TDMA (Time Division Multiple Access)

- Example: A 6-station LAN
  - ✓ Frame 1: 1, 2,4,5 have data, slots 2 and 6 idle
  - ✓ Frame 2: 2,5, 6 have data, slots 1, 3, 4 idle



- TDMA
  - Advantages
    - ✓ Collision Free
  - Disadvantages
    - ✓ Unused slot at a node goes useless while another node could not use it
    - ✓ TDMA requires synchronization between different stations
    - ✓ Why is time synchronization a headache?
      - ❖ Extra communication
      - ❖ Synchronization error
      - ❖ Does not scale

- CDMA (Code Division Multiple Access)
  - Used mostly in wireless broadcast channels such as cellular phones
  - All users share same frequency band.
  - Each station to transmit over the entire frequency spectrum all the time
  - Each user has their own orthogonal Wash code ‘chipping’ sequence to encode data
  - To detect the message, receiver should know the codeword used by transmitter
  - In CDMA, the number of users í not limited but its performance degrades

- CDMA (Code Division Multiple Access)
  - Time for sending a bit (so-called bit time) divided into m short intervals called chips
    - ✓ Typically, there are 64 chips or 128 chips per bit time
  - Each station assigned a unique code at long of m-bit code, called chip sequence
  - Chip sequence of a user used to encode and decode his data

CDMA (Code Division Multiple Access)

- Given a chip sequence 11110011
  - ✓ To send bit 1, the sender will send his chip sequence 11110011
  - ✓ To sen bit 0, the sender will send the complement of his chip sequence 00001100
- Use bipolar signal
  - ✓ Bit 0 is represented by -1
  - ✓ Bit 1 is represented by +1
- The chip sequence 11110011 becomes +1+1+1+1-1-1+1+11

CDMA (Code Division Multiple Access)

- S•T is the inner product of two code S and T

$$S \bullet T = \frac{1}{m}\sum_{i=1}^{m} S_i T_i$$

- Example

$$S = +1+1+1-1-1+1+1-1$$

$$T = +1+1+1+1-1-1+1-1$$

$$S \bullet T = \frac{+1\ +1\ +1+(-1)+1+(-1)+1+1}{8} = \frac{1}{2}$$

- If all chip sequences are pairwise orthogonal, then they can send data concurrently with low possibility of inference

CDMA (Code Division Multiple Access)

- Coding data bit for sending
  - ✓ D_i: data bit that user i want to transmit to the channel
  - ✓ C_i: chip sequence of user I
  - ✓ Encoded signal of user i:

    $Z_i = D_i \times C_i$
  - ✓ Combined signal transmitted on the channel:

$$Z = \sum_{i=1}^{n} Z_i$$

n number of users transmitting data on the channel at the same time

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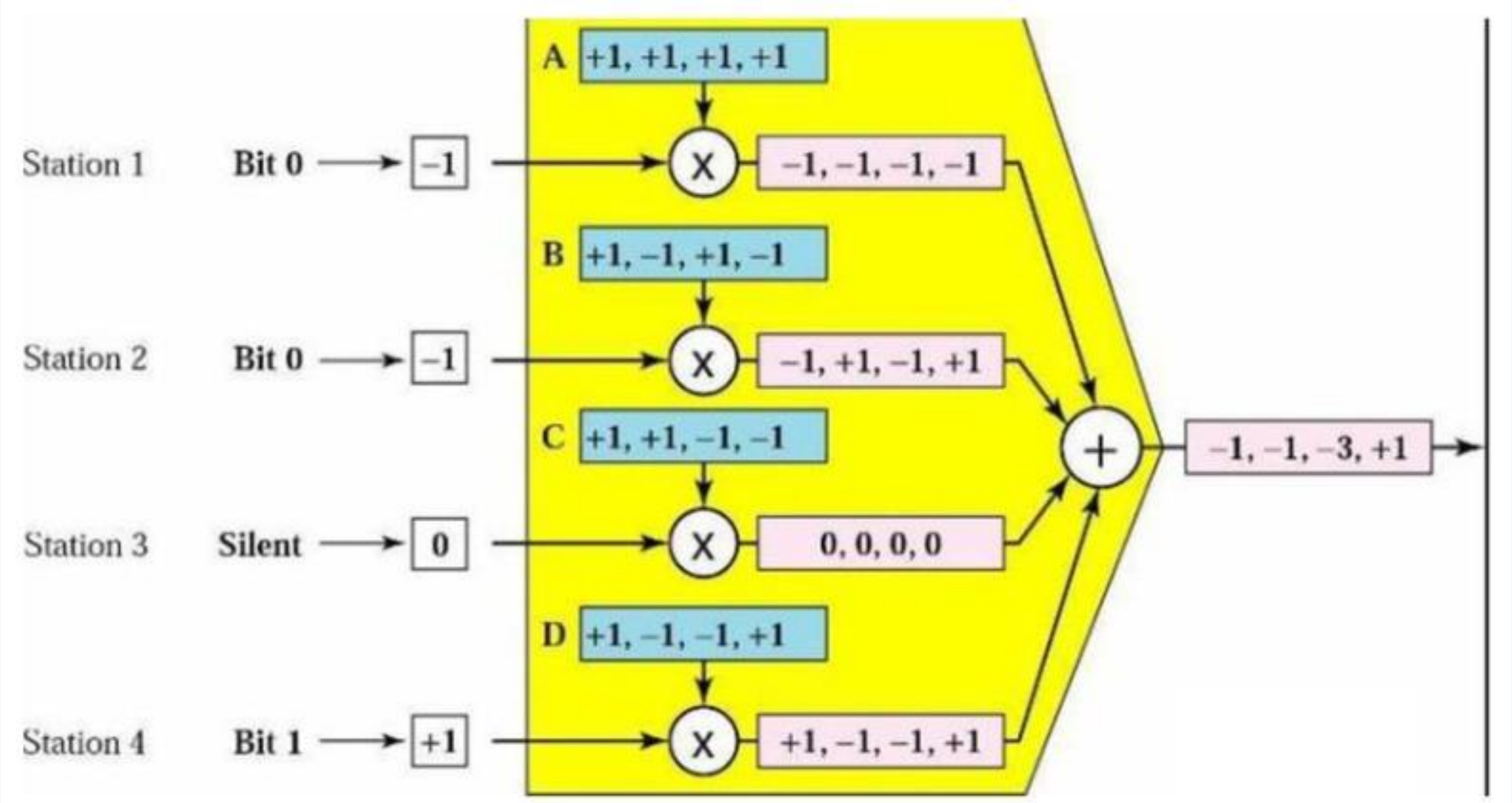
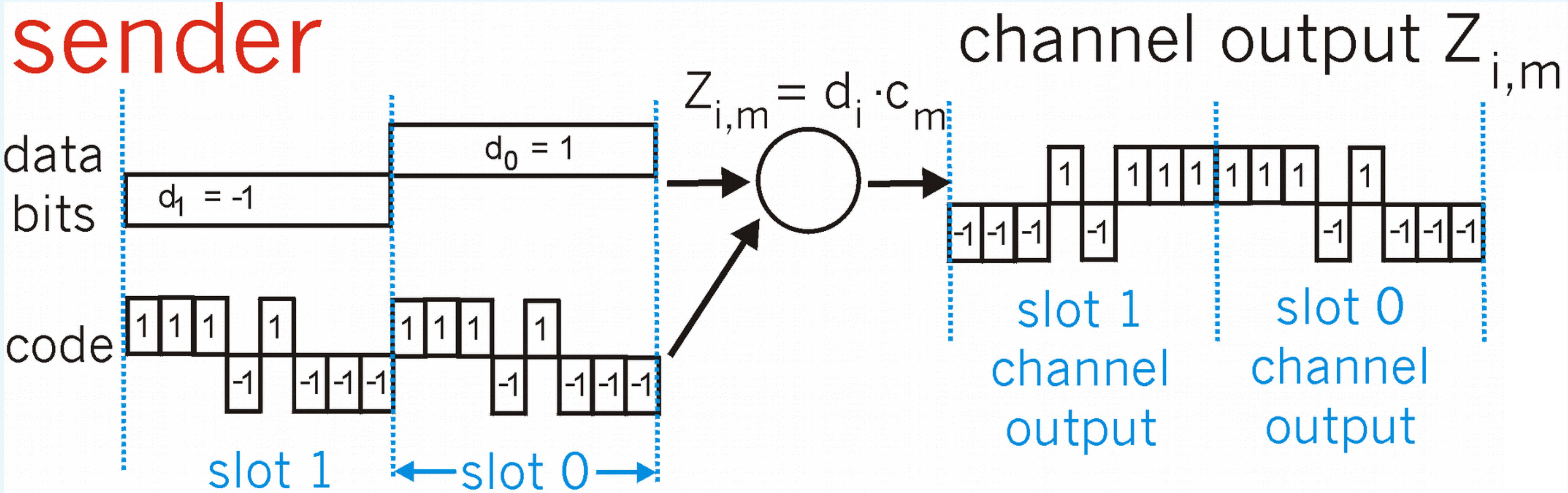
CDMA (Code Division Multiple Access)

- *Decoding data bit*
  - Extracting Data of user i from combined signal: $D_i = Z_i \bullet C_i$
  - If D_i > “threshold”, then D_i is 1, otherwise D_i is -1

