**Wireless security**

**WEP (Wireless equivaling protocol)** – The first wireless encryption protocol. Today it is considered insecure and no longer used. This protocol is vulnerable to brute-force attacks.

**WPA (Wi-Fi Protected Access)** - Uses the Temporal Key Integrity Protocol (TKIP) for encryption. TKIP dynamically changes keys as data is transmitted, making it harder for attackers to exploit the system. WPA was a significant improvement over WEP, but it was still vulnerable to certain attacks, such as brute-force attacks on the Pre-Shared Key (PSK, network password).

**WPA2** - Launched in 2004 as the official replacement for WPA. It became mandatory for all Wi-Fi devices in 2006. Uses the Advanced Encryption Standard (AES), which is much more secure than TKIP. WPA2 is significantly more secure than WPA and is still widely used today. It offers robust encryption that is difficult to crack. Supports both PSK (WPA2-Personal) and 802.1X (WPA2-Enterprise). WPA2-Enterprise is particularly secure as it uses a RADIUS server for authentication.

**WPA3** - announced in 2018 to address the shortcomings of WPA2 and to provide enhanced security for modern networks. Uses Simultaneous Authentication of Equals (SAE), also known as Dragonfly Key Exchange, which offers stronger protection against password guessing attacks. WPA3 also supports 192-bit encryption for highly sensitive networks. WPA3 introduces several new features to enhance security:

* **Forward Secrecy:** Ensures that even if a session key is compromised, it cannot be used to decrypt past sessions.
* **Protected Management Frames (PMF):** Improves security by ensuring that all management frames are encrypted and authenticated, reducing the risk of eavesdropping or spoofing attacks.
* **Easy Connect:** Simplifies the process of connecting IoT devices to a network securely.

Like WPA2, WPA3 supports both Personal and Enterprise modes. WPA3-Personal offers better protection against weak passwords, while WPA3-Enterprise provides even stronger encryption. While WPA3 is the most secure of the three, it is still relatively new, and widespread adoption is ongoing.

**Types of wireless network configurations used for connecting devices**

**Ad-Hoc Mode**

* **Direct Connection**: Devices connect directly to each other without a router or access point.
* **Use Cases**: Ideal for temporary, small networks (e.g., file sharing, local multiplayer games).
* **Advantages**: Easy setup, no need for additional hardware.
* **Disadvantages**: Limited range, less secure, not suitable for large networks.

**Infrastructure Mode**

* **Centralized Connection**: Devices connect via a central access point or router.
* **Use Cases**: Common in home, office, and public Wi-Fi networks.
* **Advantages**: Greater range, better security, supports many devices.
* **Disadvantages**: Requires an access point or router, more setup involved.

**Enterprise vs personal for WPA protocols**

* **WPA-Personal:** Uses a single Pre-Shared Key (PSK) (Wi-Fi password) for all devices. Simple setup, ideal for home and small networks.
* **WPA-Enterprise:** Uses individual user credentials (like usernames and passwords) authenticated via a RADIUS server. More secure, ideal for large organizations.

IEEE 802.11

**IEEE 802.11** is a set of standards that defines the protocols for implementing wireless local area network (WLAN) communications in various frequency bands. It is commonly known as **Wi-Fi** and is used to provide wireless internet access in homes, offices, and public spaces. The IEEE 802.11 standards cover a wide range of technologies and protocols that ensure devices can communicate wirelessly and securely.

**Frequency Bands**: IEEE 802.11 standards typically operate in the 2.4 GHz, 5 GHz, and 6 GHz frequency bands. Different amendments use these bands to avoid interference and provide better performance.

* **802.11a** (1999): Operates in the 5 GHz band with data rates up to 54 Mbps.
* **802.11b** (1999): Operates in the 2.4 GHz band with data rates up to 11 Mbps.
* **802.11g** (2003): Operates in the 2.4 GHz band with data rates up to 54 Mbps, backward-compatible with 802.11b.
* **802.11n** (2009): Introduced MIMO (Multiple Input Multiple Output) technology, supporting up to 600 Mbps in both 2.4 GHz and 5 GHz bands.
* **802.11ac** (2013): Operates in the 5 GHz band with data rates up to 1.3 Gbps, introduced wider channels and improved MIMO.
* **802.11ax** (2019): Also known as Wi-Fi 6, operates in both 2.4 GHz and 5 GHz bands (with extensions to 6 GHz in Wi-Fi 6E), offering higher data rates, improved efficiency, and better performance in crowded environments.

