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WiFi Training Program

Assignment – Module 1

1. **In which OSI layer the Wi-Fi standard/protocol fits?**

Wi-Fi (IEEE 802.11) primarily operates at the **Data Link Layer (Layer 2)** and the **Physical Layer (Layer 1)** of the **OSI model**:

Physical Layer (Layer 1)

- Defines the actual radio frequencies (e.g., 2.4 GHz, 5 GHz, 6 GHz for Wi-Fi 6E).
- Includes modulation techniques like **OFDM (Orthogonal Frequency Division Multiplexing)**.
- Specifies transmission power, antenna design, and encoding schemes.

Data Link Layer (Layer 2)

- **MAC (Medium Access Control) sublayer**:
  - Controls access to the shared wireless medium.
  - Implements protocols like **CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)** to avoid collisions.
  - Manages authentication, association, and encryption (e.g., WPA2/WPA3 security).
- **LLC (Logical Link Control) sublayer**:
  - Handles error detection and flow control.

Since Wi-Fi defines how devices communicate wirelessly over a shared medium, it does not operate at higher OSI layers like the Network (Layer 3) or Transport (Layer 4), which are handled by protocols like **IP and TCP/UDP**.

2. **Can you share the Wi-Fi devices that you are using day to day life, share that device's wireless capability/properties after connecting to network. Match your device to corresponding Wi-Fi Generations based on properties.**

Common Wi-Fi devices used in daily life, along with their wireless capabilities and corresponding **Wi-Fi generations**:

Router

- **Wireless Capability**:
    - Supports **Wi-Fi 4 (802.11n), Wi-Fi 5 (802.11ac), or Wi-Fi 6 (802.11ax)**, depending on the model.
    - Operates on **2.4 GHz, 5 GHz, and 6 GHz (for Wi-Fi 6E routers)**.
    - Uses technologies like **MIMO, MU-MIMO, Beamforming** for better performance.
    - Provides **dual-band or tri-band connectivity**.
- **Wi-Fi Generation**: **Wi-Fi 4, 5, or 6** (depends on the router model).

Smartphone (Wi-Fi Enabled)

- **Wireless Capability**:
    - Supports **Wi-Fi 5 (802.11ac) or Wi-Fi 6 (802.11ax)** in modern devices.
    - Dual-band support (2.4 GHz & 5 GHz, or even 6 GHz for Wi-Fi 6E models).
    - Features like **OFDMA, MU-MIMO, and WPA3 security**.
- **Wi-Fi Generation**: **Wi-Fi 5 or 6**, based on the phone model.

Laptop

- **Wireless Capability**:
    - Supports **Wi-Fi 5 (802.11ac) or Wi-Fi 6 (802.11ax)** for high-speed internet.
    - Dual-band or tri-band support.
    - Advanced features like **Beamforming and WPA3 security**.
- **Wi-Fi Generation**: **Wi-Fi 5 or 6**, depending on the laptop model.

Smart TV / Streaming Device

- **Wireless Capability**:
    - Supports **Wi-Fi 4, Wi-Fi 5, or Wi-Fi 6**, depending on the device model.
    - Dual-band connectivity for smooth 4K streaming.
    - Uses **5 GHz Wi-Fi for low-latency streaming**.
- **Wi-Fi Generation**: **Wi-Fi 4, 5, or 6**.

Smart Home Devices [Security Cameras]

- **Wireless Capability**:
    - Many support **Wi-Fi 4 (802.11n) at 2.4 GHz** (as 5 GHz consumes more power).
    - Security cameras may support **Wi-Fi 5 or Wi-Fi 6** for HD video streaming.
- **Wi-Fi Generation**: **Wi-Fi 4 or 5** (depends on the device).

3. What is BSS and ESS?

Basic Service Set (BSS) and Extended Service Set (ESS) in Wi-Fi

In Wi-Fi networks, **BSS (Basic Service Set) and ESS (Extended Service Set)** are terms that define how wireless networks are structured and how devices connect to them.

