## Week 6:

## 1. Introduction to the Link Layer

The Link Layer is responsible for node-to-node communication within a network.

It provides framing, error detection, error correction, flow control, and addressing.

The primary function of the link layer is to encapsulate network-layer datagrams into frames for transmission.

### Key Terminology:

* Nodes: Devices such as hosts, routers, and switches.
* Links: Communication channels connecting adjacent nodes (e.g., wired, wireless, LANs).
* Frames: Link-layer packets that encapsulate network-layer datagrams.
* MAC (Media Access Control) Address: A unique identifier assigned to network interfaces.

## 2. Link Layer Services

### Framing & Link Access

* Data from the network layer is encapsulated into frames.
* A frame consists of a header, data, and trailer.
* Frame Headers contain source and destination MAC addresses.

### Reliable Delivery

* Ensures error-free transmission between two nodes.
* Typically used in wireless networks due to high error rates.
* Not commonly used on wired networks (low bit-error rates).

### Error Detection & Correction

* Error Detection: Identifies if an error occurred during transmission.
* Error Correction: Some protocols allow the receiver to correct errors without retransmission.

### Flow Control

* Regulates the pace of data transfer between sender and receiver.
* Prevents buffer overflow and packet loss.
* Half-Duplex vs. Full-Duplex Communication
* Half-Duplex: Nodes can transmit or receive, but not both at the same time.
* Full-Duplex: Both nodes can send and receive simultaneously.

## 3. Error Detection & Correction

### Types of Error Detection:

### Parity Checking

* Single-Bit Parity: Adds a single parity bit to detect single-bit errors.
* Two-Dimensional Parity: Can detect and correct single-bit errors.

### Internet Checksum

* Used in UDP, TCP, and IP headers.
* The sender adds the binary sum of data segments.
* The receiver checks if the sum is correct.

### Cyclic Redundancy Check (CRC)

* Uses polynomial division to detect errors.
* More powerful than parity checking or checksums.
* Used in Ethernet, Wi-Fi, and other network protocols.

## 4. Multiple Access Protocols

Multiple nodes must share the same transmission medium without interfering.

### Categories:

* Channel Partitioning (TDMA, FDMA)
* Random Access (ALOHA, CSMA)
* Taking Turns (Polling, Token Passing)

### Channel Partitioning

* TDMA (Time Division Multiple Access):
* Time is divided into fixed-length slots, with each station assigned a slot.
* Unused slots go idle, leading to inefficiency.
* FDMA (Frequency Division Multiple Access):
* The channel is divided into frequency bands assigned to each station.
* Unused frequencies remain idle, wasting bandwidth.

### Random Access

* Nodes transmit whenever they have data, but collisions may occur.

### Protocols:

* Pure ALOHA: Nodes transmit immediately, but collisions can occur.
* Slotted ALOHA: Nodes transmit at fixed time slots, improving efficiency.
* CSMA (Carrier Sense Multiple Access): Nodes listen before transmitting.
* CSMA/CD (Collision Detection): If a collision occurs, nodes abort transmission and retry.
* CSMA/CA (Collision Avoidance): Used in Wi-Fi networks, nodes wait for a clear channel before sending.

### Taking Turns

* Polling: A master node invites other nodes to transmit.
* Token Passing: A control token is passed between nodes to allow transmission.

## 5. Ethernet & MAC Addresses

### Ethernet

* The dominant wired LAN technology due to its simplicity and cost-effectiveness.
* Uses CSMA/CD (Carrier Sense Multiple Access with Collision Detection) for medium access control.
* MAC Addressing
* 48-bit unique identifier for each network interface.
* Assigned by device manufacturers (IEEE standard).
* Format: 1A-2F-BB-76-09-AD
* Comparison with IP Addressing:
* MAC Address: Physical, permanent, used for local communication.
* IP Address: Logical, hierarchical, can change based on network.
* Address Resolution Protocol (ARP)
* Used to map an IP address to a MAC address.

### Process:

* A device sends an ARP request asking for the MAC address of an IP.
* The target replies with its MAC address.
* The sender stores this in an ARP table for future use.

## 6. Switching & VLANs

### Ethernet Switches

* Store and forward frames based on MAC addresses.
* Reduce collisions by creating a separate collision domain for each connection.

### Self-Learning:

* A switch learns which MAC addresses are reachable through each interface.
* It maintains a forwarding table.

### Virtual LANs (VLANs)

* Segment a physical network into multiple logical networks.
* Improve security, scalability, and network efficiency.

## 7. A Day in the Life of a Web Request

Step-by-Step Process

* Device Joins the Network
* Uses DHCP (Dynamic Host Configuration Protocol) to obtain:
* IP Address
* Default Gateway
* DNS Server Address
* Address Resolution
* Uses ARP to find the MAC address of the default gateway.
* DNS Resolution
* Sends a DNS query to resolve www.google.com to an IP address.
* Establishing a TCP Connection
* Uses the TCP three-way handshake:
* SYN (Client → Server)
* SYN-ACK (Server → Client)
* ACK (Client → Server)
* Sending an HTTP Request
* HTTP request is sent to the web server.
* The web server processes the request and returns an HTTP response.
* Receiving and Displaying the Web Page
* The browser receives the HTML, CSS, JavaScript files and renders the page.

## 8. Summary

The Link Layer is crucial for efficient data transmission.

### Key Functions:

* Error Detection & Correction (Parity, CRC)
* Multiple Access Control (ALOHA, CSMA/CD, TDMA, FDMA)
* Addressing & Switching (MAC addresses, ARP, VLANs)
* Ethernet & Switches improve efficiency in modern networks.
* A web request involves multiple link-layer functions for successful data transfer.