Overview

- LAN, MAN, WAN, GAN, DAN
- Topologies: Star, ring, tree, bus
- Baseband and broadband
- IEEE 802.3: Ethernet or
- IEEE 802.5: Token ring
- Fiber Distributed Data Interface (FDDI)
- IEEE 802.2: Logical Link Control
**LAN vs WAN**

**LAN**
- Usually shared medium
- Broadcast
- No intermediate stations
- Access protocols
- Infrastructure owned by a private organization

**WAN**
- Point-to-point
- Unicast
- Intermediate Routers/switches
- Access protocols
- Infrastructure owned by a public telecommunication company

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**Classification of Networks**

- **WAN** = Wide Area Network
- **LAN** = Local Area Network
- **MAN** = Metropolitan Area Network
- **CAN** = Campus Area Network
- **DAN** = Desk Area Network
- **GAN** = Global Area Network
Transmission Media [Self-Reading]

- Unshielded Twisted Pair
- Shielded Twisted Pair
- Coaxial Cable
- Optical fiber
Baseband

Packet Absorbed  Packet Read  Packet Travels In both Directions  Packet Transmitted

Broadband

- Broadband: Mid-split Headend/Frequency Converter
  - Receive on f2
  - Transmit on f1

- Broadband: Dual Cable
  - Receive on f1
  - Transmit on f1
Baseband vs Broadband

- Baseband
  - One frequency band
  - Bidirectional repeaters
  - Bidirectional signal flow
  - No headend required
  - Simple

- Broadband
  - Multiple frequency band
  - Unidirectional repeaters
  - Unidirectional signal flow
  - Headend required for return path
  - Complex

Ethernet or IEEE 802.3

- 10 Mbps, 500 m segments, 2500 span, 100 nodes per segment, 2.5 m between stations, 0.4 in thick coaxial cable (10BASE5)
- 10 Mbps, 200 m segments, 1000 span, 30 nodes per segment, 0.5 m between stations, 0.25 in thin coaxial cable (10BASE2)
10BASE-T

- Unshielded twisted pair, hub (repeater), signal broadcast to all stations. Max 100 m to hub at 10 Mbps

Multilevel Hierarchy

- HUB
- RHUB
- Intermediate hub
- Station

Fig 9.4
Fig 9.5
Ring Issues

- Per hop Clock Synch: Need synchronous transmission
- Around the ring clock synch: Need buffers
- Frame removal
- Reliability: N repeaters in a series

Bypass

Fig 9.9
Star-Shaped Ring

- Bus Topology
  - Token Passing: IEEE 802.4 Token bus
  - Slotted Access: IEEE 802.6 DQDB
  - Contention: IEEE 802.3 CSMACD

- Ring Topology
  - IEEE 802.5 Token Ring
  - Cambridge Ring
  - DQDB
  - Slotted Ring

The Ohio State University
Raj Jain
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 byte times)
  - Wait for a random time and reattempt (up to 16 times)
  - Random time = Uniform$[0,2^{\min(k,10)}-1]$ slots
- Collision detected by monitoring the voltage
  - High voltage ⇒ two or more transmitters ⇒ Collision
  - Length of the cable is limited to 2 km
CSMA/CD Operation

- Collision window = 2 X One-way Propagation delay = 51.2 µs
- One way delay = 25.6 ms
- Max Distance < 2.5 km

Fig 9.12

CSMA/CD PHY 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.
- **10BASE-FP**: 10 Mb/s fiber optic passive star + segments
- **10BASE-F**: 10BASE-FL, 10BASE-FB, or 10BASE-FP
Fast Ethernet Standards

- **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
- **100BASE-X**: 100BASE-TX or 100BASE-FX
- **100BASE-T**: 100BASE-T4, 100BASE-TX, or 100BASE-FX

10BASE-T

- Collision detected by the hub.
- Activity on two or more channels ⇒ Collision
  - Collision presence (CP) transmitted by hub to all stations
  - Collision window = 2X One-way delay between farthest stations

