Computer Networks

LAN & MAC

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Objectives

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

Requisites

- Learners have to be able to
  - distinguish core differences between channel allocation methods such as channel partitioning, random access, turning access
  - present the principle of channel allocation methods FDMA, TDMA, CDMA, ALOHA, CSMA, CSMA/CD, Token Passing
  - introduce characteristics and principle of Ethernet standard

Local Area Network

Classifying networks by network diameter

Diameter	Host location	Network Types
1 m	In a square meter	PAN - Personal Area Network
10 m	In a room	LAN - Local Area Network
100 m	In a building	
1 km	In a campus	
10 km	In a city	MAN - Metropolitan Area Network
100 km	In a country	WAN - Wide Area Network
1000 km	In a continent	
10000 km	Worldwide	

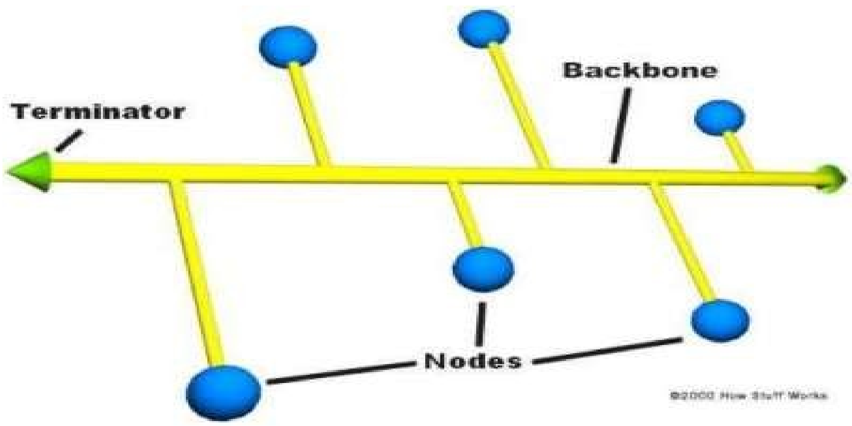
LAN characteristics

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

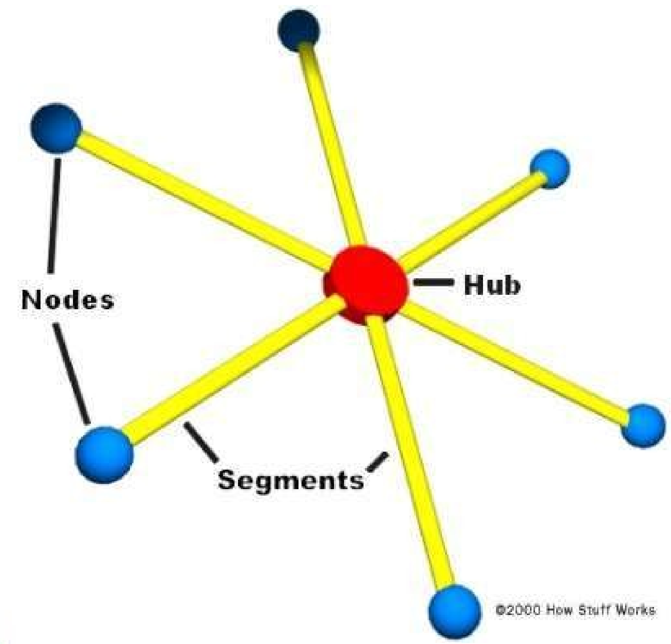
LAN parameters

- 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 (MAP – 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

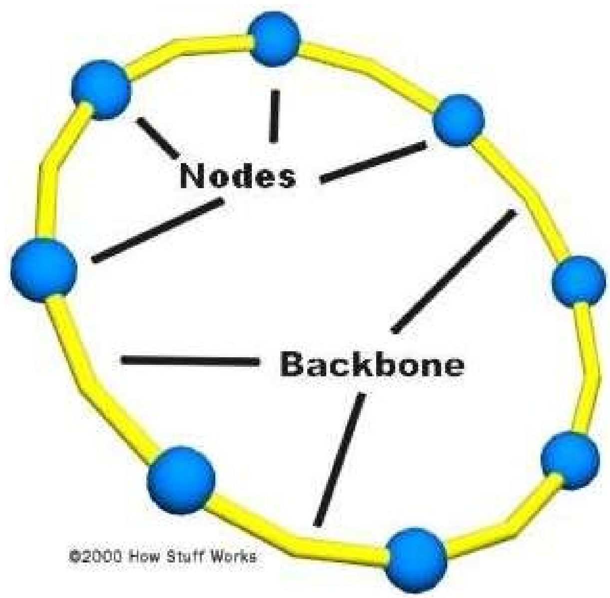
LAN topologies



BUS



STAR

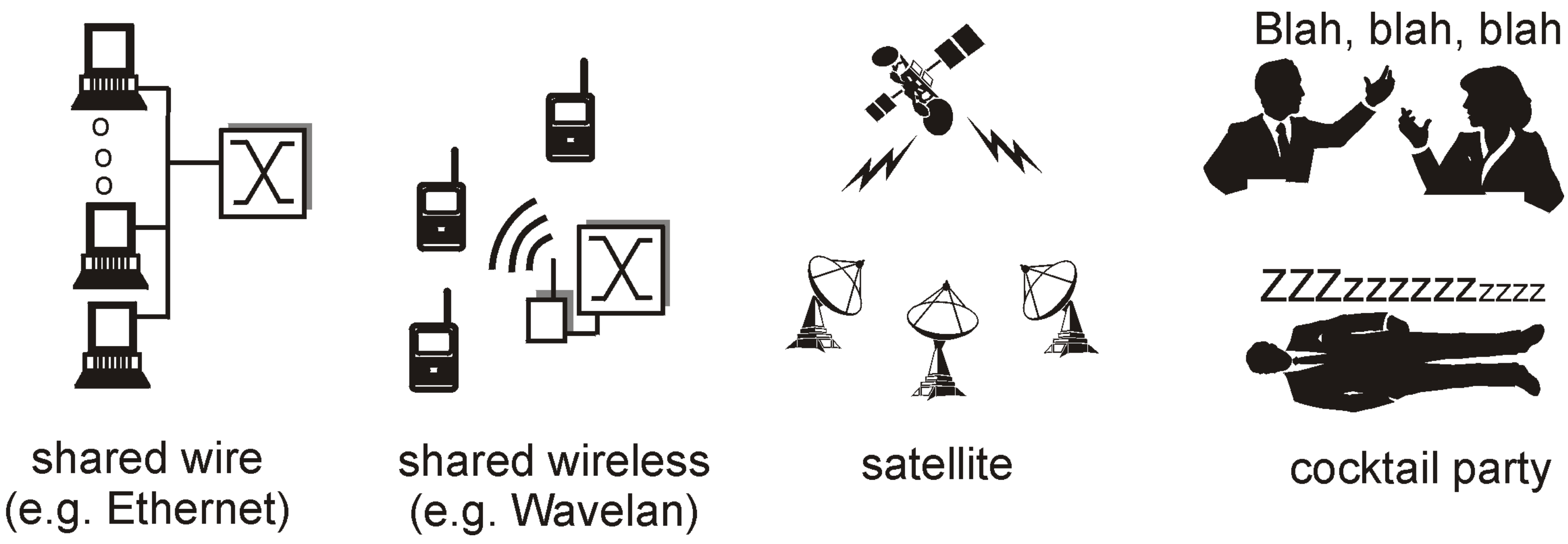


RING

MAC Layer

Multiple access links

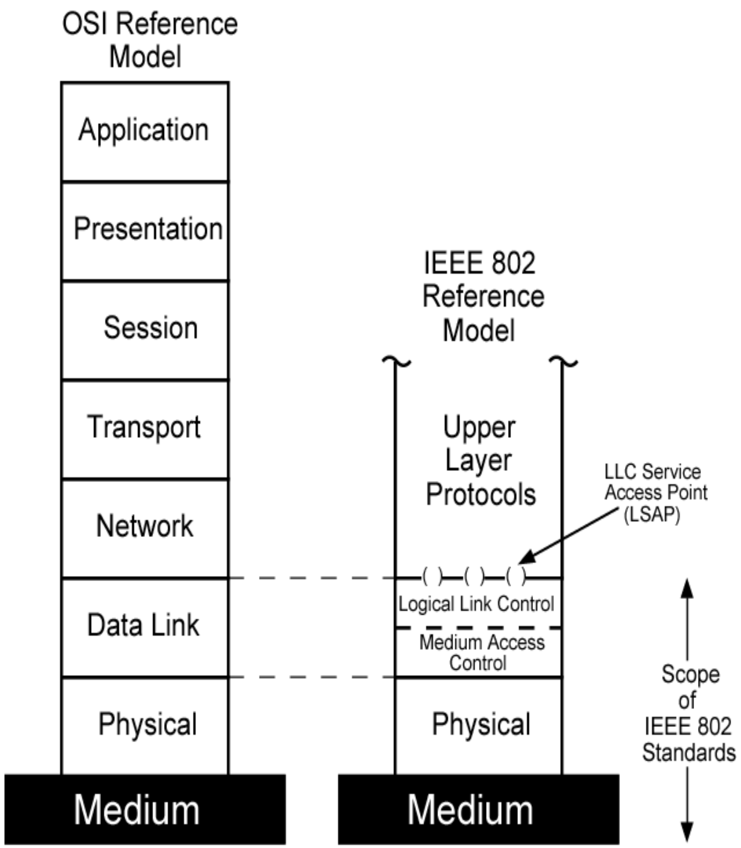
- 3 types of channel
  - Point – to – point (single wire, e.g. PPP, SLIP)
  - Broadcast (shared wire or medium; e.g, Ethernet, etc)
  - Switched (switched Ethernet, ATM)



