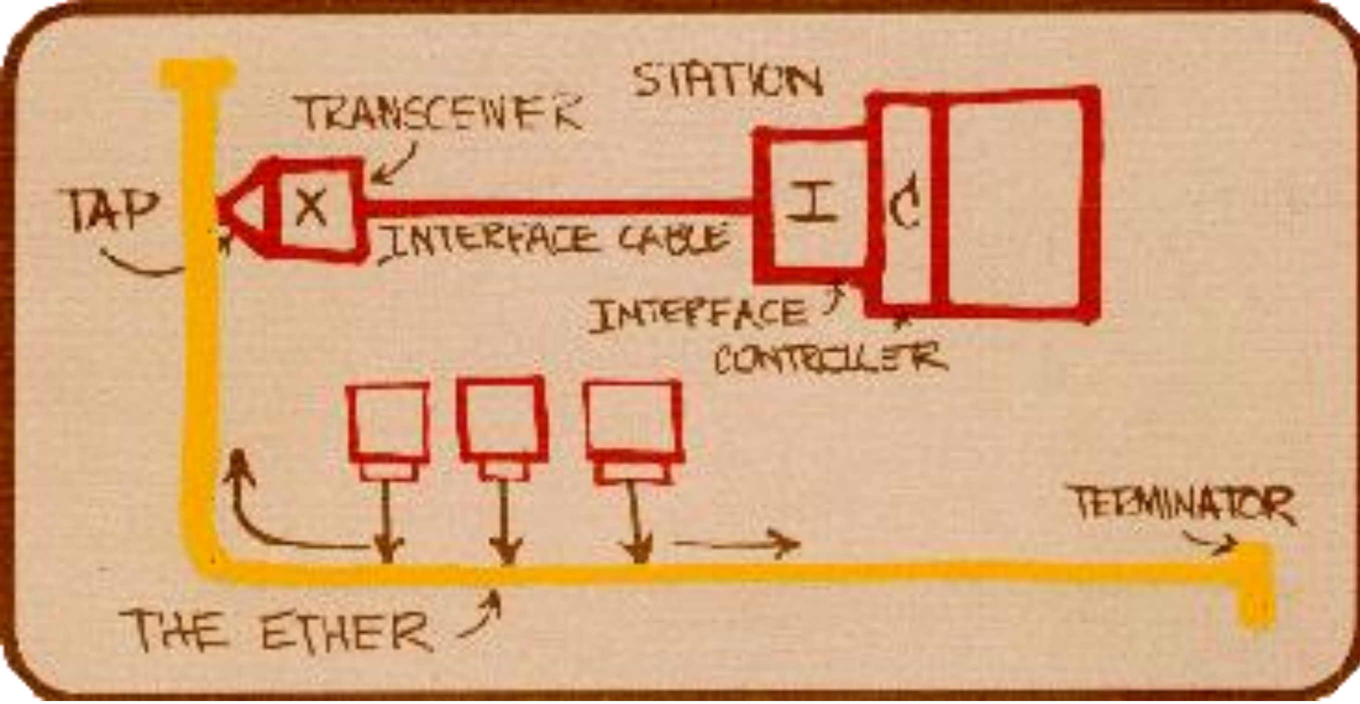
Telecommunications Networking

Local Area Networks – Layering Architecture

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical

LLC	IEEE 802.2 Logical Link Control						
MAC	IEEE 802.3 CSMA/CD	IEEE 802.4 Token bus	IEEE 802.5 Token Ring	IEEE 802.6 DQDB	IEEE 802.11 Wire-less	IEEE 802.15 PAN	ANSI X3.139 FDDI
	Ethernet				Wifi	Blue tooth	
	DEC, Intel Xerox	General Motors	IBM			Ericsson	



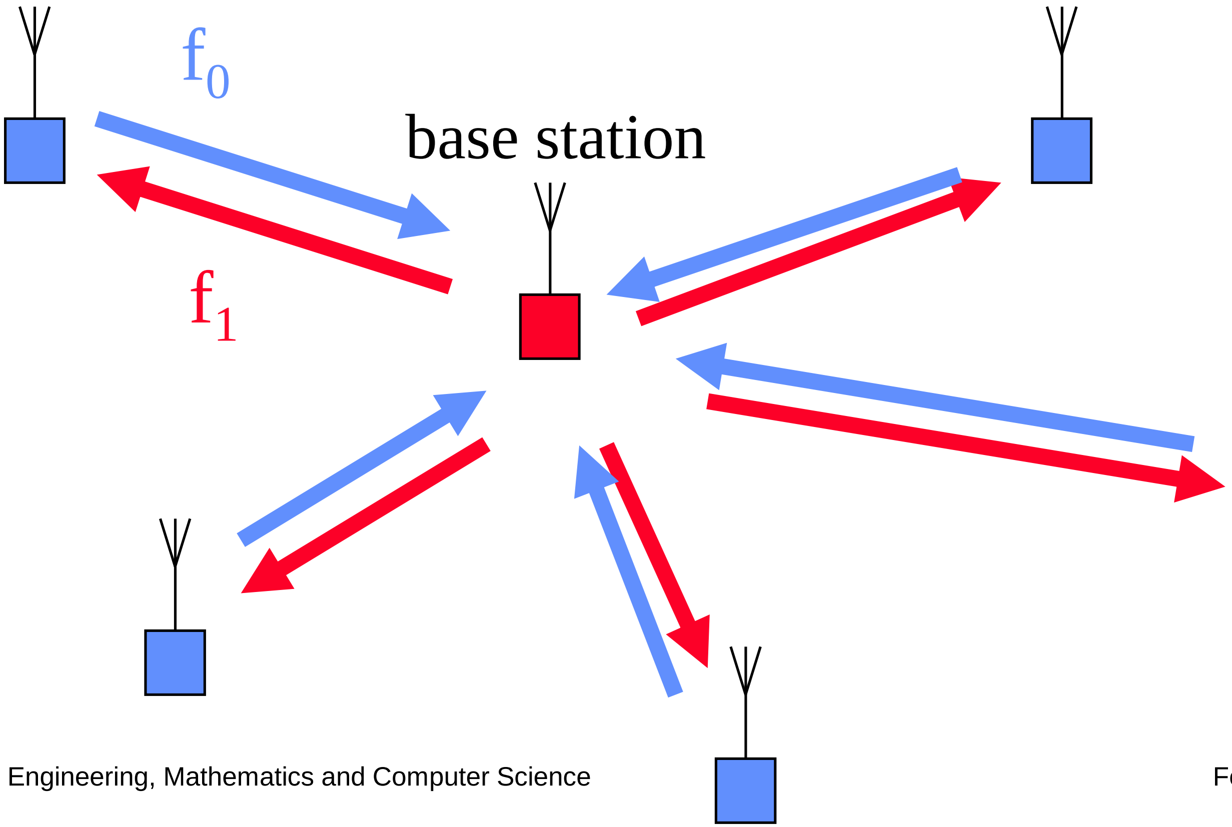
Ethernet

Original drawing by Robert Metcalfe (1976)

