1. **. What are the key features of Wi-Fi 6, 6E, and 7 and how do they differ from previous standards like Wi-Fi 5 (802.11ac)?**
   * **Wi-Fi 6 (802.11ax):**
     + OFDMA for better efficiency and lower latency.
     + MU-MIMO on uplink and downlink.
     + Target Wake Time (TWT) for improved power efficiency.
     + Higher performance in dense environments.
     + WPA3 for better security.
   * **Wi-Fi 6E:z**
     + Extends Wi-Fi 6 into the 6 GHz band.
     + Up to 1,200 MHz of extra bandwidth.
     + Less interference from legacy devices.
     + More available channels → better performance.
   * **Wi-Fi 7 (802.11be):**
     + Supports 320 MHz channels
     + 4K QAM for higher data rates.

**2. The Role of OFDMA in Wi-Fi 6 and Its Impact on Network Efficiency**

OFDMA (Orthogonal Frequency Division Multiple Access) is a critical innovation in Wi-Fi 6 (802.11ax) that enhances network efficiency, especially in high-density environments. Unlike traditional OFDM (Orthogonal Frequency Division Multiplexing), which allows a single user to transmit data over different sub-carriers, OFDMA enables simultaneous data transmission from multiple users.

By subdividing the channel into smaller sub-carriers called Resource Units (RUs), OFDMA allows multiple devices to communicate at the same time. This simultaneous communication reduces delays and increases overall network throughput, making Wi-Fi 6 more efficient in environments with numerous connected devices.

**3. Benefits of Target Wake Time (TWT) for IoT Devices in Wi-Fi 6**

Target Wake Time (TWT) improves power efficiency for IoT devices by allowing them to schedule communication times with the access point (AP). This means IoT devices only wake up at predetermined times, reducing battery consumption. It also minimizes unnecessary network congestion as devices only transmit data at their scheduled times. This feature is particularly useful for battery-powered devices in IoT ecosystems.

**4. The Importance of the 6 GHz Band in Wi-Fi 6E**

As the number of connected devices continues to rise, traditional Wi-Fi bands—2.4 GHz and 5 GHz—are becoming increasingly congested.

The 6 GHz band offers up to 1,200 MHz of additional spectrum, allowing for broader channels, reduced interference, and improved latency. This is particularly advantageous for high-demand applications such as 4K/8K streaming, augmented and virtual reality (AR/VR), video conferencing, and online gaming.

**5. Compare and contrast Wi-Fi 6 and Wi-Fi 6E in terms of range, bandwidth, and interference**

**Wi-Fi 6:**

* Frequency is 2.4 and 5ghz
* Few non-overlpaping channel
* Higher interference from legacy devices
* Suitable for general use and backward compatibility

**Wi-Fi 6E**

* Frequency is 6ghz
* Up to 59 new 20 MHz channels
* Very low interference
* Ideal for high-performance, low- latency applications

**6. Innovations in Wi-Fi 7 (802.11be)**

Wi-Fi 7, or Extremely High Throughput (EHT), introduces several advancements aimed at improving data rates, reducing latency, and enhancing reliability. Key features include:

* **Larger Channel Width**: Doubles the channel width from 160 MHz in Wi-Fi 6/6E to 320 MHz.
* **Higher Modulation**: Introduces 4096-QAM (Quadrature Amplitude Modulation), offering higher data rates and improved spectral efficiency.
* **Multi-Band Usage**: Utilizes 2.4 GHz, 5 GHz, and 6 GHz bands simultaneously for better throughput.
* **Increased Spatial Streams**: Supports 16x16 MIMO (Multiple Input, Multiple Output), further enhancing capacity and efficiency.

7.**Multi-Link Operation (MLO) and Its Impact on Throughput and Latency**

Multi-Link Operation (MLO) allows Wi-Fi devices to connect across multiple frequency bands (2.4 GHz, 5 GHz, and 6 GHz), enabling them to send and receive data simultaneously over these different links. This aggregation of links results in higher throughput and reduced latency, as the device can switch between bands dynamically to optimize performance.

**8. Purpose of 802.11k and 802.11v for Roaming**

**802.11k**: Helps Wi-Fi client devices find the best AP to connect to by providing information about nearby access points. This minimizes roaming time by allowing the device to quickly scan only the relevant channels.

**802.11v**: Assists in roaming decisions by allowing the AP to suggest the best candidate APs based on factors like signal quality, load, or network policy. While the decision to roam remains with the client, 802.11v guides the client to make an informed choice.

**9. Fast BSS Transition (802.11r) and Its Benefit for Mobile Environments**

Fast BSS Transition (FT) 802.11r standard is a feature that enhances roaming performance in wifi networks, especially for mobile devices. Its main goal is to reduce the delay that occurs when a device moves between access points (APs) within the same network.

There are two types of Fast BSS Transition:

Over-the-Air FT: The client communicates directly with the target AP during the handoff process.

Over-the-DS FT (Distribution System): The client communicates with the target AP through the current AP over the wired network (distribution system).

**10. How 802.11k, v, and r Work Together for Seamless Roaming**

Together, 802.11k, 802.11v, and 802.11r ensure smooth roaming in Wi-Fi networks:

* **802.11k** provides information about nearby APs, helping devices make informed decisions on which AP to connect to.
* **802.11v** offers guidance by suggesting the best AP based on real-time network conditions.
* **802.11r** reduces the time it takes to authenticate and connect to a new AP by sharing relevant information in advance, enabling a fast handoff.