SharkFest '18 Europe

Troubleshooting WLANs (Part 2)

Troubleshooting WLANs using
802.11 Management & Control Frames

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Introduction

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- Network Analysis & Troubleshooting
- Protocol Trainings TCP/IP, WLAN, VoIP, IPv6
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Wireshark University WIRESHARK® CERTIFIED NETWORK ANALYST

Session Objectives

- Learn why analyzing WiFi layer 2 is a demanding task
- Learn that WiFi frames looks very different from Ethernet
- Learn why WiFi frames have one to four address fields
- Learn how critical processes e.g. Joining, Roaming works
- Learn how to read Wireshark files to isolate WiFi problems

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Troubleshooting WiFi requires a full understanding of all 802.11 Management & Control frames and its associated processes!

WLAN 802.11 Management, Control and Data Frames

802.11Frame Types Overview

Management Frames:

- Beacon
- Probe Request & Response
- Authentication & Deauthentication
- Association & Disassociation
- Reassociation Request & Response
- Action

Control Frames:

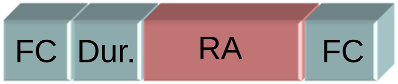
- Request to Send (RTS)
- Clear to Send (CTS)
- Acknowledge / Block Acknowledge Request / Block Acknowledge
- Power Save Poll

Data Frames:

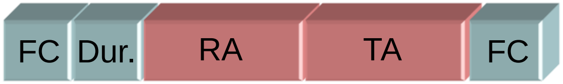
- Data
- Null Function

The IEEE 802.11 Frame Formats

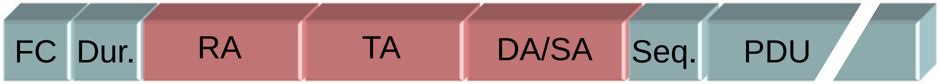
- Four different frame formats are used



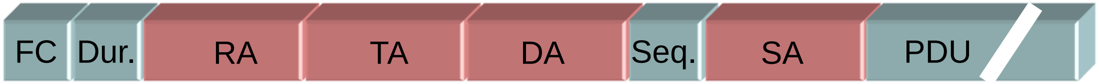
Acknowledge, Clear to Send



Request to Send



Data Frame, Beacon,
Probe Request, Probe Response,
Authentication, Deauthentication,
Association, Reassociation,
Disassociation

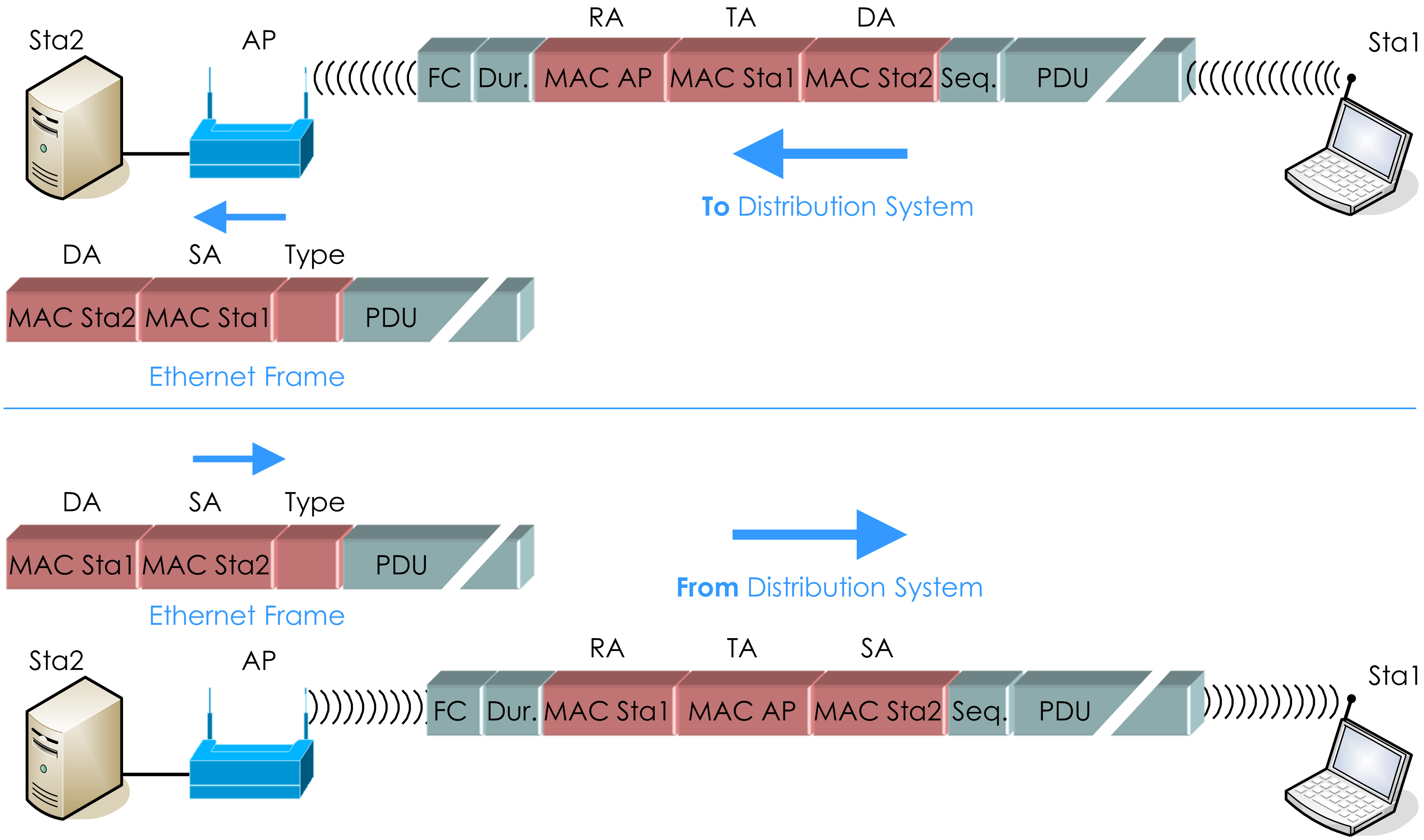


Data Frame through repeater

Field names: FC = Frame Control, Dur. = Duration, RA = Receiver MAC Address,
TA = Transmitter MAC Address; DA = Destination MAC Address,
SA = Source MAC Address, Seq. = Sequence, PDU = Protocol Data Unit,
FC = Frame Check Sequence

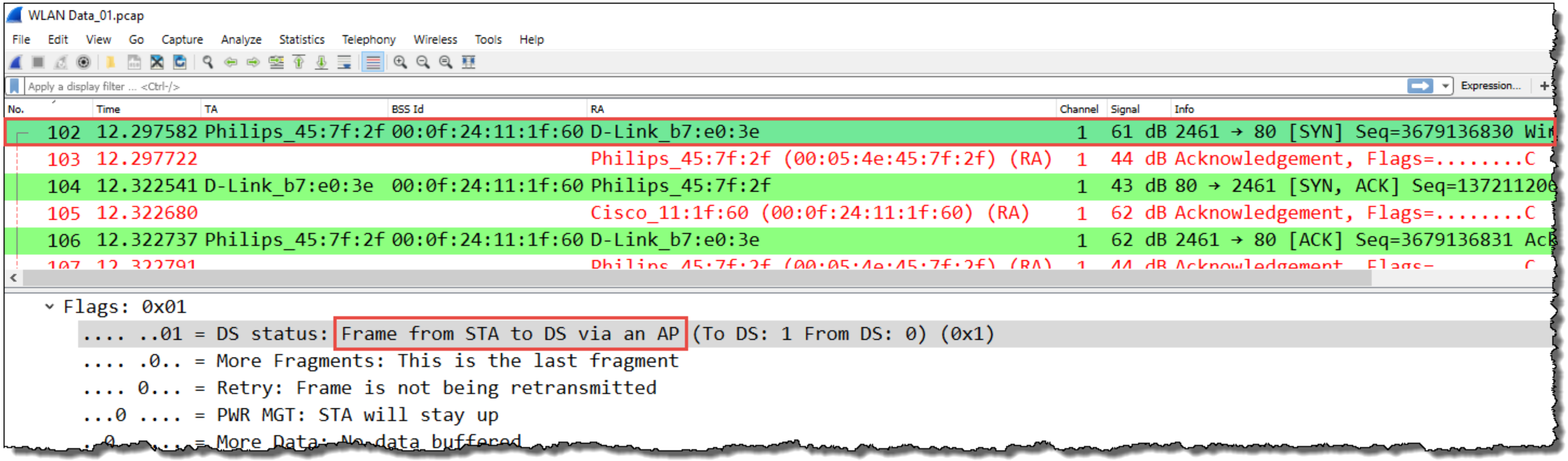
WiFi Data Transmission

- WiFi data frames have three MAC address field



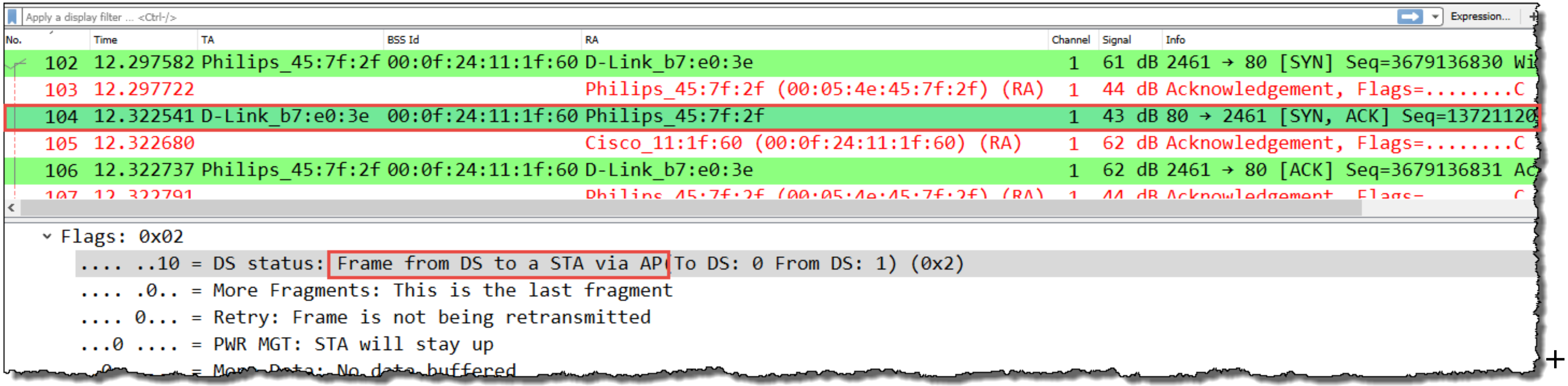
WiFi Data Transmission

- Frames are marked with a direction bit (To or From Distribution System)
- Only Data frames are marked (not management and control frames)


WLAN Data_01.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...
+

```
No.  Time      TA                BSS Id            RA                                      Channel Signal Info
102  12.297582 Philips_45:7f:2f 00:0f:24:11:1f:60 D-Link_b7:e0:3e                          1  61 dB 2461 → 80 [SYN] Seq=3679136830 Wi
103  12.297722                                     Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA) 1  44 dB Acknowledgement, Flags=........C
104  12.322541 D-Link_b7:e0:3e  00:0f:24:11:1f:60 Philips_45:7f:2f                         1  43 dB 80 → 2461 [SYN, ACK] Seq=13721120
105  12.322680                                     Cisco_11:1f:60 (00:0f:24:11:1f:60) (RA)   1  62 dB Acknowledgement, Flags=........C
106  12.322737 Philips_45:7f:2f 00:0f:24:11:1f:60 D-Link_b7:e0:3e                          1  62 dB 2461 → 80 [ACK] Seq=3679136831 Ac
107  12.322791                                     Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA) 1  44 dB Acknowledgement, Flags=........C
```

```
⌄ Flags: 0x01
    .... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)
    .... .0.. = More Fragments: This is the last fragment
    .... 0... = Retry: Frame is not being retransmitted
    ...0 .... = PWR MGT: STA will stay up
    ..0. .... = More Data: No data buffered
```

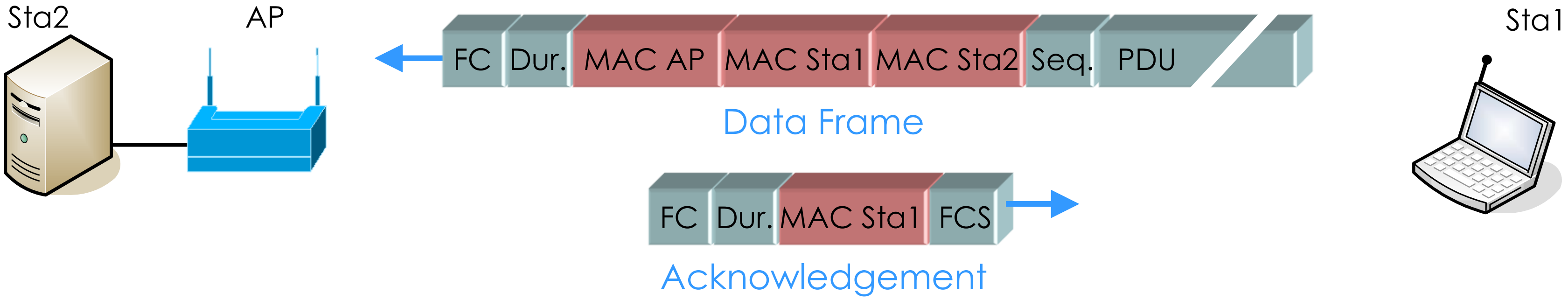


```
No.  Time      TA                BSS Id            RA                                      Channel Signal Info
102  12.297582 Philips_45:7f:2f 00:0f:24:11:1f:60 D-Link_b7:e0:3e                          1  61 dB 2461 → 80 [SYN] Seq=3679136830 Wi
103  12.297722                                     Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA) 1  44 dB Acknowledgement, Flags=........C
104  12.322541 D-Link_b7:e0:3e  00:0f:24:11:1f:60 Philips_45:7f:2f                         1  43 dB 80 → 2461 [SYN, ACK] Seq=13721120
105  12.322680                                     Cisco_11:1f:60 (00:0f:24:11:1f:60) (RA)   1  62 dB Acknowledgement, Flags=........C
106  12.322737 Philips_45:7f:2f 00:0f:24:11:1f:60 D-Link_b7:e0:3e                          1  62 dB 2461 → 80 [ACK] Seq=3679136831 Ac
107  12.322791                                     Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA) 1  44 dB Acknowledgement, Flags=........C
```

```
⌄ Flags: 0x02
    .... ..10 = DS status: Frame from DS to a STA via AP(To DS: 0 From DS: 1) (0x2)
    .... .0.. = More Fragments: This is the last fragment
    .... 0... = Retry: Frame is not being retransmitted
    ...0 .... = PWR MGT: STA will stay up
    ..0. .... = More Data: No data buffered
```

WiFi Data Transmission & Retransmission

- WiFi data frames are acknowledged or retransmitted



Sta2

AP

Sta1

FC	Dur.	MAC AP	MAC Sta1	MAC Sta2	Seq.	PDU

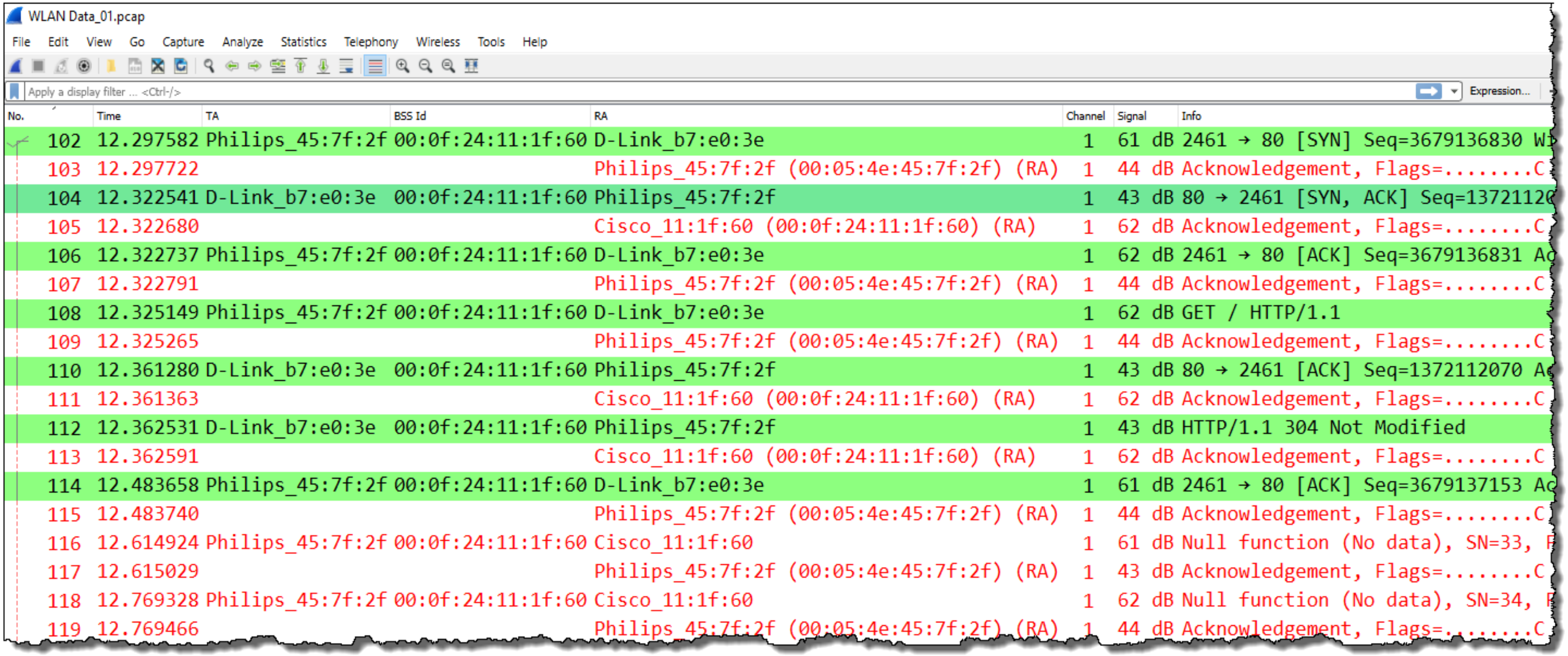
Data Frame

FC	Dur.	MAC Sta1	FCS

Acknowledgement

WiFi Data Transmission

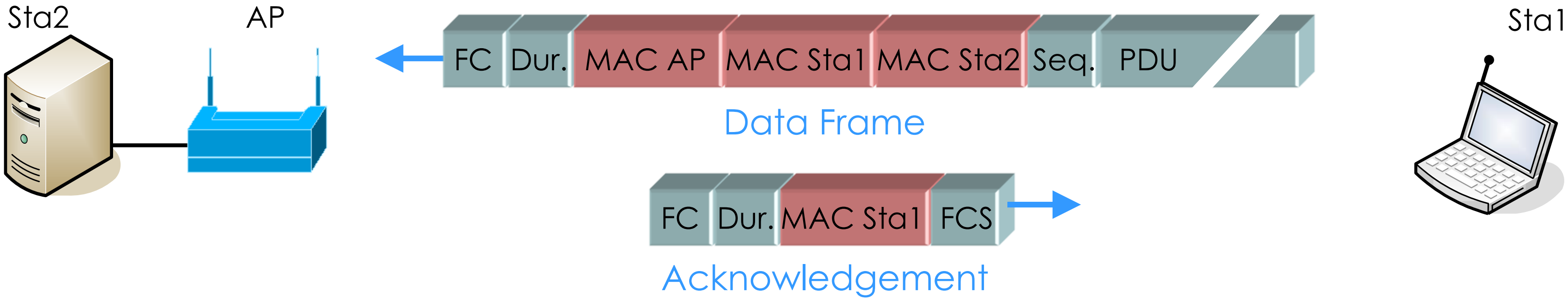
- In non-aggregation mode each packet is acknowledged individually
- The acknowledge frame follows immediately after each data frame
- The (single) acknowledge has no source address field


WLAN Data_01.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...

