

Introduction to Networking

Network Components

- **Hosts (End Systems):** Laptops, smart-phones, devices
- **Routers (Switches):** Forward data between hosts
- **Links:** Wired or wireless connections

The Internet

- A global network of interconnected networks
- Uses the **Internet Protocol (IP)** for communication

Packet vs. Circuit Switching

Circuit Switching

- Dedicated communication path between hosts
- **Pros:** Predictable performance
- **Cons:** Inefficient resource usage

Packet Switching

- Data sent in packets over shared network
- **Pros:** Efficient resource usage
- **Cons:** Variable performance due to congestion

Performance Metrics

Delays

- **Processing Delay** (d_{proc})
- **Queuing Delay** (d_{queue})
- **Transmission Delay** ($d_{\text{trans}} = \frac{L}{R}$)
- **Propagation Delay** ($d_{\text{prop}} = \frac{d}{s}$)

Total Delay:

$$d_{\text{total}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

Throughput

$$\text{Throughput} = \frac{\text{Total Data Transferred}}{\text{Total Time}}$$

Layers and Protocols

Internet Protocol Stack

1. **Application Layer:** HTTP, SMTP, FTP
2. **Transport Layer:** TCP, UDP
3. **Network Layer:** IP
4. **Link Layer:** Ethernet, Wi-Fi
5. **Physical Layer:** Hardware transmission technologies

Protocol

- Set of rules governing communication between entities
- Defines message formats and exchange sequences

The Web and HTTP

Hypertext Transfer Protocol (HTTP)

- **Request-Response Protocol:** Clients send requests; servers send responses
- **Methods:** GET, POST, HEAD, PUT, DELETE
- **Status Codes:** 200 OK, 404 Not Found

Persistent Connections

- Reuse the same TCP connection for multiple requests

Domain Name System (DNS)

Purpose

- Translates human-readable domain names to IP addresses

Hierarchy

- **Root Servers:** Top-level of the DNS hierarchy
- **Top-Level Domain (TLD) Servers:** .com, .org, .edu
- **Authoritative DNS Servers:** Organization-specific servers

Resource Records

- **Type A:** Maps a name to an IP address
- **Type NS:** Delegates a DNS zone to use the given authoritative name servers
- **Type CNAME:** Alias of one name to another

Content Distribution Networks (CDNs)

Purpose

- Distribute content to servers located close to users to reduce latency

Mechanism

- Use DNS to redirect users to the nearest CDN server
- Replicate content across multiple geographically distributed servers

Video Streaming

DASH (Dynamic Adaptive Streaming over HTTP)

- Client-driven adaptation of video quality based on available bandwidth
- Video is divided into chunks, each encoded at multiple quality levels

Transport Layer Protocols

TCP (Transmission Control Protocol)

- **Reliable, ordered, and connection-oriented**
- Implements **flow control** and **congestion control**
- Uses **three-way handshake**: SYN, SYN-ACK, ACK

UDP (User Datagram Protocol)

- **Unreliable, unordered, and connectionless**
- Minimal overhead, suitable for applications needing speed over reliability

TCP Congestion Control

- **Slow Start:** Begin with a small congestion window and increase exponentially
- **Congestion Avoidance:** Increase congestion window linearly
- **Fast Retransmit and Fast Recovery:** Detect and recover from packet loss quickly

Network Performance

Little's Law

$$L = \lambda \times W$$

- L : Average number of items in the system
- λ : Average arrival rate
- W : Average time an item spends in the system

Datacenters

Purpose

- Host large-scale applications and services (e.g., cloud computing)

Network Architecture

- Hierarchical structure with **Core**, **Aggregation**, and **Edge (Top-of-Rack)** switches
- Designed for high **bandwidth** and **low latency**

Challenges

- Scalability, reliability, cost efficiency

Key Equations and Concepts

Transmission Delay

$$d_{\text{trans}} = \frac{L}{R}$$

- L : Packet length (bits)
- R : Link bandwidth (bps)

Propagation Delay

$$d_{\text{prop}} = \frac{d}{s}$$

- d : Distance between nodes
- s : Propagation speed (typically 2×10^8 m/s)

Effective Delay

$$d_{\text{eff}} = d_{\text{trans}} + d_{\text{prop}}$$

Packet Loss

- Occurs when packets are dropped due to congestion (e.g., router buffer overflow)

Summary

- Networking involves multiple layers, each with specific protocols and functions
- Performance metrics are essential for evaluating network efficiency
- The Internet relies on various technologies and protocols to deliver data reliably