Medium Access Control Protocol

- Problems of multiple access in a LAN
  - One channel is 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)

MAC protocol in OSI Model



- Data link layer is divided into two sub-layers
  - Logical Link Control layer (LLC layer)
  - Medium Access Control layer (MAC layer)

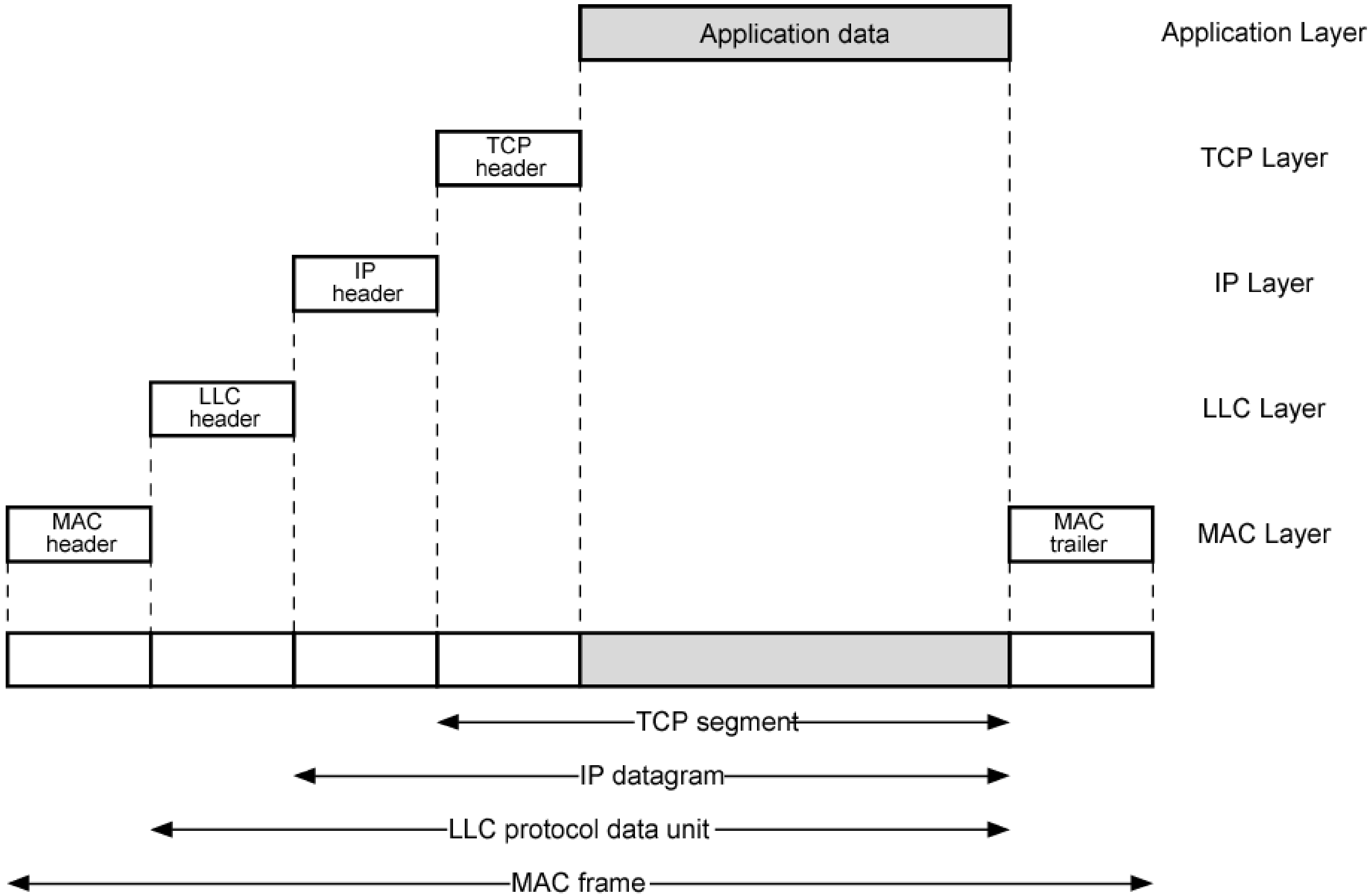
LLC layer

- 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), transmission data and checksum for sending
- Receives frame, extracts sender address and receiver address, transmission data, and detects frame error
- Controls access to medium
  - This function is not included in tradition data link layer
- One LLC layer can have many types of MAC layer

Data units of LAN



MAC Layer Protocols

MAC protocols

- 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

Channel partitioning protocols

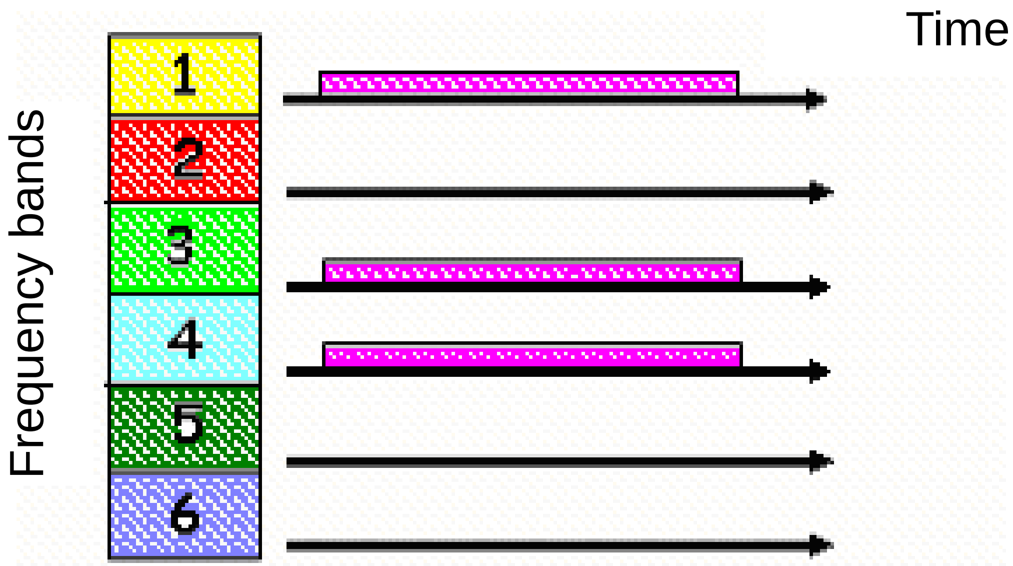
- Partition the channel into many parts
- Allocate each part to a host for using
- Three principle methods
  - FDMA (Frequency Division Multiple Access)
  - TDMA (Time Division Multiple Access)
  - CDMA (Code Division Multiple Access)

Frequency Division Multiple Access

- Bandwidth of the channel is divided into different frequency band
- Each host is assigned a frequency band
- Frequency bands of hosts having no data to transmit will be in idle state

Frequency Division Multiple Access

- Example
  - A LAN has 6 stations
  - Stations 1, 3 and 4 have data for transmission
  - Stations 2, 5 and 6 are idle



Frequency Division Multiple Access

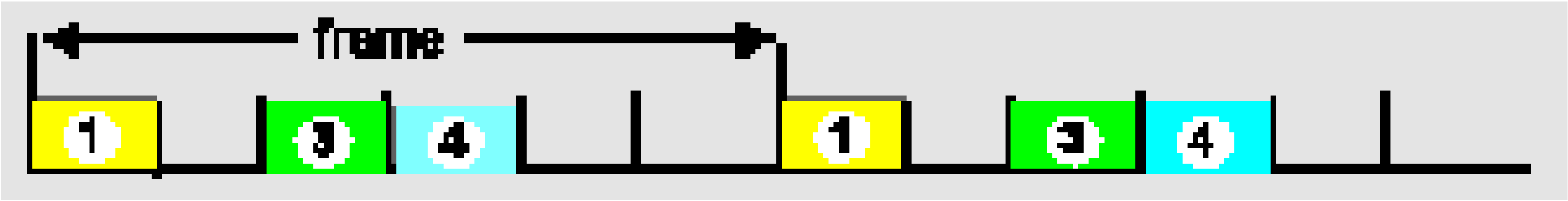
- Advantages
  - No collision between hosts
  - Efficient in systems with small and stable number of users; each user is always required to send data
- Disadvantages
  - Wast of channel if the number of users is smaller than the number of frequency bands
  - User request is denied if the number of users is larger than the number of frequency bands
  - Not explore in maximum the capacity of the channel

