Chapter 4: Network Access

Introduction to Networks

Chapter 4

4.1 Physical Layer Protocols
4.2 Network Media
4.3 Data Link Layer Protocols
4.4 Media Access Control
4.5 Summary

4.4 Media Access Control
Connecting to the Network

- Network Interface Cards
  - Connecting to the Wireless LAN with a Range Extender

Purpose of the Physical Layer
  - The Physical Layer
Purpose of the Physical Layer

Physical Layer Media

- Electrical Signals - Copper cable
- Light Pulse - Fiberoptic cable
- Microwave Signals - Wireless

Physical Layer Standards

<table>
<thead>
<tr>
<th>Standard Organization</th>
<th>Networking Standards</th>
</tr>
</thead>
</table>
| ISO                   | - ISO 8877: Offically adopted the RJ connectors (e.g., RJ-11, RJ-45)  
                        | - ISO 11801: Network cabling standard similar to EIA/TIA 568. |
| EIA/TIA               | - TIA-568-C: Telecommunications cabling standards, used by nearly all  
                        | voice, video, and data networks.  
                        | - TIA-569-B: Commercial Building Standards for Telecommunications  
                        | Pathways and Spaces.  
                        | - TIA-598-C: Fiber-optic color coding  
                        | - TIA-942: Telecommunications Infrastructure Standard for Data Centers |
| ANSI                  | - 568-C: RJ-45 pinouts. Co-developed with EIA/TIA |
| ITU-T                | - G.992: ADSL |
| IEEE                  | - 802.3: Ethernet  
                        | - 802.11: Wireless LAN (WLAN) & Mesh (Wi-Fi certification)  
                        | - 802.15: Bluetooth |

Fundamental Principles of Layer 1

Physical Layer Fundamental Principles

<table>
<thead>
<tr>
<th>Media</th>
<th>Physical Components</th>
<th>Frame Encoding Technique</th>
<th>Signalling Method</th>
</tr>
</thead>
</table>
| Copper Cable   | - UTP  
                 | - Coaxial  
                 | - NICs  
                 | - Ports  
                 | - Interfaces | - Manchester Encoding  
                 | - Non-Return to Zero (NRZ) techniques  
                 | - 4B/5B codes are used with MultiLevel Transition Level 3 (MLT-3) signaling  
                 | - PAM5                            | - Changes in the electromagnetic field  
                 |                     | - Intensity of the electromagnetic field  
                 |                     | - Phase of the electromagnetic wave |
| Fiber Optic Cable | - Single-mode Fiber  
                       | - Multimode Fiber  
                       | - Connectors  
                       | - NICs  
                       | - Interfaces  
                       | - Lasers and LEDs  
                       | - Photoreceivers | - Pulses of light  
                       |                     | - Wavelength multiplexing using different colors | - A pulse equals 1.  
                       |                     |                     | - No pulse is 0. |
| Wireless Media | - Access Points  
                     | - NICs  
                     | - Radio  
                     | - Antennae | - DSSS (direct-sequence spread-spectrum)  
                     |                     |                     | - OFDM (orthogonal frequency division multiplexing) | - Radio waves |

Bandwidth

<table>
<thead>
<tr>
<th>Unit of Bandwidth</th>
<th>Abbreviation</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bits per second</td>
<td>bps</td>
<td>1 bps = fundamental unit of bandwidth</td>
</tr>
<tr>
<td>Kibits per second</td>
<td>kbps</td>
<td>1 kbps = 1000 bps = 10^3 bps</td>
</tr>
<tr>
<td>Megabits per second</td>
<td>Mbps</td>
<td>1 Mbps = 1,000,000 bps = 10^6 bps</td>
</tr>
<tr>
<td>Gigabits per second</td>
<td>Gbps</td>
<td>1 Gbps = 1,000,000,000 bps = 10^9 bps</td>
</tr>
<tr>
<td>Terabits per second</td>
<td>Tbps</td>
<td>1 Tbps = 1,000,000,000,000 bps = 10^12 bps</td>
</tr>
</tbody>
</table>
Throughput

Types of Physical Media

- SHDSL Interface
- Management Ports
- Gigabit Ethernet Interfaces
- USB Type A Connector
- Fast Ethernet Switch Ports
- USB Mini-B Connector

Fundamental Principles of Layer 1

Copper Cabling
Characteristics of Copper Media

4.2 Network Media
Copper Cabling

Copper Media

Unshielded Twisted Pair (UTP) Cable

Shielded Twisted Pair (STP) Cable

Coaxial Cable

Copper Cabling

UTP Cable

Outer Jacket
Protects the copper wires from physical damage

Twisted-Pair
Protects the signal from interference

Color-Coded Plastic Insulation
Electrically isolates wires from each other and identifies each pair

Copper Cabling

STP Cable

Braided or Foil Shield

Twisted Pairs

Foil Shields

Jacket

Copper Cabling

Coaxial Cable

Outer Jacket

Finished Copper Shielding

Copper Conductor

Plastic Insulation

Coaxial Connectors

BNC

N-type

Type
Copper Cabling

Cooper Media Safety

- The separation of data and electrical power cabling must comply with safety codes.
- Cables must be connected correctly.
- Installations must be inspected for damage.
- Equipment must be grounded correctly.

