Wi-Fi TRAINING - MODULE 1

Akash S, embedUR Systems

Qn 1:

In which OSL layer the Wi-Fi standard/protocol fits.

Layer?

- Wi-Fi (IEEE 802.11) operates primarily in
    - **Data Link Layer (L2)**
    - **Physical Layer (L1)**

Why?

- It fits into the lower two layers of OSI model because it handles the physical transmission of data and logical organization of frames over **wireless** medium

Wi-Fi in Layer 1:

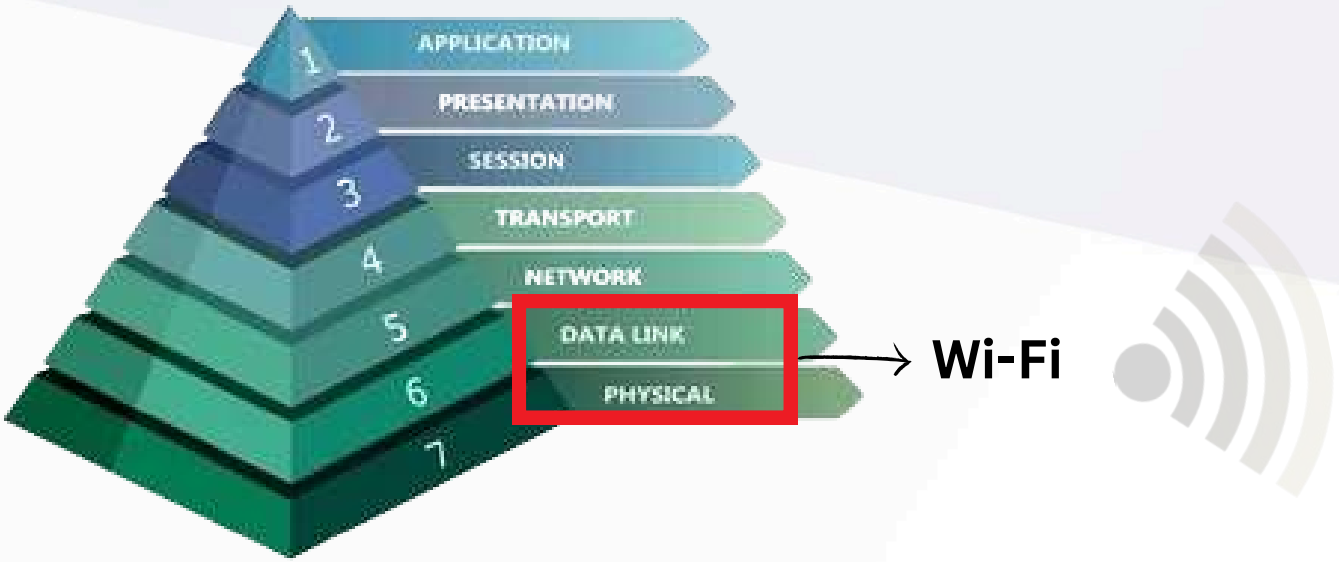
- Physical layer is responsible for the transmission of data over a physical medium
- In this case, the medium is **radio waves**
- WiFi uses frequency range like **2.4GHz, 5GHz, 6GHz** (802.11ax)
- **Example:**
    - When a Wi-Fi device sends a signal, Layer 1 defines how that signal is modulated onto a carrier wave and transmitted through the air.

Wi-Fi in Layer 2:

- Data link layer ensures reliable data transfer between devices on the same network
- MAC address is assigned, Packets are Framed, Error detection and Retransmission are carried out in this layer

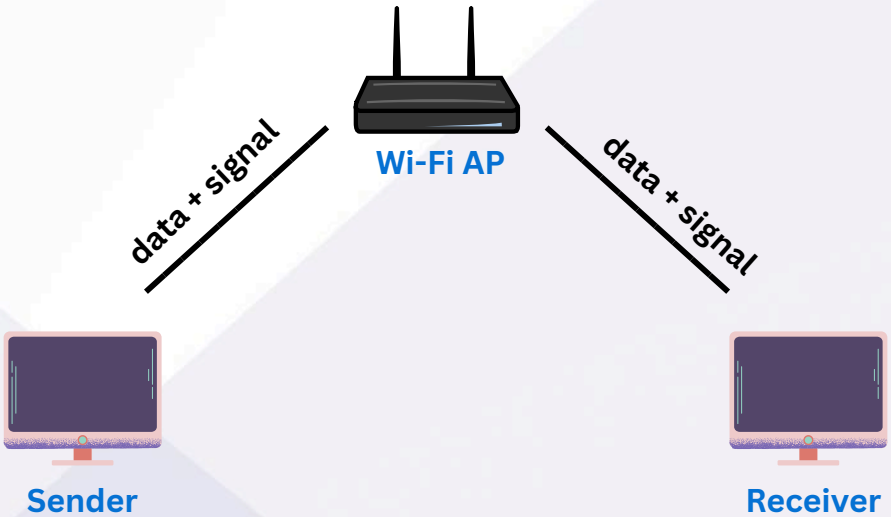
Why not on higher layers?

- WiFi core standards do not extend to the Network Layer or beyond
- Because it focuses on **local wireless connectivity.**



How Wi-Fi works?

- WiFi uses **radio frequencies** to send and receive data wirelessly
- Our device connects to a Wi-Fi **Access Point**
- Routers convert digital data into radio signals and broadcast them
- On the receiving end, the device picks up the radio signals and convert them back to data
- Every device will have a unique MAC address to avoid confusions
- To avoid signal clashes, WiFi uses **CSMA/CA**



Qn 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

My everyday Wi-Fi devices:

Laptop (HP):

Wireless Properties:

- Frequency Band: **5 GHz**
- Max Speed: **325 Mbps** (Receive/Transmit Rate)
- Protocol: **802.11ac**
- Signal: **90%** (-40 to -50 dBm)
- Channel: **153** (40 MHz width)
- Authentication: **WPA2-Personal**

Wi-Fi Generation Match:

- Wi-Fi 5 (802.11ac)

How I checked?

```
PS C:\Users\akash> netsh wlan show interfaces

There is 1 interface on the system:

    Name                   : Wi-Fi
    Description            : Realtek RTL8822CE 802.11ac PCIe Adapter
    GUID                   : f0395c50-ded1-47c0-ba61-fb770de881e5
    Physical address       : c8:94:02:34:f1:69
    Interface type         : Primary
    State                  : connected
    SSID                   : Ajay Aakash_5G
    BSSID                  : 04:ab:08:b6:f2:03
    Network type           : Infrastructure
    Radio type             : 802.11ac
    Authentication         : WPA2-Personal
    Cipher                 : CCMP
    Connection mode        : Profile
    Band                   : 5 GHz
    Channel                : 153
    Receive rate (Mbps)    : 325
    Transmit rate (Mbps)   : 325
    Signal                 : 90%
    Profile                : Ajay Aakash_5G

    Hosted network status  : Not available
```

