Advanced Mutation Fuzzing Method For Wireless Protocols

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About us

Lidong LI:

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CTFer
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Protocol Security Research

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Agenda

- protocol stack analysis
- Attack vulnerable drivers
- Advanced Mutation Fuzzing
- Conclusion

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About Wireless Fuzzing ?

- After the target receives the malformed data……
- Our target is **Phone , Wireless** adapter , Smart Devices , IOT Devices…
- All wifi connected smart devices
- **OverFlow** ? **Crash** ? **Denial of service** ?
- Car wireless module
- Wireless frame in the air SO….
- Exploit….**RCE** ! ! ! !

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protocol stack analysis

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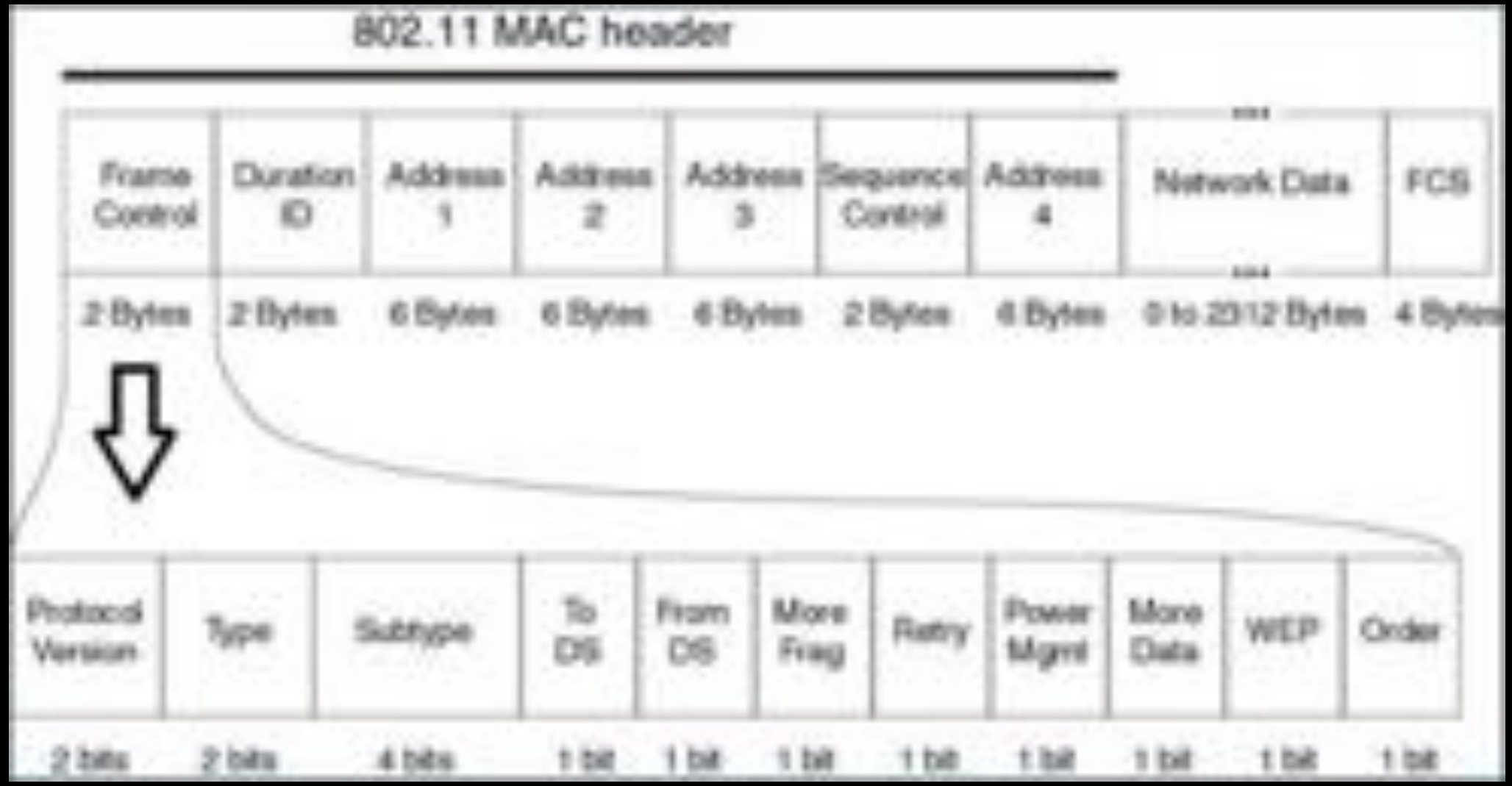
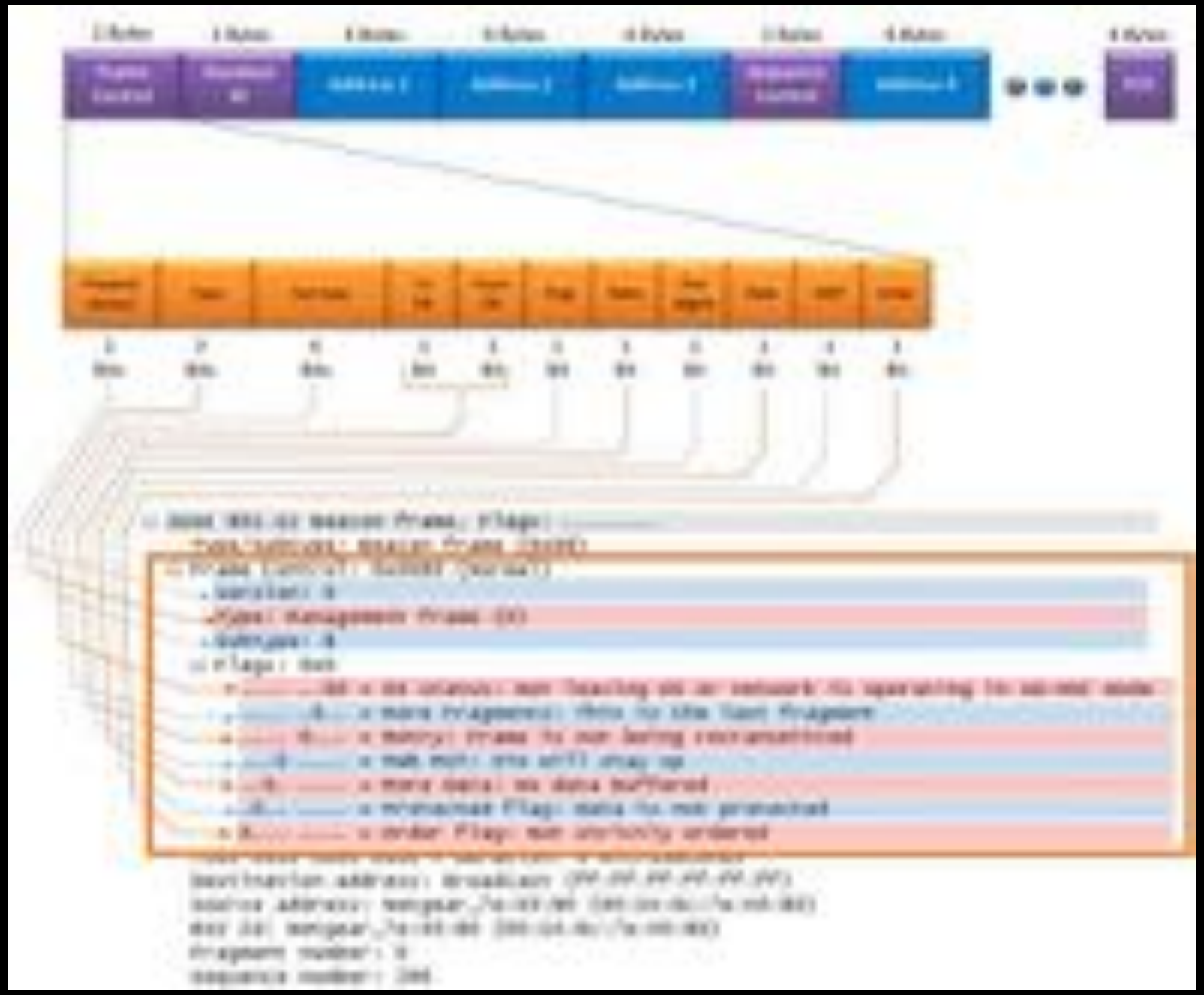
protocol stack analysis





