Data Link Layer, Part 3
Medium Access Control

Preface

- In our earlier discussion about DLL, we assumed that a link is associated with two nodes.
- When a link/medium is shared among many nodes, we need to resolve the conflicts of multiple nodes transmitting at the same time.
- This issue is addressed by a sublayer within the DLL: the **medium access control** (**MAC**) sublayer.

Two Approaches of MAC

- Compete for the medium
  - ALOHA
  - Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
- Wait for Your Turn
  - Token Passing Ring
  - Token Passing Bus
  - FDDI

Carrier Sense Multiple Access (CSMA)

- Station listens to channel for ongoing transmissions.
- If so, the station waits until the channel is idle.
- When the channel is idle, the frame is transmitted.
- Collisions may still occur. How ?

- If a collision occurs, the station waits random amount of time and retransmits.
- The longer the propagation delay, the longer the window of collisions and the worse the performance.

Collision Detection

- ❑ During a transmission, the station also listens to the channel and, if it detects collisions, it immediately aborts the transmission with a jamming signal.
- ❑ This reduces the wasted time due to collisions.
- ❑ In the worst case, how long does a station take to detect a collision ?

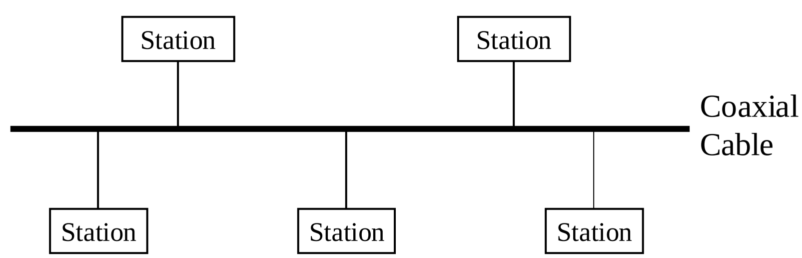
Binary Exponential Backoff

- ❑ To determine the number of time slots to wait before re-sending:
  - On the first collision, wait either 0 or 1 slots.
  - On the second, wait 0, 1, 2, or 3 slots.
  - On the third, wait 0 to 7 slots.
- ❑ In general, after n collisions, wait anywhere from 0 to $2^n - 1$ slots, if $n <= 10$; or between 0 and 1023 slots, if $n > 10$.
- ❑ After 16 collisions, give up and report that packet could not be sent.

Ethernet

- A broadcast-based LAN technology using CSMA/CD
- The official standard is IEEE 802.3.
- The Ethernet technology comprises two parts:
  - a DLL/MAC layer that defines frame format, error detection, CSMA/CD parameters, etc.
  - a family of physical layer standards

The "Classic" Ethernet



- 10 Mbps over coaxial cables
  - physical layer standard 10Base5 called "thick Ethernet"
  - standard 10Base2 called "thin Ethernet"

10Base5

- each cable segment up to 500 meters
- 4 repeaters can be used to cascade 5 segments, resulting in a diameter 2,500 meters
- signal propagation delay in the cable is approximately 2×10^8 m/sec.
- each repeater introduces a 0.5 μsec delay
- the slot time in the exponential backoff algorithm is 51.2 μsec, the transmission time of 64 bytes at speed 10 Mbps
- Manchester encoding

10Base5 Continued

- enforce a minimum frame length of 64 bytes
  – Why ?

Frame Format

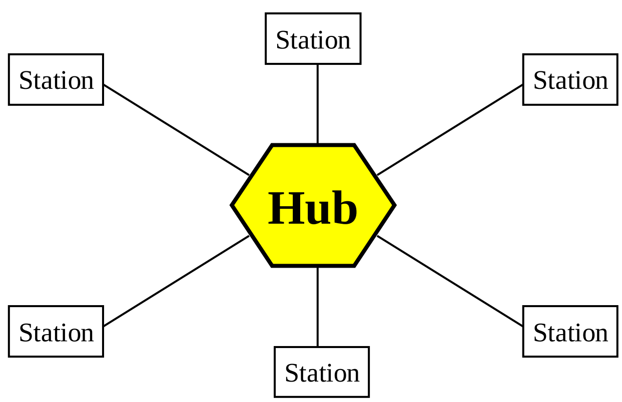
64	48	48	16	368 to 12000	32
Preamble	Destination	Source	Length/Type	frame data	CRC Checksum

