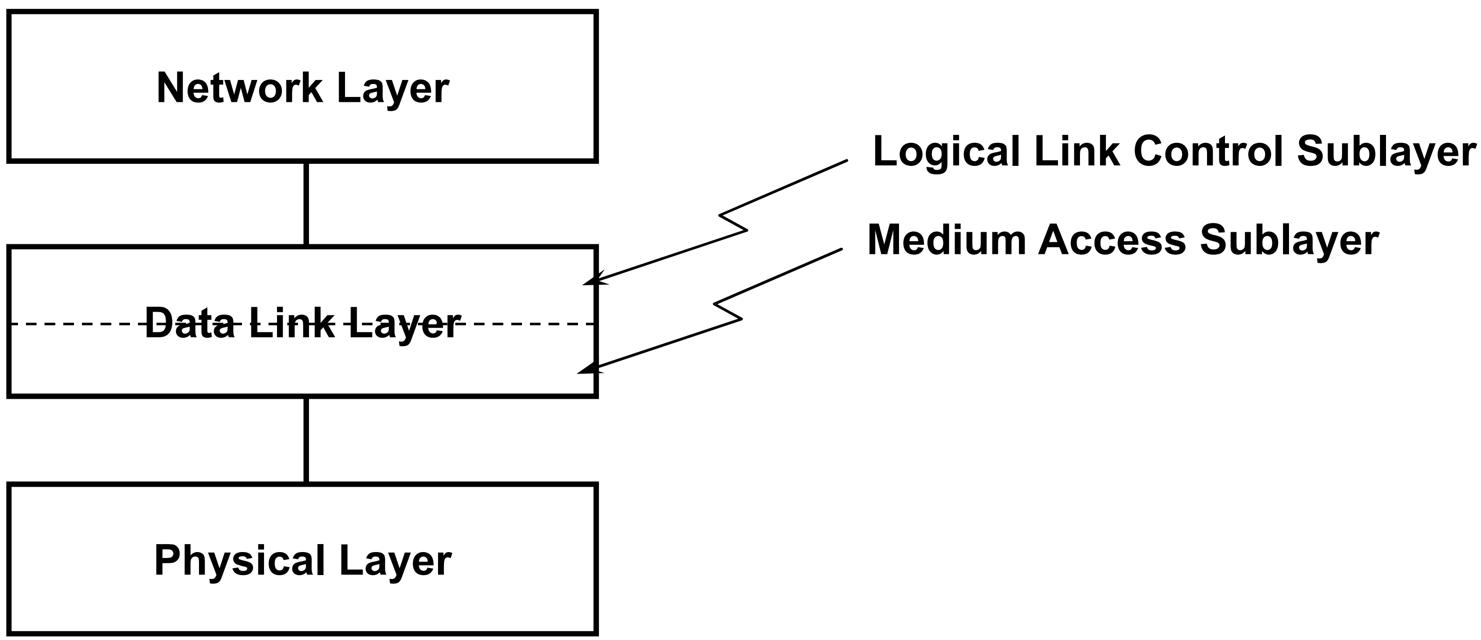