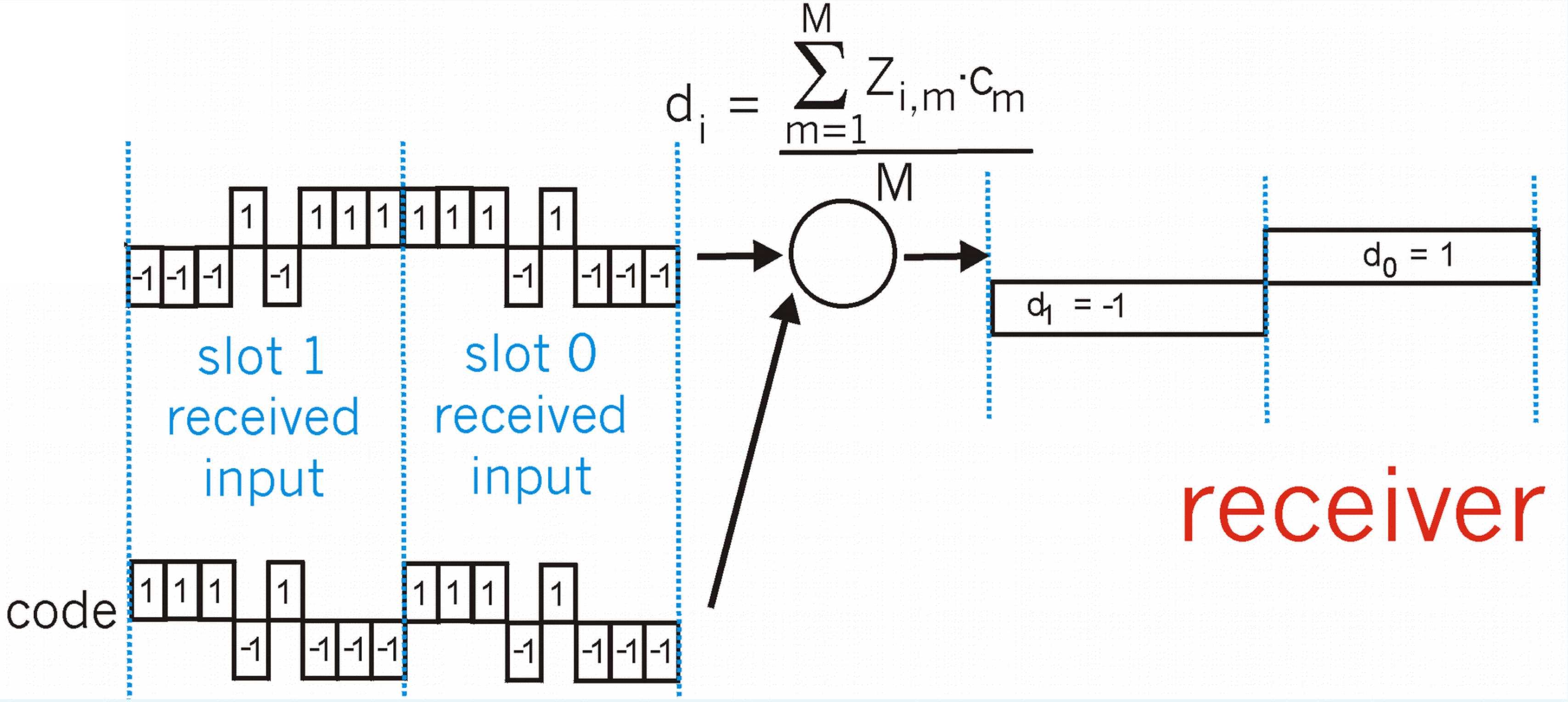
CDMA (Code Division Multiple Access)



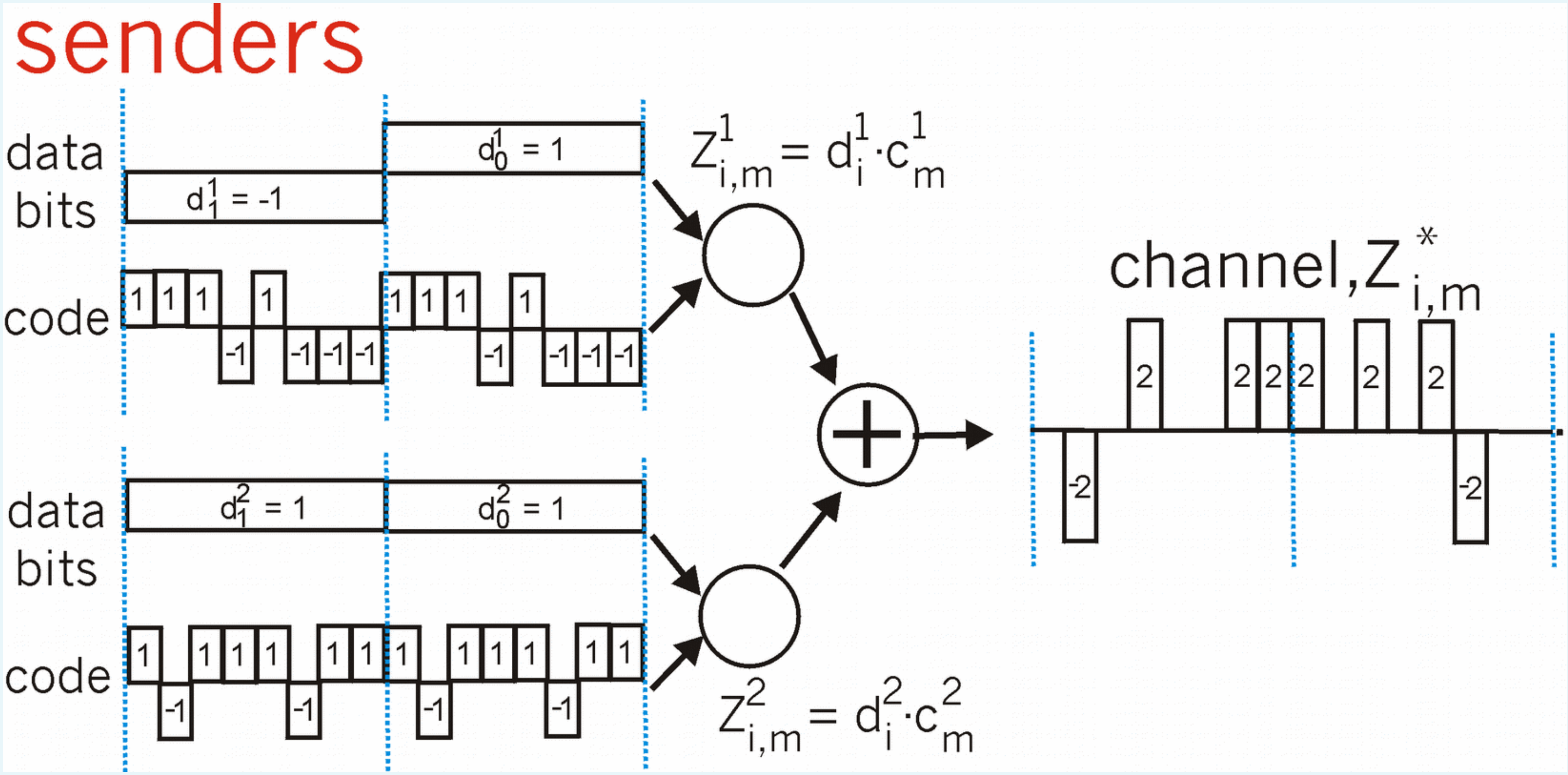
CDMA (Code Division Multiple Access)



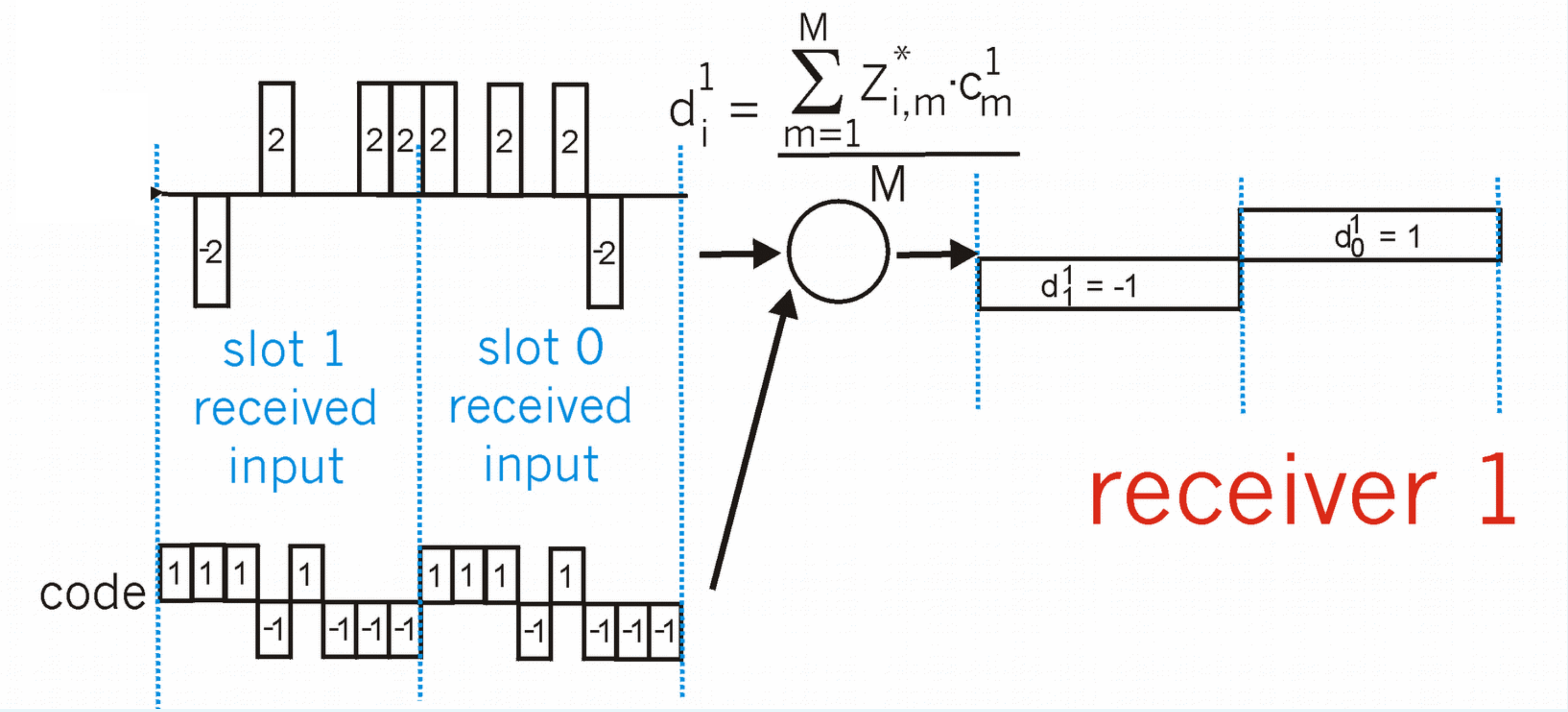
CDMA (Code Division Multiple Access)



CDMA (Code Division Multiple Access)



CDMA (Code Division Multiple Access)



CDMA (Code Division Multiple Access)

- A system with 4 user A, B, C, D having chip sequence as the following

A: 0 0 0 1 1 0 1 1
B: 0 0 1 0 1 1 1 0
C: 0 1 0 1 1 1 0 0
D: 0 1 0 0 0 0 1 0

- Representation of chip sequence in bi-polar signal

A: (–1 –1 –1 +1 +1 –1 +1 +1)
B: (–1 –1 +1 –1 +1 +1 +1 –1)
C: (–1 +1 –1 +1 +1 +1 –1 –1)
D: (–1 +1 –1 –1 –1 –1 +1 –1)

- Note that all chip sequences are orthogonal

CDMA (Code Division Multiple Access)

1. Only user C sends bit 1:
2. B sends bit 1, C send bit 1
3. A sends bit 1, B send bit 0
4. A, C send bit 1, B send bit 0
5. A, B, C, D send bit 1
6. A, B, D send bit 1, C send bit 0

