CS144
An Introduction to Computer Networks

Physical Links

Ethernet

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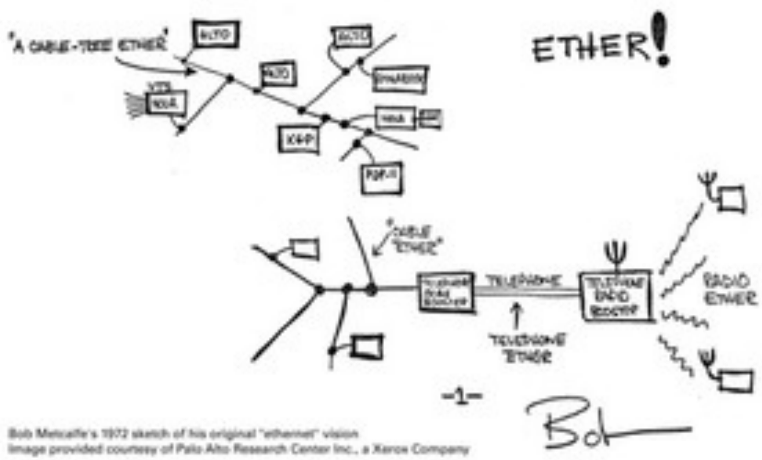
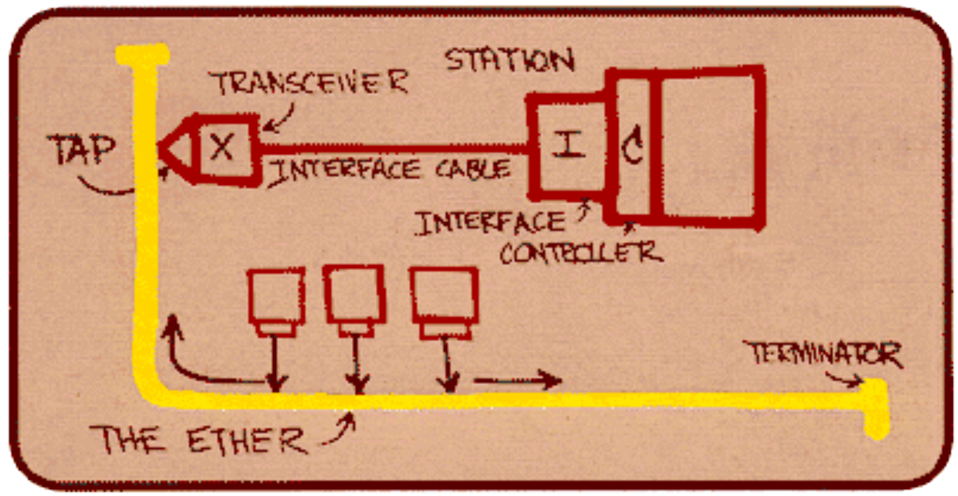
The Original Ethernet





Original pictures drawn by Bob Metcalfe,
co-inventor of Ethernet (1972 – Xerox PARC)

Ethernet Frame Format

Bytes:	7	1	6	6	2	0-1500	0-46	4
	Preamble	SFD	DA	SA	Type	Data	Pad	CRC

1. **Preamble**: trains clock-recovery circuits
2. **Start of Frame Delimiter**: indicates start of frame
3. **Destination Address**: 48-bit globally unique address assigned by manufacturer.
   - 1b: unicast/multicast
   - 1b: local/global address
4. **Type**: Indicates protocol of encapsulated data (e.g. IP = 0x0800)
5. **Pad**: Zeroes used to ensure minimum frame length
6. **Cyclic Redundancy Check**: check sequence to detect bit errors.