Smart Phone (VIVO v30):

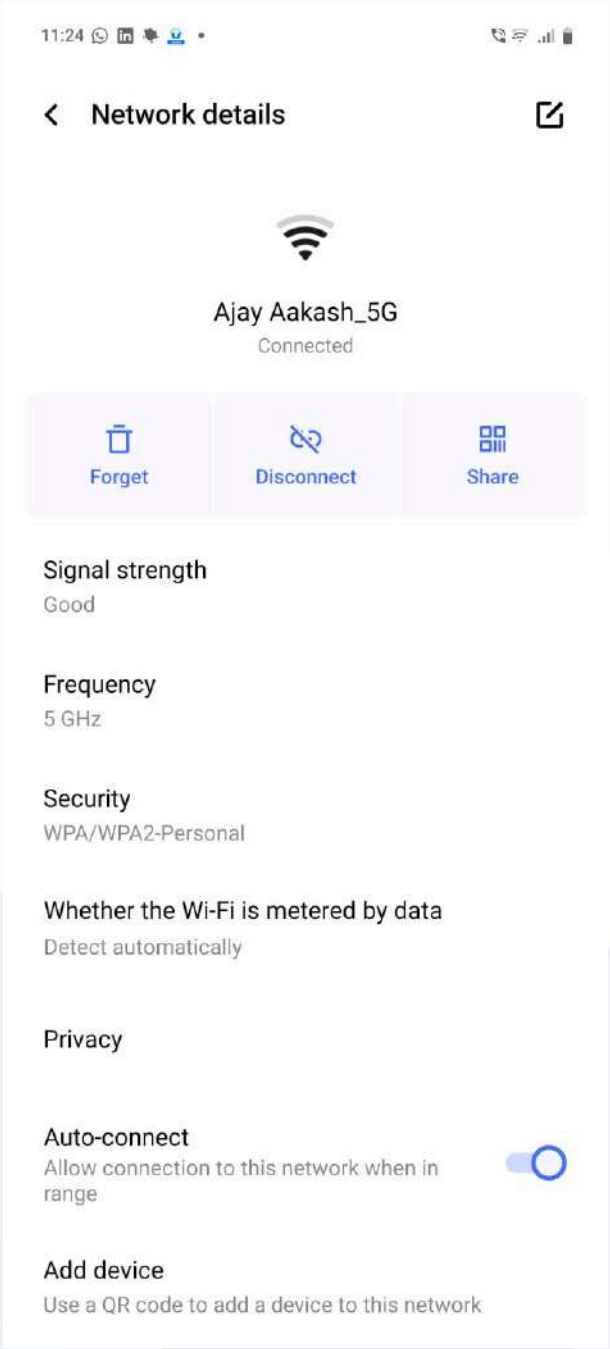
Wireless Properties:

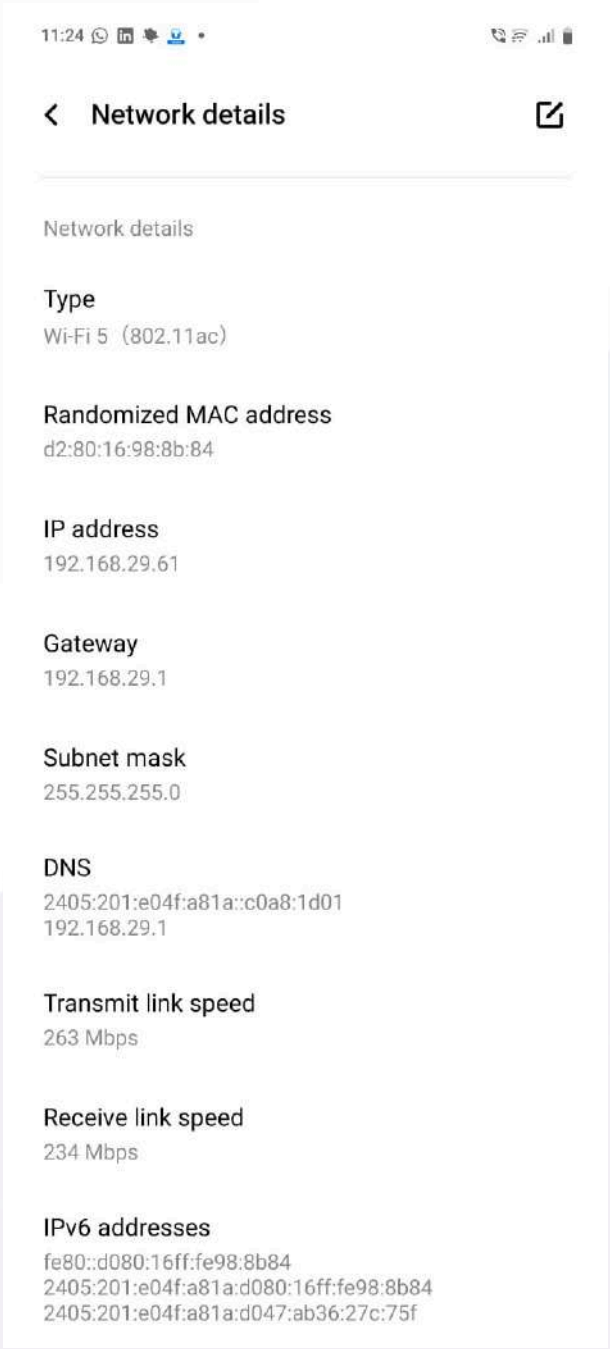
- Frequency Band: **5 GHz**
- Max Speed: **263 Mbps** (Transmit), **234 Mbps** (Receive)
- Protocol: **802.11ac** (Wi-Fi 5, as shown in the screenshot)
- Signal: **Good** (estimated ~80-90%, based on “Good” label)
- Authentication: **WPA/WPA2-Personal**

Wi-Fi Generation Match:

- Wi-Fi 5 (802.11ac)

How I checked?





