# Ethernet

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# Ethernet

The most dominant scheme for wired LANs is based on the IEEE 802.3 standard, known as the Ethernet

- 802.3: is a working group and a collection of Institute of Electrical and Electronics Engineers (IEEE) standards produced by the working group
- Defines the physical layer and data link layer's media access control (MAC) of wired Ethernet
- Earlier systems - bus-based, operating at 10Mbps
- Now - switch-based operating up to 100 Gbps

# Question

In the contention technique (also called random access),

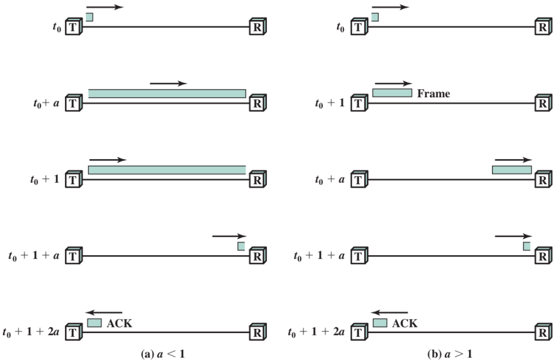
(A) stations transmit in a logical sequence

(B) stations reserve time slots ahead of transmission

(C) there is no predictable or scheduled time for any station to transmit

# Propagation and transmission times

- Transmission time: the time it takes for a station to emit all of the bits of a frame onto the medium (proportional to the length of the frame)
- Propagation delay: The time it takes a bit to propagate from one node to the next.



# Propagation and transmission times

- B $=$ length of the link in bits; this is the number of bits present on the link at an instance in time when a stream of bits fully occupies the link
- L is the number of bits in the frame (length of the frame in bits)
- Then the propagation time (propagation delay)

$$a = B/L$$

Assume that transmission time $= 1$

- $a < 1$, the propagation time is less than the transmission time
- $a > 1$, the propagation time is more than the transmission time — larger values of a are consistent with higher data rates and/or longer distances between stations.

# Traditional Ethernet : the MAC layer

Uses CSMA/CD. To understand CSMA/CD, let us understand the ALOHA technique

- Maximum round-trip propagation delay: twice the time it takes to send a frame between the two most widely separated stations
- A station may transmit a frame at any time
- The station then listens for an amount of time equal to the maximum possible round-trip propagation delay on the network
- If the station hears an acknowledgment during that time, fine; otherwise, it resends the frame
- If the station fails to receive an acknowledgment after repeated transmissions, it gives up

# ALOHA technique contd.

- A receiving station determines the correctness of an incoming frame
- If the frame is valid and if the destination address in the frame header matches the receivers address, the station immediately sends an acknowledgment
- If the frame is invalid, a receiving station ignores the frame
- A frame may be invalid due to noise or due to collision

# Question

In the ALOHA technique for medium access, when the load of the network increases, the maximum utilization of the channel

(A) increases

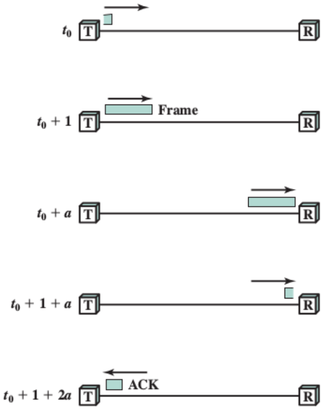
(B) remains the same

(C) decreases

# Slotted ALOHA

- Time on the channel is organized into uniform slots whose size equals the frame transmission time
- All stations are synchronized with respect to a common clock
- Transmission is permitted to begin only at a slot boundary
- Frames that overlap will do so completely
- This increases the maximum utilization of the system