The 10Mb/s Ethernet Standard

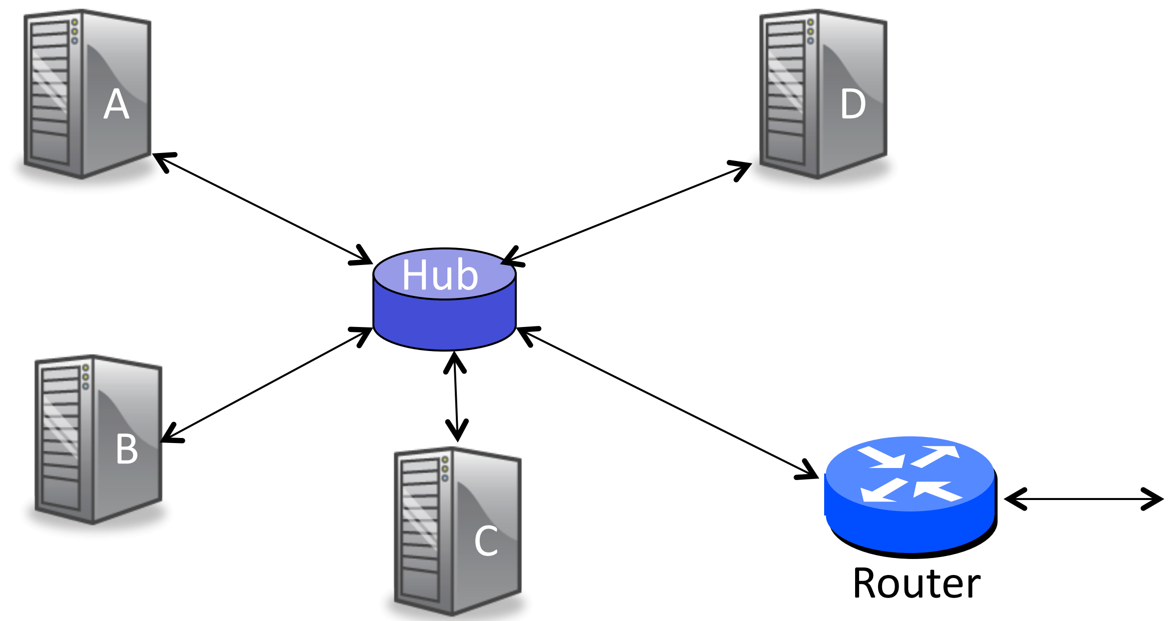
IEEE 802.3

Ethernet MAC Protocol			
10Base-5	10Base-2	10Base-T	10Base-F

10Base-5: Original Ethernet: large thick coaxial cable.
10Base-2: Thin coaxial cable version.
10Base-T: Voice-grade unshielded twisted-pair Category-3 telephone cable.
10Base-F: Two optical fibers in a single cable.

10Base-T

"Twisted pair Ethernet"



- Ran over existing voice-grade "Category-3" twisted pair telephone wire.
- "Star" wiring worked well with wiring closets.
- Centralized management made networks easier to manage.
- Led to a huge growth in Ethernet in mid 1980s.

Increasing the data rate

10Mb/s -> 100Mb/s -> 1Gb/s -> 10Gb/s

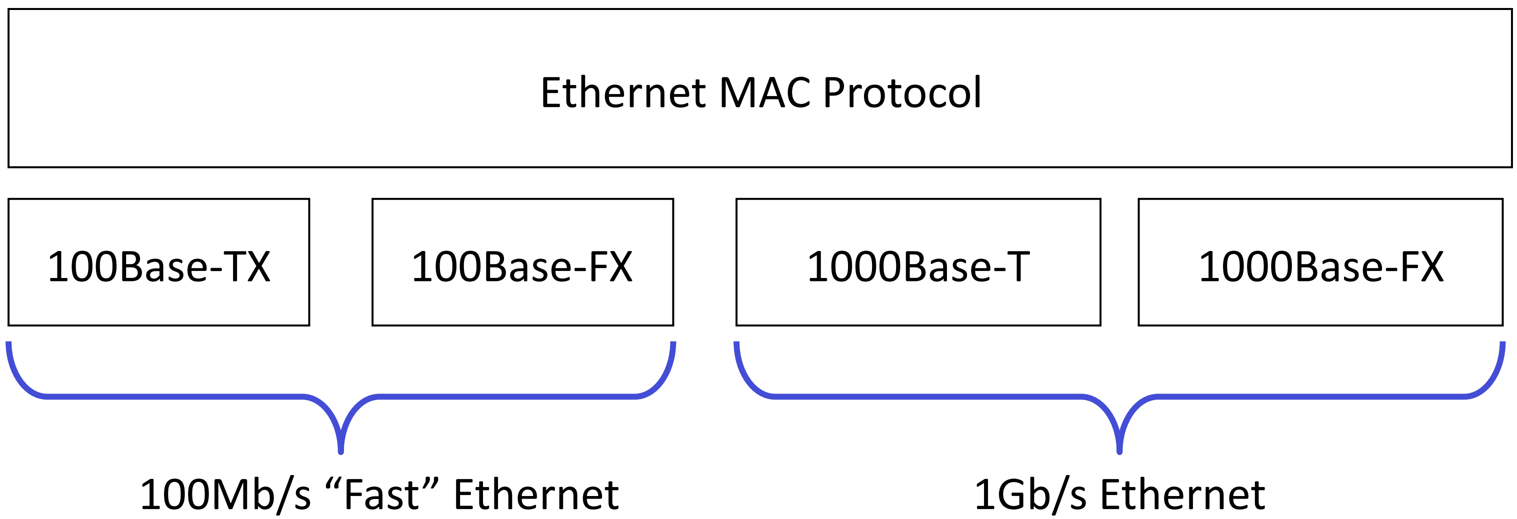
Problem: $P/R > 2L/c$

When R increases by 10x and 100x, should we make P larger, or L smaller?

