Lecture 11: WiFi Security

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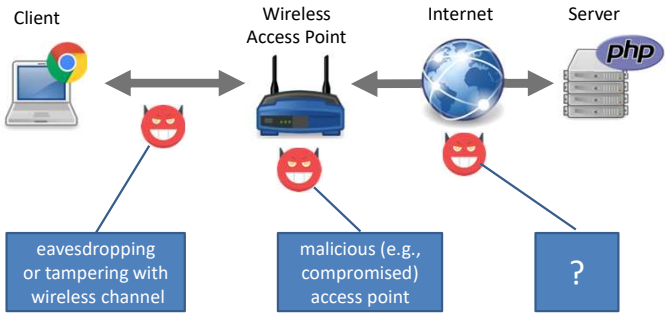
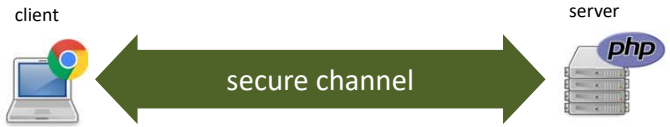
IEEE 802.11 specifies technical standard for implementing Wireless LAN (WLAN) computer communication.

1. Security Protocol

- Communication Threats in Practice



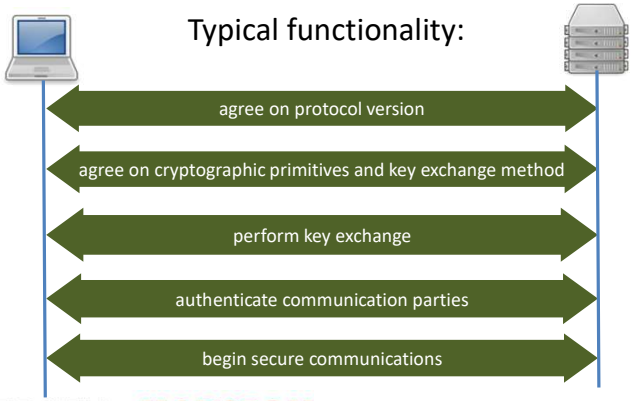
Security



How can devices, software products, etc. from different vendors, manufacturers, etc. communicate with each other?

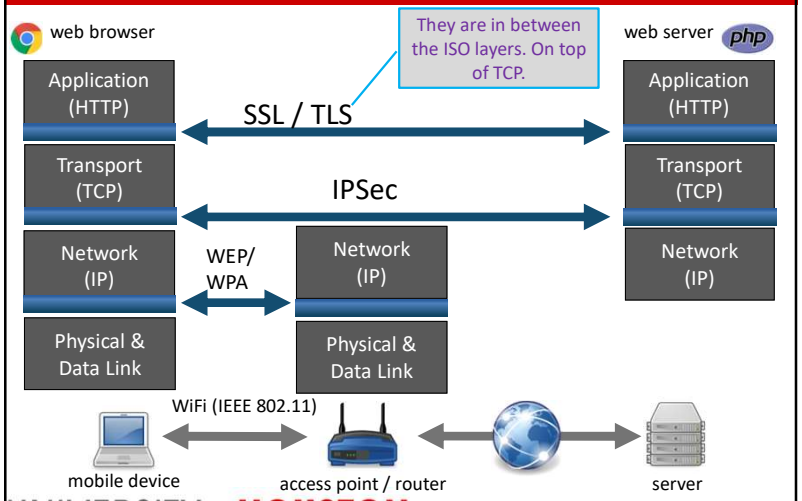
Security Protocols

- Standard security protocols specify messages, data structures, and the usage of cryptographic primitives to provide interoperability.



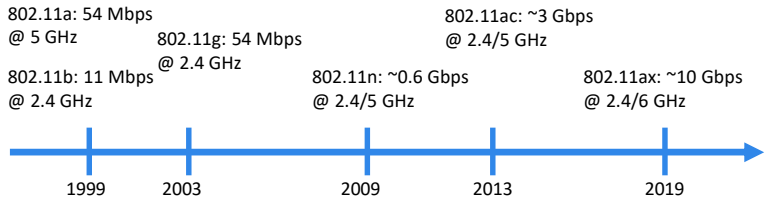
Communication in Practice

Protocol Stack in Practice



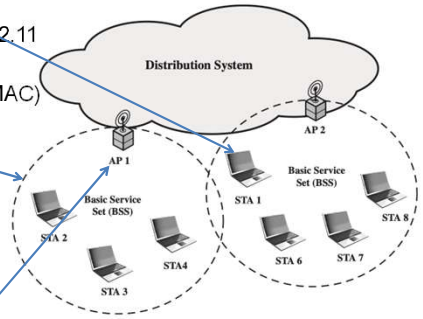
2. IEEE 802.11 Standard

- IEEE 802.11: set of standards for wireless local area networks (WLANs). It was accepted by ISO/OSI as standard.
- Wi-Fi Alliance
  - non-profit organization of companies, certifies devices for interoperability
  - WiFi = WLAN based on 802.11 standard