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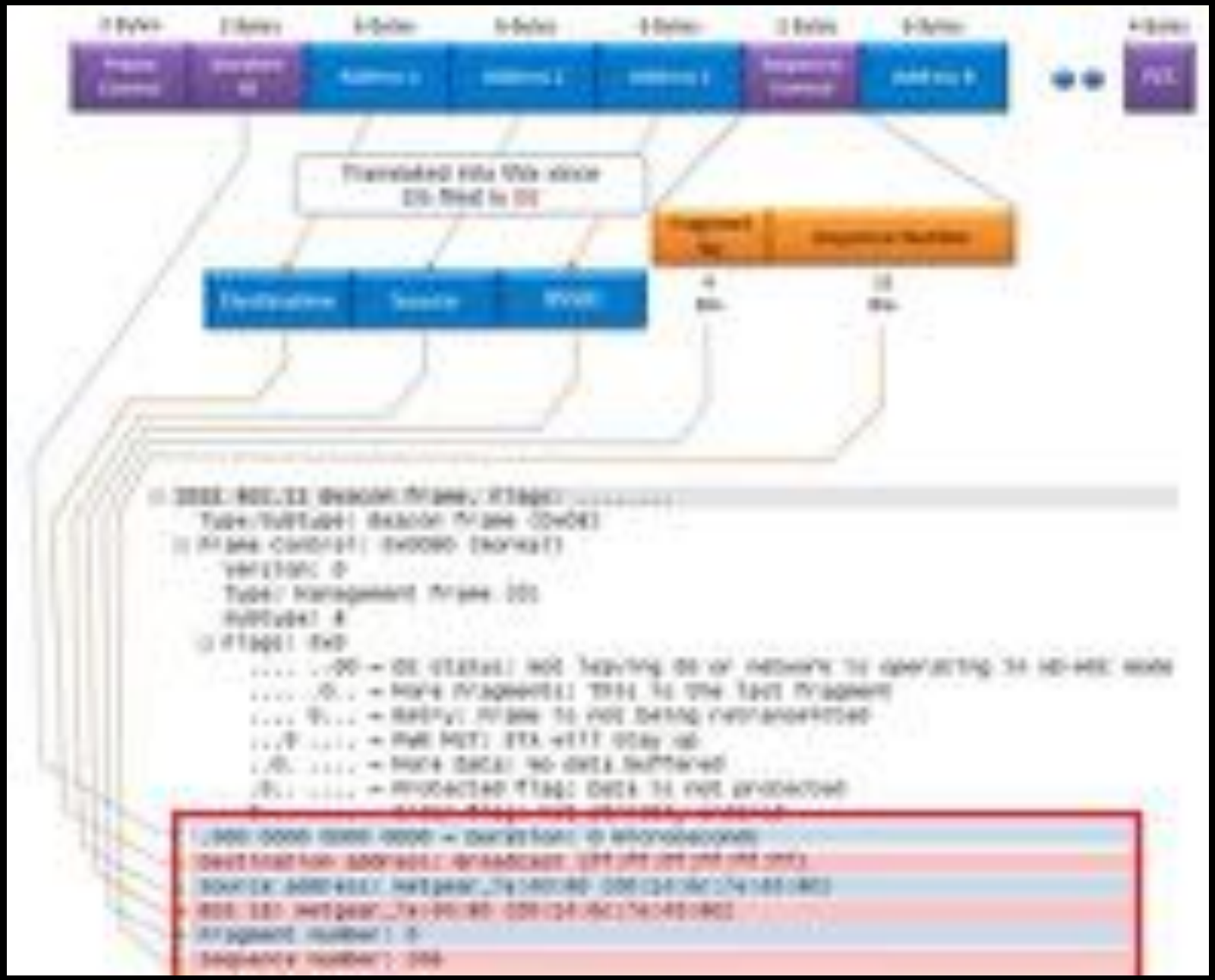

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Attack vulnerable drivers

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Classic fuzzing

example:

```
brcmf_cfg80211_start_ap(   struct cfg80211_ap_settings *settings ) {
        s32  ie_offset;
        struct brcmf_tlv *ssid_ie;
        struct brcmf_ssid_le ssid_le;

        memset( &ssid_le, 0, sizeof(ssid_le) );

        if  ( settings->ssid == NULL || settings->ssid_len == 0 ) {
                ie_offset = DOT11_MGMT_HDR_LEN +
DOT11_BCN_PRB_FIXED_LEN;
                ssid_ie = brcmf_parse_tlvs( (u8
*)&settings->beacon.head[ie_offset], settings->beacon.head_len -
ie_offset, WLAN_EID_SSID );
                if ( !ssid_ie )
                        return -EINVAL;

                memcpy( ssid_le.SSID, ssid_ie->data,
ssid_ie->len );   //overflow here.
                ssid_le.SSID_len = cpu_to_le32( ssid_ie->len );
        }
        else {
                memcpy( ssid_le.SSID, settings->ssid,
settings->ssid_len );
                ssid_le.SSID_len = cput_to_le32( (u32)settings->ssid_len);
        }
        ...
    });
        }
```

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Fuzzing testing example

- Management frame tag other than SSID?
- Supported Rates….
- Channel…
- EXRates…
- Traffic Indication Map (TIM)

```
▸Frame 12: 322 bytes on wire (2576 bits), 322 bytes captured (2576 bits) on
▸Radiotap Header v0, Length 18
▸802.11 radio information
▸IEEE 802.11 Beacon frame, Flags: ........
▾IEEE 802.11 wireless LAN
  Fixed parameters (12 bytes)
  ▾Tagged parameters (268 bytes)
    ▸Tag: SSID parameter set: DIRECT-xZSAKURAKHCRmsLW
    ▸Tag: Supported Rates 6(B), 9, 12(B), 18, 24(B), 36, 48, 54, [Mbit/sec]
    ▸Tag: DS Parameter set: Current Channel: 8
    ▸Tag: Traffic Indication Map (TIM): DTIM 0 of 0 bitmap
```

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Different types of frame bodies contain different information elements.

- 802.11 protocol certain the minimum and maximum length of each element-certain information field.

- **Long or short IE length in fuzzing testing.**

- **Each type of frame contains its own** certain **information elements.**

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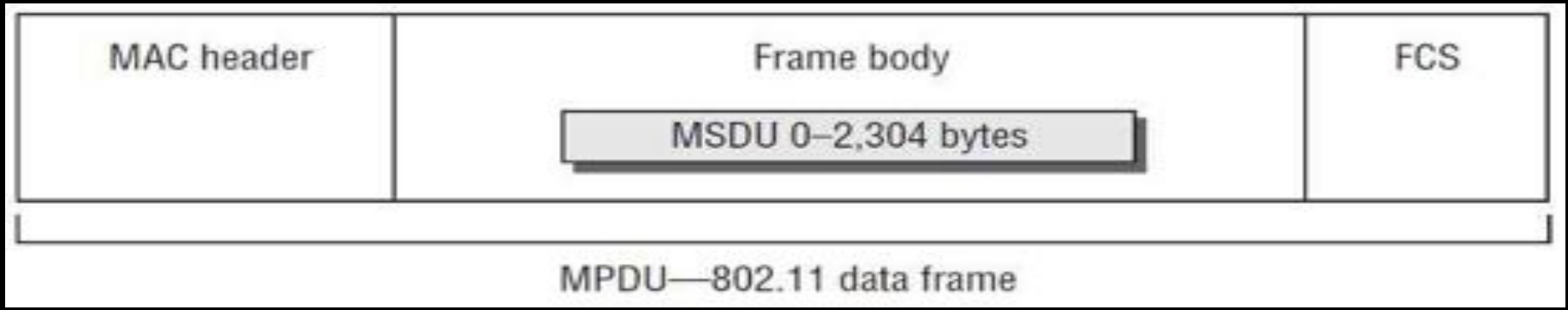

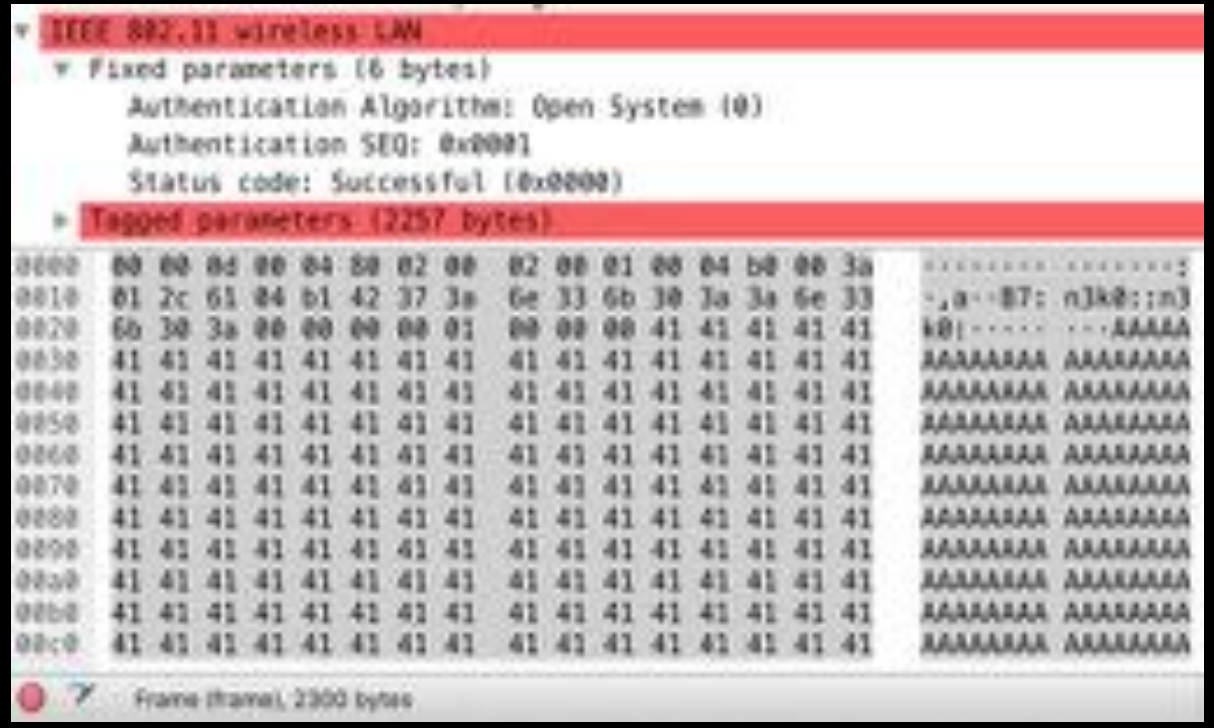

- **The maximum 802.11 MTU is 2304 bytes!!!**

MTU + MAC Header + Encryption Header

- **WEP : 2304 + 34 + 8 = 2346 bytes**
- **WPA (TKIP) : 2304 + 34 + 20 = 2358 bytes**
- **WPA2 (CCMP) : 2304 + 34 + 16 = 2354 bytes**