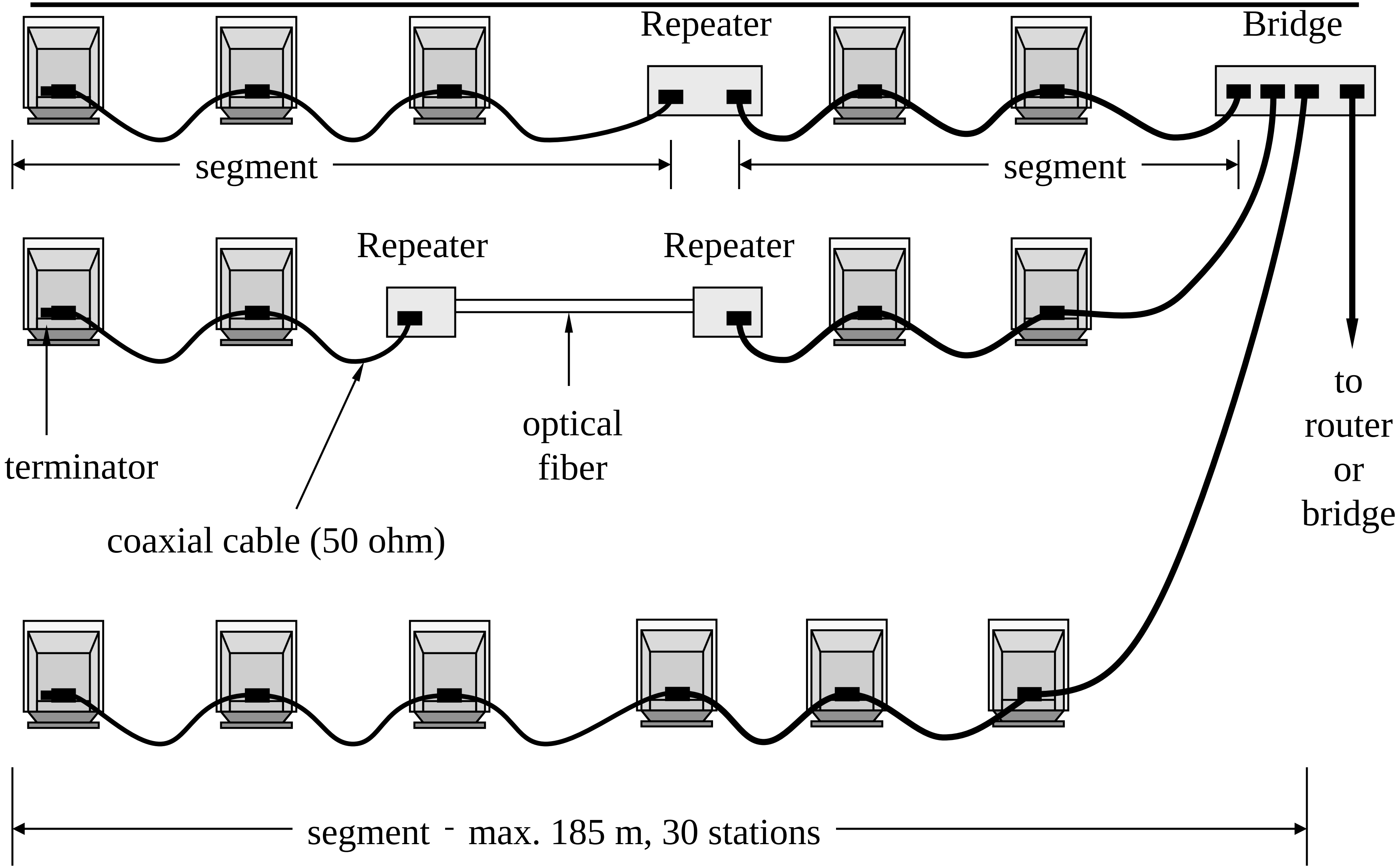
- *Bus (Ether)*: all stations share a single communication channel (distributed access control)
- *Broadcast*:
  - all transceivers receive every transmission
  - host interface filters among packets those intended for the corresponding computer
- *Best-effort delivery*: no notification about packet receipt