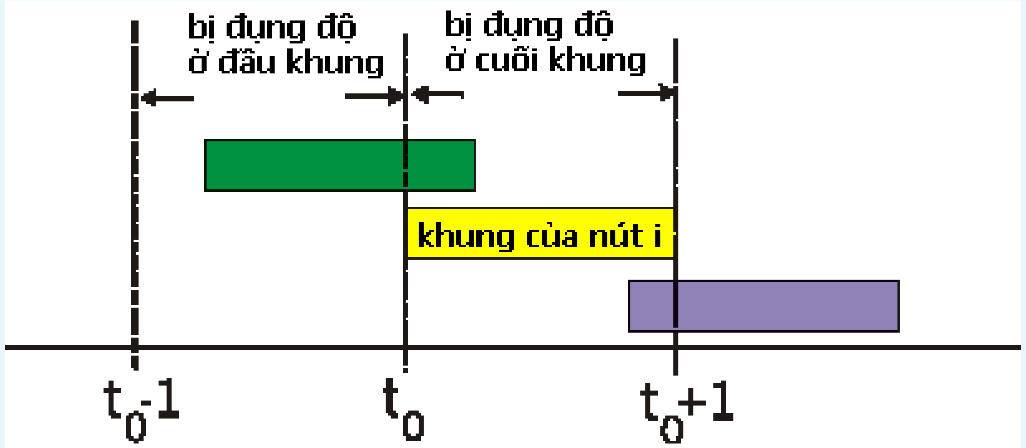
1)	– – 1 –	C	$Z = (-1 +1 -1 +1 +1 +1 -1 -1)$
2)	– 1 1 –	$B + C$	$Z = (-2\ 0\ 0\ 0 +2 +2\ 0 -2)$
3)	1 0 – –	$A + \bar{B}$	$Z = (\ 0\ 0 -2 +2\ 0 -2\ 0 +2)$
4)	1 0 1 –	$A + \bar{B} + C$	$Z = (-1 +1 -3 +3 +1 -1 -1 +1)$
5)	1 1 1 1	$A + B + C + D$	$Z = (-4\ 0 -2\ 0 +2\ 0 +2 -2)$
6)	1 1 0 1	$A + B + \bar{C} + D$	$Z = (-2 -2\ 0 -2\ 0 -2 +4\ 0)$

Calculate original bit of user C from combine signal

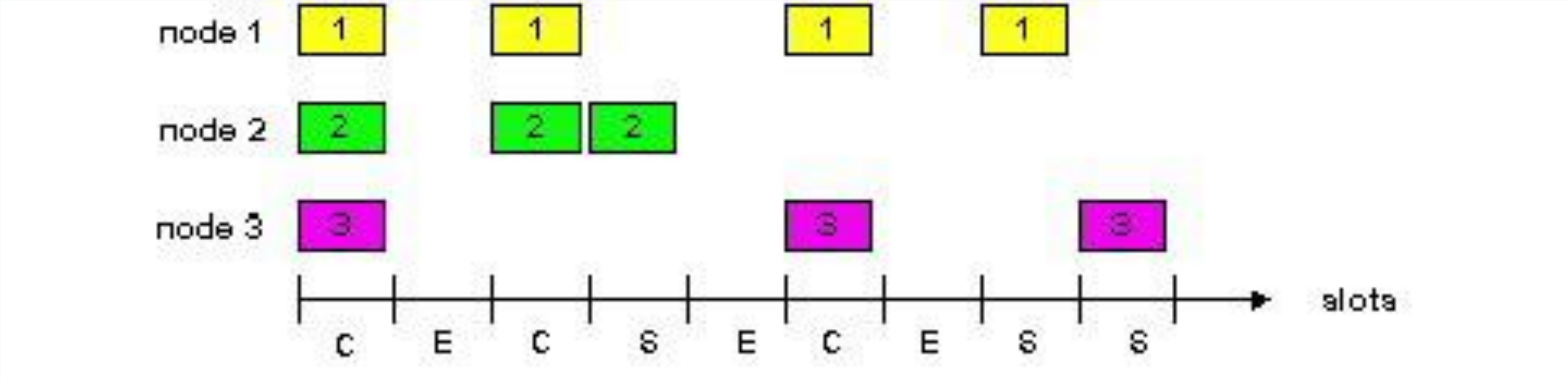
- If a station need to send a frame
  - ✓ It will send the frame onto the entire bandwidth of the channel
  - ✓ There is no cooperation between stations
- If there are two stations sending frame at the same time then collision will occur, both two frame will be damaged.
- Random access protocols have to propose methods for
  - ✓ Detecting collision
  - ✓ Redoing after a collision
- Example of random access protocols: Slotted ALOHA, Pure ALOHA, CSMA and CSMA/CD

- Pure (Unslotted) ALOHA
  - Let users transmit whenever they have data to be sent
  - Whenever two frames try to occupy the channel at the same time, there will be a collision and both will be garbled/destroyed

  - Sender just waits a random amount of time and sends the frame again
  - A frame sent at moment t0 will conflict with frames sent in period [t0-1, t0+1]



- Slotted ALOHA
  - Time is divided into discrete intervals called slots, each interval corresponding to one frame time
  - A station will send a frame at the beginning of the next slot
  - If collision occurs, the station will retransmit the frame at the following slots



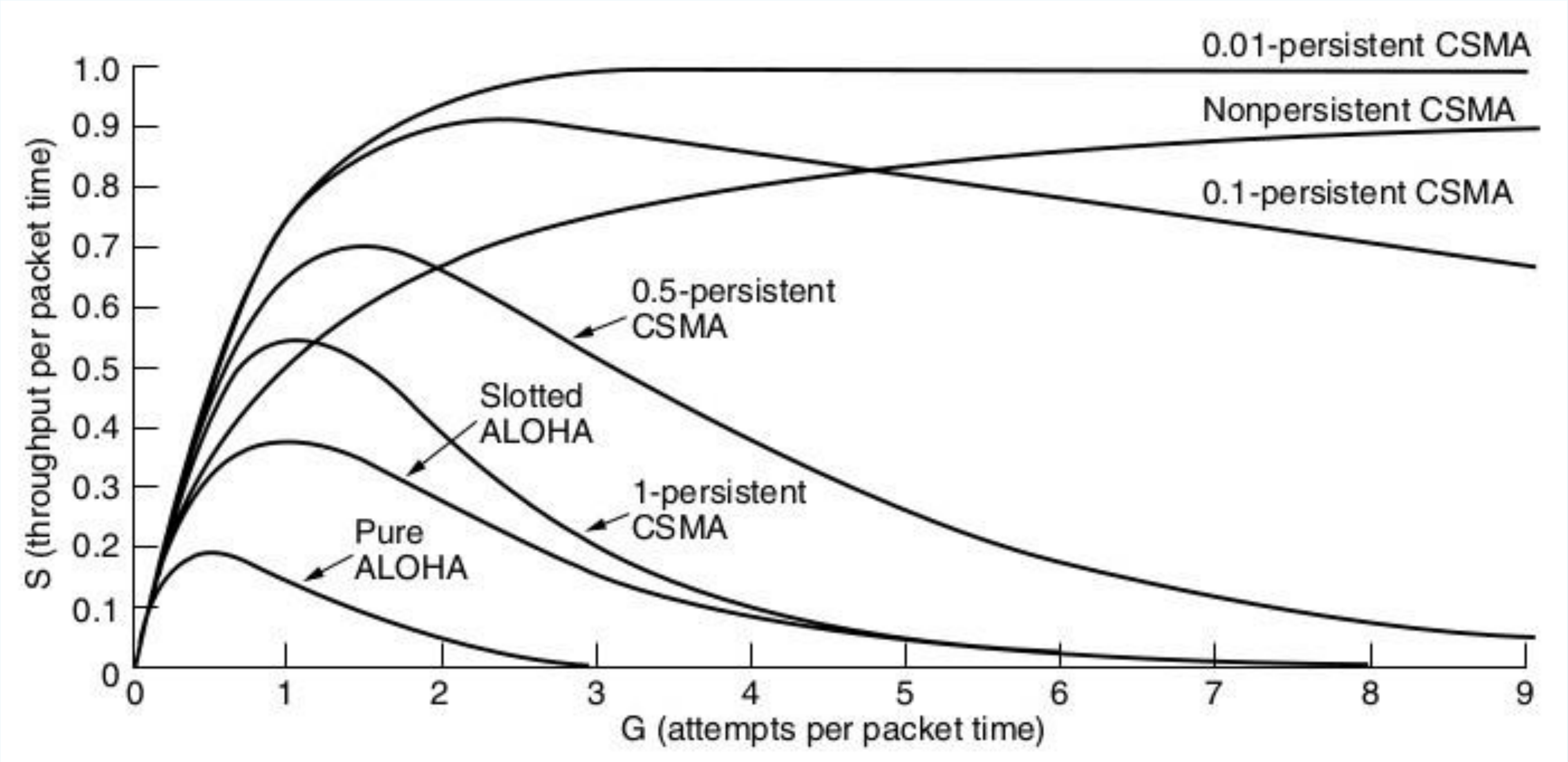
Success (S), Collision (C), Empty (E) slots

- CSMA - Carrier Sense Multiple Access protocol
  - Stations listen for a carrier (i.e., a transmission) and act accordingly
  - When a station has data to send, it first listens to the channel to see if anyone else is transmitting at that moment
  - If the channel is idle, the stations transmit entire frame immediately
    - ✓ If a collision occurs, wait for a random period then repeat the transmission again.

