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Wi-Fi Training Programme

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)?

Ans.

- **Wi-Fi 5 (802.11ac)**
    - It works on only the 5 GHz band.
    - Supports 80/160 MHz channels.
    - Added MU-MIMO (only downlink).
    - Poor performance in crowded areas.

- **Wi-Fi 6 (802.11ax)**
    - Works on both 2.4 GHz and 5 GHz frequencies.
    - Adds OFDMA and uplink MU-MIMO.
    - Adds support for 1024-QAM (higher data density).
    - Better efficiency, especially in dense areas.
    - Adds Target Wake Time (TWT) to conserve battery.

- **Wi-Fi 6E**
    - Works exactly like Wi-Fi 6 but adds the 6 GHz band.
    - Saves as many as 14 additional 80 MHz or 7 additional 160 MHz channels.
    - Eliminates unused 6 GHz spectrum interference.
    - Perfect for bandwidth-hungry applications such as VR and 8K video.

- **Wi-Fi 7 (802.11be)**
    - Supports usage on 2.4 GHz, 5 GHz, and 6 GHz bands.
    - Supports 320 MHz ultra-wide channels.
    - uses 4096-QAM (4K-QAM) to cram more information into each signal.
    - Multi-Link Operation (MLO) combines several bands to provide better performance.

- Built for low-latency, high-throughput, and real-time applications.

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

Ans. Orthogonal Frequency Division Multiple Access (OFDMA) redefines Wi-Fi efficiency:

- **Channel division:** Divides channels into smaller frequency blocks called Resource Units (RUs).
- **Simultaneous transmission:** Allows up to 9 devices to share one channel simultaneously.
- **Dynamic allocation:** Access points may assign RUs based on traffic requirements in real-time
- **Bidirectional implementation:** Implemented in both downlink (AP to client) and uplink (client to AP) paths.
- **Efficiency gains:** Best in high-density situations with large numbers of low-bandwidth clients.
- **Reduced overhead:** Shortens contention period and acknowledgement load.
- **Technical roll-out:** Splits 20/40/80/160 MHz channels into RUs up to 2 MHz wide.
- **Real-world benefit:** Increases aggregate network throughput 4-10x in high-density deployment.

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

Ans. TWT creates a power efficiency revolution for IoT devices:

- **Timed communications:** IoT devices allocate the wake-up and transmit/receive data times
- **Deep sleep advantage:** Units remain in ultra-low-power state with the exception of their windows.
- **Battery life enhancement:** Stretch battery life up to 7x and beyond for IoT sensors and devices.
- **Network congestion elimination:** Spreads device communications over time to reduce transmissions at the same time.
- **Personal or group scheduling:** Per device or group with the same needs.
- **Broadcast TWT:** Allows control of numerous devices through a single broadcast messages.
- **Flexibility in implementation:** Supports both deterministic (fixed) and opportunistic (flexible) operation.

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

Ans. The importance of the 6 GHz frequency band in Wi-Fi 6E is:-

- It adds a huge new spectrum (1,200 MHz) on top of existing 2.4 and 5 GHz bands. More channels (up to 59 non-overlapping 20 MHz).
- It has wider channels for higher throughput (160 MHz and beyond).
- Less interference from legacy devices (since 6 GHz is new and unused).
- It enables ultra-high-speed use cases like cloud gaming, AR/VR, and 4K/8K streaming.

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

Wi-Fi 6 (802.11ax)	**Wi-Fi 6E (802.11ax Extended)**
1. It has frequency bands 2.4 GHz & 5 GHz	1. It has frequency bands 2.4 GHz, 5 GHz & 6 GHz
2. Better at longer range (especially 2.4 GHz)	2. Shorter range due to higher 6 GHz frequency
3. Limited spectrum (especially in crowded areas)	3. Much larger spectrum (up to 1.2 GHz extra)
4. Fewer wide channels (e.g. 160 MHz)	4. More non-overlapping 160 MHz channels
5. More prone to interference (legacy devices)	5. Lower interference in clean 6 GHz band

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

Ans. Key features of Wi-Fi 7 (802.11be) are:-

1. **Higher Speed:** It supports Speed up to 46 Gbps, nearly 5 times higher speed than Wi-Fi 6

2. **320 MHz Channel:** It has 320 MHz Channel.It doubles the channel bandwidth for increased data transfer.

3. **4096-QAM Modulation:** It supports 4096-QAM Modulation which Increases density by 20%, thus being more efficient.

4. **Multi-Link Operation (MLO):** Allows devices to talk on several frequency bands simultaneously,

reducing latency.

5. **Enhanced MU-MIMO:** Employs 16×16 multi-user multiple-input multiple-output, boosting device connection.

6. **Preamble Puncturing:** Avoids interference by bypassing parts of a channel.

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

Ans. MLO is potentially the single biggest architectural innovation ever in Wi-Fi history:

• **Simultaneous multi-band capability:** Allows for devices to possess active links over 2.4, 5, and 6 GHz bands simultaneously

• Modes of implementation:

- Improved Multi-Link Single-radio (EMLSR): Time-partitions one radio across many bands
- Multi-Link Multi-radio (MLMR): Utilizes dedicated radios by band in simultaneous fashion

• **Throughput multiplexing:** Has the capacity to join bands together across band to yield impressive speed gain.

• **Redundancy advantages:** Can duplicate vital traffic between bands for near-zero packet loss.

• **Load balancing capabilities:** Dynamically redistributes traffic based on band conditions and congestion.

• **Latency reduction:** Lowers latency by 100ms+ by selecting best band for each transmission.

• **Smooth band switching:** Avoids loss of connection when switching frequency bands.

• **Channel utilization optimization:** Distributes traffic optimally across all available spectrum.

• **Application benefits:** Particularly valuable for gaming, video conferencing, AR/VR, and industrial control systems.

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

Ans. These requirements provide critical information for intelligent roaming decisions:

802.11k (Radio Resource Management):

• Neighbour reports: Clients can request lists of neighbouring access points with channel and signal information

• Beacon measurement: Allows clients to measure beacon signals without having to disconnect

• Channel load assessment: Provides information on congestion for different channels

• Noise histogram reports: Provides the degree of interference across the frequency band

• Client statistics: Accumulates performance statistics to inform roaming decisions

• Proactive information: Provides information before connection quality declines noticeably

802.11v (Wireless Network Management):

• BSS transition management: Network may suggest better access points to clients

• Network-directed roaming: Infrastructure may forward clients to specified APs for load distribution

• Sleep mode coordination: Cooperative power savings options across network

•Timing measurements: Synchronizes client and network timing for proper operation

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

Ans. Designed for fast handoff between APs, reducing re-authentication time. Performs pre-authentication with neighbouring APs before roaming. Speeds up transitions in milliseconds vs seconds.

Essential for:

- VoIP calls, video conferencing.
- Mobility scenarios like hospitals, campuses, and offices.

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

Ans. Together, they enable fast, efficient, and smart transitions across access points:

1. 802.11k helps device learn about neighbouring APs.
2. 802.11v helps guide device to the best AP based on load/signal.
3. 802.11r ensures quick handoff with minimal authentication delay.

Combined benefit:

- They have no dropped calls or buffering while moving.
- Provides better user experience in large enterprise networks or public Wi-Fi areas.