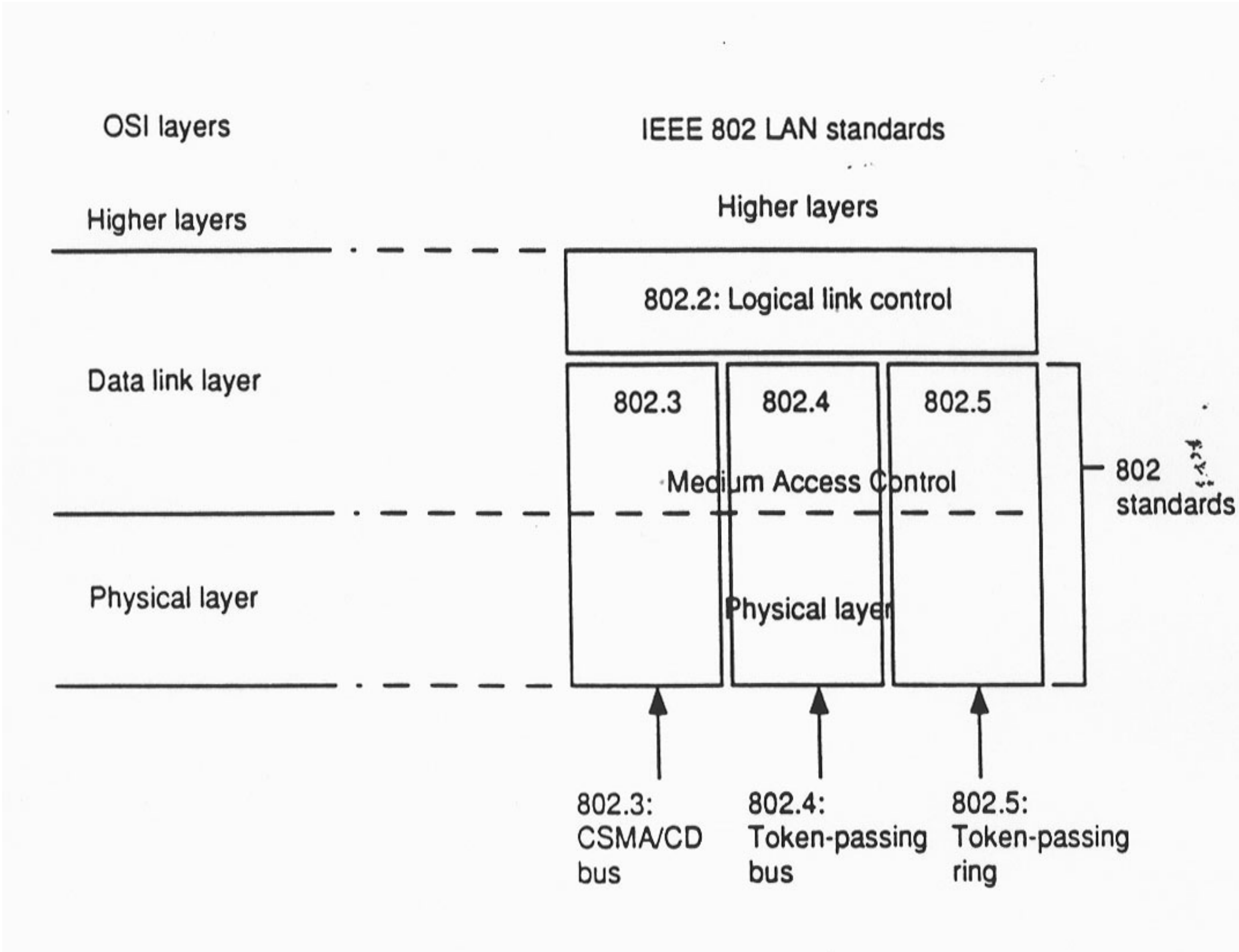
Medium Access Sublayer