Success (S), Collision (C), Empty (E) slots

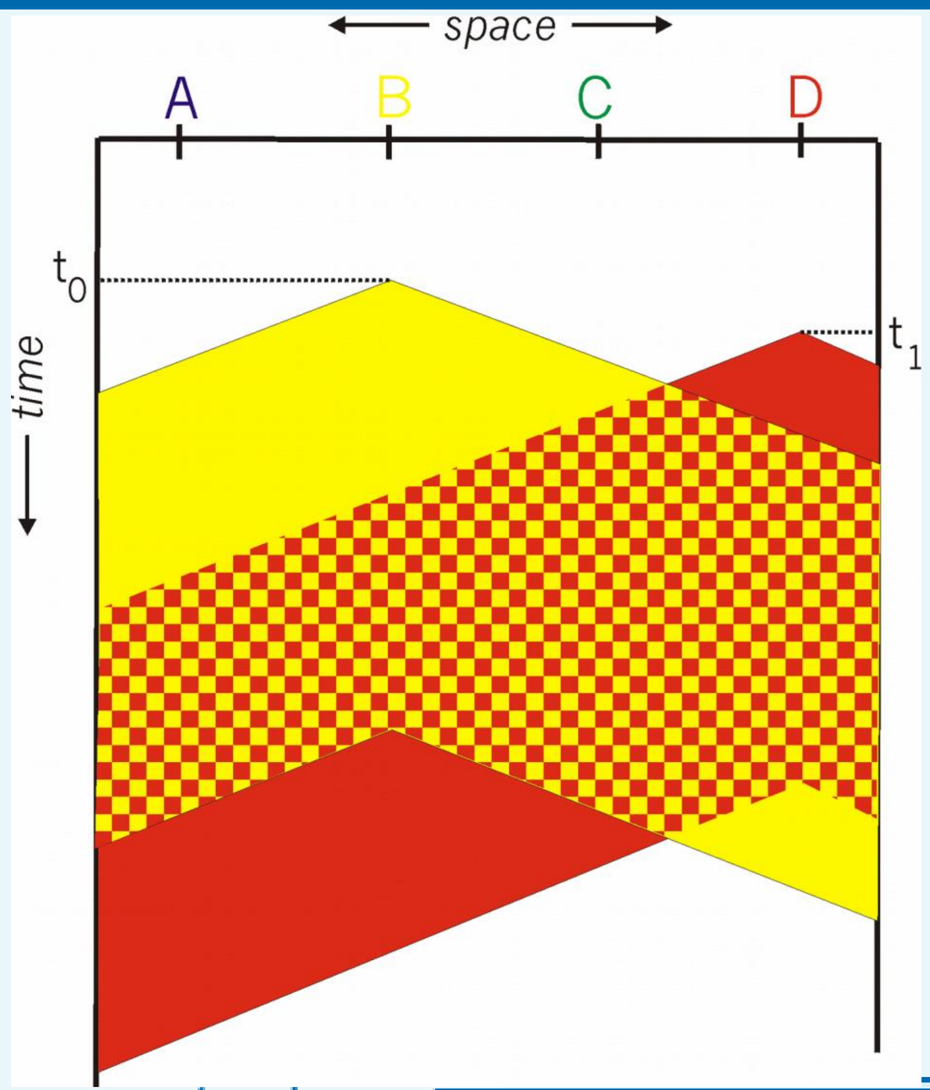
- CSMA - Carrier Sense Multiple Access protocol
  - If the channel is busy:
    - ✓ 1-persistent: Listen until the channel is available then the station transmits immediately (with probability of 1)
    - ✓ Non-persistent CSMA:
      - o waits a random time period and then check the medium again
      - o Transmitting immediately when the channel available
    - ✓ P-persistent CSMA: Listen until the channel is available then the station transmits with the possibility p

Comparison of the channel utilization versus load



CSMA collisions

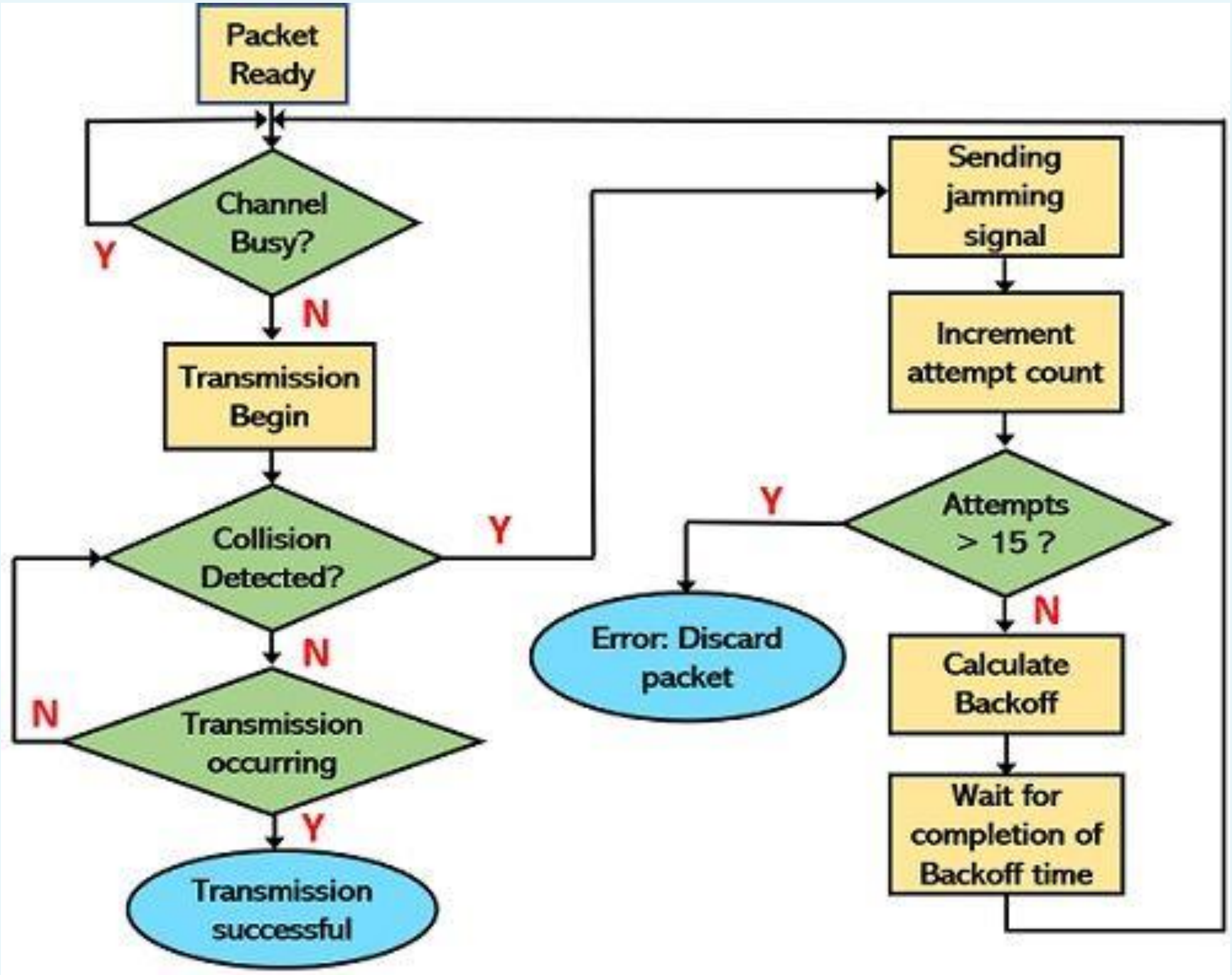
- Collision can still: propagation delay means two nodes can't hear each other‘s transmission
- Collision: entire frame transmission time wasted
- The distance between two stations and the propagation delay have an important effect on collisions



CSMA/CD (CDMA with Collision Detection)

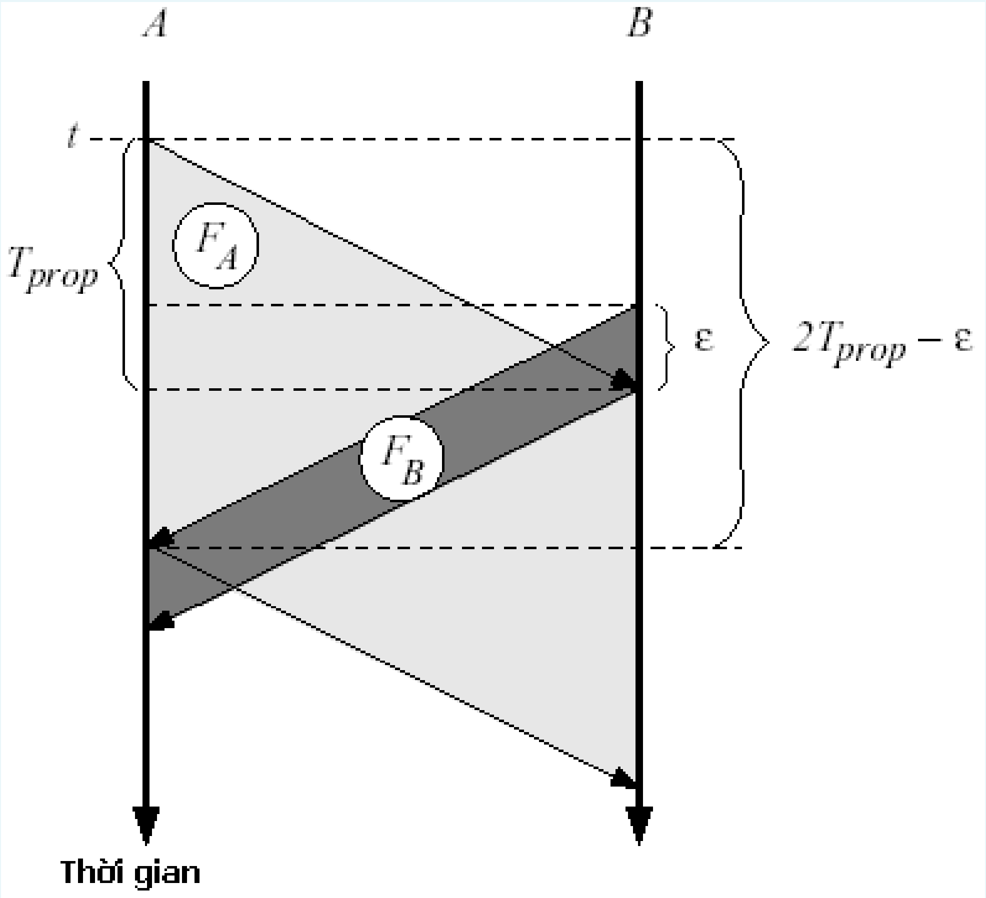
- Use a carrier sensing scheme in which station continue detecting other signal while transmitting a frame
- When collision detected, station:
  - ✓ Stops transmitting that frame
  - ✓ Sends jamming signals to tell other stations that collision has occurred
  - ✓ Waits for random interval (backoff) before trying to resend the frame
- Used to improve CSMA performance by terminating transmission as soon as a collision detected