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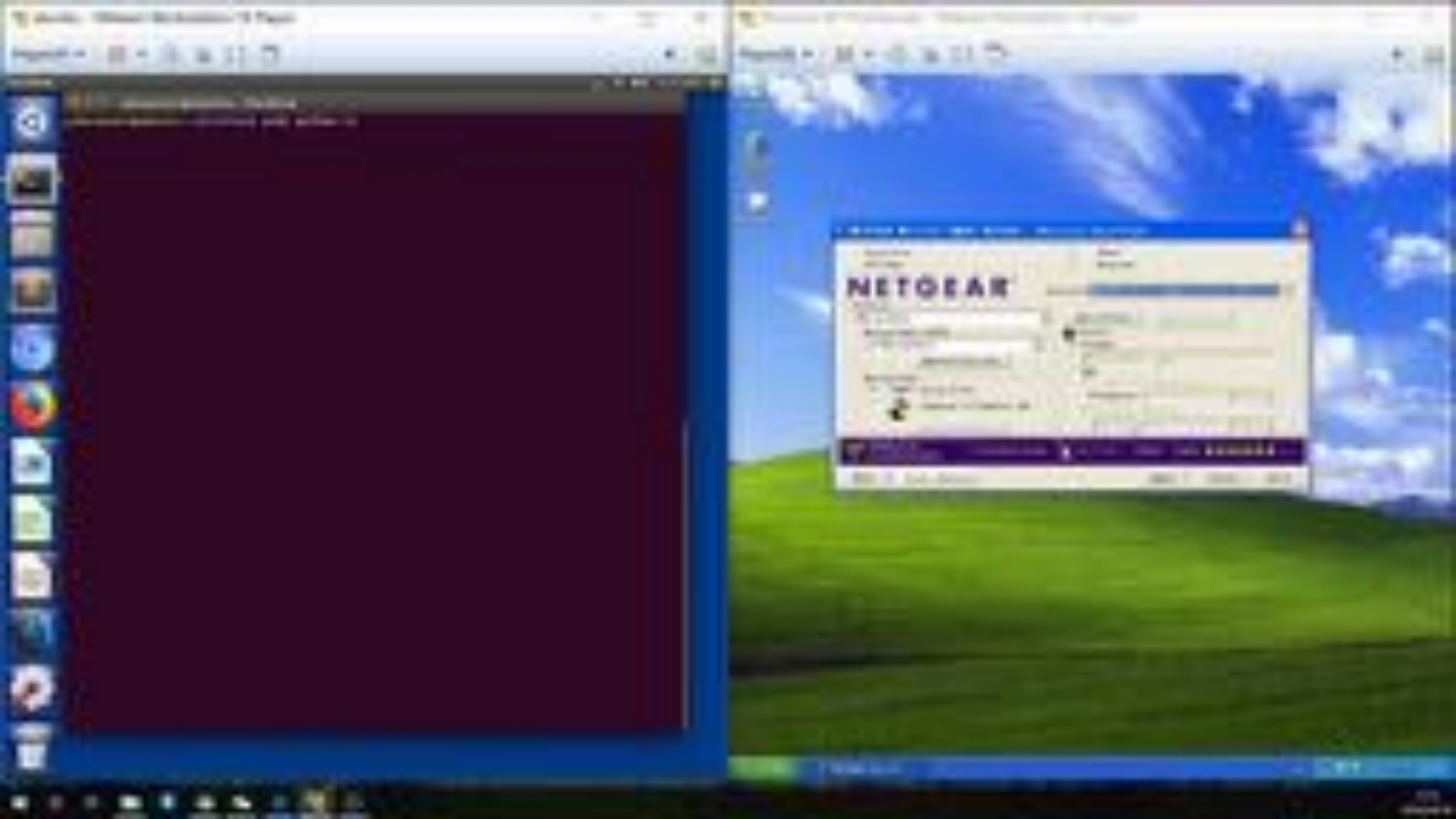
Demo


NETGEAR

Advanced Mutation Fuzzing

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How to design a smart mutation strategy? ?

Frequency range / Type	PHY	Protocol	Release date[1]	Frequency	Bandwidth	Stream data rate[1]	Kilometer (MIMO streams)	Modulation	Approximate range[Indoor/outdoor assumed]	
				(GHz)	(MHz)	(Mbit/s)			Indoor	Outdoor
1-6GHz	[illegible]	802.11-1997	Jun 1997	2.4	22	1, 2	n/a	[illegible], FHSS	20 m (66 ft)	100 m (330 ft)
	HR [illegible][2]	802.11b	Sep 1999	2.4	22	1, 2, 5.5, 11	n/a	[illegible]	35 m (115 ft)	140 m (460 ft)
	OFDM	802.11a	Sep 1999	5	[illegible]	6, 9, 12, 18, 24, 36, 48, 54 (for 20MHz bandwidth, divide by 2 and 4 for 10 and 5 MHz)	n/a	OFDM	35 m (115 ft)	120 m (390 ft)
		802.11j	Nov 2002	4.9/5.0[3][4][5]					-	-
		802.11p	Jul 2010	5.9					-	1,000 m (3,300 ft)[6][7]
		802.11n	Nov 2009	2.4/5[8]					-	5,000 m (16,500 ft)[8]
	DSSS-CHSM, etc.)	802.11g	Jun 2003	2.4					38 m (125 ft)	140 m (460 ft)
	HT-OFDM[9]	802.11n	Oct 2009	2.4/5	20	Up to 288.8[10]	4	MIMO-OFDM	70 m (230 ft)	250 m (820 ft)[10]
					40	Up to 600[10]				
	VHT-OFDM[11]	802.11ac	Dec 2013	5	20	Up to 346.8[10]	8	MIMO-OFDM	35 m (115 ft)[12]	-
					40	Up to 800[10]				
					80	Up to 1733.2[10]				
					160	Up to 3466.8[10]				

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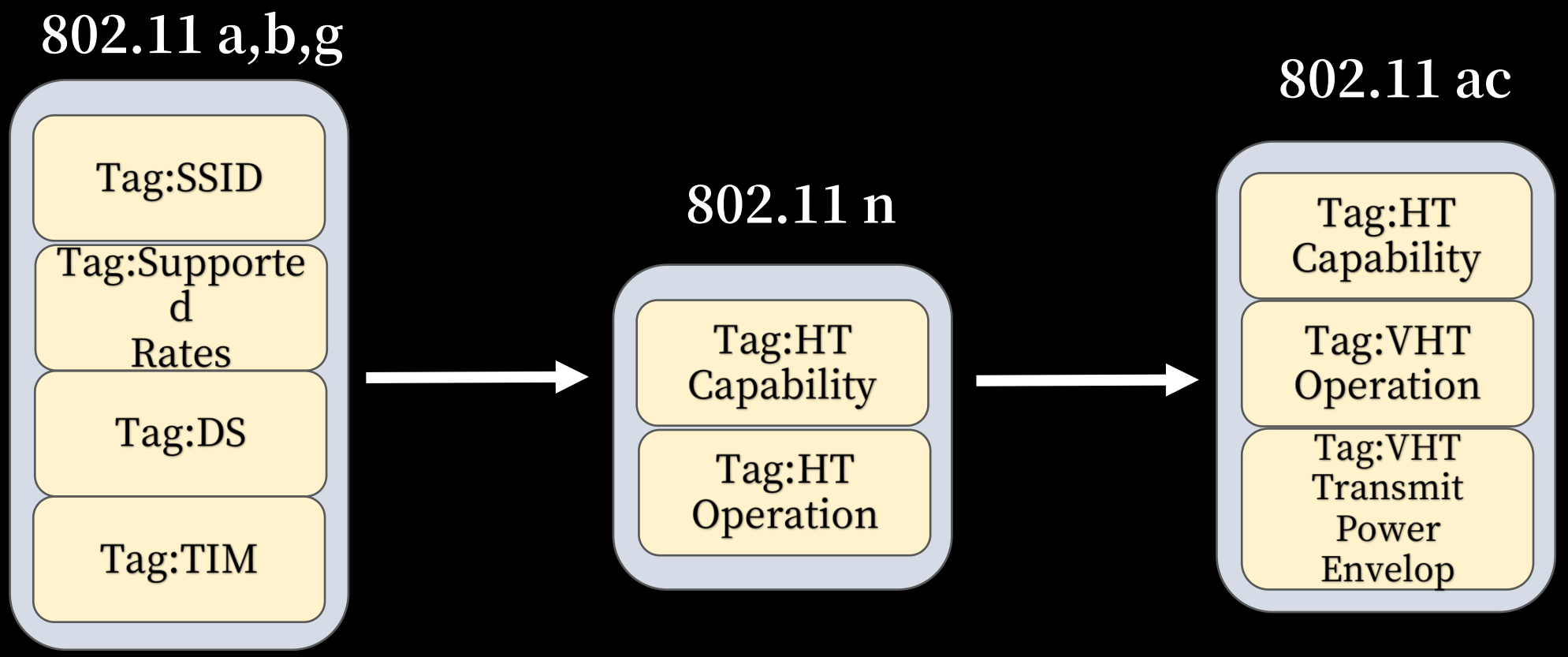