Slide Set were original prepared by Dr. Tatsuya Susa

Medium Access Sublayer



IEEE 802 Standards



Medium Access Sublayer *(cont'd)*

- Medium access (MAC) sublayer is not important on point-to-point links
- The MAC sublayer is only used in broadcast or shared channel networks
- Examples: Satellite, Ethernet, Cellular

Logical Link Control Sublayer

- Logical Link Control (LLC) sublayer provides mechanisms for reliable communications
  - acknowledgement, etc

MAC Sublayer: Contents

- Fixed Assignment Protocols
- Demand Assignment Protocols
- Contention Access Protocols
- Ethernet

1. Fixed Assignment Protocols

- Static and predetermined allocation of channel access: independent of user activity
- Idle users may be assigned to the channel, in which case channel capacity is wasted
- Examples: TDMA, FDMA, WDMA

2. Demand Assignment Protocols

- Allocate channel capacity to hosts on a demand basis (i.e., only to active users)
- Requires methods for measuring the demand for the channel
  - Polling
  - Reservation schemes
  - Token Passing Scheme

2.1 Polling

- A central controller interrogates each host and allocates channel capacity to those who need it
- Good for systems with:
  - Short propagation delay
  - Small polling messages
  - Non-bursty traffic

2.2 Token Passing Scheme

- A token always circulates around a ring net.
- A user grabs a token to transmit data
- Will discuss details later in the Token Ring LAN

3. Contention Access Protocols

- Single channel shared by a large number of hosts
- No coordination between hosts
- Control is completely distributed
- Examples: ALOHA, CSMA, CSMA/CD

Contention Access *(cont'd)*

- Advantages:
  - Short delay for bursty traffic
  - Simple (due to distributed control)
  - Flexible to fluctuations in the number of hosts
  - Fairness

Contention Access *(cont'd)*

- Disadvantages:
  - Low channel efficiency with a large number of hosts
  - Not good for continuous traffic (e.g., voice)
  - Cannot support priority traffic
  - High variance in transmission delays

Contention Access Methods

- Pure ALOHA
- Slotted ALOHA
- CSMA
  - 1-Persistent CSMA
  - Non-Persistent CSMA
  - P-Persistent CSMA
- CSMA/CD

3.1 Pure ALOHA

- Originally developed for ground-based packet radio communications in 1970
- Goal: let users transmit whenever they have something to send

The Pure ALOHA Algorithm

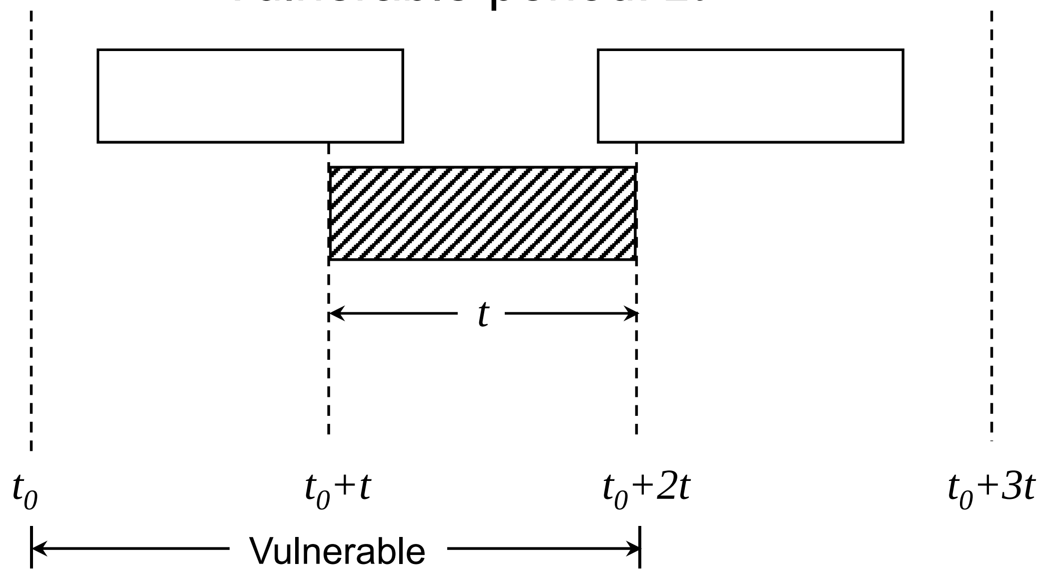
1. Transmit whenever you have data to send
2. Listen to the broadcast
   - Because broadcast is fed back, the sending host can always find out if its packet was destroyed just by listening to the downward broadcast one round-trip time after sending the packet
3. If the packet was destroyed, wait a random amount of time and send it again
   - The waiting time must be random to prevent the same packets from colliding over and over again

Pure ALOHA *(cont'd)*

- Note that if the first bit of a new packet overlaps with the last bit of a packet almost finished, both packets are totally destroyed.

t : one packet transmission time

Vulnerable period: $2t$



Pure ALOHA (cont'd)

- Due to collisions and idle periods, pure ALOHA is limited to approximately 18% throughput in the best case
- Can we improve this?