CSMA/CD

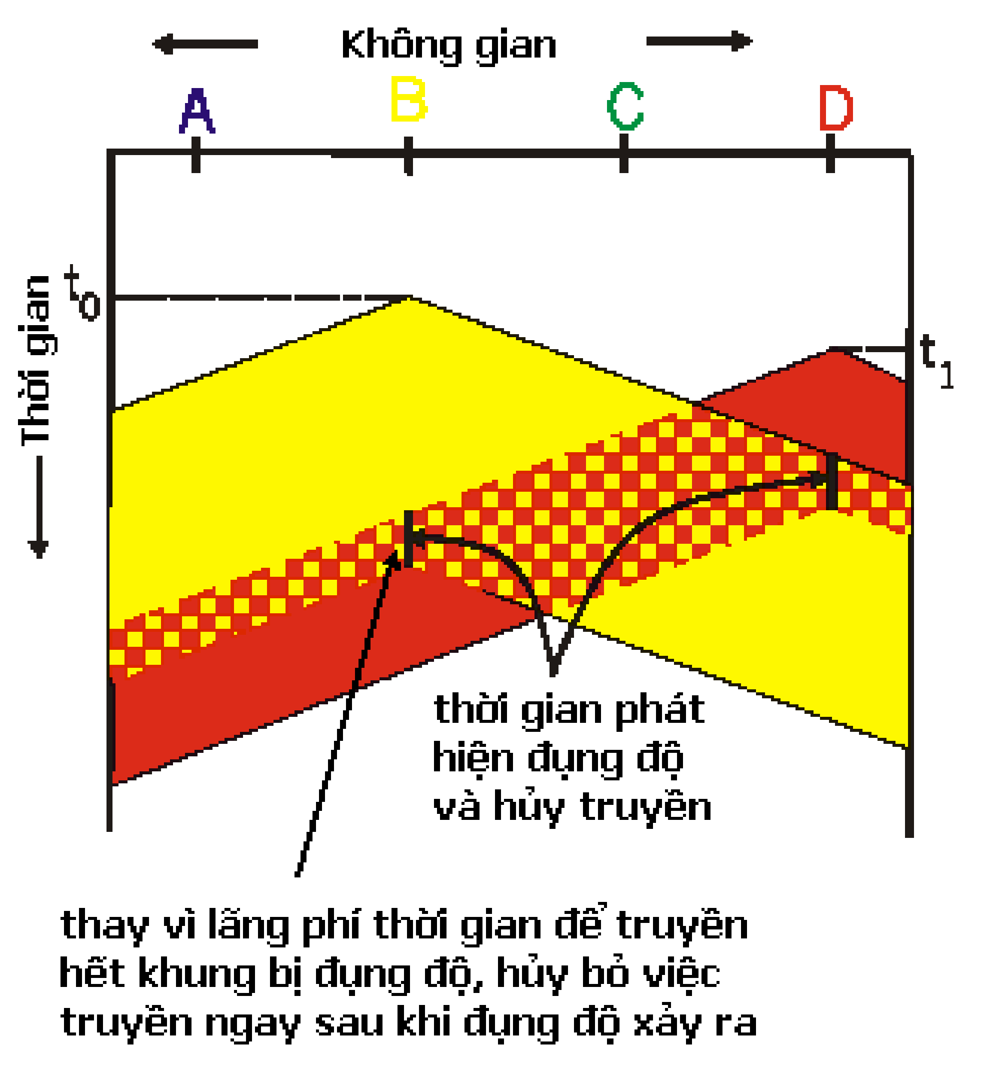

Packet Ready
Channel Busy?
Y
N
Transmission Begin
Collision Detected?
Y
N
Transmission occurring
N
Y
Transmission successful
Sending jamming signal
Increment attempt count
Attempts > 15 ?
Y
N
Error: Discard packet
Calculate Backoff
Wait for completion of Backoff time

CSMA/CD: Time of frame transmission

- T_{prop} is propagation time between the two farthest station on a channel
- At point of time t, A begins to transmit a frame
- At point of time t+T_{prop}-ε, B find that the channel is idle, so it transmits its frame
- At point of time t+T_{prop}, B detect a collision
- At point of time t+2T_{prop}-ε, A detect a collision



CSMA/CD: Point of time for destroying a collided frame



CSMA/CD: redo after a collision

- After detecting the frame collided, the station runs back-off algorithm to calculate amount of time it has to wait for before retransmitting the frame
  - ✓ The time must be random to avoid a collision occurring again
- Back-off algorithm
  1) Get a random an integer number M, $0<M<2^k$
     - ✓ k=min(n,10)
     - ✓ n: number of collision times for the current frame
  2) A mount of time the station has to wait for before retransmitting the frame: M*Tw
  3) If n reaches 16 times, cancel the transmission for this frame

Medium Access Control Protocols: Taking turn protocols

- Channel partitioning protocols
  - ✓ Channel is divided effectively and fairly for channel with high bandwidth
  - ✓ Ineffective with the channel having low traffic
- Random access protocols
  - ✓ Effective with the channel having low bandwidth
  - ✓ Ineffective with the channel having high traffic, high collision rate
- Taking turn protocol
  - ✓ Taking advantages of the two above protocols
  - ✓ Avoid collision occurring by queuing requests of accessing the channel

Medium Access Control Protocols: Taking turn protocols

Polling protocol

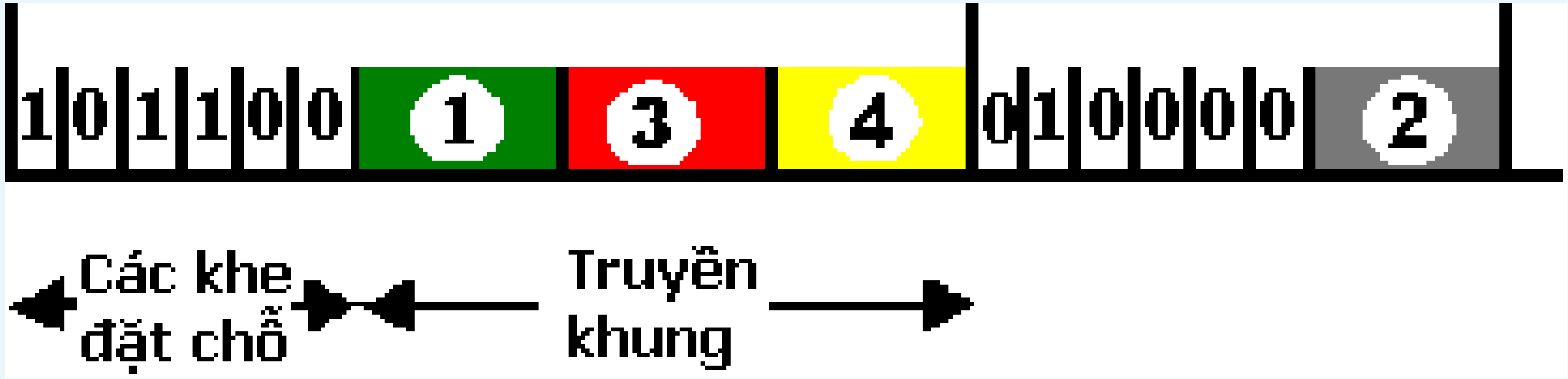
- ✓ Master station demands a slave station to send
- ✓ Master station schedule accessing channel for every slave stations or master station accepts a request for accessing the channel from a slave
- ✓ Issues: Polling cost, delay, out-off control when master station is died

Token passing protocol

- ✓ A token will be passed from one station to other.
- ✓ When a station holds the token, it has the permission to transmit a frame.
- ✓ A station pass the token to the next station after finishing a frame transmission
- ✓ Issues: Cost for token management, delay in waiting the token, loss of token

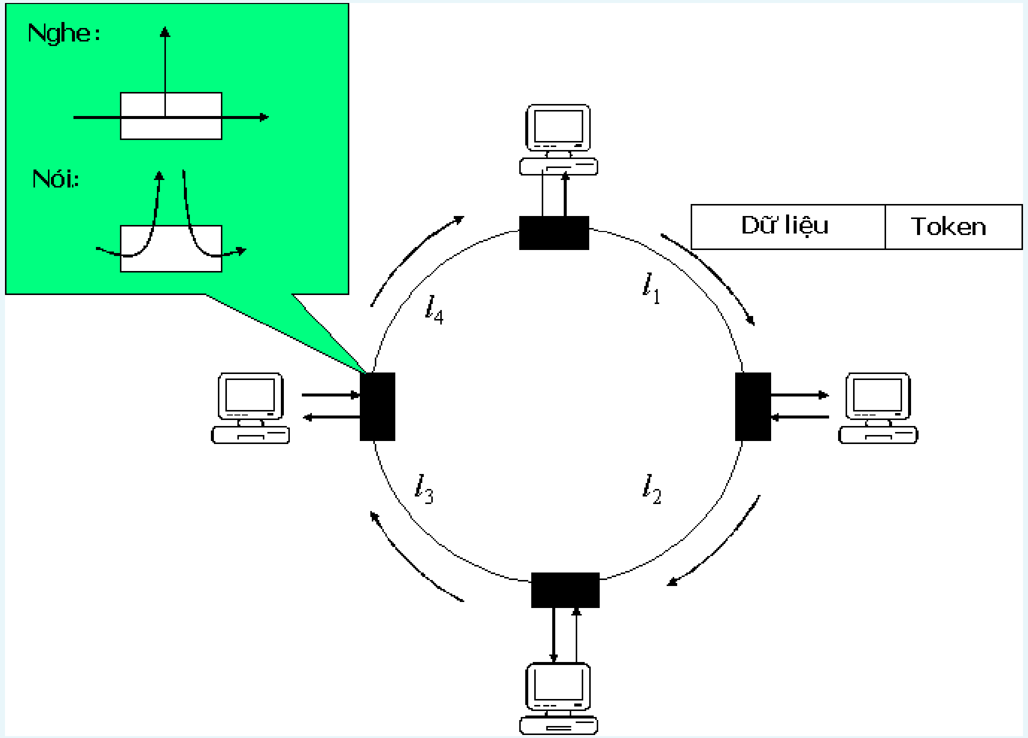
Polling protocol

- Consisting of reservation phase and transmission phase
- Reservation phase consists N bits (reservation bit) corresponding to N stations
  - ✓ If station i have data to send, it set its reservation bit into 1
- Transmission phase
  - ✓ Stations begin transmitting frames in numerical order