UTP Cabling

Properties of UTP Cabling

UTP cable does not use shielding to counter the effects of EMI and RFI. Instead, cable designers have discovered that they can limit the negative effect of crosstalk by:
- Cancellation
- Varying the number of twists per wire pair

UTP Cabling Standards

- Category 3 Cable (UTP)
- Category 5 Cable (UTP)
- Category 6 Cable (UTP)
- Category 5 and 6e Cable (UTP)

UTP Connectors

- RJ-45 UTP Plugs
- RJ-45 UTP Socket
UTP Cabling

Types of UTP Cable

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Standard</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet Straight-Through</td>
<td>Both ends T568A or both ends T568B</td>
<td>Connects a network host to a network device such as a switch or hub.</td>
</tr>
<tr>
<td>Ethernet Crossover</td>
<td>One end T568A, other end T568B</td>
<td>Connects two network hosts.</td>
</tr>
<tr>
<td>Rollover</td>
<td>Cisco proprietary</td>
<td>Connects a workstation serial port to a router console port, using an adapter.</td>
</tr>
</tbody>
</table>

Testing UTP Cables

After installation, a UTP cable tester should be used to test for the following parameters:
- Wire map
- Cable length
- Signal loss due to attenuation
- Crosstalk

Fiber Optic Cabling

Properties of Fiber Optic Cabling

Fiber-optic cabling is now being used in four types of industry:
- Enterprise Networks
- Fiber-to-the-home (FTTH) and Access Networks
- Long-Haul Networks
- Submarine Networks
**Fiber Optic Cabling**

**Types of Fiber Media**

- **Single Mode**
  - Produces single straight path for light
  - Smaller core
  - Used for long-distance applications
  - Commonly used in campus backbone for distances of several thousand meters

- **Multimode**
  - Produces multiple paths for light
  - Larger core than single mode cable
  - Allows greater dispersion and lower bit rates
  - Used in short, high-bandwidth applications, but not in long-distance applications
  - Commonly used in backbone or distribution systems within a building

**Network Fiber Connectors**

- ST Connectors
- SC Connectors
- LC Connector
- Duplex Multimode LC Connectors

**Testing Fiber Cables**

- Optical Time Domain Reflectometer (OTDR)

**Fiber versus Copper**

<table>
<thead>
<tr>
<th>Implementation Issues</th>
<th>Copper Media</th>
<th>Fiber Optic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth Supported</td>
<td>10 Mbps – 10 Gbps</td>
<td>10 Mbps – 100 Gbps</td>
</tr>
<tr>
<td>Distance</td>
<td>Relatively short (1 – 100 meters)</td>
<td>Relatively High (1 – 100,000 meters)</td>
</tr>
<tr>
<td>Immunity To EMI And RFI</td>
<td>Low</td>
<td>High (Completely immune)</td>
</tr>
<tr>
<td>Immunity To Electrical Hazards</td>
<td>Low</td>
<td>High (Completely immune)</td>
</tr>
<tr>
<td>Media And Connector Costs</td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>Installation Skills Required</td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>Safety Precautions</td>
<td>Lowest</td>
<td>Highest</td>
</tr>
</tbody>
</table>
Wireless Media

Properties of Wireless Media

Wireless does have some areas of concern including:

- Coverage area
- Interference
- Security

Wireless Media

Types of Wireless Media

- IEEE 802.11 standards
  - Commonly referred to as Wi-Fi
  - Uses CSMA/CA
  - Variations include:
    - 802.11a: 54 Mbps, 5 GHz
    - 802.11b: 11 Mbps, 2.4 GHz
    - 802.11g: 54 Mbps, 2.4 GHz
    - 802.11n: 600 Mbps, 2.4 and 5 GHz
    - 802.11ac: 1 Gbps, 5 GHz
    - 802.11ad: 7 Gbps, 2.4 GHz, 5 GHz, and 60 GHz

- IEEE 802.15 standard
  - Supports speeds up to 3 Mb/s
  - Provides device pairing over distances from 1 to 100 meters.

- IEEE 802.16 standard
  - Provides speeds up to 1 Gbps
  - Uses a point-to-multipoint topology to provide wireless broadband access.

