Hi-Speed LANs

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These slides are available on-line at:
http://www.cse.wustl.edu/~jain/cse473-05/
Overview

LAN Topologies
Media Access Control (MAC), CSMA/CD
Ethernet Standards
CSMA/CD Performance
Ethernet vs Fast Ethernet
Full-Duplex Ethernet
IEEE 802 Address Format
LAN Topologies

(a) Bus

(b) Tree

(c) Ring

(d) Star

Tap  Flow of data  Terminating resistance

Station  Repeater

Headend

Central Hub, Switch, or Repeater
## Media Access Control (MAC)

<table>
<thead>
<tr>
<th>Bus Topology</th>
<th>Ring Topology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Token Passing</strong></td>
<td>IEEE 802.4 Token bus</td>
</tr>
<tr>
<td><strong>Slotted Access</strong></td>
<td>IEEE 802.6 DQDB</td>
</tr>
<tr>
<td><strong>Contention</strong></td>
<td>IEEE 802.3 CSMACD</td>
</tr>
</tbody>
</table>
CSMA/CD

Aloha at Univ of Hawaii:
Transmit whenever you like
Worst case utilization = \(1/(2e) = 18\%\)

Slotted Aloha: Fixed size transmission slots
Worst case utilization = \(1/e = 37\%\)

CSMA: Carrier Sense Multiple Access
Listen before you transmit

p-Persistent CSMA: If idle, transmit with probability \(p\).
Delay by one time unit with probability \(1-p\)

CSMA/CD: CSMA with Collision Detection
Listen while transmitting. Stop if you hear someone else
IEEE 802.3 CSMA/CD

If the medium is idle, transmit (1-persistent).
If the medium is busy, wait until idle and then transmit immediately.
If a collision is detected while transmitting,
  Transmit a jam signal for one slot
  \((= 51.2 \mu s = 64\text{ byte times})\)
  Wait for a random time and reattempt (up to 16 times)
  Random time \(= \text{Uniform}[0,2^{\min(k,10)}-1]\) slots
Collision detected by monitoring the voltage
High voltage \(\Rightarrow\) two or more transmitters \(\Rightarrow\) Collision
\(\Rightarrow\) Length of the cable is limited to 2 km
CSMA/CD Operation
**CSMA/CD Operation**

- **t=0**: A starts transmitting
- **t=1**: C starts transmitting
- **t=2**: C detects collision and sends jam
- **t=3**: A detects collision and sends jam
- **t=2+51.2μs**: C stops jam
- **t=3+51.2μs**: A stops jam
- Both A and C sense idle
- **t=3+51.2+9.6μs**: A and C draw random numbers
  - A gets 1 and C gets 0
  - C starts transmitting

Collision window = $2 \times \text{One-way Propagation delay} = 51.2 \ \mu s$

One way delay = $25.6 \ \mu s \Rightarrow \text{Max Distance } < 2.5 \ km$
Original Ethernet Configuration

Fig 12.9
10BASE-T

Hub repeats the signal on all ports
Activity on two or more channels $\Rightarrow$ Collision
Collision presence (CP) transmitted by hub to all stations
Collision window $= 2 \times$ One-way delay between farthest stations
Ethernet Standards

10BASE5: 10 Mb/s over coaxial cable (ThickWire)
10BROAD36: 10 Mb/s over broadband cable, 3600 m max segments
1BASE5: 1 Mb/s over 2 pairs of UTP
10BASE2: 10 Mb/s over thin RG58 coaxial cable (ThinWire), 185 m max segments
10BASE-T: 10 Mb/s over 2 pairs of UTP
10BASE-FL: 10 Mb/s fiber optic point-to-point link
10BASE-FB: 10 Mb/s fiber optic backbone (between repeaters). Also, known as synchronous Ethernet.
Ethernet Standards (Cont)