- ❑ Preamble:
  - – 7 10101010's followed by 10101011
  - – Marks the beginning of the frame and
  - – Establish understanding of "bit periods"
- ❑ Source Address:
  - – 48 bits each; first 24 bits vendor ID; second 24 bits assigned by the vendor
  - – all Ethernet addresses are globally unique

- ❑ Destination Address:
  - – due to the broadcast nature of Ethernet, every frame will be seen by the physical layer modules at all stations
  - – only the physical layer module at the destination station delivers the frame to its DLL layer
  - – this filtering is performed by hardware
  - – the destination address of all 1's is called the broadcast address; frames destined to the address will be delivered to the DLL modules of all stations

- Length/Type:
  - If value < 1536 (0x0600), length of data
  - Otherwise, protocol type of data
    - 0x0800 for IP, 0x0806 for ARP, etc.
- Frame Data:
  - 46 to 1500 bytes
  - when necessary, this field is padded to 46 bytes, to ensure the 64-byte minimum frame length from destination address to checksum
- CRC Checksum
  - using the CRC-32 generator polynomial
- The frame ends with a HH bit period.

10Base-T: Twisted-pair Ethernet



- Uses twisted pairs as the physical medium.
- uses the star topology
- A hub is basically a multiway repeater; it relays incoming signals to all ports
  - This is still a broadcast technology

Fast Ethernet

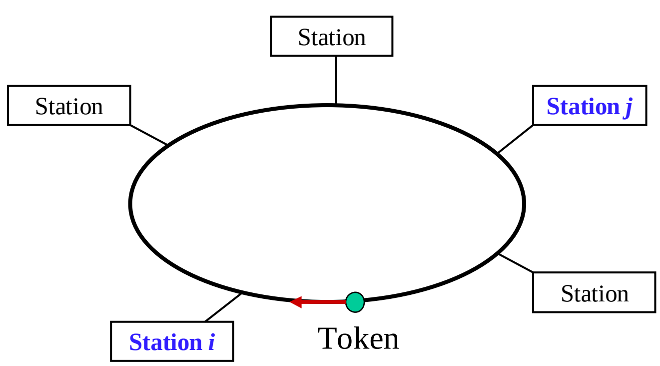
- 100 Mpbs
- use the original Ethernet MAC and format but operates at ten times the speed
- The network diameter is reduced by a factor of 10. Why ?
- Again, different physical layer standards support different transmission media:
  - 100Base-T and 100Base-T4 for twisted pairs
  - 100Base-F for fibers
- Use the star topology.

Gigabit Ethernet

- 1 Gbps
- Basically the original Ethernet MAC and frame format operating at 100 times the speed.
- However, this extremely high speed forces two changes:
  - Frames padded to a minimum length of 4K bits.
  - Allows burst transmission: transmitting multiple frames once a station gains the "right of the road."

MAC Approach Two: Wait for Your Turn

- A token circulates among all stations.
  - the token is a miniature, 3-byte frame (including start and end flags)



- When the token arrives, a station either seizes the token and sends a frame or passes the token to the next station.
- Assuming that station i has a frame f to send to station j.
- Station i waits for the arrival of the token and seizes the token.
- Station i sends f to station $i + 1$, which in turns passes f to station $i + 2$

- When frame f arrives at station j, station j picks up f and simultaneously forwards f to station $j + 1$.
- Eventually, f returns to station i, which passes the token, rather than f, to station $i + 1$

Discussion

- This is a broadcast-based technology because all stations see every frame.
- The forwarding of both the token and data frames is performed by NICs in hardware.
- Three token-based LAN technologies
  - 802.4 token bus
  - 802.5 token ring
  - Fiber Distributed Data Interface (FDDI)

Token-Based MAC *vs* CSMA/CD

- When the medium is quite, a sending station
  - wastes no time in waiting with CSMA/CD
  - must wait for the arrival of the token with token-based approaches
  - thus, CSMA/CD outperforms token-based approaches in light traffic.
- Token-based MAC handles heavy loads better than CSMA/CD.
  - no waste of bandwidth due to collisions

- Moreover, token-based MAC has advantages in handling real-time traffic
  - fairness: stations access the medium in a round-robin manner
  - bounded delays: a station can predict the next time the token returns to it (in CSMA/CD, a station waits for a "random period of time" before retransmission)

A Word about LAN and MAC

- The Broadcast/MAC technologies discussed in this talk are inherently LAN technologies.
- However, the reverse is not always true; many LANs are based on switching .
  - ATM
  - switched Ethernet