The data rate in Wi-Fi, measured in bits per second (e.g., Mbps or Gbps), is calculated based on several factors related to the PHY layer, including modulation, coding rate, channel bandwidth, and the number of spatial streams. The formula and process vary across standards (e.g., 802.11a/b/g/n/ac/ax), but the general approach involves determining the number of bits transmitted per symbol and the symbol rate.

General Formula for Data Rate

Data Rate = (Number of Data Bits per Symbol x Number of Symbols per Second) / Overhead Factor

Where:
Number of Data Bits per Symbol: Depends on the modulation scheme (e.g., BPSK = 1 bit, 64-QAM = 6 bits) and coding rate (e.g., 1/2, 3/4).
Number of Symbols per Second: Determined by the channel bandwidth and guard interval.
Overhead Factor: Accounts for preamble, header, and guard interval, reducing effective throughput.

Step-by-Step Calculation

1. **Modulation and Coding Scheme (MCS):**
Each modulation scheme (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM) defines the bits per symbol.
The coding rate (e.g., 1/2, 2/3, 3/4, 5/6) indicates the proportion of error-correcting bits, reducing the effective bits per symbol.
Example: 64-QAM with a 3/4 coding rate carries \(6 x 0.75 = 4.5 \) bits per subcarrier per symbol.

2**.Number of Data Subcarriers:**
The channel bandwidth (e.g., 20 MHz, 40 MHz, 80 MHz, 160 MHz) is divided into orthogonal subcarriers (e.g., 52 data subcarriers in 20 MHz for 802.11a).
The number of data subcarriers varies by standard and bandwidth (e.g., 242 subcarriers in 20 MHz for 802.11ax).

3. **Symbol Duration and Rate:**
Symbol duration is the time to transmit one OFDM symbol, including the guard interval (e.g., 4 µs with 800 ns GI in 802.11a).
Symbol rate = 1 / (Symbol Duration) (e.g., 1/4 x 10^(-6) = 250,000 symbols/second).
A shorter guard interval (e.g., 400 ns) increases the symbol rate slightly (e.g., 250,000 to 266,667 symbols/second).

4. **Spatial Streams:**
MIMO and MU-MIMO add spatial streams (e.g., 1, 2, 4, 8), multiplying the bits per symbol by the number of streams.

Example: 2x2 MIMO with 64-QAM (6 bits) and 3/4 coding yields (6 x 0.75 x 2 = 9 \) bits per symbol.

5.**Effective Data Rate:**

Total bits per second = Bits per Symbol x Number of Data Subcarriers x Symbol Rate
Overhead (preamble, header, GI) reduces the net rate, typically by 10-20%, depending on the standard.
Example :

802.11a (20 MHz, 64-QAM, 3/4, 1 Stream):
- Bits per symbol = (6 x 0.75 = 4.5).
- Data subcarriers = 52.
- Symbol duration = 4 µs (800 ns GI), symbol rate = 250,000 symbols/s.
- Raw rate = 4.5 x 52 x 250,000 = 58.5 Mbps.
- Effective rate (after overhead) ≈ 54 Mbps.

802.11n (40 MHz, 64-QAM, 5/6, 2 Streams):
- Bits per symbol = 6 x 0.833 x 2 = 10 .
- Data subcarriers ≈ 108.
- Symbol rate = 250,000 symbols/s (800 ns GI).
- Raw rate = 10 x 108 x 250,000 = 270 Mbps
- Effective rate (after overhead) ≈ 240-300 Mbps, depending on GI.

802.11ac (80 MHz, 256-QAM, 5/6, 4 Streams):
- Bits per symbol = 8 x 0.833 x 4 = 26.67
- Data subcarriers ≈ 234.
- Symbol rate = 250,000 symbols/s.
- Raw rate = 26.67 x 234 x 250,000 approx 1.56 Gbps
- Effective rate ≈ 1.3 Gbps (after overhead).

802.11ax (160 MHz, 1024-QAM, 5/6, 8 Streams):
- Bits per symbol = 10 x 0.833 x 8 = 66.67
- Data subcarriers ≈ 468.
- Symbol rate = 250,000 symbols/s (or higher with 400 ns GI).
- Raw rate = 66.67 x 468 x 250,000 approx 7.8 Gbps
- Effective rate ≈ 9.6 Gbps (with optimization and OFDMA).

Key Factors Affecting Data Rate
Channel Bandwidth: Wider channels (e.g., 160 MHz) increase subcarriers and rate.
Guard Interval: Shorter GI (400 ns) boosts symbol rate by ~10%.
MCS Index: Higher modulation (e.g., 1024-QAM) and coding rates increase bits per symbol.
Spatial Streams: More streams (e.g., 8 in 802.11ax) multiply the rate.
Overhead: Preamble, header, and protocol inefficiencies reduce the final throughput.