**Wi-Fi Training Program**

**Assignment Solutions – Module 3**

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

| **Standard** | **Frequency Band** | **Max Data Rate** | **Modulation Used** | **Channel Width** | **MIMO Support** | **Key Features** |
| --- | --- | --- | --- | --- | --- | --- |
| **802.11b** | 2.4 GHz | 11 Mbps | DSSS, CCK | 20 MHz | No | Good range, but low speed |
| **802.11a** | 5 GHz | 54 Mbps | OFDM (up to 64-QAM) | 20 MHz | No | Higher speeds, shorter range |
| **802.11g** | 2.4 GHz | 54 Mbps | OFDM + DSSS compatibility | 20 MHz | No | Speed of 11a with 2.4 GHz compatibility |
| **802.11n** | 2.4 & 5 GHz | 600 Mbps | OFDM (64-QAM) | 20/40 MHz | Yes (up to 4 streams) | Introduced MIMO, wider channels |
| **802.11ac** | 5 GHz | 6.9 Gbps | OFDM (256-QAM) | 20/40/80/160 MHz | Yes (up to 8 streams) | Massive speed boosts, beamforming |
| **802.11ax** | 2.4, 5, 6 GHz | ~10 Gbps | OFDMA, 1024-QAM | 20–160 MHz | Yes (MU-MIMO) | Extremely efficient, good for crowded areas |

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

Both are spread spectrum techniques. DSSS stands for Direct Sequence Spread Spectrum — it spreads the signal over a wider band using a code, so it's more resistant to interference. FHSS, or Frequency Hopping Spread Spectrum, jumps rapidly between different frequencies in a pattern, making it hard to jam or intercept.  
DSSS is what 802.11b uses, while FHSS was used earlier in 802.11 legacy modes.

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

| **Modulation Type** | **Bits/Symbol** | **Used In Standards** | **Data Rate Potential** | **Signal Strength Needed (SNR)** | **Reliability** |
| --- | --- | --- | --- | --- | --- |
| **BPSK** | 1 | 802.11a/b/g/n/ax | Low | Very Low | Very High |
| **QPSK** | 2 | 802.11a/b/g/n/ax | Low–Medium | Low | High |
| **16-QAM** | 4 | 802.11a/g/n/ac/ax | Medium | Medium | Decent |
| **64-QAM** | 6 | 802.11n/ac/ax | High | High | Needs clean signals |
| **256-QAM** | 8 | 802.11ac/ax | Very High | Higher | Error-prone if noisy |
| **1024-QAM** | 10 | 802.11ax | Ultra High | Very High | Very sensitive |

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

OFDM stands for Orthogonal Frequency Division Multiplexing. It splits a channel into many narrow sub-carriers and sends data in parallel. The cool thing is — these sub-carriers don’t interfere with each other. It’s more resistant to interference and multipath effects. That’s why it’s used in 802.11a/g/n/ac — it boosts reliability and speed, especially in noisy or indoor environments.

**5. How are frequency bands divided for Wi-Fi? Explain different bands and their channels.**

1. **2.4 GHz Band**: This was the original Wi-Fi band. It has only **3 non-overlapping channels** (1, 6, 11). It’s good for long range but suffers from interference (microwaves, Bluetooth, etc.).
2. **5 GHz Band**: Faster speeds and many more non-overlapping channels. But shorter range compared to 2.4 GHz.
3. **6 GHz Band (Wi-Fi 6E)**: Brand new and super clean right now. Offers even more channels and very high speeds, but again, range is a little lower.

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

Guard intervals help prevent inter-symbol interference — which happens due to multipath signals. Basically, it’s a small pause between transmissions.  
A normal guard interval is 800ns, but some standards allow 400ns (short guard interval). Shorter interval means less overhead and more efficiency, which boosts the data rate — but only if the environment can handle it (i.e., not too much reflection or interference).

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

The PHY frame is called a PPDU — Physical Layer Protocol Data Unit. It includes:

* **Preamble**: used for synchronization.
* **Header**: contains info like length, modulation, coding.
* **Payload**: this is where the MAC frame/data goes.  
  The structure changes a bit across versions (e.g., 802.11n vs ax), but this is the basic layout.

**8. What is the difference between OFDM and OFDMA?**

OFDM sends data to one user at a time over all sub-carriers. OFDMA, introduced in Wi-Fi 6, takes that and divides the sub-carriers among multiple users. So you can serve many users simultaneously.  
Think of OFDM as one user using the whole highway, and OFDMA as multiple users getting different lanes — more efficient for crowded environments.

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

MIMO (Multiple Input Multiple Output) uses multiple antennas to increase speed and reliability. But in traditional MIMO, it still serves one user at a time.  
MU-MIMO (Multi-User MIMO) can serve multiple users simultaneously — each with their own stream. MU-MIMO started with downlink in 802.11ac and expanded to uplink in 802.11ax.

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

1. **PPDU**: The complete PHY frame — what gets transmitted over the air.
2. **PLCP (Physical Layer Convergence Protocol)**: It's part of the PHY that preps data for transmission. It adds headers and helps with synchronization.
3. **PMD (Physical Medium Dependent)**: This is the lowest part — handles actual signal transmission and reception over the medium (radio waves).  
   So, PLCP builds the frame, PMD sends it.

**11. What are the types of PPDU? Explain the PPDU frame format across different Wi-Fi generations.**

PPDU formats vary across generations:

* 802.11a/g: Legacy OFDM PPDU
* 802.11n: HT (High Throughput) PPDU
* 802.11ac: VHT (Very High Throughput) PPDU
* 802.11ax: HE (High Efficiency) PPDU — adds things like longer preambles and OFDMA support  
  Each version includes more fields and better structure to support new features and devices.

**12. How is the data rate calculated?**

Data rate is calculated using this formula:  
Data Rate = (Bits per subcarrier × Number of subcarriers × Coding rate × Number of spatial streams) / Symbol duration