**CHANNEL MANAGEMENT**

**I. Frequency Channel Saturation (Sự Bão Hoà Kênh Tần Số):**

- Definition: Frequency channel saturation is when a wireless communication channel becomes overloaded, leading to performance degradation.

- Primary Causes:

* **High Device Density**: Too many devices in a small area.
* **High Data Demand**: Bandwidth-intensive applications (video, gaming).
* **Interference:** From other wireless or electronic devices.
* **Environmental Obstacles**: Walls, buildings, etc.
* **Poor Channel** Planning: Inefficient frequency allocation.

- Resulting Effects:

* Reduced Throughput: Slower data transfer speeds.
* Increased Latency: Delays in data transmission.
* Packet Loss: Data packets lost during transmission.
* Connection Instability: Dropped connections.
* Lower SNR (Signal-to-Noise Ratio): Degraded signal quality.

- Crucial Mitigation Strategies:

* **Effective Channel Planning**: Choosing less congested channels.
* **Frequency Reuse: Reusing** frequencies in different areas.
* **Bandwidth Management**: Prioritizing traffic with QoS.
* **Power Control**: Adjusting transmit power to minimize interference.
* **Advanced Technologies**: MIMO, beamforming, 5G, and advanced Wifi standards.
* **Network Segmentation** (VLANs): Reducing traffic per channel.

- Importance:

* Understanding saturation is vital for designing reliable wireless networks.
* Proper planning and management are essential for optimal performance, especially in high-density environments.
* It is very important to use tools to analyze the spectrum, so that you can see where the congestion is, and the noise floor is.

**II. DSSS (Direct-Sequence Spread Spectrum)**

- Purpose:

* Spreads a signal across a wider frequency band to make it harder to detect or jam.
* Originally developed for secure military communication.
* Used in 802.11b to reduce interference in the 2.4 GHz band.

- How it Works:

* Modifies the signal to distribute its power over a broader frequency range, lowering its peak power.
* A receiver with the correct "key" can undo this spreading and recover the original signal.

- Benefit:

* Increases resistance to interference and jamming.
* Makes the signal less noticeable to unintended receivers.

A diagram of an oscillating signal

AI-generated content may be incorrect.

**III. FHSS (Frequency-Hopping Spread Spectrum)**

- Core Idea:

* Transmits data by rapidly switching the carrier signal between multiple frequency channels.
* Sender and receiver must synchronize to follow the same "hopping" pattern.

- Benefits:

* Improved resistance to interference and jamming.
* More efficient use of available frequency channels.
* Reduces channel congestion.

- Applications:

* Original 802.11 standard.
* Walkie-talkies and 900 MHz cordless phones.
* Bluetooth (uses a modified version).

- How it Works:

* The signal "jumps" between frequencies according to a pre-determined sequence.
* Only a receiver that knows the sequence can correctly receive the signal.

**IV. OFDM (Orthogonal Frequency-Division Multiplexing)**

- Concept:

* Divides a single communication channel into many closely spaced sub-channels.
* These sub-channels are "orthogonal," meaning they overlap without causing interference.

- Key Feature:

* Highly efficient use of available bandwidth.
* Improved resistance to multipath interference (signal reflections).

- Applications:

* 802.11a/g/n/ac Wi-Fi standards.
* 802.11ax (Wi-Fi 6) uses OFDMA, a variation for multi-user access.

- Benefit: Increases data capacity and reliability by using many sub carriers.

**V. Comparision**

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| **Feature** | **OFDM** | **FHSS** | **DSSS** |
| Method | Divides channel into multiple orthogonal sub-channels | Rapidly switches carrier frequency between channels | Spreads signal over wide frequency band using PN code |
| Purpose | High bandwidth efficiency, multipath resistance | Interference reduction, security | Interference/jamming resistance, signal hiding |
| Bandwidth Use | Efficient, divides into sub-channels | Hops between multiple channels | Wide spread over large bandwidth |
| Interference handling | Strong against multipath interference | Strong against narrowband interference | Strong against narrowband interference |
| Data Rate | High | Low to mediumLow to medium | |
| Synchronization | Requires sub carrier synchronization | Requires frequency hopping sequence synchronization | Requires code synchronization. |
| Complexity | More complex signal processing | Moderate hopping pattern | Moderate, code generation. |
| Applications | 802.11a/g/n/ac/ax (Wi-Fi), digital TV | Original 802.11, Bluetooth, walkie-talkies | 802.11b (older Wi-Fi) |
| Key Advantage | High data rates, robust in complex environments | Excellent against interference, frequency diversity | Resists intentional jamming, signal hiding |