7. Ethernet – A Case Study of Physical and Data Link Layer
Origin of Ethernet

- Found by Xerox Palo Alto Research Center (PARC) in 1975
- Original designed as a 2.94 Mbps system to connect 100 computers on a 1 km cable
- Later, Xerox, Intel and DEC drew up a standard support 10 Mbps
- Basis for the IEEE’s 802.3 specification
## Ethernet Basics

- **Topologies**: Linear bus, Star bus
- **Signaling**: Mainly baseband (digital)
- **Access method**: CSMA/CD
- **Specifications**: IEEE 802.3
- **Transfer speed**: 10 Mbps, 100 Mbps, or above
- **Cable types**: Coaxial cables, UTP
Ethernet Frame Format

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Des. Add</th>
<th>Sour. Add</th>
<th>Type</th>
<th>Data</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Bytes</td>
<td>6 Bytes</td>
<td>6 Bytes</td>
<td>2</td>
<td>46 - 1500 Bytes</td>
<td>4 Bytes</td>
</tr>
</tbody>
</table>

- **Preamble**: For synchronization
- **Des. Add**: Destination address
- **Sour. Add**: Source address
- **FCS**: Frame Check Sequence
Frame operation
Ethernet Address

00 00 E2 15 1A CA
Ethernet addresses are 48 bits long.

Ethernet addresses are governed by IEEE and are usually imprinted on Ethernet cards when the cards are manufactured.

**Examples of Manufacturer IDs**

- Cisco  : 00-00-0C-
- 3Com  : 00-60-8C-
-         : 00-60-09-     : 00-60-08-
- Xircom : 00-80-C7-
- IBM    : 08-00-5A-
- Sun    : 08-00-20-
- Nokia  : 00-40-43-
IEEE 802.3 Frame Format

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Des. Add</th>
<th>Sour. Add</th>
<th>Length</th>
<th>Data</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Bytes</td>
<td>1 Byte</td>
<td>2/6 Bytes</td>
<td>2/6 Bytes</td>
<td>2 Bytes</td>
<td>46 - 1500 Bytes</td>
</tr>
</tbody>
</table>

**Original Ethernet II Frame Format**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Des. Add</th>
<th>Sour. Add</th>
<th>Type</th>
<th>Data</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Bytes</td>
<td>6 Bytes</td>
<td>6 Bytes</td>
<td>2 Bytes</td>
<td>46 - 1500 Bytes</td>
<td>4 Bytes</td>
</tr>
</tbody>
</table>
Access Method - CSMA/CD

• Carrier Sense Multiple Access / Collision Detection

Check the line
If no packet, OK to transmit
If computers are too far away, carrier detection before transmission doesn’t always work.

Check the line Find no packet OK to transmit

Check the line Find no packet OK to transmit

Long distance
After transmit, keep listening to the line

Compare the data on the line with the ones being transmitted

If different, stop transmission immediately (to minimize wasted time — because there is no use continuing)

Wait for a random time and try all over again
CSMA/CD — Design Considerations

• More computers on the LAN, higher chance of collisions

• Retransmission may result in collision again and cause further delay

• As the result, the network becomes standstill

• Hence, Ethernet is suitable for low traffic networks
10 Mbps IEEE Standards

- **10BaseT**

  - 10BaseT ⇒ 10 Mbps, baseband, over Twisted-pair cable
  - Running Ethernet over twisted-pair wiring as specified by IEEE 802.3
  - Configure in a star pattern
**Baseband Transmission**
- Entire channel is used to transmit a single digital signal
- Complete **bandwidth** of the cable is used by a single signal
- The transmission distance is **shorter**
- The electrical interference is **lower**

**Broadband Transmission**
- Use **analog** signaling and a range of frequencies
- **Continuous** signals flow in the form of waves
- Support **multiple analog transmission** (channels)
• Twisted Pair Cables

• Unshielded Twisted Pair Cable (UTP)
  • most popular
  • maximum length 100 m
  • more susceptible to noise

• EIA/TIA 568 Commercial Building Wire Standard

<table>
<thead>
<tr>
<th>Category</th>
<th>Transmission capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>Voice transmission of traditional telephone</td>
</tr>
<tr>
<td>Category 2</td>
<td>For data up to 4 Mbps, 4 pairs full-duplex</td>
</tr>
<tr>
<td>Category 3</td>
<td>For data up to 10 Mbps, 4 pairs full-duplex</td>
</tr>
<tr>
<td>Category 4</td>
<td>For data up to 16 Mbps, 4 pairs full-duplex</td>
</tr>
<tr>
<td>Category 5</td>
<td>For data up to 100 Mbps, 4 pairs full-duplex</td>
</tr>
<tr>
<td>Category 6</td>
<td>For data up to 1000 Mbps, 4 pairs full-duplex</td>
</tr>
</tbody>
</table>
- **Shielded Twisted Pair Cable (STP)**
  - Shielding to reduce **crosstalk**
  - **Crosstalk**: signal from one line getting mixed with signals from another line

