14-760:
ETHERNET OVER COPPER

LECTURE 4 * 14-760 * SPRING 2020

QUICK HISTORY
PURE ALOHA (SATELLITE)

- Circa 1970

- Originally developed for terrestrial radio at Univ. of Hawaii, it illustrates the principles of a *contention-based* MAC protocol on any broadcast media.

- Senders transmit whenever they want

- If any two transmission over lap – even by one bit, they are garbled. This is called a *collision*.

- Collisions are detected by listening and verifying checksum.

- Garbled frames are resent after a random delay.

- Resent frames may also collide.

- Resending frames does, of course, waste the channel

QUICK HISTORY:
PURE ALOHA (SATELLITE)
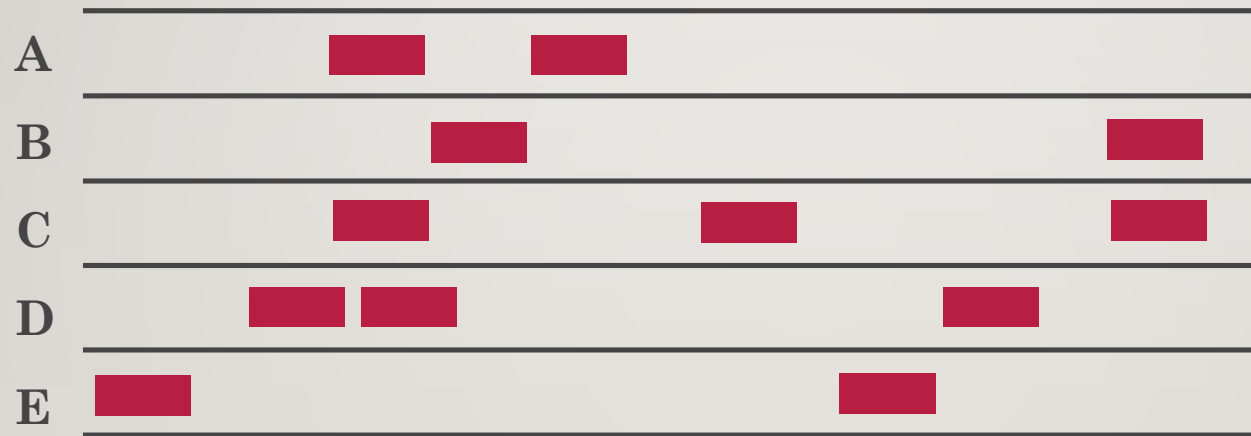
QUICK HISTORY: SLOTTED ALOHA

- Circa 1972
- Stations agree on slot boundaries. These might be maintained by a special station that produces a timing signal.
- Tolerance needs to be built in for timing signal's transmission latency
- Send only at beginning of slot.
- This reduces the window of vulnerability to a single frame's transmission time (1 slot)
- Of course, if contention is low and collision is not likely, it will increase average transmission latency.

QUICK HISTORY: SLOTTED ALOHA

CARRIER SENSE MULTIPLE ACCESS (CSMA)

- What if, instead of using slots, we just "listen" first, and only transmit if no one else is?

- This means that collisions would only occur in the event of a "tie" – two stations listened and then transmitted?

- This leads to much better performance – the window of vulnerability is very small – just the transmission latency.

PERSISTENT CSMA

- Under *persistent CSMA* stations continually sense the channel and transmit as soon as it is free.
- The problem is that a queue could have been building up during the prior transmission.
- This ensures almost certain collision to follow.

NONPERSISTENT CSMA

- *Nonpersistent CSMA* will transmit immediately if the channel is free. The recent past is a good indicator of the near future. A collision isn't likely.

- If however, a station listens and hears a transmission, it stops listening and waits a random amount of time before trying again.

- This helps to mitigate the queuing of requests during a transmission from leading to a collision

P-PERSISTENT CSMA

- p is a parameter. It specifies the probability with which a station should transmit upon detecting an idle channel.

- In other words, if the channel is free, a station begins to transmit immediately with a probability of p.

- The other (1-p) time, the station waits a random amount of time. After this random delay, it rolls the dice again – and transmits or waits, accordingly.

- This system is designed to further reduce the likelihood of collision by spreading out bursts.