ALOHANET

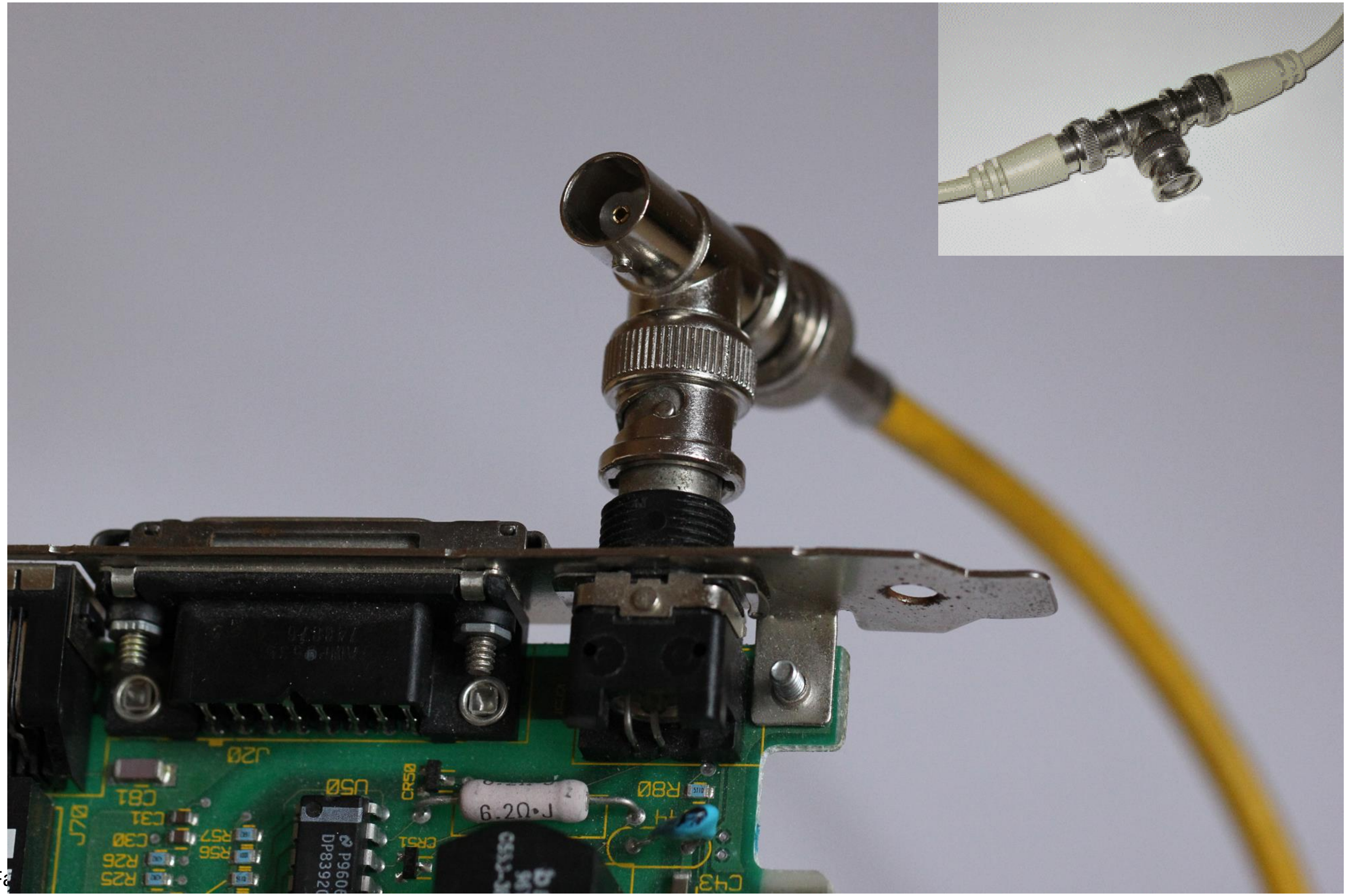
- First wireless packet data network, University of Hawaii, early ’70s
- Served as inspiration for Metcalfe when developing Ethernet
- ALOHA means *Hello* in the Hawaiian Language. The protocol in its original form allows for packets to enter the medium without any restriction.



