### Q8)OFDM vs. OFDMA: Key Differences in Wi-Fi Transmission

**1. Basic Definitions**

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| Technology | Description | Primary Use Case |
| OFDM (Orthogonal Frequency Division Multiplexing) | Divides a channel into multiple **orthogonal subcarriers** for single-user transmission. | Found in **802.11a/g/n/ac**. |
| OFDMA (Orthogonal Frequency Division Multiple Access) | Extends OFDM by assigning **subsets of subcarriers to multiple users simultaneously**. | Introduced in **802.11ax (Wi-Fi 6/6E)**. |

**2. Key Differences**

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| Feature | OFDM | OFDMA |
| User Allocation | Entire channel used by **one user at a time**. | Subcarriers divided among **multiple users** (like cellular LTE/5G). |
| Efficiency | Wastes bandwidth if a user doesn’t need full capacity. | **Dynamically allocates resources**, reducing waste. |
| Latency | Higher (users wait turns). | Lower (parallel transmissions). |
| Scalability | Struggles in dense networks. | Optimized for **high-density environments** (e.g., stadiums, IoT). |
| Subcarrier Groups | N/A | Uses **Resource Units (RUs)** (e.g., 26, 52, 106 subcarriers per user). |

**3. How OFDMA Works (802.11ax)**

* **Splits a 20/40/80/160 MHz channel** into smaller **Resource Units (RUs)**.
  + Example: A 20 MHz channel → **9 RUs of 26 subcarriers each**.
* **AP assigns RUs to devices** based on demand:
  + A smart light (low data) → **Small RU**.
  + A 4K streaming device → **Large RU**.

**4. Real-World Analogies**

* **OFDM** = A single-lane highway where cars (data packets) take turns.
* **OFDMA** = A multi-lane highway where cars (users) travel side-by-side in assigned lanes.

**5. Performance Comparison**

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| Metric | OFDM (802.11ac) | OFDMA (802.11ax) |
| Max Devices Supported | ~25-50 | **100+** (ideal for IoT). |
| Throughput Efficiency | Moderate | **Up to 4× better** in crowded networks. |
| Power Saving | Less efficient | **Target Wake Time (TWT)** reduces device energy use. |

**6. When Each is Used?**

* **Use OFDM** for:
  + Legacy devices (802.11a/g/n/ac).
  + Low-user-count environments (e.g., home networks).
* **Use OFDMA** for:
  + High-density scenarios (offices, airports).
  + Mixed traffic (4K video + smart sensors).

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| Aspect | OFDM | OFDMA |
| User Capacity | Single-user | Multi-user |
| Efficiency | Low in crowded areas | High (no wasted bandwidth) |
| Wi-Fi Standard | Up to 802.11ac | 802.11ax (Wi-Fi 6/6E) and later |
| Future-Proofing | Legacy | Essential for Wi-Fi 6/7 |