SharkFest '17 Europe

Troubleshooting 802.11 with monitoring mode Finding Patterns in your pcaps

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#sf17eu

Freelance Network & Security Troubleshooter | iwaxx Sàrl

About

- Freelance Network & Security troubleshooter
- Professional services in Switzerland
- Wireshark trainer
  - Practical hands-on onsite trainings
  - Custom needs: proprietary protocols, Lua dissection, malware analysis
- Creator of Debookee, a macOS network analyzer
  - Includes Wireshark & Lua scripts
  - Wi-Fi Monitoring module

Wi-Fi Monitoring ≠ Promiscuous mode

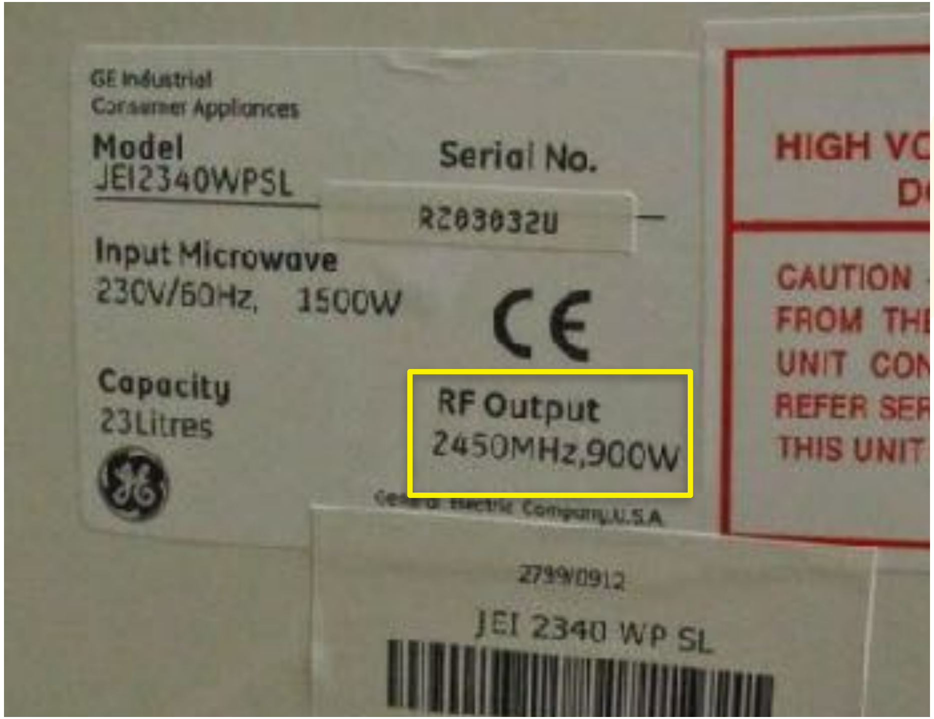
Demo!

(Yes on slide 4!)

Practical theory of 802.11

- Characteristics of a Wi-Fi connection
  - TX Signal Power (emitted by the AP)
    - From 1dBm (1 mW) to 20 dBm (100 mW)
  - RX Signal Power (received by the Client)
    - -30 dBm (0.001 mW) - Client is touching the AP (signal divided by 100’000 directly when going out the AP)
    - -50 dBm (10 nW) - Excellent
    - -60 dBm (1 nW) - Good
    - -70 dBm (100 pW) - Time to roam
    - -80 dBm (10 pW) - Time to cable?
    - -90 dBm (1 pW - 1 billion of mW) - Common noise

