Major Innovations in Wi-Fi 7 (802.11be)

1. **320 MHz Channel Bandwidth**:
    - **Description**: Wi-Fi 7 doubles the maximum channel width from 160 MHz (Wi-Fi 6/6E) to **320 MHz**, primarily in the 6 GHz band, with support for contiguous and non-contiguous (e.g., 160+160 MHz) channels.
    - **Impact**: Wider channels allow significantly higher data throughput, contributing to a theoretical maximum speed of **~46 Gbps** (up to 4.8x faster than Wi-Fi 6/6E's ~9.6 Gbps). This is ideal for bandwidth-intensive applications like 8K video and immersive VR/AR.
    - **Comparison**: Wi-Fi 6/6E is limited to 160 MHz, which constrains throughput in high-demand scenarios. The 320 MHz channels in Wi-Fi 7 leverage the 6 GHz band's expanded spectrum for greater capacity.

2. **4096-QAM (Quadrature Amplitude Modulation)**:
    - **Description**: Wi-Fi 7 uses **4096-QAM**, which encodes more data per symbol (12 bits vs. 10 bits in Wi-Fi 6/6E's 1024-QAM), increasing data efficiency by ~20%.
    - **Impact**: Higher modulation enables faster data rates without requiring additional bandwidth, boosting throughput for applications like ultra-high-definition streaming. However, it requires strong signal quality to function effectively.
    - **Comparison**: Wi-Fi 6/6E's 1024-QAM is less efficient, limiting data density per transmission compared to Wi-Fi 7's 4096-QAM.

3. **Multi-Link Operation (MLO)**:
    - **Description**: MLO allows devices to simultaneously use multiple frequency bands (2.4 GHz, 5 GHz, 6 GHz) and channels for data transmission and reception. It supports modes like **Enhanced Multi-Link Single Radio (EMLSR)**, **Enhanced Multi-Link Multi-Radio (EMLMR)**, and **Simultaneous Transmit and Receive (STR)** or **Non-STR**.
    - **Impact**: MLO increases throughput, reduces latency, and enhances reliability by aggregating bands or switching to less congested ones. For example, a device can use 6 GHz for high-speed data and 2.4 GHz for fallback, ensuring seamless connectivity. This is critical for real-time applications like gaming and VR.
    - **Comparison**: Wi-Fi 6/6E devices are limited to single-band operation at a time, leading to potential delays when switching bands or handling congestion. MLO is a revolutionary feature unique to Wi-Fi 7.

4. **Multiple Resource Units (MRU) and Puncturing**:
    - **Description**: Wi-Fi 7 enhances **OFDMA** (introduced in Wi-Fi 6) with **Multiple Resource Units (MRU)**, allowing devices to use combinations of resource units (e.g., 26-, 52-, 106-, 242-, 484-, 996-, 2x996-, or 4x996-tone RUs) within a channel. **Puncturing** enables the use of partially occupied channels by "punching out" interfered segments, maximizing spectrum efficiency.
    - **Impact**: MRU and puncturing improve throughput and reduce latency in dense environments by enabling more flexible and efficient spectrum allocation. This ensures better performance in crowded networks like stadiums or offices.

    - **Comparison**: Wi-Fi 6/6E's OFDMA uses single RUs without puncturing, which can waste spectrum if parts of a channel are interfered. Wi-Fi 7's approach is more adaptive and efficient.

5. **16x16 MU-MIMO**:
    - **Description**: Wi-Fi 7 supports up to **16x16 Multi-User Multiple Input Multiple Output (MU-MIMO)**, doubling Wi-Fi 6/6E's 8x8 MU-MIMO. This allows access points to communicate with up to 16 devices simultaneously in both uplink and downlink.
    - **Impact**: Higher MU-MIMO capacity supports more devices in dense environments, increasing network efficiency and reducing contention. This is crucial for enterprise settings or smart homes with numerous connected devices.

    - **Comparison**: Wi-Fi 6/6E's 8x8 MU-MIMO is less capable of handling large numbers of simultaneous connections, limiting performance in high-density scenarios.

6. **Multi-Access Point (AP) Coordination**:
    - **Description**: Wi-Fi 7 introduces coordinated and joint transmission between multiple access points, enabling techniques like **Coordinated OFDMA**, **Coordinated Beamforming**, and **Joint Transmission**.
    - **Impact**: AP coordination improves network efficiency, reduces interference, and enhances coverage in large-scale deployments (e.g., campuses, stadiums). It ensures consistent performance across multiple APs, benefiting mobile devices during roaming.

    - **Comparison**: Wi-Fi 6/6E lacks standardized AP coordination, leading to potential interference and inefficiencies in multi-AP environments.