HOW WELL DO THEY WORK?
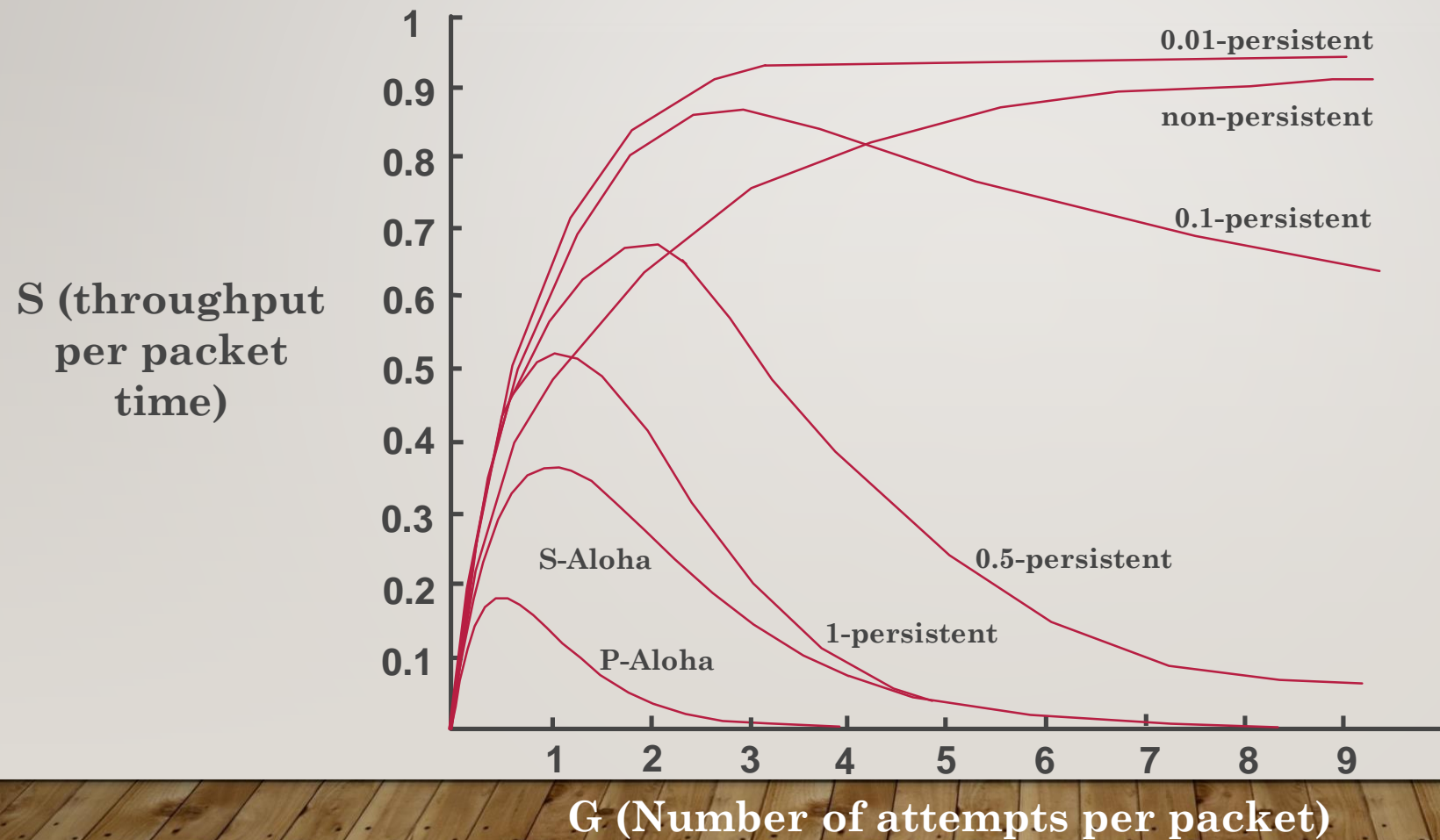
CSMA/CD

- Another level of sophistication is the addition of *collision detection*.
- Stations listen while transmitting
- If a station hears something different than what it is sending, it immediate stops
- What it hears is different from what it sends, if another transmission garbles the original.
- Additionally, if any station detects a collision, it sends a *jamming signal* to make sure that the colliding signals don't cancel each other out, preventing detection after attenuation.
- This reduces the time wasted in the event of a collision sending already garbled packets.
- IEEE 802.3 (including Ethernet) protocols are 1-persistent CSMA/CD.

MINIMUM FRAME SIZE FOR CSMA/CD

- Because of latency, collisions cannot be detected immediately. This signal from one transmitter much reach the other transmitter.

- In practice, this imposes a minimum size on the length of a frame. The frame must be long enough to permit a collision to be detected.

- If the frame is too short, it will be gone before the signal from one transmitter reaches another.

- The frames will be corrupted as the "cross in the mail"

- But neither sender will be able to detect it, until the whole frame has been sent, which defeats the purpose.

MINIMUM FRAME SIZE FOR CSMA/CD

- The frame needs to be sufficiently long to require more than a round-trip time for transmission.

- We must consider the bit-rate of the channel as well as its length to determine the round trip time.

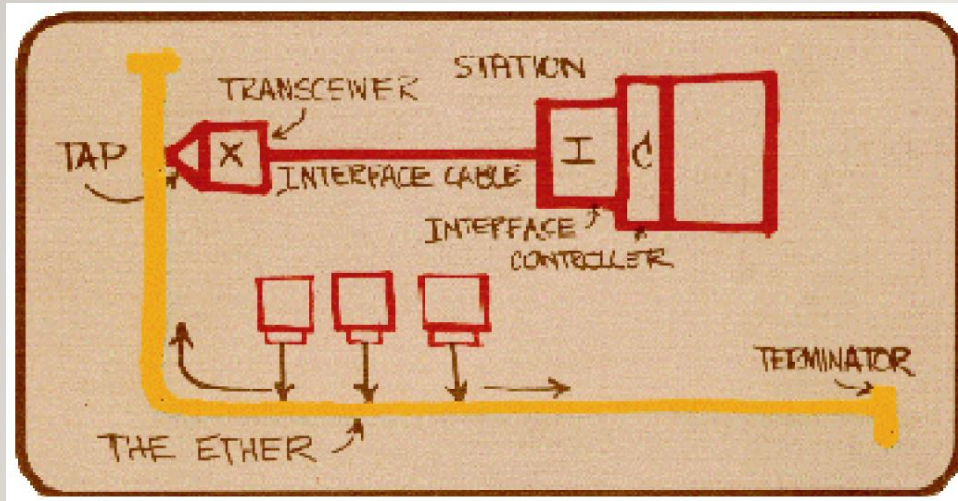- The frame must require more than this round-trip time for transmission.

B*S

Sender1

- B bits/second
- S seconds
- B*S bit time
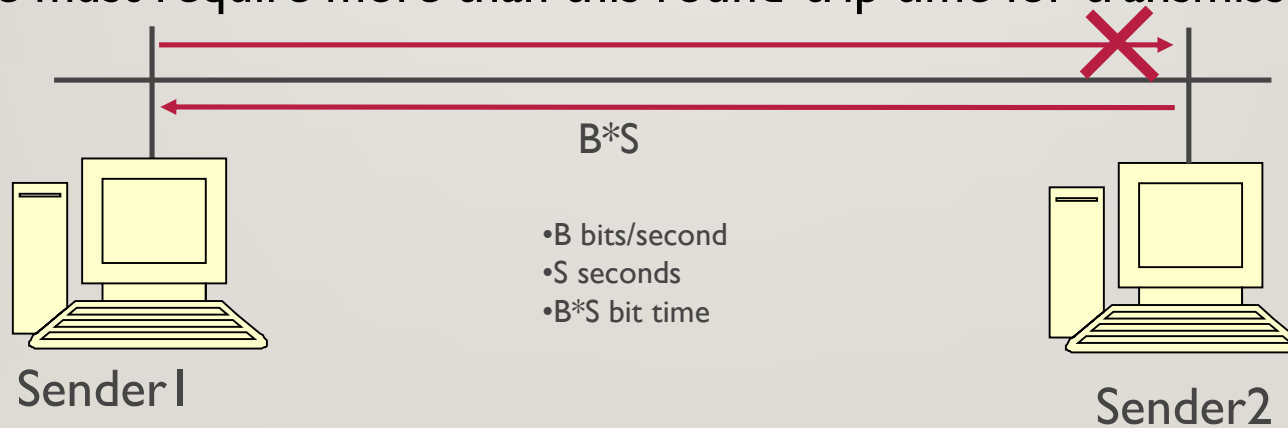
Sender2