- Let's buy a Microwave Oven



GE Industrial
Consumer Appliances

Model
JEI2340WPSL

Serial No.
RZ03032U

Input Microwave
230V/60Hz, 1500W

CE

Capacity
23Litres

RF Output
2450MHz,900W

General Electric Company,U.S.A

2799/0912

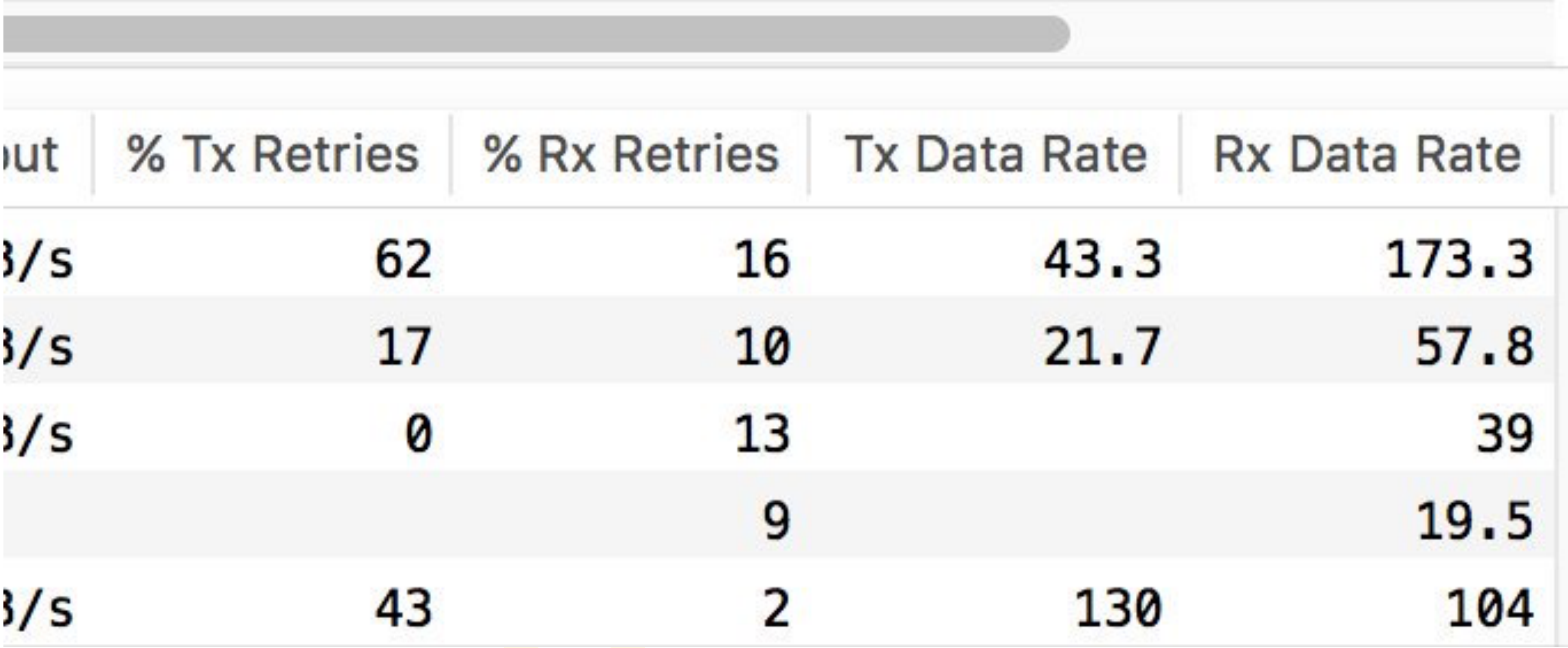
JEI 2340 WP SL

HIGH VO
D

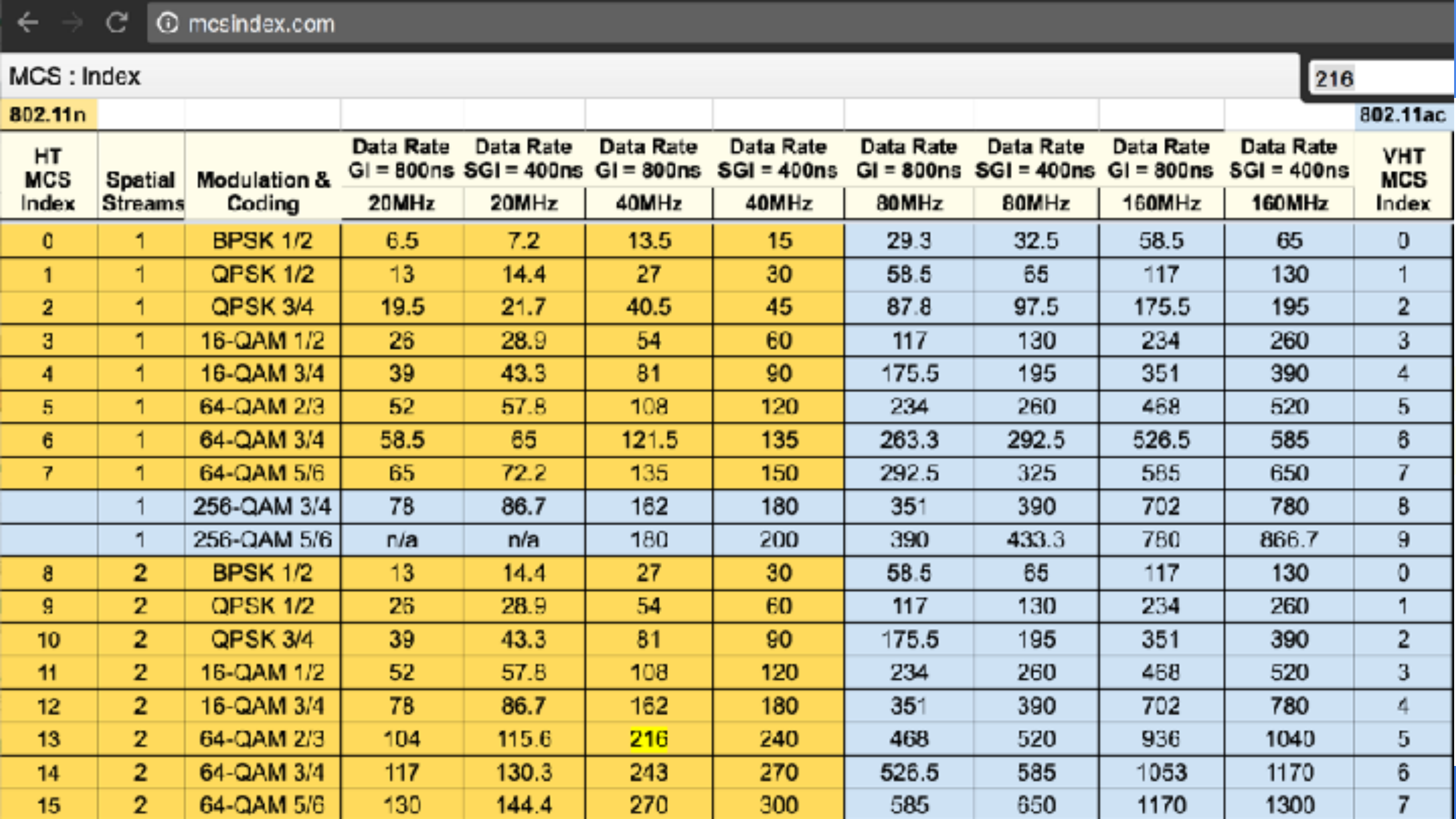
CAUTION
FROM THE
UNIT CON
REFER SER
THIS UNIT

Let's compare
0.9kg and 1ng

- Speed is the correlation of:
  - Channel width (20, 40, 80, 160 MHz)
  - Number of streams (1-3, coming 4 they say in blogs/coffee machine)
  - Guard Interval (Short or Long - Time interval between each frames)
  - Modulation or MCS index
- Speed is set **per packet**, not once per connection
- Speed is asymmetric: Tx / Rx speed?
- Your best friend: http://mcsindex.com



ut	% Tx Retries	% Rx Retries	Tx Data Rate	Rx Data Rate
B/s	62	16	43.3	173.3
B/s	17	10	21.7	57.8
B/s	0	13		39
		9		19.5
B/s	43	2	130	104



MCS : Index

216

802.11n												802.11ac
HT MCS Index	Spatial Streams	Modulation & Coding	Data Rate GI = 800ns	Data Rate SGI = 400ns	Data Rate GI = 800ns	Data Rate SGI = 400ns	Data Rate GI = 800ns	Data Rate SGI = 400ns	Data Rate GI = 800ns	Data Rate SGI = 400ns	VHT MCS Index
			20MHz	20MHz	40MHz	40MHz	80MHz	80MHz	160MHz	160MHz	
0	1	BPSK 1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65	0
1	1	QPSK 1/2	13	14.4	27	30	58.5	65	117	130	1
2	1	QPSK 3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195	2
3	1	16-QAM 1/2	26	28.9	54	60	117	130	234	260	3
4	1	16-QAM 3/4	39	43.3	81	90	175.5	195	351	390	4
5	1	64-QAM 2/3	52	57.8	108	120	234	260	468	520	5
6	1	64-QAM 3/4	58.5	65	121.5	135	263.3	292.5	526.5	585	6
7	1	64-QAM 5/6	65	72.2	135	150	292.5	325	585	650	7
	1	256-QAM 3/4	78	86.7	162	180	351	390	702	780	8
	1	256-QAM 5/6	n/a	n/a	180	200	390	433.3	780	866.7	9
8	2	BPSK 1/2	13	14.4	27	30	58.5	65	117	130	0
9	2	QPSK 1/2	26	28.9	54	60	117	130	234	260	1
10	2	QPSK 3/4	39	43.3	81	90	175.5	195	351	390	2
11	2	16-QAM 1/2	52	57.8	108	120	234	260	468	520	3
12	2	16-QAM 3/4	78	86.7	162	180	351	390	702	780	4
13	2	64-QAM 2/3	104	115.6	216	240	468	520	936	1040	5
14	2	64-QAM 3/4	117	130.3	243	270	526.5	585	1053	1170	6
15	2	64-QAM 5/6	130	144.4	270	300	585	650	1170	1300	7

The forgotten theory:
The talkie-walkie (or CSMA/CA)

Common to 802.11b/g/a/na/ng/ac/ac_wave_2

- What does a device do before sending a packet?
  - Listen in the air for energy / ED (Energy Detection)
    - Is a microwave oven currently speaking?
    - Am I hearing bad CRC frames as noise?
  - Listen in the air for 802.11 frames / CS (Carrier Sense)
    - Save the NAV timer of heard packet (indicate when media will be freed)
  - When free, calculate a random number and wait while decreasing it
  - If media busy meanwhile, put random timer on hold
  - When random timer ends, if clear, send packet(s)
  - Wait for ACK, else resend packet with wlan.fc.retry = 1

The most important WLAN processes

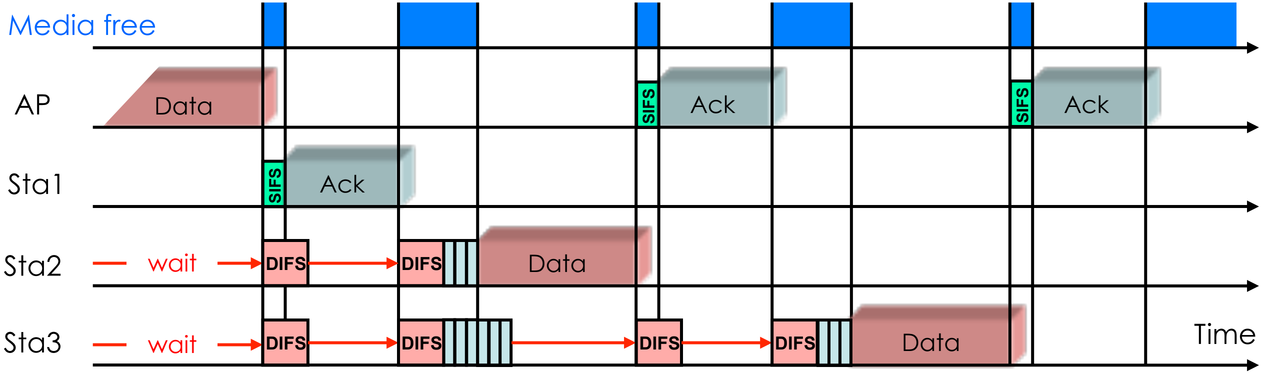
Access Control with CSMA/CA

CSMA/CA offers different Inter Frame Spaces (IFS) to control media access:

SIFS (Short Inter Frame Space) 802.11b/g = 10 µs 802.11a = 16 µs

DIFS (DCF Inter Frame Space) (2x Slot time + SIFS) 802.11b=50µs 802.11g=28µs 802.11a=34µs

Slot Time 802.11b = 20 µs (max. 31x) **Short Slot Time** 802.11a/g = 9 µs (max. 15x)



- Stations can send anytime if media is free, but hold back if media is busy.
- If air becomes free, stations are waiting DIFS and a random number of Slot Times before sending
- Receiving stations verify Frame Check Sequence and if OK are sending ACK after SIFS

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Forget Throughput - Think Airtime

- I have 802.11ac Wave 2 MU-MIMO 1.3Gbps but ...

