The 802.11 PHY (Physical Layer) frame structure is designed to facilitate reliable wireless transmission in WLANs, encapsulating data for modulation and transmission over the air. It consists of a preamble, header, and payload, with variations across standards

Structure of 802.11 PHY Layer Frame
Preamble: The initial section used for synchronization and signal detection.
Header: Contains control information for demodulation and error checking.
Payload: The actual data being transmitted, modulated according to the standard.

Key Components

Preamble:

Purpose:
Facilitates timing synchronization, frequency offset correction, and channel estimation to ensure accurate signal reception.
Subcomponents:
Short Training Field (STF): Comprises a sequence of short, repetitive pulses (e.g., 10 short symbols over 8 μs in 802.11a) designed for initial signal detection, automatic gain control (AGC) adjustment, and coarse timing/frequency synchronization. In MIMO systems (e.g., 802.11n), multiple STFs support multiple spatial streams.
Long Training Field (LTF): Consists of two long symbols (e.g., 8 μs total in 802.11a) for fine frequency and phase synchronization, precise channel estimation, and equalization to compensate for multipath effects. In 802.11n/ac/ax, additional LTFs (e.g., HT-LTF, VHT-LTF, HE-LTF) are included to handle multiple antennas and users.
Legacy Preamble (in 802.11n/ac/ax): Retains the 802.11a/g preamble structure (STF + LTF) for backward compatibility with legacy devices, ensuring interoperability.
Structure Variation: The preamble length increases with MIMO and multi-user features (e.g., 802.11ax may include up to 8 HE-LTFs for 8 spatial streams), adapting to complexity.

Header:

Purpose:
Encodes critical control information to instruct the receiver on how to demodulate and process the payload, including error detection.
Subcomponents:

- **Signal Field (SIG)**: A 24-bit field in 802.11a that includes:
    - **RATE**: Specifies the modulation and coding scheme (e.g., 6 Mbps with BPSK 1/2).
    - **LENGTH**: Indicates the number of octets in the payload.
    - **Parity Bit**: For error checking within the SIG field.
    - **Tail Bits**: 6 zeros to flush the convolutional encoder.

- **Service Field**: A 7-bit field (with 1 reserved bit) to initialize the data scrambler, ensuring randomized data for better transmission.
- **Tail Bits**: An additional 6 bits of zeros to terminate the header's encoding process.
- **Cyclic Redundancy Check (CRC)**: A 16-bit FCS (Frame Check Sequence) to detect errors in the header.

Additional SIG Fields (in later standards):
HT-SIG (802.11n): 40 bits with modulation, channel width (20/40 MHz), and MIMO details.
VHT-SIG-A/B (802.11ac): 52+26 bits for beamforming, 80/160 MHz support, and group ID.
HE-SIG-A/B (802.11ax): Up to 52 bits per field, including resource unit allocation for OFDMA and multi-user scheduling.

Structure Variation: The header expands with each standard to accommodate advanced features like beamforming, wider channels, and multi-user support, with SIG fields split into multiple parts for efficiency.

<u>Payload:</u>

Purpose:
Transports the MAC layer data (e.g., user data, management, or control frames) to the destination.
Structure:
Data Field: Variable length, typically up to 4095 bytes (limited by MAC), containing the PSDU (PLCP Service Data Unit).
Padding:
Optional bits to align the data to the encoder's block size.
Tail Bits:
6 zeros to reset the convolutional encoder at the end of the payload.
Pad Bits:
Additional zeros to ensure the total length fits the OFDM symbol duration.
Encoding and Modulation:
The payload is scrambled to reduce DC bias, encoded with forward error correction (e.g., convolutional coding with rates like 1/2 or 3/4), and modulated using schemes such as BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, or 1024-QAM (in 802.11ax), depending on the standard and signal quality.
Structure Variation:
In 802.11ax, the payload supports OFDMA, dividing it into resource units (RUs) for multiple users, enhancing efficiency in dense environments.