Basic Service Set (BSS)

- A **BSS is a single Wi-Fi network with one Access Point (AP)** and the connected devices (also called **stations** or **STAs**).
- The **BSSID (Basic Service Set Identifier)** is a **unique MAC address** assigned to the AP.
- Communication occurs **only within this set of devices**.
- **Two types of BSS:**
    - **Infrastructure BSS**: Involves an **Access Point (AP)**, and clients (e.g., laptop, phone) communicate **through the AP**.
    - **Independent BSS (IBSS)**: A Wi-Fi **Ad-Hoc** mode where devices communicate **directly without an AP**.

Example:
A home router with Wi-Fi enabled and connected devices (laptop, phone) forms a **BSS**.

Extended Service Set (ESS)

- An **ESS is a collection of multiple BSSs**, all connected to the **same wired network (Distribution System, DS)**.
- The APs in an ESS have the **same SSID (Wi-Fi network name)** to allow **seamless roaming** between them.
- Each AP still has a unique **BSSID**, but clients can move between them while staying connected to the same Wi-Fi network.

Example:
In an office or university, multiple Wi-Fi access points cover the entire area under a single **SSID**, allowing users to roam without disconnecting.

4. What are the basic functionalities of Wi-Fi Accesspoint?

Basic Functionalities of a Wi-Fi Access Point (AP)

A **Wi-Fi Access Point (AP)** is a device that allows wireless devices to connect to a wired network using **Wi-Fi**. Here are its key functionalities:

Wireless Connectivity

- Provides a **wireless network** for devices like laptops, smartphones, and IoT devices to connect.
- Uses Wi-Fi **radio frequencies** (**2.4 GHz, 5 GHz, 6 GHz**) to transmit data.

Example: Your home router's Wi-Fi AP lets your phone connect to the internet wirelessly.

Signal Transmission and Reception

- Converts wired network signals (Ethernet) into **wireless radio signals**.
- Uses **modulation techniques** like **OFDM (Orthogonal Frequency Division Multiplexing)** to send data.
- Supports **MIMO (Multiple Input Multiple Output)** for better performance.

Example: Wi-Fi 6 APs use **MU-MIMO (Multi-User MIMO)** to serve multiple devices efficiently.

Network Bridging (Wired to Wireless)

- Acts as a **bridge** between **wired (Ethernet) and wireless networks**.
- Devices connected to the AP can communicate with **wired servers, printers, and other network devices**.

Example: Office Wi-Fi APs connect wireless devices to **wired servers**.

Assigning IP Addresses (via DHCP or Static Configuration)

- Can act as a **DHCP relay** or work with a **DHCP server** to assign **IP addresses** to connected devices.
- If working as a **standalone AP**, it just connects devices and lets the router handle DHCP.

Example: Your Wi-Fi router's AP assigns IP addresses like **192.168.1.X** to devices.

Security & Authentication

- Implements **Wi-Fi security protocols** to prevent unauthorized access:
    - **WEP (Weak, outdated)**
    - **WPA/WPA2 (Common, secure)**
    - **WPA3 (Latest, more secure)**
- Uses **MAC address filtering** to allow/block specific devices.
- Can enable **Captive Portal** (e.g., in hotels, public Wi-Fi) for user authentication.

Example: Your home Wi-Fi requires a **WPA2 password** to connect securely.

Roaming Support (ESS with Multiple APs)

- Supports **seamless roaming** between APs in an **Extended Service Set (ESS)**.
- Uses **Fast Roaming (802.11r, 802.11k, 802.11v)** for better mobility.

Example: In a **university or office**, you move from one room to another without losing Wi-Fi.

Monitoring & Troubleshooting

- Logs device connections, signal strength, and bandwidth usage.
- Supports **SNMP (Simple Network Management Protocol)** for remote monitoring.
- Allows **Wi-Fi spectrum analysis** to detect interference.

