MODULE 3 ASSIGNMENT

1. What are the different 802.11 PHY layer standards? Compare their characteristics.

The IEEE 802.11 PHY layer defines how wireless signals are transmitted and received. Different PHY standards have evolved to support higher data rates, better spectrum efficiency, and reliability. These include 802.11a/b/g/n/ac/ax, each improving on aspects such as modulation technique, frequency band, channel width, and MIMO capabilities.

Key PHY Layer Standards and Characteristics:

• 802.11a o Operates in the 5 GHz band o Uses OFDM o Data rates up to 54 Mbps o Shorter range due to higher frequency

• 802.11b o Operates in the 2.4 GHz band o Uses DSSS o Data rates up to 11 Mbps o Prone to interference from other 2.4 GHz devices

• 802.11g o Operates in the 2.4 GHz band o Uses OFDM (also backward compatible with DSSS) o Data rates up to 54 Mbps

• 802.11n o Operates in both 2.4 and 5 GHz bands (dual-band) o Introduces MIMO and channel bonding o Data rates up to 600 Mbps

• 802.11ac o Operates in the 5 GHz band o Supports MU-MIMO, wider channels (up to 160 MHz) o Data rates over 1 Gbps

• 802.11ax (Wi-Fi 6) o Operates in both 2.4 and 5 GHz bands o Introduces OFDMA, BSS Coloring, and improved MU-MIMO o Data rates up to 9.6 Gbps

2. **What are DSSS and FHSS? How do they work?**

DSSS (Direct Sequence Spread Spectrum) and FHSS (Frequency Hopping Spread Spectrum) are two spread spectrum techniques used to transmit radio signals.

Both techniques aim to reduce interference and improve robustness but differ in how they handle frequencies.

• DSSS: Spreads data using a pseudorandom noise code, all data sent over a wider band simultaneously. Used in 802.11b Higher data rates , Better resistance to narrowband interference

• FHSS: Rapidly changes (hops) frequencies based on a sequence. , Used in legacy systems like Bluetooth , Lower throughput but strong anti-jamming ,Less prone to frequency-specific interference

3. **How do modulation schemes work in the PHY layer? Compare different modulation schemes and their performance across various Wi-Fi standards.**

Modulation in the PHY layer transforms digital signals into radio waves. Higher-order modulation increases data rates but requires better signal quality. Wi-Fi standards use schemes like BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM depending on the environment and required throughput.

• BPSK/QPSK: Robust, low-speed – used in initial connections

• 16-QAM/64-QAM: Higher throughput – used in 802.11a/g/n

• 256-QAM/1024-QAM: Very high speed – seen in 802.11ac/ax

• Performance Trade-off: Higher modulation = higher speed but more susceptible to noise

4. **What is the significance of OFDM in WLAN? How does it improve performance?**

OFDM (Orthogonal Frequency Division Multiplexing) divides a wideband channel into multiple narrowband sub-carriers, each carrying a portion of the data. It is key to efficient data transmission in noisy wireless environments.

• Reduces inter-symbol interference

• Enables higher data rates using multiple subcarriers

• More robust to multipath fading

• Used in 802.11a/g/n/ac/ax 5. How are frequency bands divided for Wi-Fi? Explain different bands and their channels. Wi-Fi primarily uses unlicensed ISM bands at 2.4 GHz, 5 GHz, and now 6 GHz. These bands are divided into channels to allow multiple devices to communicate simultaneously without interference.

• 2.4 GHz: 14 channels (20 MHz wide), only 3 non-overlapping (1, 6, 11)

• 5 GHz: More channels (20–160 MHz), less congestion, DFS channels available

• 6 GHz (Wi-Fi 6E): Offers even more spectrum and cleaner airwaves

6. What is the role of Guard Intervals in WLAN transmission? How does a short Guard Interval improve efficiency?

Guard Intervals (GI) prevent overlapping of symbols due to multipath delays. Shortening the GI increases throughput but may lead to inter-symbol interference in noisy environments. • Standard GI: 800 ns (safer in high-interference areas)

• Short GI: 400 ns (used in 802.11n/ac for better speed)

• Improves efficiency: By increasing symbol transmission rate

• Trade-off: Short GI needs good signal quality

7**. Describe the structure of an 802.11 PHY layer frame. What are its key components?**

The 802.11 PHY frame includes several components that prepare and transmit data over wireless media. Each component serves a specific purpose in synchronization, data transfer, and modulation.

• Preamble: Synchronization and channel estimation

• PLCP Header: Length and rate info for receiver

• PSDU (MAC Payload): Actual data from higher layers

• Tail and Padding Bits: Ensures decoder resets and proper alignment

8. What is the difference between OFDM and OFDMA?

While both technologies use orthogonal subcarriers, OFDMA is an enhancement over OFDM that enables simultaneous multi-user communication.

• OFDM: Entire channel for one user at a time (used in 802.11a/g/n/ac)

• OFDMA: Divides channel into smaller Resource Units (RUs) for multiple users (used in 802.11ax)

• Efficiency: OFDMA is better in dense networks

• Latency: Lower in OFDMA due to parallel access

9. What is the difference between MIMO and MU-MIMO?

MIMO (Multiple Input Multiple Output) increases data throughput using multiple antennas. MU-MIMO extends this by serving multiple clients simultaneously.

• MIMO: Point-to-point stream enhancement

• MU-MIMO: Point-to-multi-point communication (used in 802.11ac/ax)

• MU-MIMO Benefits:

o Improved efficiency

o Better network utilization

o Reduced waiting time for clients

10. What are PPDU, PLCP, and PMD in the PHY layer?

These components structure the data for transmission and handle modulation and encoding.

• PPDU (PLCP Protocol Data Unit): Complete frame to be transmitted

- PLCP (Physical Layer Convergence Protocol): Adds headers and preamble
- PMD (Physical Medium Dependent): Converts bits into radio signals for transmission
- Together, they define how data moves from MAC to the air interface