No.	Time	TA	BSS Id	RA	Channel	Signal	Info
102	12.297582	Philips_45:7f:2f	00:0f:24:11:1f:60	D-Link_b7:e0:3e	1	61 dB	2461 → 80 [SYN] Seq=3679136830 Wi
103	12.297722			Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA)	1	44 dB	Acknowledgement, Flags=........C
104	12.322541	D-Link_b7:e0:3e	00:0f:24:11:1f:60	Philips_45:7f:2f	1	43 dB	80 → 2461 [SYN, ACK] Seq=13721120
105	12.322680			Cisco_11:1f:60 (00:0f:24:11:1f:60) (RA)	1	62 dB	Acknowledgement, Flags=........C
106	12.322737	Philips_45:7f:2f	00:0f:24:11:1f:60	D-Link_b7:e0:3e	1	62 dB	2461 → 80 [ACK] Seq=3679136831 Ac
107	12.322791			Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA)	1	44 dB	Acknowledgement, Flags=........C
108	12.325149	Philips_45:7f:2f	00:0f:24:11:1f:60	D-Link_b7:e0:3e	1	62 dB	GET / HTTP/1.1
109	12.325265			Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA)	1	44 dB	Acknowledgement, Flags=........C
110	12.361280	D-Link_b7:e0:3e	00:0f:24:11:1f:60	Philips_45:7f:2f	1	43 dB	80 → 2461 [ACK] Seq=1372112070 Ac
111	12.361363			Cisco_11:1f:60 (00:0f:24:11:1f:60) (RA)	1	62 dB	Acknowledgement, Flags=........C
112	12.362531	D-Link_b7:e0:3e	00:0f:24:11:1f:60	Philips_45:7f:2f	1	43 dB	HTTP/1.1 304 Not Modified
113	12.362591			Cisco_11:1f:60 (00:0f:24:11:1f:60) (RA)	1	62 dB	Acknowledgement, Flags=........C
114	12.483658	Philips_45:7f:2f	00:0f:24:11:1f:60	D-Link_b7:e0:3e	1	61 dB	2461 → 80 [ACK] Seq=3679137153 Ac
115	12.483740			Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA)	1	44 dB	Acknowledgement, Flags=........C
116	12.614924	Philips_45:7f:2f	00:0f:24:11:1f:60	Cisco_11:1f:60	1	61 dB	Null function (No data), SN=33, F
117	12.615029			Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA)	1	43 dB	Acknowledgement, Flags=........C
118	12.769328	Philips_45:7f:2f	00:0f:24:11:1f:60	Cisco_11:1f:60	1	62 dB	Null function (No data), SN=34, F
119	12.769466			Philips_45:7f:2f (00:05:4e:45:7f:2f) (RA)	1	44 dB	Acknowledgement, Flags=........C

WiFi Data Transmission & Retransmission

- WiFi data frames are acknowledged or retransmitted



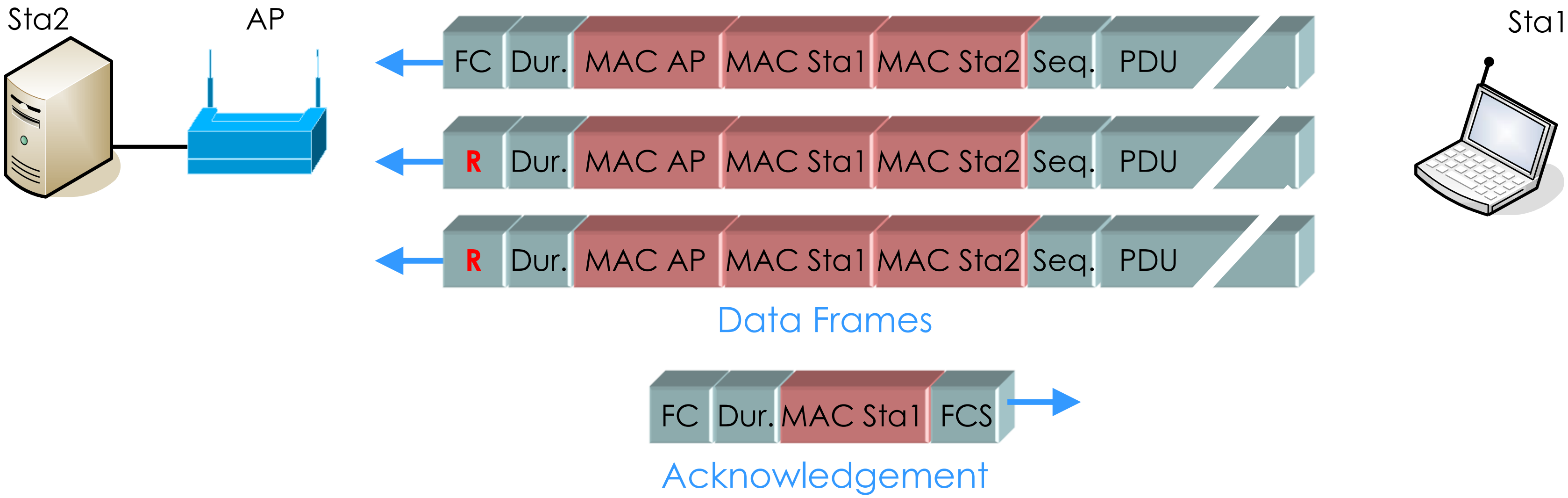
FC | Dur. | MAC AP | MAC Sta1 | MAC Sta2 | Seq. | PDU

Data Frame

FC | Dur. | MAC Sta1 | FCS

Acknowledgement

- All retransmitted frames are marked with the Retry Bit



FC | Dur. | MAC AP | MAC Sta1 | MAC Sta2 | Seq. | PDU

R | Dur. | MAC AP | MAC Sta1 | MAC Sta2 | Seq. | PDU

R | Dur. | MAC AP | MAC Sta1 | MAC Sta2 | Seq. | PDU

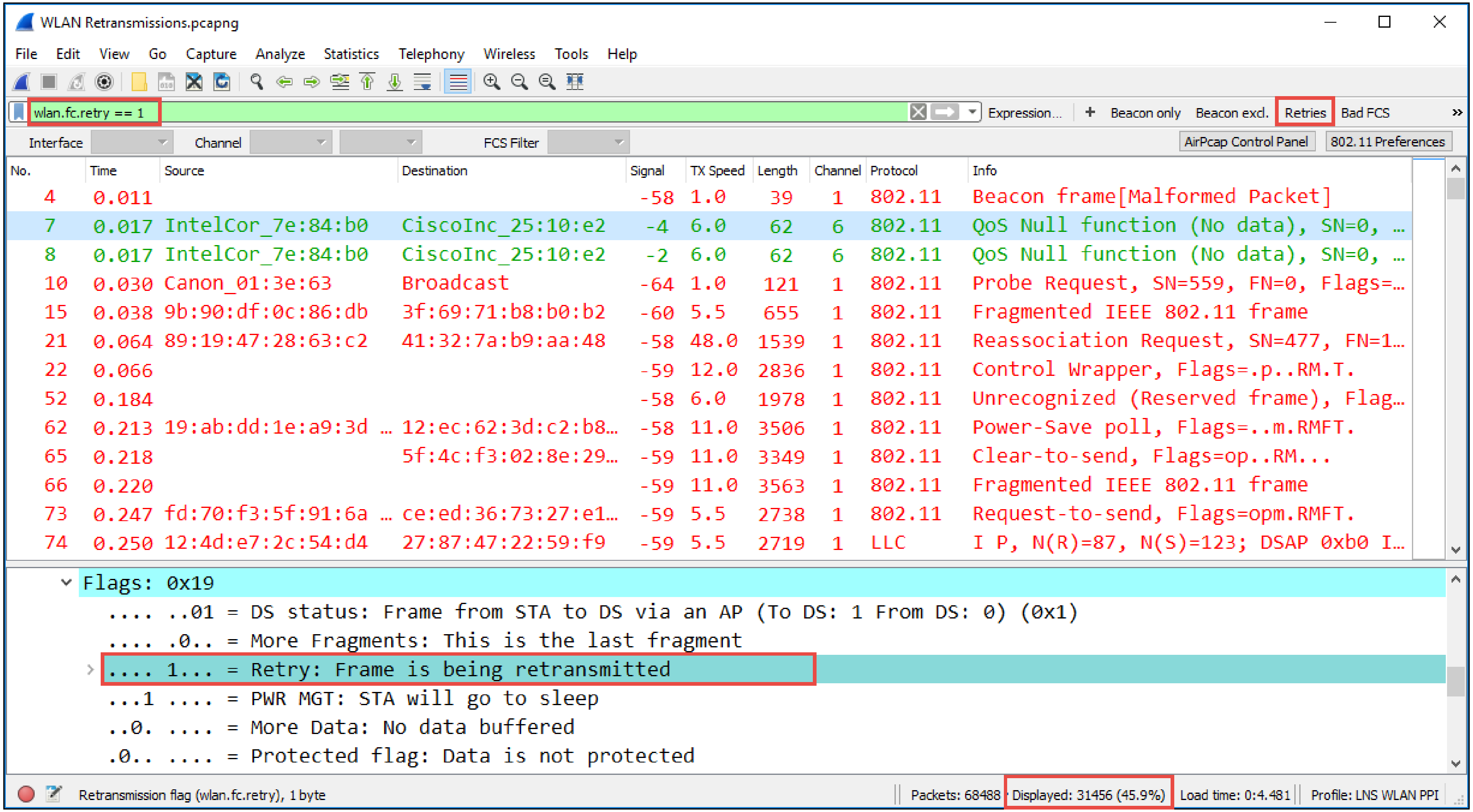
Data Frames

FC | Dur. | MAC Sta1 | FCS

Acknowledgement

WiFi Data Transmission & Retransmission

- All retransmitted frames are marked with the Retry Bit


WLAN Retransmissions.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Expression… + Beacon only Beacon excl. Retries Bad FCS
Interface Channel FCS Filter
AirPcap Control Panel 802.11 Preferences

wlan.fc.retry == 1

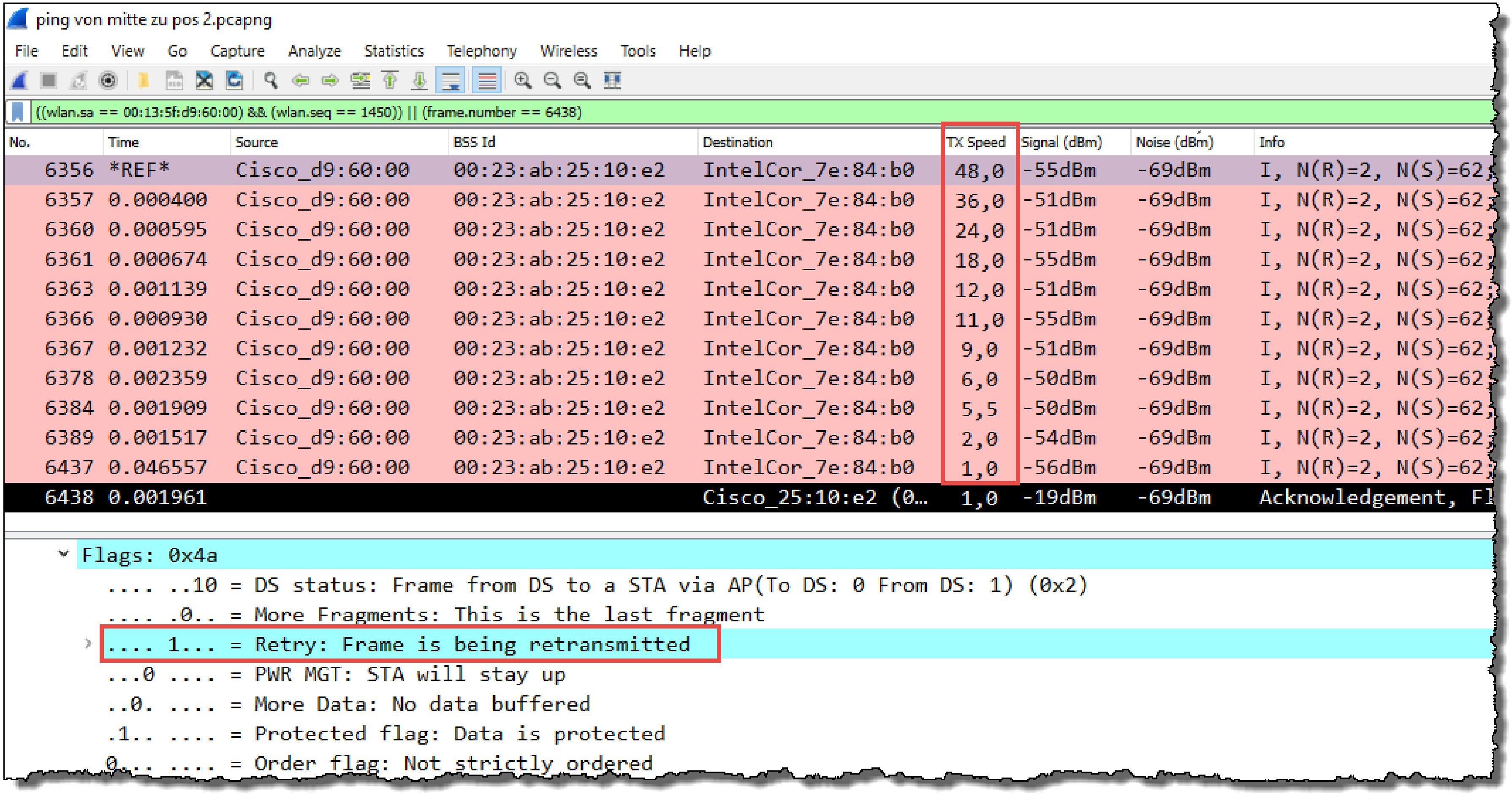
No.	Time	Source	Destination	Signal	TX Speed	Length	Channel	Protocol	Info
4	0.011			-58	1.0	39	1	802.11	Beacon frame[Malformed Packet]
7	0.017	IntelCor_7e:84:b0	CiscoInc_25:10:e2	-4	6.0	62	6	802.11	QoS Null function (No data), SN=0, …
8	0.017	IntelCor_7e:84:b0	CiscoInc_25:10:e2	-2	6.0	62	6	802.11	QoS Null function (No data), SN=0, …
10	0.030	Canon_01:3e:63	Broadcast	-64	1.0	121	1	802.11	Probe Request, SN=559, FN=0, Flags=…
15	0.038	9b:90:df:0c:86:db	3f:69:71:b8:b0:b2	-60	5.5	655	1	802.11	Fragmented IEEE 802.11 frame
21	0.064	89:19:47:28:63:c2	41:32:7a:b9:aa:48	-58	48.0	1539	1	802.11	Reassociation Request, SN=477, FN=1…
22	0.066			-59	12.0	2836	1	802.11	Control Wrapper, Flags=.p..RM.T.
52	0.184			-58	6.0	1978	1	802.11	Unrecognized (Reserved frame), Flag…
62	0.213	19:ab:dd:1e:a9:3d …	12:ec:62:3d:c2:b8…	-58	11.0	3506	1	802.11	Power-Save poll, Flags=..m.RMFT.
65	0.218		5f:4c:f3:02:8e:29…	-59	11.0	3349	1	802.11	Clear-to-send, Flags=op..RM...
66	0.220			-59	11.0	3563	1	802.11	Fragmented IEEE 802.11 frame
73	0.247	fd:70:f3:5f:91:6a …	ce:ed:36:73:27:e1…	-59	5.5	2738	1	802.11	Request-to-send, Flags=opm.RMFT.
74	0.250	12:4d:e7:2c:54:d4	27:87:47:22:59:f9	-59	5.5	2719	1	LLC	I P, N(R)=87, N(S)=123; DSAP 0xb0 I…

```
Flags: 0x19
    .... ..01 = DS status: Frame from STA to DS via an AP (To DS: 1 From DS: 0) (0x1)
    .... .0.. = More Fragments: This is the last fragment
    .... 1... = Retry: Frame is being retransmitted
    ...1 .... = PWR MGT: STA will go to sleep
    ..0. .... = More Data: No data buffered
    .0.. .... = Protected flag: Data is not protected
```

Retransmission flag (wlan.fc.retry), 1 byte | Packets: 68488 · Displayed: 31456 (45.9%) | Load time: 0:4.481 | Profile: LNS WLAN PPI

WiFi Data Transmission & Retransmission

- During retransmissions the transmit speed is reduced by the sender
- The reason for these retransmissions is the high noise level



ping von mitte zu pos 2.pcapng

((wlan.sa == 00:13:5f:d9:60:00) && (wlan.seq == 1450)) || (frame.number == 6438)

No.	Time	Source	BSS Id	Destination	TX Speed	Signal (dBm)	Noise (dBm)	Info
6356	*REF*	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	48,0	-55dBm	-69dBm	I, N(R)=2, N(S)=62;
6357	0.000400	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	36,0	-51dBm	-69dBm	I, N(R)=2, N(S)=62;
6360	0.000595	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	24,0	-51dBm	-69dBm	I, N(R)=2, N(S)=62;
6361	0.000674	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	18,0	-55dBm	-69dBm	I, N(R)=2, N(S)=62;
6363	0.001139	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	12,0	-51dBm	-69dBm	I, N(R)=2, N(S)=62;
6366	0.000930	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	11,0	-55dBm	-69dBm	I, N(R)=2, N(S)=62;
6367	0.001232	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	9,0	-51dBm	-69dBm	I, N(R)=2, N(S)=62;
6378	0.002359	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	6,0	-50dBm	-69dBm	I, N(R)=2, N(S)=62;
6384	0.001909	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	5,5	-50dBm	-69dBm	I, N(R)=2, N(S)=62;
6389	0.001517	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	2,0	-54dBm	-69dBm	I, N(R)=2, N(S)=62;
6437	0.046557	Cisco_d9:60:00	00:23:ab:25:10:e2	IntelCor_7e:84:b0	1,0	-56dBm	-69dBm	I, N(R)=2, N(S)=62;
6438	0.001961			Cisco_25:10:e2 (0…	1,0	-19dBm	-69dBm	Acknowledgement, Fl

```
  ˅ Flags: 0x4a
      .... ..10 = DS status: Frame from DS to a STA via AP(To DS: 0 From DS: 1) (0x2)
      .... .0.. = More Fragments: This is the last fragment
    › .... 1... = Retry: Frame is being retransmitted
      ...0 .... = PWR MGT: STA will stay up
      ..0. .... = More Data: No data buffered
      .1.. .... = Protected flag: Data is protected
      0... .... = Order flag: Not strictly ordered
```

Overview WiFi 802.11 Standards

Rate	Modulation	Description
1 2	Barker/DBPSK Barker/DBPSK	**802.11 DSSS** ‚Long Preamble‘
5.5 11	CCK/DQPSK CCK/DQPSK	**802.11b** **High Rate (HR)** with ‚Short Preamble‘
6, 9 12, 18 24, 36 48, 54	OFDM/BPSK OFDM/QPSK OFDM/16-QAM OFDM/64-QAM	**802.11g** **Extended Rate PHY** **(ERP)**
From 6.5 up to 600*	OFDM/16-QAM OFDM/64-QAM	**802.11n** **High Throughput (HT)** **Extensions**

2.4 GHz Band

Rate	Modulation	Description
6, 9 12, 18 24, 36 48, 54	OFDM/BPSK OFDM/QPSK OFDM/16-QAM OFDM/64-QAM	**802.11a**
From 6.5 up to 600*	OFDM/16-QAM OFDM/64-QAM	**802.11n** **HT** **Extensions**
From 86 up to 6930**	OFDM/16-QAM OFDM/64-QAM OFDM/256-QAM	**802.11ac** **Very High** **Throughput (VHT)**