TDMA (Time Division Multiple Access)

- The stations will be turned around in using the channel
- Rule for scheduling
  - A circle of time will be divided into many equal time slot
  - 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 LAN has 6 stations
  - Stations 1, 3 and 4 have data for transmission
  - Stations 2, 5 and 6 are idle
- Wast if a user doesn't use an assigned time slot



Code Division Multiple Access

- CDMA allows each station to transmit over the entire frequency spectrum all the time.
- Data transmitted concurrently by different stations will be extracted by coding technique
- CDMA proves that many signal concurrently transmitted can be combined into a linear signal
- CDMA is usually used in broadcast wireless network

Code Division Multiple Access

- Time for sending a bit (so-called bit time) is subdivided into m short intervals called *chips*; Typycally, there are 64 chips or 128 chips per bit time
- All users share the same frequency band
- Each station is assigned a unique code at long of m-bit code, called *chip sequence*
- Chip sequence of a user will be used to encode and decode his proper data sent in a shared channel

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

Code Division Multiple Access

- Use bipolar signal
  - Bit 0 is represented by -1
  - Bit 1 is represented by +1
- S•T is the inner product of two code S and T

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

- Example

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

Code Division Multiple Access

- Two code S and T of m bits are called orthogonal, if S•T = 0
- Example

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

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

$$S \cdot T = \frac{(-1)+(-1)+(-1)+1+1+1+(-1)+1}{8} = 0$$

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

Code Division Multiple Access

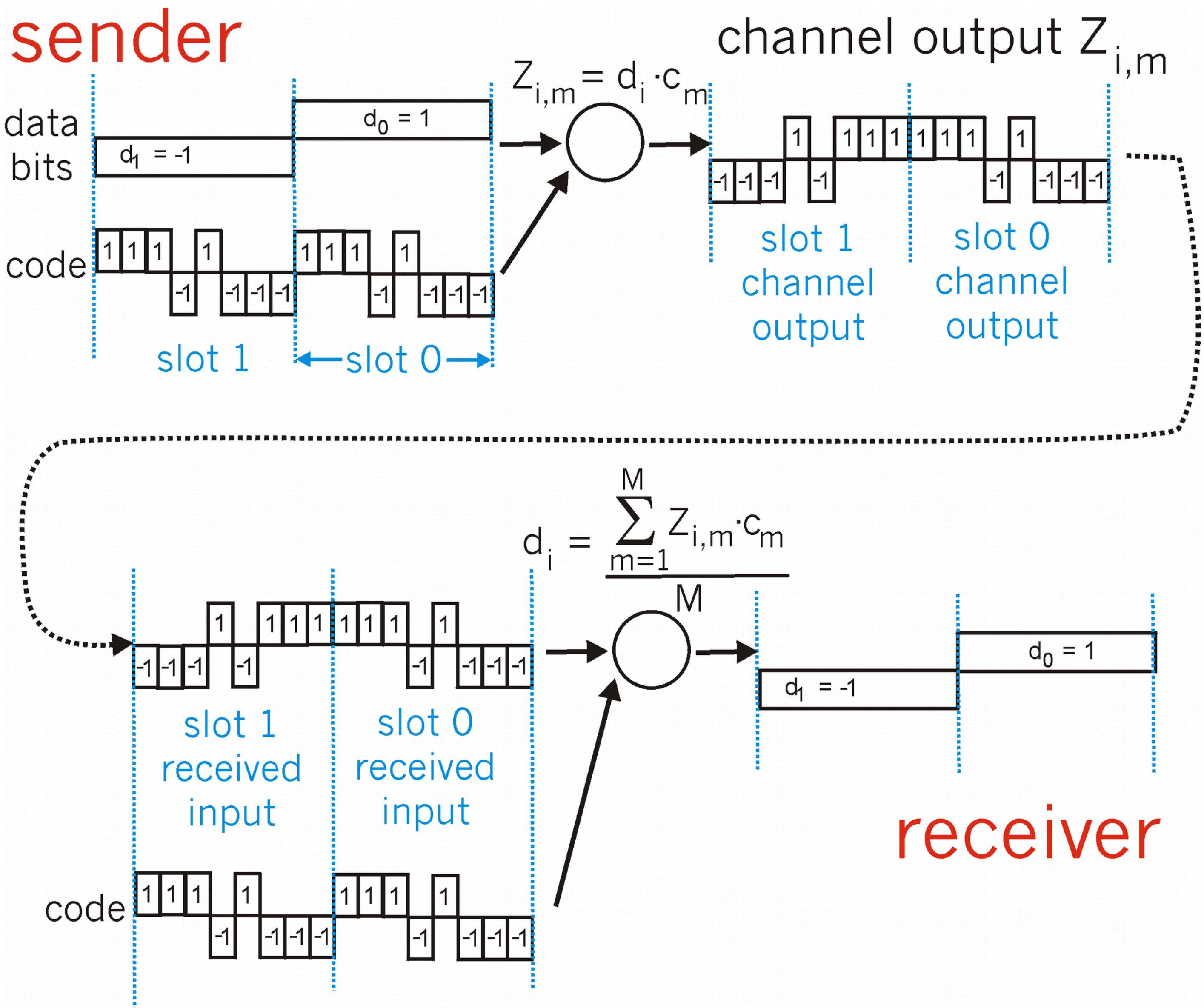
- Coding data bit for sending
  - Di: data bit that user i want to encode to transmit to the channel
  - Ci: is chip sequence of user i
  - Encoded signal of user i:
    - Zi = Di x Ci
  - *Combined signal transmitted on the signal:*

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

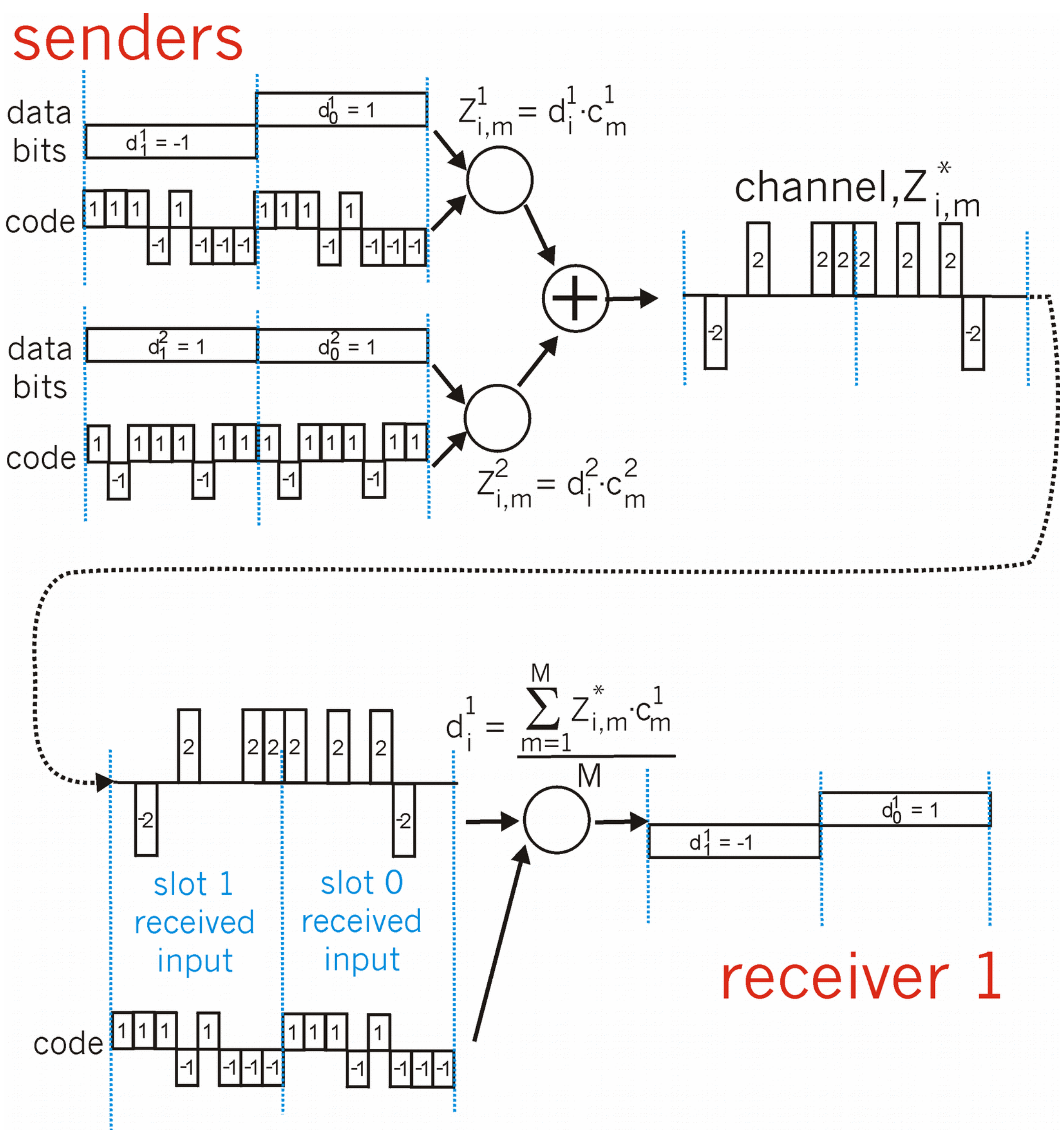
n number of users transmitting data on the channel at the same time

