### Q9)Fast BSS Transition (802.11r): Seamless Roaming for Mobile Devices

**Fast BSS Transition (802.11r)** is an IEEE standard designed to minimize **handoff delays** when a Wi-Fi client (e.g., smartphone, VoIP phone) moves between access points (APs) in the same network. It’s critical for **real-time applications** (voice calls, video conferencing, industrial IoT) where even a brief disconnect can disrupt performance.

**1. How 802.11r Works**

**Traditional Roaming (Without 802.11r):**

1. **Reauthentication Required**: Each time a client roams, it must:

* Perform a full **802.1X authentication** (for enterprise networks).
* Re-establish encryption keys (4-way handshake).

1. **Result**: **50–200 ms delay**, causing dropped calls or buffering.

**With 802.11r:**

1. **Pre-Authentication & Key Caching**:

* The client authenticates **once** with the network.
* Encryption keys are **pre-distributed** to nearby APs.

1. **Fast Transition**: When roaming, the client simply:

* Sends a request to the new AP.
* Receives a pre-shared key (no full handshake).

1. **Result**: **Handoff completes in <10 ms** (near-instantaneous).

**2. Key Benefits in Mobile Environments**

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| --- | --- | --- |
| Scenario | Without 802.11r | With 802.11r |
| VoIP/Video Calls | Drops during roaming | No interruptions |
| Industrial Automation | Robot control lags | Seamless movement |
| Healthcare (VoWiFi) | Critical delays | Stable connections |
| Public Venues (Stadiums) | Poor user experience | Smooth streaming |

**3. Technical Components**

* **PMK-R0 (Root Key)**: Generated during initial authentication and shared across APs.
* **PMK-R1 (Derived Key)**: Unique per AP, derived from PMK-R0 for faster transitions.
* **FT Protocol**: Skips the 4-way handshake during roaming.

**4. 802.11r vs. Other Roaming Aids**

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| --- | --- | --- |
| Standard | Role | Works With 802.11r? |
| 802.11k | Provides neighbor AP reports | ✅ Yes (optimizes AP selection) |
| 802.11v | Guides clients to better APs | ✅ Yes (steers clients faster) |
| 802.11r | Eliminates reauthentication | **Core roaming enabler** |

**5. Limitations**

* **Requires enterprise APs** (consumer routers rarely support it).
* **Clients must support 802.11r** (most modern smartphones/tablets do).
* **Not for open/public networks** (relies on pre-shared keys).