Example: IT admins monitor **AP usage and performance** in large networks.

5. Difference between Bridge mode and Repeater mode.

Bridge Mode vs. Repeater Mode

Both **Bridge Mode** and **Repeater Mode** are used in networking to extend Wi-Fi coverage or connect different network segments.

Bridge Mode

- **Purpose**: **Connects two separate networks** (usually wired), allowing devices on each network to communicate.
- **How It Works**:
    - **Bridge mode** connects **two routers** (or APs) over a wired connection (Ethernet cable).
    - The second router/AP **bridges** the network, passing traffic between the two segments. The devices connected to both routers are treated as part of the same network.
    - **IP address management** is usually handled by the primary router (the second router may disable its DHCP server).
- **Key Characteristics**:
    - **Extends a wired network** between two locations (e.g., two buildings).
    - Provides **full bandwidth** for devices on both sides since the connection is **wired**.
    - The **second device does not create a separate wireless network**. Instead, it extends the primary network.

- **Use Cases**:
    - Connecting devices in two distant rooms/buildings using Ethernet to bridge them over Wi-Fi.
    - Expanding the range of a wired network.
- **Example**:
  Presence of a router in the living room and another router in the garage. By setting the second router to **bridge mode**, it will extend the primary network to the garage via a wired Ethernet connection.

Repeater Mode

- **Purpose**: **Extends the range of a wireless network** by **rebroadcasting** the signal from the primary router.
- **How It Works**:
    - **Repeater mode** takes the existing wireless signal from your router and **repeats it** to areas with weak or no signal.
    - The **repeater does not create a new network**; it simply boosts the current Wi-Fi signal.
    - Devices that connect to the repeater are usually assigned **IP addresses** from the main router via DHCP.
- **Key Characteristics**:
    - **Wireless connection** between the main router and the repeater, meaning bandwidth is shared.
    - **Reduced speed**: Since the repeater uses the same channel to receive and send signals, the bandwidth can be halved.
    - **Easy to set up**: No Ethernet cables are needed, just Wi-Fi.
- **Use Cases**:
    - Expanding Wi-Fi coverage in larger homes, offices, or areas with dead zones.
    - Enhancing the Wi-Fi signal in areas that are out of range from the main router.
- **Example**:
  Presence of a router in one corner of the home, and the Wi-Fi signal doesn't reach the farthest room. So setting up a **repeater** in the middle of the house to amplify and extend the signal into the other rooms.

6. What are the differences between 802.11a and 802.11b?

Frequency Band

Feature	802.11a	802.11b
Frequency	**5 GHz**	**2.4 GHz**
Interference	Less interference (fewer devices on 5 GHz)	More interference (crowded 2.4 GHz band)

- **802.11a operates on the 5 GHz band**, which has **less interference** but **shorter range**.
- **802.11b operates on the 2.4 GHz band**, which is **more crowded** (microwaves, Bluetooth, baby monitors) but **has better range**.

Data Transfer Speed

Feature	802.11a	802.11b
Maximum Speed	**54 Mbps**	**11 Mbps**
Real-world Speed	Around **25-30 Mbps**	Around **4-6 Mbps**

- **802.11a is much faster** (up to **54 Mbps**) compared to **802.11b (11 Mbps)**.
- 802.11b was **cheaper and more widely adopted** despite being slower.

Range & Coverage

Feature	802.11a	802.11b
Maximum Range (Indoor)	**~50 feet (15m)**	**~150 feet (45m)**
Maximum Range (Outdoor)	**~100 feet (30m)**	**~300 feet (90m)**

- **802.11a has a shorter range** because 5 GHz signals are absorbed more by walls and obstacles.
- **802.11b has a longer range** as 2.4 GHz waves travel farther.