In the wireless world:

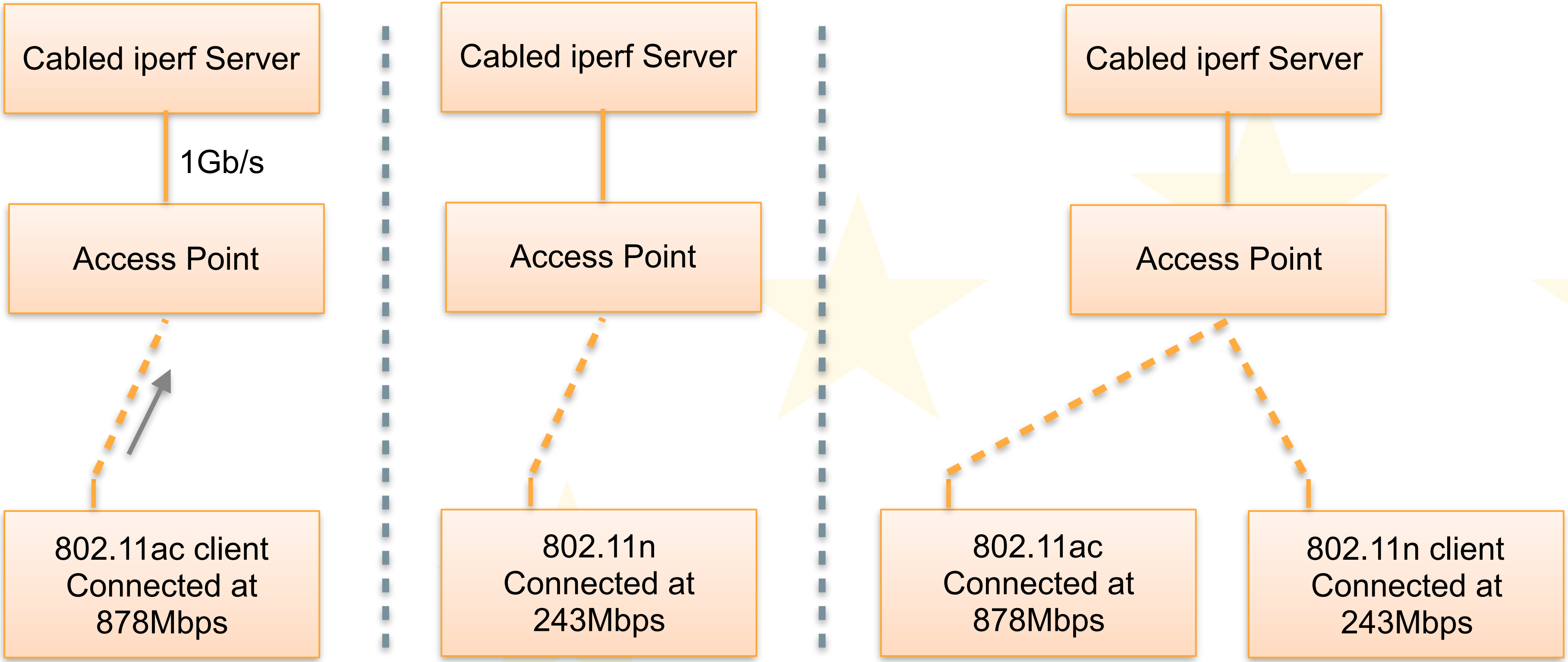
- A fast client must wait before speaking
- A fast client must stop speaking when it hears some "energy"
- A fast client must repeat if he wasn't understood (ACKed)

- Also think Airtime/2 if 1xAP and all wireless clients
  - Transmitter -> AP
  - AP -> Receiver

Your turn to be AP & Wi-Fi clients!

#Lab
iperf - Let see slowness in the air

3 scenarios - Alone on channel 100



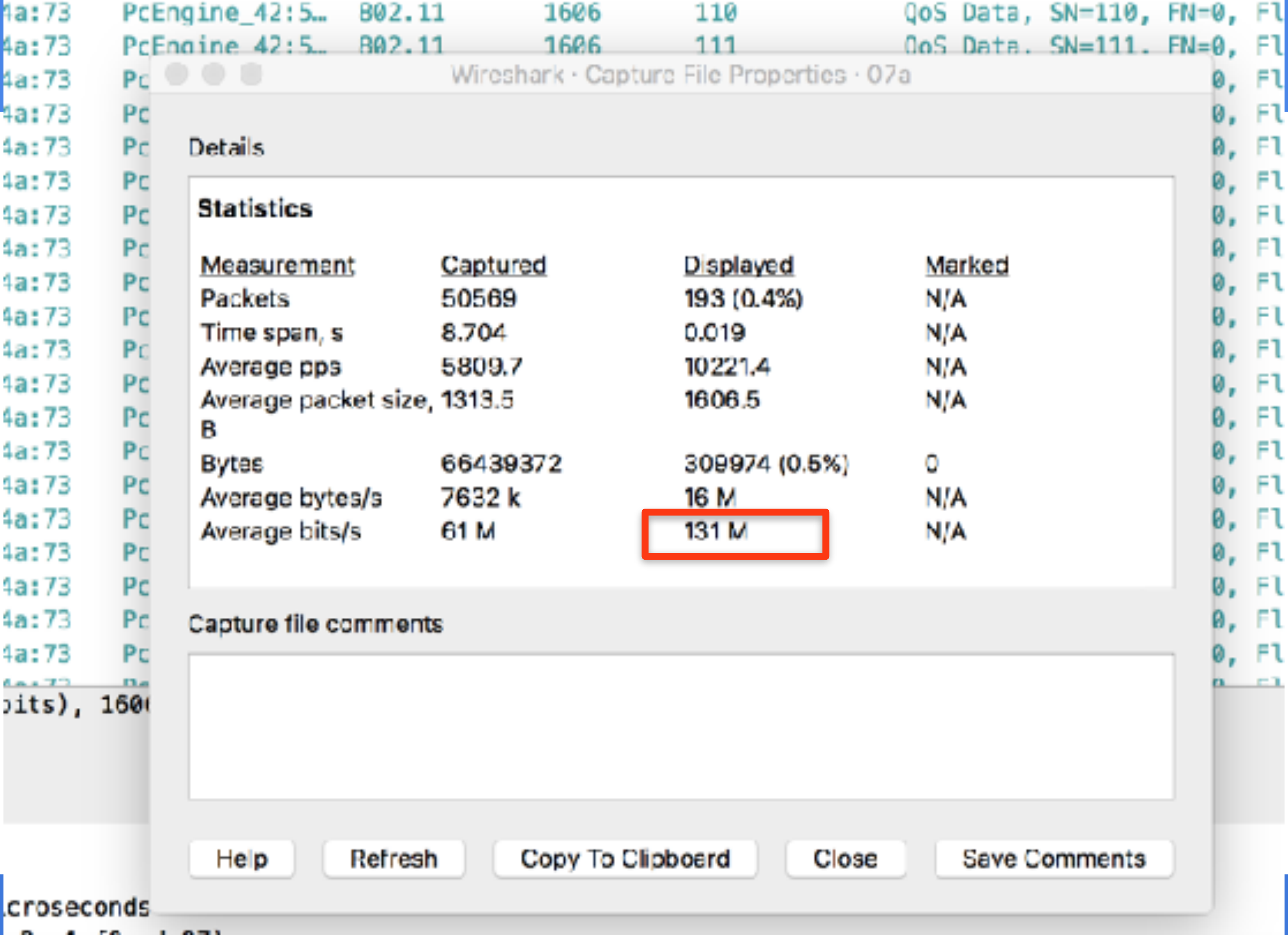
Cabled iperf Server
1Gb/s
Access Point
802.11ac client Connected at 878Mbps
Cabled iperf Server
Access Point
802.11n Connected at 243Mbps
Cabled iperf Server
Access Point
802.11ac Connected at 878Mbps
802.11n client Connected at 243Mbps

Upload: **536Mb/s**

145Mb/s

215Mb/s

90Mb/s



```
4a:73    PcEngine_42:5…  802.11    1606    110    QoS Data, SN=110, FN=0, Fl
4a:73    PcEngine_42:5…  802.11    1606    111    QoS Data, SN=111, FN=0, Fl
```

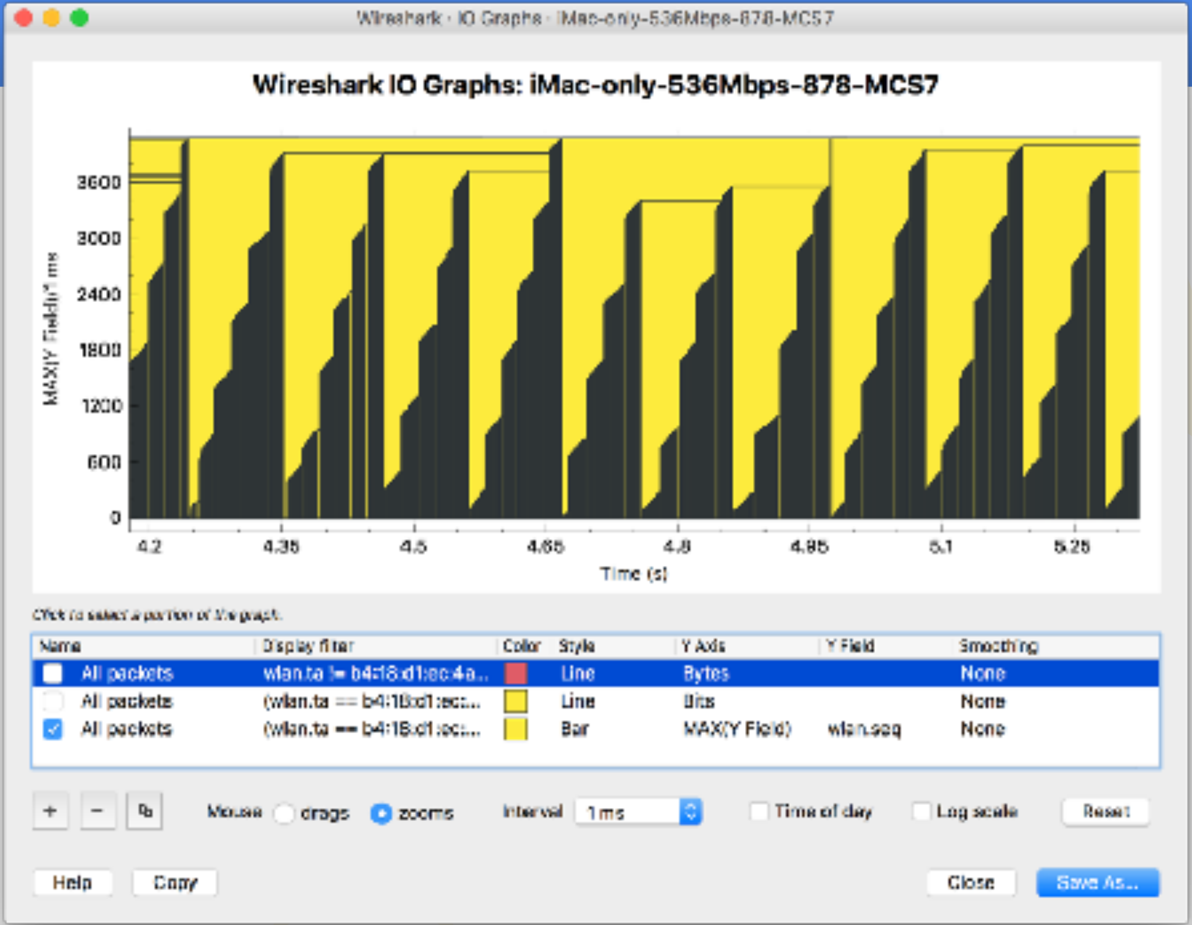
Wireshark · Capture File Properties · 07a