3.2 Slotted ALOHA

- Slotted ALOHA cuts the vulnerable period for packets from $2t$ to t.
- This doubles the best possible throughput from 18.4% to 36.8%
- How?
  - Time is slotted. Packets must be transmitted within a slot

The Slotted ALOHA Algorithm

1. If a host has a packet to transmit, it waits until the beginning of the next slot before sending
2. Listen to the broadcast and check if the packet was destroyed
3. If there was a collision, wait a random number of slots and try to send again

3.3 CSMA

- We could achieve better throughput if we could listen to the channel before transmitting a packet
- This way, we would stop avoidable collisions.
- To do this, we need “Carrier Sense Multiple Access,” or CSMA, protocols

Propagation Delay and CSMA

- Contention (vulnerable) period in Pure ALOHA
  - two packet transmission times
- Contention period in Slotted ALOHA
  - one packet transmission time
- Contention period in CSMA
  - up to 2 x end-to-end propagation delay

Performance of CSMA >
Performance of Slotted ALOHA >
Performance of Pure ALOHA

CSMA *(cont'd)*

- There are several types of CSMA protocols:
  - 1-Persistent CSMA
  - Non-Persistent CSMA
  - P-Persistent CSMA

3.3.1 1-Persistent CSMA

- Sense the channel.
  - If busy, keep listening to the channel and transmit immediately when the channel becomes idle.
  - If idle, transmit a packet immediately.
- If collision occurs,
  - Wait a random amount of time and start over again.

1-Persistent CSMA *(cont'd)*

The protocol is called 1-persistent because the host transmits with a probability of 1 whenever it finds the channel idle.

1-Persistent CSMA *(cont'd)*

- Even if prop. delay is zero, there will be collisions
- Example:
  - If stations B and C become ready in the middle of A's transmission, B and C will wait until the end of A's transmission and then both will begin transmitted simultaneously, resulting in a collision.
- If B and C were not so greedy, there would be fewer collisions

3.3.2 Non-Persistent CSMA

- Sense the channel.
  - If busy, wait a random amount of time and sense the channel again
  - If idle, transmit a packet immediately
- If collision occurs
  - wait a random amount of time and start all over again

Tradeoff between 1- and Non-Persistent CSMA

- If B and C become ready in the middle of A’s transmission,
  - 1-Persistent: B and C collide
  - Non-Persistent: B and C probably do not collide
- If only B becomes ready in the middle of A’s transmission,
  - 1-Persistent: B succeeds as soon as A ends
  - Non-Persistent: B may have to wait

3.3.3 P-Persistent CSMA

- Optimal strategy: use P-Persistent CSMA
- Assume channels are slotted
- One slot = contention period (i.e., one round trip propagation delay)