- *Decoding data bit*:
  - Data that user i receives from combined signal: $D_i = Z \cdot C_i$
  - If Di > “threshold”, then Di is 1, reversly Di is -1

Code Division Multiple Access



Code Division Multiple Access



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

Code Division Multiple Access

$$A: (-1\ -1\ -1\ +1\ +1\ -1\ +1\ +1)$$
$$B: (-1\ -1\ +1\ -1\ +1\ +1\ +1\ -1)$$
$$C: (-1\ +1\ -1\ +1\ +1\ +1\ -1\ -1)$$
$$D: (-1\ +1\ -1\ -1\ -1\ -1\ +1\ -1)$$

1. Only user C sends bit 1:	1) – – 1 –	C	$Z = (-1\ +1\ -1\ +1\ +1\ +1\ -1\ -1)$
2. B sends bit 1, C send bit 1	2) – 1 1 –	$B + C$	$Z = (-2\ \ 0\ \ 0\ \ 0\ +2\ +2\ \ 0\ -2)$
3. A sends bit 1, B send bit 0	3) 1 0 – –	$A + \overline{B}$	$Z = (\ 0\ \ 0\ -2\ +2\ \ 0\ -2\ \ 0\ +2)$
4. A, C send bit 1, B send bit 0	4) 1 0 1 –	$A + \overline{B} + C$	$Z = (-1\ +1\ -3\ +3\ +1\ -1\ -1\ +1)$
5. A, B, C, D send bit 1	5) 1 1 1 1	$A + B + C + D$	$Z = (-4\ \ 0\ -2\ \ 0\ +2\ \ 0\ +2\ -2)$
6. A, B, D send bit 1, C send bit 0	6) 1 1 0 1	$A + B + \overline{C} + D$	$Z = (-2\ -2\ \ 0\ -2\ \ 0\ -2\ +4\ \ 0)$

Calculate original bit of user C from combine signal

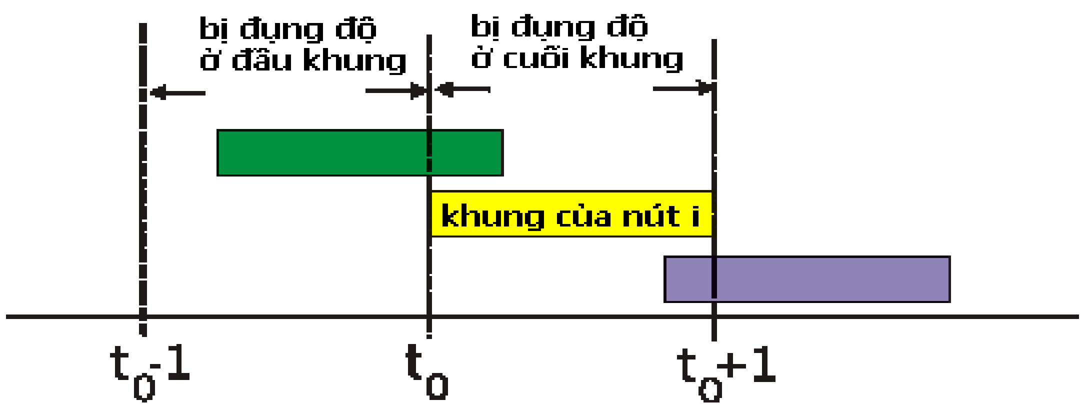
1) $Z \bullet C = (1\ +1\ +1\ +1\ +1\ +1\ +1\ +1)/8 = 1$
2) $Z \bullet C = (2\ +0\ +0\ +0\ +2\ +2\ +0\ +2)/8 = 1$
3) $Z \bullet C = (0\ +0\ +2\ +2\ +0\ -2\ +0\ -2)/8 = 0$
4) $Z \bullet C = (1\ +1\ +3\ +3\ +1\ -1\ +1\ -1)/8 = 1$
5) $Z \bullet C = (4\ +0\ +2\ +0\ +2\ +0\ -2\ +2)/8 = 1$
6) $Z \bullet C = (2\ -2\ +0\ -2\ +0\ -2\ -4\ +0)/8 = -1$

Random access protocols

- If a station need to send a frame
  - It will send the frame onto the whole 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

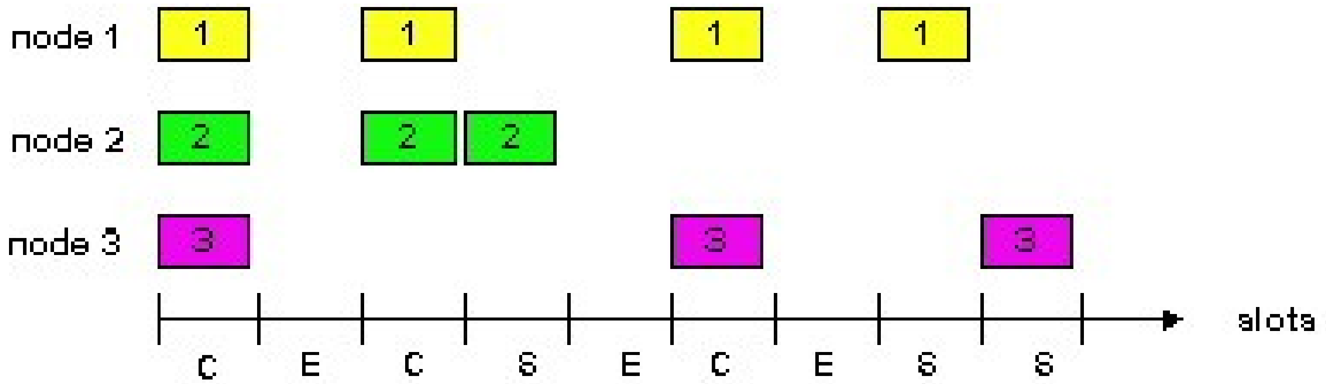
Pure (Unslotted) ALOHA

- 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 t_0 will conflict with frames sent in period $[t_0-1, t_0+1]$



