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

PPDU stands for Physical Layer Protocol Data Unit. It is the actual frame that is transmitted over the air by the physical layer in Wi-Fi communication. It includes all the necessary information for the receiver to properly decode and interpret the transmitted data. Every Wi-Fi transmission starts with a PPDU, and its format varies depending on the Wi-Fi standard being used.

**General PPDU Structure:**

Essentially, a PPDU is the complete PHY layer frame that is transmitted. It contains:

* **Preamble:** For synchronization and channel estimation.
* **PHY Header:** Control information for decoding.
* **Data (PSDU):** The actual payload.

**Legacy PPDU (802.11a/b/g)**

* Used in older Wi-Fi standards.
* Frame has a Preamble (for synchronization), Header (with control info), and Payload (the actual data).
* Very basic structure and supports only single-user transmission.
* Lower data rates and no support for advanced features like MIMO or wider channels.

**HT PPDU (High Throughput Mode – 802.11n / Wi-Fi 4)**

* Introduced MIMO, allowing multiple data streams.
* Supports 20 MHz and 40 MHz channels.
* Contains new fields like HT-SIG to describe the MIMO setup.
* Offers optional short guard intervals (400 ns) to improve efficiency.

**VHT PPDU (Very High Throughput Mode – 802.11ac / Wi-Fi 5)**

* Supports wider channels (up to 160 MHz) and MU-MIMO.
* Adds VHT-SIG-A and VHT-SIG-B fields that carry more detailed info about modulation, coding, and user configuration.
* Uses 256-QAM for higher data rates.
* More efficient than HT, especially in multi-user scenarios.

**HE (High Efficiency Mode – 802.11ax / Wi-Fi 6/6E)**

* Designed for high-efficiency in dense environments.
* Supports OFDMA, BSS coloring, target wake time, and UL/DL MU-MIMO.
* Has formats like:

**HE SU PPDU** – for single user

**HE MU PPDU** – for multiple users

**HE TB PPDU** – for uplink random access

**HE ER PPDU** – for extended range

* Includes HE-SIG-A and HE-SIG-B to provide advanced control info.