P-Persistent CSMA *(cont'd)*

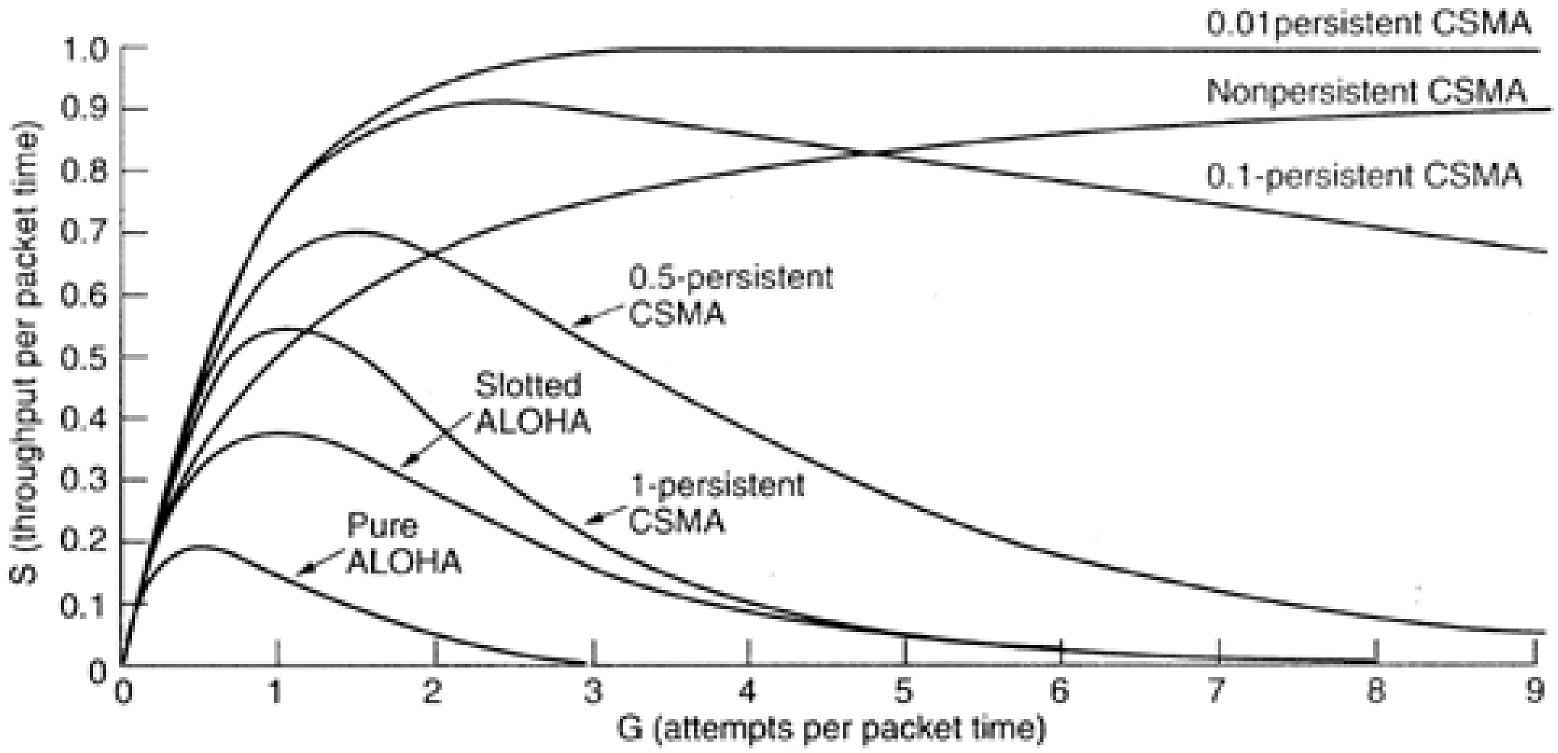
1. Sense the channel
   - If channel is idle, transmit a packet with probability p
     - if a packet was transmitted, go to step 2
     - if a packet was not transmitted, wait one slot and go to step 1
   - If channel is busy, wait one slot and go to step 1.
2. Detect collisions
   - If a collision occurs, wait a random amount of time and go to step 1

P-Persistent CSMA *(cont'd)*

- Consider p-persistent CSMA with p=0.5
  - When a host senses an idle channel, it will only send a packet with 50% probability
  - If it does not send, it tries again in the next slot.
  - The average number of tries is:

$$\frac{1}{p}$$

Comparison of CSMA and ALOHA Protocols



(Number of Channel Contenders)

3.4 CSMA/CD

- In CSMA protocols
  - If two stations begin transmitting at the same time, each will transmit its complete packet, thus wasting the channel for an entire packet time
- In CSMA/CD protocols
  - The transmission is terminated immediately upon the detection of a collision
  - CD = Collision Detect

CSMA/CD

- Sense the channel
  - If idle, transmit immediately
  - If busy, wait until the channel becomes idle
- Collision detection
  - Abort a transmission immediately if a collision is detected
  - Try again later after waiting a random amount of time