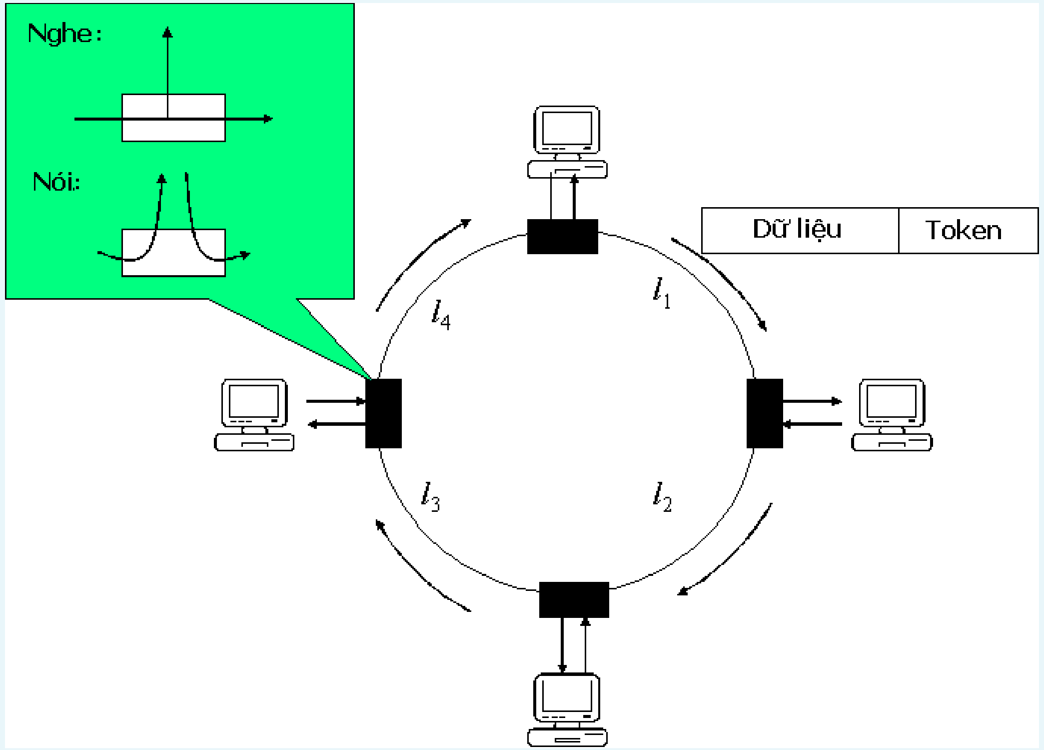
Token passing protocol

- Token - small message passed from one station to the next in the predefined order.
- Token represents permission to send
- If a station has a frame queued for transmission when it receives the token, it send that frame before it passes the token to the next station
- If it has no queued frame, it simply passes the token

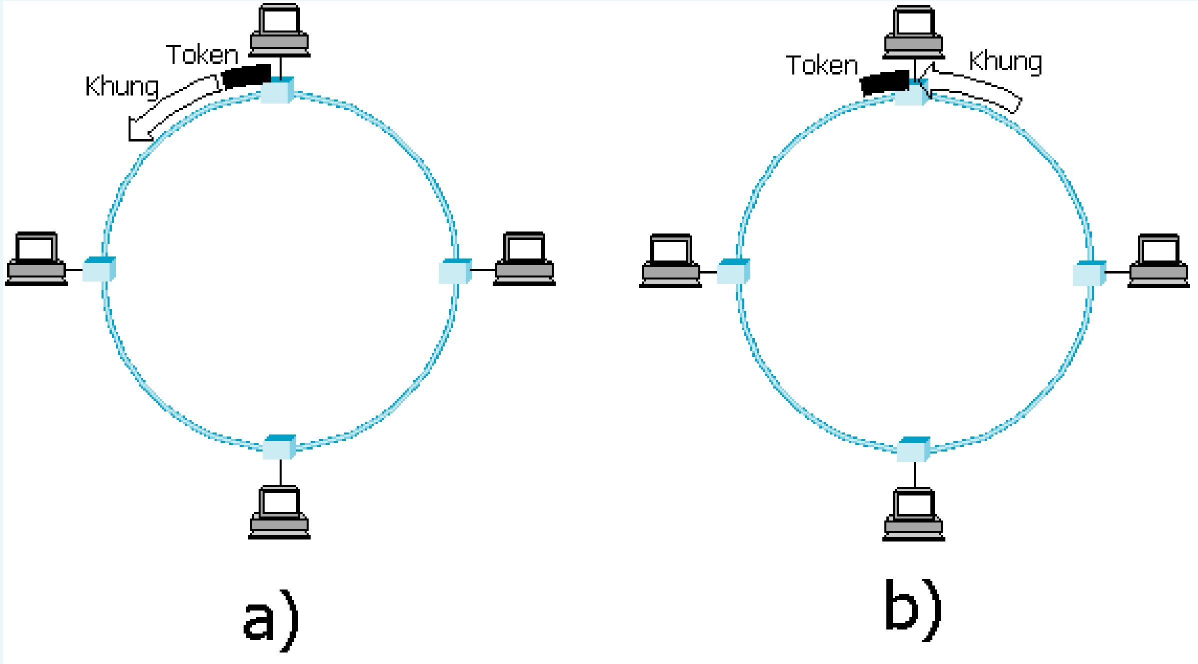


Token passing protocol

- When a frame arrives a station:
  - ✓ If the station's address is equal to receiver's address of the frame: it copy the frame into it buffer
  - ✓ If the station's address is equal to sender's address of the frame, it remove the frame from the ring
  - ✓ Otherwise, it simply passes the frame to the next station



Token passing protocol: Time to release the token



a) RAT- Release After Transmission

b) RAR- Release After Reception

Token passing protocol

Given

- ✓ THT: Token Holding Time
- ✓ TRT: Token Rotation Time
- ✓ Active station: Station in working
- ✓ Ring delay: Amount of time that the token passes through all nodes where these is no active station

Then

- ✓ TRT <= number of active station * THT + ring delay

Token passing protocol: Manage the ring

- One station is proposed to play the role of monitor
  - ✓ Monitor takes care of the health of the ring
  - ✓ Any station can become the monitor
  - ✓ A campaign for electing a monitor happens when the ring is initiated or the current monitor is not active
  - ✓ A healthy monitor will send to all stations periodically a special message that indicates the present of the monitor
  - ✓ If a station hasn't received the special message from the current monitor in a predefined interval, it will try to promote itself to be a monitor

Token passing protocol: Manage the ring

- ✓ If a station wants to become the monitor, it will send a demand message to all stations to announce that it would like to be the monitor
- ✓ If this announcement message passes all stations and return, it thinks that everyone agree to its demand and then it begins to play the role of a monitor
- ✓ If many stations want to be the monitor, several rules applied to select one station for the monitor role, such as the station with the highest address.

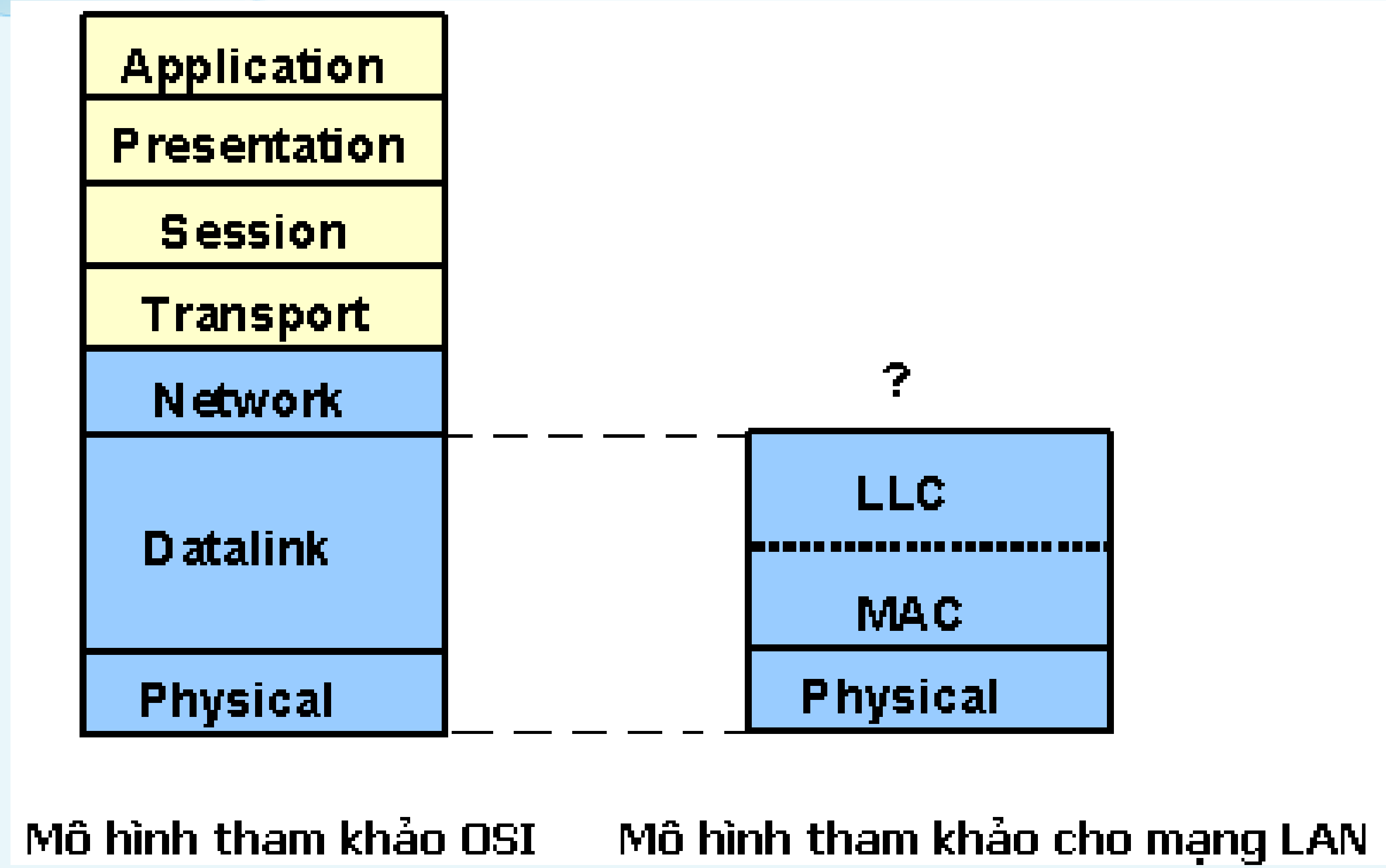
Token passing protocol: Functions of a monitor

