**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):**
  + 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 (double from Wi-Fi 6).
  + 4K QAM for higher data rates.
  + Multi-Link Operation (MLO) for better throughput and reliability.
  + Reduced latency for AR/VR and real-time use cases.

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

* Divides a Wi-Fi channel into multiple smaller sub-channels (RUs).
* Allows simultaneous data transfer for multiple devices.
* Reduces latency by serving multiple users in one transmission.
* Enhances performance in congested environments.
* Improves spectrum utilization.

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

* Allows scheduling when devices wake to send/receive data.
* Minimizes power usage — ideal for battery-powered IoT.
* Reduces contention and network congestion.
* Extends battery life of devices.
* Supports scalable and energy-efficient networks.

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

* Offers a clean, uncongested spectrum.
* Supports up to 59 new 20 MHz channels.
* Reduces interference from legacy devices.
* Enables wider channels (up to 160 MHz) for high throughput.
* Ideal for high-bandwidth applications like 4K/8K streaming and VR.

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

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| --- | --- | --- |
| **Feature** | **Wi-Fi 6** | **Wi-Fi 6E** |
| **Frequency Bands** | 2.4 GHz and 5 GHz | 6 GHz (new spectrum) |
| **Range** | Better range, especially on 2.4 GHz | Slightly reduced range due to higher frequency |
| **Bandwidth** | Limited by existing 5 GHz spectrum | Supports more channels and wider bandwidth |
| **Channel Availability** | Fewer non-overlapping channels | Up to 59 new 20 MHz channels |
| **Interference** | Higher interference from legacy devices | Very low interference (clean 6 GHz band) |
| **Use Case** | Suitable for general use and backward compatibility | Ideal for high-performance, low-latency applications |
| **Device Support** | Compatible with most modern Wi-Fi devices | Requires Wi-Fi 6E compatible devices |

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

* 320 MHz channel width.
* 4K QAM for up to 20-30% more throughput.
* Multi-Link Operation (MLO) across multiple bands.
* Enhanced Channel Sounding and beamforming.
* Lower latency and jitter for real-time applications.

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

* Allows simultaneous use of multiple links (e.g., 5 GHz + 6 GHz).
* Increases total throughput by combining bandwidth.
* Improves link reliability and load balancing.
* Reduces latency and supports seamless data flow.
* Enhances performance for time-sensitive applications.

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

* **802.11k:**
  + Devices receive neighbor reports for nearby APs.
  + Speeds up scanning and selection of best AP.
* **802.11v:**
  + AP suggests optimal APs for roaming.
  + Devices can transition more intelligently.
* Improves roaming experience and reduces disruptions.

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

* Enables fast and secure handoff between APs.
* Reduces latency during roaming.
* Pre-authenticates client with nearby APs.
* Ideal for applications like VoIP, video conferencing.
* Supports smooth transitions without service interruption.

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

* 802.11k: Helps client discover nearby APs.
* 802.11v: Assists in choosing the best AP based on signal and load.
* 802.11r: Speeds up authentication during handoff.
* Together, they:
  + Enhance roaming decisions.
  + Reduce delay and packet loss.
  + Improve user experience in enterprise and large networks.