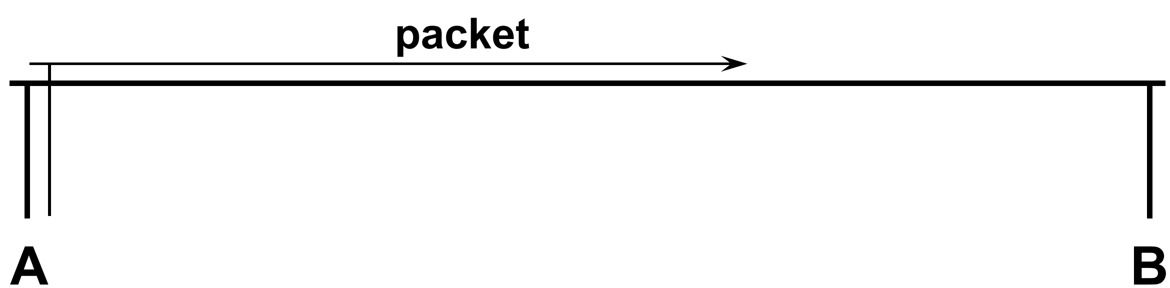
CSMA/CD *(cont'd)*

- Carrier sense
  - reduces the number of collisions
- Collision detection
  - reduces the effect of collisions, making the channel ready to use sooner

Collision detection time

How long does it take to realize there has been a collision?

Worst case: 2 x end-to-end prop. delay



4. IEEE 802 LANs

- LAN: Local Area Network
- What is a local area network?
  - A LAN is a network that resides in a geographically restricted area
  - LANs usually span a building or a campus

IEEE 802 Standards

802.1: Introduction

802.2: Logical Link Control (LLC)

802.3: CSMA/CD (Ethernet)

802.4: Token Bus

802.5: Token Ring

802.6: DQDB

802.11: CSMA/CA (Wireless LAN)

IEEE 802 Standards *(cont'd)*

- 802 standards define:
  - Physical layer protocol
  - Data link layer protocol
    - Medium Access (MAC) Sublayer
    - Logical Link Control (LLC) Sublayer

OSI Layers and IEEE 802

OSI layers	IEEE 802 LAN standards		
Higher Layers	Higher Layers		
Data Link Layer	802.2 Logical Link Control		
	802.3	802.4	802.5
	Medium Access Control		
Physical Layer	CSMA/CD bus	Token-passing bus	Token-passing ring

4.1 Ethernet (CSMA/CD)

- IEEE 802.3 defines Ethernet
- Layers specified by 802.3:
  - Ethernet Physical Layer
  - Ethernet Medium Access (MAC) Sublayer

Ethernet Synchronization

- 64-bit frame preamble used to synchronize reception
- 7 bytes of 10101010 followed by a byte containing 10101011