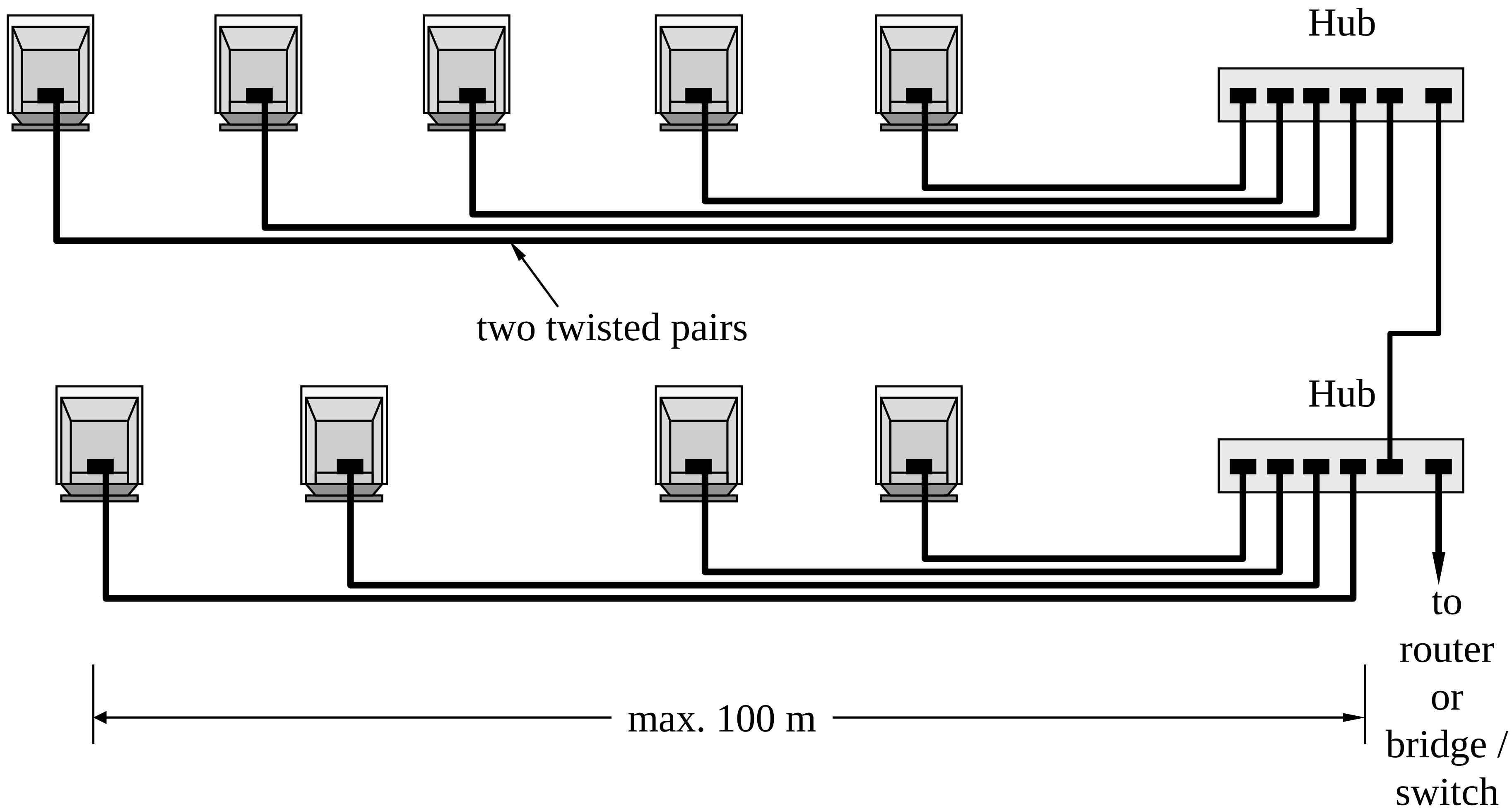
Ethernet: 10BASE2 network



Ethernet: 10BASE2 network



Ethernet: 10BASET network



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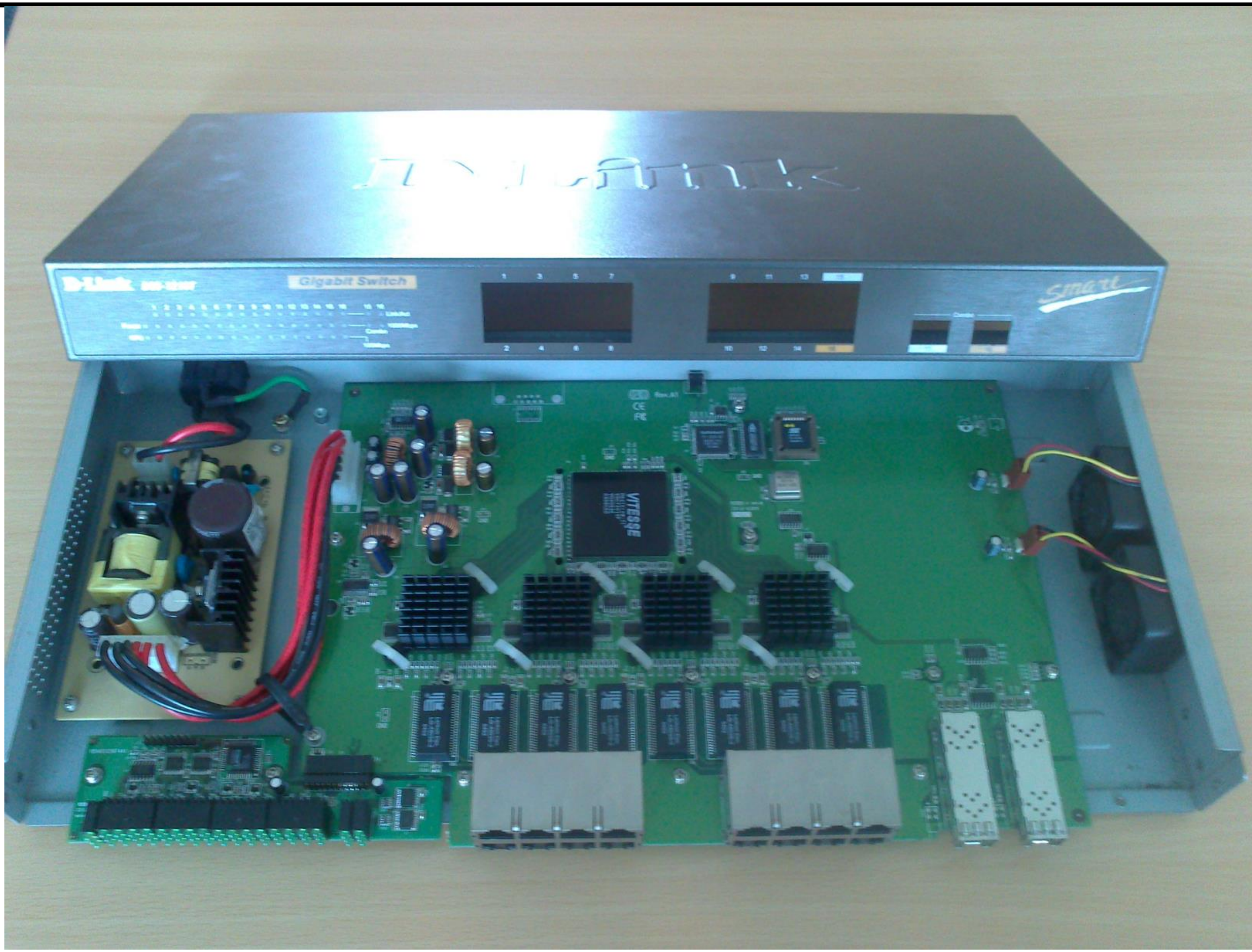
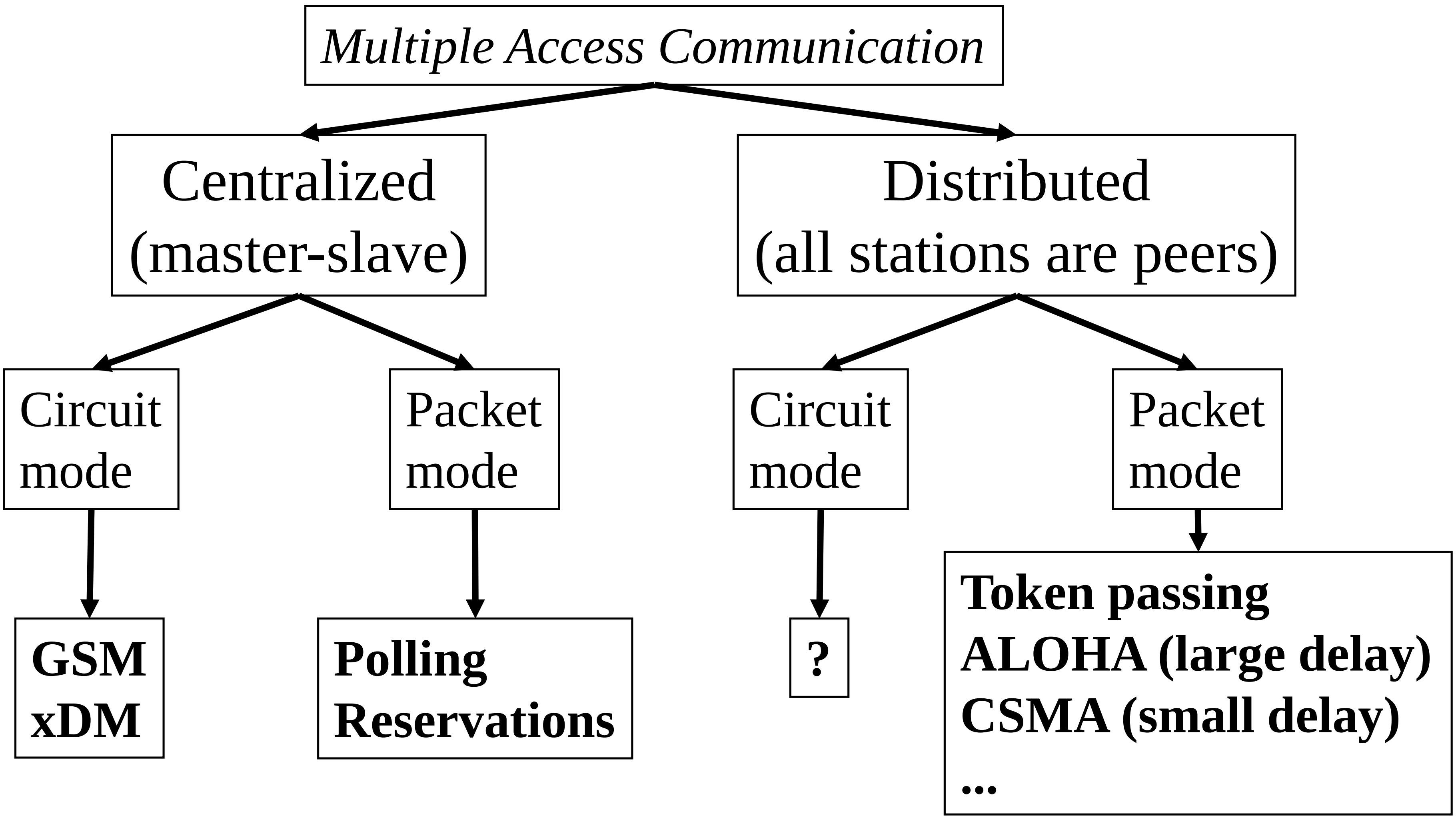
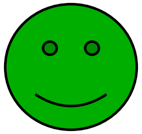
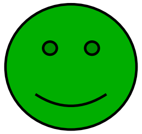
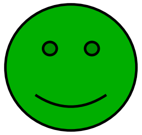
Ethernet Gigabit Switch