Smart TV (TCL HD):

Wireless Properties:

- Frequency Band: **2.4 GHz and 5 GHz** (dual band)
- Max Speed: **300-867 Mbps** (on 5 GHz)
- Protocol: **802.11ac** (varies by model)
- Features: **Basic MIMO** (802.11ac)

Wi-Fi Generation Match:

- Wi-Fi 5 (802.11ac)

Jio Fiber Router:

Wireless Properties:

- Frequency Band: **2.4 GHz and 5 GHz**
- Max Speed: **300 Mbps** (2.4 GHz), **867 Mbps** (5 GHz)
- Protocol: **802.11ac**
- Features: **Dual-band, 4x4 MIMO**

Wi-Fi Generation Match:

- Wi-Fi 5 (802.11ac)

Wi-Fi Generation Matching:

Device	Wi-Fi Standard	Generation	Max Speed	Frequency Band
Laptop (HP)	802.11ac	Wi-Fi 5	325 Mbps	5 GHz
Smartphone (Vivo V30)	802.11ac	Wi-Fi 5	263 Mbps (Tx), 234 Mbps (Rx)	5 GHz
Smart TV (TCL)	802.11ac	Wi-Fi 5	300-867 Mbps	2.4 GHz / 5 GHz
JioFiber Router	802.11ac	Wi-Fi 5	300 Mbps (2.4 GHz), 867 Mbps (5 GHz)	2.4 GHz / 5 GHz

Qn 3:

what is BSS and ESS?

Basic Service Set (BSS):

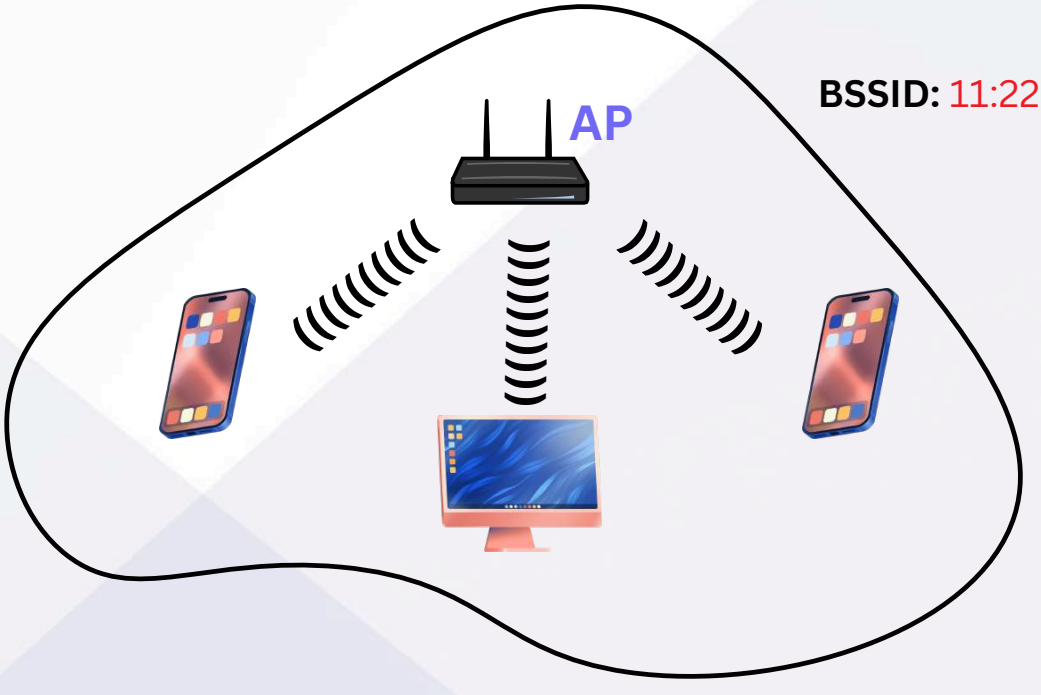
- BSS is the fundamental or basic building block of wifi network
- The architecture looks like a single **Access Point** and multiple devices connected to it
- These devices communicate over a shared wireless medium

Features of BSS:

- Each BSS is given an unique ID called **BSSID**
- BSSID is typically the **MAC Address** of the **Access Point**
- Operates on a specific channel (For example: 2.4GHz)
- Every device within BSS can communicate directly with **AP**

How BSS works?

- A single AP sends Wi-Fi signal on a specific channel to create a local network
- Devices connect to the AP using the BSSID
- AP receives data from one device and sends it to another device
- Connected devices must stay in the **AP's region** (50-100m)



Extended Service Set (ESS):

- ESS is a larger WiFi network formed by connecting multiple BSS networks
- It allows devices to roam seamlessly across different Access Points while staying connected to the same network

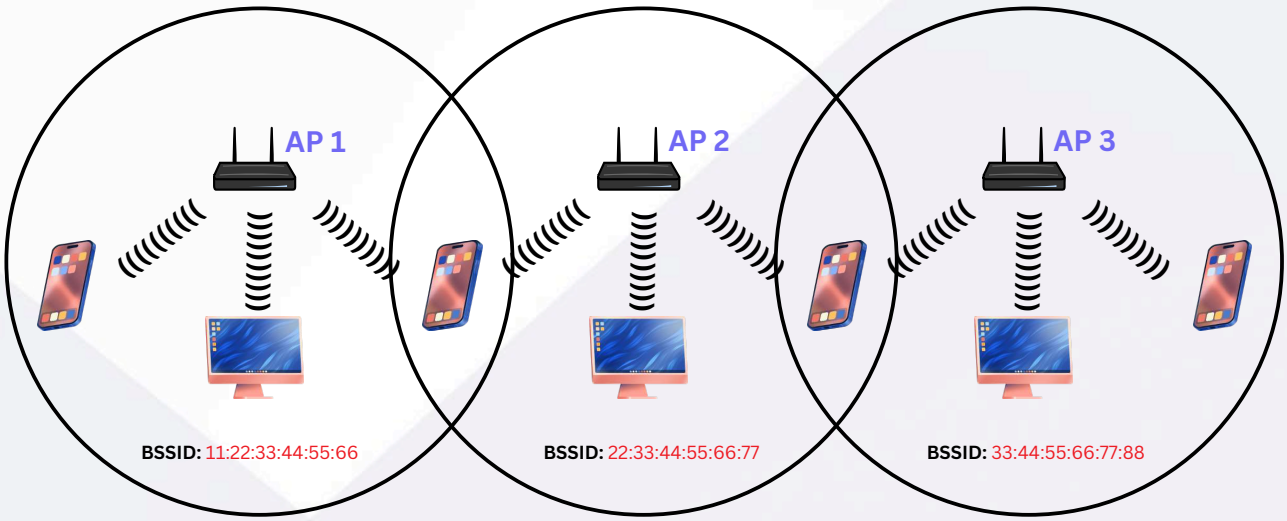
Features of ESS:

- All the **Access Points** in the ESS share the same **SSID**
- **BSSID** varies for different networks but **SSID** is same for all
- It requires wired or wireless backhaul to connect t

How ESS works?