- ✓ Ensuring the existence of the token in the ring
- ✓ When the token passes the monitor, the monitor setup a timer with a maximum time-out value being:

  number of active station * THT + ring delay

- ✓ The monitor also checks for error frames or frames that no station receives

Local Area Network
LAN Standards

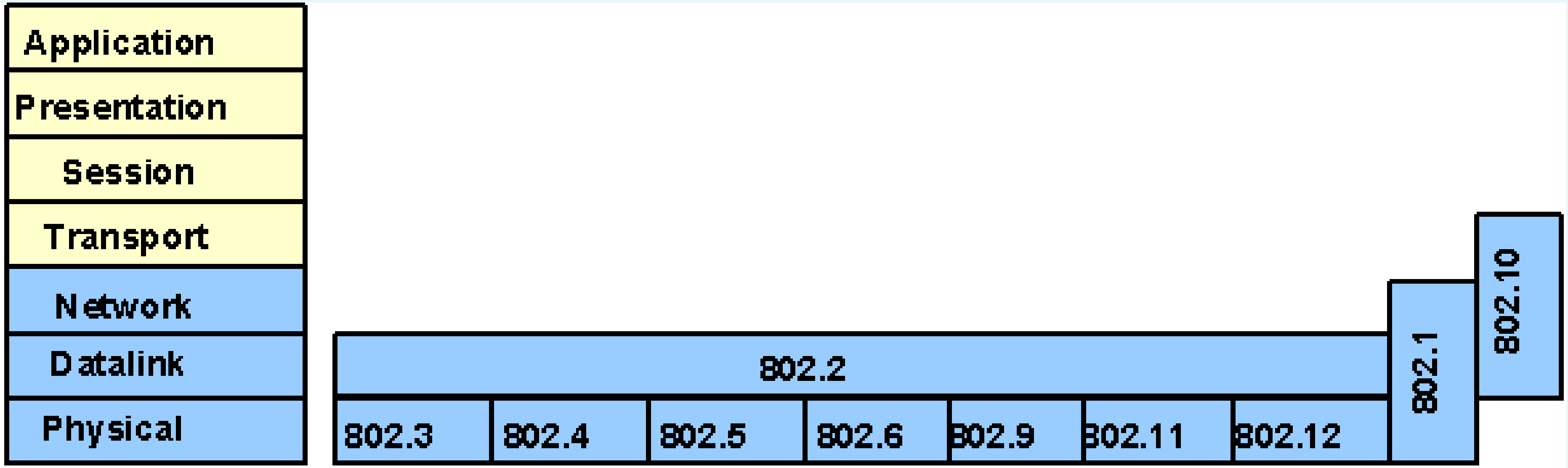


- MAC: Control access to the medium
- LLC: ensure an independence between management of links and
  - ✓ Medium
  - ✓ MAC protocols

Local Area Network
LAN Standards

IEEE (Institute of Electrical and Electronic Engineers)

- ✓ Developing standards for the computer and electronics industry.
- ✓ IEEE 802 standards for local-area networks are widely followed



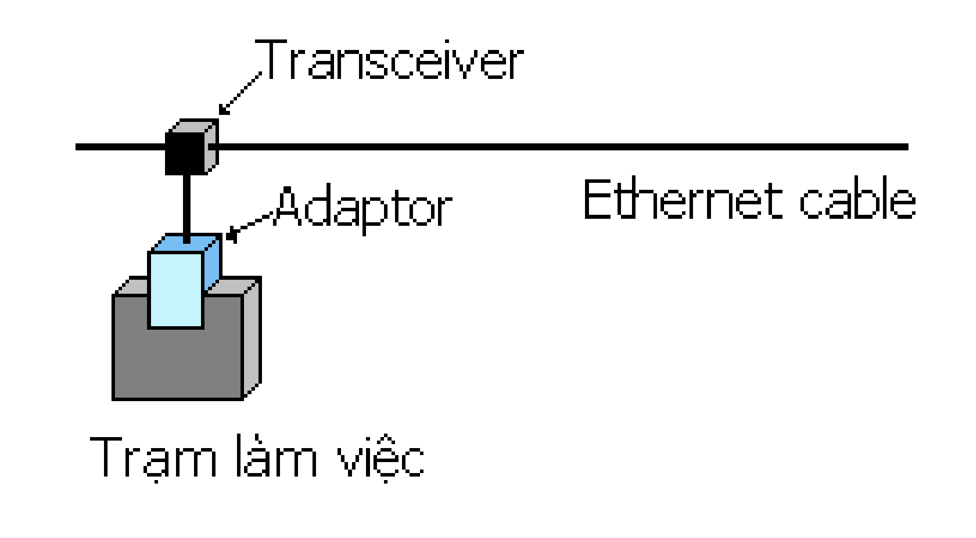
Local Area Network
LAN Standards

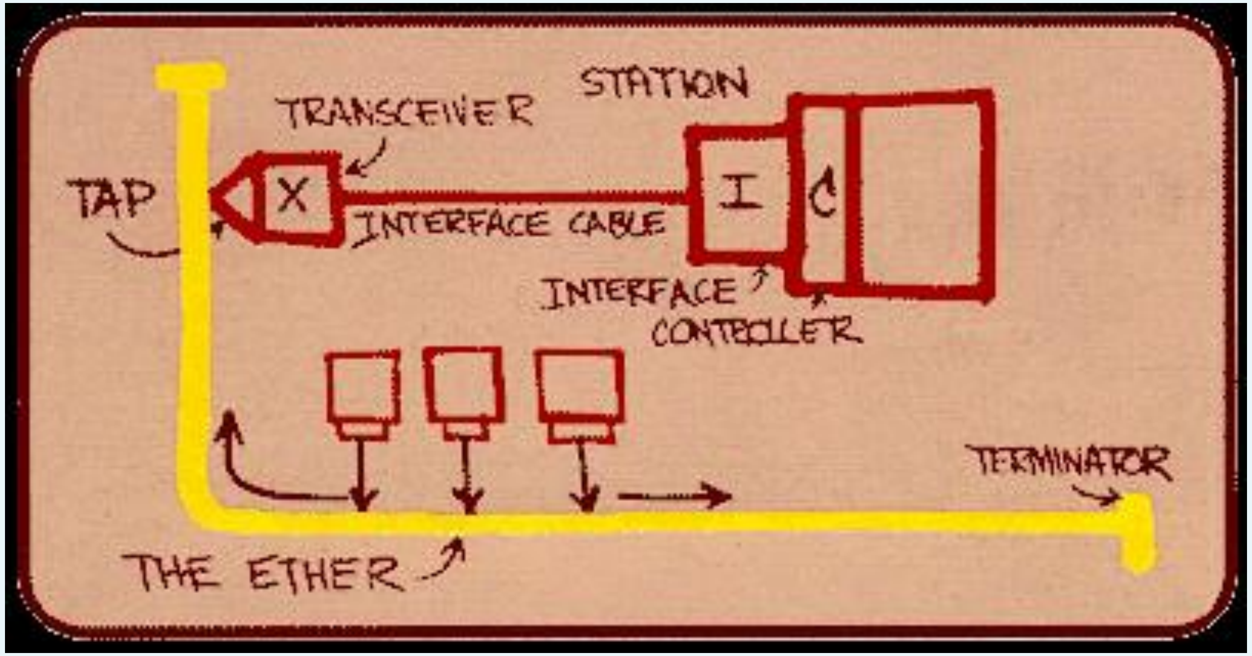
- IEEE 802.1 : High Level Interface
- IEEE 802.2 : Logical Link Control (LLC)
- IEEE 802.3: CSMA/CD
- IEEE 802.4: Token bus
- IEEE 802.5: Token ring
- IEEE 802.6: MAN
- IEEE 802.7: Broadband Technical Advisory Group
- IEEE 802.8: Fiber Technical Advisory Group
- IEEE 802.9: Integrated Data and Voice Network
- IEEE 802.10: Standard for Interoperable LAN security
- IEEE 802.11: Wireless LAN
- IEEE 802.12: 100VG – AnyLAN

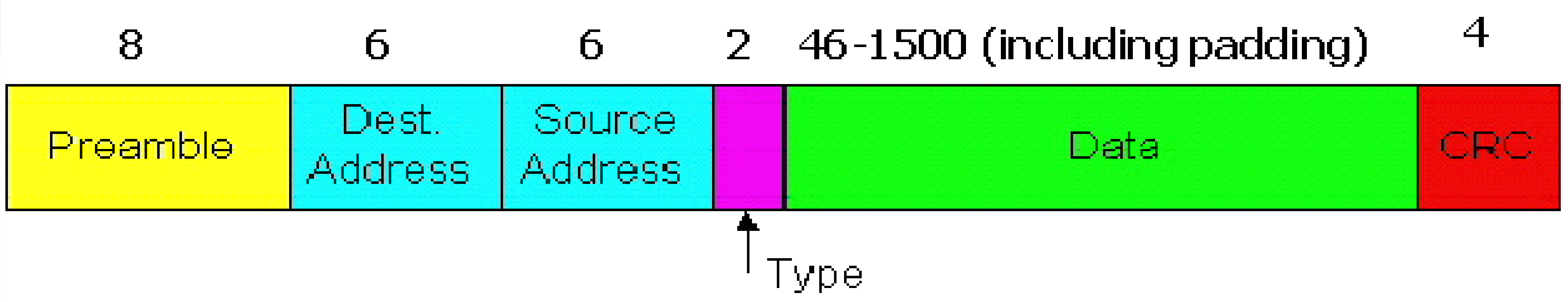
Local Area Network

LAN Standards: IEEE 802.3

Invented by Bob Metcalfe, (Xerox PARC, 1972)



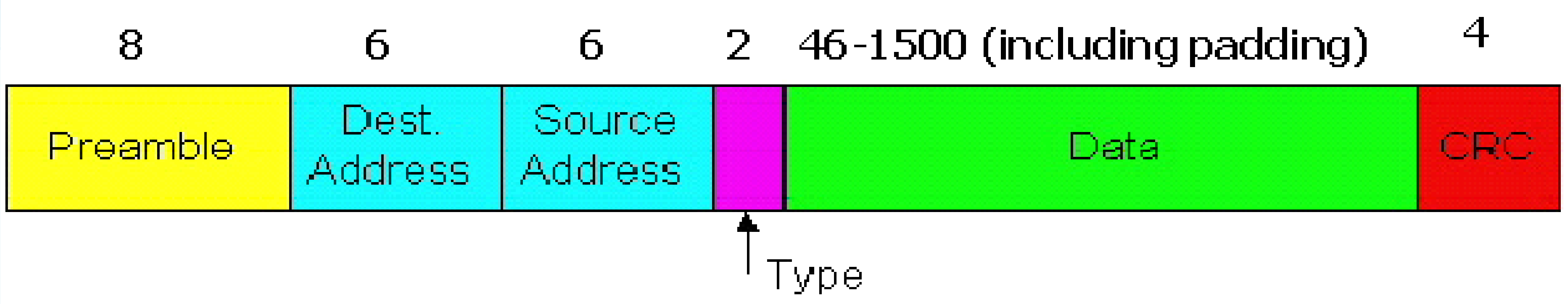




- Preamble: 7 bytes of 10101010 and 1 byte of 10101011, used to synchronize transmission rate between sender and receiver
- Source and destination addresses (6 bytes): the address of the sender and receiver off the frame, respectively
  - ✓ 8:0:2b:e4:b1:2
  - ✓ 00001000 00000000 00101011 11100100 10110001 00000010