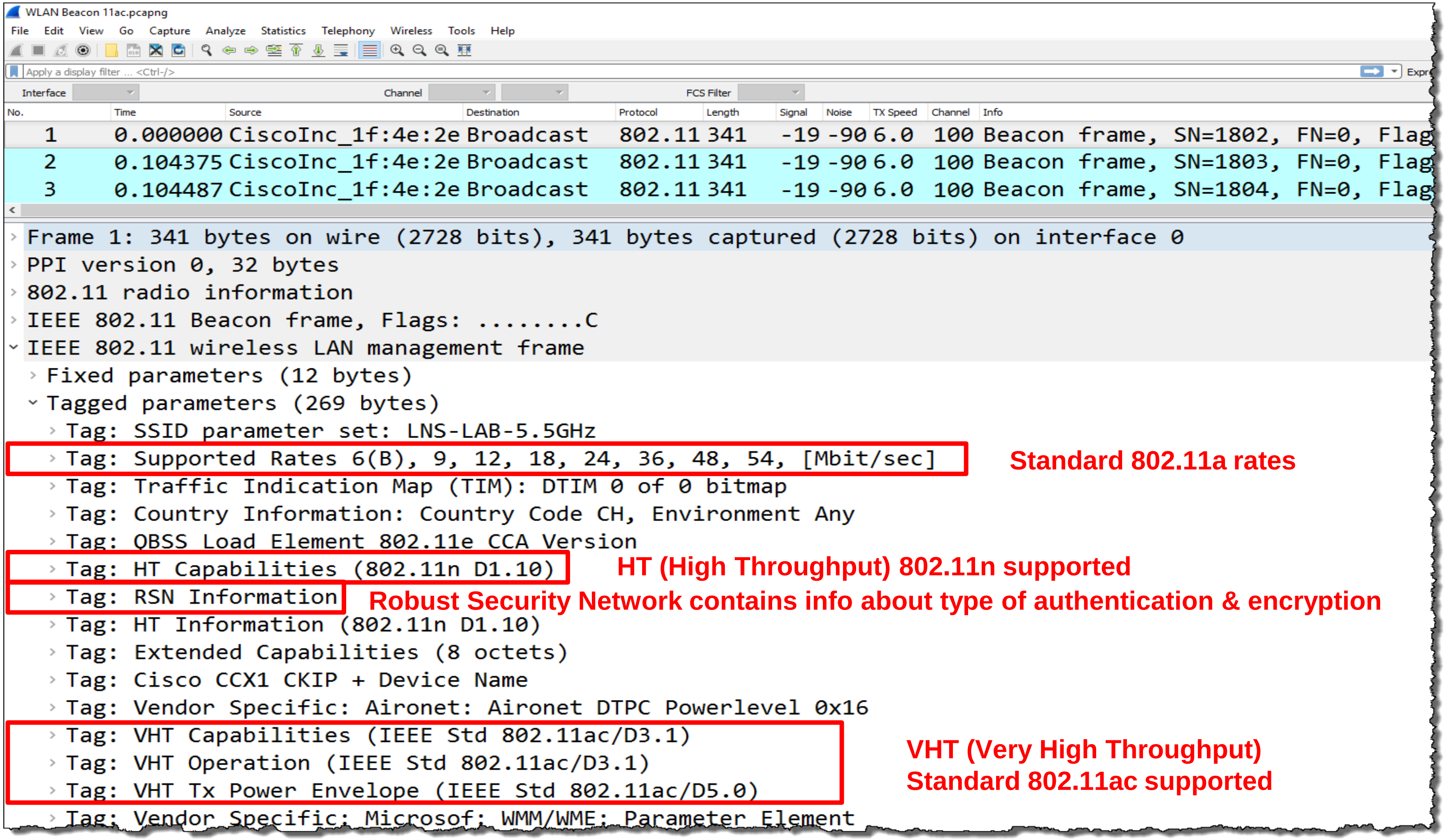
5 GHz Band

CCK = Complementary Code Keying
DBPSK = Differential Binary Phase-Shift Keying
DQPSK = Differential Quadrature Phase-Shift Keying
OFDM = Orthogonal Frequency Division Multiplexing
BPSK = Binary Phase-Shift Keying
QPSK = Quadrature Phase-Shift Keying
QAM = Quadrature Amplitude Modulation

* With up to 2 Channels
and up to 4 Streams
**With up to 8 Channels
and up to 8 Streams

Management Frame: Beacon

- Beacon tags contain information about supported and required features


WLAN Beacon 11ac.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expr
Interface
Channel
FCS Filter

```
No. Time     Source              Destination Protocol Length Signal Noise TX Speed Channel Info
  1 0.000000 CiscoInc_1f:4e:2e Broadcast 802.11 341 -19 -90 6.0 100 Beacon frame, SN=1802, FN=0, Flag
  2 0.104375 CiscoInc_1f:4e:2e Broadcast 802.11 341 -19 -90 6.0 100 Beacon frame, SN=1803, FN=0, Flag
  3 0.104487 CiscoInc_1f:4e:2e Broadcast 802.11 341 -19 -90 6.0 100 Beacon frame, SN=1804, FN=0, Flag
```

```
> Frame 1: 341 bytes on wire (2728 bits), 341 bytes captured (2728 bits) on interface 0
> PPI version 0, 32 bytes
> 802.11 radio information
> IEEE 802.11 Beacon frame, Flags: ........C
v IEEE 802.11 wireless LAN management frame
  > Fixed parameters (12 bytes)
  v Tagged parameters (269 bytes)
    > Tag: SSID parameter set: LNS-LAB-5.5GHz
    > Tag: Supported Rates 6(B), 9, 12, 18, 24, 36, 48, 54, [Mbit/sec]
    > Tag: Traffic Indication Map (TIM): DTIM 0 of 0 bitmap
    > Tag: Country Information: Country Code CH, Environment Any
    > Tag: QBSS Load Element 802.11e CCA Version
    > Tag: HT Capabilities (802.11n D1.10)
    > Tag: RSN Information
    > Tag: HT Information (802.11n D1.10)
    > Tag: Extended Capabilities (8 octets)
    > Tag: Cisco CCX1 CKIP + Device Name
    > Tag: Vendor Specific: Aironet: Aironet DTPC Powerlevel 0x16
    > Tag: VHT Capabilities (IEEE Std 802.11ac/D3.1)
    > Tag: VHT Operation (IEEE Std 802.11ac/D3.1)
    > Tag: VHT Tx Power Envelope (IEEE Std 802.11ac/D5.0)
    > Tag: Vendor Specific: Microsof: WMM/WME: Parameter Element
```

Standard 802.11a rates

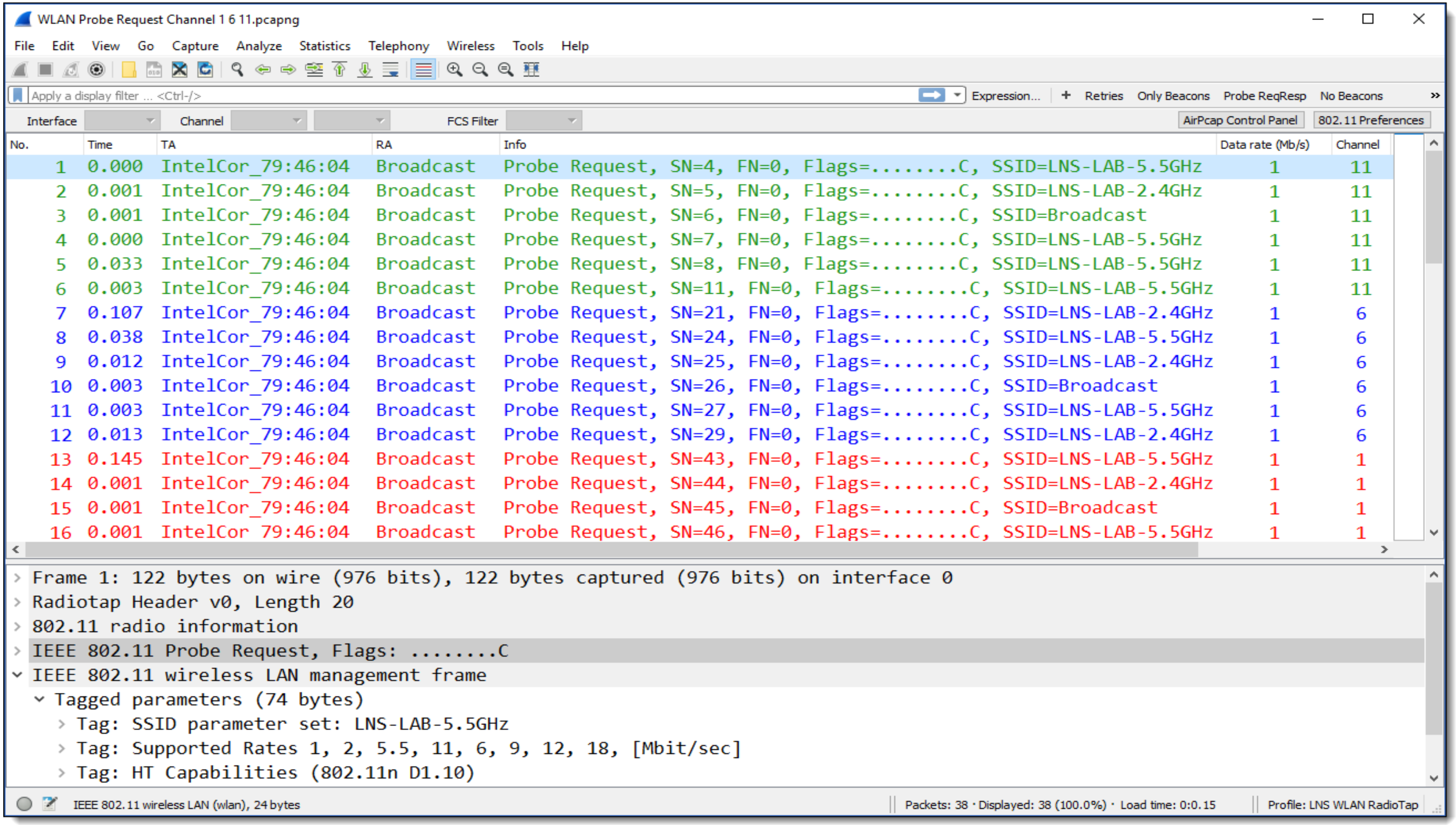
HT (High Throughput) 802.11n supported

Robust Security Network contains info about type of authentication & encryption

VHT (Very High Throughput)
Standard 802.11ac supported

Management Frames: Probe Request & Response

- A client sends Probe Requests to scan the channels for Access Points
- Capturing with multiple AirPcaps shows the scanning process



No.	Time	TA	RA	Info	Data rate (Mb/s)	Channel
1	0.000	IntelCor_79:46:04	Broadcast	Probe Request, SN=4, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	11
2	0.001	IntelCor_79:46:04	Broadcast	Probe Request, SN=5, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz	1	11
3	0.001	IntelCor_79:46:04	Broadcast	Probe Request, SN=6, FN=0, Flags=........C, SSID=Broadcast	1	11
4	0.000	IntelCor_79:46:04	Broadcast	Probe Request, SN=7, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	11
5	0.033	IntelCor_79:46:04	Broadcast	Probe Request, SN=8, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	11
6	0.003	IntelCor_79:46:04	Broadcast	Probe Request, SN=11, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	11
7	0.107	IntelCor_79:46:04	Broadcast	Probe Request, SN=21, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz	1	6
8	0.038	IntelCor_79:46:04	Broadcast	Probe Request, SN=24, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	6
9	0.012	IntelCor_79:46:04	Broadcast	Probe Request, SN=25, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz	1	6
10	0.003	IntelCor_79:46:04	Broadcast	Probe Request, SN=26, FN=0, Flags=........C, SSID=Broadcast	1	6
11	0.003	IntelCor_79:46:04	Broadcast	Probe Request, SN=27, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	6
12	0.013	IntelCor_79:46:04	Broadcast	Probe Request, SN=29, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz	1	6
13	0.145	IntelCor_79:46:04	Broadcast	Probe Request, SN=43, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	1
14	0.001	IntelCor_79:46:04	Broadcast	Probe Request, SN=44, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz	1	1
15	0.001	IntelCor_79:46:04	Broadcast	Probe Request, SN=45, FN=0, Flags=........C, SSID=Broadcast	1	1
16	0.001	IntelCor_79:46:04	Broadcast	Probe Request, SN=46, FN=0, Flags=........C, SSID=LNS-LAB-5.5GHz	1	1

```
> Frame 1: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) on interface 0
> Radiotap Header v0, Length 20
> 802.11 radio information
> IEEE 802.11 Probe Request, Flags: ........C
v IEEE 802.11 wireless LAN management frame
  v Tagged parameters (74 bytes)
    > Tag: SSID parameter set: LNS-LAB-5.5GHz
    > Tag: Supported Rates 1, 2, 5.5, 11, 6, 9, 12, 18, [Mbit/sec]
    > Tag: HT Capabilities (802.11n D1.10)
```

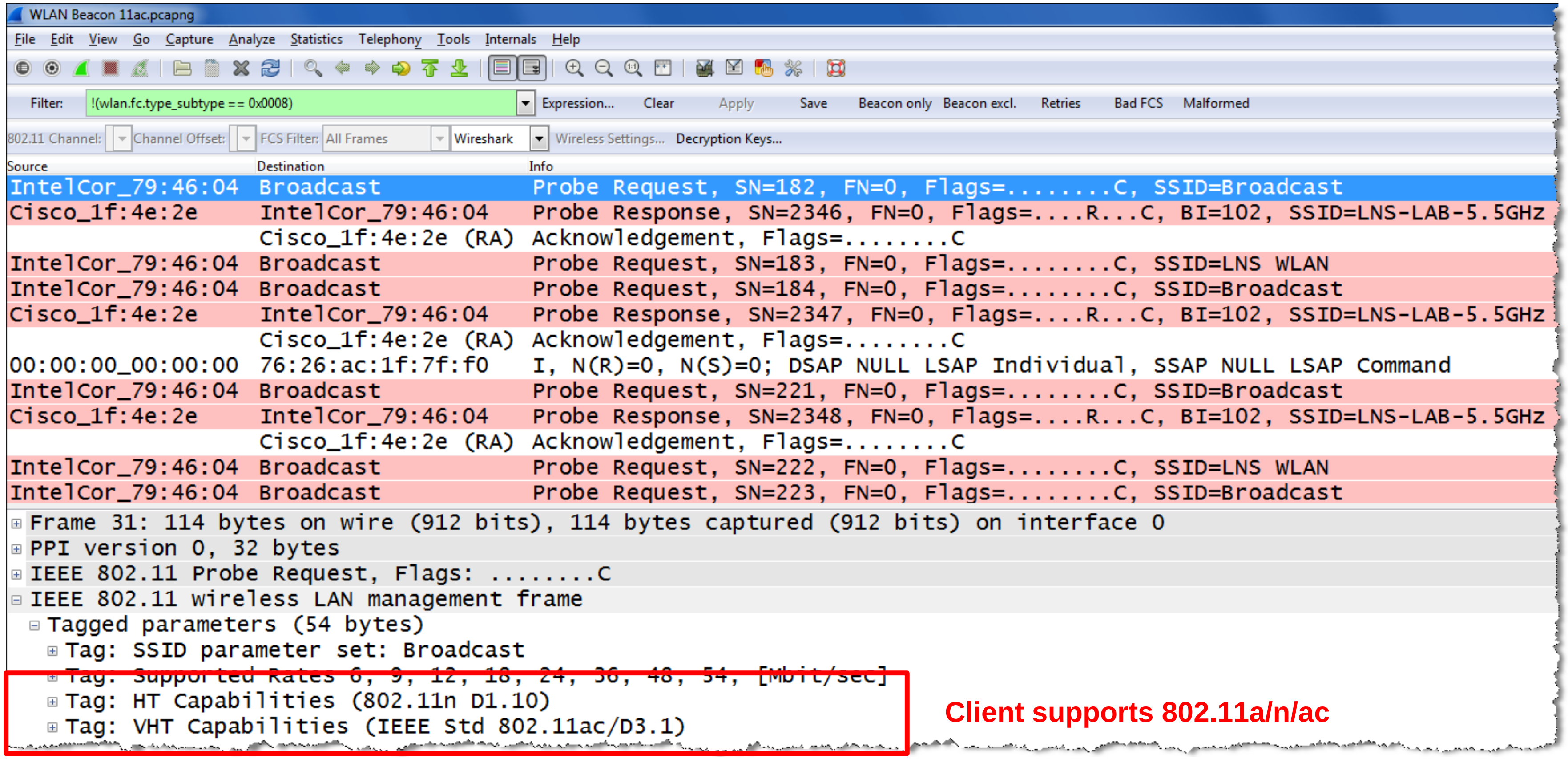
IEEE 802.11 wireless LAN (wlan), 24 bytes

Packets: 38 · Displayed: 38 (100.0%) · Load time: 0:0.15

Profile: LNS WLAN RadioTap

Management Frames: Probe Request & Response

- Probe Request contains client features and specific or broadcast SSID
- Access Points reply with Probe Response, containing same fields as Beacon


WLAN Beacon 11ac.pcapng
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Expression... Clear Apply Save Beacon only Beacon excl. Retries Bad FCS Malformed
802.11 Channel: Channel Offset: FCS Filter: All Frames Wireshark Wireless Settings... Decryption Keys...

Filter: !(wlan.fc.type_subtype == 0x0008)

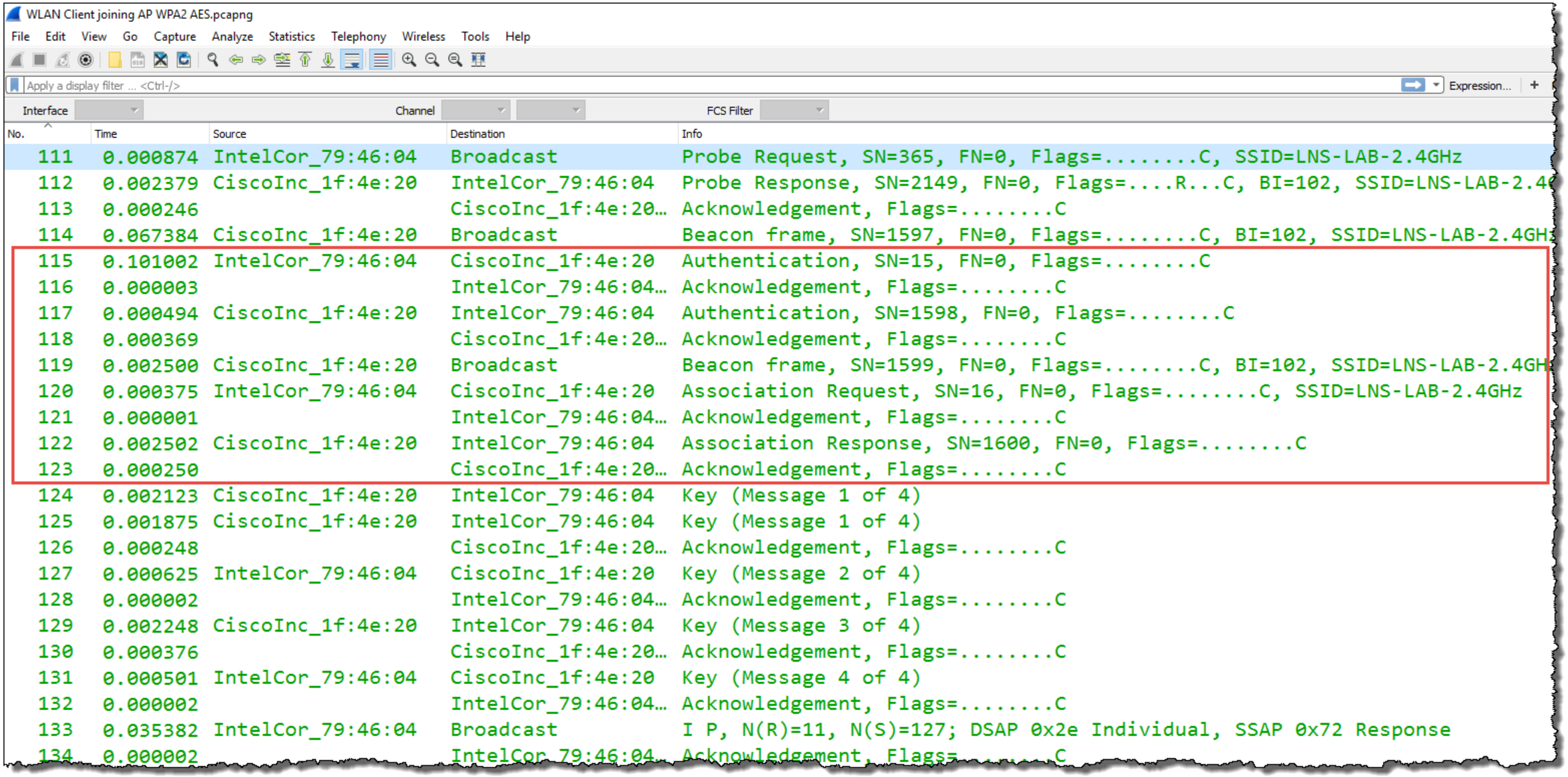
```
Source             Destination         Info
IntelCor_79:46:04  Broadcast           Probe Request, SN=182, FN=0, Flags=........C, SSID=Broadcast
Cisco_1f:4e:2e     IntelCor_79:46:04   Probe Response, SN=2346, FN=0, Flags=....R...C, BI=102, SSID=LNS-LAB-5.5GHz
                   Cisco_1f:4e:2e (RA) Acknowledgement, Flags=........C
IntelCor_79:46:04  Broadcast           Probe Request, SN=183, FN=0, Flags=........C, SSID=LNS WLAN
IntelCor_79:46:04  Broadcast           Probe Request, SN=184, FN=0, Flags=........C, SSID=Broadcast
Cisco_1f:4e:2e     IntelCor_79:46:04   Probe Response, SN=2347, FN=0, Flags=....R...C, BI=102, SSID=LNS-LAB-5.5GHz
                   Cisco_1f:4e:2e (RA) Acknowledgement, Flags=........C
00:00:00_00:00:00  76:26:ac:1f:7f:f0   I, N(R)=0, N(S)=0; DSAP NULL LSAP Individual, SSAP NULL LSAP Command
IntelCor_79:46:04  Broadcast           Probe Request, SN=221, FN=0, Flags=........C, SSID=Broadcast
Cisco_1f:4e:2e     IntelCor_79:46:04   Probe Response, SN=2348, FN=0, Flags=....R...C, BI=102, SSID=LNS-LAB-5.5GHz
                   Cisco_1f:4e:2e (RA) Acknowledgement, Flags=........C
IntelCor_79:46:04  Broadcast           Probe Request, SN=222, FN=0, Flags=........C, SSID=LNS WLAN
IntelCor_79:46:04  Broadcast           Probe Request, SN=223, FN=0, Flags=........C, SSID=Broadcast
```

```
⊞ Frame 31: 114 bytes on wire (912 bits), 114 bytes captured (912 bits) on interface 0
⊞ PPI version 0, 32 bytes
⊞ IEEE 802.11 Probe Request, Flags: ........C
⊟ IEEE 802.11 wireless LAN management frame
  ⊟ Tagged parameters (54 bytes)
    ⊞ Tag: SSID parameter set: Broadcast
    ⊞ Tag: Supported Rates 6, 9, 12, 18, 24, 36, 48, 54, [Mbit/sec]
    ⊞ Tag: HT Capabilities (802.11n D1.10)
    ⊞ Tag: VHT Capabilities (IEEE Std 802.11ac/D3.1)
```