Details

Statistics

Measurement	Captured	Displayed	Marked
Packets	50569	193 (0.4%)	N/A
Time span, s	8.704	0.019	N/A
Average pps	5809.7	10221.4	N/A
Average packet size, B	1313.5	1606.5	N/A
Bytes	66439372	309974 (0.5%)	0
Average bytes/s	7632 k	16 M	N/A
Average bits/s	61 M	131 M	N/A

Capture file comments



Wireshark · IO Graphs · iMac-only-536Mbps-878-MCS7

Wireshark IO Graphs: iMac-only-536Mbps-878-MCS7

Click to select a portion of the graph.

	Name	Display filter	Color	Style	Y Axis	Y Field	Smoothing
□	All packets	wlan.ta != b4:18:d1:ec:4a...	🟥	Line	Bytes		None
□	All packets	(wlan.ta == b4:18:d1:ec:...	🟨	Line	Bits		None
☑	All packets	(wlan.ta == b4:18:d1:ec:...	🟨	Bar	MAX(Y Field)	wlan.seq	None

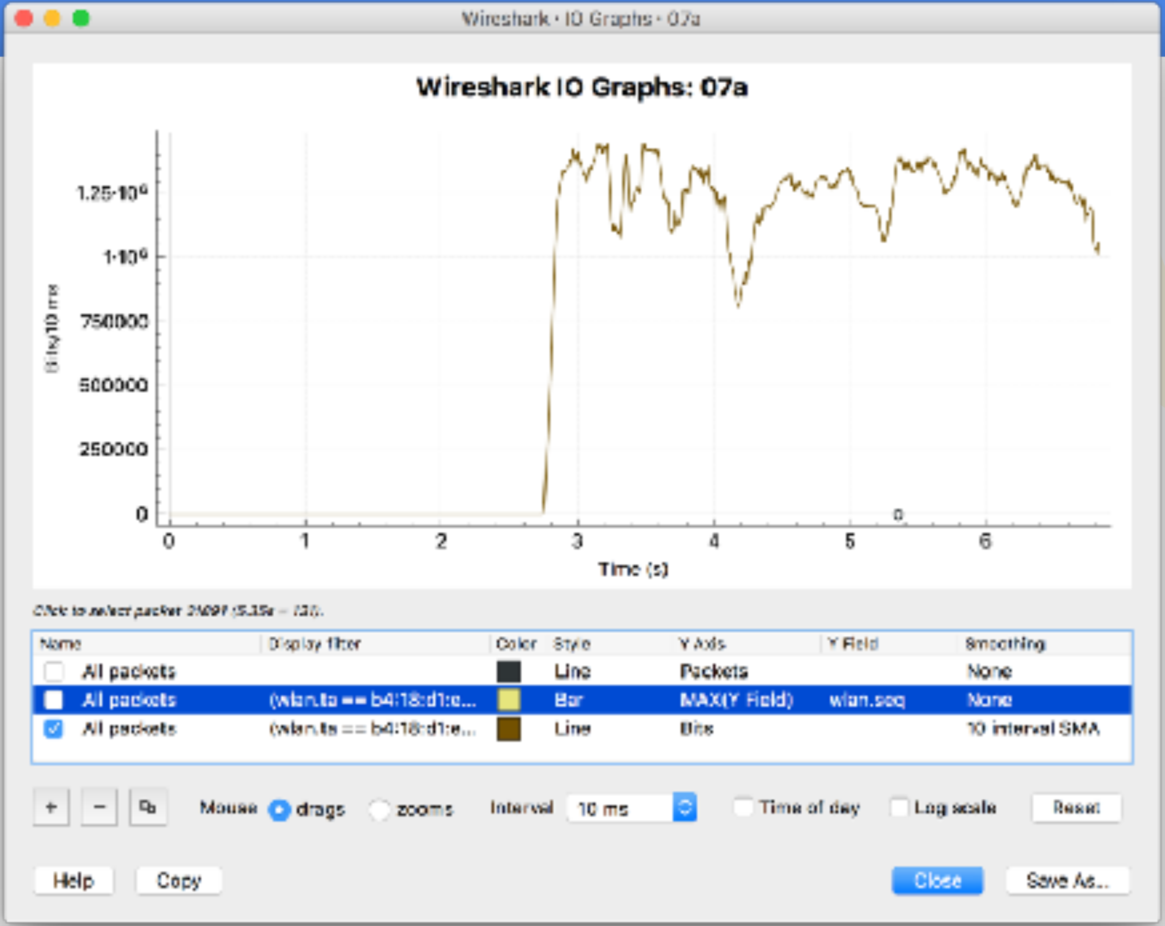
Mouse ○ drags ● zooms

Interval 1 ms

□ Time of day □ Log scale

- True fact: capture is dropping packet
  - We see gaps in sequence number every 18-20ms
  - Internal buffer of the laptop drops packet to reach a max of 172Mbps
  - Should increase buffer? (default 2M, to be tested)
  - Most of time, only need Mgt/Ctrl frames, not Data

(wlan.ta == b4:18:d1:ec:4a:73 && wlan.fc.type == 2) && (wlan.da == 00:0d:b9:42:57:a0)



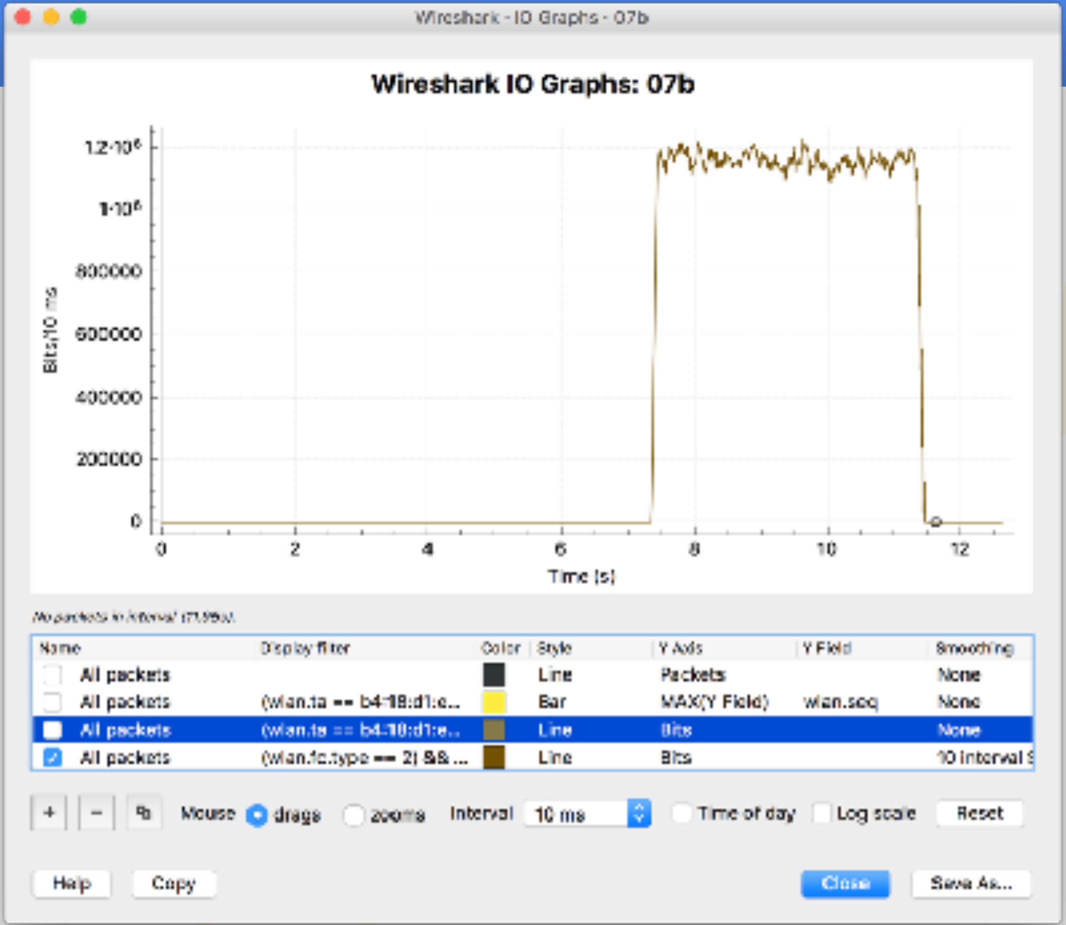
Click to select packet 24097 (5.35s – 131).