- **10BASE-FP**: 10 Mb/s fiber optic passive star + segments
- **10BASE-F**: 10BASE-FL, 10BASE-FB, or 10BASE-FP
- **100BASE-T4**: 100 Mb/s over 4 pairs of CAT-3, 4, 5 UTP
- **100BASE-TX**: 100 Mb/s over 2 pairs of CAT-5 UTP or STP
- **100BASE-FX**: 100 Mbps CSMA/CD over 2 optical fiber
Ethernet Standards (Cont)

- 100BASE-X: 100BASE-TX or 100BASE-FX
- 100BASE-T: 100BASE-T4, 100BASE-TX, or 100BASE-FX
- 1000BASE-T: 1 Gbps (Gigabit Ethernet)
- 10GBASE-T: 10 Gbps Ethernet
CSMA/CD Performance

$\alpha = \text{Propagation delay/Frame time}$

$U = \text{Frame Time}/(\text{Propagation delay} + \text{Frame Time}) = 1/(1+\alpha)$

(a) Transmission time = 1; propagation time = $a < 1$

(b) Transmission time = 1; propagation time = $a > 1$
CSMA/CD Performance (Cont)

\[ U = \frac{1}{1 + 2\alpha (1-A)/A}, \text{ where } A = (1-1/N)^{N-1} \rightarrow e^{-1} \]

Worst case \( U = 1/(1+3.44a) \) with \( N = \infty \)
Distance-B/W Principle

Efficiency = Max throughput/Media bandwidth
Efficiency is a non-increasing function of $\alpha$
$\alpha = \text{Propagation delay} / \text{Transmission time}
= (\text{Distance}/\text{Speed of light})/(\text{Transmission size}/\text{Bits/sec})$
$= \text{Distance} \times \text{Bits/sec}/(\text{Speed of light})(\text{Transmission size})$

Bit rate-distance-transmission size tradeoff.
100 Mb/s $\Rightarrow$ Change distance or frame size
### Ethernet vs Fast Ethernet

<table>
<thead>
<tr>
<th></th>
<th>Ethernet</th>
<th>Fast Ethernet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed</strong></td>
<td>10 Mbps</td>
<td>100 Mbps</td>
</tr>
<tr>
<td><strong>MAC</strong></td>
<td>CSMA/CD</td>
<td>CSMA/CD</td>
</tr>
<tr>
<td><strong>Network diameter</strong></td>
<td>2.5 km</td>
<td>205 m</td>
</tr>
<tr>
<td><strong>Topology</strong></td>
<td>Bus, star</td>
<td>Star</td>
</tr>
<tr>
<td><strong>Cable</strong></td>
<td>Coax, UTP, Fiber</td>
<td>UTP, Fiber</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>802.3</td>
<td>802.3u</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>X</td>
<td>2X</td>
</tr>
</tbody>
</table>
**Full-Duplex Ethernet**

Uses point-to-point links between **TWO** nodes

Full-duplex bi-directional transmission

Transmit any time

Not yet standardized in IEEE 802

Many vendors are shipping switch/bridge/NICs with full duplex

No collisions $\Rightarrow$ 50+ Km on fiber.

Between servers and switches or between switches
IEEE 802 Address Format

48-bit: 1000 0000 : 0000 0001 : 0100 0011
: 0000 0000 : 1000 0000 : 0000 1100
= 80:01:43:00:80:0C

<table>
<thead>
<tr>
<th>Organizationally Unique Identifier (OUI)</th>
<th>24 bits assigned by OUI Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual/Group</td>
<td>Universal/Local</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>

Multicast = “To all bridges on this LAN”
Broadcast = “To all stations”
= 111111....111 = FF:FF:FF:FF:FF:FF:FF
Summary

- Ring, Bus, Tree, Star topologies
- CSMA, CD, and $p$-persistence
- Binary exponential backoff
- 10BASE-T vs 100BASE-T
- Full-duplex Ethernet
- Multicast and unicast Ethernet frames
Reading Assignment