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

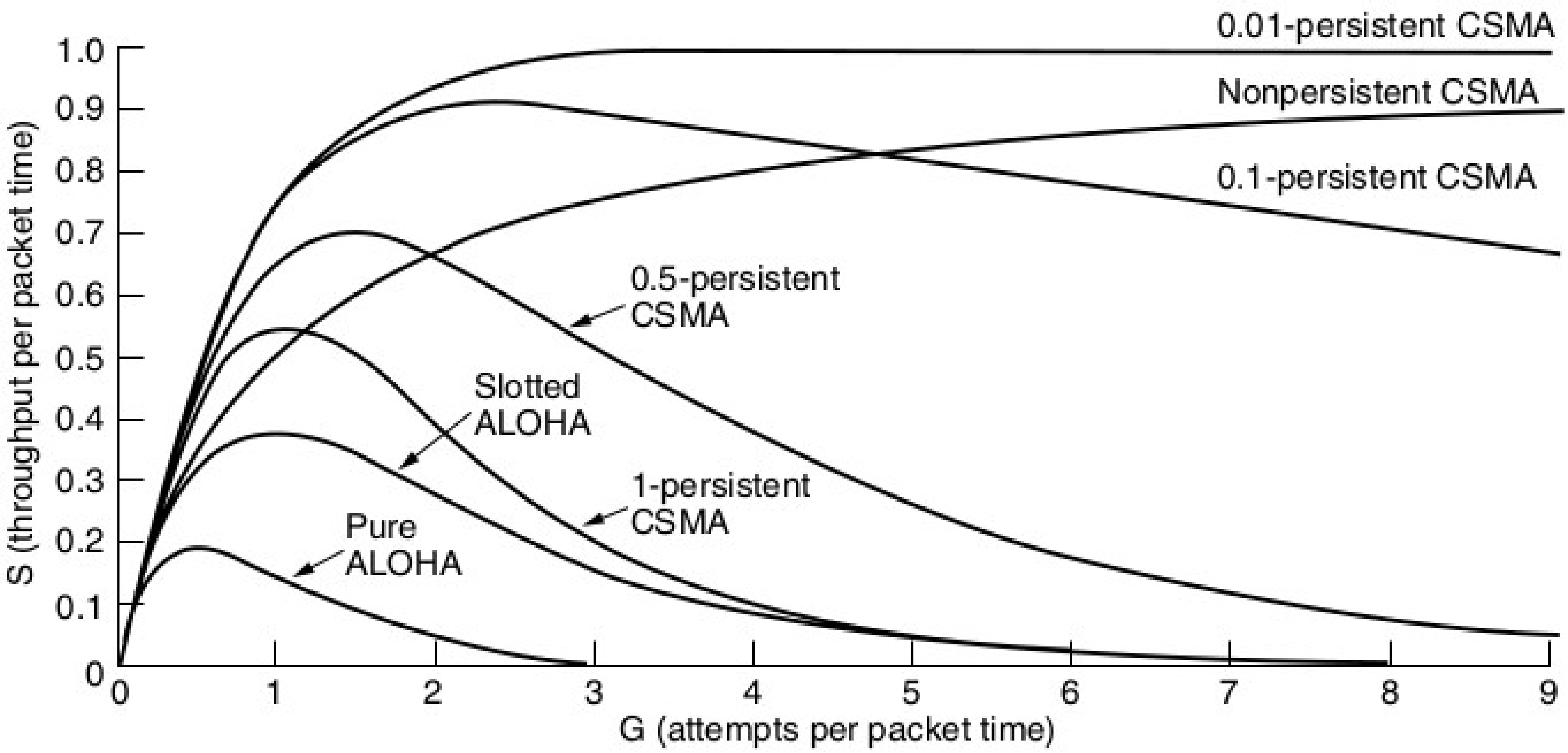


Success (S), Collision (C), Empty (E) slots

CSMA - Carrier Sense Multiple Access protocol

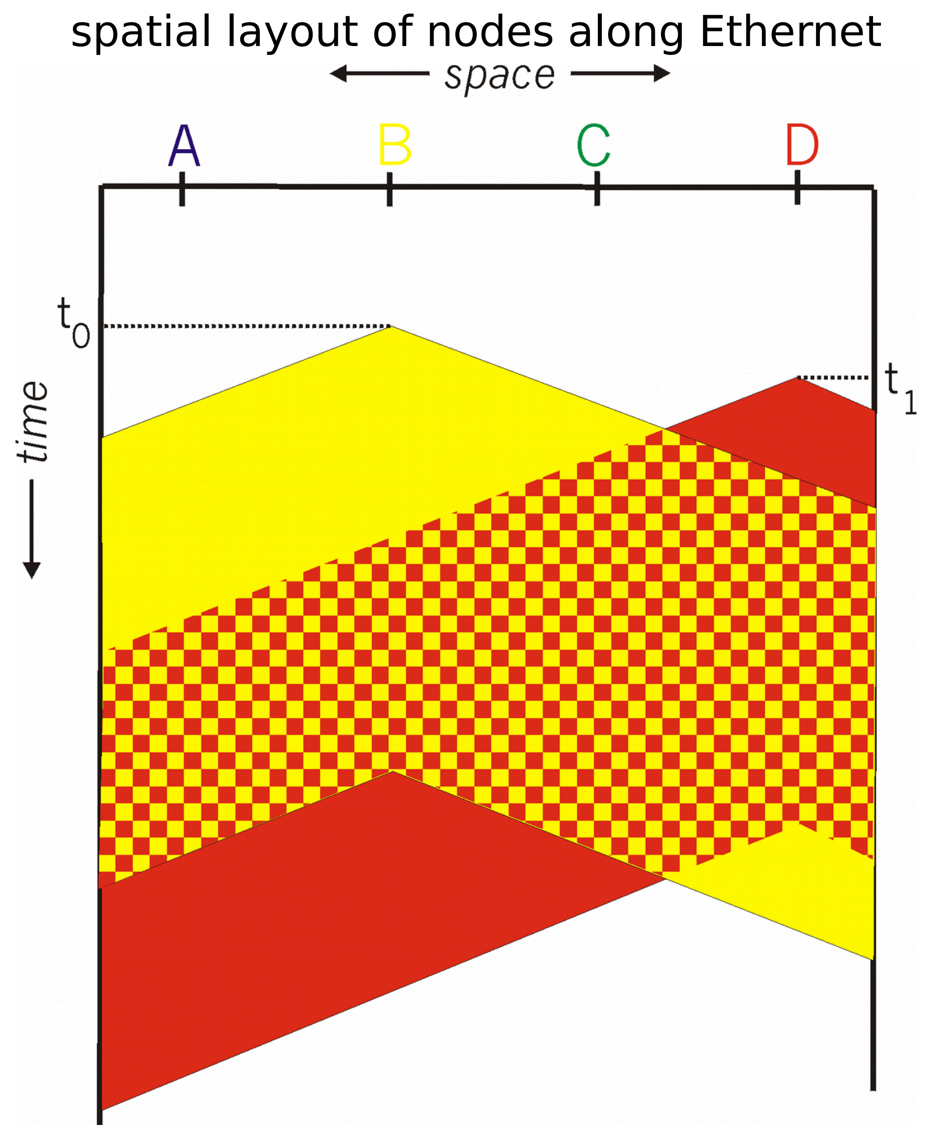
- Stations listen for a carrier (i.e., a transmission) and act accordingly
- When a station has data to send, it first listens to the channel to see if anyone else is transmitting at that moment
  - If the channel is idle, the stations sends its data.
  - Otherwise, if the channel is busy, the station just waits until the channel becomes idle. Then the station transmits a frame.
  - If a collision occurs, the station waits a random amount of time and starts all over again.
    - 1-persistent: the station transmits with a probability of 1 when it finds the channel idle
    - Non-persistent CSMA: waits a random period of time and then repeats the algorithm
    - Persistent CSMA: continue to listen on the channel until the channel is idle then send the frame with the possibility 1
    - P-persistent CSMA: continue to listen on the channel until the channel is idle then send the frame with the possibility p

Comparison of the channel utilization versus load



CSMA collisions

- Collision may occur because of the propagation delay : one stations can't hear the transmission of the other
- When a collision occurs all frames are discarded
- The distance between two stations and the propagation delay have an important effect on collisions

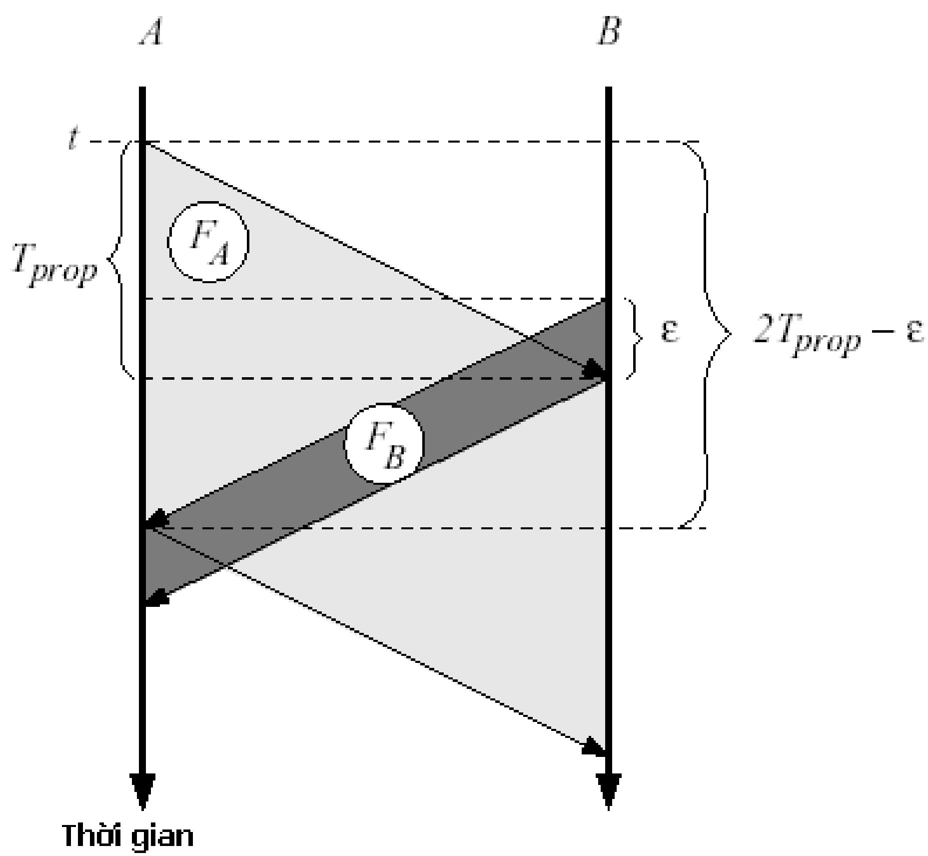


CSMA/CD (CDMA with Collision Detection)