Sender 1 must wait for its frame to (almost) make it to Sender2, when the collision occurs, and then for the energy from Sender2's frame to make it back, before detecting the collision.

Sender2 detects the Collision almost immediately

"ETHER" NET

http://www.ieee802.org/3/ethernet_diag.html

- Presented at 1976 National Computer Conference
- 3 Mbps
- Key improvement of satellite based Aloha Net
  - Backoff was exponential random, not just random
  - More load = more retries = more delay

- Circa 1973
- Robert Metcalf's Memo @ Xerox PARC

1ST IEEE 802.3 STANDARD

- 1985
- Half-duplex
  - One pair of wires, send or receive, but not both simultaneously
- CSMA/CD
  - Listen before sending to reduce likelihood of collision
  - Listen while sending to detect collision if messages cross
  - Forces minimum message size
- 10 Mb/s
- Medium Attachment Unit (MAU) for coaxial cable bus topology
  - Heavily insulated and shielded
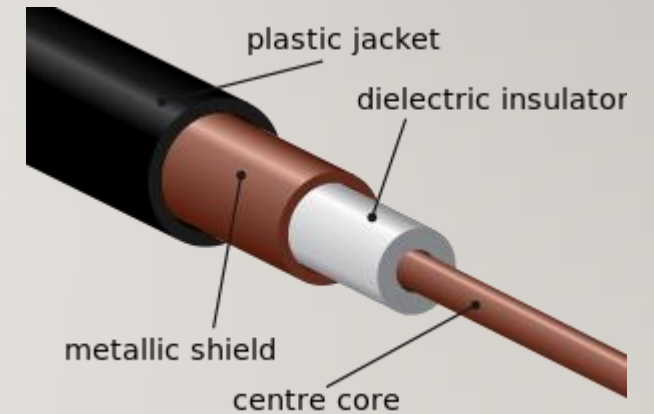
https://en.wikipedia.org/wiki/Coaxial_cable

EVOLUTION MILESTONES

- 1988: Twisted Pair (Among other cabling)
- 1995: 100Mbps
  - 10 years after 1st standard
- 1997: Full duplex
- 1998: Gigabit (1000Mbps)
- 2002: 10 Gps (10,000Mbps)
- 2010: 40Gps and 100Gps standards
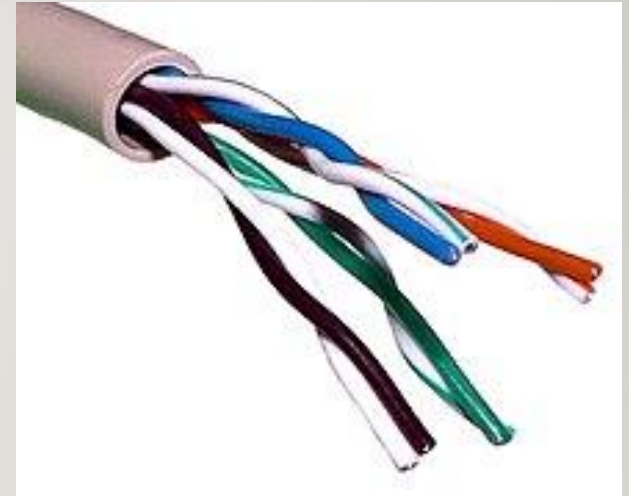
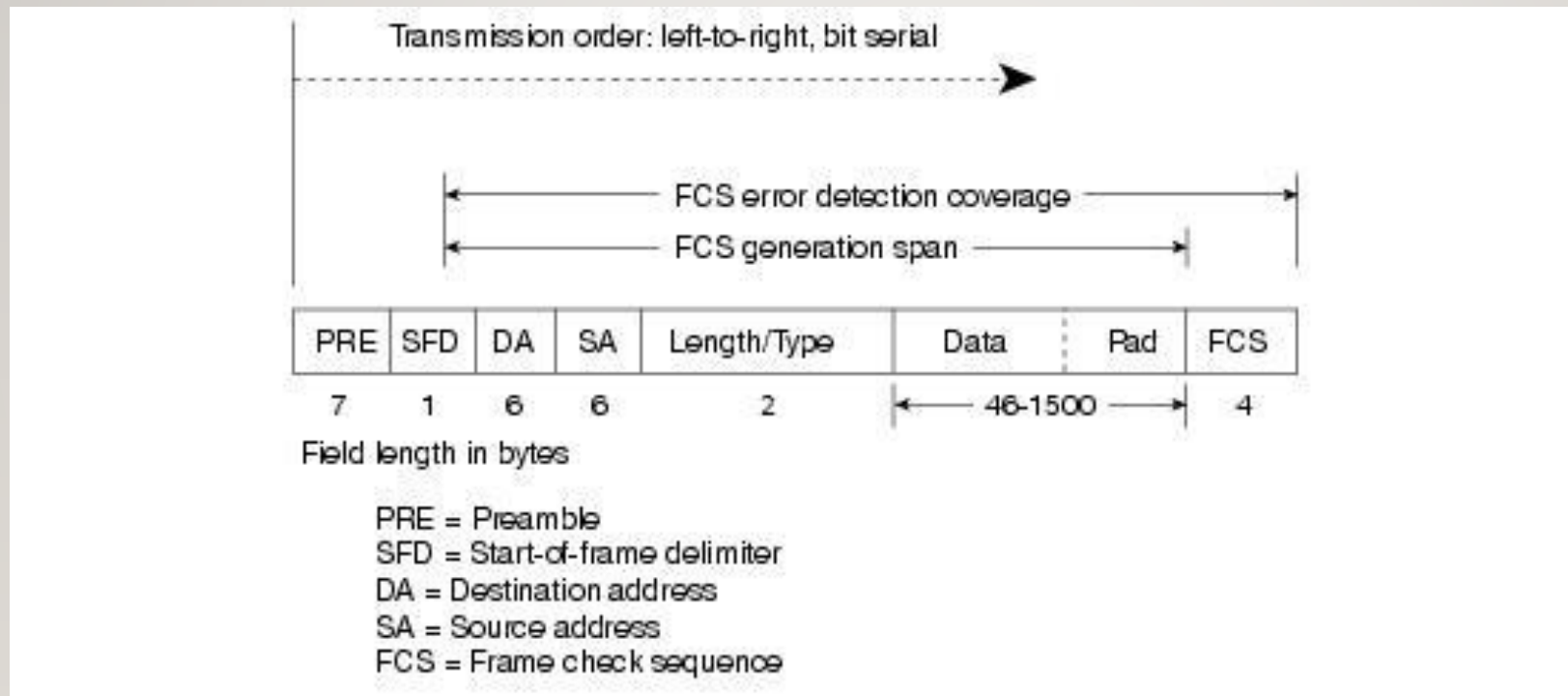https://en.wikipedia.org/wiki/Twisted_pair