Solution:

- Limit L to 100m for 100Mb/s and 1Gb/s.
- Ethernet switching

Faster and Faster



100Base-TX:
- “Category 5” cable, RJ45 connector.
- Full duplex: one pair for 100Mb/s in each direction.
- Physical layer: 4B5B encoding.
- 100m max distance

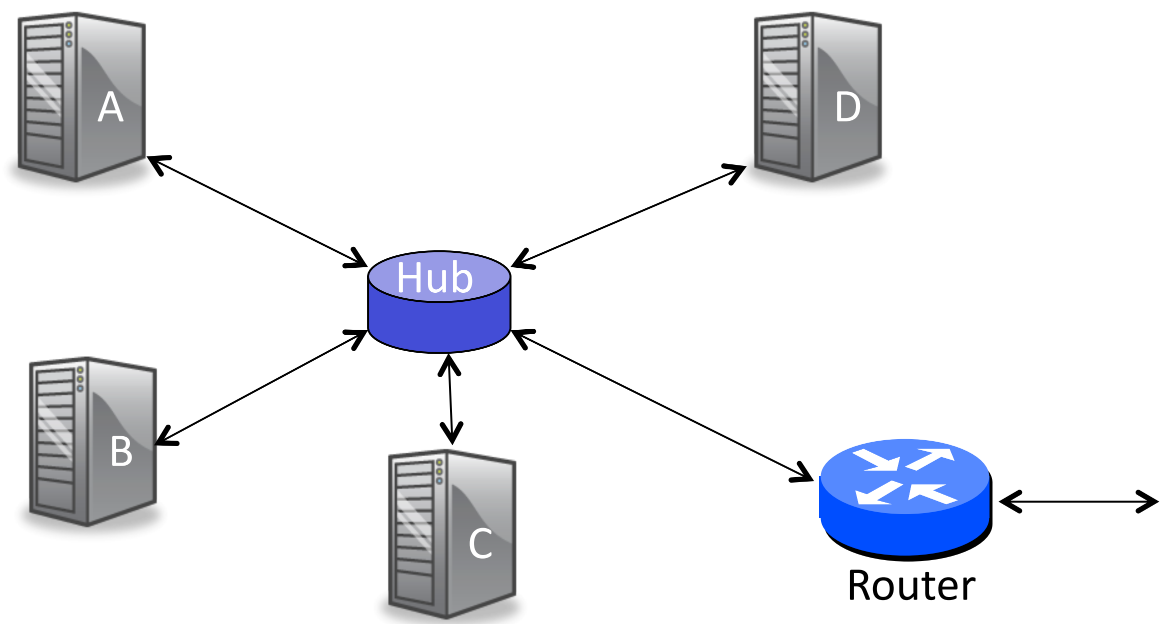
1000Base-T:
- “Category 5” cable, RJ45 connector.
- Four pairs used simultaneously in both directions.
- Complex coding; 5-level signaling.
- 100m max distance