IEEE 802.11 Network Components

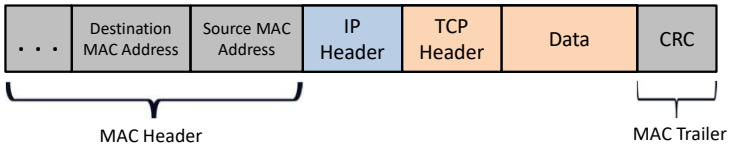
- Station (STA)
  - any device using IEEE 802.11
  - interface identified by a medium access control (MAC) address
- Basic Service Set
  - set of stations executing the same medium access control protocol
  - identified by a service set identifier (SSID)
- Access Point (AP)
  - has station functionality and provides access to the distribution system



MAC

- A media access control (MAC) address is a computer's unique identification number used by the network.
- MAC addresses are hardcoded into the Network Interface Card (NIC) when it's manufactured.
- The MAC is globally unique, so two devices can't have the same MAC address.
- MAC is represented in a hexadecimal format like this: `00:0a:45:2e:52:28`.
- Applications: MAC filtering (white-listing), MAC masking (black-listing).
- MAC Address Spoofing.
- MAC address randomization (iOS) can be used to prevent device tracking..

IEEE 802 Frame



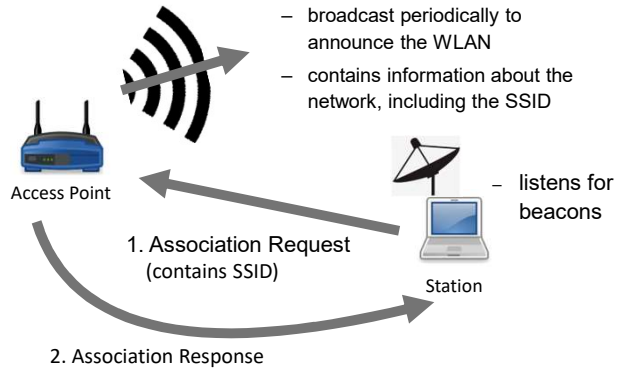
Medium Access Control (MAC) frame format:

- Destination MAC address: destination's physical address on the LAN.
- Source MAC address: source's physical address on the LAN.
- MAC Service Data Unit: data from higher laye.
- CRC: cyclic redundancy check field for transmission error detection.

IEEE 802.11 Beacons and Association

Beacon:

- broadcast periodically to announce the WLAN
- contains information about the network, including the SSID

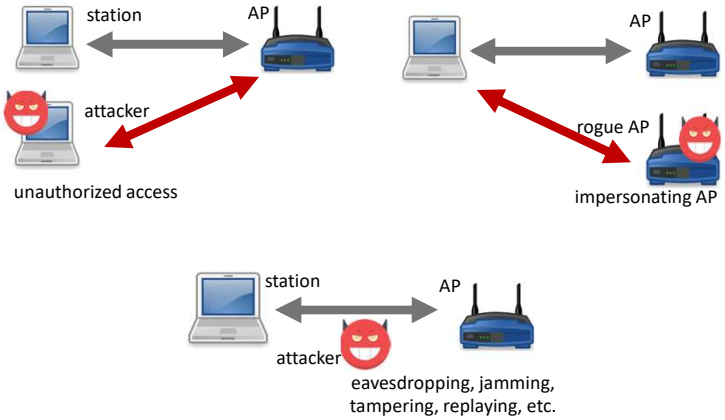


3. Wireless Security

Problem: no inherent physical protection

- Joining a network does not require physical access.
- Radio transmissions are broadcast → Anyone in range can eavesdrop.
- Injecting new messages or replaying old messages is possible.
- Jamming attacks against availability.
- Jamming and injecting messages can be combined into tampering attacks.