- Several APs are connected via Ethernet or wireless backhaul and configured a single SSID for the entire large network
- Devices can move freely as they are connected to the same SSID
- APs work together to handle **Handoffs**
- Together it makes a large network (For example: Campus)

SSID: 99:88:77:66:55:44



Qn 4:

what are the basic functionalities of Wi-Fi Accesspoint

Access Point:

- A Wi-Fi Access Point (AP) is a networking device that allows wireless devices to connect to a wired network.
- It acts as a bridge between wireless clients and the wired network

Features of BSS:

Wireless Tx & Rx:

- AP transmits and receives **radio signals** to enable communication between wireless devices
- It uses WiFi standards like 802.11a/b/g/n/ac/ax to provide connectivity

SSID Broadcast:

- APs broadcast the network name for the clients to discover it
- AP has security features like **WPA2/WPA3** to restrict access

Multiple Clients:

- APs can manage multiple devices and allocate bandwidth dynamically to ensure the network is stable using **load balancing and QoS techniques**

Frequency:

- Operates in **2.4GHz, 5GHz** and **6GHz** (modern)
- It uses channel selection algorithm to avoid interference

Roaming:

- Seamless transition between multiple APs in ESS

Power:

- Can be powered using **Power over Ethernet (PoE)**
- Can save energy using sleep modes and power saving modes

VLAN:

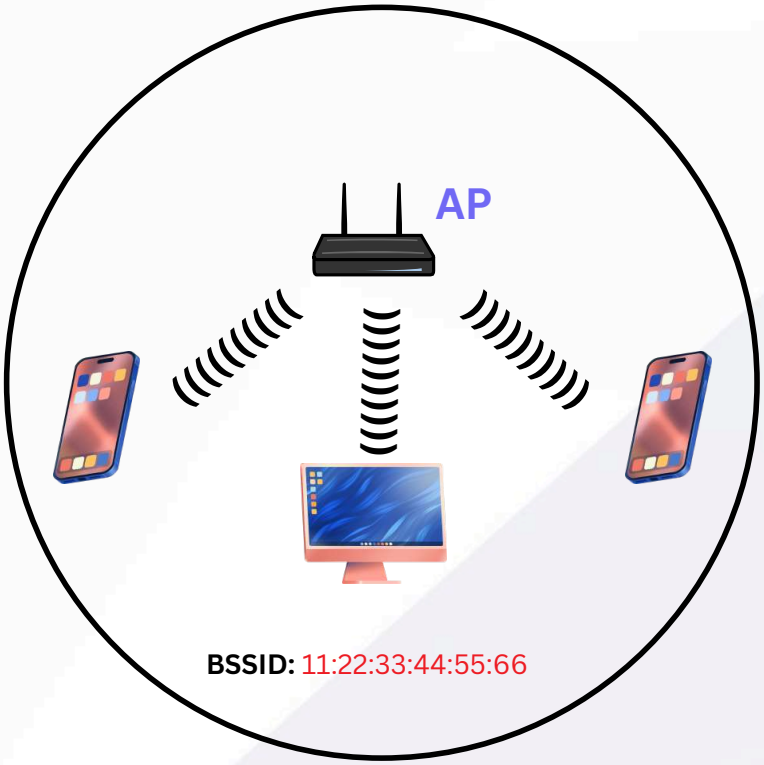
- Can integrate VLANs to isolate networks and reduce traffic

MAC & ACL:

- Provides MAC address filtering and **Access Control List** features to restrict accesses

Mesh WiFi:

- Provides wider coverage area
- To eliminate dead zones



Qn 5:

Difference between Bridge mode and Repeater mode

Bridged Mode:

- Bridge Mode is used to connect two separate networks and enable communication between them.
- It works by linking two routers or Access Points so that devices on both sides can communicate while remaining in different subnets

Key features:

- Operates at the **Data Link Layer** of the OSI model
- It will not assign any IP, it will just forward the traffic - **No NAT**
- Commonly used in large networks like campuses to connect different distant networks
- A bridge can be a wired (Ethernet) or wireless (WiFi bridge)

Repeater Mode:

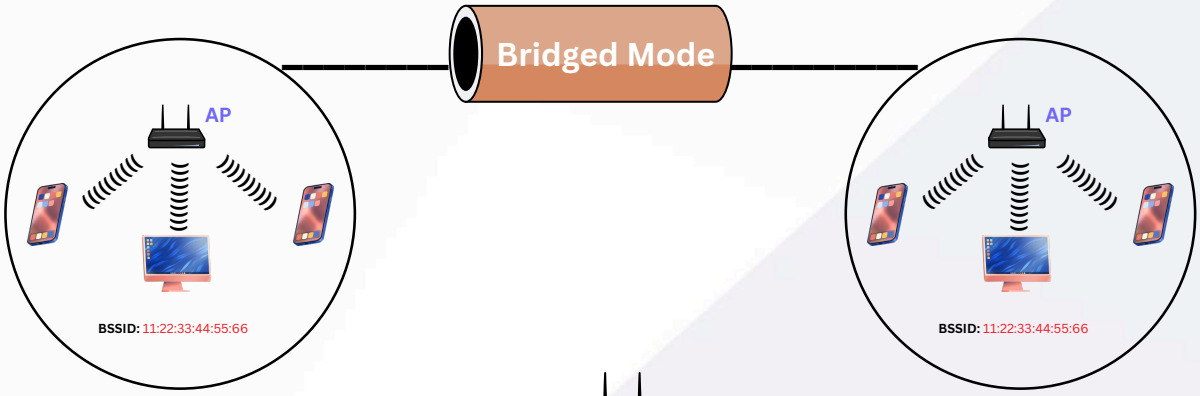
- Repeater Mode is used to extend the range of an existing Wi-Fi network by retransmitting signals.
- Unlike Bridge Mode, it does not create a new network but simply amplifies an existing one to cover dead zones.

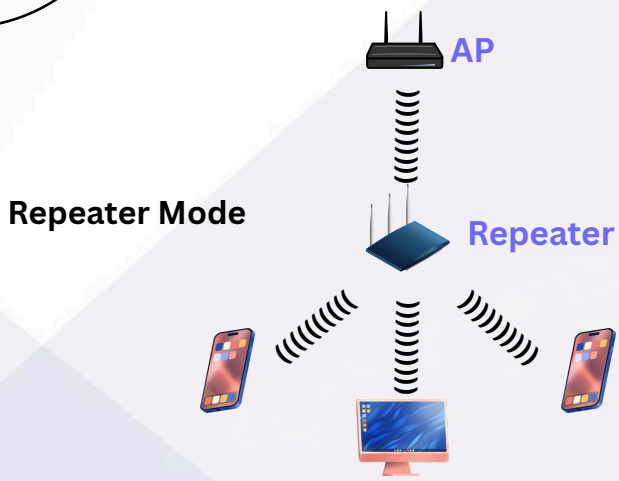
Key features:

- Works at the **Physical Layer** of the OSI model by capturing and repeating signals
- Devices connected to the repeater must remain in the same network
- Since it rebroadcasts the same frequency -> speed and performance drops
- Works entirely wirelessly - easy!