Multiple Access



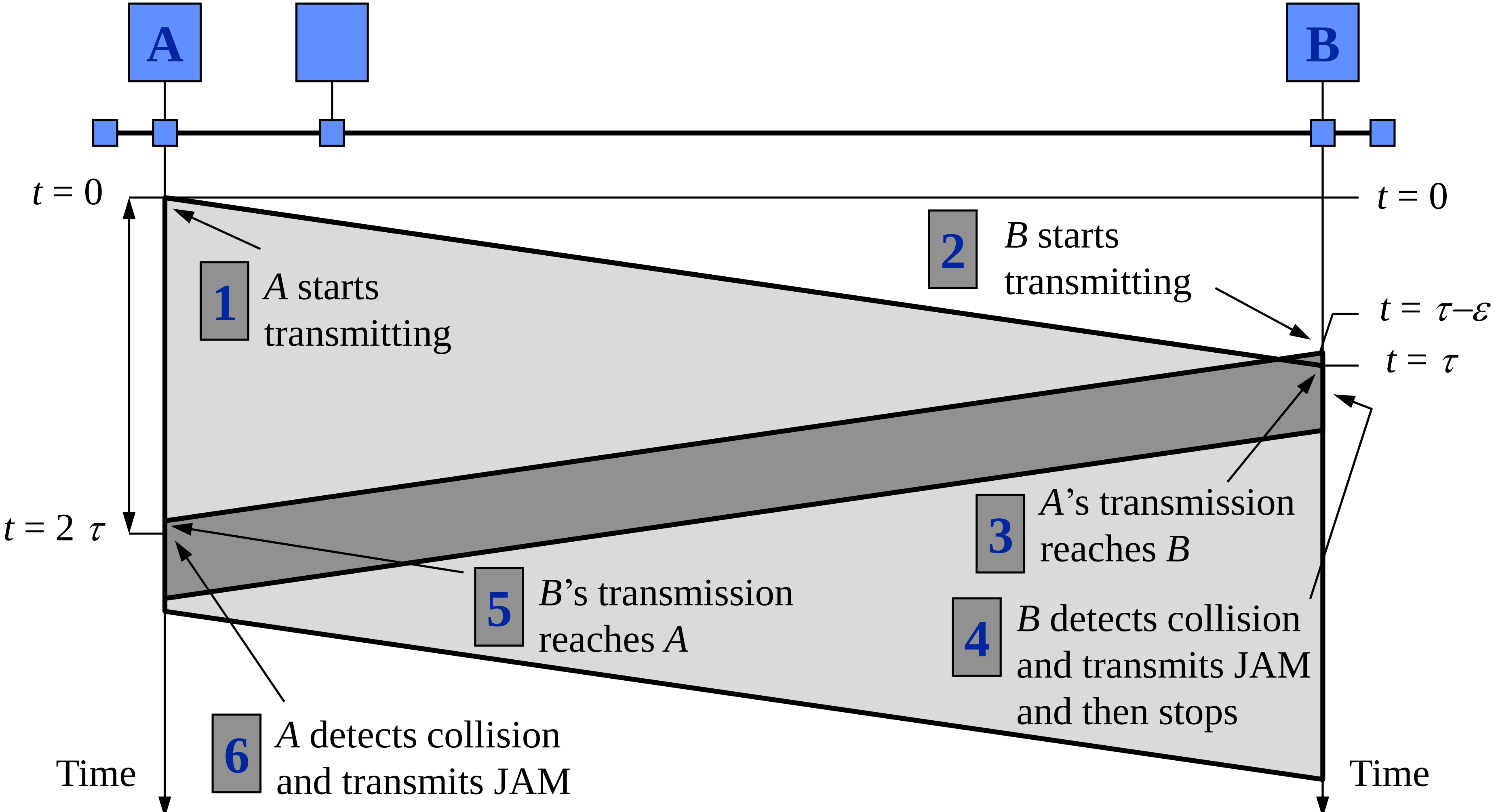
Control modes

	Centralized control	Distributed control
Complexity		
Robustness		
Scalability		

Ethernet Access: CSMA/CD

- Distributed access:
  - no central authority
- Carrier Sense Multiple Access (CSMA)
  - multiple machines can access the Ethernet simultaneously
  - each machine determines whether the "ether" is free by sensing carrier wave propagation
  - each transmission is limited in duration to prevent monopolization of the network
- Collision Detection (CD)
  - **Collision**: when two electrical waves cross, they become scrambled and meaningless.
  - **Collision detection**: each transceiver monitors the cable while transmitting to search for foreign signal interferences