Ethernet Switching

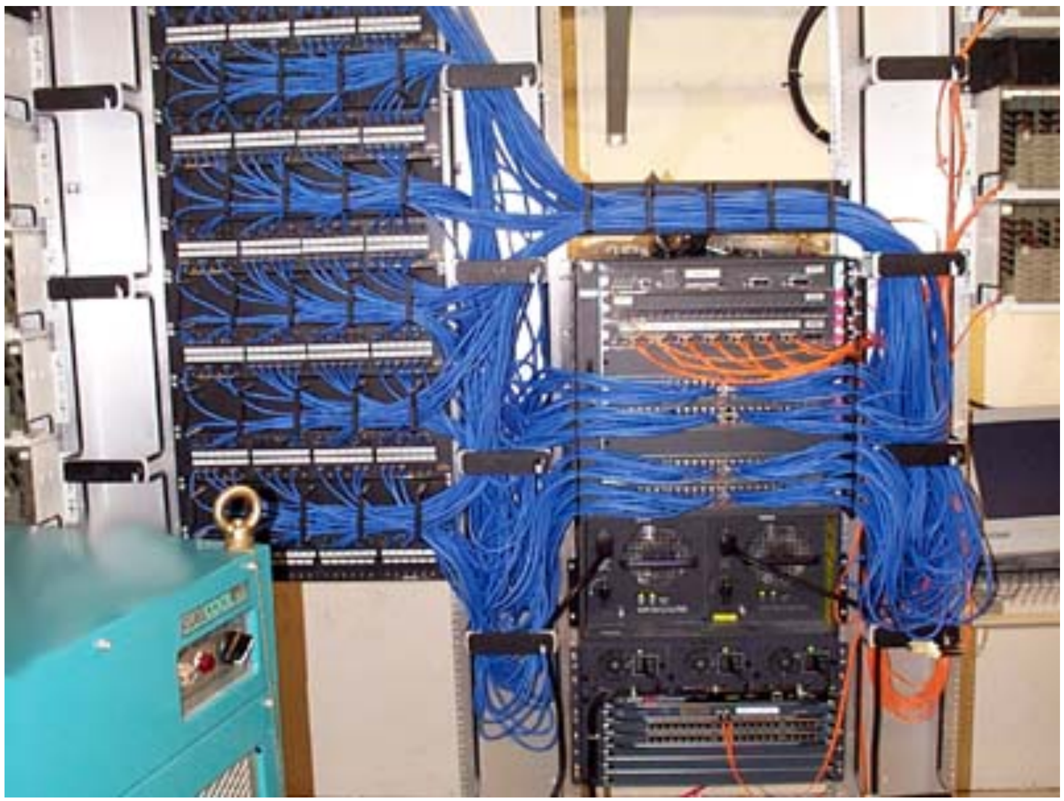
- 10BaseT meant hubs/repeaters in the wiring closet.
- 100Mb/s and 1Gb/s Ethernet meant 100m limit.
- The need to partition Ethernet networks to reduce the "collision domain".
- Cost of switching hardware came down.

