Network Layers

Internet Protocol Stack (5 Layers)

1. **Application** (HTTP, DNS, SMTP)
2. **Transport** (TCP, UDP)
3. **Network** (IP)
4. **Link** (Ethernet, WiFi)
5. **Physical** (Cables, signals)

Encapsulation

Data → Segment → Packet → Frame → Bits

Key Protocols

HTTP

- Request-response protocol
- Methods: GET, POST, HEAD, PUT, DELETE
- Status codes: 200 OK, 404 Not Found, etc.

DNS

- Hierarchical: Root, TLD, Authoritative servers
- Resource Records: A, NS, CNAME, MX
- Caching for performance

TCP

- Reliable, ordered, connection-oriented
- Flow control, congestion control
- Three-way handshake: SYN, SYN-ACK, ACK

UDP

- Unreliable, unordered, connectionless
- Lightweight, low latency

Packet vs. Circuit Switching

Packet Switching

- Store-and-forward transmission
- Statistical multiplexing
- No call setup required

Circuit Switching

- Dedicated end-to-end resources
- Guaranteed performance
- Inefficient for bursty data

Performance Metrics

Delays

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

Total Delay:

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

Throughput:

$$\text{Throughput} = \min\left\{R_s, R_c, \frac{R}{N}\right\}$$

Where R_s is server rate, R_c is client rate, R is bottleneck link rate, and N is number of flows.
Packet Loss: Occurs when router buffers overflow

Web Technologies & CDNs

Web Technologies

- **HTTP/1.1**: Persistent connections
- **HTTP/2**: Multiplexing, server push
- **HTTPS**: HTTP over TLS/SSL
- **Cookies**: Client-side state management

CDNs (Content Delivery Networks)

- Replicate content on many servers
- DNS-based redirection
- Akamai example: uses DNS hierarchy

Video Streaming

DASH (Dynamic Adaptive Streaming over HTTP)

- Client determines:
  - When to request chunk
  - What encoding rate to request
  - Where to request chunk from
- Server:
  - Divides video into chunks
  - Encodes each chunk at multiple rates
  - Sends manifest file to client

Content Distribution Networks (CDNs)

- Netflix: Own CDN (Open Connect)
- YouTube: Uses Google's CDN

Additional Key Points

DNS Resolution Process:

1. Local DNS cache
2. Recursive query to local DNS server
3. Root DNS server
4. TLD DNS server
5. Authoritative DNS server

TCP Congestion Control:

- Slow start
- Congestion avoidance
- Fast recovery

Network Address Translation (NAT):

- Allows multiple devices to share one public IP
- Modifies IP addresses in packet headers

Socket Programming:

- API for network communication
- TCP sockets: connection-oriented
- UDP sockets: connectionless