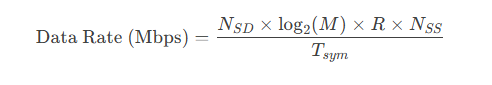
### Q12)How Wi-Fi Data Rate is Calculated

The data rate in Wi-Fi depends on multiple PHY-layer parameters, including modulation, coding rate, channel bandwidth, and spatial streams.

**1. Key Variables in Data Rate Calculation**

|  |  |  |
| --- | --- | --- |
| Parameter | Symbol | Description |
| Modulation Order | M*M* | Bits per symbol (e.g., 6 for 64-QAM). |
| Coding Rate | R*R* | Ratio of data bits to total bits (e.g., 3/4 = 75% useful data). |
| Channel Bandwidth | B*B* | 20, 40, 80, 160, or 320 MHz. |
| Subcarriers | NSD*NSD*​ | Number of data subcarriers (e.g., 52 for 20 MHz OFDM). |
| Symbol Duration | Tsym*Tsym*​ | Time per OFDM symbol (4 μs with GI). |
| Spatial Streams | NSS*NSS*​ | Number of MIMO streams (e.g., 4 in 802.11ac). |

**2. Formula for Data Rate**



**3. Step-by-Step Calculation (Example: 802.11ac, 256-QAM, 80 MHz)**

1. **Modulation Order (M*M*)**:
   * 256-QAM → log⁡2(256)=8log2​(256)=8 bits per symbol.
2. **Coding Rate (R*R*)**:
   * Typical 5/6 → R=0.833*R*=0.833.
3. **Subcarriers (NSD*NSD*​)**:
   * 80 MHz OFDM → 234 data subcarriers.
4. **Symbol Time (Tsym*Tsym*​)**:
   * 3.6 μs (802.11ac with 0.4 μs short GI).
5. **Spatial Streams (NSS-*NSS*​)**:
   * Assume 4 streams.

Data Rate=234×8×0.833×43.6×10−6≈1733 Mbps

Data Rate=3.6×10−6234×8×0.833×4​≈1733 Mbps

**4. Standard-Specific Adjustments**

**A. 802.11n (HT)**

* **Subcarriers**: 52 (20 MHz) or 108 (40 MHz).
* **Max Rate Example**:
  + 64-QAM, 5/6 coding, 4 streams, 40 MHz → **600 Mbps**.

**B. 802.11ac (VHT)**

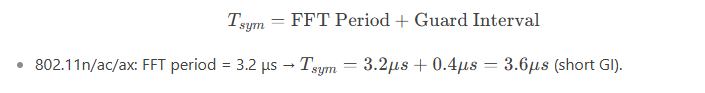
* **Subcarriers**: 234 (80 MHz) or 468 (160 MHz).
* **Max Rate Example**:
  + 256-QAM, 5/6 coding, 8 streams, 160 MHz → **6.9 Gbps**.

### ****8. Advanced Considerations in Data Rate Calculation****

#### ****A. Guard Interval (GI) Impact****

* **Standard GI (800 ns)**: Adds overhead but improves multipath resistance.
* **Short GI (400 ns)**: Increases data rate by ~10% but requires strong signal conditions.

**Adjusted Formula**:



#### ****B. OFDMA Efficiency (802.11ax)****

* **Resource Units (RUs)**: Subcarriers allocated to users dynamically.
* **Example**: A 20 MHz channel has 234 subcarriers = 9 RUs of 26 subcarriers each.
* **Throughput Gain**: More efficient than OFDM in multi-user scenarios.

#### ****C. MIMO/Spatial Streams****

* **Spatial Multiplexing**: Each stream carries independent data.
* **Limit**: Max streams = min(AP antennas, client antennas).
  + Wi-Fi 6: Up to 8 streams.
  + Wi-Fi 7: Up to 16 streams.

### ****9. Example Calculations for Common Scenarios****

#### ****Scenario 1: 802.11ac (5 GHz, 80 MHz, 3 Streams)****

* **Modulation**: 256-QAM (log⁡2(256)=8log2​(256)=8 bits/symbol).
* **Coding Rate**: 5/6 (R=0.833*R*=0.833).
* **Subcarriers**: 234 (80 MHz).
* **Symbol Time**: 3.6 μs (short GI).
* **Spatial Streams**: 3.

Data Rate=234×8×0.833×33.6×10−6≈1300 Mbps

Data Rate=3.6×10−6234×8×0.833×3​≈1300 Mbps

#### ****Scenario 2: 802.11ax (Wi-Fi 6, 160 MHz, 4 Streams)****

* **Modulation**: 1024-QAM (log⁡2(1024)=10log2​(1024)=10 bits/symbol).
* **Coding Rate**: 5/6 (R=0.833*R*=0.833).
* **Subcarriers**: 980 (160 MHz).
* **Symbol Time**: 3.6 μs (short GI).
* **Spatial Streams**: 4.

Data Rate=980×10×0.833×43.6×10−6≈9.1 Gbps

Data Rate=3.6×10−6980×10×0.833×4​≈9.1 Gbps

### ****10. Tools for Data Rate Estimation****

1. **Router Specs**: Check datasheets for NSS
2. *NSS*​, supported modulation, and bandwidth.
3. **Online Calculators**:

### ****11. Practical Implications****

* **Wi-Fi 6 vs. Wi-Fi 5**:
  + A Wi-Fi 6 router (1024-QAM, OFDMA) can deliver **2–4× more throughput** in crowded environments than Wi-Fi 5 (256-QAM, OFDM).
* **Wi-Fi 7 (802.11be)**:
  + 320 MHz channels + 4096-QAM → **40+ Gbps** under ideal conditions.