PROTOCOL STACK
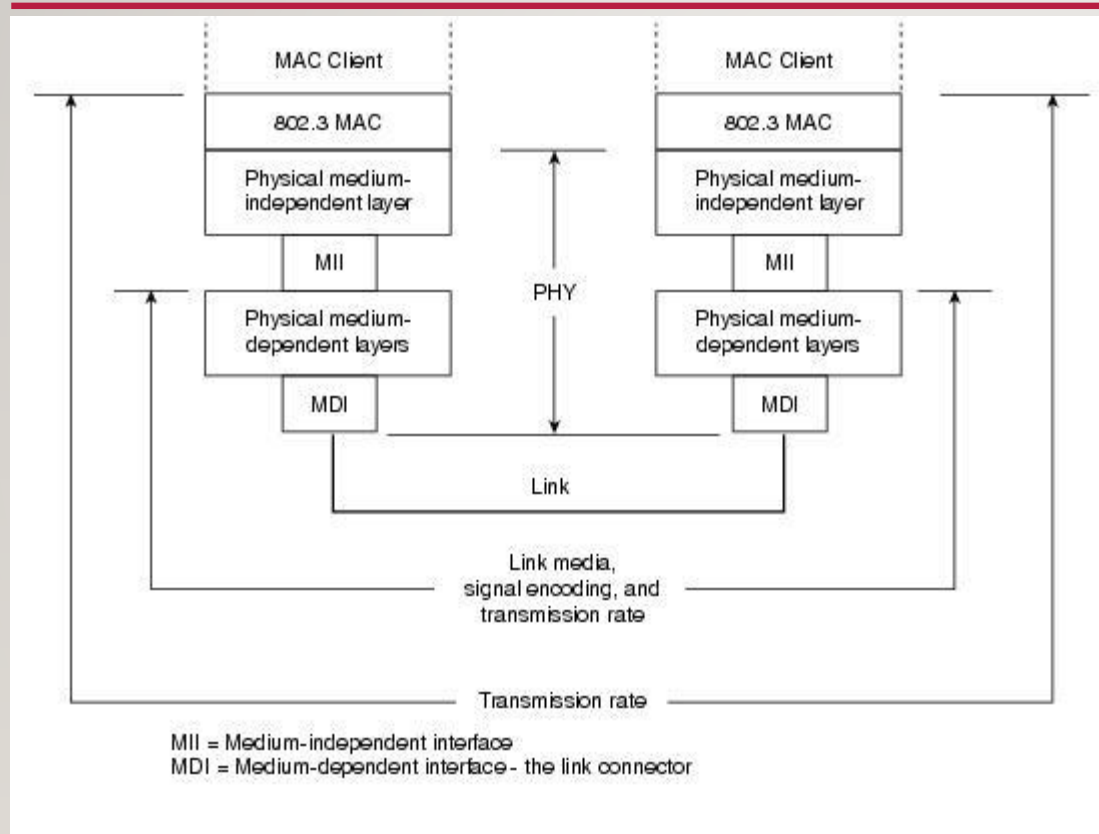
MAC Client = Higher level protocol
MII = Medium Independent Interface
MDI = Medium Dependent Interface