**1. IEEE 802.11 (1997)**

* **Frequency Band**: 2.4 GHz
* **Maximum Speed**: 2 Mbps
* **Description**: The original standard, providing very basic wireless communication.

**2. IEEE 802.11b (1999)**

* **Frequency Band**: 2.4 GHz
* **Maximum Speed**: 11 Mbps
* **Description**: An improvement over the original standard, widely adopted for home and small business networks.

**3. IEEE 802.11a (1999)**

* **Frequency Band**: 5 GHz
* **Maximum Speed**: 54 Mbps
* **Description**: Offered higher speeds but had a shorter range compared to 802.11b due to the higher frequency band.

**4. IEEE 802.11g (2003)**

* **Frequency Band**: 2.4 GHz
* **Maximum Speed**: 54 Mbps
* **Description**: Combined the best of both 802.11a and 802.11b, providing the higher speeds of 802.11a while maintaining compatibility with 802.11b devices.

**5. IEEE 802.11n (2009)**

* **Frequency Bands**: 2.4 GHz and 5 GHz (dual-band)
* **Maximum Speed**: 600 Mbps
* **Description**: Introduced MIMO (Multiple Input Multiple Output) technology, which allowed for multiple antennas to be used for both transmission and reception, significantly improving speed and range.

**6. IEEE 802.11ac (2013)**

* **Frequency Band**: 5 GHz
* **Maximum Speed**: 1.3 Gbps (Wave 1) to 3.5 Gbps (Wave 2)
* **Description**: Known as Wi-Fi 5, this standard brought improvements in speed and efficiency, including wider channel bandwidths (up to 160 MHz) and more MIMO streams.

**7. IEEE 802.11ax (2019)**

* **Frequency Bands**: 2.4 GHz, 5 GHz, and 6 GHz (Wi-Fi 6E)
* **Maximum Speed**: 9.6 Gbps
* **Description**: Known as Wi-Fi 6, it focuses on improving network efficiency, especially in crowded environments, with features like OFDMA (Orthogonal Frequency-Division Multiple Access) and improved MIMO. Wi-Fi 6E extends this to the 6 GHz band, providing more channels and less congestion.

**8. IEEE 802.11ad (2012)**

* **Frequency Band**: 60 GHz
* **Maximum Speed**: 7 Gbps
* **Description**: Known as WiGig, this standard is used for very high-speed short-range communication, typically within a room.

**9. IEEE 802.11ay (2021)**

* **Frequency Band**: 60 GHz
* **Maximum Speed**: 176 Gbps
* **Description**: An evolution of 802.11ad, aiming to improve data rates, range, and reliability in the 60 GHz band.

**Other wireless standards**

**Zigbee** is a wireless communication standard designed for low-power, low-data-rate applications, often used in smart home devices and IoT networks. It supports mesh networking, allowing devices to communicate over longer distances by relaying messages through other devices. Zigbee is known for its efficiency and low energy consumption.

**Z-Wave** is a wireless communication standard designed for smart home and IoT devices. It operates in the sub-1 GHz frequency range, which helps avoid interference with Wi-Fi and Bluetooth. Z-Wave is known for its low power consumption, reliability, and mesh networking capabilities, allowing devices to communicate over long distances by passing messages through other devices in the network.

**LoRa (Long Range)** is a wireless communication technology designed for long-range, low-power IoT applications. It operates in the sub-GHz frequency bands and is ideal for transmitting small amounts of data over distances that can reach several kilometers, even in rural or remote areas. LoRa is well-suited for applications like smart agriculture, environmental monitoring, and asset tracking, where low power and long-range connectivity are crucial.

**WiMAX (Worldwide Interoperability for Microwave Access)** is a wireless communication technology designed to provide high-speed broadband internet access over long distances. It operates in various frequency bands, including 2.3 GHz, 2.5 GHz, and 3.5 GHz. WiMAX supports both fixed and mobile applications and can deliver internet speeds comparable to those of DSL or cable, with a coverage range that can extend up to 50 kilometers (about 31 miles) in some configurations. It is often used for providing internet access in underserved areas and as a backhaul solution for cellular networks.