Unit 10

Ethernet, ARQ

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Some Answers and Clarifications…
Framing Review

- Physical Layer encoding (e.g., NRZ, NRZI, Manchester, 4B/5B)

- Link Layer frames
  - Byte oriented (e.g., BISYNC, DDCMP)
  - Bit oriented (e.g., HDLC)
  - Clock based (e.g., SONET)
Internet Checksum Update

- See RFC 1624
- Basic idea: Update the checksum using the old checksum and the difference in the updated 16 bit field of interest
- Algorithm:
  - New_Checksum = \sim(\sim Old_Checksum + (m' - m))
  - \sim denotes one’s complement, m and m’ are the old and new 16 bit fields of interest
Continue Ethernet Discussion…
Observe 802.11 MAC is common to all 802.11 Physical Layer (PHY) standards

802.11 PHY is split into Physical Layer Convergence Procedure (PLCP) and Physical Medium Dependent (PMD) sublayers
Names

- Structure: [rate][modulation][media or distance]
  - 10Base5 (10Mbps, baseband, coax, 500m)
  - 10Base-T (10Mbps, baseband, twisted pair)
  - 100Base-TX (100Mbps, baseband, 2 pair)
  - 100Base-FX (100Mbps, baseband, fiber)
  - 1000Base-CX for two pairs balanced copper cabling
  - 1000Base-LX for long wavelength optical transmission
  - 1000Base-SX for short wavelength optical transmission.

- Wireless:
  - Wi-Fi = 802.11
  - Versions: a, b, g, n
8 byte preamble (DIX Ethernet): alternating 1/0 combination producing 10Mhz square wave [@ 10Mbps] for 6.4 µsec; used for receiver synchronization
Ethernet Addresses

- Ethernet (and other IEEE 802) protocols make use of 48 bit addresses

<table>
<thead>
<tr>
<th>I/G</th>
<th>U/L</th>
<th>46 BIT ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I/G = 0 Individual Address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I/G = 1 Group Address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U/L = 0 Globally Administered Address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U/L = 1 Locally Administered Address</td>
</tr>
</tbody>
</table>

- IEEE allows for per-port and per-host addressing
  - Ports connecting to the same “subnet” need unique addresses
  - Locally Administered Addresses (LALs) can be used for distinguishing such ports
  - LALs are rarely used in Ethernet, but more commonly used in Token Ring
Ethernet Addresses – More Details

Addresses are allocated by IEEE in blocks containing $2^{24}$ (16,777,216) addresses

The first 3 bytes identify the vendor and are called Organizationally Unique Identifier (OUI) (e.g., 00-00-0C is Cisco)

Each byte is transmitted with LSB first

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**Table:**

<table>
<thead>
<tr>
<th>MAC Type</th>
<th>Address range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globally Unique</td>
<td>00-00-0C, 00-01-00, 00-02-00, 00-03-00, 00-04-00</td>
</tr>
<tr>
<td>Locally Administered</td>
<td>02-00-00, 02-01-00, 02-02-00, 02-03-00, 02-04-00</td>
</tr>
<tr>
<td>Multicast</td>
<td>10-00-00, 10-01-00, 10-02-00, 10-03-00, 10-04-00</td>
</tr>
<tr>
<td>Broadcast</td>
<td>FF-FF-FF, FF-FF-FF, FF-FF-FF, FF-FF-FF, FF-FF-FF</td>
</tr>
</tbody>
</table>

Note: except broadcast address

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**Diagram:**

- **Individual**
- **Valid Use**
  - Source address: Globally Unique, Locally Administered
  - Destination address: Globally Unique, Locally Administered, Multicast, Broadcast

- **Individual**
Addressing

- 48 bit Ethernet/MAC/Hardware Addresses
- Prefix assigned per-vendor by IEEE
- Unique per-adapter, burned in ID PROM
- Multicast & Broadcast (all 1’s) addresses
- Many adapters support *promiscuous* mode
Addressing - Multicast

- Each vendor assignment supports $2^{24}$ individual and group (multicast) addresses.
- Each adapter supports multiple group “subscriptions”:
  - Usually implemented as hash table.
  - Thus, software may have to filter at higher layer.
Fast Ethernet

“Fast Ethernet” (1995) adds:

- 10x speed increase (100m max cable length retains min 64 byte frames)
- replace Manchester with 4B/5B (from FDDI)
- full-duplex operation using switches
- speed & duplex auto-negotiation
Gigabit Ethernet
IEEE 802.3{z,ab} 1000 Mb/s

- “Gigabit Ethernet” (1998,9) adds:
  - 100x speed increase
  - carrier extension (invisible padding...)
  - packet bursting
Each port belongs to a set of VLANs and transmits only packets that belong to these VLANs.
Link Aggregation

Links are combined. Hello protocol determines which links are working and transmits across working links.
XON/XOFF is a backpressure scheme designed to prevent nodes from saturating links. Unfortunately, in its present version, the scheme is not very effective – it stops too many flows.
Automatic Repeat Request (ARQ)
Reliable Transmission: Error correction or Retransmission?

- Error Correction requires a lot of redundancy
  - Wasteful if errors are unlikely
- Retransmission strategies are more popular
  - As links get reliable this is just done at the transport layer
- Error correction is useful when retransmission is costly (satellite links, multicast)
Reliable Transmission: Error correction or Retransmission?

- Model:
  - Assume Packets have $P$ bits
  - $D$ extra bits for error detection $\rightarrow P(\text{error}) = e$
  - $C$ extra bits for error correction ($C > D$)

- Question: What is more efficient?

- Answer:
  - Error Correction $\rightarrow P + C$ bits/packet
  - Error Detection $\rightarrow (P + D)/(1 - e)$ bits/packet
  - Hence: ED if $e < (C - D)/(P + C)$
Reliable Transmission: 
Link by Link or End-to-End?

- **Model:**
  - Assume L links with $P(error) = e$ for each (ind.)

- **Link by Link:**
  - $L/(1 - e)$ transmissions per packet
  - However, there is a processing time $T$ per link
  - Hence $TL + L/(1 - e)$

- **E2E:**
  - $L/s$ transmissions per packet where $s = (1 - e)^L$

- Hence:
  - E2E if $L/(1 - e)^L < L(T + 1/(1 - e))$, which is the case if $e << T/L$
Connection Throughput

- Connection:
  - Send W bits (window size)
  - Wait for ACKs
  - Repeat
- Assume that the round-trip time is RTT seconds
- Throughput = \( \frac{W}{RTT} \) bps

Numerical Example:
- \( W = 64\text{KBytes} = 512 \text{kbits} \)
  \[ = 512 \times 1,024 = 524,288 \text{ bits} \]
- RTT = 200ms
- Throughput = \( \frac{W}{T} = 2.6\text{Mbps} \)
Stop-and-Wait Scenarios

- Transmit one packet, wait for ack, and repeat
- Set timeout for retransmission

[Peterson & Davie]
Sliding Window

- Start with a window size of $W$ packets
- Decrement available window size for each packet transmitted
- Increment available window size for each ack received

[Peterson & Davie]
Sliding Window Algorithm

- Sending side
  - Last Frame Sent (LFS) – Last Ack Rcvd ≤ Send Window Size (SWS)

- Receiving Side
  - Largest Acceptable Frame (LAF) – Last Frame Rcvd ≤ Receive Window Size (RWS)

- Typically RWS = 1 or RWS = SWS