Local Area Network

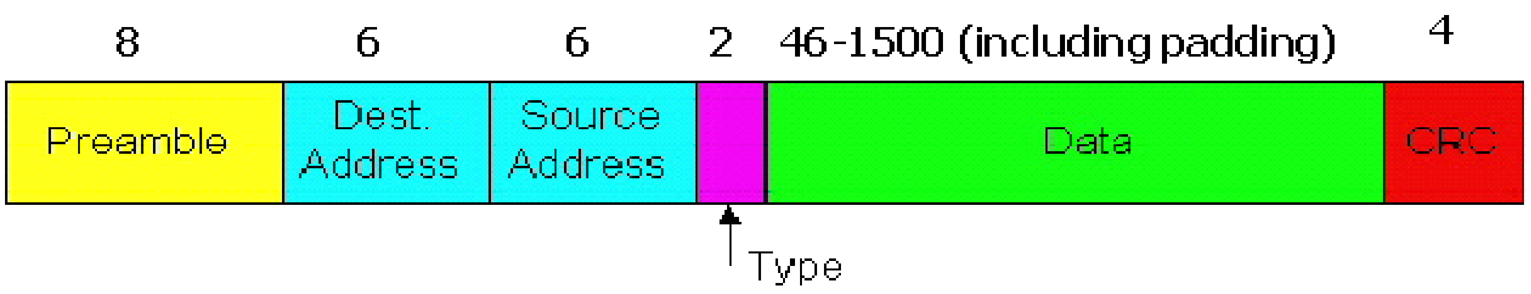
LAN Standards: IEEE 802.3



- Type: Protocol used by network layer, such as IP, Novell IPX, AppleTalk...
- CRC: Used by receiver to detect error

Local Area Network

LAN Standards: IEEE 802.3



- MAC address: Every Ethernet adapter has a unique address
  - ✓ Media Access Control (MAC)
- Burned into ROM in hardware
- Sequence of six numbers separated by colons
  - ✓ Six binary numbers
  - ✓ Usually displayed in hex for humans
- Example:
  - 00001000 00000000 00101011 11100100 10110001 00000010
  - 8:0:2b:e4:b1:2

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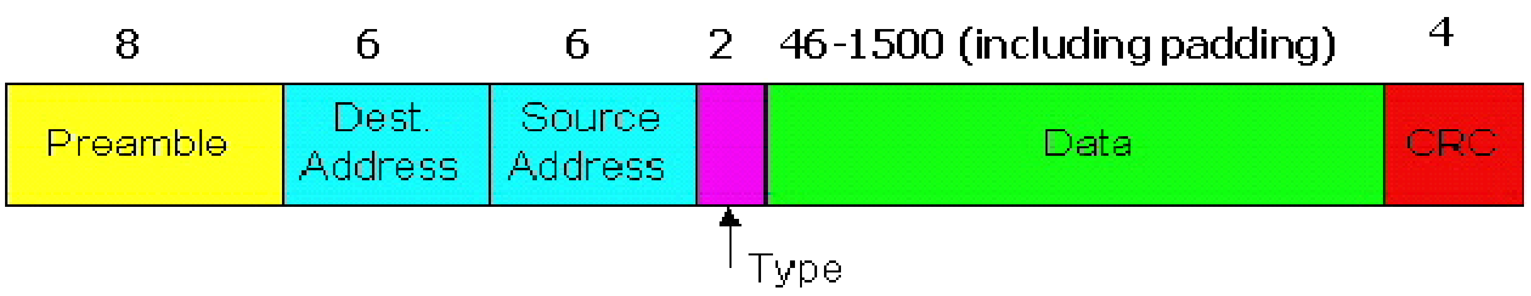
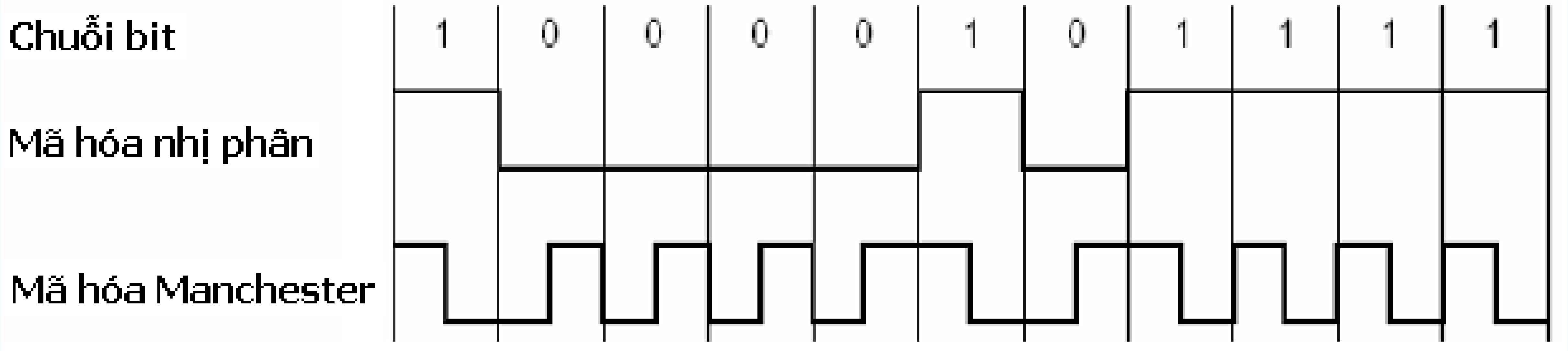


- MAC address: Every Ethernet adapter has a unique address
  - ✓ Ethernet Adapter receives all frames and accepts frame that are addressed to
    - o Its own address
    - o Broadcast address (all 1's)
    - o Multicast address that it has been program to accept
  - ✓ Can also be put into promiscuous mode to accept all frames
    - o Only used in network debugging and hacking

Line coding method: Manchester



CSMA/CD+Exponential backoff

Receive a packet from higher layer

- K := 0; n :=0; // K: a random waiting time; n: number of collision times
- Repeat:

    Wait for K*512 bit-time;
    while (line is busy) wait;
    Wait for 96 bit-time after the line is idle
    Send frame and listen for collision
    if (collision occurred) {
        Stop transmission and transmit 48-bits to emphasize the collision;
    n ++;
    m:= min(n, 10);
    Choose K randomly from the set of {0, 1, 2, …, 2m-1}.
    if (n < 16) goto repeat;
    else cancel the transmitting frame;

}

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- **10BaseT: (**T “twisted”): hoạt động tốc độ 10 Mb/s, dựa trên hệ thống cáp UTP Cat 3 trở lên, chiều dài cáp tối đa cho 1 phân đoạn mạng là 100m
- **10BaseF** (F là viết tắt của Fiber Optic): hoạt động ở tốc độ 10 Mb/s, dựa trên hệ thống cáp quang, chiều dài cáp tối đa cho 1 phân đoạn mạng là 2000m

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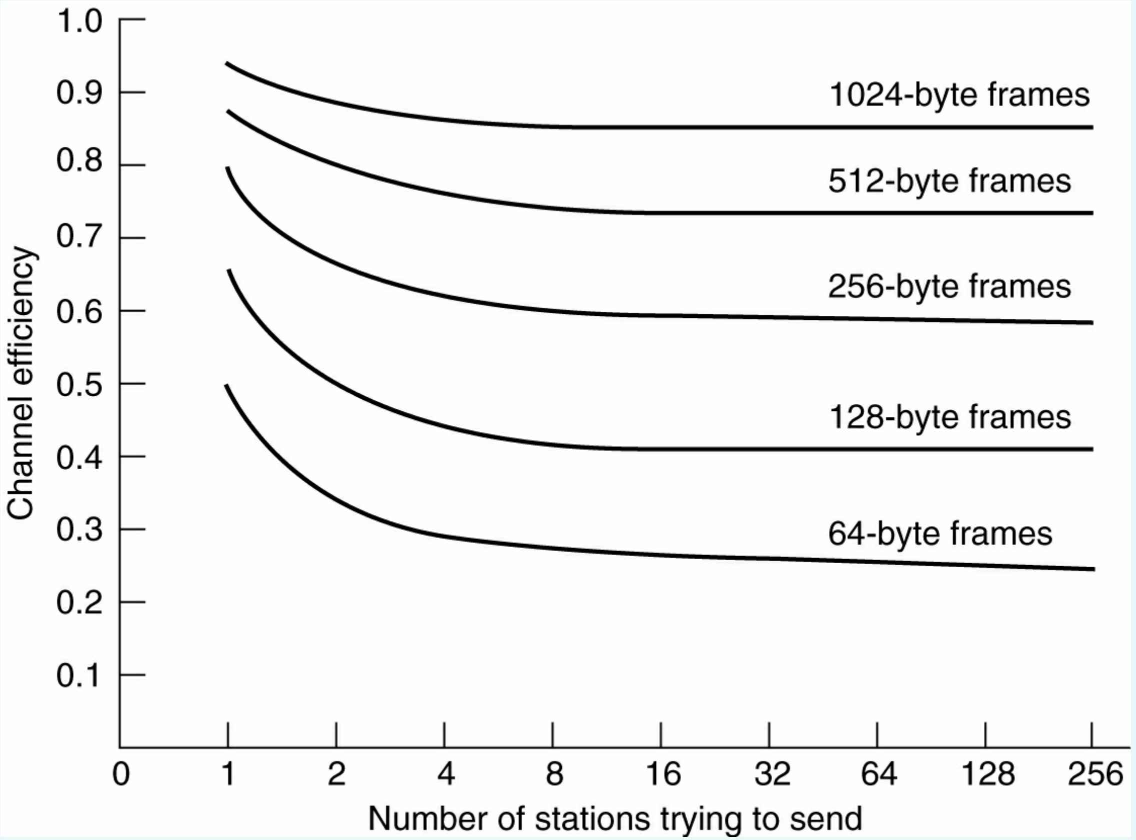
Ethernet Performance



Efficiency of Ethernet at 10 Mbps with 512-bit slot times.

Local Area Network
Ethernet

Original IEEE	IEEE Shorthand Name	Informal Name(s)	Speed	Typical Cabling
802.3i	10BASE-T	Ethernet	10 Mbps	UTP
802.3u	100BASE-T	Fast Ethernet (Fast E)	100 Mbps	UTP
802.3z	1000BASE-X	Gigabit Ethernet (Gig E, GbE)	1000 Mbps	Fiber
802.3ab	1000BASE-T	Gigabit Ethernet (Gig E, GbE)	1000 Mbps	UTP
802.3ae	10GBASE-X	10 GbE	10 Gbps	Fiber
802.3an	10GBASE-T	10 GbE	10 Gbps	UTP
802.3ba	40GBASE-X	40GbE (40 GigE)	40 Gbps	Fiber
802.3ba	100GBASE-X	100GbE (100 GigE)	100 Gbps	Fiber