Client supports 802.11a/n/ac

Management Frames: Authentication & Association

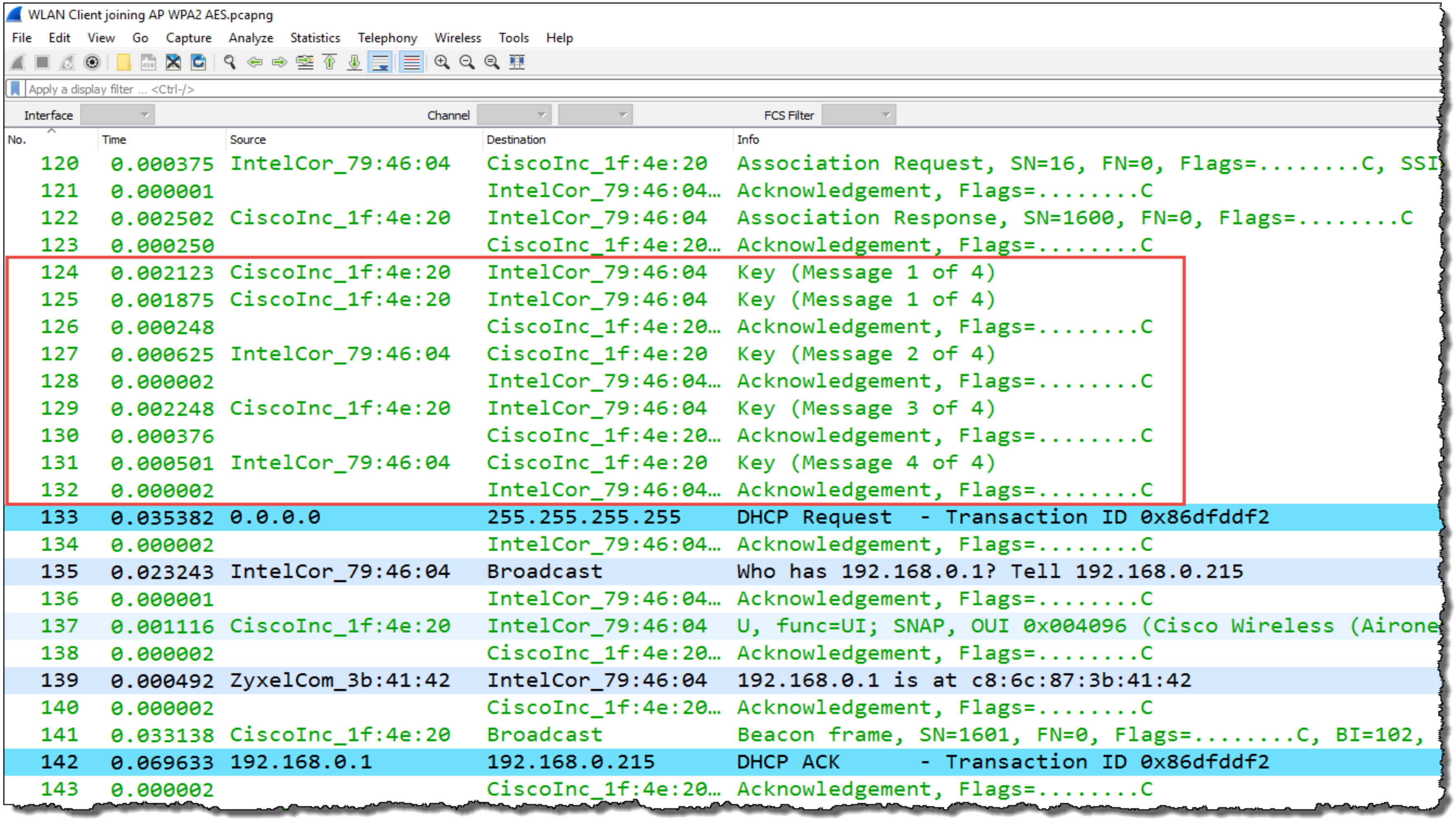
- The client selects an Access Point and sends Authenticate & Associate requests
- Both processes must be successful in order to join the Access Point



```
No.  Time      Source            Destination        Info
111  0.000874  IntelCor_79:46:04 Broadcast          Probe Request, SN=365, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz
112  0.002379  CiscoInc_1f:4e:20 IntelCor_79:46:04  Probe Response, SN=2149, FN=0, Flags=....R...C, BI=102, SSID=LNS-LAB-2.4
113  0.000246                    CiscoInc_1f:4e:20… Acknowledgement, Flags=........C
114  0.067384  CiscoInc_1f:4e:20 Broadcast          Beacon frame, SN=1597, FN=0, Flags=........C, BI=102, SSID=LNS-LAB-2.4GH
115  0.101002  IntelCor_79:46:04 CiscoInc_1f:4e:20  Authentication, SN=15, FN=0, Flags=........C
116  0.000003                    IntelCor_79:46:04… Acknowledgement, Flags=........C
117  0.000494  CiscoInc_1f:4e:20 IntelCor_79:46:04  Authentication, SN=1598, FN=0, Flags=........C
118  0.000369                    CiscoInc_1f:4e:20… Acknowledgement, Flags=........C
119  0.002500  CiscoInc_1f:4e:20 Broadcast          Beacon frame, SN=1599, FN=0, Flags=........C, BI=102, SSID=LNS-LAB-2.4GH
120  0.000375  IntelCor_79:46:04 CiscoInc_1f:4e:20  Association Request, SN=16, FN=0, Flags=........C, SSID=LNS-LAB-2.4GHz
121  0.000001                    IntelCor_79:46:04… Acknowledgement, Flags=........C
122  0.002502  CiscoInc_1f:4e:20 IntelCor_79:46:04  Association Response, SN=1600, FN=0, Flags=........C
123  0.000250                    CiscoInc_1f:4e:20… Acknowledgement, Flags=........C
124  0.002123  CiscoInc_1f:4e:20 IntelCor_79:46:04  Key (Message 1 of 4)
125  0.001875  CiscoInc_1f:4e:20 IntelCor_79:46:04  Key (Message 1 of 4)
126  0.000248                    CiscoInc_1f:4e:20… Acknowledgement, Flags=........C
127  0.000625  IntelCor_79:46:04 CiscoInc_1f:4e:20  Key (Message 2 of 4)
128  0.000002                    IntelCor_79:46:04… Acknowledgement, Flags=........C
129  0.002248  CiscoInc_1f:4e:20 IntelCor_79:46:04  Key (Message 3 of 4)
130  0.000376                    CiscoInc_1f:4e:20… Acknowledgement, Flags=........C
131  0.000501  IntelCor_79:46:04 CiscoInc_1f:4e:20  Key (Message 4 of 4)
132  0.000002                    IntelCor_79:46:04… Acknowledgement, Flags=........C
133  0.035382  IntelCor_79:46:04 Broadcast          I P, N(R)=11, N(S)=127; DSAP 0x2e Individual, SSAP 0x72 Response
134  0.000002                    IntelCor_79:46:04… Acknowledgement, Flags=........C
```

Decrypting WEP, WPA & WPA2 PSK

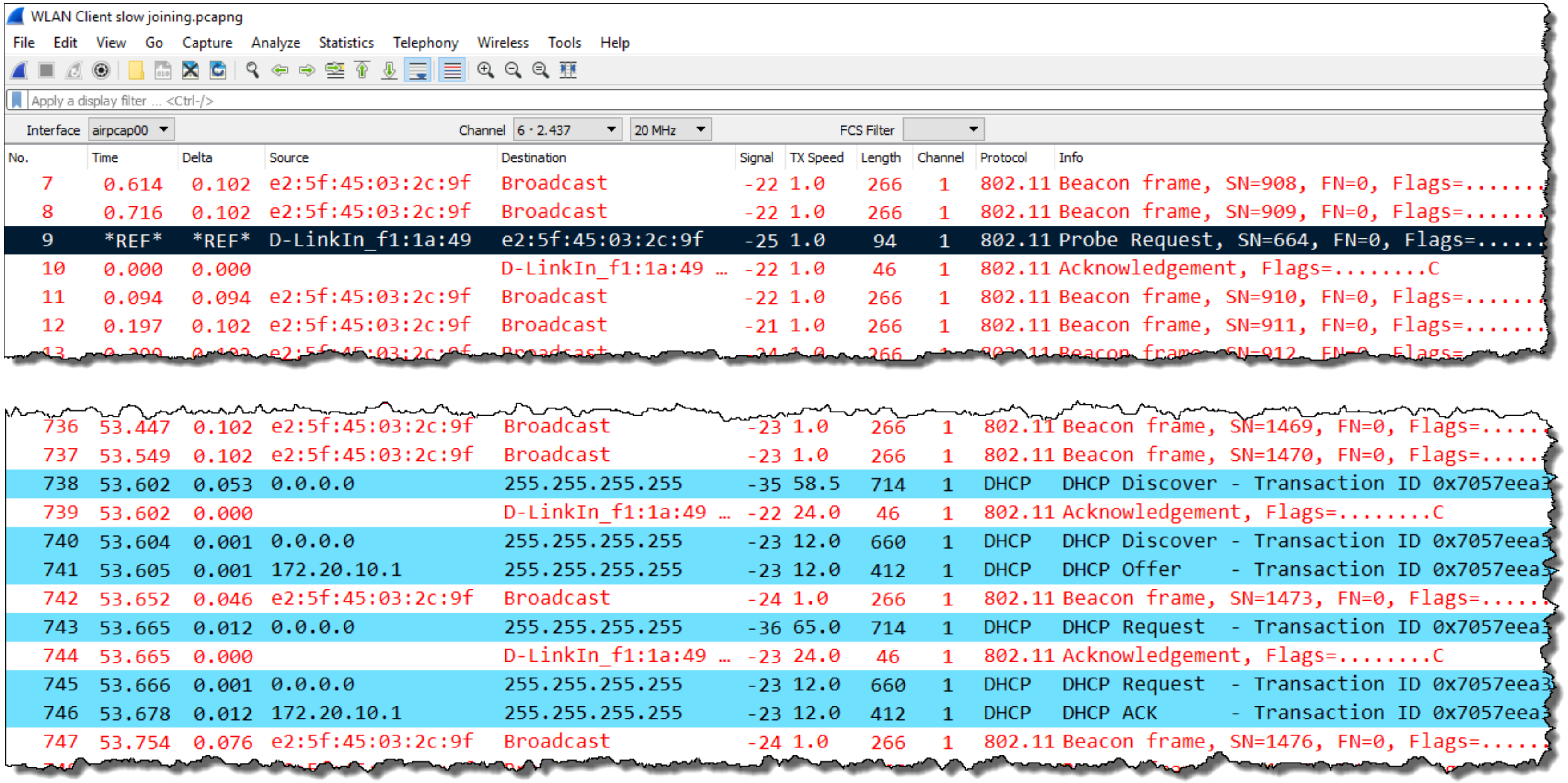
- Wireshark can decrypt WEP, WPA & WPA2 PSK if the key is available
- To decrypt WPA & WPA2 the key negotiation process must be captured


WLAN Client joining AP WPA2 AES.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Interface
Channel
FCS Filter

```
No.   Time      Source              Destination          Info
 120  0.000375  IntelCor_79:46:04   CiscoInc_1f:4e:20    Association Request, SN=16, FN=0, Flags=........C, SSI
 121  0.000001                      IntelCor_79:46:04…   Acknowledgement, Flags=........C
 122  0.002502  CiscoInc_1f:4e:20   IntelCor_79:46:04    Association Response, SN=1600, FN=0, Flags=........C
 123  0.000250                      CiscoInc_1f:4e:20…   Acknowledgement, Flags=........C
 124  0.002123  CiscoInc_1f:4e:20   IntelCor_79:46:04    Key (Message 1 of 4)
 125  0.001875  CiscoInc_1f:4e:20   IntelCor_79:46:04    Key (Message 1 of 4)
 126  0.000248                      CiscoInc_1f:4e:20…   Acknowledgement, Flags=........C
 127  0.000625  IntelCor_79:46:04   CiscoInc_1f:4e:20    Key (Message 2 of 4)
 128  0.000002                      IntelCor_79:46:04…   Acknowledgement, Flags=........C
 129  0.002248  CiscoInc_1f:4e:20   IntelCor_79:46:04    Key (Message 3 of 4)
 130  0.000376                      CiscoInc_1f:4e:20…   Acknowledgement, Flags=........C
 131  0.000501  IntelCor_79:46:04   CiscoInc_1f:4e:20    Key (Message 4 of 4)
 132  0.000002                      IntelCor_79:46:04…   Acknowledgement, Flags=........C
 133  0.035382  0.0.0.0             255.255.255.255      DHCP Request  - Transaction ID 0x86dfddf2
 134  0.000002                      IntelCor_79:46:04…   Acknowledgement, Flags=........C
 135  0.023243  IntelCor_79:46:04   Broadcast            Who has 192.168.0.1? Tell 192.168.0.215
 136  0.000001                      IntelCor_79:46:04…   Acknowledgement, Flags=........C
 137  0.001116  CiscoInc_1f:4e:20   IntelCor_79:46:04    U, func=UI; SNAP, OUI 0x004096 (Cisco Wireless (Airone
 138  0.000002                      CiscoInc_1f:4e:20…   Acknowledgement, Flags=........C
 139  0.000492  ZyxelCom_3b:41:42   IntelCor_79:46:04    192.168.0.1 is at c8:6c:87:3b:41:42
 140  0.000002                      CiscoInc_1f:4e:20…   Acknowledgement, Flags=........C
 141  0.033138  CiscoInc_1f:4e:20   Broadcast            Beacon frame, SN=1601, FN=0, Flags=........C, BI=102,
 142  0.069633  192.168.0.1         192.168.0.215        DHCP ACK      - Transaction ID 0x86dfddf2
 143  0.000002                      CiscoInc_1f:4e:20…   Acknowledgement, Flags=........C
```

Client joining problem

- A client needs up to a minute duration to join an Access Point
- Analyzing the trace file discloses the reason: Access Point, Media or Client?



WLAN Client slow joining.pcapng
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

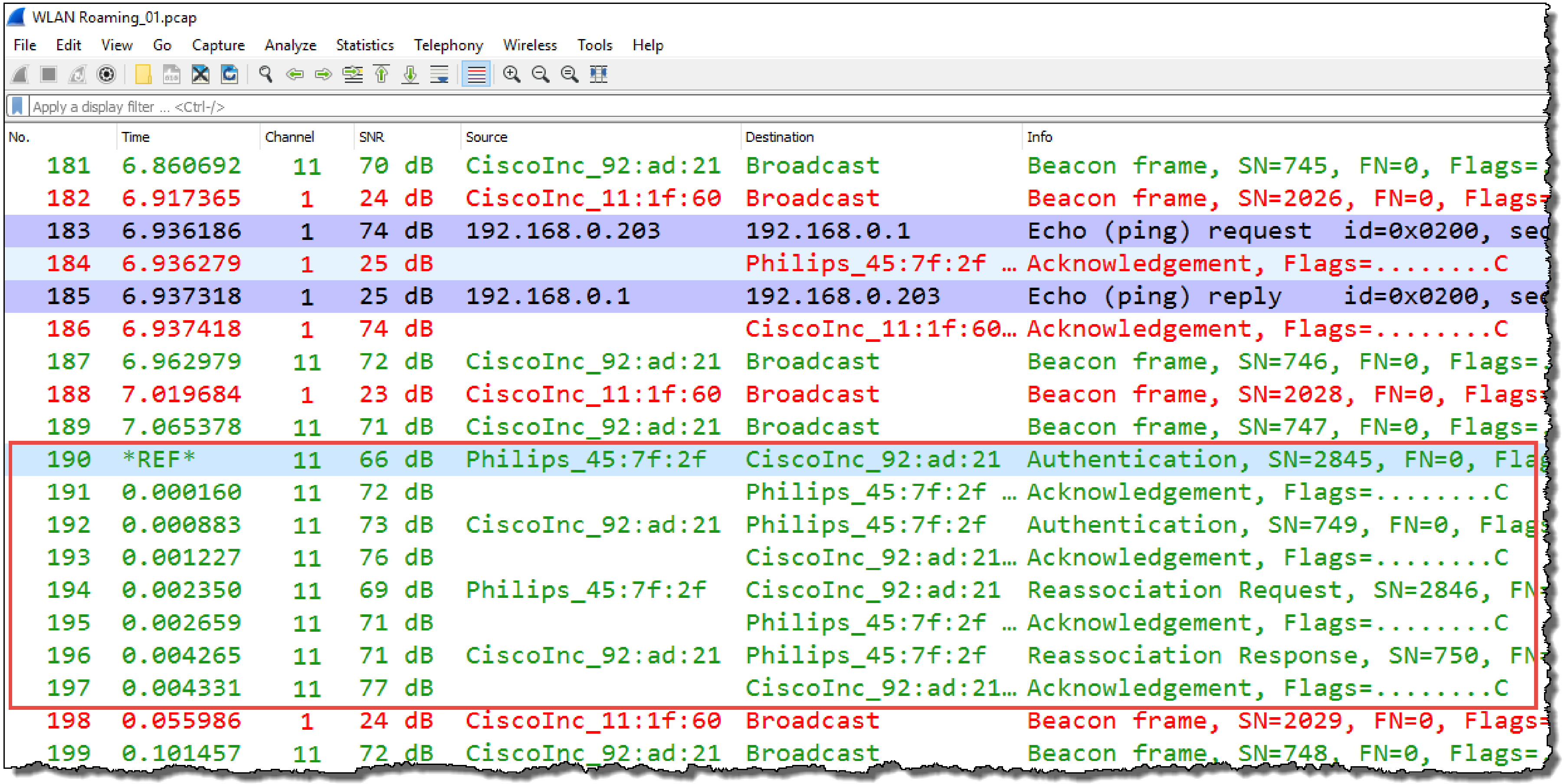
Interface: airpcap00 — Channel: 6 · 2.437 — 20 MHz — FCS Filter

```
No.  Time    Delta   Source              Destination          Signal TX Speed Length Channel Protocol Info
7    0.614   0.102   e2:5f:45:03:2c:9f   Broadcast            -22  1.0   266  1  802.11 Beacon frame, SN=908, FN=0, Flags=......
8    0.716   0.102   e2:5f:45:03:2c:9f   Broadcast            -22  1.0   266  1  802.11 Beacon frame, SN=909, FN=0, Flags=......
9    *REF*   *REF*   D-LinkIn_f1:1a:49   e2:5f:45:03:2c:9f    -25  1.0   94   1  802.11 Probe Request, SN=664, FN=0, Flags=.....
10   0.000   0.000                       D-LinkIn_f1:1a:49 …  -22  1.0   46   1  802.11 Acknowledgement, Flags=........C
11   0.094   0.094   e2:5f:45:03:2c:9f   Broadcast            -22  1.0   266  1  802.11 Beacon frame, SN=910, FN=0, Flags=......
12   0.197   0.102   e2:5f:45:03:2c:9f   Broadcast            -21  1.0   266  1  802.11 Beacon frame, SN=911, FN=0, Flags=......
13   0.299   0.102   e2:5f:45:03:2c:9f   Broadcast            -24  1.0   266  1  802.11 Beacon frame, SN=912, FN=0, Flags=

736  53.447  0.102   e2:5f:45:03:2c:9f   Broadcast            -23  1.0   266  1  802.11 Beacon frame, SN=1469, FN=0, Flags=.....
737  53.549  0.102   e2:5f:45:03:2c:9f   Broadcast            -23  1.0   266  1  802.11 Beacon frame, SN=1470, FN=0, Flags=.....
738  53.602  0.053   0.0.0.0             255.255.255.255      -35  58.5  714  1  DHCP   DHCP Discover - Transaction ID 0x7057eea3
739  53.602  0.000                       D-LinkIn_f1:1a:49 …  -22  24.0  46   1  802.11 Acknowledgement, Flags=........C
740  53.604  0.001   0.0.0.0             255.255.255.255      -23  12.0  660  1  DHCP   DHCP Discover - Transaction ID 0x7057eea3
741  53.605  0.001   172.20.10.1         255.255.255.255      -23  12.0  412  1  DHCP   DHCP Offer    - Transaction ID 0x7057eea3
742  53.652  0.046   e2:5f:45:03:2c:9f   Broadcast            -24  1.0   266  1  802.11 Beacon frame, SN=1473, FN=0, Flags=.....
743  53.665  0.012   0.0.0.0             255.255.255.255      -36  65.0  714  1  DHCP   DHCP Request  - Transaction ID 0x7057eea3
744  53.665  0.000                       D-LinkIn_f1:1a:49 …  -23  24.0  46   1  802.11 Acknowledgement, Flags=........C
745  53.666  0.001   0.0.0.0             255.255.255.255      -23  12.0  660  1  DHCP   DHCP Request  - Transaction ID 0x7057eea3
746  53.678  0.012   172.20.10.1         255.255.255.255      -23  12.0  412  1  DHCP   DHCP ACK      - Transaction ID 0x7057eea3
747  53.754  0.076   e2:5f:45:03:2c:9f   Broadcast            -24  1.0   266  1  802.11 Beacon frame, SN=1476, FN=0, Flags=.....
```