Differences:

FEATURE	BRIDGED MODE	REPEATER MODE
Function	Connects 2 networks	Extends an existing network
OSI Layer	Data Link Layer (2)	Physical Layer (1)
IP Subnet	Different	Same
Signal Type	Wired or Wireless	Wireless only
Performance	Stable	Speed is reduced due to re-tx
NAT	No NAT, just forwarding	No IP address changes
Best for	Enterprise, VLANs	Home, Offices





Qn 6:

what are the differences between 802.11a and 802.11b.

IEEE 802.11a:

- Developed for **high-speed wireless networking** in professional and enterprise environments
- Uses the **5 GHz** frequency band, reducing interference from household devices
- Faster but has a shorter range due to higher frequency signal attenuation

Key features:

- Operates in the **5** GHz band.
- Supports up to **54** Mbps data rate.
- Shorter range due to higher frequency (**25-30** meters indoors).
- **Less interference** because 5 GHz is less crowded.
- Preferred for business/enterprise networks where speed is more critical than range.

Frequency Bands:

- Less crowded - so less interference issues
- **23 Non overlapping** channels are provided
- High frequency waves do not penetrate through walls

IEEE 802.11b:

- Designed for **wider adoption** in homes and public areas due to affordability.
- Operates in the **2.4 GHz** frequency band, making it compatible with most devices.
- Slower than 802.11a but provides better range.

Key features:

- Operates in the 2.4 GHz band.
- Supports up to 11 Mbps data rate.
- Longer range (35-40 meters indoors) because 2.4 GHz signals travel farther.
- More prone to interference from Bluetooth, microwaves, and other 2.4 GHz devices.
- Popular for home networks and long-range applications.

Frequency Bands:

- More prone to interference
- Only **3 non-overlapping channels -** so congestion increases
- Better penetration through walls leading to longer-range connectivity.

Comparison:

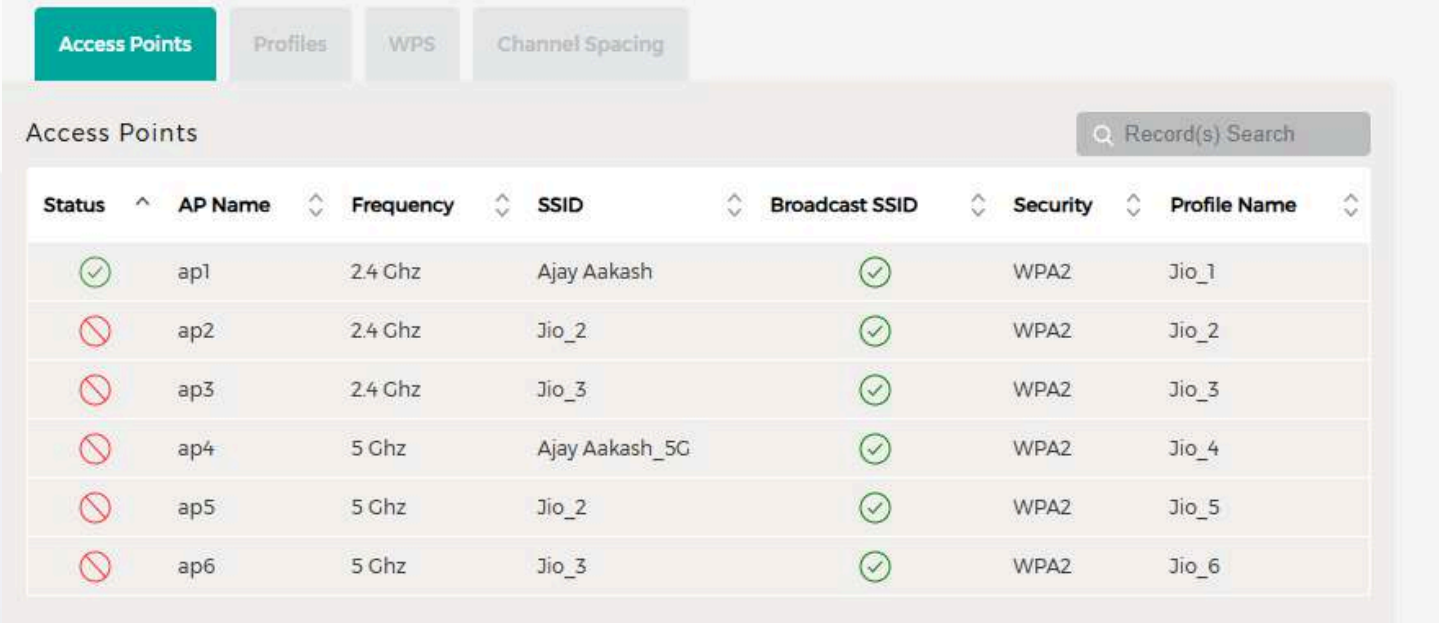
FEATURE	802.11a	802.11b
Function	5 GHz	2.4 GHz
Speed	Upto 54 Mbps	Upto 11 Mbps
Range	Shorter (25-30m)	Longer (30-40m)
Interference	Less Interference (few)	More Interference (crowd)
Overlapping Channel	23 non-overlapping	3 non-overlapping
Power Consumption	Higher	Lower
Best for	Office, Enterprises	Home, Public Wifi

Qn 7:

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

Steps to Configure:

- I opened my browser and typed "**192.168.29.1**" to access my **Jio** router's admin page. I entered the username and password
    - username: **admin**
    - password: **Jiocentrum**
- I went to the "Wireless Settings" tab, found the band options, and unchecked the 5 GHz box to disable it. I kept the 2.4 GHz band active with my SSID "**AkashWiFi**" and saved the changes.
- I grabbed my laptop, clicked the Wi-Fi icon, selected "AkashWiFi," and connected. I checked the properties in "**Network & Internet**" → "**Wi-Fi Properties**" on Windows.
- Back in the rputer's settings, I re-enabled 5 GHz, unchecked 2.4 GHz, and saved again. I reconnected my laptop to "AkashWiFi" (now on 5 GHz) and noted the new properties.
- For both bands, I right-clicked the Wi-Fi icon, opened **Network and Sharing Center**, clicked my network, and viewed the "Details" tab to get the specs.