Modulation & Performance

Feature	802.11a	802.11b
Modulation	**OFDM (Orthogonal Frequency Division Multiplexing)**	**DSSS (Direct Sequence Spread Spectrum)**
Efficiency	More efficient, supports multiple users	Less efficient, lower data rates

- **802.11a uses OFDM**, which is more **efficient for high-speed data** and supports more devices.
- **802.11b uses DSSS**, which is simpler but **slower**.

Cost & Adoption

Feature	802.11a	802.11b
Cost	More expensive	Cheaper
Popularity	Less common	More widely adopted

- **802.11b was cheaper** and became **more popular in early consumer Wi-Fi devices**.
- **802.11a was mainly used in businesses and enterprise networks** due to higher cost and speed.

7. Configure your modem/hotspot to operate only in 2.4 Ghz and connect your laptop/Wi-Fi device, and capture the capability/properties in your Wi-Fi device. Repeat the same in 5 Ghz and tabulate all the differences your observed during this.

Connect the laptop to 2.4 Ghz and run **'netsh wlan show interfaces'** in the cmd. Repeat the same after connecting it to 5 Ghz. The differences observed during the execution of commands are as follows:

Feature	2.4 Ghz	5 Ghz
Radio type	802.11n	802.11ac
Band	2.4 Ghz	5 Ghz
Channel	1	40
Receive Rate (Mbps)	144.4	526.5
Transmit Rate (Mbps)	130	180

8. What is the difference between IEEE and WFA?

IEEE (Institute of Electrical and Electronics Engineers)

- **What it does**:
    - IEEE is a global **standards development organization** that creates and maintains technical standards.
    - It defines the **802.11 Wi-Fi standards** (e.g., 802.11a/b/g/n/ac/ax).
- **Role in Wi-Fi**:
    - IEEE develops **technical specifications** for Wi-Fi (e.g., speed, frequency bands, modulation).
    - Examples of IEEE Wi-Fi standards:

        - **802.11a (1999) – 5 GHz, 54 Mbps**
        - **802.11b (1999) – 2.4 GHz, 11 Mbps**
        - **802.11g (2003) – 2.4 GHz, 54 Mbps**
        - **802.11n (2009) – Dual-band, up to 600 Mbps**
        - **802.11ac (2013) – 5 GHz, Gigabit speeds**
        - **802.11ax (Wi-Fi 6, 2019) – More efficiency, better range**
- **Key Point**: IEEE **defines Wi-Fi standards but does not enforce them**.

WFA (Wi-Fi Alliance)

- **What it does**:
    - The Wi-Fi Alliance (WFA) is a **global industry organization** that **certifies** Wi-Fi products.
    - It ensures devices **follow IEEE 802.11 standards** and **work with other Wi-Fi devices**.
- **Role in Wi-Fi**:
    - WFA **tests and certifies** devices for compatibility, security, and performance.
    - Introduced **Wi-Fi branding** (e.g., Wi-Fi 4, Wi-Fi 5, Wi-Fi 6).
    - Ensures **interoperability** between different manufacturers.
- **Wi-Fi Certification Examples**:
    - **WPA, WPA2, WPA3** (Wi-Fi security standards).
    - **Wi-Fi 6 Certified** (devices meeting IEEE 802.11ax standards).
    - **Wi-Fi Direct** (peer-to-peer connections without a router).
- **Key Point**: WFA **certifies devices but does not create the standards**.

9. **List down the type of Wi-Fi internet connectivity backhaul, share your home/college's wireless internet connectivity backhaul name and its properties.**

Types of Wi-Fi Internet Connectivity Backhaul

A **Wi-Fi backhaul** refers to the method used to connect **Wi-Fi router or access point to the internet** (or to other routers in a mesh system). The backhaul can be **wired** (fiber, Ethernet) or **wireless** (Wi-Fi, satellite, cellular).

