### Q11)Types of PPDU and Frame Formats Across Wi-Fi Generations

The **PPDU (PHY Protocol Data Unit)** is the complete physical-layer frame in Wi-Fi, and its structure evolves with each standard to improve efficiency, speed, and reliability. Below is a breakdown of PPDU types and their formats across Wi-Fi generations.

**1. PPDU Types by Wi-Fi Standard**

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| Wi-Fi Standard | PPDU Type | Key Features |
| 802.11a/g | Legacy PPDU | Fixed 20 MHz bandwidth, OFDM modulation. |
| 802.11n (Wi-Fi 4) | HT (High Throughput) PPDU | Introduced MIMO, 40 MHz channels, Greenfield mode. |
| 802.11ac (Wi-Fi 5) | VHT (Very High Throughput) PPDU | 80/160 MHz channels, MU-MIMO (downlink), 256-QAM. |
| 802.11ax (Wi-Fi 6/6E) | HE (High Efficiency) PPDU | OFDMA, UL/DL MU-MIMO, 1024-QAM, BSS coloring. |
| 802.11be (Wi-Fi 7) | EHT (Extremely High Throughput) PPDU | 320 MHz channels, 4096-QAM, Multi-Link Operation (MLO). |

**2. PPDU Frame Structure Comparison**

All PPDUs consist of three main parts:

1. **Preamble** (Synchronization + Channel Estimation)
2. **PHY Header** (Metadata: Rate, Length, Modulation)
3. **Data Field** (PSDU – MAC Layer Payload)

* **Preamble**:
* **Short Training Field (STF)**: Synchronization.
* **Long Training Field (LTF)**: Channel estimation.
* **SIG Field**: Specifies data rate (e.g., 6, 12, 24 Mbps) and frame length.
* **PSDU**: MAC data (up to 54 Mbps in 802.11a/g).

**B. HT-PPDU (802.11n)**

* **Legacy Preamble**: Backward compatibility with 802.11a/g.
* **HT-SIG**: Adds MIMO info (e.g., number of spatial streams).
* **HT-STF/HT-LTFs**: Fine-tune MIMO channel estimation.
* **Supports 40 MHz channels** and up to 600 Mbps.

**C. VHT-PPDU (802.11ac)**

* **VHT-SIG-A**: Bandwidth (80/160 MHz), MU-MIMO group ID.
* **VHT-SIG-B**: User-specific modulation (256-QAM).
* **MU-MIMO**: Downlink simultaneous transmissions to multiple users.

**D. HE-PPDU (802.11ax)**

* **HE-SIG-A/B**: OFDMA resource allocation (RUs), BSS coloring.
* **HE-LTFs**: Enhanced channel estimation for MU-MIMO.
* **OFDMA**: Splits channel into **Resource Units (RUs)** for multi-user efficiency.

**E. EHT-PPDU (802.11be – Wi-Fi 7)**

* **EHT-SIG**: 320 MHz channels, 4096-QAM, Multi-Link Operation (MLO).
* **Preamble Overhead Reduction**: Shorter headers for higher efficiency.

**3. Key Innovations in Each PPDU Type**

|  |  |  |
| --- | --- | --- |
| PPDU Type | Key Advancement | Impact |
| Legacy | Basic OFDM | Enabled 54 Mbps speeds. |
| HT | MIMO, 40 MHz | Boosted throughput to 600 Mbps. |
| VHT | MU-MIMO, 160 MHz | Gigabit Wi-Fi (6.9 Gbps). |
| HE | OFDMA, 1024-QAM | 4× capacity in dense networks. |
| EHT | 320 MHz, 4096-QAM | Wi-Fi 7’s 46 Gbps speeds. |

* **Legacy PPDU**: Simple, single-user OFDM.
* **HT-PPDU**: Introduced MIMO and channel bonding.
* **VHT-PPDU**: Added MU-MIMO and wider channels.
* **HE-PPDU**: Revolutionized efficiency with OFDMA.
* **EHT-PPDU**: Pushes limits with 320 MHz and 4096-QAM.