The Ohio State University

Raj Jain
Token Ring

4 Mb/s
16 Mb/s

Priorities

- Received Priority = Pr ⇒ This token/frame’s priority
- Received reservation = Rr ⇒ Someone on the ring wants to transmit at Rr
- To transmit a message of priority Pm, you should get a free token with Pr < Pm
- If free but Pr>Pm and Rr<Pm, reserve token by setting Rr=Pm
- If busy and Rr<Pm then reserve by setting Rr ← Pm
- If busy and Rr>Pm, wait
- When you transmit, set Rr=0, and busy=1. After transmission, issue a new token with Pr=Max{Pr,Pm,Rr}, Rr=Max{Rr,Pm}
Homework 9A

Fill in the table with all 8 possible combinations

<table>
<thead>
<tr>
<th>Busy</th>
<th>PregPm</th>
<th>RregPm</th>
<th>Action</th>
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Priority Stack

- If you issue a higher priority token, remember the new and old priority. Next time grab the higher priority token and reset the priority to old value.

Fig 9.19(1-4)
FDDI

- Fiber Distributed Data Interface
- ANSI Standard for 100 Mbps over Fiber and twisted pair
- Timed token access
- Up to 500 stations on a single FDDI network
- Inter-node links of up to 2km on multimode fiber, 60+ km on single mode fiber, Longer SONET links, 100 m on UTP.
- Round-trip signal path limited to 200 km $\Rightarrow$ 100 km cable.
- Maximum frame size is 4500 bytes.
- Eight priority levels
- Synchronous (guaranteed access delay) and asynchronous traffic
- Arranged as single- or dual-ring logical topology
Timed Token Access

- Two classes of traffic: Synchronous, Asynchronous
- Asynchronous: Timed token access
- Stations agree on a target token rotation time (TTRT)
- Stations monitor token rotation time (TRT)
- A station can transmit TTRT-TRT
  - Token Holding Time (THT)
- Yellow Light Rule:
  - Complete the frame if THT expires in the middle of a frame
- Immediate Release:
  - Release the token at the end of frame transmission
- If TRT>TTRT, Increment late count (LC)
- Reinitialize the ring if LC = 2
- Synchronous: ith station can transmit SAi (pre-allocated)
Example

Ring Latency = D = 3
TTRT = T = 15

TRT

- Maximum TRT = TTRT + Max Frame time + Token Time + \( \sum S_A_i \)
- It is required that \( \sum S_A_i < TTRT - \text{Max Frame time} - \text{Token Time} \)
- Maximum TRT = 2 TTRT
- If D = Ring latency, then
  - Utilization \( U = (TRT - D) / TRT = 1 - D / TTRT \)
- Max U = 1 - D / TTRT
- High load \( \Leftrightarrow \) High TRT
  - Low load \( \Leftrightarrow \) Low TRT
- Lower priority traffic allowed only if TRT is low
- Set \( TTRT_0 < TTRT_1 < TTRT_2 < \ldots < TTRT_6 < TTRT \)
Priorities

\[ U = 1 - \frac{D}{TRT} \]
\[ TRT = \min\{\frac{D}{(1-U)}, 2TTRT\} \]

TP-PMD

- Twisted-Pair Physical Media Dependent
  - Copper FDDI or CDDI
- Allows 100 m over Cat-5 unshielded twisted pair (UTP)
  - Cat-3: 15 MHz Voice grade
  - Cat-4: 20 MHz
  - Cat-5: 100 MHz data grade
- Uses scrambling and 3-level encoding
**Full Duplex FDDI**

- The stations transmit and receive simultaneously.
- Works only on a 2-station ring.
- 200 Mbps.
- Network starts in ring mode.
- After detecting a two node ring using SMT frames, the stations negotiate and enter full duplex mode.
- On error, stations enter the ring mode.
- Patented and licensed by Digital.