Name	Display filter	Color	Style	Y Axis	Y Field	Smoothing
□ All packets		■	Line	Packets		None
□ All packets	(wlan.ta == b4:18:d1:e...	■	Bar	MAX(Y Field)	wlan.seq	None
☑ All packets	(wlan.ta == b4:18:d1:e...	■	Line	Bits		10 interval SMA

Mouse ● drags ○ zooms Interval 10 ms □ Time of day □ Log scale

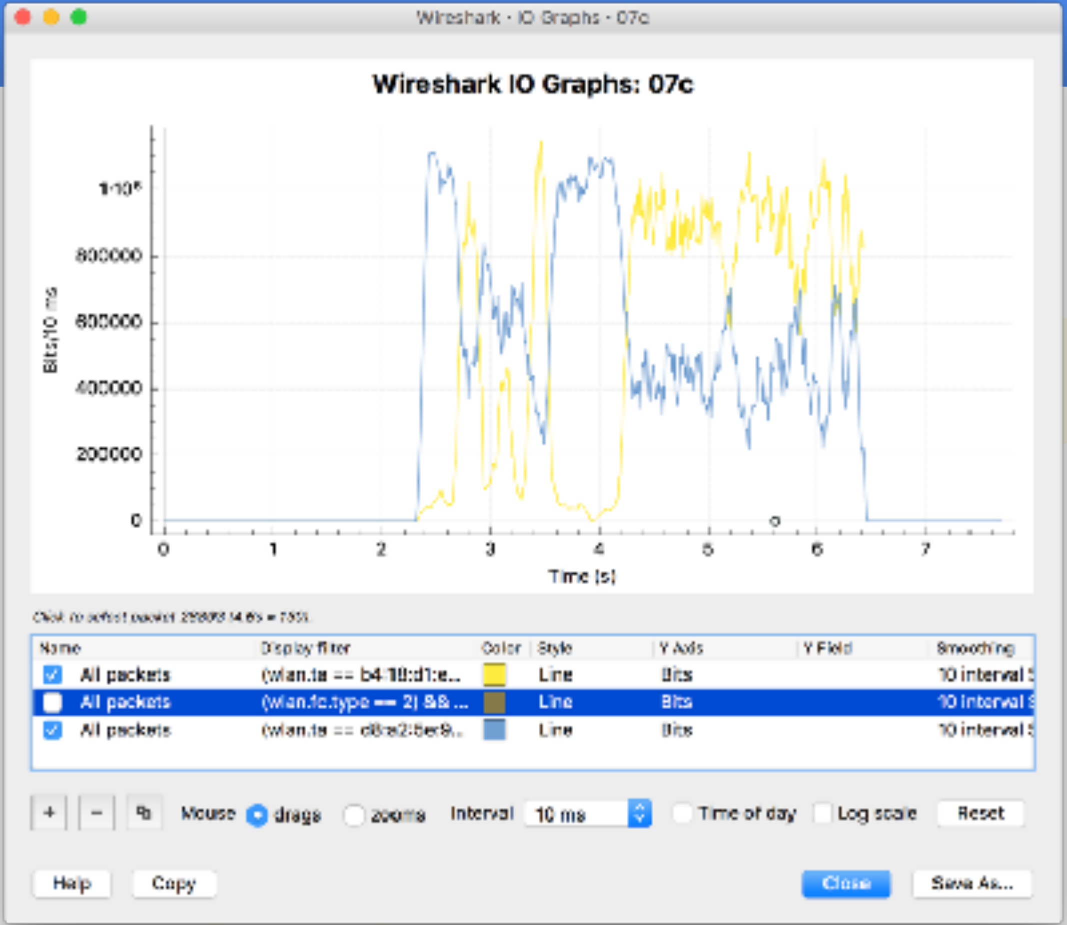
536Mb/s
Retries: 1%

145Mb/s
Retries: 1.6%



No packets in interval (11.99s).

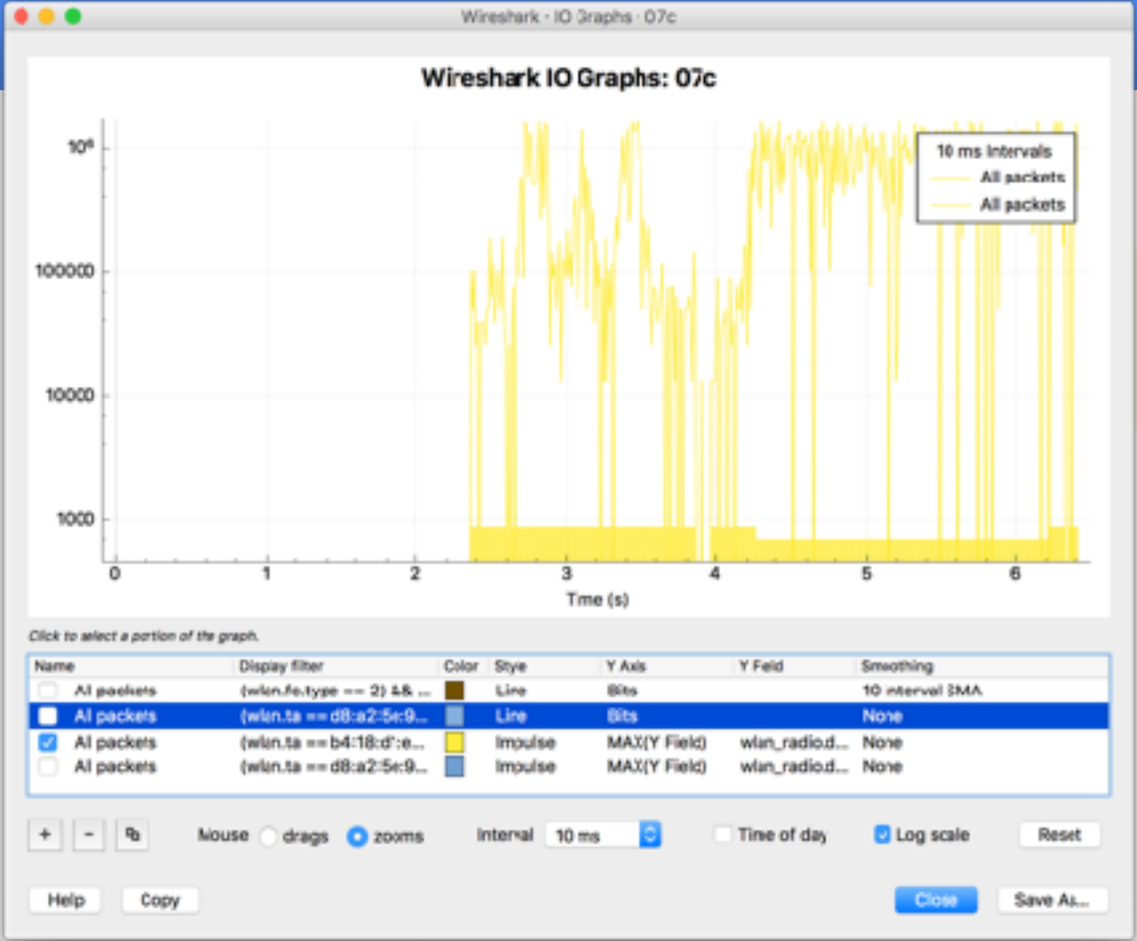
Name	Display filter	Color	Style	Y Axis	Y Field	Smoothing
□ All packets		■	Line	Packets		None
□ All packets	(wlan.ta == b4:18:d1:e...	■	Bar	MAX(Y Field)	wlan.seq	None
□ All packets	(wlan.ta == b4:18:d1:e...	■	Line	Bits		None
☑ All packets	(wlan.fc.type == 2) && ...	■	Line	Bits		10 interval S



Click to select packet 29808 (4.6s = 7353.

