**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)**: Introduced OFDMA, Target Wake Time (TWT), BSS Coloring, improved MU-MIMO (both uplink and downlink), and better efficiency in dense environments.
* **Wi-Fi 6E**: Same technology as Wi-Fi 6 but expanded into the **6 GHz** band, providing more channels and reducing congestion.
* **Wi-Fi 7 (802.11be)**: Adds 320 MHz channels, Multi-Link Operation (MLO), 4K-QAM modulation, Enhanced MU-MIMO, and Coordinated Multi-AP.

Compared to **Wi-Fi 5 (802.11ac)**, which mainly improved speed using 5 GHz and wider channels (80/160 MHz), Wi-Fi 6/6E/7 focus more on **efficiency, capacity, and latency reduction**.

**2. Explain the role of OFDMA in Wi-Fi 6 and how it improves network efficiency.**

**OFDMA (Orthogonal Frequency Division Multiple Access)** allows multiple users to share the same channel simultaneously by dividing it into smaller units called **Resource Units (RUs)**.  
Instead of one device occupying the entire channel, OFDMA lets many devices transmit small packets at the same time, reducing contention, increasing efficiency, and improving performance, especially in environments with many small-data devices (IoT, phones).

**3. Discuss the benefits of Target Wake Time (TWT) in Wi-Fi 6 for IoT devices.**

**TWT** allows devices to **negotiate scheduled wake and sleep times** with the AP, avoiding unnecessary listening and reducing battery consumption.  
For IoT devices, which only need occasional communication, TWT drastically extends battery life and improves network efficiency by minimizing channel contention.

**4. Explain the significance of the 6 GHz frequency band in Wi-Fi 6E.**

The **6 GHz band** offers **1200 MHz** of additional spectrum (in many regions), meaning:

* **More channels** (up to 59 new 20 MHz channels).
* **Less interference** (since only Wi-Fi 6E devices operate there, no legacy interference).
* **Higher performance** for bandwidth-intensive applications like AR/VR, 4K/8K video, and gaming.

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

| **Feature** | **Wi-Fi 6 (5 GHz)** | **Wi-Fi 6E (6 GHz)** |
| --- | --- | --- |
| **Range** | Good, even through walls | Slightly lower indoors |
| **Bandwidth** | Up to 160 MHz channels | Wider 160 MHz channels available, cleaner spectrum |
| **Interference** | Some (other 5 GHz devices) | Very low (new clean band) |

**Summary**: Wi-Fi 6E offers more bandwidth and less interference, but slightly less range than Wi-Fi 6 on 5 GHz due to higher frequency characteristics.

**6. What are the major innovations introduced in Wi-Fi 7 (802.11be)?**

Key innovations in Wi-Fi 7:

* **320 MHz channels** (double Wi-Fi 6E).
* **4K-QAM** for higher throughput.
* **Multi-Link Operation (MLO)** for simultaneous use of multiple bands.
* **Coordinated Multi-AP** for enhanced range and reliability.
* **Low Latency Improvements** tailored for gaming, AR/VR, and real-time applications.
* **Increased MU-MIMO Streams** (up to 16 spatial streams).

**7. Explain the concept of Multi-Link Operation (MLO) and its impact on throughput and latency.**

**MLO** enables devices to **transmit and receive simultaneously** across multiple links (bands/channels).

* **Impact on Throughput**: Aggregates bandwidth from different channels (like 5 GHz + 6 GHz), boosting speeds significantly.
* **Impact on Latency**: If one link experiences delay, another link can be used instantly, ensuring **low and consistent latency**.  
  This improves performance for AR/VR, online gaming, and video conferencing.

**8. What is the purpose of 802.11k and v, and how does it aid in roaming?**

* **802.11k (Radio Resource Management)**: Devices can **quickly find better APs** by getting neighbor reports from their current APs, reducing scanning time.
* **802.11v (Network Assisted Roaming)**: APs can **suggest** better APs to clients based on signal strength and load, helping devices roam **intelligently and efficiently**.

Together, they allow clients to move faster and smarter between APs, avoiding manual scans and interruptions.

**9. Explain the concept of Fast BSS Transition (802.11r) and its benefit in mobile environments.**

**802.11r** enables **fast, secure handoffs** between APs by **pre-authenticating** with neighboring APs before actually moving.

* Reduces the roaming time from hundreds of milliseconds to just a few milliseconds.
* **Benefit**: Perfect for real-time applications like VoIP, gaming, and video streaming where any connection drop would cause noticeable interruptions.

**10. How do 802.11k/v/r work together to provide seamless roaming in enterprise networks?**

* **802.11k** provides a list of neighbor APs to the client for faster decision-making.
* **802.11v** guides the client to roam towards the best AP based on real-time conditions.
* **802.11r** ensures the handoff happens quickly and securely without the need for full reauthentication.

**Together**, they create a system where the device:

* Knows where to go (k),
* Is told when and where to go (v),
* Moves without delay (r),  
  making roaming in large Wi-Fi networks **smooth, fast, and almost invisible** to the user.