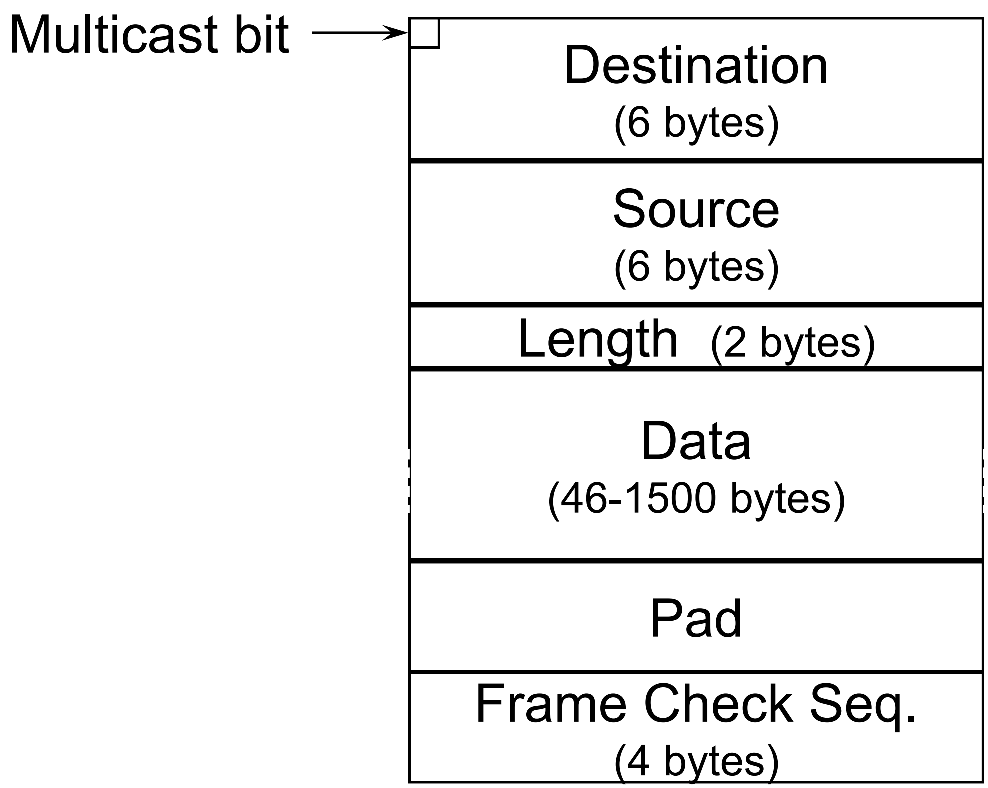
Ethernet Cabling Options

- 10Base5: Thick Coax
- 10Base2: Thin Coax (“cheapernet”)
- 10Base-T: Twisted Pair
- 10Base-F: Fiber optic
- Each cabling option carries with it a different set of physical layer constraints (e.g., max. segment size, nodes/segment, etc.)

4.1.2 Ethernet: MAC Layer

- Data encapsulation
  - Frame Format
  - Addressing
  - Error Detection
- Link Management
  - CSMA/CD
  - Backoff Algorithm

MAC Layer Ethernet Frame Format



Ethernet MAC Frame Address Field

- Destination and Source Addresses:
  - 6 bytes each
- Two types of destination addresses
  - Physical address: Unique for each user
  - Multicast address: Group of users
  - First bit of address determines which type of address is being used

    0 = physical address

    1 = multicast address

Ethernet MAC Frame
Other Fields

- Length Field
  - 2 bytes in length
  - determines length of data payload
- Data Field: between 0 and 1500 bytes
- Pad: Filled when Length < 46
- Frame Check Sequence Field
  - 4 bytes
  - Cyclic Redundancy Check (CRC-32)

CSMA/CD

- Recall:
  - CSMA/CD is a “carrier sense” protocol.
    - If channel is idle, transmit immediately
    - If busy, wait until the channel becomes idle
  - CSMA/CD can detect collections.
    - Abort transmission immediately if there is a collision
    - Try again later according to a backoff algorithm

CSMA/CD *(cont'd)*

- Carrier sense reduces the number of collisions
- Collision detection reduces the impact of collisions

CSMA/CD and Ethernet

- Ethernet:
  - Short end-to-end propagation delay
  - Broadcast channel
- Ethernet access protocol:
  - 1-Persistent CSMA/CD
  - with Binary Exponential Backoff Algorithm

Ethernet Backoff Algorithm: Binary Exponential Backoff

- If collision,
  - Choose one slot randomly from 2^k slots, where k is the number of collisions the frame has suffered.
  - One contention slot length = 2 x end-to-end propagation delay

This algorithm can adapt to changes in network load.

Binary Exponential Backoff *(cont'd)*

slot length = 2 x end-to-end delay = 15 μs

t=0μs:	Assume A and B collide ($k_A = k_B = 1$)
	A, B choose randomly from 2^1 slots: [0,1]
	Assume A chooses 1, B chooses 1
t=30μs:	A and B collide ($k_A = k_B = 2$)
	A, B choose randomly from 2^2 slots: [0,3]
	Assume A chooses 2, B chooses 0
t=45μs:	B transmits successfully
t=75μs:	A transmits successfully

Binary Exponential Backoff *(cont'd)*

- In Ethernet,
  - Binary exponential backoff will allow a maximum of 15 retransmission attempts
  - If 16 backoffs occur, the transmission of the frame is considered a failure.

4.1.4 Ethernet Performance