Wired Backhaul (More Stable & High Speed)

Type	Speed	Latency
Fiber Optic (FTTH)	1 Gbps – 10 Gbps	**Very Low** (1-5 ms)
Ethernet (Wired LAN)	100 Mbps – 10 Gbps	**Very Low** (1-2 ms)
Cable Broadband (Coaxial DOCSIS)	100 Mbps – 1 Gbps	**Low** (10-30 ms)
DSL (Phone Line - ADSL/VDSL)	10-100 Mbps	**Medium** (20-50 ms)
Powerline (PLC)	50-500 Mbps	**High** (50+ ms)

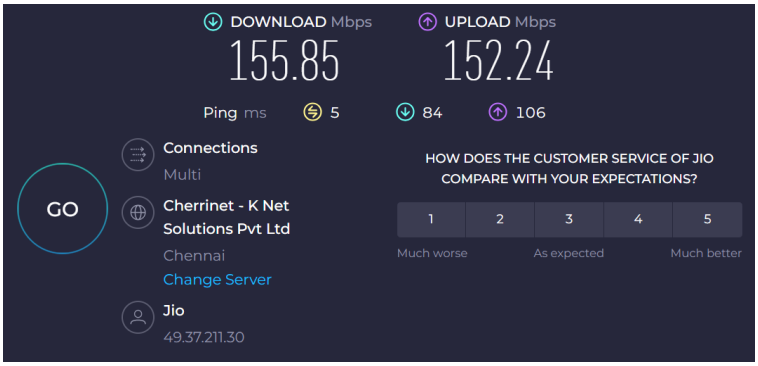
Wireless Backhaul (More Flexible, Less Stable)

Type	Speed	Latency
Wi-Fi Backhaul (Wireless Mesh Systems)	300 Mbps – 1 Gbps	**Medium** (10-50 ms)
4G LTE/5G Cellular	10 Mbps – 1 Gbps	**Medium-High** (20-100 ms)
Satellite Internet (Starlink, VSAT)	50-250 Mbps	**High** (30-100 ms)
Microwave Point-to-Point	100 Mbps – 1 Gbps	**Low-Medium** (10-30 ms)

Home Wireless Internet Connectivity Backhaul

✅ **4G LTE/5G (Wireless Cellular Backhaul)**

speedtest.net



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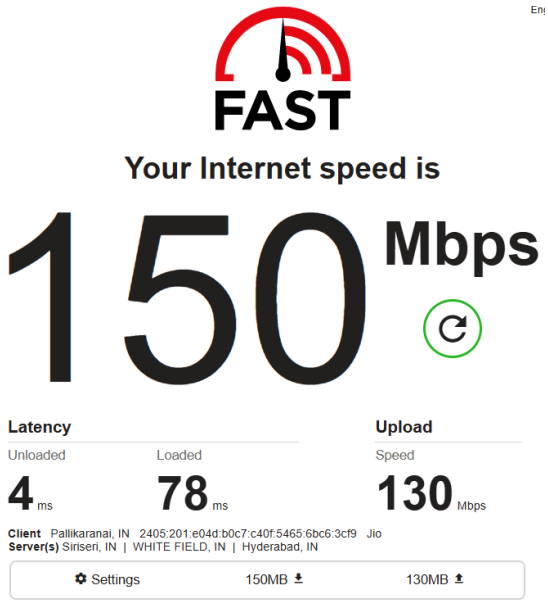

10. List down the Wi-Fi topologies and use cases of each one.

Wi-Fi Topology	Use Cases
Infrastructure Mode	Home & office networks, public Wi-Fi
Repeater Mode	Extending Wi-Fi in large areas
Bridge Mode	Connecting wired & wireless networks
Ad-Hoc Mode	Direct device-to-device communication (LAN gaming, file sharing)
Mobile Hotspot Mode	Internet sharing via phone (travel, backup internet)
Mesh Mode	Whole-home or enterprise Wi-Fi coverage
Work Group Bridge Mode	Connecting wired devices (printers, CCTV) to Wi-Fi
IoT Gateway Mode	Smart homes, industrial IoT, automation