SharkFest '18 Europe

IEEE802.11ac Debugging in Windows environment

New way of Debugging with Wireshark after AirPcap era.

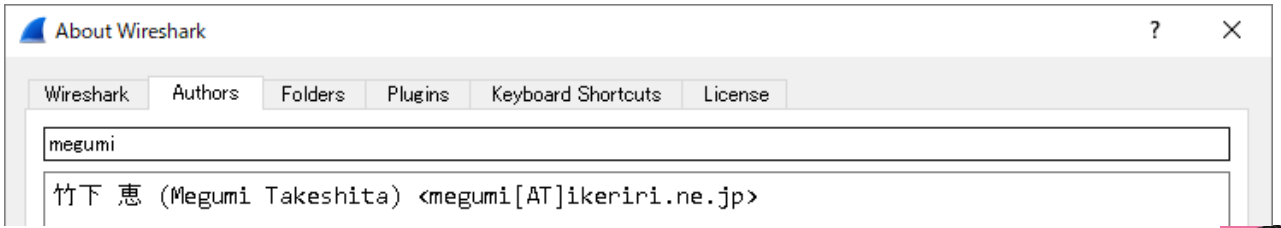
Supplemental files
http://www.ikeriri.ne.jp/sharkfest/

Megumi Takeshita

Packet Otaku
ikeriri network service

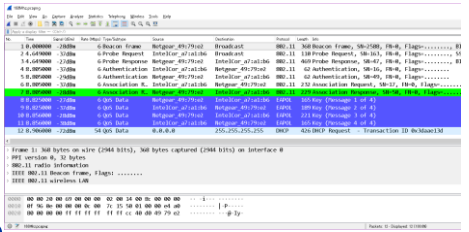
Megumi Takeshita, ikeriri network service

- Founder, ikeriri network service co.,ltd
- Wrote 10+ books about Wireshark
- Reseller of Riverbed Technology (former CACE technologies) in Japan
- Attending all Sharkfest
- Translator of QT Wireshark into Japanese



About the session

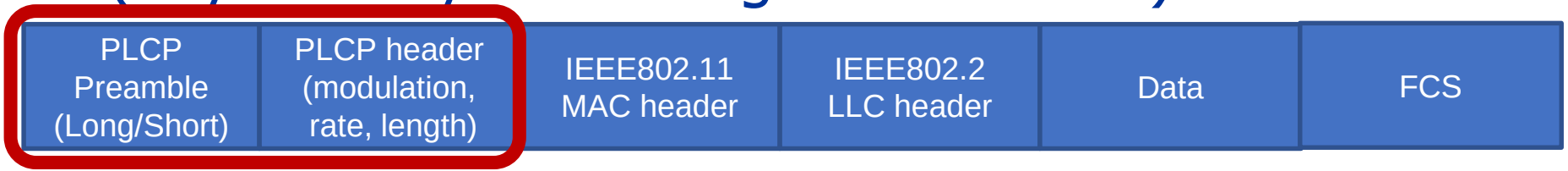
We stand at deadlock about wireless troubleshooting in Windows environments after the end of AirPcap series. But Metageek announced Eye P.A. support capturing IEEE802.11n and finally IEEE802.11ac in Windows environment ! This session show you the latest and best way to capture IEEE802.11ac in Windows environment, including AirPcap, AcrylicWiFi and Linux, macOS method.



Adding this Megumi tells you wireless troubleshooting case study using Wireshark with trace files. Utilize the power of new wireless feature of Wireshark, debugging and troubleshooting can catch up with the new spec of Wi-Fi speed.

Packet analysis before 11n

- Wireless packet capturing before IEEE802.11n, we used AirPcap and radiotap header to analyze and debug in Windows environment.
- AirPcap is easy to use and integrated into Wireshark.
- Radiotap header is old dissector of IEEE802.11, dissecting PHY physical information, PLCP signal (Physical Layer Convergence Protocol)