Analyzing the WiFi roaming process

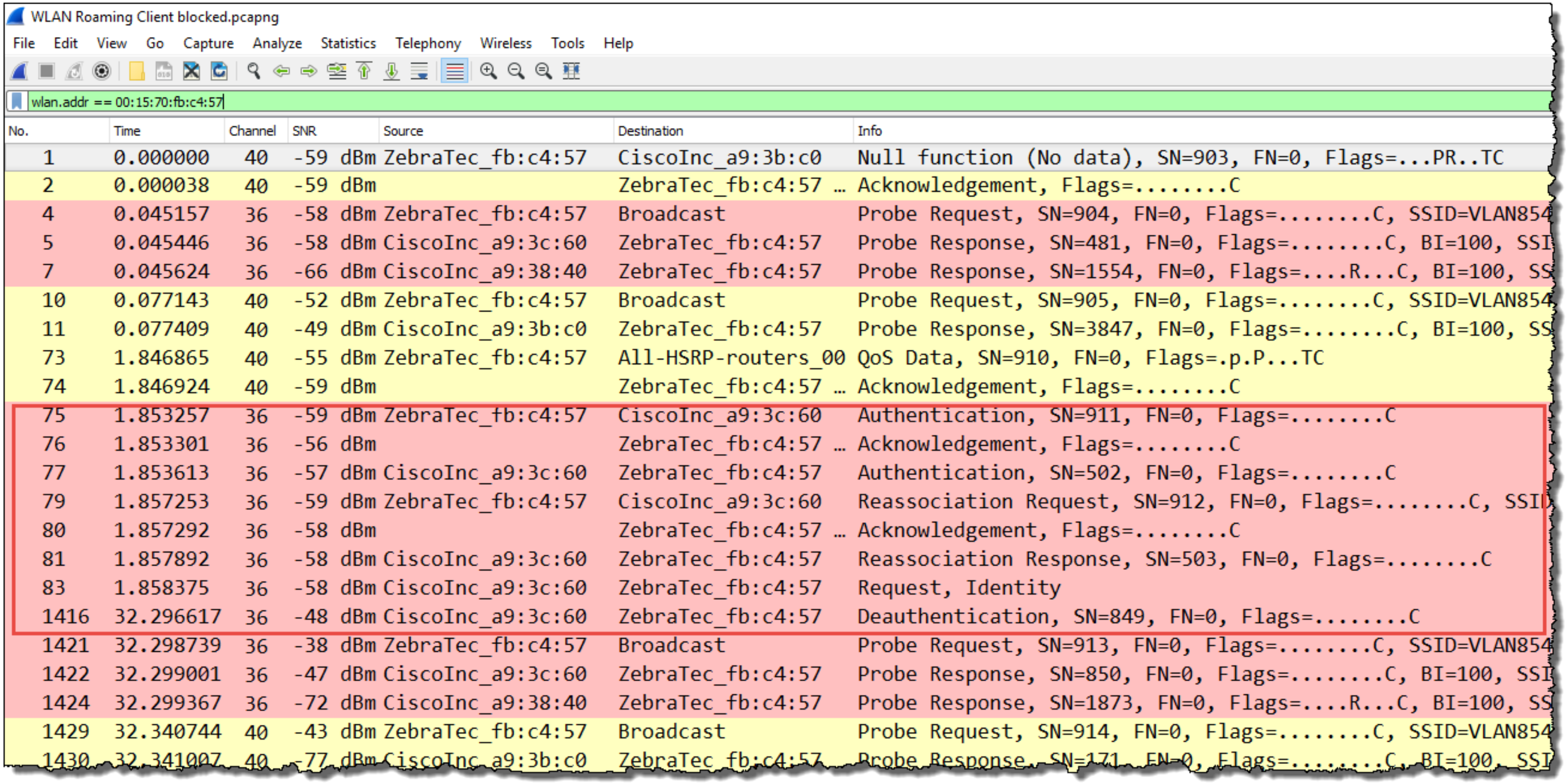
- A client is roaming from channel 1 to 11 because the SNR of the new AP is better
- Capturing the roaming process requires multi-channel equipment


WLAN Roaming_01.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

No.	Time	Channel	SNR	Source	Destination	Info
181	6.860692	11	70 dB	CiscoInc_92:ad:21	Broadcast	Beacon frame, SN=745, FN=0, Flags=
182	6.917365	1	24 dB	CiscoInc_11:1f:60	Broadcast	Beacon frame, SN=2026, FN=0, Flags
183	6.936186	1	74 dB	192.168.0.203	192.168.0.1	Echo (ping) request id=0x0200, se
184	6.936279	1	25 dB		Philips_45:7f:2f …	Acknowledgement, Flags=........C
185	6.937318	1	25 dB	192.168.0.1	192.168.0.203	Echo (ping) reply id=0x0200, se
186	6.937418	1	74 dB		CiscoInc_11:1f:60…	Acknowledgement, Flags=........C
187	6.962979	11	72 dB	CiscoInc_92:ad:21	Broadcast	Beacon frame, SN=746, FN=0, Flags=
188	7.019684	1	23 dB	CiscoInc_11:1f:60	Broadcast	Beacon frame, SN=2028, FN=0, Flags
189	7.065378	11	71 dB	CiscoInc_92:ad:21	Broadcast	Beacon frame, SN=747, FN=0, Flags=
190	*REF*	11	66 dB	Philips_45:7f:2f	CiscoInc_92:ad:21	Authentication, SN=2845, FN=0, Fla
191	0.000160	11	72 dB		Philips_45:7f:2f …	Acknowledgement, Flags=........C
192	0.000883	11	73 dB	CiscoInc_92:ad:21	Philips_45:7f:2f	Authentication, SN=749, FN=0, Flag
193	0.001227	11	76 dB		CiscoInc_92:ad:21…	Acknowledgement, Flags=........C
194	0.002350	11	69 dB	Philips_45:7f:2f	CiscoInc_92:ad:21	Reassociation Request, SN=2846, FN
195	0.002659	11	71 dB		Philips_45:7f:2f …	Acknowledgement, Flags=........C
196	0.004265	11	71 dB	CiscoInc_92:ad:21	Philips_45:7f:2f	Reassociation Response, SN=750, FN
197	0.004331	11	77 dB		CiscoInc_92:ad:21…	Acknowledgement, Flags=........C
198	0.055986	1	24 dB	CiscoInc_11:1f:60	Broadcast	Beacon frame, SN=2029, FN=0, Flags
199	0.101457	11	72 dB	CiscoInc_92:ad:21	Broadcast	Beacon frame, SN=748, FN=0, Flags=

Client roaming problem

- User is complaining about sporadic hangers in bar code scanners, up to minutes
- Vendors of mobile clients and access points are finger pointing, since month.
- Problem could be assigned to bar code vendor by analyzing trace files.

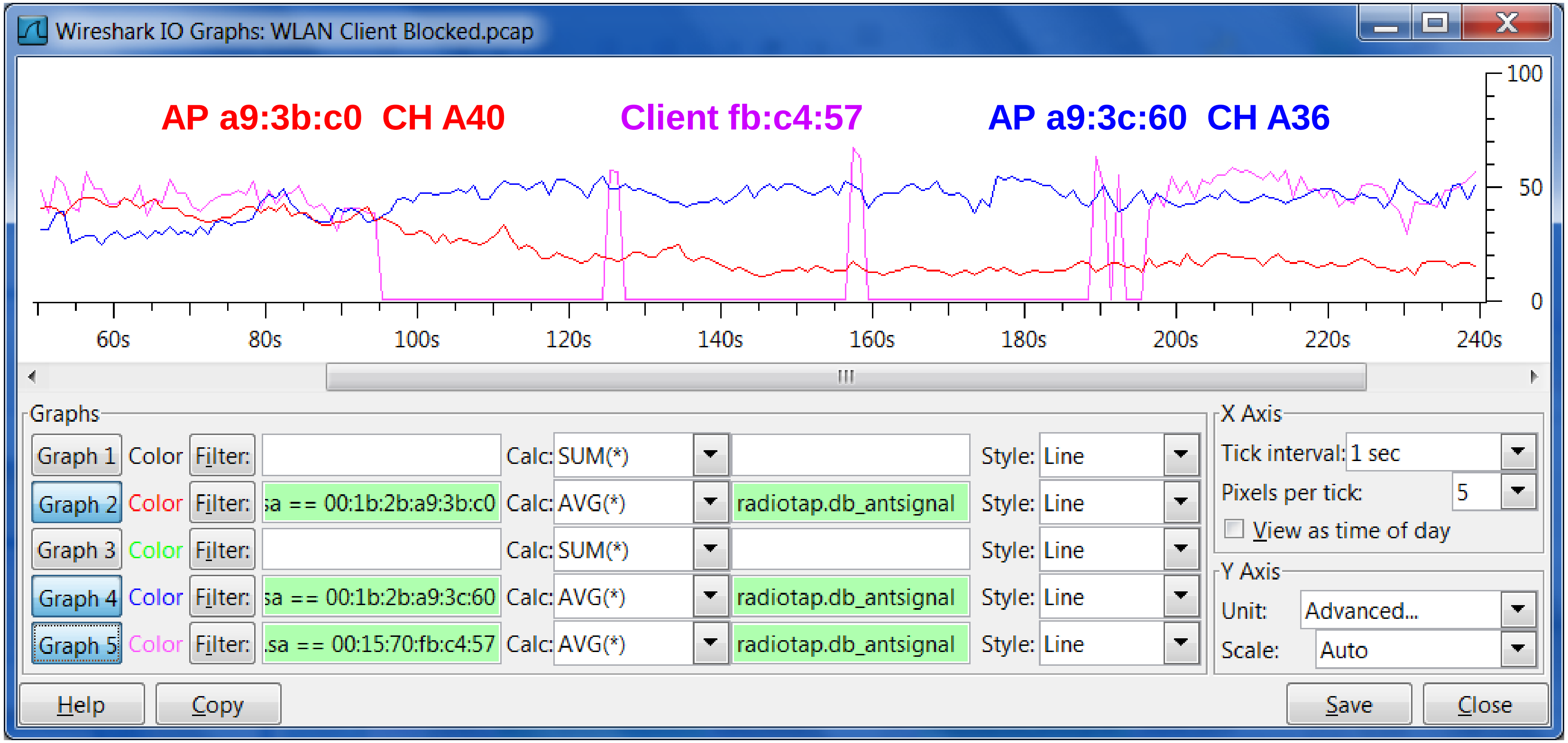


wlan.addr == 00:15:70:fb:c4:57

No.	Time	Channel	SNR	Source	Destination	Info
1	0.000000	40	-59 dBm	ZebraTec_fb:c4:57	CiscoInc_a9:3b:c0	Null function (No data), SN=903, FN=0, Flags=...PR..TC
2	0.000038	40	-59 dBm		ZebraTec_fb:c4:57 …	Acknowledgement, Flags=........C
4	0.045157	36	-58 dBm	ZebraTec_fb:c4:57	Broadcast	Probe Request, SN=904, FN=0, Flags=........C, SSID=VLAN854
5	0.045446	36	-58 dBm	CiscoInc_a9:3c:60	ZebraTec_fb:c4:57	Probe Response, SN=481, FN=0, Flags=........C, BI=100, SSI
7	0.045624	36	-66 dBm	CiscoInc_a9:38:40	ZebraTec_fb:c4:57	Probe Response, SN=1554, FN=0, Flags=....R...C, BI=100, SS
10	0.077143	40	-52 dBm	ZebraTec_fb:c4:57	Broadcast	Probe Request, SN=905, FN=0, Flags=........C, SSID=VLAN854
11	0.077409	40	-49 dBm	CiscoInc_a9:3b:c0	ZebraTec_fb:c4:57	Probe Response, SN=3847, FN=0, Flags=........C, BI=100, SS
73	1.846865	40	-55 dBm	ZebraTec_fb:c4:57	All-HSRP-routers_00	QoS Data, SN=910, FN=0, Flags=.p.P...TC
74	1.846924	40	-59 dBm		ZebraTec_fb:c4:57 …	Acknowledgement, Flags=........C
75	1.853257	36	-59 dBm	ZebraTec_fb:c4:57	CiscoInc_a9:3c:60	Authentication, SN=911, FN=0, Flags=........C
76	1.853301	36	-56 dBm		ZebraTec_fb:c4:57 …	Acknowledgement, Flags=........C
77	1.853613	36	-57 dBm	CiscoInc_a9:3c:60	ZebraTec_fb:c4:57	Authentication, SN=502, FN=0, Flags=........C
79	1.857253	36	-59 dBm	ZebraTec_fb:c4:57	CiscoInc_a9:3c:60	Reassociation Request, SN=912, FN=0, Flags=........C, SSID
80	1.857292	36	-58 dBm		ZebraTec_fb:c4:57 …	Acknowledgement, Flags=........C
81	1.857892	36	-58 dBm	CiscoInc_a9:3c:60	ZebraTec_fb:c4:57	Reassociation Response, SN=503, FN=0, Flags=........C
83	1.858375	36	-58 dBm	CiscoInc_a9:3c:60	ZebraTec_fb:c4:57	Request, Identity
1416	32.296617	36	-48 dBm	CiscoInc_a9:3c:60	ZebraTec_fb:c4:57	Deauthentication, SN=849, FN=0, Flags=........C
1421	32.298739	36	-38 dBm	ZebraTec_fb:c4:57	Broadcast	Probe Request, SN=913, FN=0, Flags=........C, SSID=VLAN854
1422	32.299001	36	-47 dBm	CiscoInc_a9:3c:60	ZebraTec_fb:c4:57	Probe Response, SN=850, FN=0, Flags=........C, BI=100, SSI
1424	32.299367	36	-72 dBm	CiscoInc_a9:38:40	ZebraTec_fb:c4:57	Probe Response, SN=1873, FN=0, Flags=....R...C, BI=100, SS
1429	32.340744	40	-43 dBm	ZebraTec_fb:c4:57	Broadcast	Probe Request, SN=914, FN=0, Flags=........C, SSID=VLAN854
1430	32.341007	40	-77 dBm	CiscoInc_a9:3b:c0	ZebraTec_fb:c4:57	Probe Response, SN=171, FN=0, Flags=........C, BI=100, SSI

Client roaming problem

- Using IO Graph to show signal strength of different sources



Wireshark IO Graphs: WLAN Client Blocked.pcap

Graphs

Graph 1	Color	Filter:		Calc: SUM(*)		Style: Line
Graph 2	Color	Filter:	sa == 00:1b:2b:a9:3b:c0	Calc: AVG(*)	radiotap.db_antsignal	Style: Line
Graph 3	Color	Filter:		Calc: SUM(*)		Style: Line
Graph 4	Color	Filter:	sa == 00:1b:2b:a9:3c:60	Calc: AVG(*)	radiotap.db_antsignal	Style: Line
Graph 5	Color	Filter:	.sa == 00:15:70:fb:c4:57	Calc: AVG(*)	radiotap.db_antsignal	Style: Line

X Axis

Tick interval: 1 sec

Pixels per tick: 5

☐ View as time of day

Y Axis

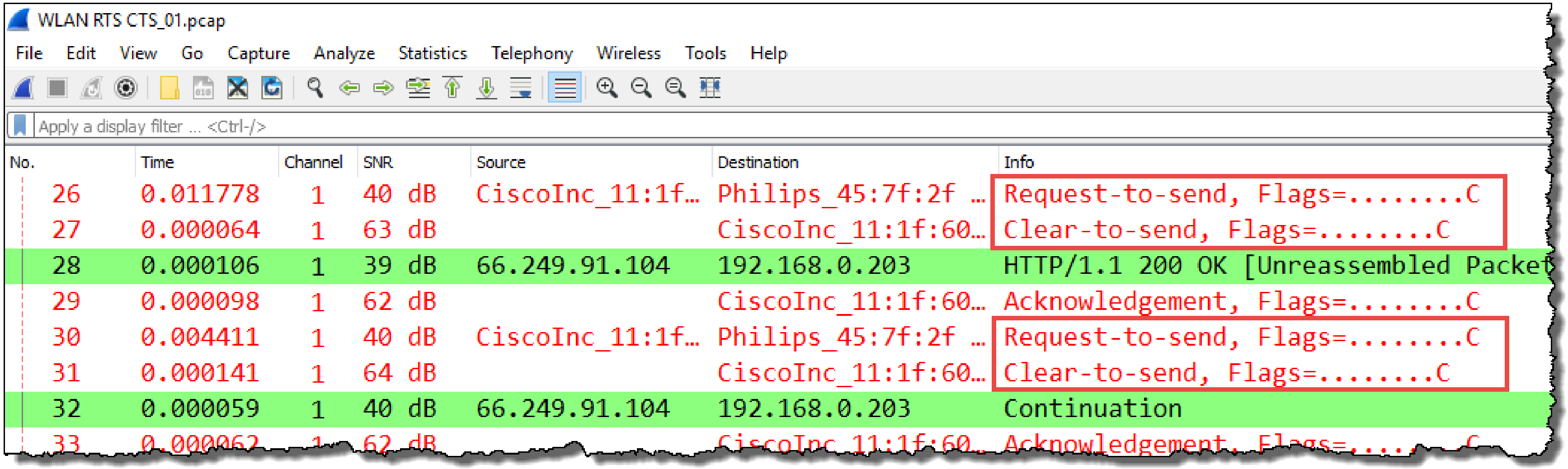
Unit: Advanced...