Led to Ethernet Switching…

Hubs to Switches



Ethernet switch at Stanford



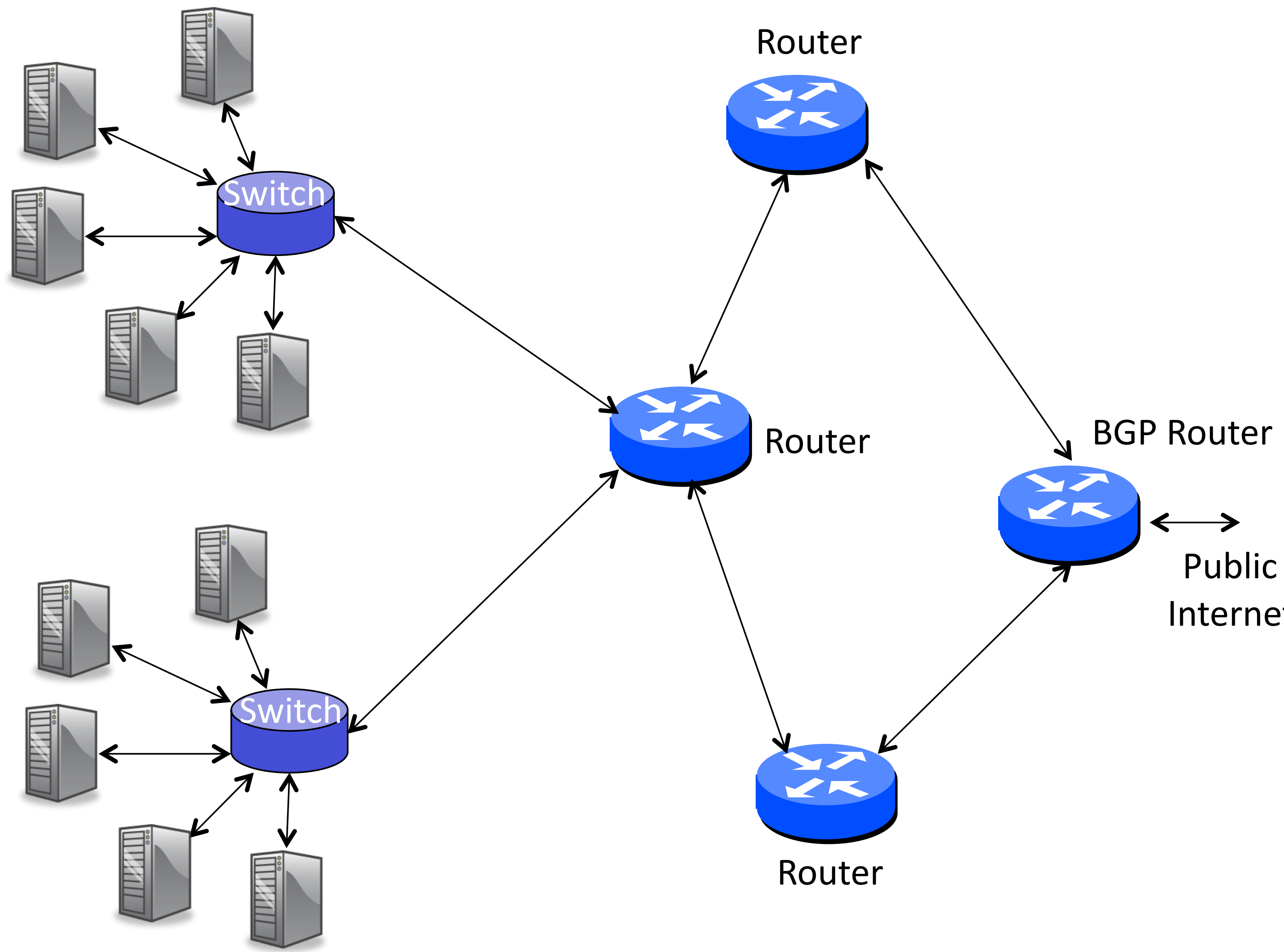
Ethernet Switch

Forwarding and Learning:

1. Examine the header of each arriving frame.
2. If the Ethernet DA is in the forwarding table, forward the frame to the correct output port(s).
3. If the Ethernet DA is not in the table, broadcast the frame to <u>all</u> ports (except the one through which the frame arrived).
4. Entries in the table are <u>learned</u> by examining the Ethernet SA of arriving packets.

Topology:

Run Spanning Tree Protocol (STP) to create loop free topology.


Switch
Switch
Router
Router
BGP Router
Public
Internet
Router

Summary

MAC Protocols: Random and Deterministic.

CSMA/CD is a simple, random access protocol used in the first 10Mb/s version of Ethernet.

Ethernet standards emerged for 100Mb/s, 1Gb/s and 10Gb/s over the last 20 years.

Limits on link size and the need for more capacity meant CSMA/CD was replaced by Ethernet switching.

<end>

Performance of CSMA/CD

We' re going to analyze the performance of a CSMA/ CD network.

Our performance metric will be Efficiency, η. This is defined to be the fraction of time spent sending useful/successful data. The more time spent causing and detecting collisions, the less efficient the protocol is. More precisely:

$$\eta = \frac{\text{Time taken to send data}}{\text{Time taken to send data + overhead}}$$

To make the analysis simple, we' ll assume that time is slotted and all packets are the same length. A time slot equals $2 \times PROP$. In any given time slot, a host will either decide to transmit or not with probability p. (This includes packets transmitted for the first time and retransmissions).

First, we will try and find the value of p that maximizes the throughput (in fact, it' s the goodput).

Then, using the optimal value of p, we' ll find the efficiency.

Performance of CSMA/CD

Maximizing goodput

Find the goodput, $\alpha(p)$:

Probability that exactly one node transmits in a given slot.

$$\alpha(p) \equiv \binom{N}{1} p(1-p)^{N-1}$$

$$\frac{d\alpha}{dp} = N(1-p)^{N-1} - pN(N-1)(1-p)^{N-2}$$

$$\therefore \alpha_{\max} \approx 36\% \approx 40\% \qquad when: \qquad p = 1/N$$

Performance of CSMA/CD

Finding the overhead

Define *A* to be the expected number of time slots wasted before a packet is transmitted successfully:

$$A = (\alpha \times 0) + (1-\alpha)(1+A)$$

$$\therefore when: \qquad \alpha = \alpha_{\max}, \qquad A = 1.5$$

[Alternatively, consider a coin with Pr(heads) = α = 0.4. The expected number of coin tosses until the first head is 1/0.4 = 2.5.
i.e. 1.5 unsuccessful attempts, followed by 1 successful one]

Performance of CSMA/CD

Finding the efficiency

$$\eta_{CSMA/CD} = \frac{TRANSP}{TRANSP + E[\text{\# of wasted slots per packet}]}$$

$$= \frac{TRANSP}{TRANSP + A(2 \times PROP)}$$

$$= \frac{TRANSP}{TRANSP + (3 \times PROP)}$$

Performance of CSMA/CD

$$\eta_{CSMA/CD} = \frac{1}{1+3a}, \quad \text{where: } a \equiv \frac{PROP}{TRANSP}$$

From simulation and more precise models:

$$\eta_{CSMA/CD} \approx \frac{1}{1+5a}$$