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Core specification

```
▾IEEE 802.11 wireless LAN
  ▸Fixed parameters (4 bytes)
  ▾Tagged parameters (15 bytes)
    ▸Tag: SSID parameter set: AAA
    ▾Tag: Supported Rates BSS requires support for mandatory features of HT PHY (IEEE 802.11 - Clause 20), BSS r
      Tag Number: Supported Rates (1)
      Tag length: 8
      Supported Rates: BSS requires support for mandatory features of HT PHY (IEEE 802.11 - Clause 20) (0xff)
      Supported Rates: BSS requires support for mandatory features of HT PHY (IEEE 802.11 - Clause 20) (0xff)
      Supported Rates: BSS requires support for mandatory features of HT PHY (IEEE 802.11 - Clause 20) (0xff)
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      Supported Rates: BSS requires support for mandatory features of HT PHY (IEEE 802.11 - Clause 20) (0xff)
```

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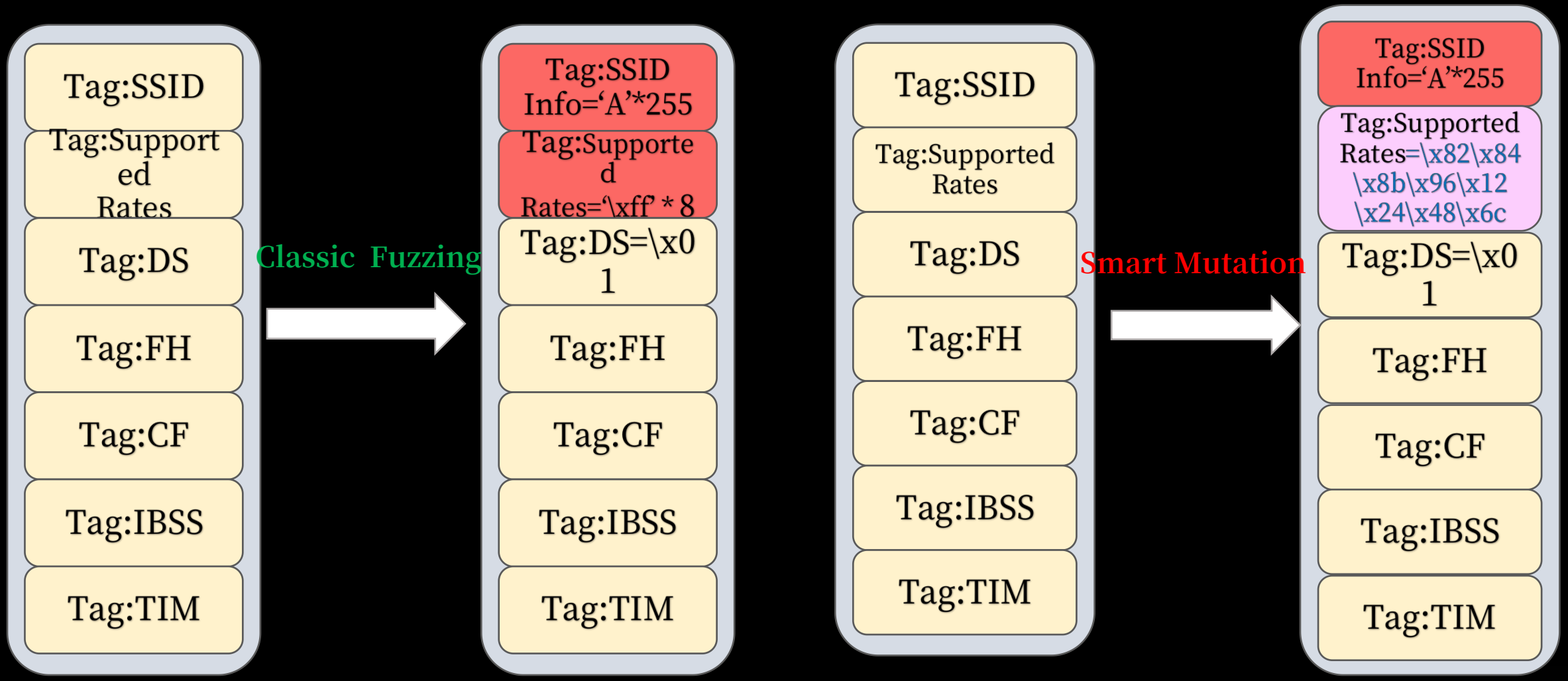

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Beacon

- Tag:SSID
- Tag:Supported Rates
- Tag:Extended Rates
- Tag:Vendor Specific
- Tag:TIM

→

ProbeResp

- Tag:SSID
- Tag:Supported Rates
- Tag:Extended Rates
- Tag:Vendor Specific
- Tag:TIM

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Detail mutation for Frame Tag subtype ?

The RSN Information Element is provided below. The Size of the RSN IE is limited to a maximum of 255 bytes

	Element ID	length	Version	Group Data Cipher Suite	Pairwise Cipher Suite Count	Pairwise Cipher Suite List
Octets	1	1	2	4	2	4 * **m**

	AKM Suite Count	AKM Suite List	RSN Capabilities	PMKIDCount	PMKID List	Group Management Cipher Suite
Octets	2	4*n	2	2	16*s	4

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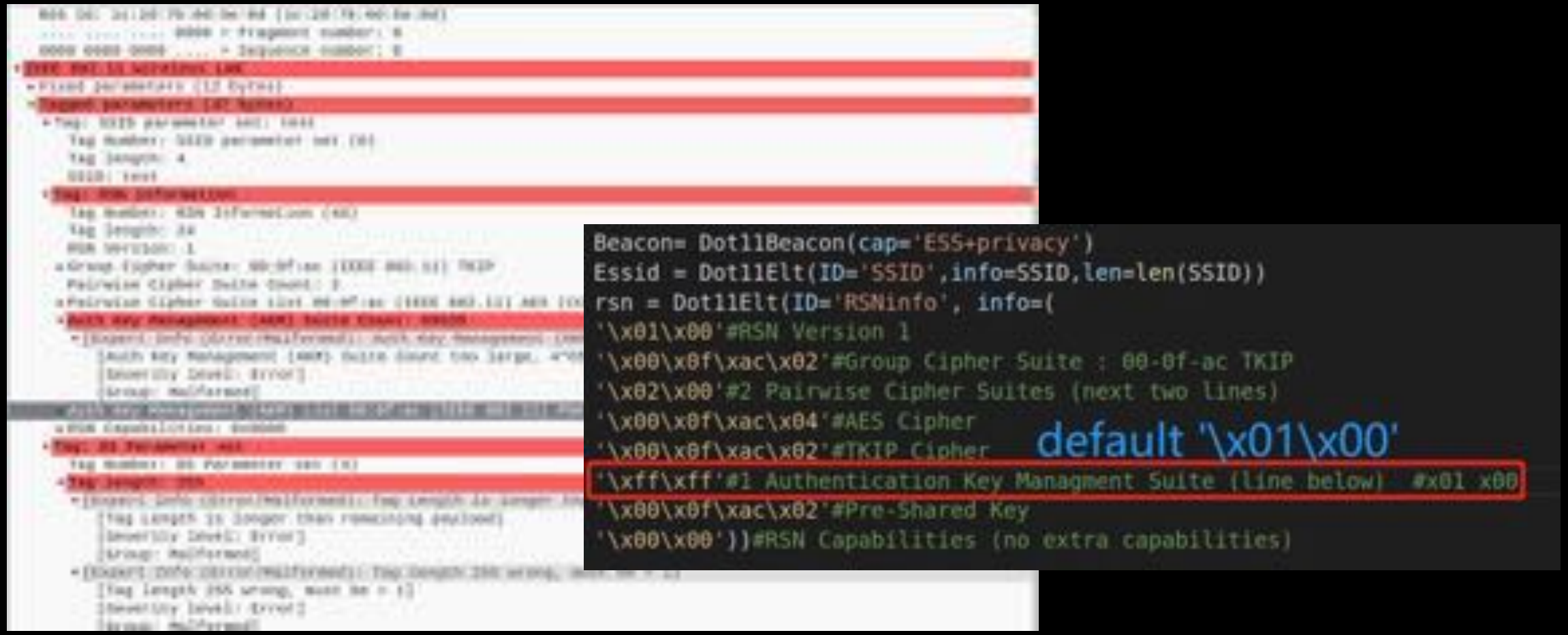
Broadcom BCM4325、BCM4329 Denial of service