	Name	Display filter	Color	Style	Y Axis	Y Field	Smoothing
☑	All packets	(wlan.ta == b4:18:d1:e...	🟨	Line	Bits		10 interval S
□	All packets	(wlan.fc.type == 2) && ...	▨	Line	Bits		10 interval S
☑	All packets	(wlan.ta == d8:a2:5e:9...	🟦	Line	Bits		10 interval S

305Mb/s
Retries: 2.1%



Click to select a portion of the graph.

	Name	Display filter	Color	Style	Y Axis	Y Field	Smoothing
☐	All packets	(wlan.fc.type == 2) && ...	🟫	Line	Bits		10 interval SMA
☐	All packets	(wlan.ta == d8:a2:5e:9...	🟦	Line	Bits		None
☑	All packets	(wlan.ta == b4:18:d1:e...	🟨	Impulse	MAX(Y Field)	wlan_radio.d...	None
☐	All packets	(wlan.ta == d8:a2:5e:9...	🟦	Impulse	MAX(Y Field)	wlan_radio.d...	None

Mouse ○ drags ● zooms

Interval 10 ms

☐ Time of day

☑ Log scale

How do I set Monitoring Mode?

Wi-Fi Monitoring

- Details for all OS: talk of Thomas d'Otreppe at SharkFest 16 US
- Linux
  - Natively with command lines or in Wireshark directly (free)
- macOS
  - Natively with command line or in Wireshark directly (free)
  - also best hardware: 802.11ac 3x3

Wi-Fi Monitoring

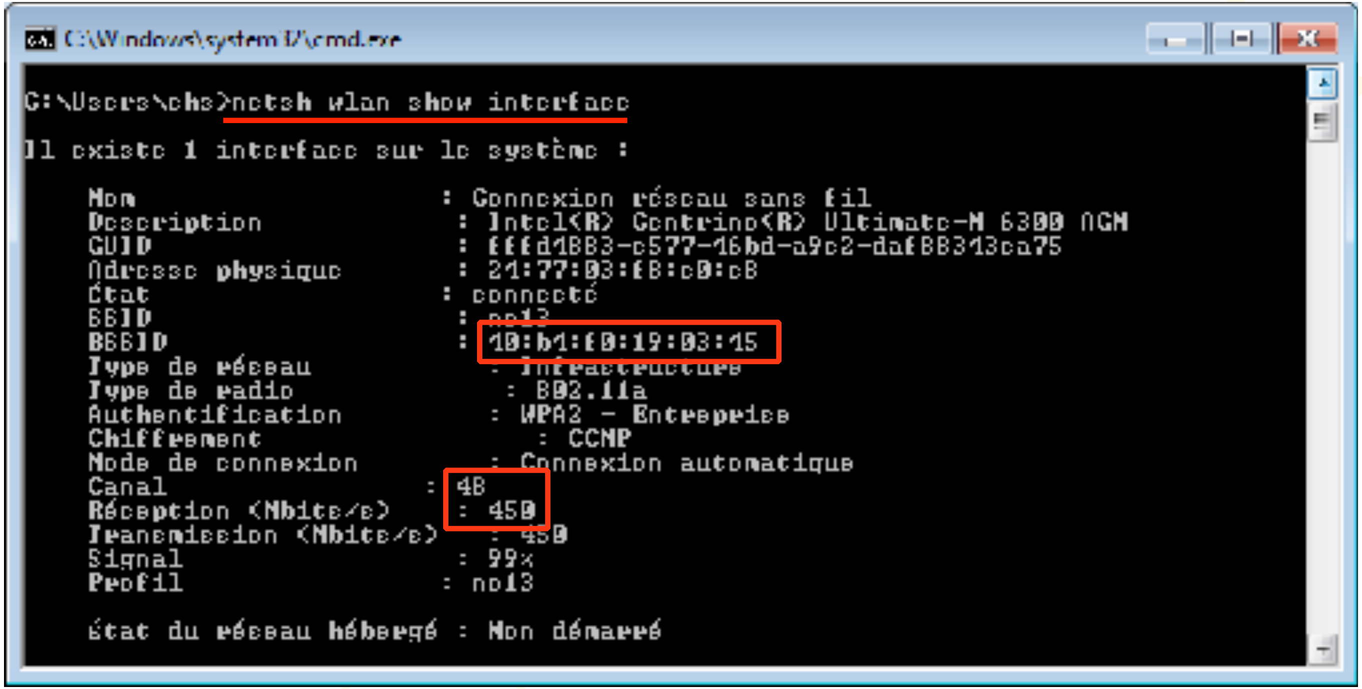
- Windows
  - External dongles:
    - Riverbed external Airpcap dongles: 802.11n 2x2 ($700!)
      Warning: Windows 7 + USB3 = BSOD!
    - ~~Savvius external dongles: 802.11n 3x3 ($60) - 802.11ac 2x2 ($150)~~
      Works with Omnipeek only, not Wireshark or need a trick with npcap
  - Using your internal Wi-Fi interface or external dongles:
    - Acrylic Wi-Fi Professional: NDIS 6 / Airpcap drivers ($40)
    - npcap: NDIS 6 (never found working hw, free, but nmap license)
    - *Does your interface support NDIS 6? Driver support your interfaces? Support of 5GHz? Ability to configure channel bandwidth?*

Ok, got hw, what should I do?

Ok, got hw, what should I do?
-> On which channel is your device?

Wi-Fi Monitoring

- netsh wlan show interface



```
C:\Users\chs>netsh wlan show interface

Il existe 1 interface sur le système :

    Nom                    : Connexion réseau sans fil
    Description             : Intel(R) Centrino(R) Ultimate-N 6300 AGN
    GUID                    : fffd1883-c577-16bd-a9c2-daf88313ca75
    Adresse physique        : 21:77:03:f8:c0:c8
    État                   : connecté
    SSID                    : no13
    BSSID                   : 10:b1:f0:19:03:15
    Type de réseau            : Infrastructure
    Type de radio              : 802.11a
    Authentification          : WPA2 - Entreprise
    Chiffrement                  : CCMP
    Mode de connexion         : Connexion automatique
    Canal                 : 48
    Réception (Mbits/s)     : 450
    Transmission (Mbits/s)    : 450
    Signal                  : 99%
    Profil                 : no13

    État du réseau hébergé : Non démarré
```

Why is my Wi-Fi slow?
Some indicators

- Is FCS a good metric in a Wi-Fi Monitoring capture?
  - NO!
  - FCS is a subjective metric of the monitoring station
  - You captured bad FCS seen by your monitoring station, not the client device
  - Lot of bad FCS if you're too close to the client
    - Radio orthogonality / Signal too strong / ...
    - Don't capture too close a client (< 2m)

- Use 802.11 Retries
  - wlan.fc.retries == 1
  - Set by the 802.11 device if previous data packet not ACKed
  - Check both Tx and Rx retries (<10-15% in a pro environment)
  - if Rx & Tx retries are high -> Check Layer 1 / Co-Channel Interferences
  - if Rx Retries >>> Tx Retries -> Power Mismatch (common with mobiles & professionnal Access Points)

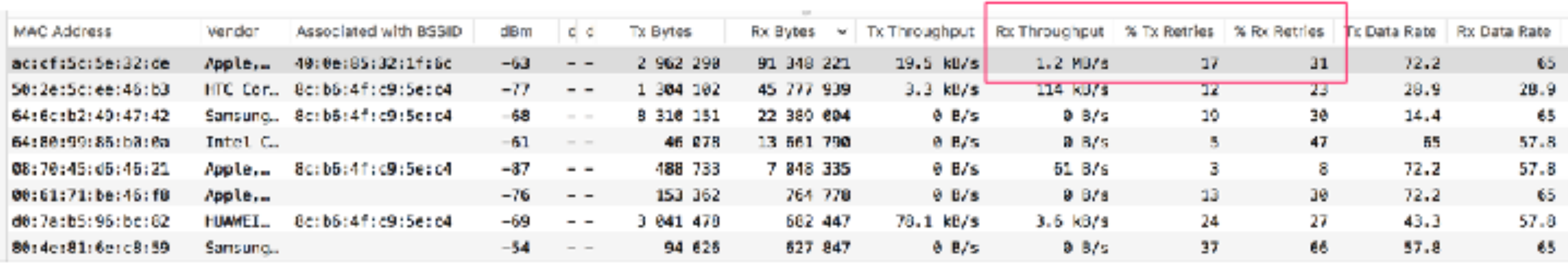
- #Lab - GUI
  - Count packets graphically in Wireshark
  - wlan.da == e0:2c:b2:3c:88:35 && wlan.fc.type == 2 && wlan.fcs.status == 1

    -> 378 pkts
  - wlan.da == e0:2c:b2:3c:88:35 && wlan.fc.type == 2 && wlan.fc.retry == 1 && wlan.fcs.status == 1