Scale: Auto

Graph 2 Color Filter: wlan.sa == 00:1b:2b:a9:3b:c0
Graph 4 Color Filter: wlan.sa == 00:1b:2b:a9:3c:60
Graph 5 Color Filter: wlan.sa == 00:15:70:fb:c4:57

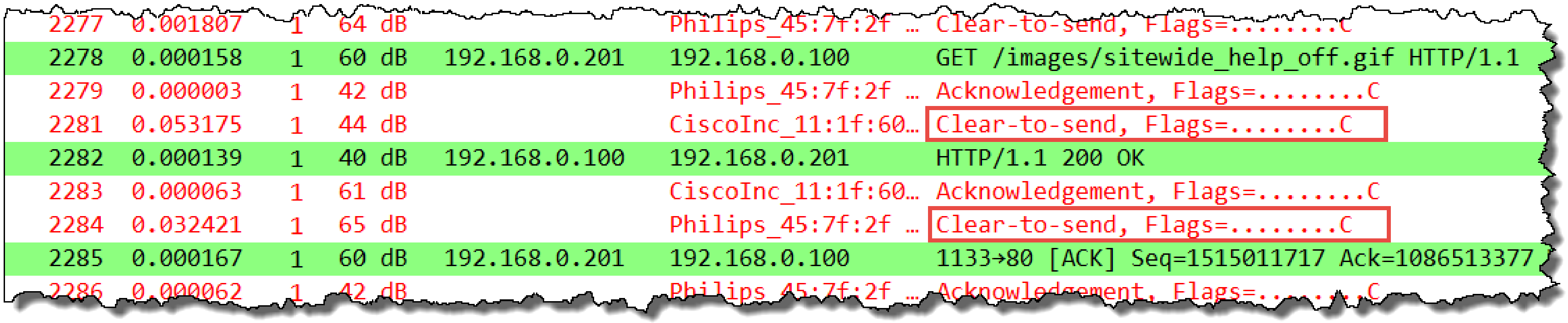
Control Frames: Request to Send / Clear to Send

- A WLAN node can reserve airtime and refrain all other stations from sending
- RTS/CTS reservation is used in busy cells, Hidden Node situations or in mixed mode



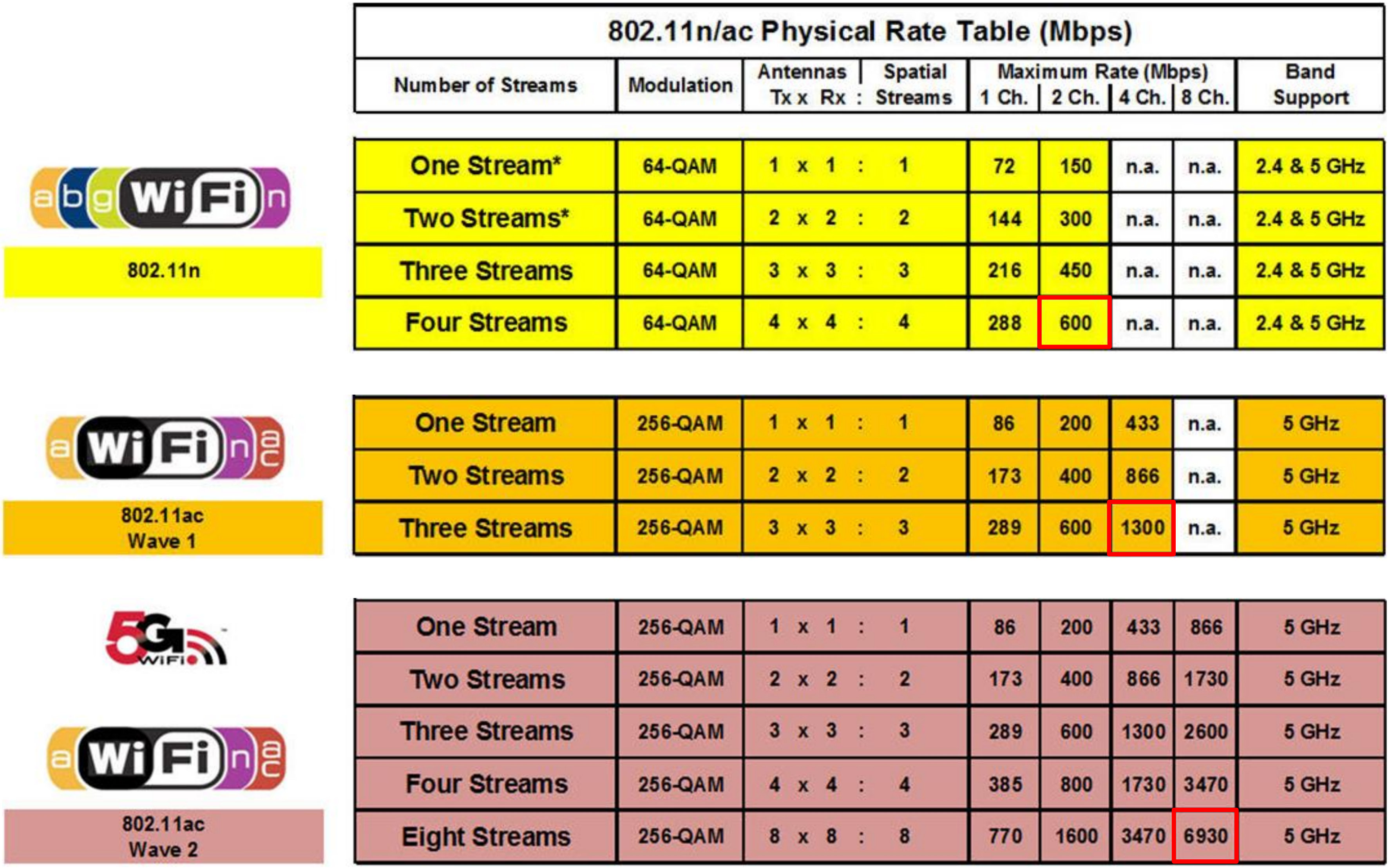
No.	Time	Channel	SNR	Source	Destination	Info
26	0.011778	1	40 dB	CiscoInc_11:1f…	Philips_45:7f:2f …	Request-to-send, Flags=........C
27	0.000064	1	63 dB		CiscoInc_11:1f:60…	Clear-to-send, Flags=........C
28	0.000106	1	39 dB	66.249.91.104	192.168.0.203	HTTP/1.1 200 OK [Unreassembled Packet
29	0.000098	1	62 dB		CiscoInc_11:1f:60…	Acknowledgement, Flags=........C
30	0.004411	1	40 dB	CiscoInc_11:1f…	Philips_45:7f:2f …	Request-to-send, Flags=........C
31	0.000141	1	64 dB		CiscoInc_11:1f:60…	Clear-to-send, Flags=........C
32	0.000059	1	40 dB	66.249.91.104	192.168.0.203	Continuation
33	0.000062	1	62 dB		CiscoInc_11:1f:60…	Acknowledgement, Flags=........C

- A short form, so-called CTS-to-Self is often used in cells with B-Only clients present



2277	0.001807	1	64 dB		Philips_45:7f:2f …	Clear-to-send, Flags=........C
2278	0.000158	1	60 dB	192.168.0.201	192.168.0.100	GET /images/sitewide_help_off.gif HTTP/1.1
2279	0.000003	1	42 dB		Philips_45:7f:2f …	Acknowledgement, Flags=........C
2281	0.053175	1	44 dB		CiscoInc_11:1f:60…	Clear-to-send, Flags=........C
2282	0.000139	1	40 dB	192.168.0.100	192.168.0.201	HTTP/1.1 200 OK
2283	0.000063	1	61 dB		CiscoInc_11:1f:60…	Acknowledgement, Flags=........C
2284	0.032421	1	65 dB		Philips_45:7f:2f …	Clear-to-send, Flags=........C
2285	0.000167	1	60 dB	192.168.0.201	192.168.0.100	1133→80 [ACK] Seq=1515011717 Ack=1086513377
2286	0.000062	1	42 dB		Philips_45:7f:2f …	Acknowledgement, Flags=........C

Overview WiFi 802.11n/ac Raw Rates



802.11n/ac Physical Rate Table (Mbps)

	Number of Streams	Modulation	Antennas	Spatial	Maximum Rate (Mbps)				Band
			Tx x Rx :	Streams	1 Ch.	2 Ch.	4 Ch.	8 Ch.	Support
802.11n	One Stream*	64-QAM	1 x 1 :	1	72	150	n.a.	n.a.	2.4 & 5 GHz
	Two Streams*	64-QAM	2 x 2 :	2	144	300	n.a.	n.a.	2.4 & 5 GHz
	Three Streams	64-QAM	3 x 3 :	3	216	450	n.a.	n.a.	2.4 & 5 GHz
	Four Streams	64-QAM	4 x 4 :	4	288	600	n.a.	n.a.	2.4 & 5 GHz
802.11ac Wave 1	One Stream	256-QAM	1 x 1 :	1	86	200	433	n.a.	5 GHz
	Two Streams	256-QAM	2 x 2 :	2	173	400	866	n.a.	5 GHz
	Three Streams	256-QAM	3 x 3 :	3	289	600	1300	n.a.	5 GHz
802.11ac Wave 2	One Stream	256-QAM	1 x 1 :	1	86	200	433	866	5 GHz
	Two Streams	256-QAM	2 x 2 :	2	173	400	866	1730	5 GHz
	Three Streams	256-QAM	3 x 3 :	3	289	600	1300	2600	5 GHz
	Four Streams	256-QAM	4 x 4 :	4	385	800	1730	3470	5 GHz
	Eight Streams	256-QAM	8 x 8 :	8	770	1600	3470	6930	5 GHz

WLAN Layer 2 capturing with AirPcap

Key features:

- WiFi radios can use multiple 20 MHz channels (n/ac) to increase throughput
- Each radio cell is a shared media and is controlled by an Access Point (AP)
- A mobile client can be associated with only one AP at the time
- Radio cell access is controlled by managements and control frames
- Wireshark with AirPcap can capture and analyze these frames
- Understanding of these frames is crucial for WLAN troubleshooting

AirPcap Nx 802.11a/b/g/n USB - adapter works with Wireshark and captures WiFi packets in both 2.4 GHz and 5 GHz bands.

END-OF-AVAILABILITY
JANUARY 1ST, 2018

WLAN Layer 2 capturing with WaveXpert

- Softing IT Networks introduces the new WaveXpert
  - Includes 4 wireless adapter with 16 integrated antennas
  - Supports 4x4 MIMO up to IEEE 802.11ac Wave 2
  - USB-C type plug for data and power
  - 2.4 GHz or 5 GHz versions available
  - 4 x 4 : 4 up to 4 Channels bonded (1’730 Mbps)
  - 2 x 2 : 2 up to 8 Channels bonded (1’730 Mbps)
  - Creates pcapng files incl. Radiotap header

Multi-Channel WLAN Sniffer

- Retail price: EUR 1’950

  Availability: planned for 1st Qu. 2019

- Requirements:
  - LINUX notebook and USB-C (Thunderbolt 3)
  - Supporting most Linux’s and Mac OS

Joint development of:

Softing IT Networks GmbH
85540 Haar, Germany and
GHMT AG
66450 Bexbach, Germany

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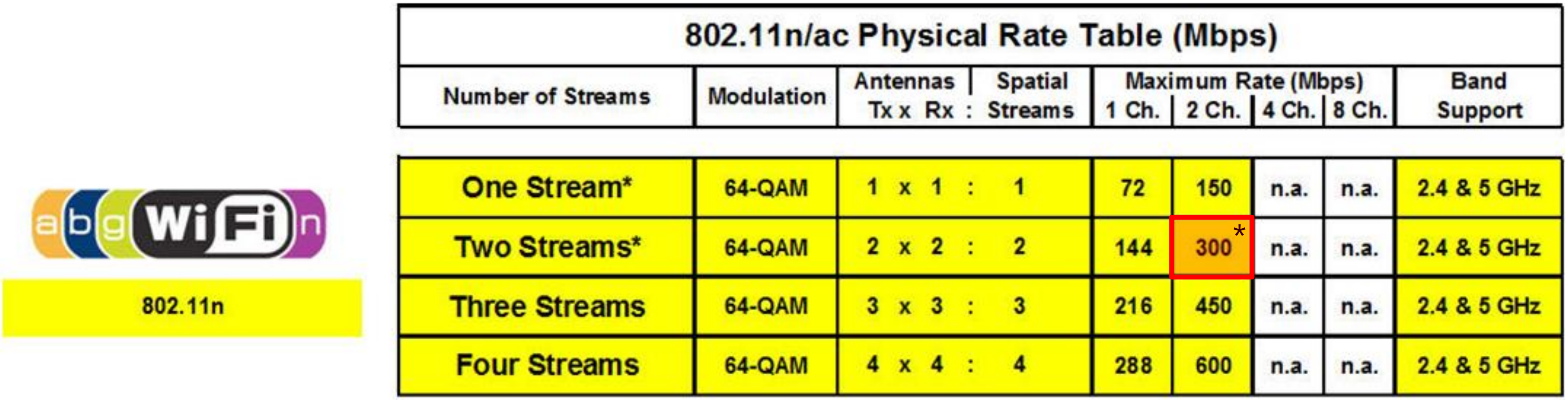
Supported maximum capture rates

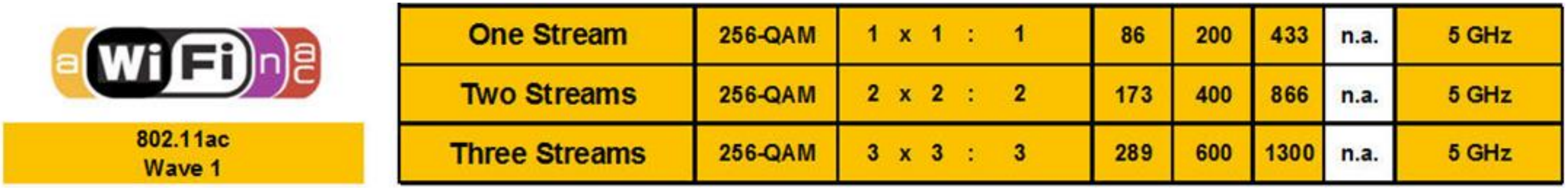


802.11n/ac Physical Rate Table (Mbps)

802.11n

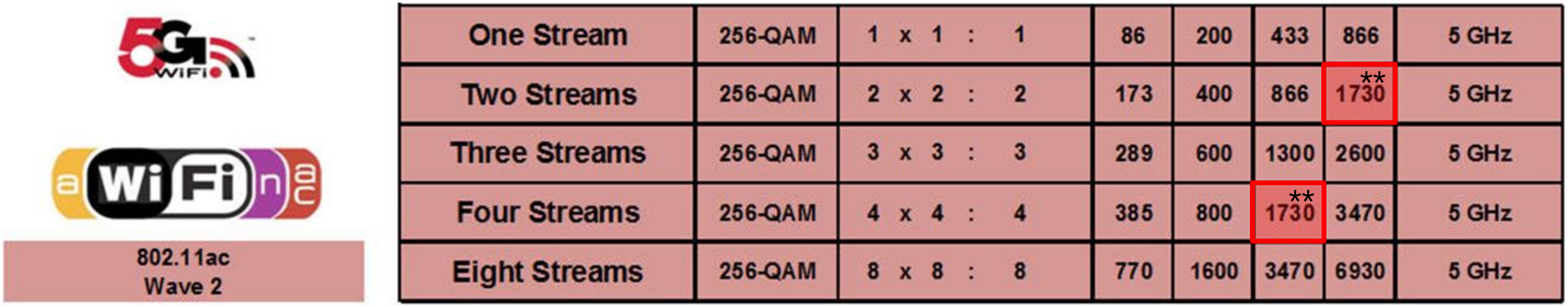
Number of Streams	Modulation	Antennas Tx x Rx : Spatial Streams	Maximum Rate (Mbps) 1 Ch.	2 Ch.	4 Ch.	8 Ch.	Band Support
One Stream*	64-QAM	1 x 1 : 1	72	150	n.a.	n.a.	2.4 & 5 GHz
Two Streams*	64-QAM	2 x 2 : 2	144	300*	n.a.	n.a.	2.4 & 5 GHz
Three Streams	64-QAM	3 x 3 : 3	216	450	n.a.	n.a.	2.4 & 5 GHz
Four Streams	64-QAM	4 x 4 : 4	288	600	n.a.	n.a.	2.4 & 5 GHz

* AirPcap Nx supports Legacy, HT20 or HT40 mode (no SGI & Greenfield mode)



802.11ac Wave 1

Number of Streams	Modulation	Antennas Tx x Rx : Spatial Streams	Maximum Rate (Mbps) 1 Ch.	2 Ch.	4 Ch.	8 Ch.	Band Support
One Stream	256-QAM	1 x 1 : 1	86	200	433	n.a.	5 GHz
Two Streams	256-QAM	2 x 2 : 2	173	400	866	n.a.	5 GHz
Three Streams	256-QAM	3 x 3 : 3	289	600	1300	n.a.	5 GHz



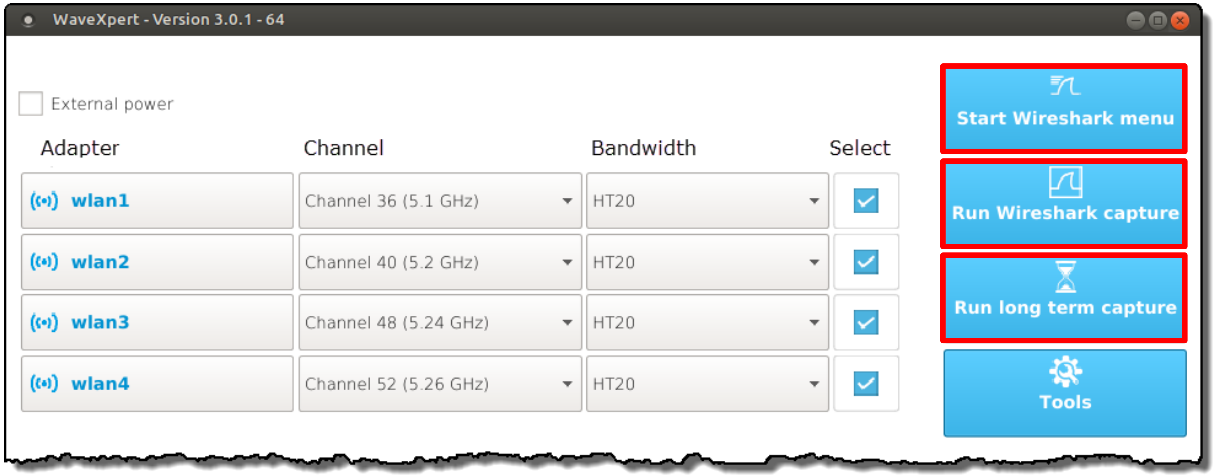
802.11ac Wave 2

Number of Streams	Modulation	Antennas Tx x Rx : Spatial Streams	Maximum Rate (Mbps) 1 Ch.	2 Ch.	4 Ch.	8 Ch.	Band Support
One Stream	256-QAM	1 x 1 : 1	86	200	433	866	5 GHz
Two Streams	256-QAM	2 x 2 : 2	173	400	866	1730**	5 GHz
Three Streams	256-QAM	3 x 3 : 3	289	600	1300	2600	5 GHz
Four Streams	256-QAM	4 x 4 : 4	385	800	1730**	3470	5 GHz
Eight Streams	256-QAM	8 x 8 : 8	770	1600	3470	6930	5 GHz

** Softing WaveXpert supports up to 8 channels per WLAN adapter

WLAN Layer 2 capturing with WaveXpert

WaveXpert configuration menu allows to select up to four adapters for capturing

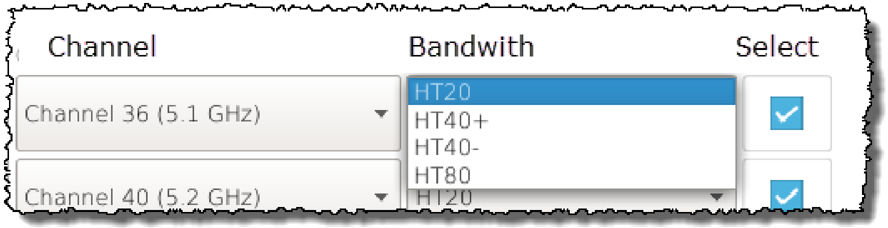


WaveXpert - Version 3.0.1 - 64

□ External power

Adapter	Channel	Bandwidth	Select
wlan1	Channel 36 (5.1 GHz)	HT20	☑
wlan2	Channel 40 (5.2 GHz)	HT20	☑
wlan3	Channel 48 (5.24 GHz)	HT20	☑
wlan4	Channel 52 (5.26 GHz)	HT20	☑

