Chapter 1 - Notes - CS 356

Chapter 1: Introduction

1.1 What is the Internet?

- **Definition**: The Internet is a global network of **interconnected networks (ISPs)** that enables data communication among billions of devices.
- **Components**:
  - **Hosts (end systems)**: laptops, PCs, mobile phones, servers.
  - **Communication links**:
    - **Guided**: fiber, copper, coaxial.
    - **Unguided**: radio, satellite, WiFi.
    - **Formula** (Transmission Rate):

      $$R = \frac{L}{t}$$

      where L = number of bits, t = time to transmit.
  - **Packet switches**: devices (routers, switches) that forward packets.
  - **Protocols**: set of rules for communication.
    - Examples: HTTP, TCP/IP, WiFi, 4G/5G.
  - **Standards organizations**:
    - **IETF**: Internet Engineering Task Force.
    - **RFC**: Request for Comments documents.

1.2 What is a Protocol?

- **Definition**: A protocol is a set of rules that define:
  - **Format** of messages.
  - **Order** of messages sent/received.

    - **Actions** taken upon sending/receiving.
- **Examples**:
    - Human protocol: “What’s the time?” → “2:00.”
    - Network protocol: TCP connection request/response.
- **Protocol layers** ensure modularity, abstraction, and ease of troubleshooting.

1.3 Network Edge

- **Hosts**:
    - Clients (request services) and Servers (provide services).
    - Servers often hosted in data centers.
- **Access Networks**:
    - **DSL (Digital Subscriber Line)**:
        - Uses telephone lines.
        - Speeds: **24–52 Mbps downstream**, **3.5–16 Mbps upstream**.
    - **Cable Broadband**:
        - Uses hybrid fiber coax (HFC).
        - Speeds: **40 Mbps – 1.2 Gbps downstream**, **30–100 Mbps upstream**.
    - **Fiber**: up to Gbps speeds.
    - **Wireless**:
        - **WiFi (802.11)**: 11 Mbps → 450 Mbps.
        - **Cellular (4G/5G)**: 10–100 Mbps.
- **Home networks**:
    - Router (NAT, firewall, DHCP).
    - Switches, WiFi AP.

1.4 The Network Core

- **Definition**: Interconnected routers forming the “mesh” backbone of the Internet.
- **Packet Switching**:
  - Breaks data into **packets**.
  - Uses **store-and-forward**:
    - Router must receive full packet before forwarding.
    - **Transmission Delay**:

      dtrans=LRd_{trans} = \frac{L}{R}

      where LL = packet length (bits), RR = link bandwidth (bps).
  - **Queueing Delay**:
    - If packets arrive faster than can be transmitted, they queue.
    - Possible **packet loss** if buffer overflows.
- **Circuit Switching**:
  - Dedicated channel reserved for call.
  - Methods: **FDM (Frequency Division Multiplexing)**, **TDM (Time Division Multiplexing)**.
  - Predictable but inefficient for idle connections.
- **Comparison**:
  - Packet switching: efficient, scalable, but may suffer from delay/loss.
  - Circuit switching: guaranteed QoS, but wasteful.

1.5 Performance Metrics

- **Delays**:
  1. **Processing delay**: time to check headers.
  2. **Queueing delay**: time in buffer waiting.
  3. **Transmission delay**: dtrans=LRd_{trans} = \frac{L}{R}.
  4. **Propagation delay**: dprop=dsd_{prop} = \frac{d}{s},

where dd = distance, ss = propagation speed (~2×1082 \times 10^8 m/s).

- **Total Nodal Delay**:

  dnodal=dproc+dqueue+dtrans+dpropd_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}

- **Throughput**:
  - Instantaneous: rate at a given time.
  - Average: total bits / total time.
  - Bottleneck link determines end-to-end throughput.

1.6 Protocol Layers

- **Five-layer stack**:
  1. **Application**: network apps, protocols (HTTP, DNS).
  2. **Transport**: reliable delivery (TCP, UDP).
  3. **Network**: routing packets (IP).
  4. **Link**: data transfer between adjacent nodes (Ethernet, WiFi).
  5. **Physical**: actual transmission of bits.
- **Encapsulation**:
  - Each layer adds its **header** to the message before passing down.

1.7 Security

- **Attacks**:
  - Malware, worms, viruses.
  - DoS, DDoS.
  - Packet sniffing.
  - IP spoofing.
- **Defenses**:
  - Firewalls, encryption (TLS/SSL), authentication, IDS/IPS.

1.8 History of Networking

- **1960s**: ARPANET.
- **1970s–80s**: TCP/IP developed and standardized.
- **1990s**: Web + commercialization.
- **2000s+**: Broadband, wireless, mobile, IoT.