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OUI	Suite Type	Meaning
00-0F-AC	0	Use group Cipher suite
00-0F-AC	2	TKIP
…	…	…

standard protocol format

OUI	Suite Type	Meaning
00-00-00	Number (Non-protocol restricted content)	unknown
FF-FF-FF		
…		

non-standard protocol format

OUI	Suite Type	Meaning
AAAAAAAAAAAA…	Number (Protocol restricted content)	unknown
\u0041\u0041\u0031…		
AA&#65…		
…		

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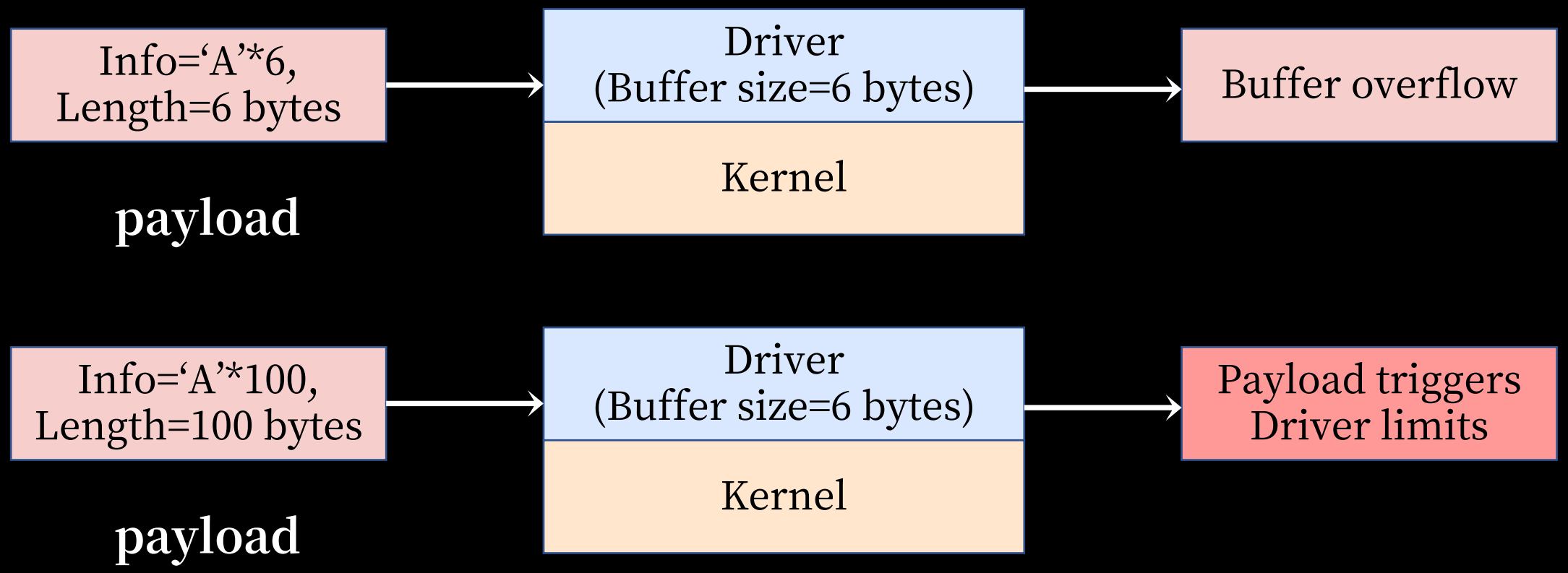

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```
RSN = Dot11EltRSN(version=1,
                  group_cipher_suite=RSNCipherSuite(oui=0x0fac,cipher=0x04),#
                  se_cipher_suites=50,
                  cipher_suites=[
                  pherSuite(oui=0x0fac,cipher=RandNum(0,0xff))
                  i in range(50)
```

```
▾ Pairwise Cipher Suite List 00:0f:ac (Ieee 802.11) Unknown 108 00:0f:ac
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 108
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (108)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 30
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (30)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 66
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (66)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 178
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (178)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 69
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (69)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 17
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (17)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 242
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (242)
  ▾ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 38
      Pairwise Cipher Suite OUI: 00:0f:ac (Ieee 802.11)
      Pairwise Cipher Suite type: Unknown (38)
```

```
▾ IEEE 802.11 wireless LAN
  ▸ Fixed parameters (12 bytes)
  ▾ Tagged parameters (278 bytes)
    ▸ Tag: Supported Rates 1(B), 2(B), 5.5(B), 11(B), 9, 18, 36, 54, [Mbit/sec]
    ▸ Tag: DS Parameter set: Current Channel: 11
    ▸ Tag: ERP Information
    ▸ Tag: SSID parameter set: n3k0
    ▾ Tag: RSN Information
        Tag Number: RSN Information (48)
        Tag length: 252
        RSN Version: 1
      ▸ Group Cipher Suite: 00:0f:ac (Ieee 802.11) AES (CCM)
      ▾ Pairwise Cipher Suite Count: 100
        ▾ [Expert Info (Error/Malformed): Pairwise Cipher Suite Count too large, 4*100 > 244]
            [Pairwise Cipher Suite Count too large, 4*100 > 244]
            [Severity level: Error]
            [Group: Malformed]
      ▾ Pairwise Cipher Suite List 00:0f:ac (Ieee 802.11) Unknown 79 00:0f:ac (Ieee 802.11) U
        ▸ Pairwise Cipher Suite: 00:0f:ac (Ieee 802.11) Unknown 79
```

Detail mutation

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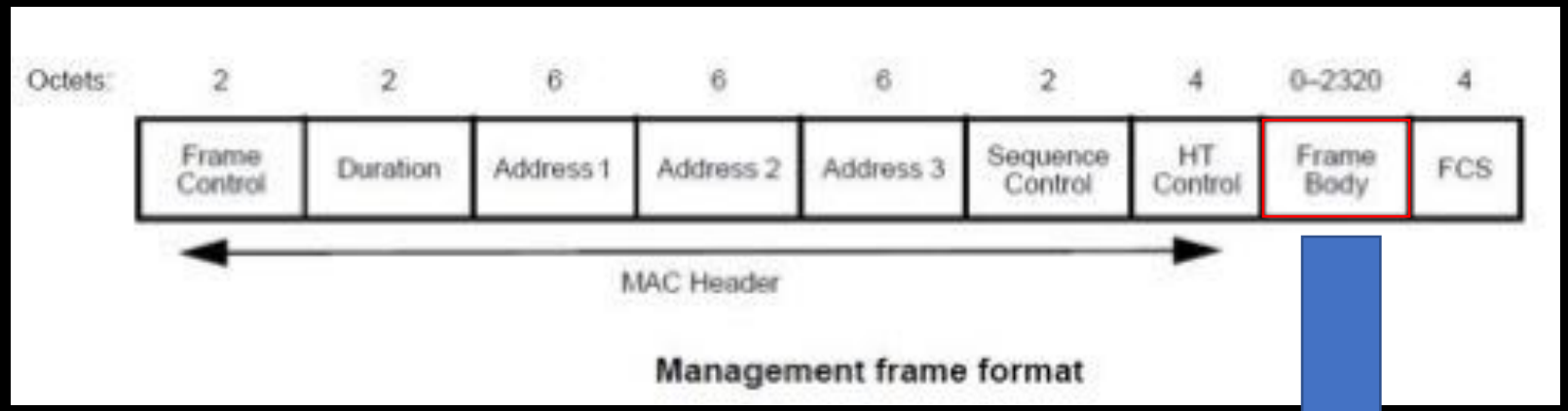

Management frame format