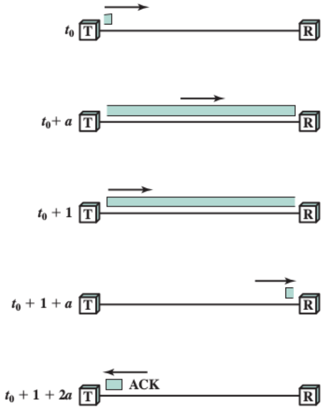
# Observations




(b) $a > 1$

- A property of LANs: propagation delay between stations may be very small compared to frame transmission time
- If the station-to-station propagation time is large compared to the frame transmission time, then, after a station launches a frame, it will be a long time before other stations know about it
- During that time, one of the other stations may transmit a frame, causing a collision

# Observations



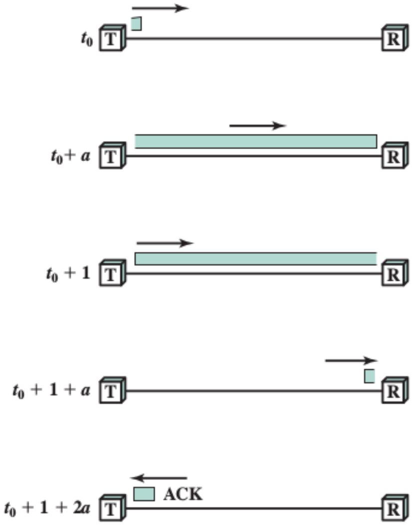
(a) $a < 1$

- But if propagation time is small compared to transmission time when a station launches a frame, all the other stations know it almost immediately
- — then the other stations must not transmit
- a short propagation delay provides the stations with better feedback about the state of the network; this information can be used to improve efficiency

# Carrier Sense Multiple Access

- A station wishing to transmit first listens to the medium to determine if another transmission is in progress
- Waits if the medium is in use
- Transmits if the medium is idle
- Waits a reasonable amount of time after transmitting for an acknowledgment, taking into account
- — the maximum round-trip propagation delay
- — the fact that the acknowledging station must also contend for the channel to respond
- Retransmits if there is no acknowledgement

# Carrier Sense Multiple Access




(a) $a < 1$

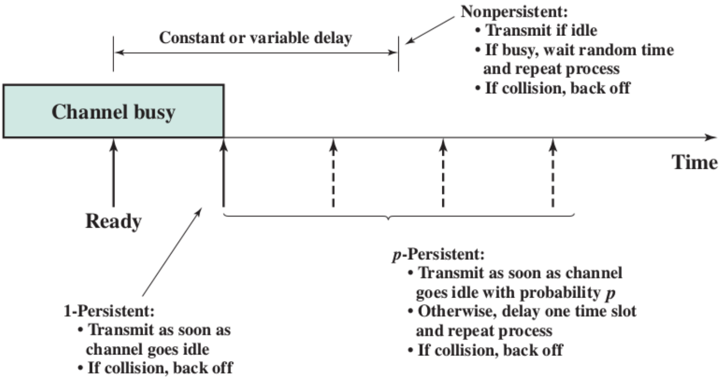
- Effective for networks in which the average frame transmission time is much longer than the propagation time
- If there are no collisions during the time it takes for the leading edge of the packet to propagate to the farthest station there will be no collisions for this frame

# Carrier Sense Multiple Access

- The maximum utilization of the medium achievable by CSMA > slotted ALOHA > ALOHA
- The maximum utilization depends on
- — the length of the frame
- — on the propagation time
- The longer the frame and the shorter the propagation time, the better the medium utilization

What must be done if the medium is found busy?

# CSMA persistence and backoff



# Nonpersistent CSMA

- + random delays reduces the probability of collisions
- - capacity is wasted because the medium will generally remain idle following the end of a transmission even if there are one or more stations waiting to transmit
- — this is solved in 1-persistent protocols

# Question

If two or more stations are waiting to transmit, a collision is guaranteed in

(A) nonpersistent protocol

(B) 1-persistent protocol

(C) neither

# Question

The ______ reduces collisions while ______ reduces idle time

(A) nonpersistent, 1-persistent

(B) 1-persistent, non-persistent

# p-persistent CSMA

A compromise between nonpersistent and 1-persistent

1. If the medium is idle, transmit with probability p, and delay one time unit with probability (1 - p). The time unit is typically equal to the maximum propagation delay.
2. If the medium is busy, continue to listen until the channel is idle and repeat step 1
3. If transmission is delayed one time unit, repeat step 1.