CSMA/CD: Maximum collision detection time



Length of a timeslot = $2 \times \tau$

Sending Rules

- **Non-persistent CSMA:**
  - Sensing is not continuously but repeated after random time.
  - If no collisions are sensed, the station sends a packet.
- **Persistent CSMA**:
  - Continuously sensing, but sending of packet probabilistically
  - **p-Persistent CSMA**:
    - send in current time slot with probability *p* and in another time slot with probability *1-p*
  - **Binary exponential back-off policy**: a sender delays a random time after the first collision, twice that time after the second and four times as long after the third collision, and so on.
  - **1-Persistent CSMA**: relies solely on back-off

p-persistent CSMA/CD

Suppose: N stations, every station transmits with probability p in any given slot.
(They all want to send)

Difficult to estimate optimal p

Expected senders in a timeslot = Np

Expect collisions at $Np > 1$

Instinctively choose $p < 1 / N$

Though if $Np << 1$ waiting time increases

p-persistent CSMA/CD

Suppose: N stations, every station transmits with probability p in any given slot.

Pr[S(uccess)] = Pr [exactly one station transmits in a given slot]:

$$\Pr[S] = Np(1-p)^{N-1}$$

The maximum value of Pr[S]:

$$\frac{d\Pr[S]}{dp} = N(1-p)^{N-1} - N(N-1)p(1-p)^{N-2} = 0$$

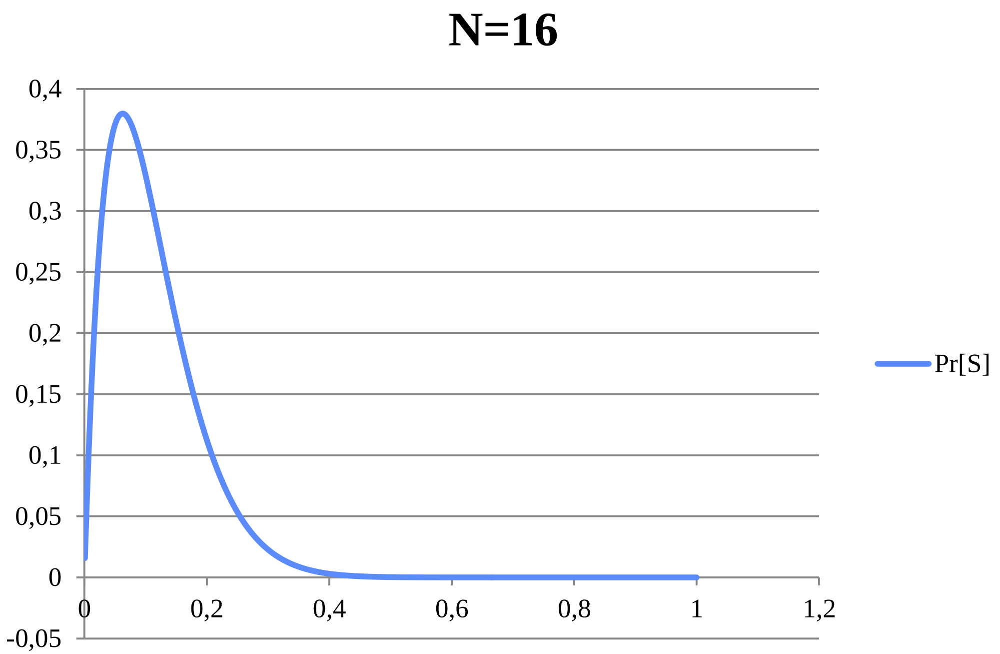
$$\Rightarrow \quad p = \frac{1}{N}, \qquad \max(\Pr[S]) = \left(1-\frac{1}{N}\right)^{N-1}$$

$$\lim_{N\to\infty}\left(1-\frac{1}{N}\right)^{N-1} = \frac{1}{e} \approx 0.368$$

p-persistent CSMA/CD

Thus, for N=16 optimum lies at p = 1/N = 0.0625

With Pr[S] ≈ 0.38



Binary exponential backoff

After each collision j a station chooses a random time uniformly in [0,2^j-1] timeslots:

IEEE 802.3:

- 1st: 0 or 1 equi-probable
- 2nd: 0 or 1 or 2 or 3
- 3rd: 0 or 1 or 2 or 3 or 4 or 5 or 6 or 7
- Increase exponentially until 10th
- Then constant until 16th
- Then failure

- Balances between prevention of collisions and waiting time

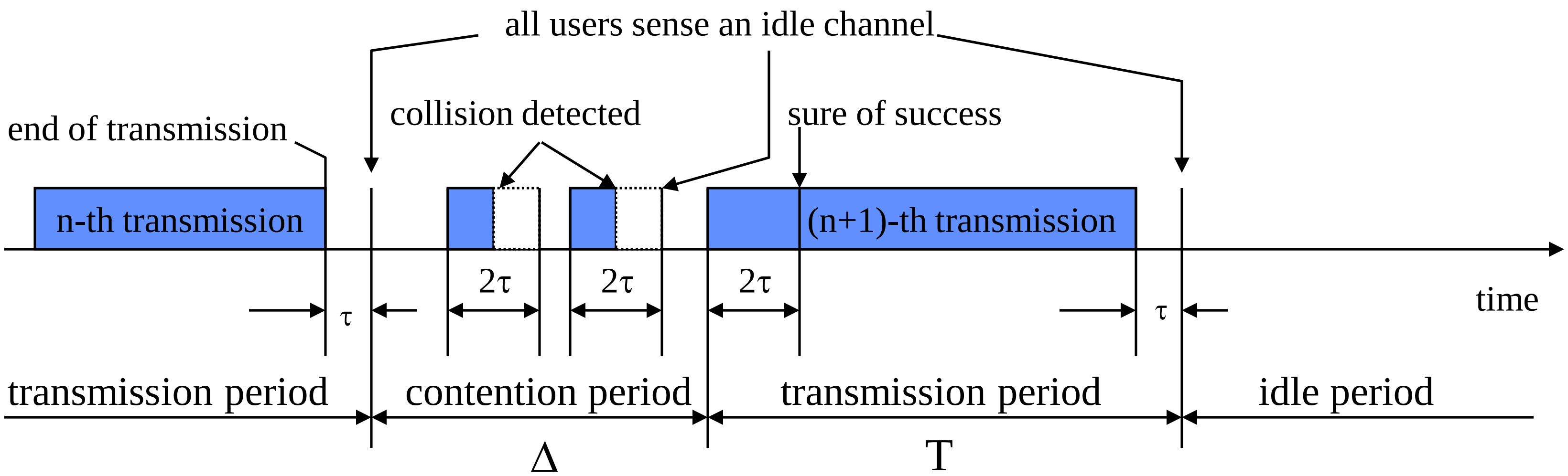
Ethernet MAC summarized

Ethernet MAC protocol:

"(1-)persistent CSMA/CD with binary exponential backoff "

1. Wait until channel idle
2. When idle: transmit (and keep listening)
3. When collision:
   - stop transmission
   - send jam signal
   - wait binary exponential random time
   - go to 1.