- Each adapter supports Bandwidth up to 80MHz (four 20MHz channels bonded)



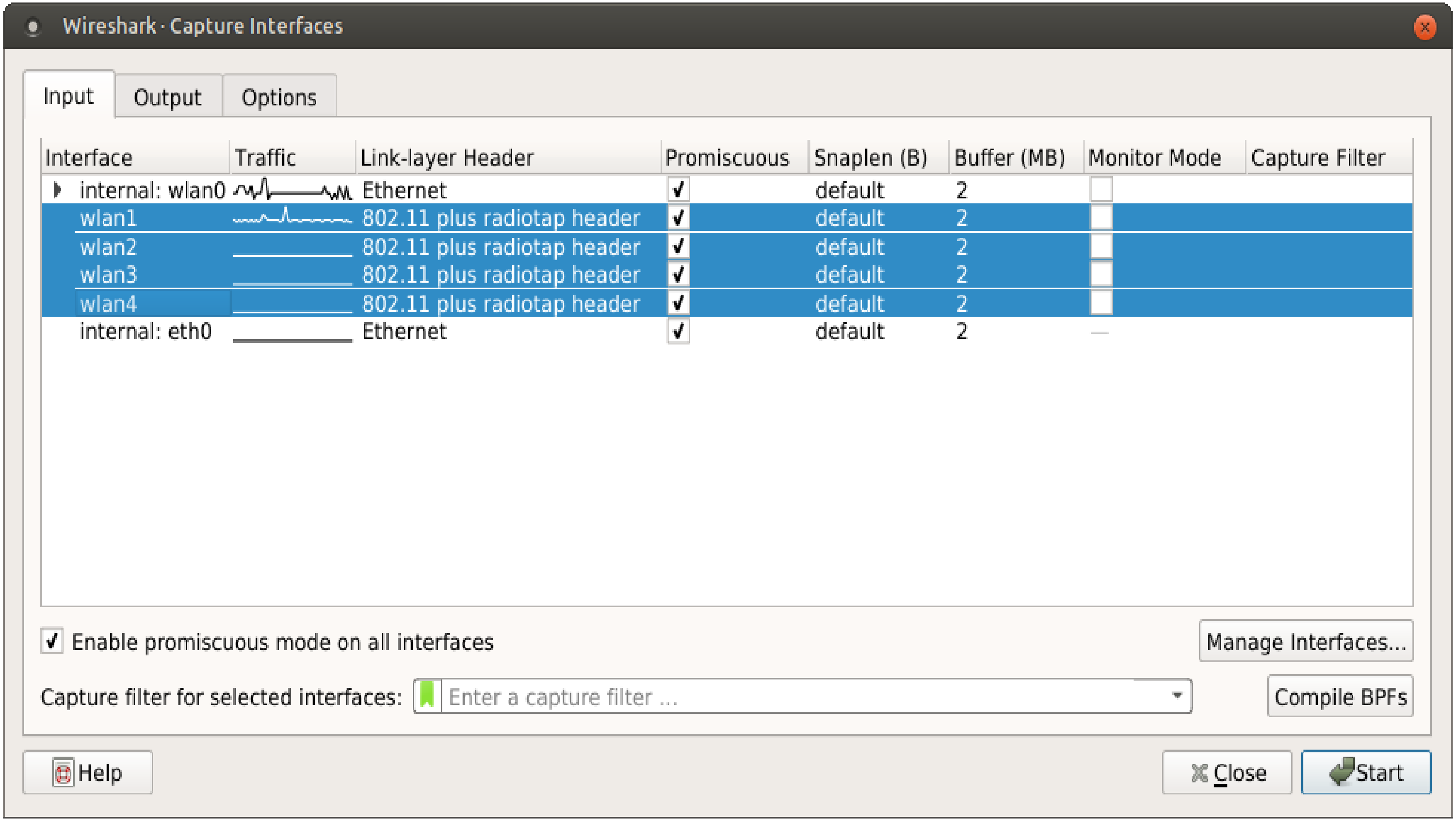
Channel	Bandwith	Select
Channel 36 (5.1 GHz)	HT20	☑
Channel 40 (5.2 GHz)	HT20	☑

- Long Term stores packets directly to files, without starting Wireshark
- Creates an individual pcapng file per WLAN adapter
- Creates a new file per adapter every 5 minutes
- Packet size (Snaplen) is set to 500 Bytes

+

WLAN Layer 2 capturing with WaveXpert

- The WaveXpert adapters and configurations will be imported to Wireshark for capturing



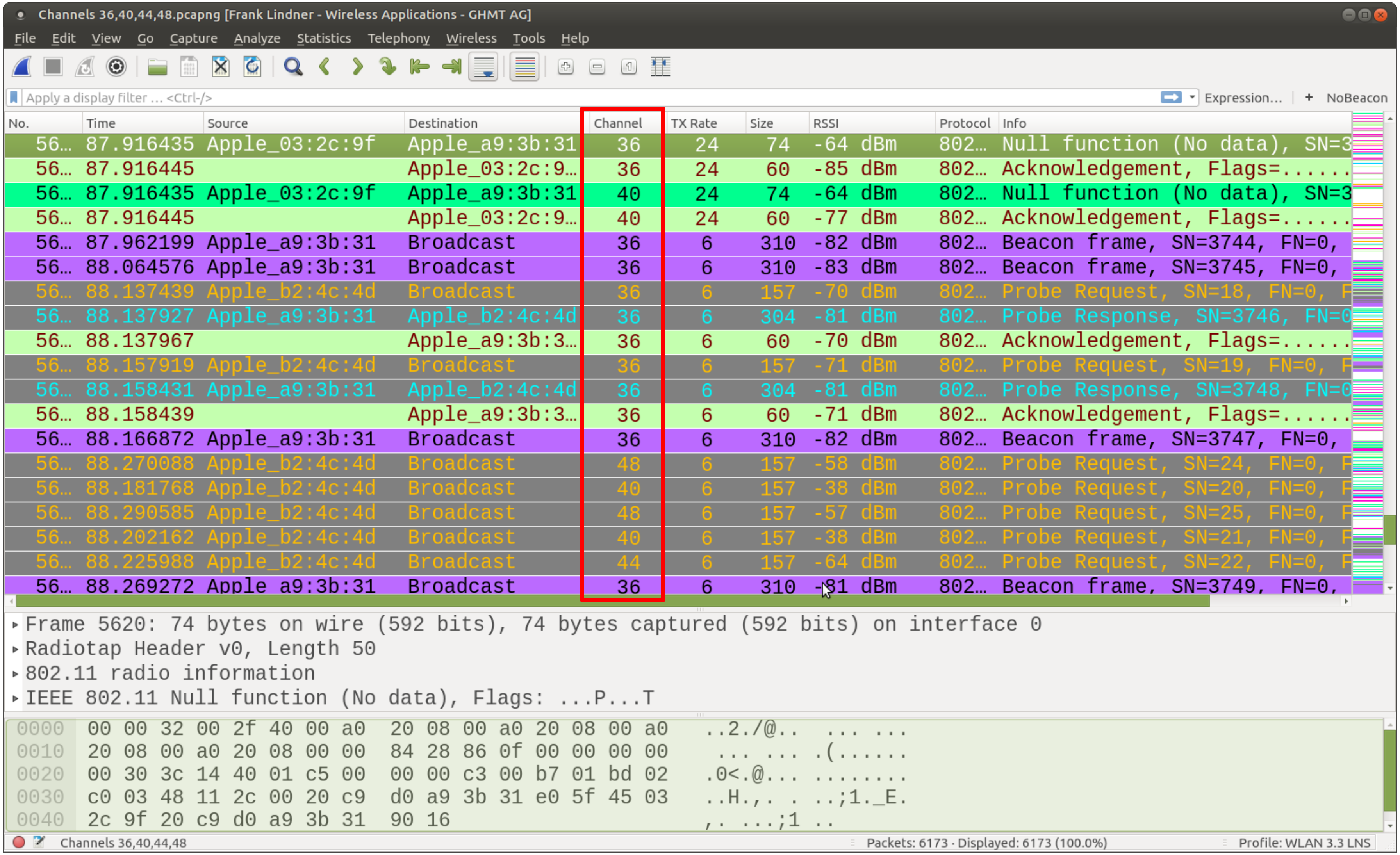
Wireshark · Capture Interfaces

Interface	Traffic	Link-layer Header	Promiscuous	Snaplen (B)	Buffer (MB)	Monitor Mode	Capture Filter
internal: wlan0		Ethernet	☑	default	2	□	
wlan1		802.11 plus radiotap header	☑	default	2	□	
wlan2		802.11 plus radiotap header	☑	default	2	□	
wlan3		802.11 plus radiotap header	☑	default	2	□	
wlan4		802.11 plus radiotap header	☑	default	2	□	
internal: eth0		Ethernet	☑	default	2	—	

☑ Enable promiscuous mode on all interfaces

Capture filter for selected interfaces: Enter a capture filter ...

WLAN Layer 2 capturing with WaveXpert


Channels 36,40,44,48.pcapng [Frank Lindner - Wireless Applications - GHMT AG]
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter … <Ctrl-/>
Expression…
+ NoBeacon
Channels 36,40,44,48
Packets: 6173 · Displayed: 6173 (100.0%)
Profile: WLAN 3.3 LNS

No.	Time	Source	Destination	Channel	TX Rate	Size	RSSI	Protocol	Info
56…	87.916435	Apple_03:2c:9f	Apple_a9:3b:31	36	24	74	-64 dBm	802…	Null function (No data), SN=3
56…	87.916445		Apple_03:2c:9…	36	24	60	-85 dBm	802…	Acknowledgement, Flags=......
56…	87.916435	Apple_03:2c:9f	Apple_a9:3b:31	40	24	74	-64 dBm	802…	Null function (No data), SN=3
56…	87.916445		Apple_03:2c:9…	40	24	60	-77 dBm	802…	Acknowledgement, Flags=......
56…	87.962199	Apple_a9:3b:31	Broadcast	36	6	310	-82 dBm	802…	Beacon frame, SN=3744, FN=0,
56…	88.064576	Apple_a9:3b:31	Broadcast	36	6	310	-83 dBm	802…	Beacon frame, SN=3745, FN=0,
56…	88.137439	Apple_b2:4c:4d	Broadcast	36	6	157	-70 dBm	802…	Probe Request, SN=18, FN=0, F
56…	88.137927	Apple_a9:3b:31	Apple_b2:4c:4d	36	6	304	-81 dBm	802…	Probe Response, SN=3746, FN=0
56…	88.137967		Apple_a9:3b:3…	36	6	60	-70 dBm	802…	Acknowledgement, Flags=......
56…	88.157919	Apple_b2:4c:4d	Broadcast	36	6	157	-71 dBm	802…	Probe Request, SN=19, FN=0, F
56…	88.158431	Apple_a9:3b:31	Apple_b2:4c:4d	36	6	304	-81 dBm	802…	Probe Response, SN=3748, FN=0
56…	88.158439		Apple_a9:3b:3…	36	6	60	-71 dBm	802…	Acknowledgement, Flags=......
56…	88.166872	Apple_a9:3b:31	Broadcast	36	6	310	-82 dBm	802…	Beacon frame, SN=3747, FN=0,
56…	88.270088	Apple_b2:4c:4d	Broadcast	48	6	157	-58 dBm	802…	Probe Request, SN=24, FN=0, F
56…	88.181768	Apple_b2:4c:4d	Broadcast	40	6	157	-38 dBm	802…	Probe Request, SN=20, FN=0, F
56…	88.290585	Apple_b2:4c:4d	Broadcast	48	6	157	-57 dBm	802…	Probe Request, SN=25, FN=0, F
56…	88.202162	Apple_b2:4c:4d	Broadcast	40	6	157	-38 dBm	802…	Probe Request, SN=21, FN=0, F
56…	88.225988	Apple_b2:4c:4d	Broadcast	44	6	157	-64 dBm	802…	Probe Request, SN=22, FN=0, F
56…	88.269272	Apple_a9:3b:31	Broadcast	36	6	310	-81 dBm	802…	Beacon frame, SN=3749, FN=0,

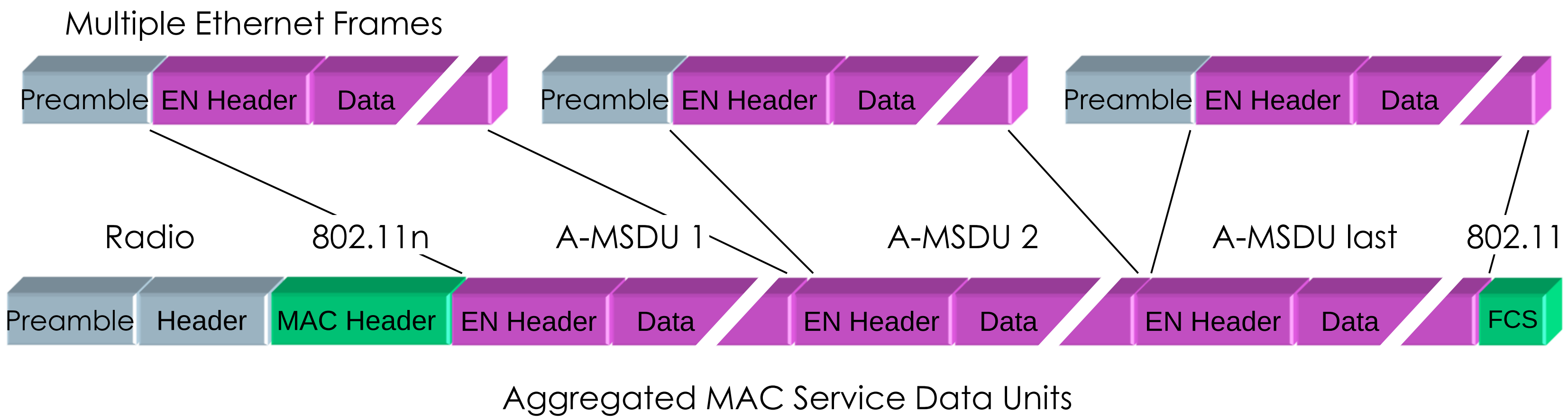
```
▸ Frame 5620: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0
▸ Radiotap Header v0, Length 50
▸ 802.11 radio information
▸ IEEE 802.11 Null function (No data), Flags: ...P...T
```

```
0000  00 00 32 00 2f 40 00 a0  20 08 00 a0 20 08 00 a0   ..2./@..  ... ...
0010  20 08 00 a0 20 08 00 00  84 28 86 0f 00 00 00 00    ... ... .(......
0020  00 30 3c 14 40 01 c5 00  00 00 c3 00 b7 01 bd 02   .0<.@... ........
0030  c0 03 48 11 2c 00 20 c9  d0 a9 3b 31 e0 5f 45 03   ..H.,. . ..;1._E.
0040  2c 9f 20 c9 d0 a9 3b 31  90 16                     ,. ...;1 ..
```

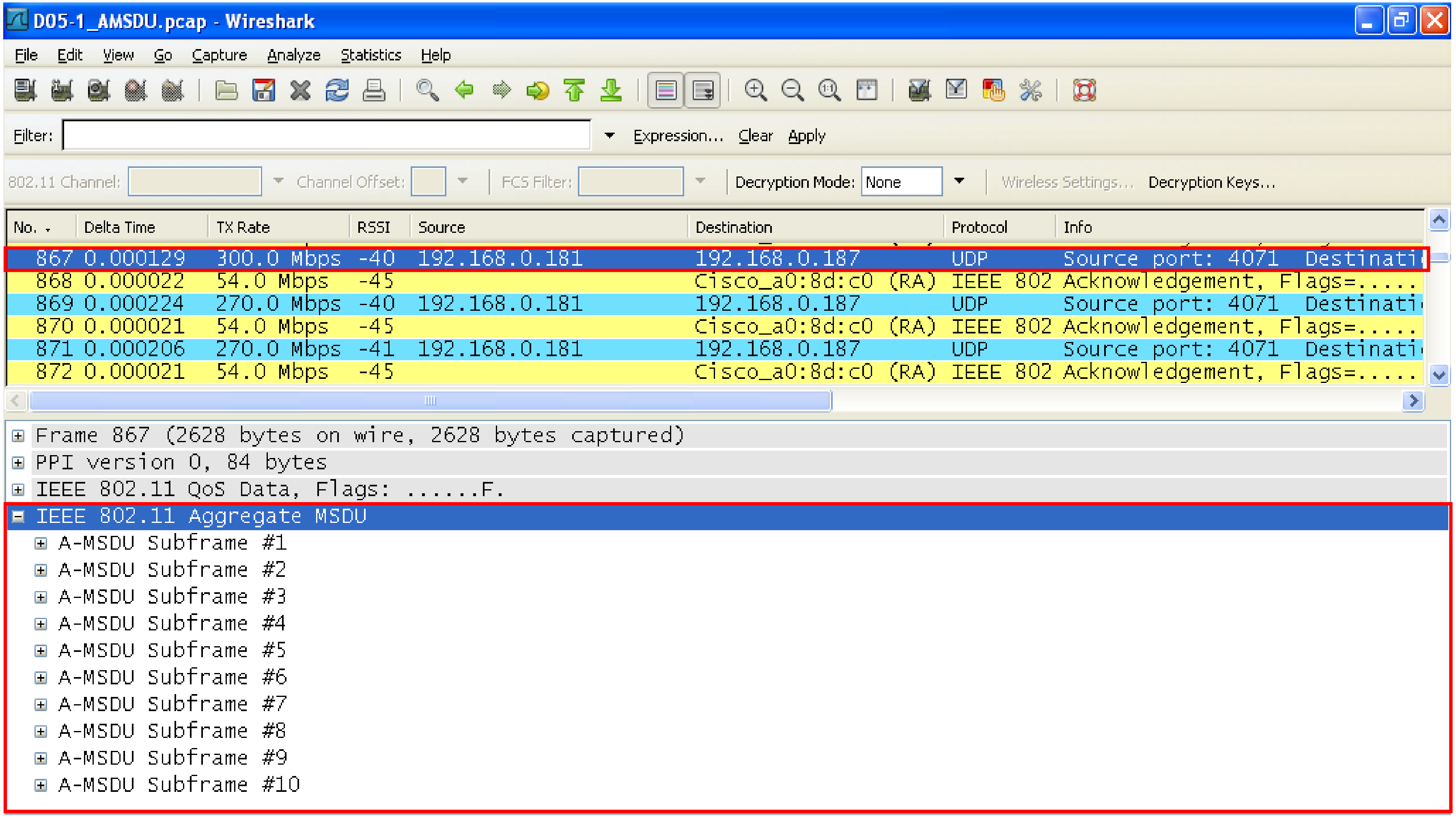
Simultaneous capturing in channels 36, 40, 44 & 48

802.11n/ac Frame Aggregation A-MSDU

- Aggregate-MAC Service Data Unit (A-MSDU) wraps multiple Ethernet frames into one 802.11 frame up to 8KB size
  - If frame has FCS error, the whole frame has to be retransmitted
  - Not suitable for noisy environment



802.11n/ac Frame Aggregation A-MSDU


D05-1_AMSDU.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter:
Expression... Clear Apply
802.11 Channel:
Channel Offset:
FCS Filter:
Wireless Settings...
Decryption Keys...