    -> 295 pkts
  - 78% Rx retries
- #Lab - Lua: https://iwaxx.com/retries.lua

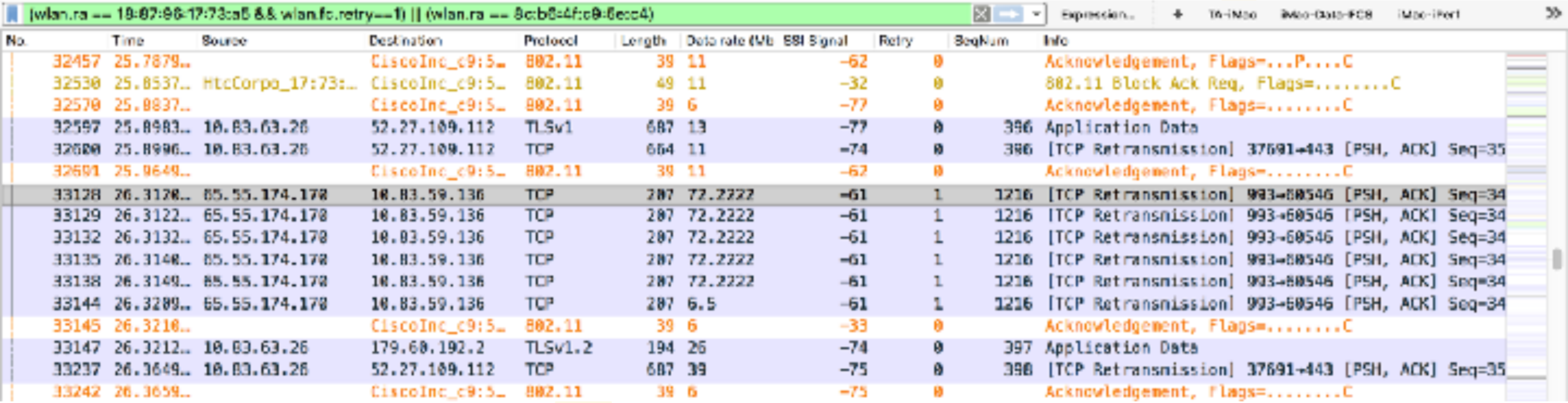
```
tshark -r 05.maria_40retries.pcapng -X lua_script:retries.lua -q
MAC address                e0:2c:b2:3c:88:35
All valid data packets     378
Retries data packet        295
%Retries                   78.042328042328
```

In Debookee



MAC Address	Vendor	Associated with BSSID	dBm	c	c	Tx Bytes	Rx Bytes	Tx Throughput	Rx Throughput	% Tx Retries	% Rx Retries	Tx Data Rate	Rx Data Rate
ac:cf:5c:5e:32:de	Apple,…	40:0e:85:32:1f:6c	-63	-	-	2 962 298	91 348 221	19.5 kB/s	1.2 MB/s	17	31	72.2	65
50:2e:5c:ee:46:b3	HTC Cor…	8c:b6:4f:c9:5e:c4	-77	-	-	1 304 102	45 777 939	3.3 kB/s	114 kB/s	12	23	28.9	28.9
64:6c:b2:40:47:42	Samsung…	8c:b6:4f:c9:5e:c4	-68	-	-	8 310 151	22 380 004	0 B/s	0 B/s	10	30	14.4	65
64:80:99:85:b8:0a	Intel C…		-61	-	-	46 078	13 661 790	0 B/s	0 B/s	5	47	65	57.8
08:70:45:d5:46:21	Apple,…	8c:b6:4f:c9:5e:c4	-87	-	-	488 733	7 848 335	0 B/s	51 B/s	3	8	72.2	57.8
00:61:71:be:46:f0	Apple,…		-76	-	-	153 362	764 770	0 B/s	0 B/s	13	30	72.2	65
d0:7a:b5:96:bc:02	HUAWEI…	8c:b6:4f:c9:5e:c4	-69	-	-	3 041 470	602 447	70.1 kB/s	3.6 kB/s	24	27	43.3	57.8
80:4e:81:6e:c8:59	Samsung…		-54	-	-	94 628	627 847	0 B/s	0 B/s	37	66	57.8	65

#Lab
Why the device doesn't ACK these valid packets?

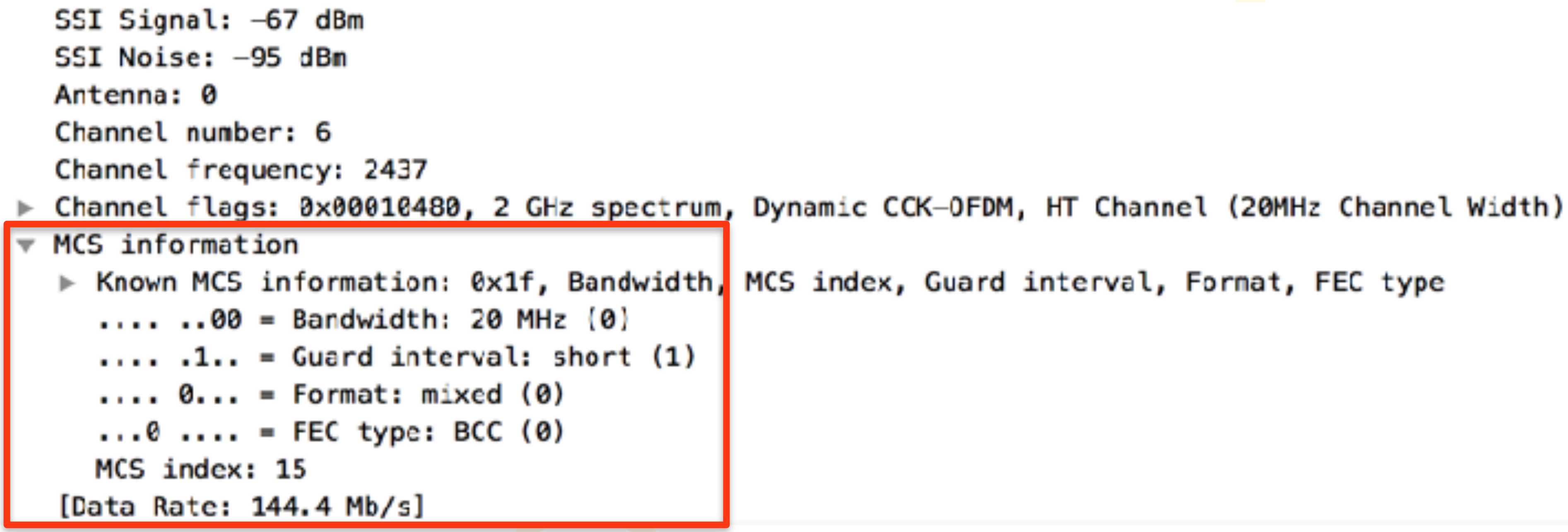


(wlan.ra == 10:07:b6:17:73:a5 && wlan.fc.retry==1) || (wlan.ra == 8c:b6:4f:c9:6e:c4)

No.	Time	Source	Destination	Protocol	Length	Data rate (Mb	SSI Signal	Retry	SeqNum	Info
32457	25.7879…		CiscoInc_c9:5…	802.11	39	11	-62	0		Acknowledgement, Flags=...P....C
32530	25.8537…	HtcCorpo_17:73:…	CiscoInc_c9:5…	802.11	49	11	-32	0		802.11 Block Ack Req, Flags=........C
32570	25.8837…		CiscoInc_c9:5…	802.11	39	6	-77	0		Acknowledgement, Flags=........C
32597	25.8983…	10.83.63.26	52.27.109.112	TLSv1	687	13	-77	0	396	Application Data
32600	25.8996…	10.83.63.26	52.27.109.112	TCP	664	11	-74	0	396	[TCP Retransmission] 37691→443 [PSH, ACK] Seq=35
32601	25.9649…		CiscoInc_c9:5…	802.11	39	11	-62	0		Acknowledgement, Flags=........C
33128	26.3120…	65.55.174.170	10.83.59.136	TCP	207	72.2222	-61	1	1216	[TCP Retransmission] 993→60546 [PSH, ACK] Seq=34
33129	26.3122…	65.55.174.170	10.83.59.136	TCP	207	72.2222	-61	1	1216	[TCP Retransmission] 993→60546 [PSH, ACK] Seq=34
33132	26.3132…	65.55.174.170	10.83.59.136	TCP	207	72.2222	-61	1	1216	[TCP Retransmission] 993→60546 [PSH, ACK] Seq=34
33135	26.3140…	65.55.174.170	10.83.59.136	TCP	207	72.2222	-61	1	1216	[TCP Retransmission] 993→60546 [PSH, ACK] Seq=34
33138	26.3149…	65.55.174.170	10.83.59.136	TCP	207	72.2222	-61	1	1216	[TCP Retransmission] 993→60546 [PSH, ACK] Seq=34
33144	26.3209…	65.55.174.170	10.83.59.136	TCP	207	6.5	-61	1	1216	[TCP Retransmission] 993→60546 [PSH, ACK] Seq=34
33145	26.3210…		CiscoInc_c9:5…	802.11	39	6	-33	0		Acknowledgement, Flags=........C
33147	26.3212…	10.83.63.26	179.60.192.2	TLSv1.2	194	26	-74	0	397	Application Data
33237	26.3649…	10.83.63.26	52.27.109.112	TCP	687	39	-75	0	398	[TCP Retransmission] 37691→443 [PSH, ACK] Seq=35
33242	26.3659…		CiscoInc_c9:5…	802.11	39	6	-75	0		Acknowledgement, Flags=........C