```
00 00 0c 00 04 80 00 00  02 00 10 00 40 00 00 00   ........ ....@...
02 1a 11 f2 2a 6b a0 ab  1b cc 75 00 02 1a 11 f2   ....*k.. ..u.....
2a 6b 00 00 00 32 27 20  55 4e 49 4f 4e 20 53 45   *k...2'  UNION SE
4c 45 43 54 20 31 2c 4c  4f 41 44 5f 46 49 4c 45   LECT 1,L OAD_FILE
28 27 2f 65 74 63 2f 70  61 73 73 77 64 27 29 2c   ('/etc/p asswd'),
31 2c 31 2c 31 3b 2d 2d  01 08 82 84 8b 96 24 30   1,1,1;-- ......$0
48 6c 03 01 06 32 04 0c  12 18 60                  Hl...2.. ..`
```

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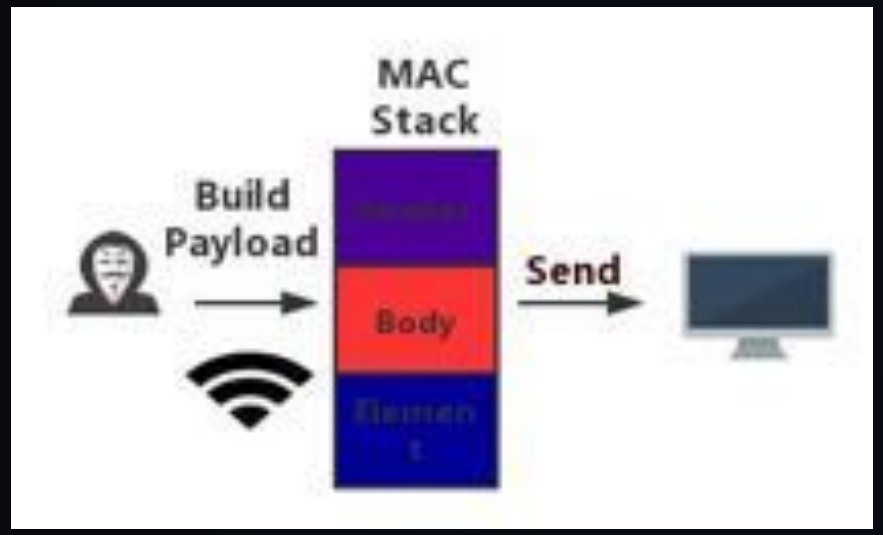
CVE-2019-12785

CPU 2 U
SLAB: Unable to allocate memory on node 0 (gfp=0x20)

cache: skbuff_head_cache, object size: 256, order: 0

CPU 2 Unable to handle kernel paging request at virtual address 013a00b0, epc == 81615270, ra == 81615258nable to handle kernel paging request at virtual address 013a00b0, epc == 81615270, ra == 81615258



Demo

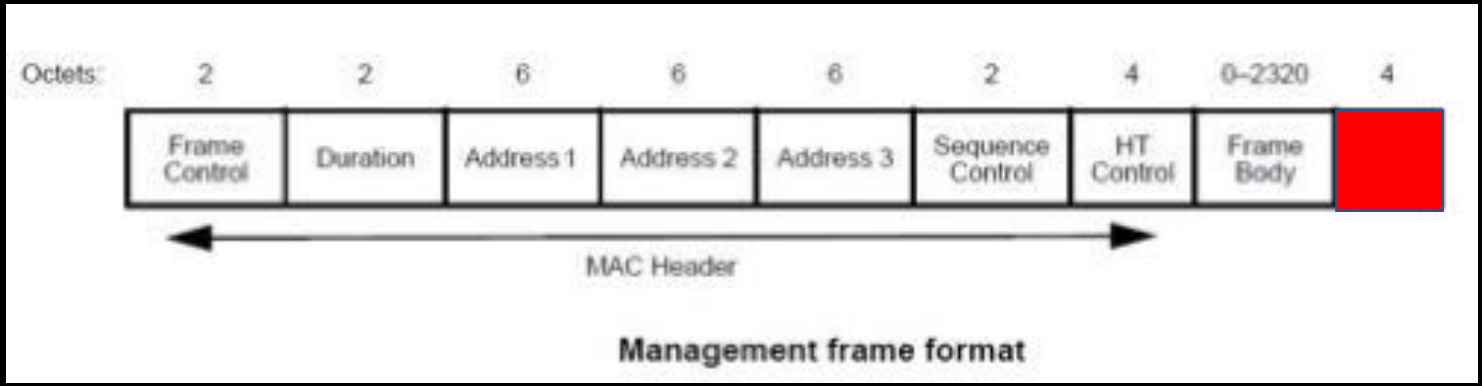
Frame check sequence

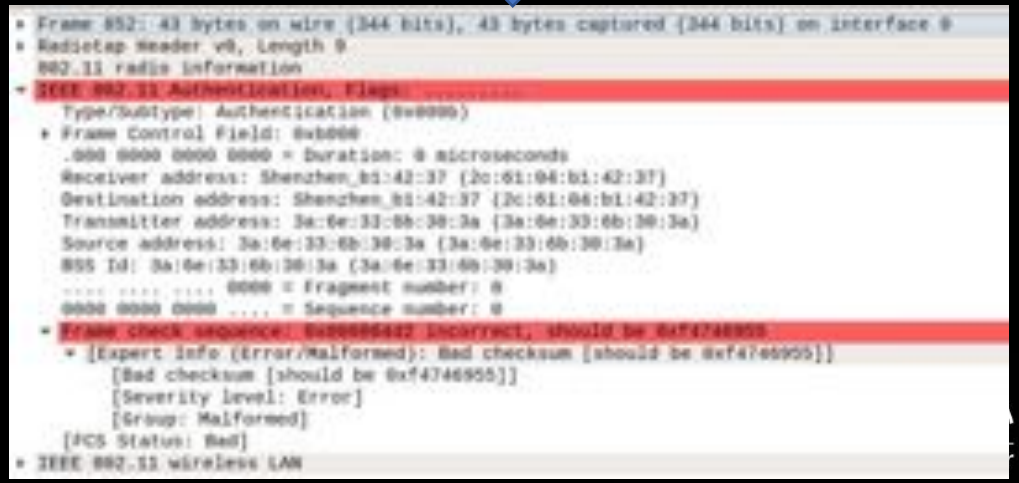
```
Fcs=binascii.crc32(bytes(data)) & 0xFFFFFFFFL
Fcs=hex(fcs)[2:].rstrip('L').decode('hex')[::-1]
```

```
.... .... .... 0000 = Fragment number: 0
0000 0000 0000 .... = Sequence number: 0
Frame check sequence: 0xf4746955 [correct]
[FCS Status: Good]
```

FCS status good------>OK

FCS status Bad------>Error





EAPOL-Type Mutation

```
9   #ifndef CONFIG_H
10  #define CONFIG_H
11
12  #define DEFAULT_EAPOL_VERSION 1
```

Default Version Value

```
66      bss->ap_max_inactivity = AP_MAX_INACTIVITY;
67      bss->eapol_version = EAPOL_VERSION;
68
69      bss->max_listen_interval = 65535;
```

Max Length Value

```
▸Frame 51: 46 bytes on wire (368 bits), 46 bytes captured (36
▸Radiotap Header v0, Length 8
 802.11 radio information
▸IEEE 802.11 QoS Data, Flags: .......T
▸Logical-Link Control
▾802.1X Authentication
  Version: Unknown (173)
  Type: MKA (5)
  Length: 57512
 MACsec Key Agreement
▸[Malformed Packet: EAPOL-MKA]
```