- **Connector**
  - **RJ-45 computer connector** (8 wires)

<table>
<thead>
<tr>
<th>Pin</th>
<th>T568A</th>
<th>T568B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rx+</td>
<td>Tx+</td>
</tr>
<tr>
<td>2</td>
<td>Rx-</td>
<td>Tx-</td>
</tr>
<tr>
<td>3</td>
<td>Tx+</td>
<td>Rx+</td>
</tr>
<tr>
<td>4</td>
<td>Unused</td>
<td>Unused</td>
</tr>
<tr>
<td>5</td>
<td>Unused</td>
<td>Unused</td>
</tr>
<tr>
<td>6</td>
<td>Tx-</td>
<td>Rx-</td>
</tr>
<tr>
<td>7</td>
<td>Unused</td>
<td>Unused</td>
</tr>
<tr>
<td>8</td>
<td>Unused</td>
<td>Unused</td>
</tr>
</tbody>
</table>
Case 1

T568A T568B
Cross-over cable

Case 2

T568B
T568B
Straight through cable

Case 3

Wall plate
Hub
Cross-over cable
Straight through cable
A typical 10BaseT network

Backbone
10BaseT Summary

- **Cable**
  - Category 3, 4, or 5 UTP

- **Connectors**
  - RJ-45 at cable ends

- **Max. distance between computer to hub**
  - 100 m. (328’)

- **Backbones for hubs**
  - Coaxial or fibre-optic

- **Total computers per LAN**
  - 1024
Pro and Cons of 10BaseT

Advantages

• Easier to manage
• Scalable
• Cable itself is relatively inexpensive

Drawback

• High attenuation leads to short segment length
• Need good infrastructure planning beforehand
10 Mbps IEEE Standards

- 10Base2

- Called 10Base2 because it carries signal roughly 2 times 100 m (actually 185 m)

- Use thin coaxial cable, thinnet

- Configure in a linear bus pattern
• Both end of a segment needed to be **terminated** to avoid energy bounce back

• Can introduce collision if without termination

• To **reduce interference**, can ground the terminator

• **Never ground both ends** as there can be voltage difference in both ends
A typical 10Base2 network

Follow 5-4-3 rule
10Base2 Summary

- Max. segment length: 185 m (607’)
- Minimum distance between T joints: 0.5 m (1.5’)
- Connectors to NIC: BNC T connector
- Cable: Coaxial, e.g. RG-58
- Follow 5-4-3 rule
- Max. total network length: 925 m (3035’)
- Computers per segment: 30
Pros and Cons of 10Base2

Advantages

• Easy to install
• Easy to configure

Drawback

• Difficult to maintain
• Cable itself is expensive
• Not extendable to 100 based systems
100 Mbps Networks

- Multimedia network applications push the development of faster networks

- Several Ethernet standards exist:
  - 100BaseVG-AnyLAN Ethernet
  - 100BaseX Ethernet (Fast Ethernet)
- 10 times faster than 10BaseX systems
- Compatible with existing cabling systems
100VG-AnyLAN

- Originally developed by Hewlett-Packard
- Currently being refined and ratified by IEEE 802.12 committee

- Specifications:
  - Minimum data rate 100 Mbps
  - Support a cascaded star topology over cat.3, 4, and 5 twisted-pair and fiber-optic cables
  - Use demand priority access method
  - Support for both Ethernet frames and Token Ring packets
• Max distance from hub to computer: 250 m
Demand priority access method

- Hub continuously scans in a round-robin way for requests from computer
- Each node has two priorities
  - High: for multimedia data
  - Low: for normal data
• If both high and low priority packets are pending to transfer, send high priority first

• Resume to serve low priority packets if all high priority packets have been served
100BaseX Ethernet

- Also called **Fast Ethernet**
- Specified by IEEE 802.3μ addendum
- Extension to the existing Ethernet standard
- Run on UTP Cat.5 cable and use CSMA/CD in a star wired bus
- Can be easily plug-and-play over the existing systems
<table>
<thead>
<tr>
<th>Value</th>
<th>Represent</th>
<th>Actual Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Transmission speed</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>Base</td>
<td>Signal type</td>
<td>Baseband</td>
</tr>
<tr>
<td>T4</td>
<td>Cable type</td>
<td>4 telephone-grade twisted-pair cable (cat. 3, 4, 5)</td>
</tr>
<tr>
<td>TX</td>
<td>Cable type</td>
<td>2 data-grade twisted-pair cable (cat. 5)</td>
</tr>
<tr>
<td>FX</td>
<td>Cable type</td>
<td>Fiber-optic link using 2 strands of fiber cable</td>
</tr>
</tbody>
</table>
Comparison with 10BaseT

- Transmit on 3 pairs vs. 1 pair  x 3.00
- 8B6T coding instead of Manchester  x 2.65
- 20 to 25 MHz clock increase  x 1.25

10.00