#Lab
Speed / #Stream / GI / Modulation

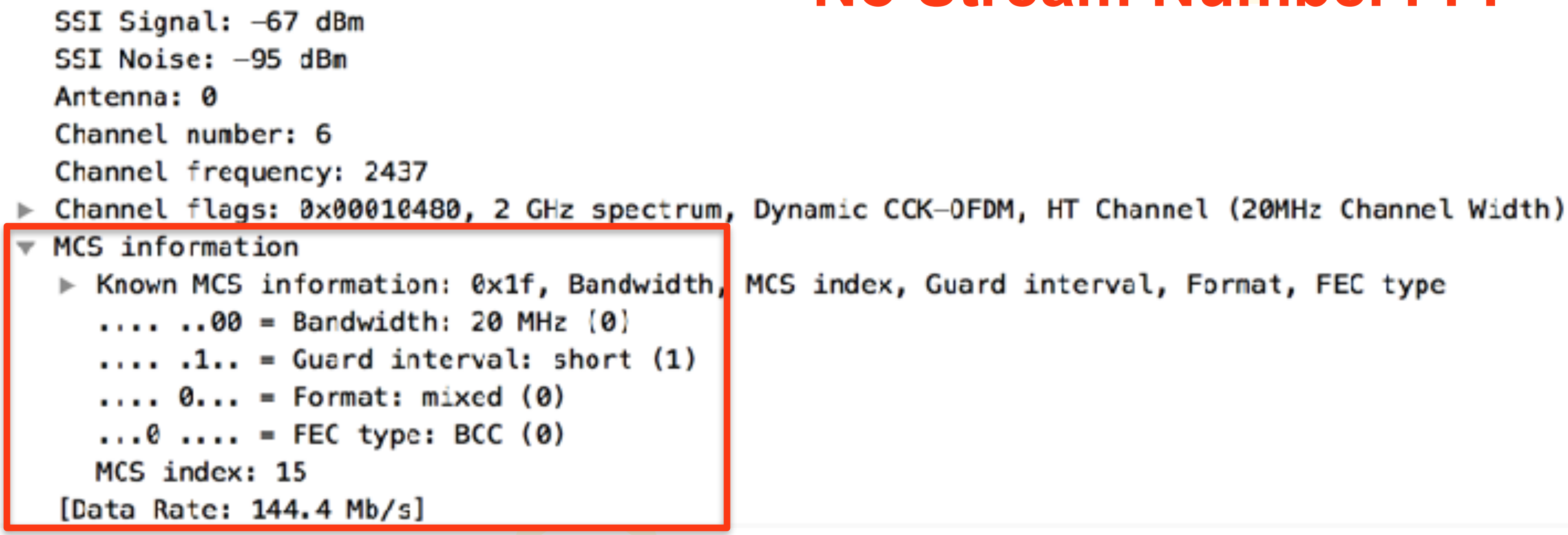
- Back to pcap



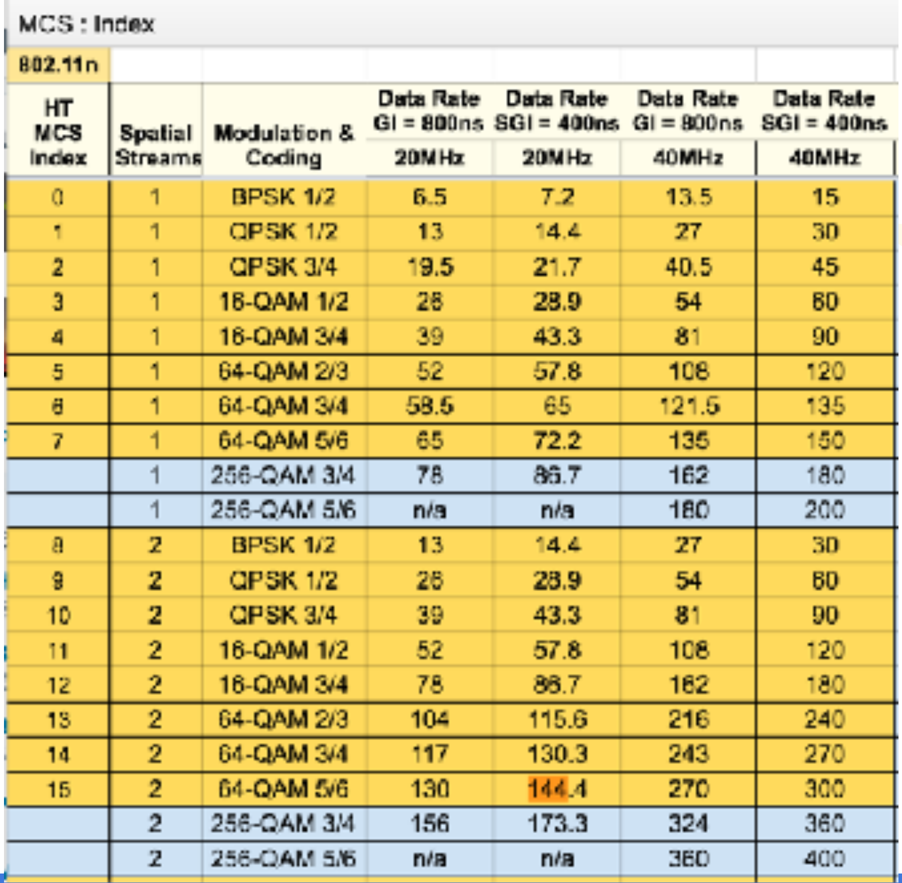
```
  SSI Signal: -67 dBm
  SSI Noise: -95 dBm
  Antenna: 0
  Channel number: 6
  Channel frequency: 2437
▶ Channel flags: 0x00010480, 2 GHz spectrum, Dynamic CCK-OFDM, HT Channel (20MHz Channel Width)
▼ MCS information
  ▶ Known MCS information: 0x1f, Bandwidth, MCS index, Guard interval, Format, FEC type
     .... ..00 = Bandwidth: 20 MHz (0)
     .... .1.. = Guard interval: short (1)
     .... 0... = Format: mixed (0)
     ...0 .... = FEC type: BCC (0)
    MCS index: 15
  [Data Rate: 144.4 Mb/s]
```

- Back to pcap

No Stream Number???



```
  SSI Signal: -67 dBm
  SSI Noise: -95 dBm
  Antenna: 0
  Channel number: 6
  Channel frequency: 2437
▶ Channel flags: 0x00010480, 2 GHz spectrum, Dynamic CCK-OFDM, HT Channel (20MHz Channel Width)
▼ MCS information
  ▶ Known MCS information: 0x1f, Bandwidth, MCS index, Guard interval, Format, FEC type
    .... ..00 = Bandwidth: 20 MHz (0)
    .... .1.. = Guard interval: short (1)
    .... 0... = Format: mixed (0)
    ...0 .... = FEC type: BCC (0)
    MCS index: 15
  [Data Rate: 144.4 Mb/s]
```



MCS : Index

802.11n

HT MCS Index	Spatial Streams	Modulation & Coding	Data Rate GI = 800ns	Data Rate SGI = 400ns	Data Rate GI = 800ns	Data Rate SGI = 400ns
			20MHz	20MHz	40MHz	40MHz
0	1	BPSK 1/2	6.5	7.2	13.5	15
1	1	QPSK 1/2	13	14.4	27	30
2	1	QPSK 3/4	19.5	21.7	40.5	45
3	1	16-QAM 1/2	26	28.9	54	60
4	1	16-QAM 3/4	39	43.3	81	90
5	1	64-QAM 2/3	52	57.8	108	120
6	1	64-QAM 3/4	58.5	65	121.5	135
7	1	64-QAM 5/6	65	72.2	135	150
	1	256-QAM 3/4	78	86.7	162	180
	1	256-QAM 5/6	n/a	n/a	180	200
8	2	BPSK 1/2	13	14.4	27	30
9	2	QPSK 1/2	26	28.9	54	60
10	2	QPSK 3/4	39	43.3	81	90
11	2	16-QAM 1/2	52	57.8	108	120
12	2	16-QAM 3/4	78	86.7	162	180
13	2	64-QAM 2/3	104	115.6	216	240
14	2	64-QAM 3/4	117	130.3	243	270
15	2	64-QAM 5/6	130	144.4	270	300
	2	256-QAM 3/4	156	173.3	324	360
	2	256-QAM 5/6	n/a	n/a	360	400

#Lab
Why don't I see any data packets?

Some Topic

- CWNP Certification Program
  - https://www.cwnp.com

- Some Wi-Fi guys
  - https://twitter.com/KeithRParsons
  - https://twitter.com/MackenzieWiFi
  - http://www.revolutionwifi.net/revolutionwifi/
  - http://divdyn.com/blog/
  - http://wlanbook.com/twitter-ids-of-cwnp-certified-wireless-network-expert-cwne/

Thank you!

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