Wireless Media

Wireless LAN

Cisco Linksys EA6500 802.11ac Wireless Router

Wireless Media

802.11 Wi-Fi Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Maximum Speed</th>
<th>Frequency</th>
<th>Backwards Compatible</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11a</td>
<td>54 Mbps</td>
<td>5 GHz</td>
<td>No</td>
</tr>
<tr>
<td>802.11b</td>
<td>11 Mbps</td>
<td>2.4 GHz</td>
<td>No</td>
</tr>
<tr>
<td>802.11g</td>
<td>54 Mbps</td>
<td>2.4 GHz</td>
<td>802.11b</td>
</tr>
<tr>
<td>802.11n</td>
<td>600 Mbps</td>
<td>2.4 GHz or 5 GHz</td>
<td>802.11b/g</td>
</tr>
<tr>
<td>802.11ac</td>
<td>1.3 Gbps (1300 Mbps)</td>
<td>2.4 GHz and 5.5 GHz</td>
<td>802.11b/g/n</td>
</tr>
<tr>
<td>802.11ad</td>
<td>7 Gbps (7000 Mbps)</td>
<td>2.4 GHz, 5 GHz and 60 GHz</td>
<td>802.11b/g/n/ac</td>
</tr>
</tbody>
</table>
4.3 Data Link Layer Protocols

Purpose of the Data Link Layer

Data Link Sublayers

<table>
<thead>
<tr>
<th>Network</th>
<th>Data Link</th>
<th>Physical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LLC Sublayer</td>
<td>802.3 Ethernet</td>
</tr>
<tr>
<td></td>
<td>MAC Sublayer</td>
<td>802.15 Bluetooth</td>
</tr>
</tbody>
</table>

Media Access Control

The Data Link Layer

Different protocols may be in use for different media.

At each hop along the path, an intermediary device accepts frames from one medium, decapsulates the frame and then forwards the packets in a new frame. The headers of each frame are formatted for the specific medium that it will cross.
### Purpose of the Data Link Layer

**Providing Access to Media**

The Data Link layer is responsible for controlling the transfer of frames across the media.

### Data Link Layer

**Formatting Data for Transmission**

![Diagram](image)

### Layer 2 Frame Structure

**Creating a Frame**

![Diagram](image)

### Layer 2 Standards

**Data Link Layer Standards**

<table>
<thead>
<tr>
<th>Standard organization</th>
<th>Networking Standards</th>
</tr>
</thead>
</table>
| **IEEE**              | - 802.2: Logical Link Control (LLC)  
- 802.3: Ethernet  
- 802.4: Token bus  
- 802.5: Token passing  
- 802.11: Wireless LAN (WLAN) & Mesh (Wi-Fi certification)  
- 802.15: Bluetooth  
- 802.16: WiMax |
| **ITU-T**             | - G.992: ADSL  
- G.8100: G.8129: MPLS over Transport aspects  
- G.921: ISDN  
- G.922: Frame Relay |
| **ISO**               | - HDLC (High Level Data Link Control)  
- ISO 8802: Media Access Control (MAC) |
| **ANSI**              | - X.25 and X.28: Fiber Distributed Data Interface (FDDI) |
Topologies

Controlling Access to the Media

Sharing the Media

We need rules for how to share the media.

We need rules for how to share the media.

Topologies

Physical and Logical Topologies

Physical Topology

Topologies

Physical and Logical Topologies (cont.)

Logical Topology

WAN Topologies

Common Physical WAN Topologies

Point-to-point topology

Hub and spoke topology

Full mesh topology
WAN Topologies

Physical Point-to-Point Topology

- Limited to two nodes

Logical Point-to-Point Topology

- Adding intermediate physical connections may not change the logical topology.

The logical point-to-point connection is the same.

WAN Topologies

Half- and Full-Duplex

- Half-Duplex
- Full-Duplex

LAN Topologies

Physical LAN Topologies

- Star topology
- Extended star topology
- Bus topology
- Ring topology
LAN Topologies

**Logical Topology for Shared Media**

**Contestion-Based Access**

- I try to send when I am ready.
- I try to send when I am ready.
- I try to send when I am ready.

**Characteristics**

- Contention-based: Stations compete for the media.
- Collision exists.
- Media access is not guaranteed.
- Requires collision detection and resolution mechanisms.

**Controlled Access**

- I have nothing to send.
- I have a packet to send, but I am not my turn. I’ll wait.
- It is my turn to send. I will send now.

**Characteristics**

- Guaranteed access: Only one station can send at a time.
- Requires a control mechanism to coordinate access.

**Contention-Based Technologies**

- CSMA/CD for 802.3 Ethernet networks
- CSMA/CA for 802.11 wireless networks

**Controlled Access Technologies**

- Token Ring (IEEE 802.5)
- FDDI
LAN Topologies
Ring Topology

Data Link Frame
The Frame

In a full-duplex environment, more controls are needed to ensure delivery. The header and trailer fields are larger as more control information is needed.

Data Link Frame
The Header

In a half-duplex environment, we can count on the frame arriving at its destination. Fewer controls are needed, resulting in smaller fields and smaller frames.

Data Link Frame
Layer 2 Address
Data Link Frame

The Trailer

<table>
<thead>
<tr>
<th>START FRAME</th>
<th>ADDRESS</th>
<th>TYPE/LENGTH</th>
<th>Data</th>
<th>Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FCS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stop-Frame</td>
</tr>
</tbody>
</table>

Frame Check Sequence

This field is used for error checking. The source calculates a number based on the frame’s data and appends that number in the FCS field. The destination then recalculates the data to see if the FCS matches. If they don’t match, the destination deletes the frame.

Stop Frame

This field, also called the Frame Trailer, is an optional field that is used when the length of the frame is not specified in the Type/Length field. It indicates the end of the frame when transmitted.