What is an effective value of p?

# p-persistent: Avoiding instability under heavy load

- n stations have frames to send while a transmission is taking place
- At the end of the transmission, the expected number of stations that will attempt to transmit is np
- If $np > 1$, on average, multiple stations will attempt to transmit and there will be a collision
- These stations will try to retransmit and there will be more collisions
- They will also compete with new transmissions
- Eventually all stations will try to send causing continuous collisions

Therefore p must be low

# Question

As p is made smaller, what happens?

(A) stations transmit very fast at low loads

(B) stations must wait longer to attempt transmission, causing long delays at low loads

(C) p has no impact on the transmission rate

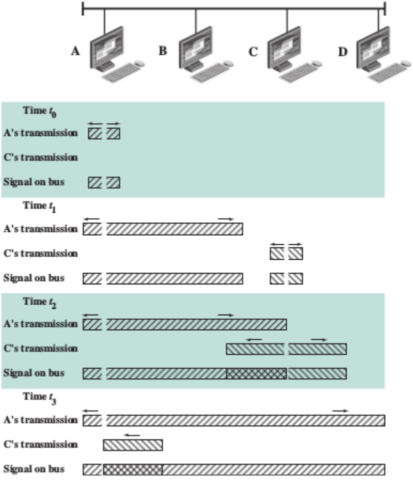
# Carrier Sense Multiple Access / Collision Detection (CSMA/CD)

- CSMA has an inefficiency: When two frames collide, the medium remains unusable for the duration of transmission of both damaged frames.
- Bad for long frames
- This waste can be reduced if a station continues to listen to the medium while transmitting

# CSMA/CD

1. If the medium is idle, transmit; otherwise, go to step 2
2. If the medium is busy, continue to listen until the channel is idle, then transmit immediately
3. If a collision is detected during transmission, transmit a brief jamming signal to assure that all stations know that there has been a collision and then cease transmission.
4. After transmitting the jamming signal, wait a random amount of time, referred to as the backoff, then attempt to transmit again (repeat from step 1).

# CSMA/CD




- At t0, A is transmitting to D
- At t1, B and C are ready to transmit
- At t2, A's transmission reaches C
- At t3, A detects that there is a collision and ceases transmission

# Collision Detection in CSMA/CD

- The amount of time that it takes to detect a collision is no greater than twice the end-to-end propagation delay
- Frames should be long enough to allow collision detection prior to the end of transmission
- If shorter frames are used, collision detection does not occur prior to the end of transmission

# Persistence algorithm used for Ethernet

- 1-persistent algorithm is used
- non-persistent: capacity is wasted even if there are stations waiting to send
- p-persistent case, p must be set low enough to avoid instability, causing long delays under light load
- Why is 1-persistent better?
- — Wasted time due to collisions is short if frames are long compared to propagation delay
- — With random backoff, the two stations involved in a collision are unlikely to collide on their next tries
- IEEE 802.3 uses exponential binary backoff

# Exponential binary backoff

- The transmitter randomly selects a k between 0 and $2^n - 1$ and waits $k * 51.2\mu s$ for the nth retransmisson.
- The maximum value of n=10
- The first time the transmitter detects a collision, it waits either for 0*51.2 $\mu$s or 1*51.2 $\mu$s
- The second time it detects a collision, it waits for one of 0, 51.2, 102.4, or 153.6 $\mu$s, selected randomly
- After the first 10 attempts, the value remains the same for the next 6 attempts
- After a total of 16 unsuccessful attempts, the station gives up and reports an error.