2.4 GHz Enabled
5 GHz Disabled

```
Windows PowerShell

Install the latest PowerShell for new features and improvements! http

PS C:\Users\akash> netsh wlan show interfaces

There is 1 interface on the system:

    Name                   : Wi-Fi
    Description            : Realtek RTL8822CE 802.11ac PCIe Adapter
    GUID                   : f0395c50-ded1-47c0-ba61-fb770de881e5
    Physical address       : c8:94:02:34:f1:69
    Interface type         : Primary
    State                  : connected
    SSID                   : Ajay Aakash
    BSSID                  : 04:ab:08:b6:f2:02
    Network type           : Infrastructure
    Radio type             : 802.11n
    Authentication         : WPA2-Personal
    Cipher                 : CCMP
    Connection mode        : Auto Connect
    Band                   : 2.4 GHz
    Channel                : 6
    Receive rate (Mbps)    : 130
    Transmit rate (Mbps)   : 130
    Signal                 : 95%
    Profile                : Ajay Aakash

    Hosted network status  : Not available
```

5 GHz enabled
2.4 GHz disabled

Access Points

Record(s) Search

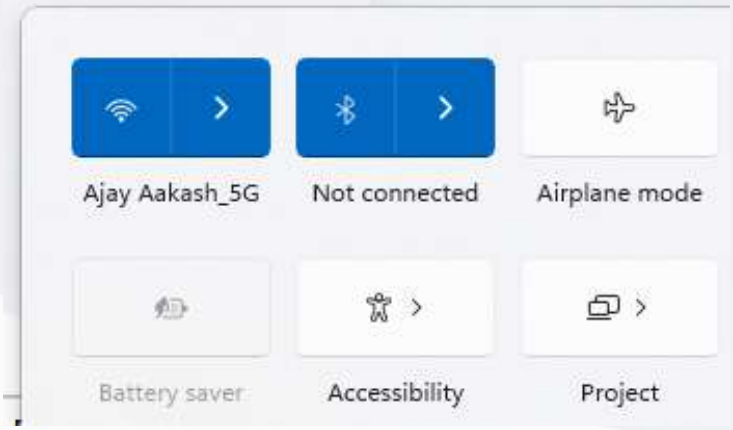
Status	AP Name	Frequency	SSID	Broadcast SSID	Security	Profile Name
⊘	ap1	2.4 Ghz	Ajay Aakash	✓	WPA2	Jio_1
⊘	ap2	2.4 Ghz	Jio_2	✓	WPA2	Jio_2
⊘	ap3	2.4 Ghz	Jio_3	✓	WPA2	Jio_3
✓	ap4	5 Ghz	Ajay Aakash_5G	✓	WPA2	Jio_4
⊘	ap5	5 Ghz	Jio_2	✓	WPA2	Jio_5
⊘	ap6	5 Ghz	Jio_3	✓	WPA2	Jio_6

5 GHz enabled
2.4 GHz disabled

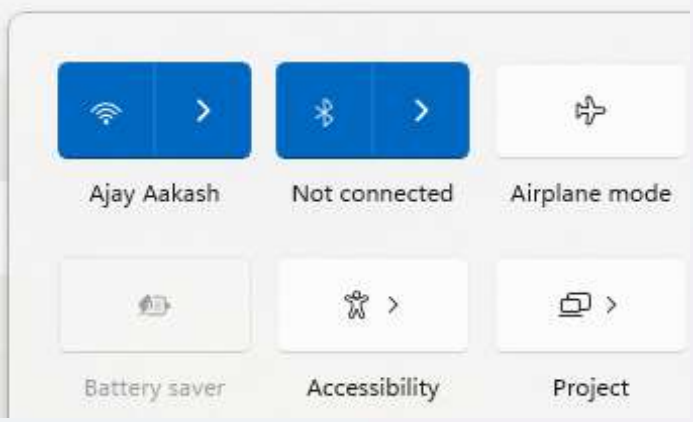
```
Name                   : Wi-Fi
Description            : Realtek RTL8822CE 802.11ac PCIe Adapter
GUID                   : f0395c50-ded1-47c0-ba61-fb770de881e5
Physical address       : c8:94:02:34:f1:69
Interface type         : Primary
State                  : connected
SSID                   : Ajay Aakash_5G
BSSID                  : 04:ab:08:b6:f2:03
Network type           : Infrastructure
Radio type             : 802.11ac
Authentication         : WPA2-Personal
Cipher                 : CCMP
Connection mode        : Profile
Band                   : 5 GHz
Channel                : 153
Receive rate (Mbps)    : 325
Transmit rate (Mbps)   : 325
Signal                 : 90%
Profile                : Ajay Aakash_5G

Hosted network status  : Not available
```

5 GHz



2.4 GHz



Tabulating the observations:

Parameter	2.4 GHz (Ajay Aakash)	5 GHz (Ajay Aakash_5G)
Radio Type	802.11n	802.11ac
Channel	6	153
Receive Rate (Mbps)	130	325
Transmit Rate (Mbps)	130	325
Signal Strength	95%	90%
Band	2.4 GHz	5 GHz
BSSID	04:ab:08:b6:f2:02	04:ab:08:b6:f2:03

Key observations:

- **Speed:** 5 GHz (325 Mbps) is significantly faster than 2.4 GHz (130 Mbps).
- **Radio Type:** 2.4 GHz uses 802.11n, while 5 GHz uses 802.11ac (which supports higher speeds).
- **Signal Strength:** 2.4 GHz has a slightly stronger signal than 5 GHz.
- **Channel Differences**: 2.4 GHz operates on channel 6, while 5 GHz is on channel 153 (higher frequency)

Qn 8:

What is the difference between IEEE and WFA

Overview:

Since I'm an IEEE **Chairman** and Member, I have access to all the IEEE Standards, Magazines, Publications, Chapters and Societies!