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**MAC Performance: Baseband Bus**

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

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*Fig 9.24*
Token Ring

- $a>1$, token is released at $t_0+a$, reaches next station at $t_0+a+a/N$, $U=1/(a+a/N)$

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Token Ring (Continued)

- $a<1$, Token is released at $t_0+a$, $U=1/(1+a/N)$
CSMA/CD

- $U = 1/[1+2a(1-A)/A]$, where $A = (1-1/N)^{N-1} \rightarrow e^{-1}$
- Worst case $U = 1/(1+3.44a)$ with $N = \infty$

CSMA/CD (continued)

Lower $a$
Bridges

- Filtering, switching, buffering

Hub Functions

- Signal Restoration (timing and amplitude)
- Data forwarding
- Collision detection (by monitoring receive ports)
- Jam signal propagation to all ports
- Fault detection and recover: autopartition and restore
**Interconnection Devices**

- **Repeater**: PHY device that restores data and collision signals
- **Hub**: Multiport repeater + collision detection, notification and signal broadcast
- **Bridge**: Datalink layer device connecting two or more collision domains
- **Router**: Network layer device (does propagate MAC multicasts)

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**Logical Link Control (LLC)**

- **Type 1**: Unacknowledged connectionless (Used on 802.3)
  No flow or error control. Provides protocol multiplexing.
  Uses 3 types of protocol data units (PDUs):
  - UI = Unnumbered information
  - XID = Exchange ID = Types of operation supported, window
  - Test = Loop back test
- **Type 2**: Acknowledged connection oriented (Used on 802.5)
  Provides flow control, error control. Uses
  - SABME (Set asynchronous balanced mode), UA (unnumbered ack), DM (disconnected mode), DISC (disconnect)
- **Type 3**: Acknowledged connectionless
  Uses one-bit sequence number
  AC command PDUs acked by AC response PDUs
LLC Multiplexing

- Multiplexing allows multiple users (network layer protocols) to share a datalink
- Each user is identified by a “service access point (SAP)”

<table>
<thead>
<tr>
<th>DSAP</th>
<th>SSAP</th>
<th>Control</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

- Eight-bit SAP
  - Only 256 standard values possible
- Even IP couldn’t get a standard SAP.
  - Use Subnetwork Access Protocol SAP (SNAP SAP)

Multiplexing in Ethernet

- Original (not IEEE 802.3) Ethernet had protocol type field for multiplexing

<table>
<thead>
<tr>
<th>Destination Address</th>
<th>Source Address</th>
<th>Type</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>48</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

- Internet Engineering Task Force (IETF) assigned protocol types (Ethernet Types) for most protocols including IP, IPX, Appletalk, etc. (RFC 1042).
- Length <1518, Protocol type > 1518
SNAP SAP

- SubNetwork Access Protocol Service Access Point
- When DSAP=AA, SSAP=AA, Control=UI, protocol ID field is used for multiplexing

<table>
<thead>
<tr>
<th>DSAP</th>
<th>SSAP</th>
<th>Control</th>
<th>Protocol ID</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>AA</td>
<td>03</td>
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</table>

- Protocol ID is 40 bit long. The first 24 bits are Organizationally Unique Identifiers (OUI). OUI of 0 is used. The Ethernet type values are used in the last 16 bits. Protocol ID = 00-00-00-xx-xx

IEEE 802

- 802.1 Network management and bridging
- 802.2 Logical link control
- 802.3 Ethernet (CSMA/CD)
- 802.4 Token Bus
- 802.5 Token Ring
- 802.6 DQDB
- 802.7 Broadband technical advisory group
- 802.8 Fiber-optic technical advisory group
- 802.9 Integrated data and voice
- 802.10 Security and privacy
IEEE 802 (Cont)

- 802.11 Wireless LANs
- 802.12 100VG-AnyLAN
- 802.13 ?Bad Luck
- 802.14

Summary

- Ring, Bus, Tree, Star topologies
- Ethernet/IEEE 802.3: CSMA/CD, Baseband, broadband
- Token ring/IEEE 802.5
- FDDI Timed token access
- LLC type 1, 2, 3
Homework 9B

- 9.4, 9.19, 9.20, 9.21