Security Challenges



Access Control: Hidden SSID

- SSID: Service Set Identifier, a network's name.
- The association request must contain the network's SSID. By default, the AP broadcasts it periodically in the beacon.
- AP may be configured to stop announcing the SSID. SSID may be used as a "password".
- However,
  - SSID must be hard to guess.
  - every authorized user must know the SSID.
  - SSID can be easily eavesdropped whenever an authorized station connects to the network. It does not provide any security.
  - Tools are available for eavesdropping.

https://www.aircrack-ng.org/

Access Control: MAC Address-Based Filtering

- AP may be configured to allow only devices with certain MAC addresses to connect.
  - MAC addresses of all authorized devices must be registered in advance.
- However,
  - MAC address is sent in plaintext in every packet
  - Many WLAN devices allow their MAC addresses to be changed. An attacker can easily impersonate an authorized user.
- *Example*: changing MAC address of macOS

```
$ sudo ifconfig en0 ether 6c:40:aa:11:22:33
```

IEEE 802.11 Security Standards

- WEP (Wired Equivalent Privacy)
  - introduced in 1997 as part of the original 802.11 standard
  - shown to be insecure in 2001
- WPA (WiFi Protected Access)
  - introduced in 2003, as a quick fix to WEP
  - subset of draft IEEE 802.11i
- WPA-2 (IEEE 802.11i)
  - standardized in 2004
- WPA-3
  - announced in 2018
  - very similar to WPA-2

4. WEP

- How not to design a security protocol…
- WEP: Wired Equivalent Privacy (IEEE 802.11)

Wired Equivalent Privacy (WEP)

- Goal: Making WiFi at least as secure as wired networks.
  - Not a very ambitious goal, but fell short of even this goal …
- Design overview
  - Security is based on a 40- or 104-bit **secret key**
    - WiFi "password" shared by all users
  - **Confidentiality**: RC4 stream cipher
    - The key is extended by a 24-bit IV, which is changed for each message → used as a nonce to prevent key reuse problems
  - **Integrity**: encrypted CRC32 (Cyclic Redundancy Check) checksum.
  - **Access control**: challenge-response between AP and station.

WEP Design Flaws

- Authentication
  - One-way authentication (only for the station to AP), AP can be impersonated.
- Integrity Protection
  - Based on error-detection code (CRC32) instead of cryptographic hash → forging authentication tags is trivial.
  - No message replay protection.
- Key usage
  - No session key: long-term key used for all purposes (authentication, encryption, integrity protection).
  - Short nonce (i.e., 24-bit IV) → danger of key reuse for stream cipher
    - busy network with 1000 packets per second reuses in less than 5 hours.

Fluhrer-Mantin-Shamir Attack (2001)

- The attacker knows the first three bytes of RC4 key (i.e., the 24-bit IV).
- Due to RC4 weaknesses, attacker can guess the 4th key byte (i.e., 1st secret byte) correctly with a probability of ≈ 0.58% using a single ciphertext-plaintext pair.
  - random guess should be correct only with probability = 1/256 ≈ 0.39%
- With enough ciphertext-plaintext pairs, an attacker can discover the 4th key byte (with probability ≈ 100%)
- Then, the attacker can discover the 5th, 6th, … bytes using the same approach (i.e., 2nd, 3rd, … secret bytes)
- In practice, WEP keys can be broken in a matter of minutes (or less) → WEP is not secure
  - easy to use tools for breaking WEP are available

Lessons Learned from WEP

- Aiming for mediocre security will likely result in no security.
- Follow design principles (or face the consequences)
  - do not use error-detection codes for message authentication.
  - use session keys for data encryption and authentication.
- …
- Do not use WEP!
- Problem: WEP needed to be replaced very quickly in 2001
  - existing devices (e.g., access points, wireless interface cards) had hardware support only for WEP (e.g., for RC4)
  - many networking devices had low computational performance

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WiFi Protected Access (WPA)

Standard: 802.11i TKIP (Temporal Key Integrity Protocol)

- Design goals: fix the flaws of WEP and be compatible with legacy hardware
- Overview
  - key usage: the session key is established during a secure two-way authentication
  - confidentiality: RC4 encryption, but with 48-bit IV, which is mixed thoroughly with the session key and source MAC address
    - prevents key reuse and the Fluhrer-Mantin-Shamir attack
  - integrity: 64-bit message integrity codes computed using Michael, which is computationally very efficient but provides only ~20 bits of effective security
    - after the wrong code, the station is banned for a minute and needs to re-authenticate
- Deprecated in later revisions of the standard

Next Topic

- Protocol, WiFi Security
- WPA2 and IP Security
- Transportation Layer Security