IEEE:

- IEEE - **Institute of Electrical and Electronics Engineers**
- A professional organization that develops and standardizes networking protocols, including Wifi
- Responsible for defining the 802.11 Wifi standards
    - 802.11a/b/g/n/ac/ax)
- Provides the technical foundation for how Wifi devices communicate
- IEEE's 802.11 Working Group continuously works on improving wireless standards, addressing issues such as latency, power consumption, spectral efficiency and congestion
- Apart from WiFi, IEEE also governs other networking standards such as Ethernet (IEEE 802.3), Bluetooth (IEEE 802.15), and wireless personal area networks

WiFi Alliance:

- A non-profit association that certifies WiFi products, ensuring that devices from different manufacturers can seamlessly connect and function together
- Ensures that WiFi devices meet performance, security, and compatibility benchmarks, preventing fragmentation in the market.
- Introduces Wi-Fi branding like Wi-Fi 4, 5, 6 for easy consumer access to identify the generation of wifi

- There is a program called Wi-Fi CERTIFIED and it is a main function of the WFA, ensuring that products adhere to industry best practices before they are released to the market
- Wi-Fi security standards
    - WPA (Wi-Fi Protected Access) protocols - provide encryption and authentication mechanisms to protect wireless networks
- WFA is full of ISPs and device manufacturers but IEEE is full of academic researchers
- Works along with IEEE for certification

Comparison:

Aspect	IEEE	WFA
Main	Develops & standardizes Wifi networking protocols	Certifies Wifi products for interoperability
Function	Defines 802.11 standards	Ensures devices follow Wi-Fi CERTIFIED guidelines
Goal	R&D, Innovation	Adoption & branding
Output	Technical Specifications for WiFi	Certification Programs
Naming	802.11 naming	Simple user friendly names like Wi-Fi 4, Wi-Fi 5 , etc.
Scope	WiFi, Ethernet, Bluetooth	Only Wifi ecosystem
Interaction	Defines standards	Test and certify

Qn 9:

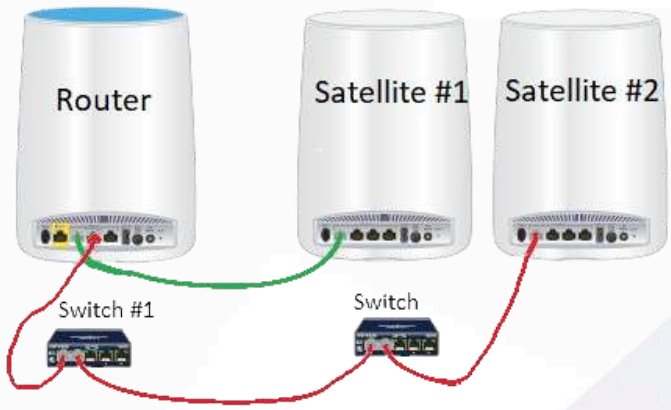
List down the type of Wi-Fi internet connectivity backhaul, share your home/college's wireless internet connectivity backhaul name and its properties

Backhaul:

- Wi-Fi backhaul is the connection between the **Access Point** and the **internet or core network**
- Seamless data transfer between Wifi network and ISP

Wired Backhaul:

- Uses cables like Ethernet or fiber to connect the AP to the internet
- Offers high speed (up to multi-Gbps) and low latency
- Requires physical installation but limited by cable reach

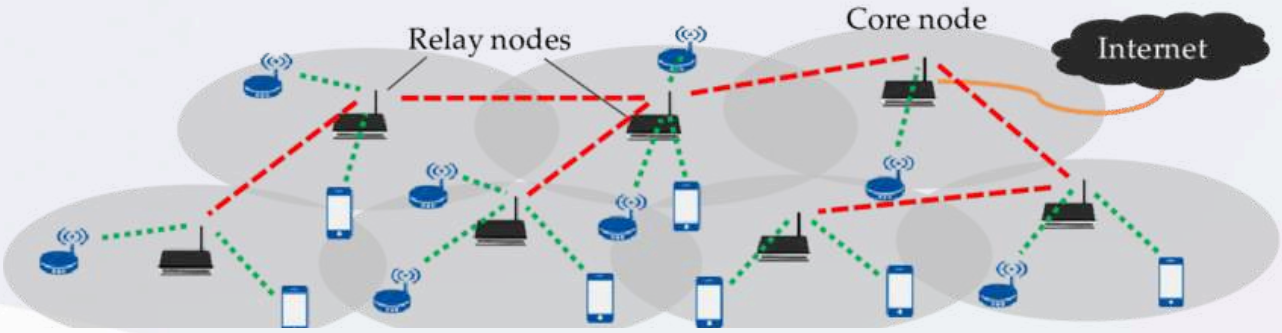


Subtypes:

- **Ethernet -** Common cables (e.g., Cat6) for up to 1 Gbps
- **Fiber Optic -** Super-fast optical lines for multi Gbps

Wired Backhaul:

- Connects using wireless signals, no cables
- Flexible setup, good for remote areas
- Slower speeds and higher latency than wired



Subtypes:

- **Wi-Fi (Mesh) -** APs link wirelessly to extend range
- **Microwave -** Long-distance radio links (5-50 km)
- **Cellular (5G) -** Uses mobile data as backhaul

Powerline Backhaul:

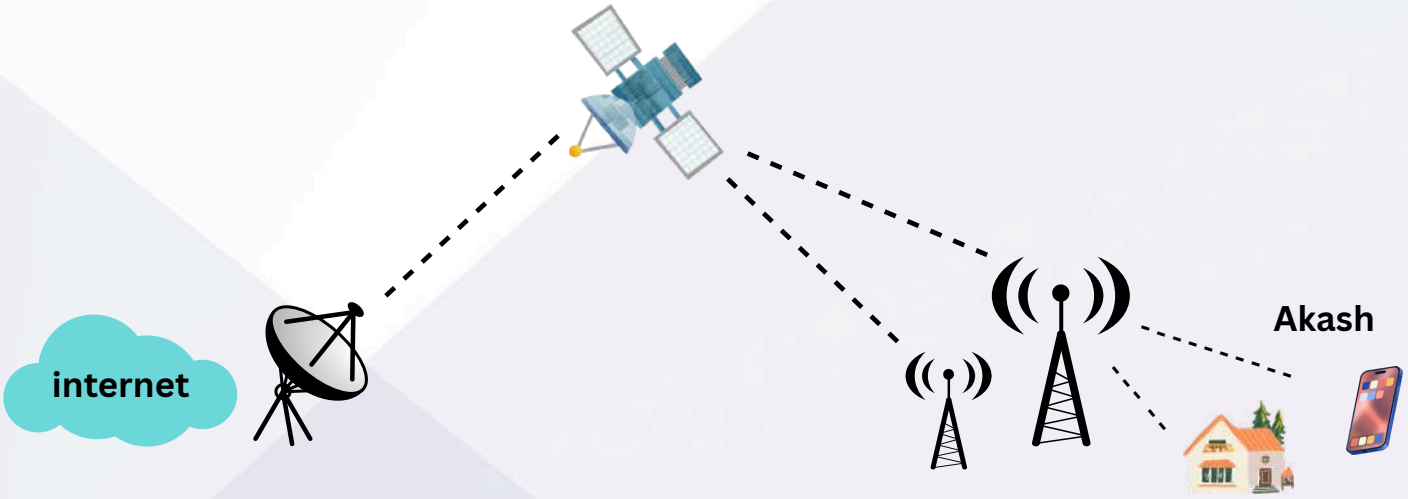
- Electrical wiring to carry internet
- Easy to install and decent speeds (up to 1 Gbps)
- Varies with wiring quality, can be spotty

