Module 5

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), Wi-Fi 6E, and Wi-Fi 7 (802.11be) are advanced wireless communication standards that offer significant improvements over Wi-Fi 5 (802.11ac).

- **Wi-Fi 6 (802.11ax):**
    - Uses OFDMA for efficient spectrum utilization.
    - Supports MU-MIMO for uplink and downlink.
    - Improved battery life through Target Wake Time (TWT).
    - Better performance in congested areas.
    - 1024-QAM modulation for increased throughput.
- **Wi-Fi 6E:**
    - Extends Wi-Fi 6 to the 6 GHz band, adding 1200 MHz of new spectrum.
    - Less interference, more non-overlapping channels.
    - Ideal for AR/VR, HD video, and low-latency applications.
- **Wi-Fi 7 (802.11be):**
    - Supports Multi-Link Operation (MLO).
    - Doubles channel width to 320 MHz.
    - 4096-QAM modulation.
    - Enhanced MU-MIMO and OFDMA.
    - Reduced latency and higher throughput.

Differences from Wi-Fi 5: Wi-Fi 5 lacks OFDMA, uplink MU-MIMO, and support for the 6 GHz band, offering lower efficiency and more interference in dense environments.

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

Orthogonal Frequency Division Multiple Access (OFDMA) divides a channel into smaller sub-channels called Resource Units (RUs), allowing multiple devices to transmit simultaneously.

- **Efficiency:** Reduces latency and overhead by avoiding contention.
- **Parallelism:** Multiple users share the channel at the same time.
- **Improved QoS:** Ensures smoother performance for real-time applications.

OFDMA is especially beneficial in high-density environments such as stadiums or airports.

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

Target Wake Time (TWT) allows devices to negotiate sleep and wake intervals with the access point.

- **Power Efficiency:** Devices stay asleep longer, saving battery life.
- **Scheduled Access:** Reduces contention and improves predictability.
- **Better Scalability:** Supports more IoT devices with lower power requirements.

TWT is ideal for battery-operated devices like sensors and wearables.

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

The 6 GHz band offers:

- **More Spectrum:** Up to 1200 MHz of additional spectrum.
- **Less Interference:** Not shared with legacy Wi-Fi devices.
- **Higher Capacity:** Enables more 80 MHz and 160 MHz channels.

This allows for better performance in environments demanding high-speed and low-latency communication.

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

- **Range:** Wi-Fi 6 (2.4/5 GHz) has better penetration than Wi-Fi 6E (6 GHz).
- **Bandwidth:** Wi-Fi 6E supports more wide channels (up to 14 x 80 MHz or 7 x 160 MHz).
- **Interference:** Wi-Fi 6E operates in a cleaner spectrum, reducing congestion.

Wi-Fi 6E is better for high-throughput applications, while Wi-Fi 6 is more versatile in varied environments.

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

- **Multi-Link Operation (MLO):** Simultaneous use of multiple channels for reliability and throughput.
- **320 MHz Channel Widths:** Doubling capacity.
- **4096-QAM:** Higher modulation for better speeds.
- **Preamble Puncturing:** Flexible use of spectrum despite interference.
- **Improved Latency and Throughput:** Ideal for VR, gaming, and 8K streaming.

Wi-Fi 7 is set to deliver multi-gigabit performance and lower latency across demanding use cases.

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

MLO allows devices to transmit and receive data over multiple links (e.g., 2.4, 5, and 6 GHz) simultaneously.

- **Higher Throughput:** Data is split across links to maximize speed.
- **Lower Latency:** Quick fallback and link aggregation.
- **Resilience:** If one link fails, others can maintain the connection.

MLO improves reliability and performance, especially for time-sensitive applications.

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

These standards help in efficient roaming across access points:

- **802.11r (Fast BSS Transition):** Enables fast handoff by pre-authenticating with neighboring APs.
- **802.11k:** Assists the device in finding the best AP by collecting information about neighboring APs.
- **802.11v:** Provides network-assisted roaming decisions, including steering clients to better APs.

Together, they reduce roaming delays and improve user experience.

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

802.11r allows devices to roam quickly between APs by enabling pre-authentication.

- **Reduced Latency:** Seamless handoff with minimal delay.
- **Improved VoIP/Video Calls:** Maintains session continuity.
- **Efficient Roaming:** Especially useful in enterprise and public Wi-Fi networks.

802.11r is crucial for time-sensitive applications in mobile environments.

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

- **802.11k:** Helps the device understand its wireless environment.
- **802.11v:** Assists the device in making smart roaming decisions.

- **802.11r:** Ensures fast and secure transition between APs.

Together, they:

- Minimize roaming time.
- Reduce dropped connections.
- Maintain application continuity (e.g., video calls, online meetings).