# Question

In CSMA/CD, as congestion increases

(A) stations back off by smaller and smaller amounts to reduce the probability of collision

(B) stations back off by larger and larger amounts to reduce the probability of collision

(C) stations back off by larger and larger amounts to increase the probability of collision

# 1-persistent algorithm with exponential backoff

- Advantage: efficient over a wide range of loads
- – low load: 1-persistence guarantees that a station can transmit as soon as the line goes idle
- – high loads: at least as stable as other techniques
- Disadvantage: stations with no or few collisions will have a chance to transmit before stations that have waited longer (due to backoff)

# Collision detection

Baseband bus

- A transmitter will detect a collision if the signal on the cable at the transmitter tap point exceeds the maximum that could be produced by the transmitter alone
- If two stations are far apart, it may not be possible to detect collisions due to signal attenuation
- Therefore the IEEE standard restricts the maximum length of coaxial cable to 500 m for 10BASE5 and 200 m for 10BASE2

Hub on a twisted pair star toplogy: Hubs can detect collisions and send special signals

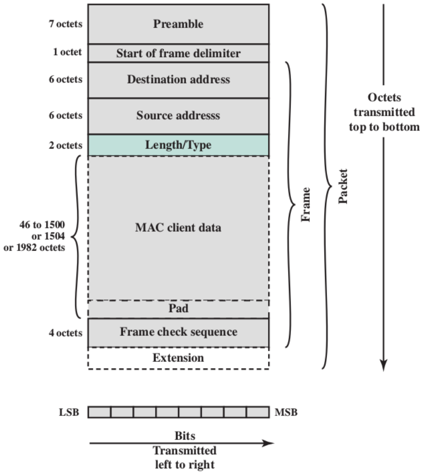
# Question

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

# Question

The distance between two stations A and C is 2000m. The propagation speed is $2 * 10^8$m/s. Station A starts sending a long frame at time t1=0$\mu$s. Station C starts sending a long frame at t2=3$\mu$s. The size of the frame is long enough to guarantee the detection of collision at both the stations. Find a) the time when station C hears the collision (t3) b) the time when station A hears the collision (t4). c) the number of bits A has sent before detecting the collision d) the number of bits C has sent before detecting the collision.

# IEEE 802.3 MAC header




- Preamble: A 7-octet pattern of alternating 0s and 1s - bit sync. by receiver
- SFD: 10101011 to enable the receiver to locate the first bit of the frame
- Length/Type: If $\leq 1500$ decimal, indicates the number of MAC Client Data octets. If $\geq 1536$, nature of MAC client protocol (accomodates other types of frames)
- Pad: added to ensure that the frame is long enough for proper CD operation (to ensure that the transmitter knows there is a collision)

# IEEE 802.3 10-Mbps Specifications (Ethernet)

-data rate in Mbps-signaling method-maximum segment length in hundreds of meters

| | 10BASE5 | 10BASE2 | 10BASE-T | 10BASE-FP |
|---|---|---|---|---|
| **Transmission Medium** | Coaxial cable (50 Ω) | Coaxial cable (50 Ω) | Unshielded twisted pair | 850-nm optical fiber pair |
| **Signaling Technique** | Baseband (Manchester) | Baseband (Manchester) | Baseband (Manchester) | Manchester/ on-off |
| **Topology** | Bus | Bus | Star | Star |
| **Maximum Segment Length (m)** | 500 | 185 | 100 | 500 |
| **Nodes per Segment** | 100 | 30 | — | 33 |
| **Cable Diameter (mm)** | 10 | 5 | 0.4–0.6 | 62.5/125 $\mu$m |

10BaseF

- a passive-star topology for interconnecting stations and repeaters with up to 500 m per segment
- a point-to-point link that can be used to connect stations and repeaters up to 2 km
- a point-to-point link that can be used to connect repeaters up to 2 km

# Question

In 10BASE5, a maximum of 4 repeaters can be used between any two stations, extending the length up to ______

(A) 2 km

(B) 2.5 km

(C) 500 m