Satellite Backhaul:

- AP to internet via satellite
- Works anywhere, speeds up to 150 Mbps
- High latency (20-600 m) and best for remote use

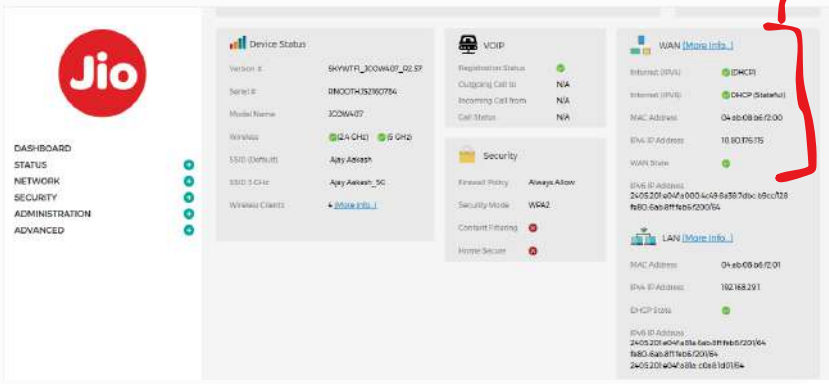
Subtypes:

- **GEO (Geostationary) -** High orbit - higher latency
- **LEO (Low Earth Orbit) -** Lower orbit - less latency

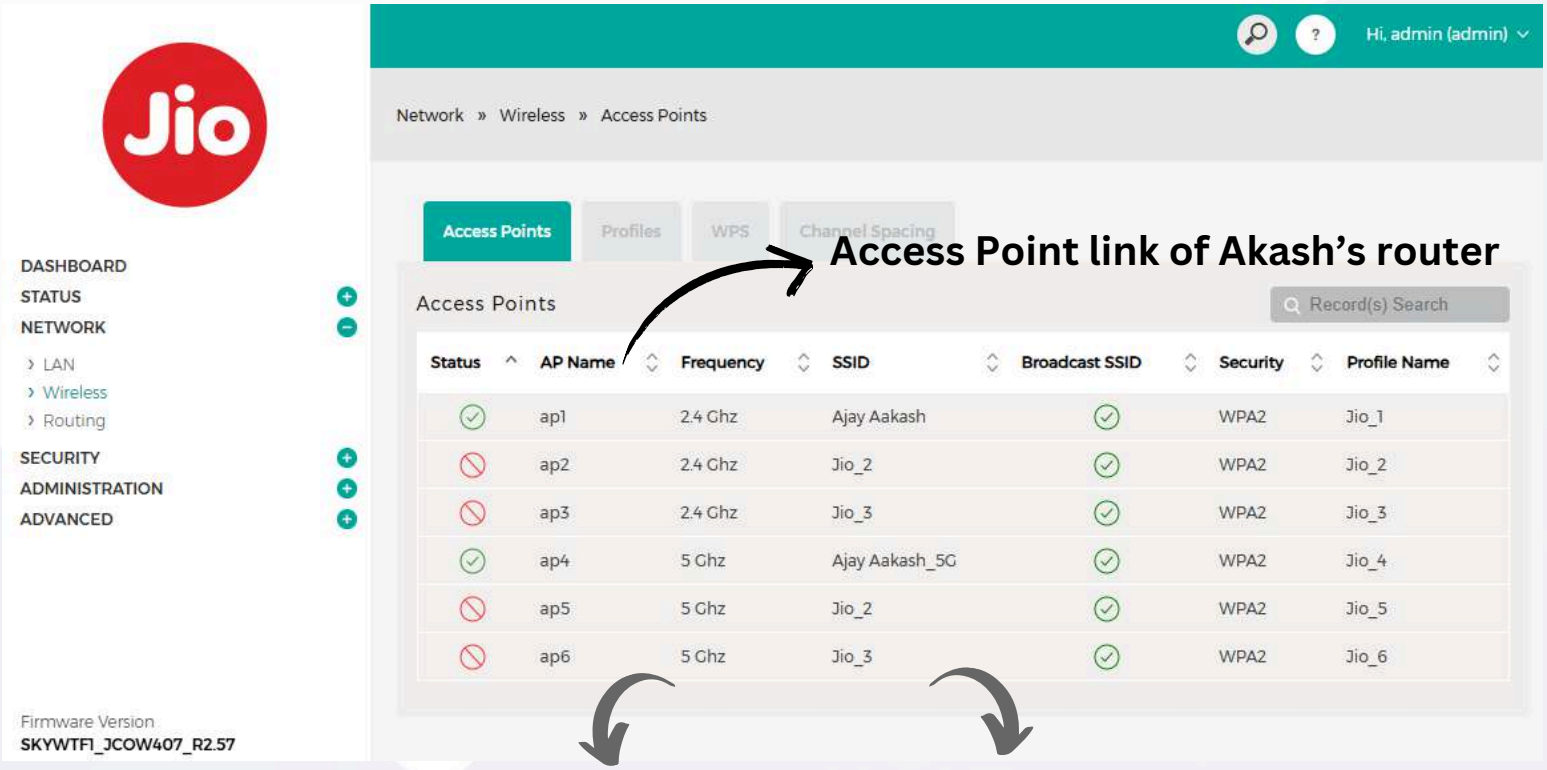


My Backhaul info:

- I logged in to my default gateway of the router at **192.168.29.1**



Connection Type is **Broadband connection with Fiber / DSL**



2.4 GHz & **5 GHz** frequency bands

SSID

Qn 10:

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

Comparison:

Topology	Description	Application
Infrastructure (BSS/ESS)	Devices connect to a central Access Point	BSS: • Home • Office • Public Wi-Fi ESS: • Enterprise with roaming • Campus with roaming
Ad-Hoc Mode	Devices communicate directly without an AP (peer to peer network)	• Temporary network • File sharing • IoT devices
Mesh Network	Multiple APs form a self healing network with dynamic routing	• Large campus • Smart cities • Industrial Automation
Wi-Fi direct	Device to device communication without AP	• Wireless printing • Gaming console • File sharing
Bridge	Access Point links two wired networks wirelessly	• Building - Building link
Repeater	AP extends an existing Wi-Fi network by receiving and retransmitting signals from another AP	• Extend wifi to rural areas (Chennai rural areas) • Boosting signal in small offices

THE END

AKASH S