- Basis of the classic Ethernet LAN
- The station's hardware must listen to the channel while it is transmitting
  - If the signal it reads back is different from the signal it is putting out, it knows that a collision is occurring
- If two or more stations decide to transmit simultaneously, there will be a collision.
- If a station detects a collision, it aborts its transmission, waits a random period of time, and then tries again (assuming that no other station has started transmitting in the meantime)

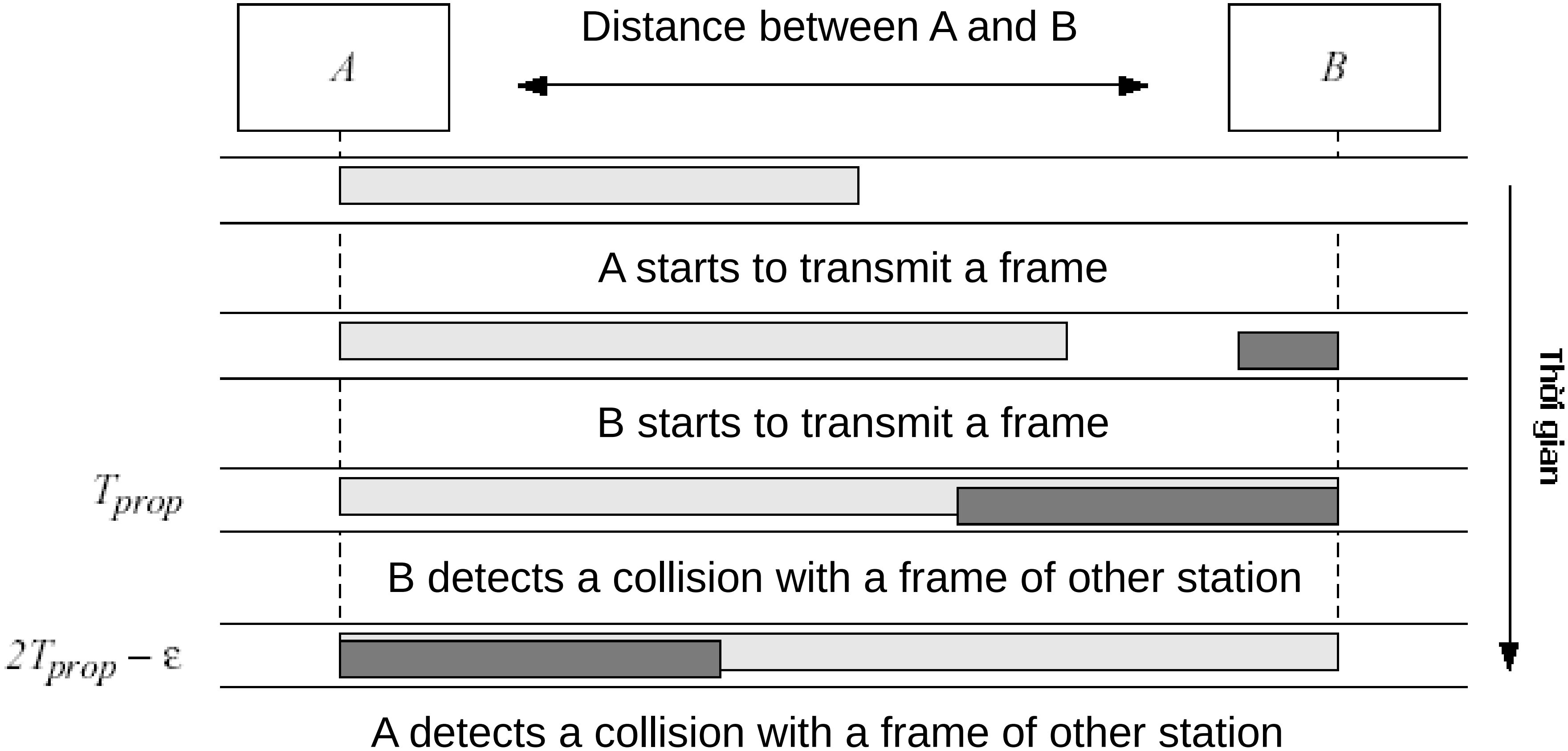
Time of frame transmission

- Tprop 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+Tprop-ε, B find that the channel is idle, so it transmits its frame
- At point of time t+Tprop, B detect a collision
- At point of time t+2Tprop-ε, A detect a collision

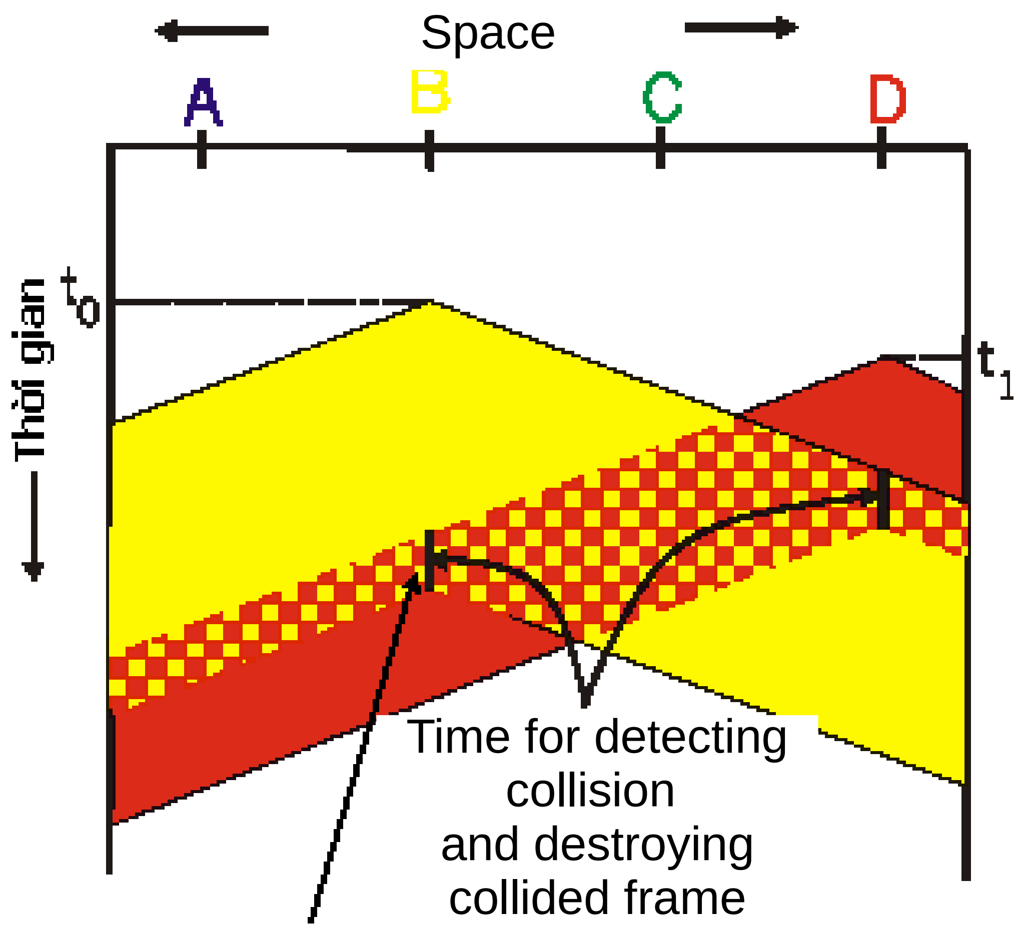


Time of frame transmission

Tw = 2Tprop



Point of time for destroying a collided frame



Cancel frame transmission immediately after detecting a collision

React after a collision

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

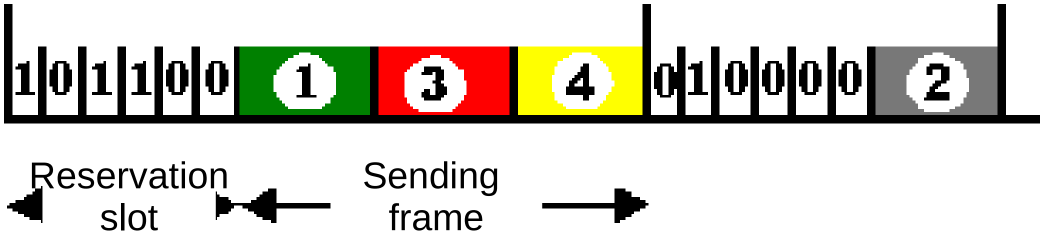
Taking turn protocols

- 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

Taking turn protocols

- Polling protocol
  - Master station demands a slave station to send when it's the turn of slave station. Master station will schedule accessing channel for every slave stations or master station accepts a request for accessing the channel from a slave
  - Issues: Pooling cost, delay in waiting turn, 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 will 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