```
802… Probe Request, SN=2064, FN=0, Flags=........, SSID=AD-LAB
802… Probe Response, SN=3852, FN=0, Flags=........, BI=100, SSID=…
802… Probe Response, SN=3853, FN=0, Flags=........, BI=100, SSID=…
802… Authentication, SN=2065, FN=0, Flags=........
802… Probe Response, SN=3854, FN=0, Flags=........, BI=100, SSID=…
802… Authentication, SN=3855, FN=0, Flags=........
802… Association Request, SN=2066, FN=0, Flags=........, SSID=AD-…
802… Association Response, SN=3856, FN=0, Flags=........
EAP… Key (Message 1 of 4)
802… Action, SN=3859, FN=0, Flags=........
802… Action, SN=901, FN=0, Flags=........
EAP… Key (Message 2 of 4)
EAP… Key (Message 3 of 4)
EAP… Key (Message 4 of 4)
```

Demo

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AD LAB 5G

802.11 state machine

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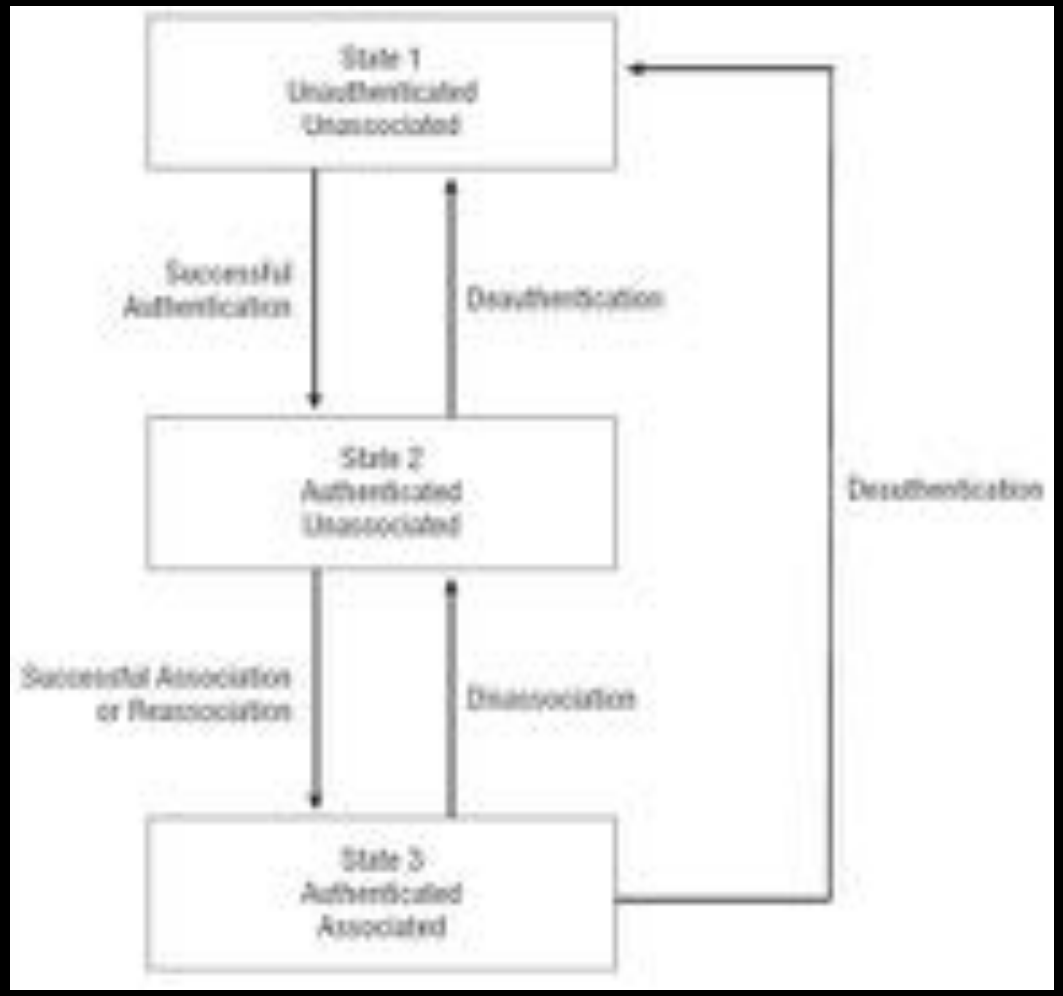
802.11 state machine detailed



- **State 1: A state that does not require too much interaction**

- **State 2: More types of packets are accepted**

- **State 3 : Keep connection and AP interacts with the STA**

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What’s the difference between fuzz AP and fuzz STA?

- Fuzz AP ----------> request frame

- **Fuzz STA** ----------> response frame

How to fuzz STA?

- FAKE AP: sniff and response

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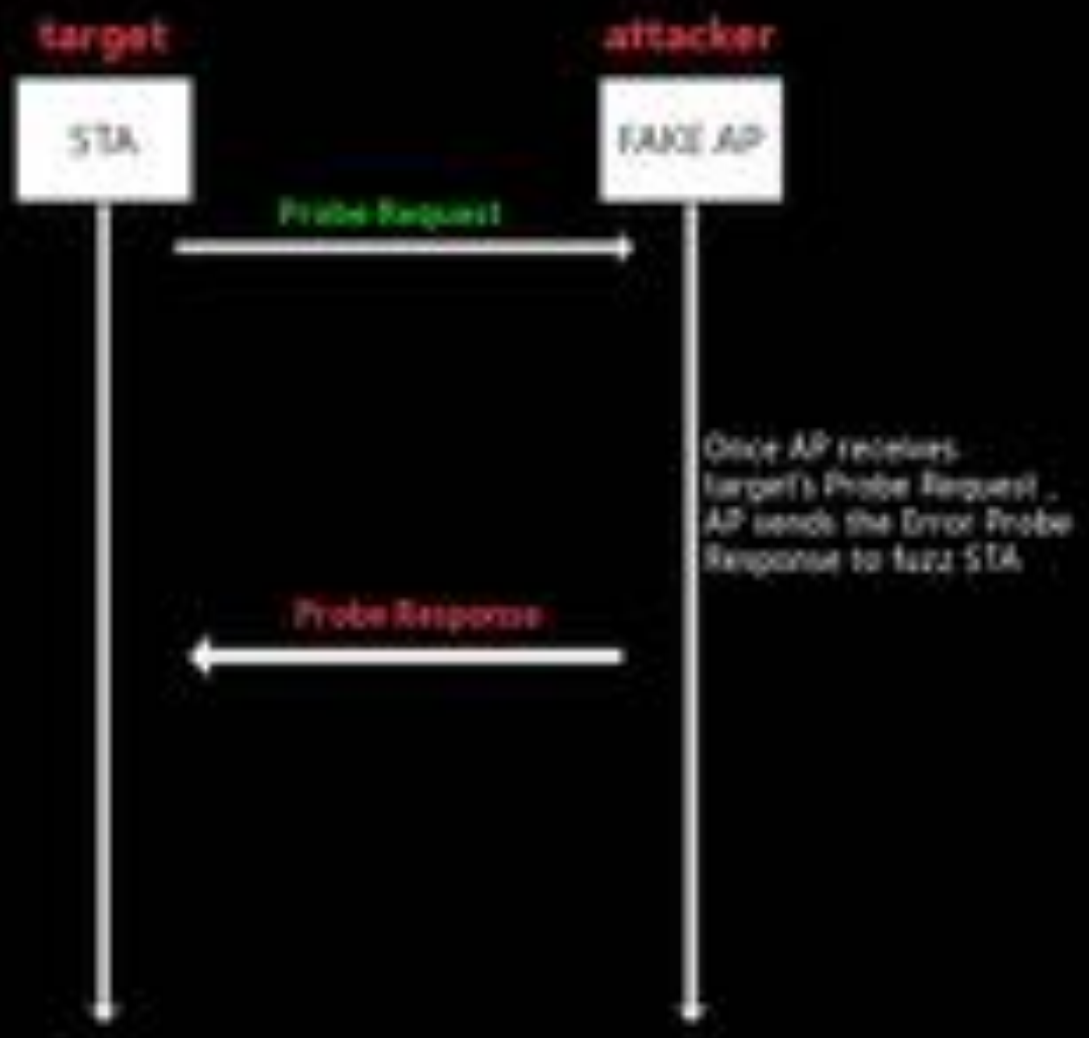

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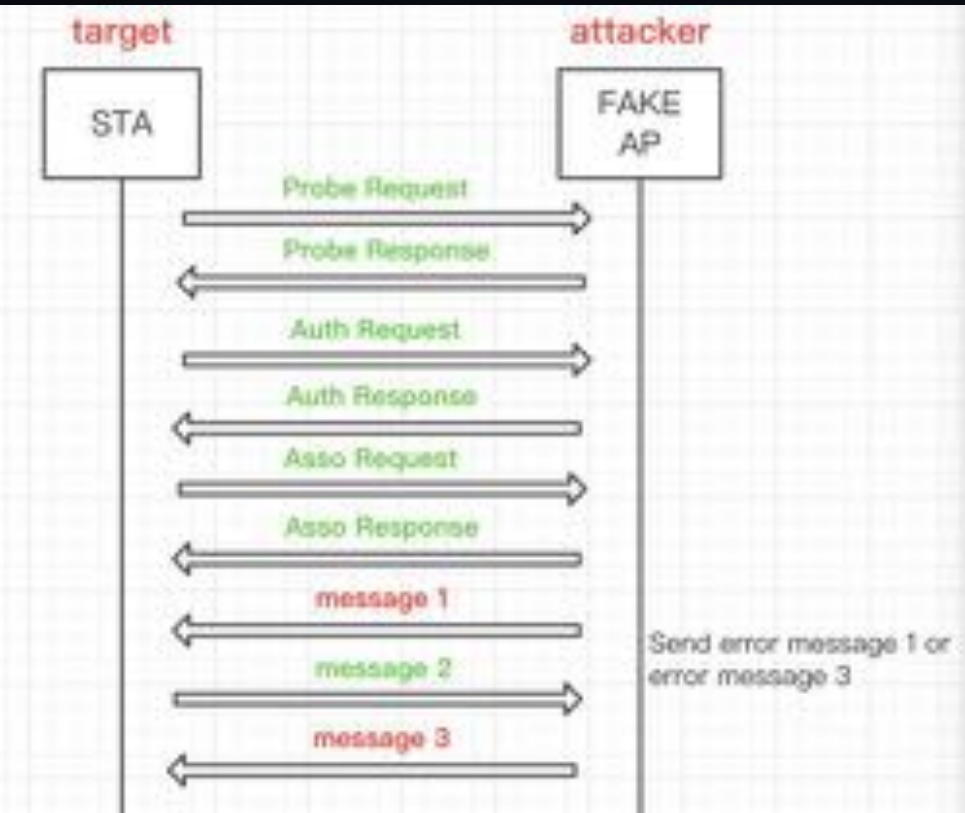
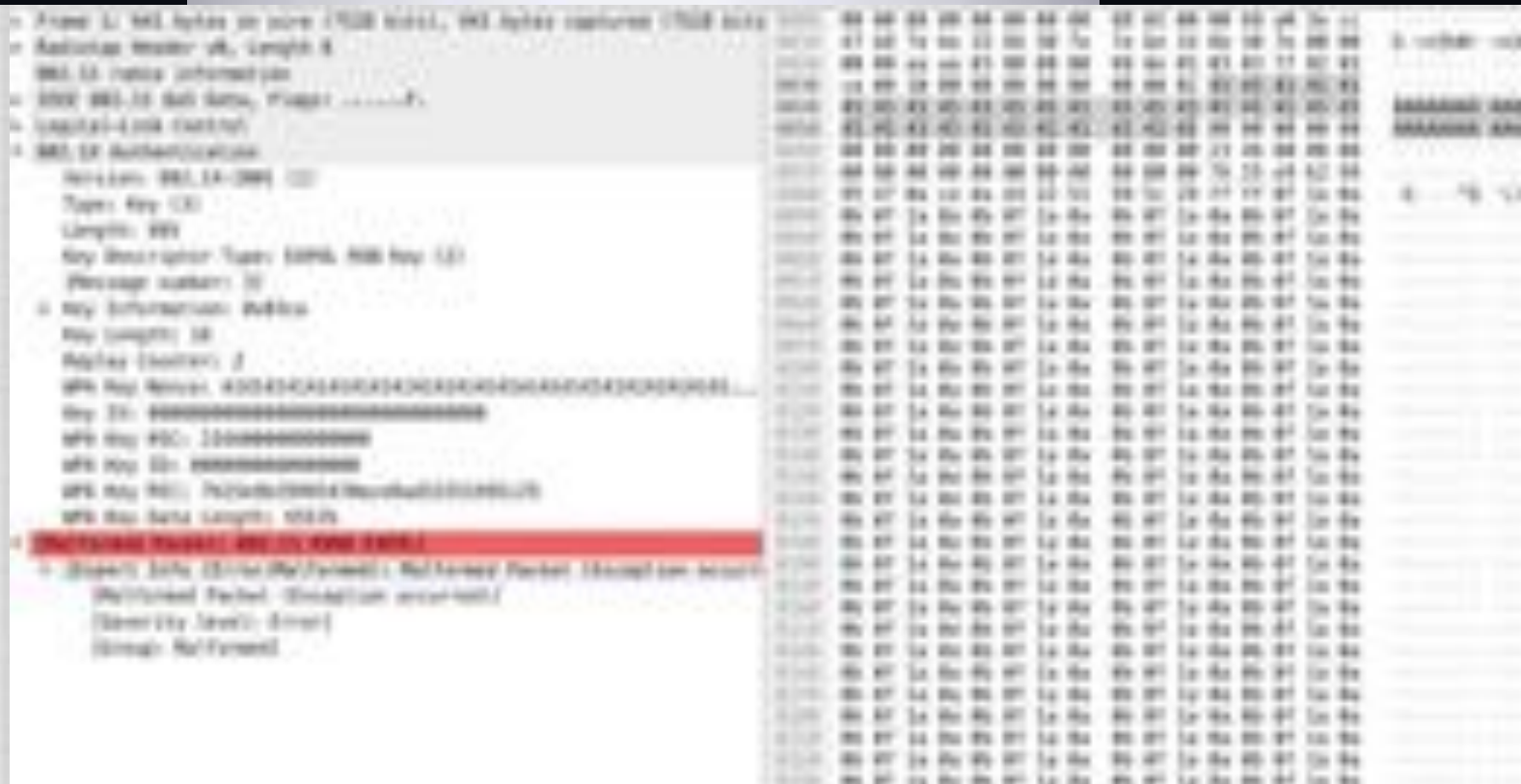
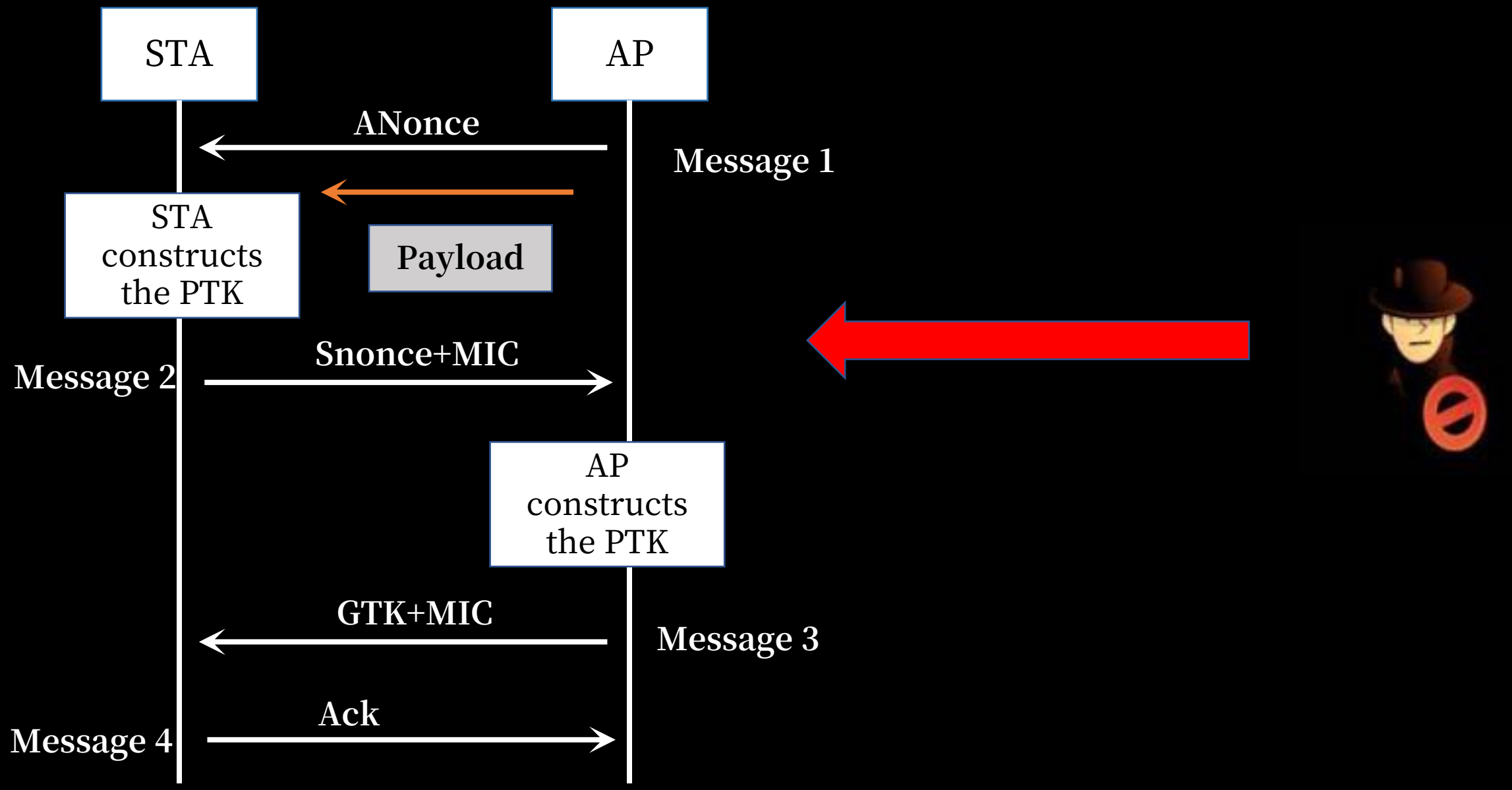
Attack HandShake