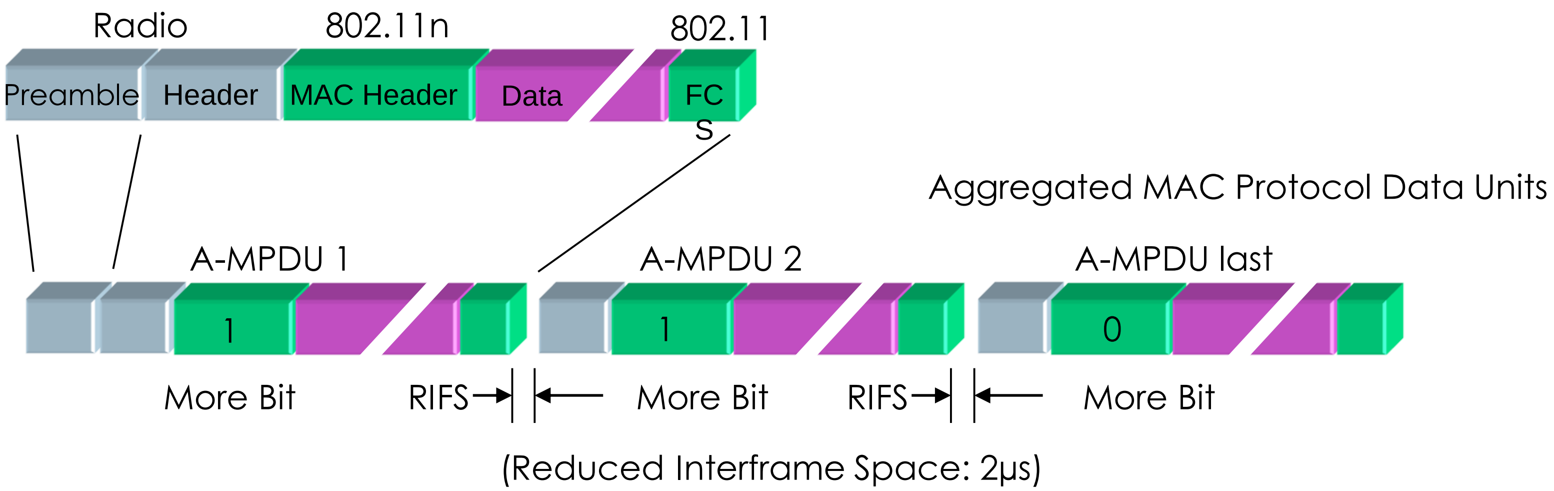
Decryption Mode: None

```
No.  Delta Time  TX Rate      RSSI  Source          Destination               Protocol  Info
 867 0.000129    300.0 Mbps   -40   192.168.0.181   192.168.0.187             UDP       Source port: 4071  Destinati
 868 0.000022    54.0 Mbps    -45                   Cisco_a0:8d:c0 (RA)       IEEE 802  Acknowledgement, Flags=.....
 869 0.000224    270.0 Mbps   -40   192.168.0.181   192.168.0.187             UDP       Source port: 4071  Destinati
 870 0.000021    54.0 Mbps    -45                   Cisco_a0:8d:c0 (RA)       IEEE 802  Acknowledgement, Flags=.....
 871 0.000206    270.0 Mbps   -41   192.168.0.181   192.168.0.187             UDP       Source port: 4071  Destinati
 872 0.000021    54.0 Mbps    -45                   Cisco_a0:8d:c0 (RA)       IEEE 802  Acknowledgement, Flags=.....
```

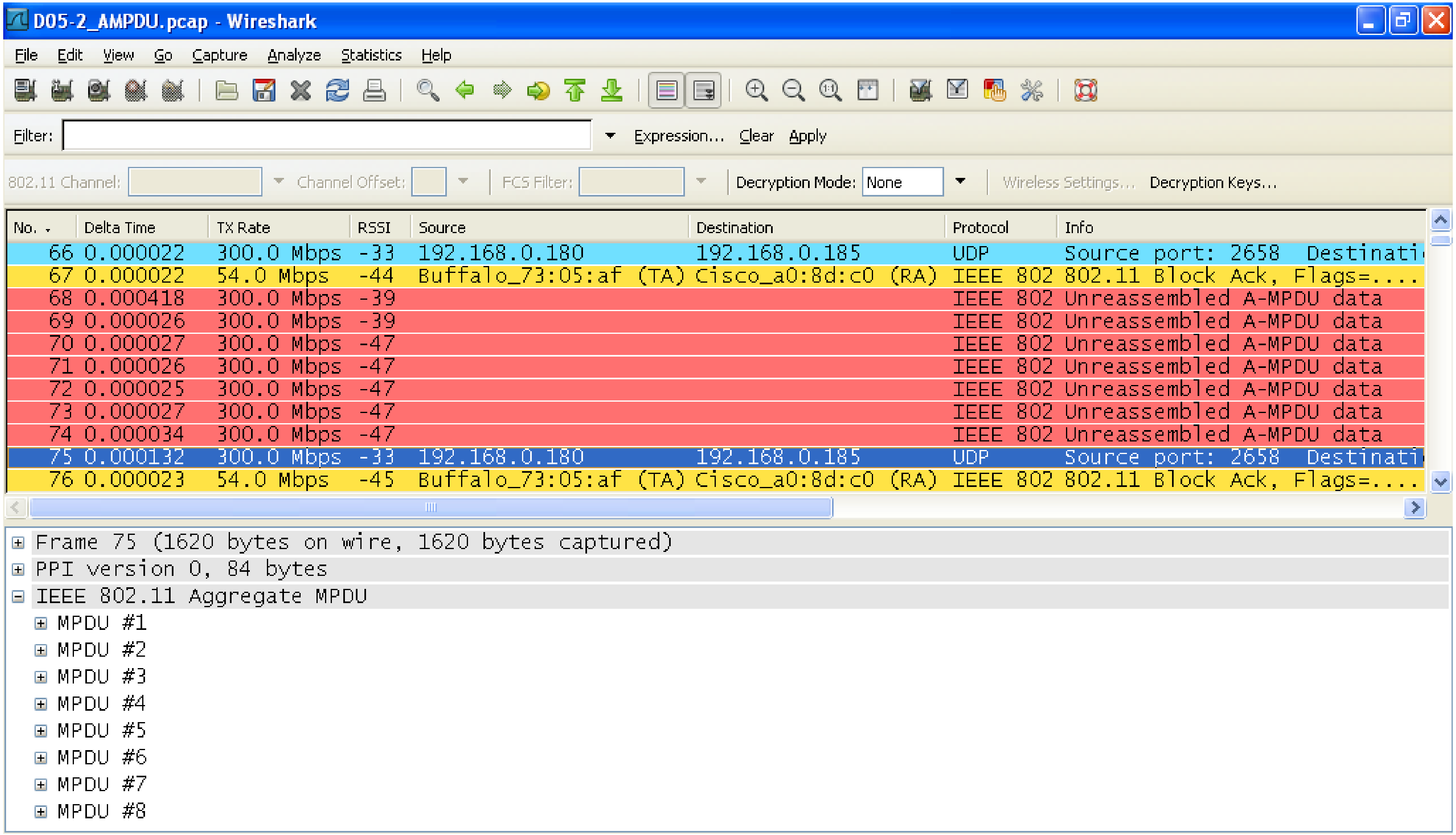
```
⊞ Frame 867 (2628 bytes on wire, 2628 bytes captured)
⊞ PPI version 0, 84 bytes
⊞ IEEE 802.11 QoS Data, Flags: ......F.
⊟ IEEE 802.11 Aggregate MSDU
    ⊞ A-MSDU Subframe #1
    ⊞ A-MSDU Subframe #2
    ⊞ A-MSDU Subframe #3
    ⊞ A-MSDU Subframe #4
    ⊞ A-MSDU Subframe #5
    ⊞ A-MSDU Subframe #6
    ⊞ A-MSDU Subframe #7
    ⊞ A-MSDU Subframe #8
    ⊞ A-MSDU Subframe #9
    ⊞ A-MSDU Subframe #10
```

802.11n/ac Frame Aggregation A-MPDU

- Aggregate-MAC Protocol Data Unit (A-MPDU) allows bursting up to 64 802.11 frames
  - Reduced Interframe Space keeps receiver synchronized
  - New Block ACK allows to confirm up to 64 frames individually
  - Only bad frames need to be retransmitted



802.11n/ac Frame Aggregation A-MPDU

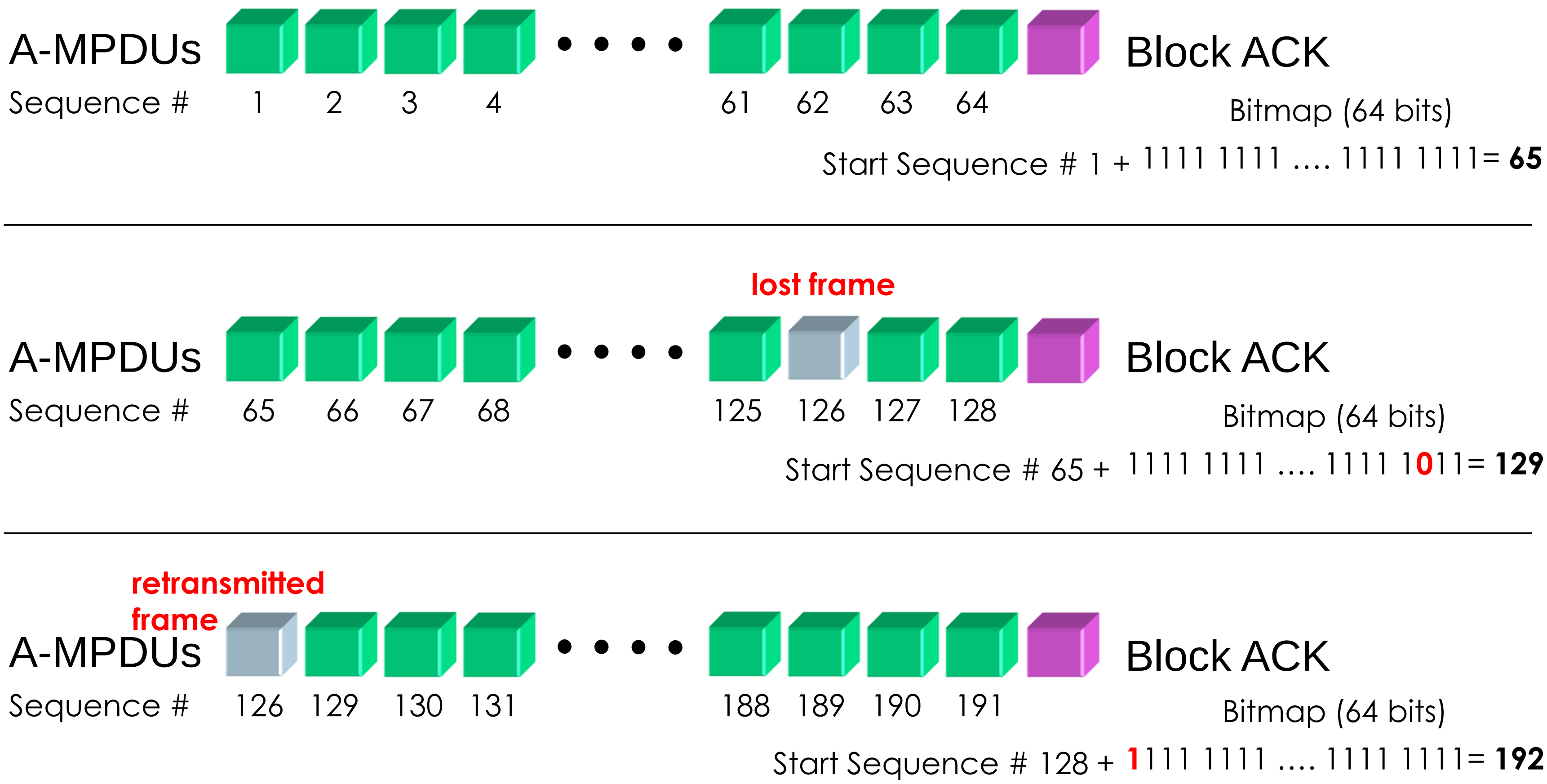


Decryption Mode: None

```
No.  Delta Time  TX Rate     RSSI  Source                  Destination             Protocol   Info
 66 0.000022    300.0 Mbps  -33   192.168.0.180           192.168.0.185           UDP        Source port: 2658  Destinati
 67 0.000022    54.0 Mbps   -44   Buffalo_73:05:af (TA)   Cisco_a0:8d:c0 (RA)     IEEE 802   802.11 Block Ack, Flags=....
 68 0.000418    300.0 Mbps  -39                                                   IEEE 802   Unreassembled A-MPDU data
 69 0.000026    300.0 Mbps  -39                                                   IEEE 802   Unreassembled A-MPDU data
 70 0.000027    300.0 Mbps  -47                                                   IEEE 802   Unreassembled A-MPDU data
 71 0.000026    300.0 Mbps  -47                                                   IEEE 802   Unreassembled A-MPDU data
 72 0.000025    300.0 Mbps  -47                                                   IEEE 802   Unreassembled A-MPDU data
 73 0.000027    300.0 Mbps  -47                                                   IEEE 802   Unreassembled A-MPDU data
 74 0.000034    300.0 Mbps  -47                                                   IEEE 802   Unreassembled A-MPDU data
 75 0.000132    300.0 Mbps  -33   192.168.0.180           192.168.0.185           UDP        Source port: 2658  Destinati
 76 0.000023    54.0 Mbps   -45   Buffalo_73:05:af (TA)   Cisco_a0:8d:c0 (RA)     IEEE 802   802.11 Block Ack, Flags=....
```

```
⊞ Frame 75 (1620 bytes on wire, 1620 bytes captured)
⊞ PPI version 0, 84 bytes
⊟ IEEE 802.11 Aggregate MPDU
    ⊞ MPDU #1
    ⊞ MPDU #2
    ⊞ MPDU #3
    ⊞ MPDU #4
    ⊞ MPDU #5
    ⊞ MPDU #6
    ⊞ MPDU #7
    ⊞ MPDU #8
```

802.11n/ac Frame Aggregation A-MPDU Block-Ack



A-MPDUs • • • • Block ACK

Sequence # 1 2 3 4 61 62 63 64

Bitmap (64 bits)

Start Sequence # 1 + 1111 1111 .... 1111 1111= **65**

lost frame

A-MPDUs • • • • Block ACK

Sequence # 65 66 67 68 125 126 127 128

Bitmap (64 bits)

Start Sequence # 65 + 1111 1111 .... 1111 1011= **129**

retransmitted frame

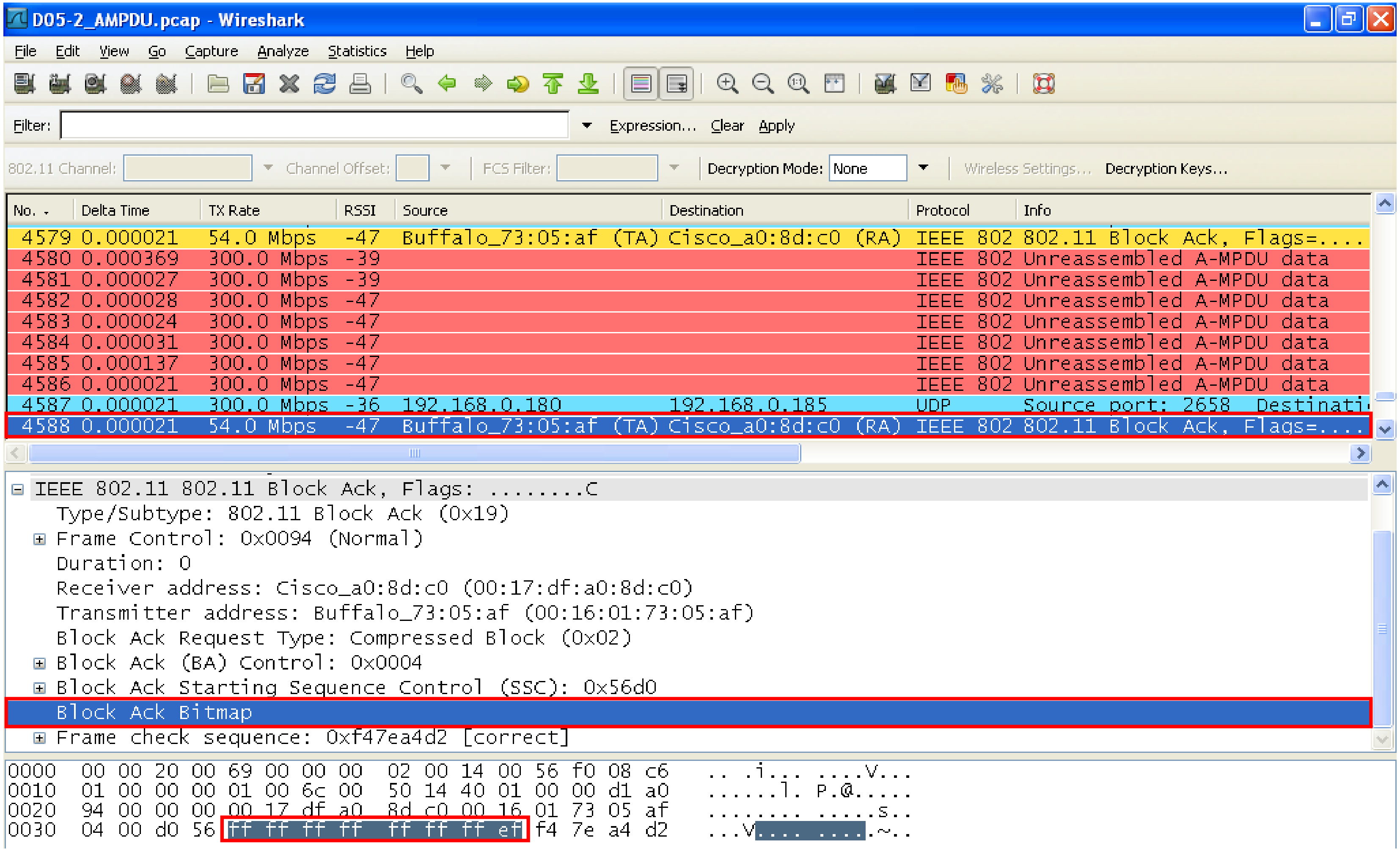
A-MPDUs • • • • Block ACK

Sequence # 126 129 130 131 188 189 190 191

Bitmap (64 bits)

Start Sequence # 128 + 1111 1111 .... 1111 1111= **192**

802.11n/ac Frame Aggregation A-MPDU Block-Ack


D05-2_AMPDU.pcap - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter:
Expression... Clear Apply
802.11 Channel:
Channel Offset:
FCS Filter:
Decryption Mode:
Wireless Settings...
Decryption Keys...

Decryption Mode: None

```
No. .  Delta Time  TX Rate      RSSI  Source                  Destination              Protocol  Info
4579 0.000021  54.0 Mbps    -47  Buffalo_73:05:af (TA) Cisco_a0:8d:c0 (RA) IEEE 802 802.11 Block Ack, Flags=....
4580 0.000369  300.0 Mbps -39                                              IEEE 802 Unreassembled A-MPDU data
4581 0.000027  300.0 Mbps -39                                              IEEE 802 Unreassembled A-MPDU data
4582 0.000028  300.0 Mbps -47                                              IEEE 802 Unreassembled A-MPDU data
4583 0.000024  300.0 Mbps -47                                              IEEE 802 Unreassembled A-MPDU data
4584 0.000031  300.0 Mbps -47                                              IEEE 802 Unreassembled A-MPDU data
4585 0.000137  300.0 Mbps -47                                              IEEE 802 Unreassembled A-MPDU data
4586 0.000021  300.0 Mbps -47                                              IEEE 802 Unreassembled A-MPDU data
4587 0.000021  300.0 Mbps -36  192.168.0.180         192.168.0.185         UDP      Source port: 2658  Destinati
4588 0.000021  54.0 Mbps    -47  Buffalo_73:05:af (TA) Cisco_a0:8d:c0 (RA) IEEE 802 802.11 Block Ack, Flags=....
```

```
⊟ IEEE 802.11 802.11 Block Ack, Flags: ........C
    Type/Subtype: 802.11 Block Ack (0x19)
  ⊞ Frame Control: 0x0094 (Normal)
    Duration: 0
    Receiver address: Cisco_a0:8d:c0 (00:17:df:a0:8d:c0)
    Transmitter address: Buffalo_73:05:af (00:16:01:73:05:af)
    Block Ack Request Type: Compressed Block (0x02)
  ⊞ Block Ack (BA) Control: 0x0004
  ⊞ Block Ack Starting Sequence Control (SSC): 0x56d0
    Block Ack Bitmap
  ⊞ Frame check sequence: 0xf47ea4d2 [correct]
```

```
0000  00 00 20 00 69 00 00 00  02 00 14 00 56 f0 08 c6   .. .i... ....V...
0010  01 00 00 00 01 00 6c 00  50 14 40 01 00 00 d1 a0   ......l. P.@.....
0020  94 00 00 00 00 17 df a0  8d c0 00 16 01 73 05 af   ........ .....s..
0030  04 00 d0 56 ff ff ff ff  ff ff ff ef f4 7e a4 d2   ...V.... .....~..
```

Hope you learned something useful!

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