http://docwiki.cisco.com/wiki/Ethernet_Technologies

ETHERNET FRAME
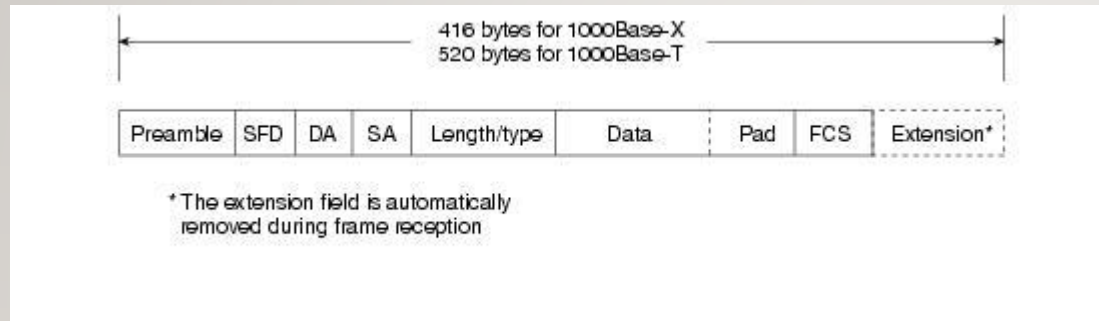

http://docwiki.cisco.com/wiki/Ethernet_Technologies

GIGABIT ETHERNET: FRAME SIZE CHALLENGE

- Detecting Collision requires a frame size = RTT bit distance

  - Without this a collision cannot be "heard" by the sender

- As data rate increases

  - Either minimum frame sizes increases

  - Or maximum segment length decreases

- Prior solutions cut network length

  - 20M wouldn't quite cut it for gigabit ethernet
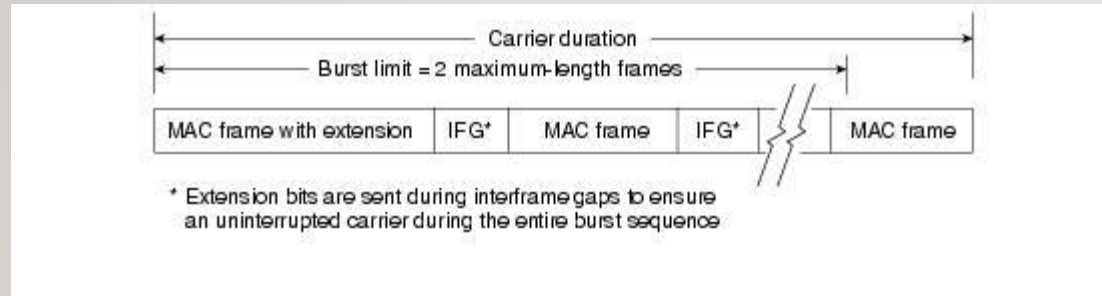
GIGABIT ETHERNET FRAME: SOLUTION, PART 1

416 bytes for 1000Base-X
520 bytes for 1000Base-T

| Preamble | SFD | DA | SA | Length/type | Data | Pad | FCS | Extension* |

* The extension field is automatically removed during frame reception

http://docwiki.cisco.com/wiki/Ethernet_Technologies

- Add "extension" bits to make small frames larger

GIGABIT ETHERNET FRAME: SOLUTION, PART 2

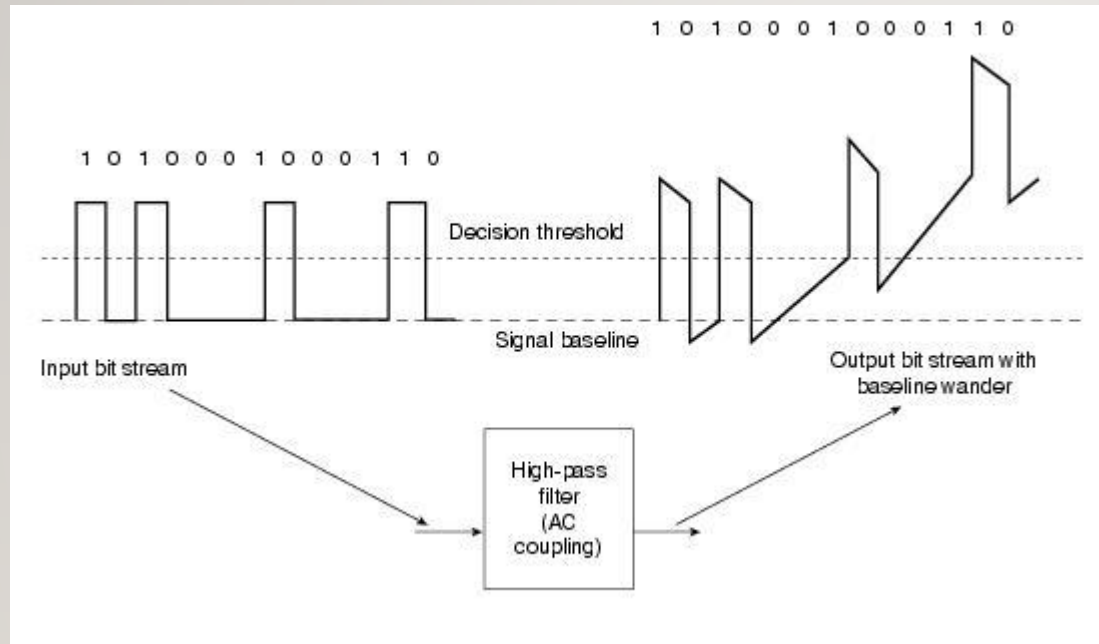http://docwiki.cisco.com/wiki/Ethernet_Technologies

- Allow a "burst" of frames

- An extension in only required after the first one, so it is compliant

- The IFG is filled with bits, so the carrier is never quiet.

ENCODING:

- Too many ones or zeros in a row are hard to "clock"
  - Sender and receiver might time long sequence of high or low voltage differently
- Made worst by AC Coupling, e.g. use of capacitance as high-pass noise filter
  - Capaciters have charge-discharge curves. They aren't flat. Rounding, esp. at edges.
- Transitions synchronize clocks
- Need a coding that guarantees transitions
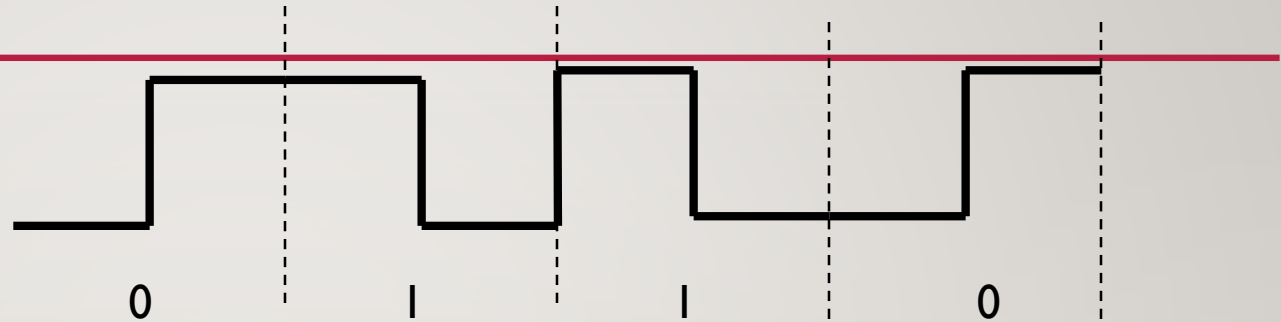
BASELINE WANDER FROM CAPACITANCE

http://docwiki.cisco.com/wiki/Ethernet_Technologies

- Example of impact of capacitance as high-pass filter.