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308	4.415850233	0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	802.11	32 Null function (No data),
309	4.416914598	0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	802.11	32 Null function (No data),
310	4.417099339		0a:0a:0a:0a:0a:0a (0a:0a…	802.11	28 Acknowledgement, Flags=.
311	4.418115471	0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	802.11	32 Null function (No data),
312	4.418211483		0a:0a:0a:0a:0a:0a (0a:0a…	802.11	28 Acknowledgement, Flags=.
313	4.418497108	Shenzhen_c1:62:c2	0a:0a:0a:0a:0a:0a	802.11	44 Deauthentication, SN=627
314	4.419326794	0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	802.11	32 Null function (No data),
315	4.420202878	0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	802.11	32 Null function (No data),
316	4.420949257	0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	802.11	32 Null function (No data),

Unusual attack

Shenzhen_c1:62:c2	0a:0a:0a:0a:0a:0a	EAPOL	151 Key (Message 1 of 4)
Shenzhen_c1:62:c2	0a:0a:0a:0a:0a:0a	EAPOL	151 Key (Message 1 of 4)
0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	EAPOL	163 Key (Message 2 of 4)
0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	EAPOL	168 Key (Message 2 of 4)
Shenzhen_c1:62:c2	0a:0a:0a:0a:0a:0a	EAPOL	207 Key (Message 3 of 4)
Shenzhen_c1:62:c2	0a:0a:0a:0a:0a:0a	EAPOL	207 Key (Message 3 of 4)
0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	EAPOL	141 Key (Message 4 of 4)
0a:0a:0a:0a:0a:0a	Shenzhen_c1:62:c2	EAPOL	146 Key (Message 4 of 4)

Demo

Conclusion

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Q&A

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THANKS

Happy Hackingg