### Q10)PPDU, PLCP, and PMD in the Wi-Fi PHY Layer

The **Physical (PHY) layer** in 802.11 Wi-Fi is divided into sublayers and frame types to manage wireless transmission. Here’s a breakdown of these key components:

**1. PPDU (PHY Protocol Data Unit)**

* **Definition**: The complete **PHY-layer frame** transmitted over the air.
* **Preamble**: Synchronization and channel estimation (STF/LTF).
* **PLCP Header**: Metadata (data rate, length, modulation).
* **PSDU (PLCP Service Data Unit)**: The actual MAC-layer data.
* **Types**: Varies by Wi-Fi standard (e.g., **HT-PPDU** for 802.11n, **VHT-PPDU** for 802.11ac).

**2. PLCP (Physical Layer Convergence Procedure)**

* **Definition**: A sublayer that **adapts the MAC frame** for transmission over the wireless medium.
* **Functions**:
* **Framing**: Adds preamble/header to MAC data (creating PPDU).
* **Rate Matching**: Selects modulation (e.g., BPSK, 256-QAM) based on channel conditions.
* **Clear Channel Assessment (CCA)**: Checks if the medium is free before transmitting.
* **PLCP Header Fields**:
* **Signal (SIG)**: Data rate, frame length.
* **Service**: Scrambler initialization.
* **Tail/Pad**: Ensures proper symbol alignment.

**3. PMD (Physical Medium Dependent)**

* **Definition**: The lowest sublayer that **handles raw signal transmission/reception**.
* **Functions**:
* **Modulation/Demodulation**: Converts bits to radio waves (e.g., OFDM, DSSS).
* **Beamforming**: Directs signals using antenna arrays (in 802.11n/ac/ax).
* **Channel Bonding**: Combines channels (e.g., 40 MHz in 802.11n).
* **Components**:
* **Transmitter**: Encodes data into RF signals.
* **Receiver**: Decodes RF signals back to bits.

**4. How They Work Together**

1. **MAC Layer** passes data to the **PLCP**.
2. **PLCP** constructs the **PPDU** (adds preamble/header).
3. **PMD** converts the PPDU into **radio waves** using OFDM/DSSS.
4. The receiver’s **PMD** demodulates the signal, and **PLCP** extracts the MAC data.

**5. Comparison Across Wi-Fi Standards**

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| Standard | PPDU Type | PLCP Enhancements | PMD Features |
| 802.11a/g | Legacy PPDU | Fixed 20 MHz preamble | OFDM modulation. |
| 802.11n | HT-PPDU | Greenfield mode (skips legacy preamble) | MIMO, 40 MHz channels. |
| 802.11ac | VHT-PPDU | Supports 160 MHz bandwidth | MU-MIMO, 256-QAM. |
| 802.11ax | HE-PPDU | OFDMA preamble (BSS coloring) | 1024-QAM, UL/DL MU-MIMO. |

* **PPDU**: The full PHY frame (preamble + header + data).
* **PLCP**: Prepares MAC data for transmission (framing, rate selection).
* **PMD**: Handles the physical signal (modulation, beamforming).
* **Evolution**: Newer standards (e.g., Wi-Fi 6/7) optimize PPDU efficiency with shorter preambles and advanced PMD techniques.