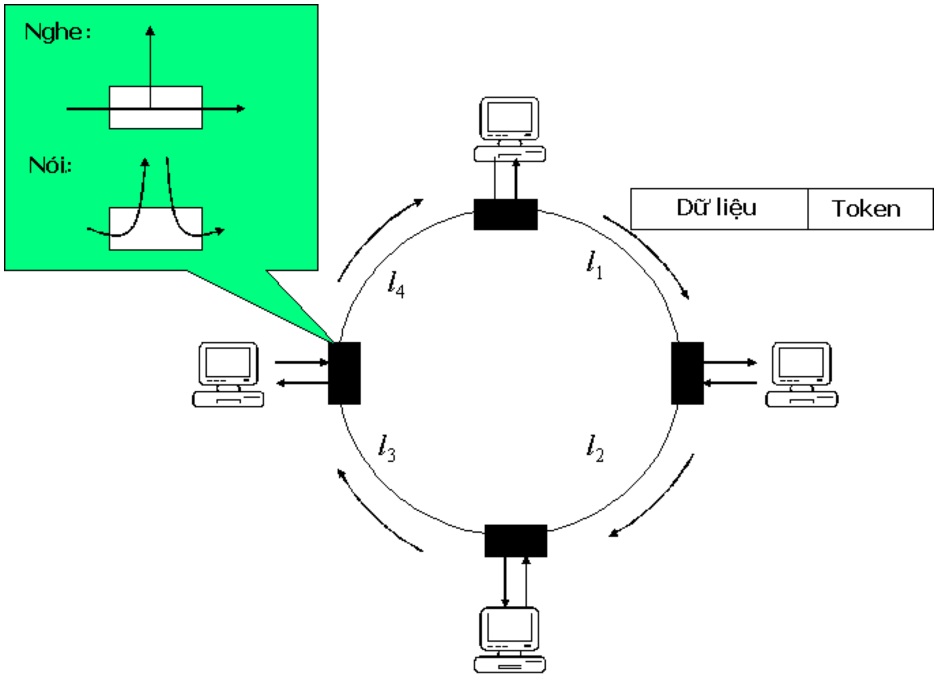
Pooling protocol



- 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 same predefined order.
- The token represents permission to send.
- If a station has a frame queued for transmission when it receives the token, it can send that frame before it passes the token to the next station. If it has no queued frame, it simply passes the token
- When a frame passes a station, if its address is
  - In the receiver address of the frame, it copy the frame into it buffer
  - In the sender address of the frame, it remove the frame from the ring

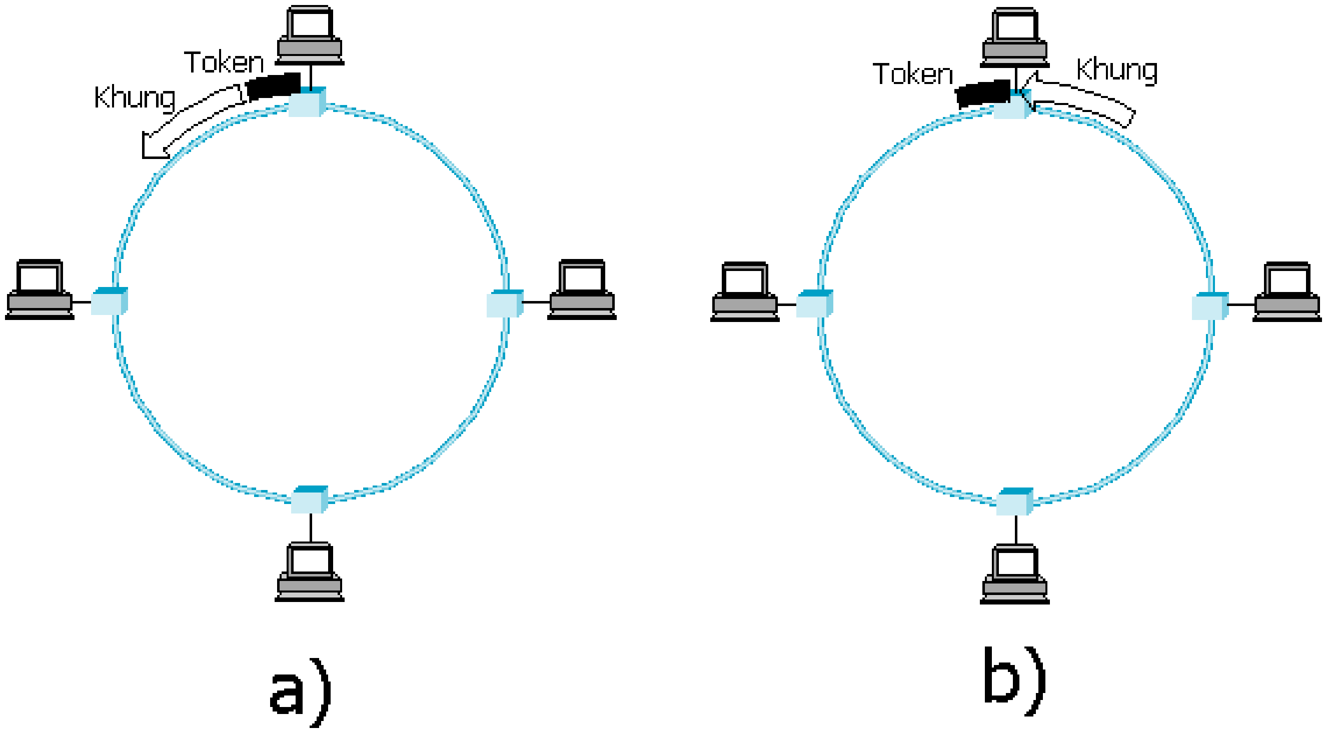


Token passing protocol

- Given
  - THT: Token Holding Time
  - TRT: Tolen 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

- Time to release the token



a) RAT- Release After Transmission
b) RAR- Release After Reception

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

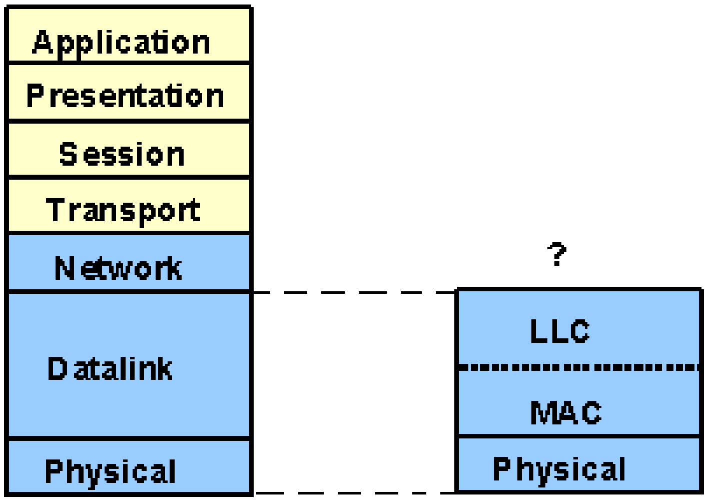
- Manage the ring
  - If a station wants to become the monitor of the ring, it will send a demand message to all stations to announce that it would like to be the monitor
  - If this announcement message passes all stations and return to the station, it thinks that everyone agree to its demand and then he begins to play the role of a monitor
  - If there are many stations demand to be the monitor, several rules are 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