OLD SOLUTION: MANCHESTER ENCODING

0 = rising transition
1 = falling transition

0   1   1   0

- 1 transitions per bit, but twice as much bandwidth
- High-low pattern has good electrical properties
- Balanced signal – no net DC voltage.
- This allows AC coupled power supply on receiver.
- If code had a DC bias, it would be lost in the transformer on the receiver side.
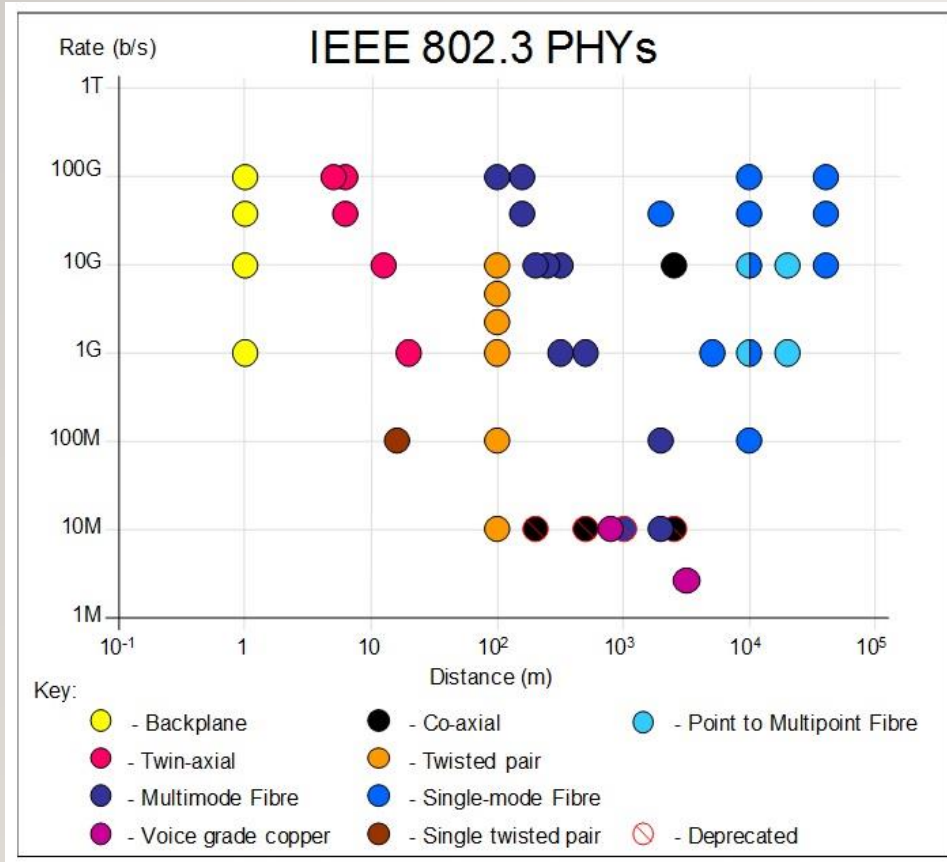
CHALLENGES TO MANCHESTER ENCODING

- Requires a clock rate of 2x data rate

- Just can't work for higher data rates

- The frequency space isn't high enough

- Modern ethernets, e.g. gigabit use specific bit encodings

  - Specific bit patterns are encoded in larger patterns to guarantee transitions

  - But, not 2x as long

MODERN ETHERNET ENCODINGS: FORWARD ERROR CORRECTION

- Block-based schemes
  - Encode redundancy in stream

- Gigabit ethernet
  - Trellis coding, a type of lattice-based convolution
  - Implicit FEC

- 10G ethernet
  - Reed Soloman Encoding
  - Used across many transmission and storage domains
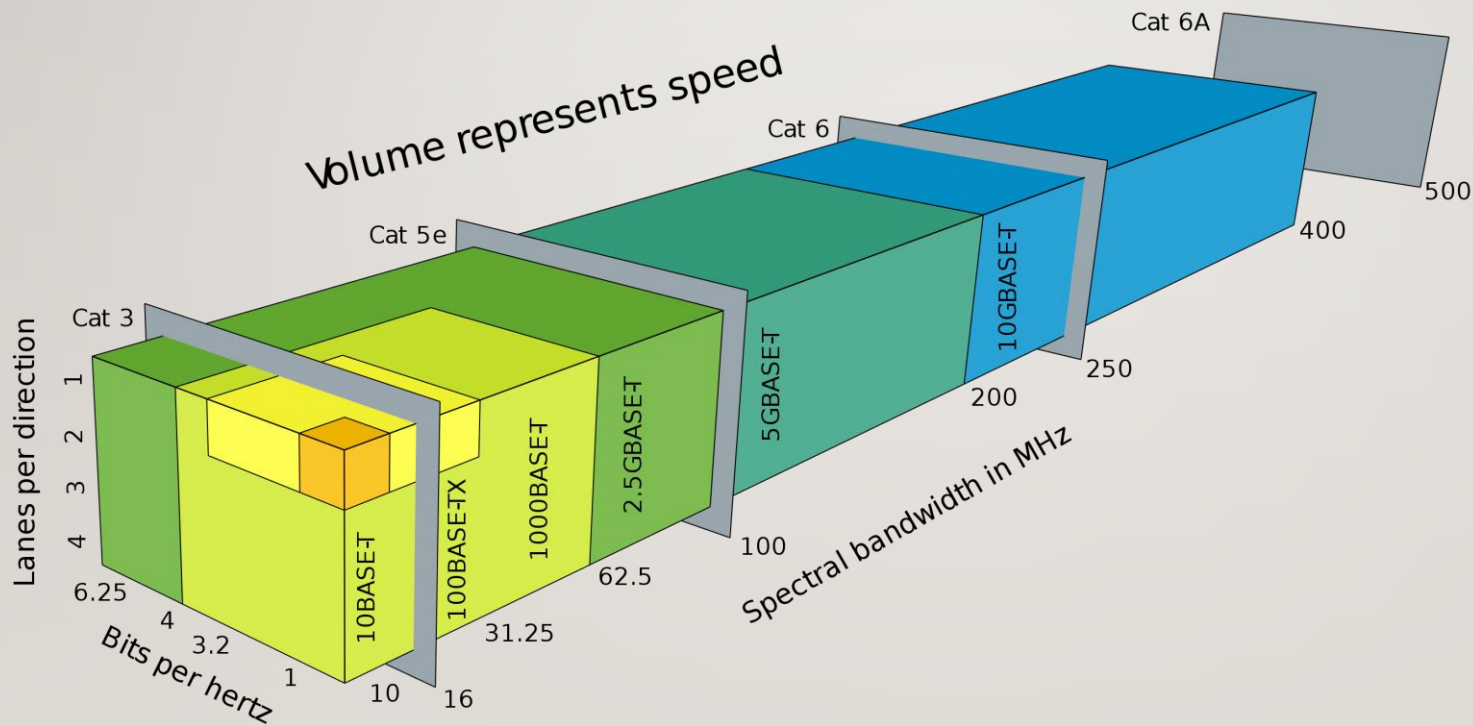 - Block based forward error corretion