Approximate Analysis



The efficiency of CSMA/CD is defined as

$$\eta_{\text{CSMA/CD}} = \frac{E[T]}{E[T] + E[\Delta]}$$

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CSMA/CD - efficiency

Δ = the number of contention slots is a geometric r.v.: $\Pr[\Delta = k] = p_s(1-p_s)^k$

$$E[\Delta] = p_s \sum_{n=0}^{\infty} n(1-p_s)^n = \frac{1}{p_s} - 1 \qquad E[\Delta] \approx 1.5 \text{ (with } p_s = 0.4)$$

The unit of one timeslot is 2τ

$$\eta_{\text{CSMA/CD}} = \frac{E[T]}{E[T] + E[\Delta]} = \frac{1}{1 + \frac{E[\Delta]}{E[T]}} = \frac{1}{1 + \frac{2\tau}{E[T]}\left(\frac{1}{p_s} - 1\right)}$$

$$\boxed{\Rightarrow \eta_{CSMA/CD} = \frac{1}{1 + 3.5a}, \text{ with } a = \frac{\tau}{E[T]}}$$

From simulations:

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

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CSMA/CD - efficiency

$$\eta_{\text{CSMA/CD}} = \frac{1}{1 + \frac{2\tau}{E[T]}\left(\frac{1}{p_s} - 1\right)}$$

Practice:

$$E[T] = \frac{E[L]}{B} \qquad \tau = \frac{D}{0.8c} \qquad \nu = 2\left(\frac{1}{p_s} - 1\right)$$

$$\eta_{CSMA/CD} = \frac{1}{1 + f(\nu)\frac{BD}{E[L]}}, \text{ with } \quad f(\nu) = \frac{\nu}{0.8c}$$

L: length of frame (bits)
B: capacity (bits/s)
D: extent of LAN (m)
c: velocity of light (vacuum)

Ethernet address

- 48-bit IEEE 802 MAC address:
  - 24-bit company/manufacturer ID
  - 24-bit extension/board ID

- Multicast address: first bit set to 1
- Broadcast address: all bits set to 1

- IEEE Extended Unique Identifier 64 (EUI-64) address:
  - 24-bit company ID / 40-bit extension ID

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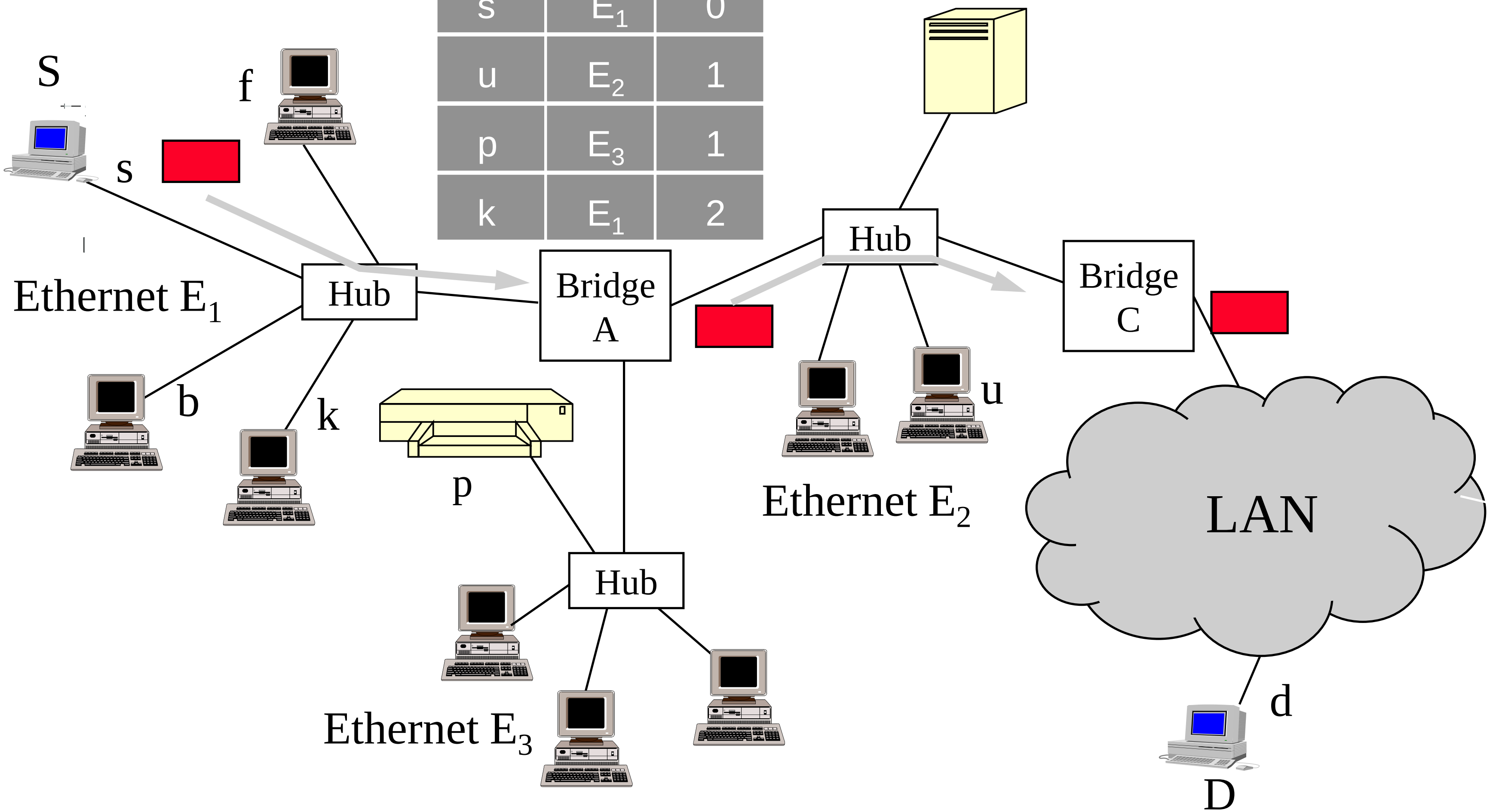
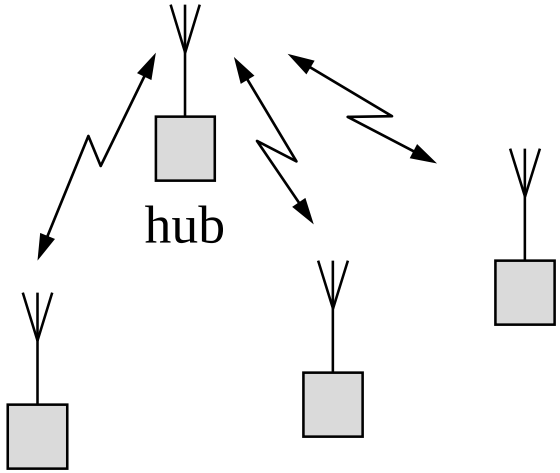
Example of an Ethernet:

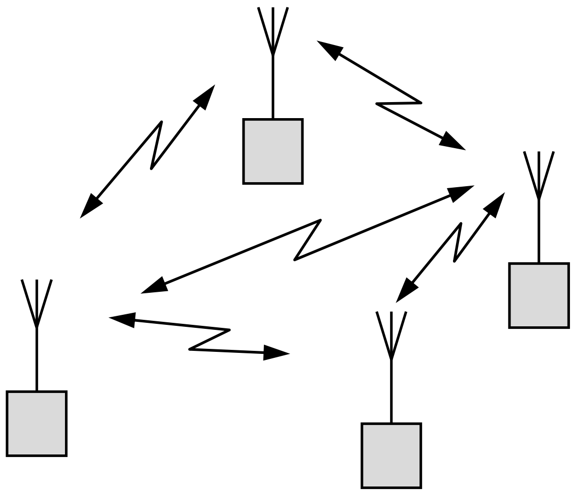
MAC	E-net	Time
s	E_1	0
u	E_2	1
p	E_3	1
k	E_1	2



Wireless LANs



Master-slave



Ad-hoc network

Wireless MAC

CSMA/CD:

- carrier sensing is done by the sender

Wireless MAC IEEE 802.11: CSMA/CA (Collision Avoidance with reservation)

Sender S:

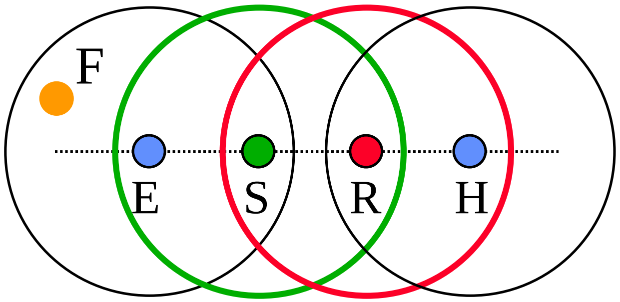
- send RTS-message (RequestToSend)
- contains length of message

Receiver R:

- replies CTS-message (ClearToSend)
- echoes length of message

- Other stations in range of *S* wait to not disturb CTS from *R*
- Other stations in range of *R* wait for a time corresponding to the length of message in CTS

Hidden & Exposed Terminal



Hidden terminal (H): potential sending node in receiver *R's* neighborhood which cannot detect the sender *S* and may disrupt the current transmission

Exposed terminal (E): Node *E* in neighborhood of sender *S* and does not hear receiver *R*.
Node *E* unnecessarily refrains from sending to a station *F* (another station than *S)* within its transmission range.

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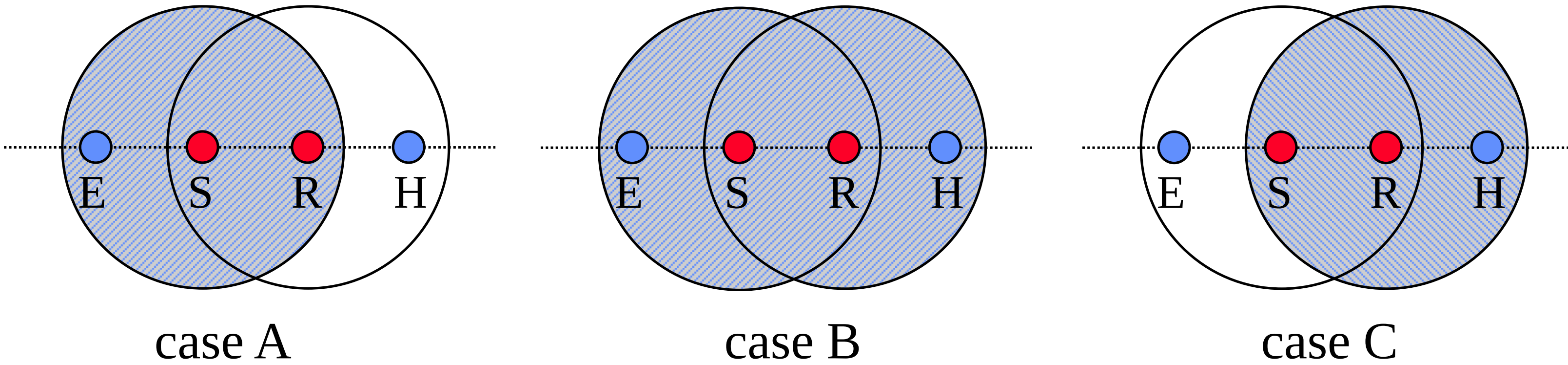
Three variations

General Solution:

Hidden terminal: hears CTS and is mute during transmission

Exposed terminal: hears RTS but no CTS, can transmit



Case A: nor hidden-, nor exposed-terminal problem is solved

Case B: only hidden-terminal problem is solved

Case C: both hidden- and exposed-terminal problem are solved

Questions Ch. 2

- Explain why, in a shared medium, we need multiple access control (MAC).
- Explain non-persistent CSMA, p-persistent CSMA, and the exponential back-off policy.
- Explain the hidden-terminal and exposed-terminal problems and their solutions.