LAN Standards

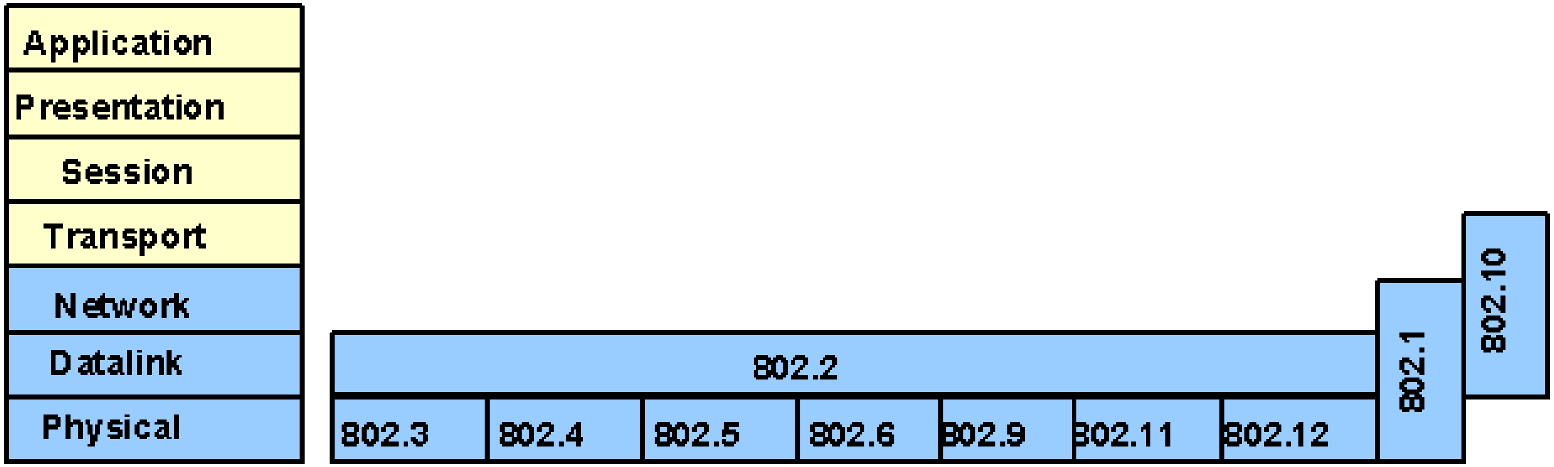


OSI model Reference model for LAN

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

LAN standardization

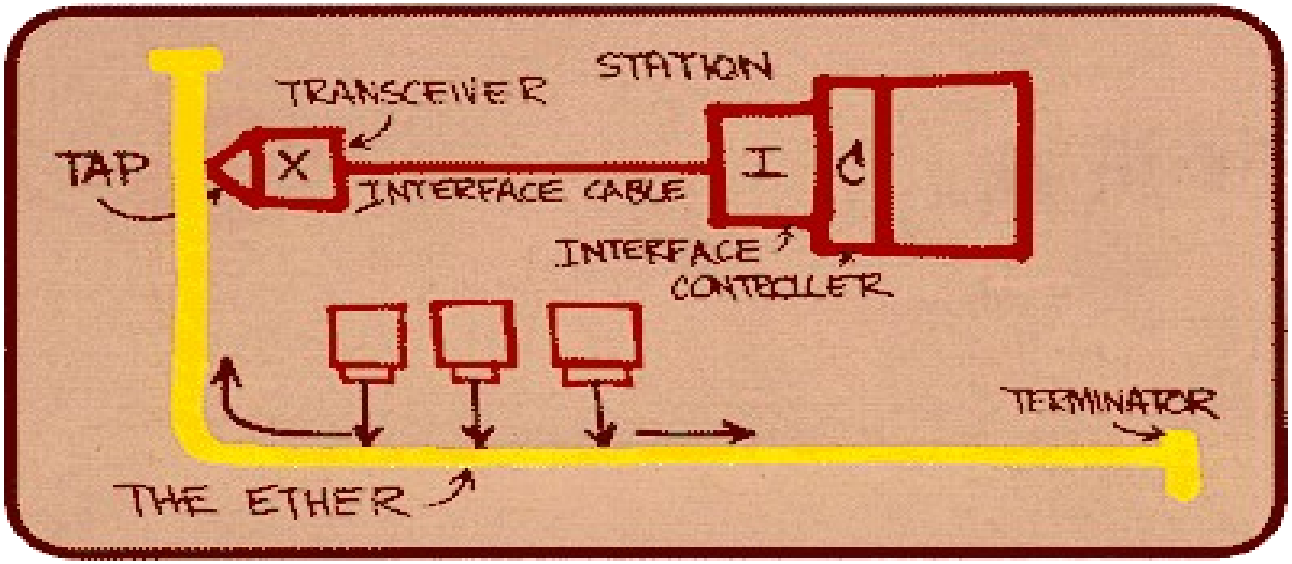
- IEEE (Institute of Electrical and Electronic Engineers)
  - Developing standards for the computer and electronics industry.
  - the IEEE 802 standards for local-area networks are widely followed



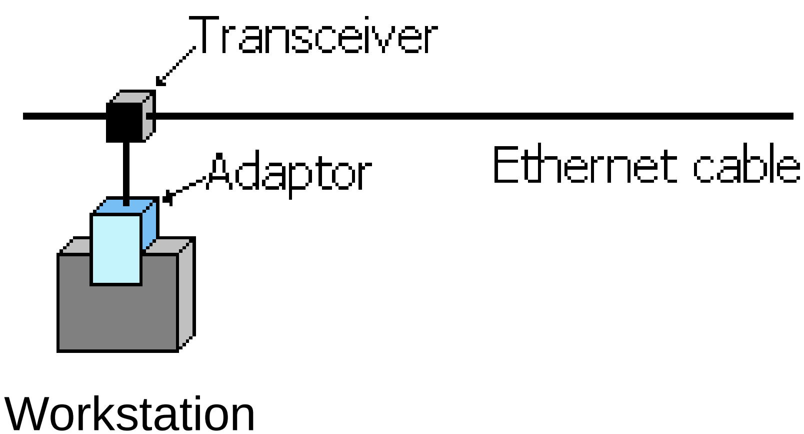
IEEE 802.x

- 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: Intergrated Data and Voice Network
- IEEE 802.10: Standard for Interoperable LAN security
- IEEE 802.11: Wireless LAN
- IEEE 802.12: 100VG – AnyLAN

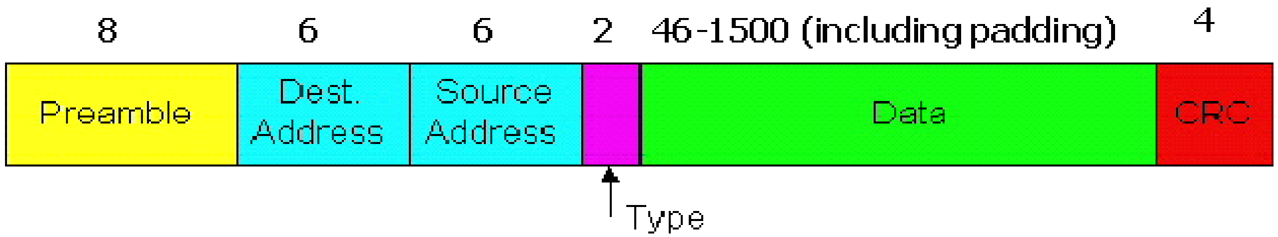
Ethernet network – IEEE 802.3



- Invented by Bob Metcalfe, (Xerox PARC, 1972)



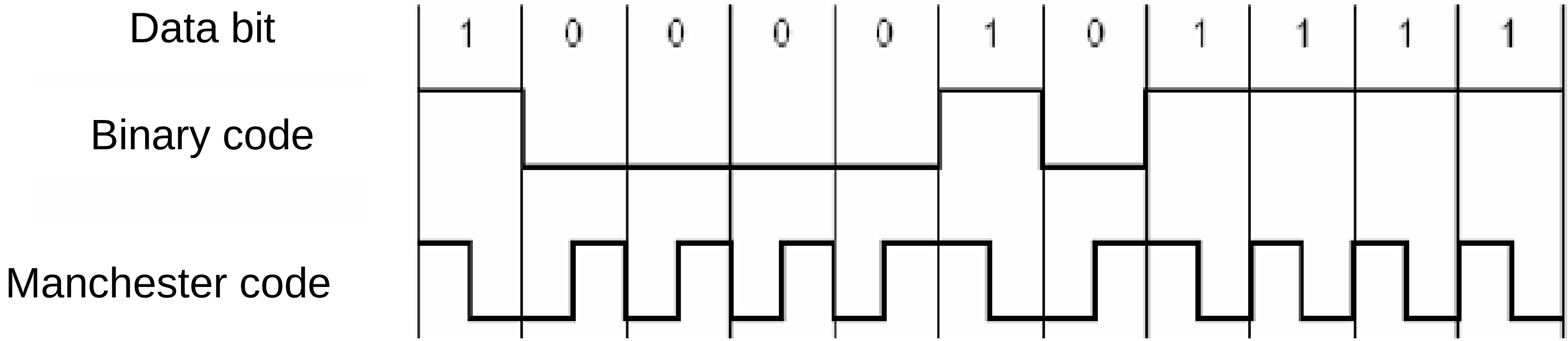
Ethernet network – IEEE 802.3



- 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. Frame is received by all stations in a LAN. Frame is discarded if destination address is not a MAC address of any station in the LAN or not a multicast address.
  - 8:0:2b:e4:b1:2
  - 00001000 00000000 00101011 11100100 10110001 00000010
- Type: Protocol used by network layer, such as IP, Novell IPX, AppleTalk...
- CRC: Used by receiver to detect error

Ethernet network – IEEE 802.3

- Line coding method: Manchester



- MAC Protocol: CSMA/CD+Exponential backoff
- Receive a packet from higher layer
- K := 0; n :=0; // K: a random witing time; n: number of collision times
- Repeat:
  - Wail 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 imphasize the collision;

n ++;

m:= min(n, 10);

Choose K randomly from the set of {0, 1, 2, …, 2^{m}-1}.

if (n < 16) goto repeat;

else cancel the transmitting frame;

}