802.3 PHY COMPARISON

https://www.standardsuniversity.org/e-magazine/august-2016-volume-6/evolution-ethernet-standards-ieee-802-3-working-group/

PHYSICAL LAYER:
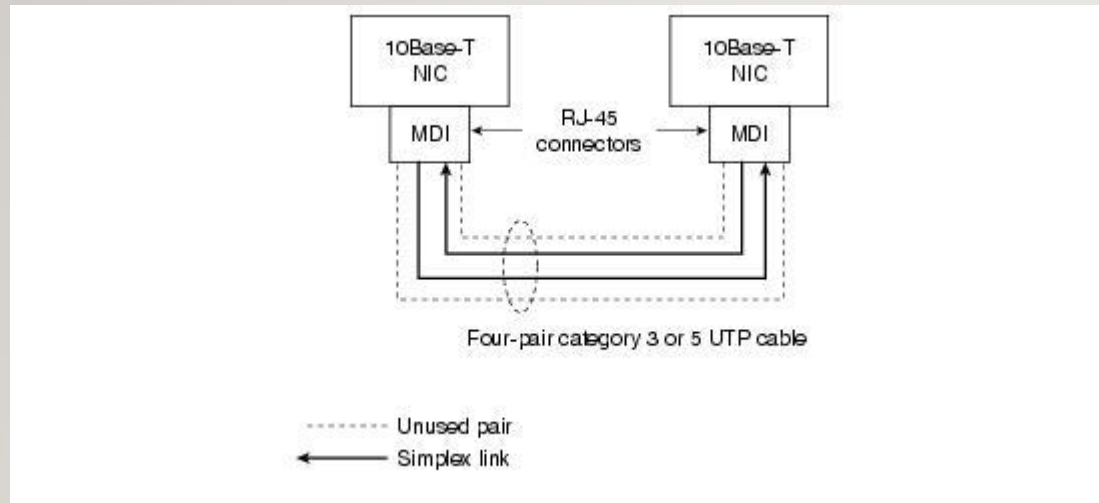# TWISTED PAIR COMPARISON

https://en.wikipedia.org/wiki/Ethernet_over_twisted_pair

10MBPS 10-BASE-T

http://docwiki.cisco.com/wiki/Ethernet_Technologies

- Cat-3 or Cat-5

- 4-pair cable

- 2 pairs unused

- RJ45 8-pin connector

GIGABIT ETHERNET (1000MBS)

http://docwiki.cisco.com/wiki/Ethernet_Technologies
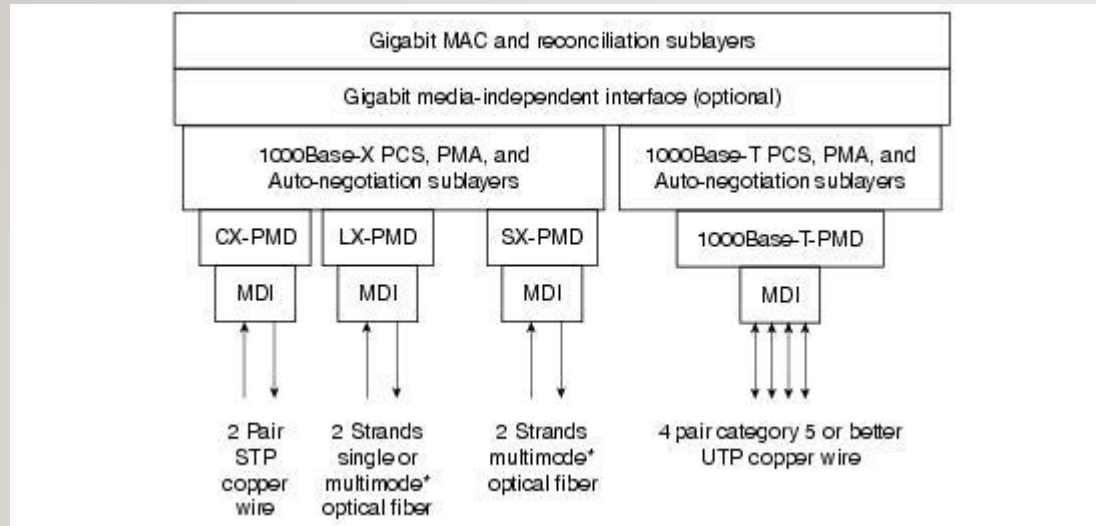
- Shielded Twisted Pair (STP)

