Network Architecture and Layers

Layer Model:

- Application: End-user services (e.g., HTTP, FTP)
- Transport: Process-to-process data transfer (e.g., TCP, UDP)
- Network: Routing of datagrams (e.g., IP)
- Link: Data transfer between adjacent nodes (e.g., Ethernet, WiFi)
- Physical: Transmission of raw bits (e.g., cabling, RF)

Encapsulation:

```
Application Data (M)
    Transport Header (H_t)
    Network Header (H_n)
    Link Header (H_l)
```

Layer Responsibilities:

- **Application:** Network process to application. (e.g., HTTP, DNS)
- **Transport:** Reliable/unreliable data transfer. (e.g., TCP, UDP).
- **Network:** Logical addressing, routing. (e.g., IP).
- **Link:** Physical addressing, frame transmission. (e.g., Ethernet).
- **Physical:** Media, signal, and binary transmission.

Key Protocols

HTTP: HyperText Transfer Protocol; used for transmitting web pages.
DNS: Domain Name System; translates domain names to IP addresses.
TCP/UDP:

- **TCP:** Connection-oriented, reliable, flow control, congestion control.
- **UDP:** Connectionless, unreliable, low overhead.

IP: Internet Protocol; handles routing of packets between source and destination.

TCP Services:

- Connection-Oriented: Handshake; prepares for data exchange.
- Reliable Data Transfer: Ensures error-free, in-order delivery.

UDP Services:

- Connectionless: No handshake before data transfer.
- Unreliable: No guarantees on message delivery.

Packet vs. Circuit Switching

Packet Switching:

- Data sent in packets.
- Each packet routed independently.
- Pros: Efficient, shared links.
- Cons: Variable delays.

Circuit Switching:

- Dedicated path for duration of the connection.
- Pros: Consistent E2E delay.
- Cons: Inefficient for bursty traffic.

Diagrams:

```
Packet:
    [Host] -- [Router] -- [Router] -- [Host]
Circuit:
    [Host] == [Router] == [Router] == [Host] (dedicated)
```

Performance Metrics

Types of Delays:

- Processing Delay: Time for router to process the packet header.
- Queuing Delay: Time waiting at the queue for transmission.
- Transmission Delay: L/R (packet length / transmission rate).
- Propagation Delay: d/s (distance / propagation speed).

Throughput: Rate at which data is successfully transferred (bits/sec).
Packet Loss: Packets that don't reach the destination.
Formula:

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

Web Technologies and CDNs

Web Technologies:

- HTTP(S), HTML, CSS, JavaScript.
- Client-server model.

CDN: Content Delivery Network; distributes content to servers closer to end-users to reduce latency.
Diagram:

```
[Client] -- [Edge Server]
  \/ CDN \/       ||
[Data Center] -- [Origin Server]
```

Video Streaming Concepts

Streaming Types:

- **Live:** Real-time broadcasting.
- **On-Demand:** Pre-recorded content.

Important Metrics:

- Bandwidth
- Buffering
- Bitrate (e.g., 360p, 720p, 1080p)

Example: Bitrate Calculation

$$\text{Total size} = \text{Bitrate} \times \text{Duration}$$