- Unshielded Twisted Pair (UTP)

GIGABIT ETHERNET (1000MBS): 1000BASE-T
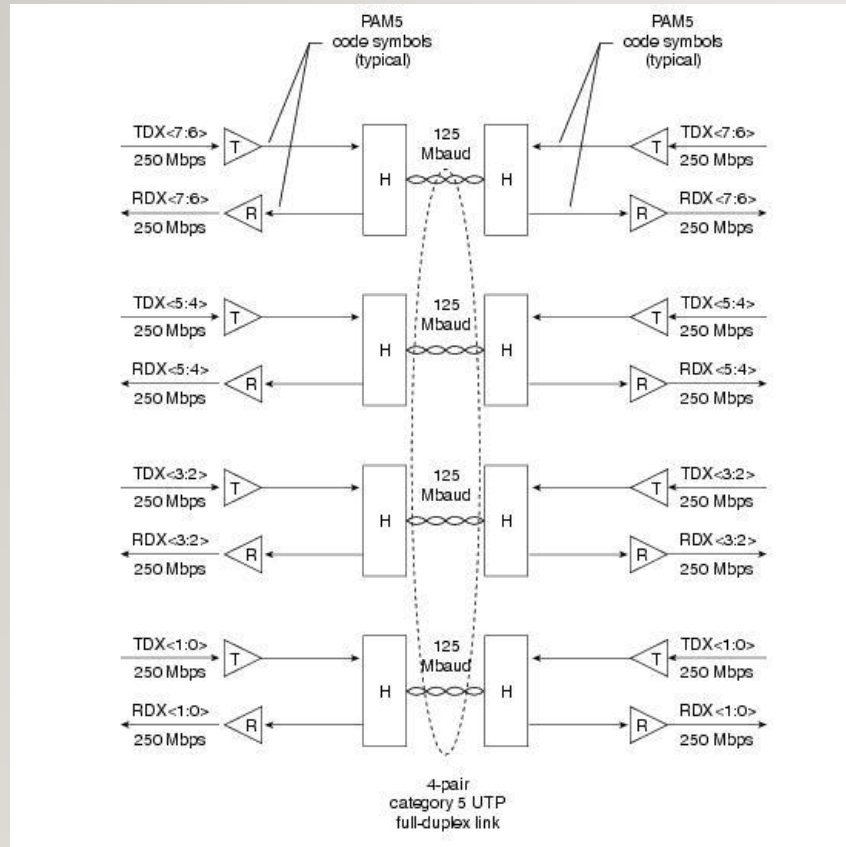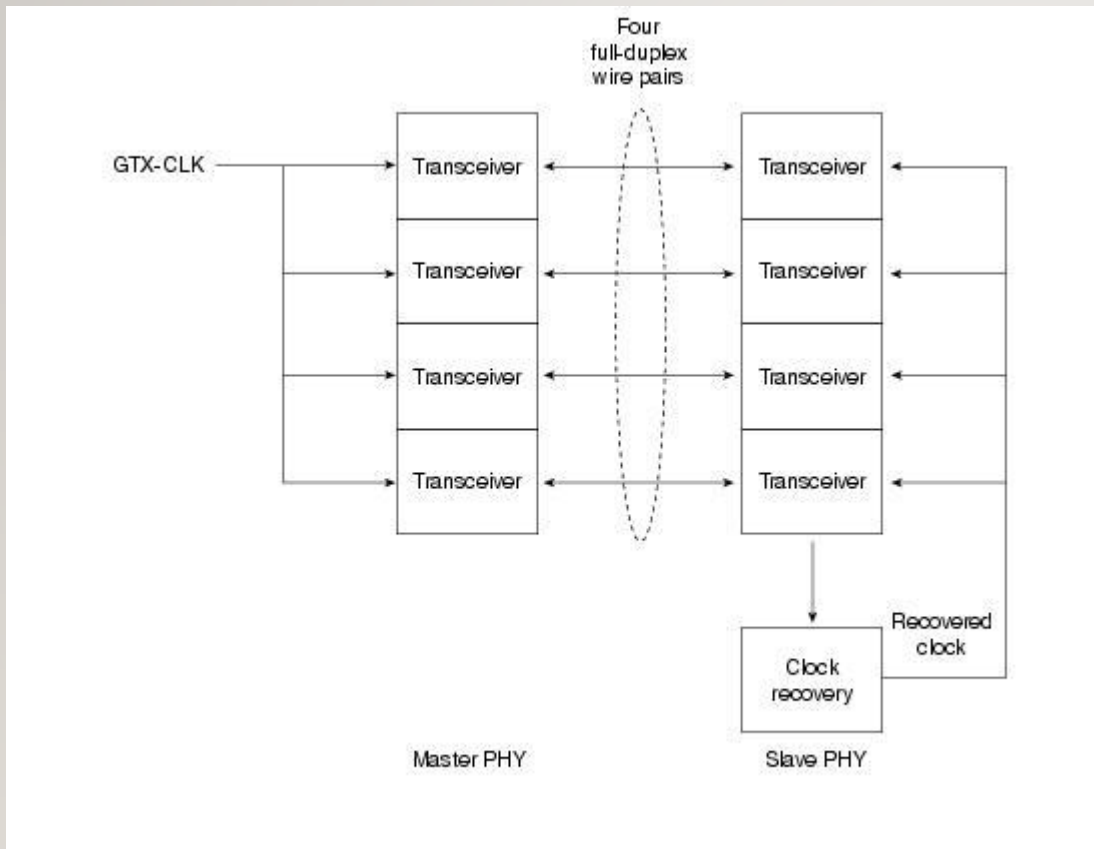

- PAM5 Encoding
  - Pulse Amplitude Modulation
  - 5-level

http://docwiki.cisco.com/wiki/Ethernet_Technologies

GIGABIT ETHERNET (1000MBS): 1000BASE-T

- Maintaining the clock:
  - Start of Frame Delimiters
  - End of frame delimiters
  - Idle codes during inter-frame gap