Radiotap header

```
Radiotap Header v0, Length 20
    Header revision: 0
    Header pad: 0
    Header length: 20
  Present flags
      .... .... .... .... .... .... .... ...0 = TSFT: Absent
      .... .... .... .... .... .... .... ..1. = Flags: Present
      .... .... .... .... .... .... .... .1.. = Rate: Present
      .... .... .... .... .... .... .... 1... = Channel: Present
      .... .... .... .... .... .... ...0 .... = FHSS: Absent
      .... .... .... .... .... .... ..1. .... = dBm Antenna Signal: Present
      .... .... .... .... .... .... .1.. .... = dBm Antenna Noise: Present
      .... .... .... .... .... .... 1... .... = Lock Quality: Present
      .... .... .... .... .... ...0 .... .... = TX Attenuation: Absent
      .... .... .... .... .... ..0. .... .... = dB TX Attenuation: Absent
      .... .... .... .... .... .0.. .... .... = dBm TX Power: Absent
      .... .... .... .... .... 1... .... .... = Antenna: Present
      .... .... .... .... ...1 .... .... .... = dB Antenna Signal: Present
      .... .... .... .... ..0. .... .... .... = dB Antenna Noise: Absent
      .... .... .... .... .0.. .... .... .... = RX flags: Absent
      .... .... .... .... .0.. .... .... .... = Channel+: Absent
      .... .... .... 0... .... .... .... .... = MCS information: Absent
      .... .... ...0 .... .... .... .... .... = A-MPDU Status: Absent
      .... .... ..0. .... .... .... .... .... = VHT information: Absent
      ...0 0000 00.. .... .... .... .... .... = Reserved: 0x00000000
      ..0. .... .... .... .... .... .... .... = Radiotap NS next: False
      .0.. .... .... .... .... .... .... .... = Vendor NS next: False
      0... .... .... .... .... .... .... .... = Ext: Absent
  Flags: 0x10
      .... ...0 = CFP: False
      .... ..0. = Preamble: Long
      .... .0.. = WEP: False
      .... 0... = Fragmentation: False
      ...1 .... = FCS at end: True
      ..0. .... = Data Pad: False
      .0.. .... = Bad FCS: False
      0... .... = Short GI: False
    Data Rate: 54.0 Mb/s
    Channel frequency: 2427 [BG 4]
```

```
  Channel flags: 0x00c0, Orthogonal Frequency-Division Multiplexing (OFDM), 2 GHz spectrum
      .... .... ...0 .... = Turbo: False
      .... .... ..0. .... = Complementary Code Keying (CCK): False
      .... .... .1.. .... = Orthogonal Frequency-Division Multiplexing (OFDM): True
      .... .... 1... .... = 2 GHz spectrum: True
      .... ...0 .... .... = 5 GHz spectrum: False
      .... ..0. .... .... = Passive: False
      .... .0.. .... .... = Dynamic CCK-OFDM: False
      .... 0... .... .... = Gaussian Frequency Shift Keying (GFSK): False
      ...0 .... .... .... = GSM (900MHz): False
      ..0. .... .... .... = Static Turbo: False
      .0.. .... .... .... = Half Rate Channel (10MHz Channel Width): False
      0... .... .... .... = Quarter Rate Channel (5MHz Channel Width): False
    SSI Signal: -43 dBm
    SSI Noise: -100 dBm
    Signal Quality: 86
    Antenna: 0
    SSI Signal: 57 dB
```

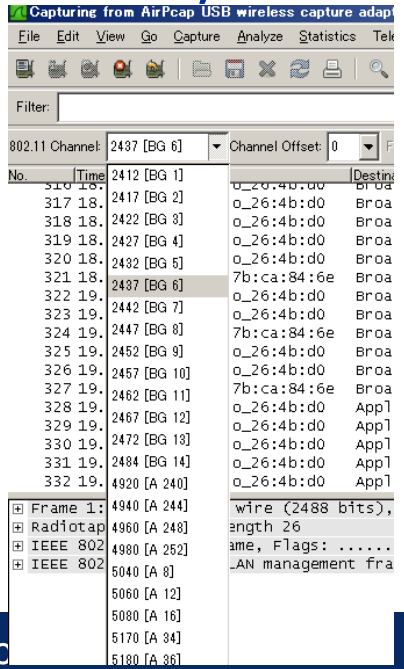
Fixed field

Simple and easy to read

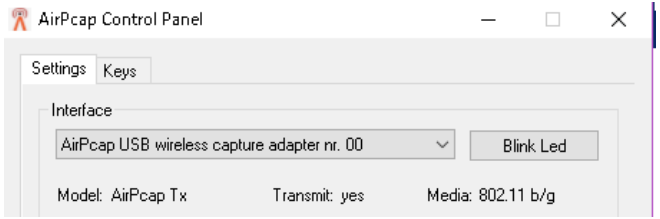
Short display filter string supported by many commercial products (old style)

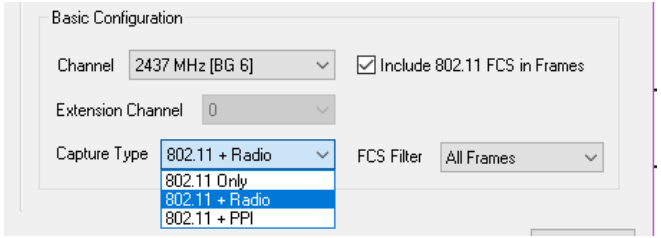
AirPcap in Windows environment

- Plug in AirPcapNX and start Wireshark, tshark, etc.
- View > Wireless toolbar to select ch, bandwidth, etc.
- Set Capture type (radiotap/ppi), etc.
- Start capturing.
- Use Wireshark / tshark to analyze
- Easy and best way until **.11n**
- AirPcap NX and TX can also transmit IEEE802.11 frames.



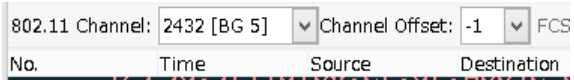
AirPcap live demonstration in Windows10

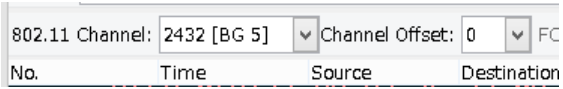


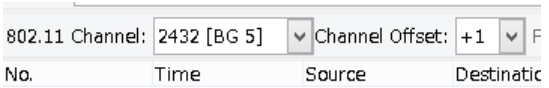


Capture Type
802.11 Only (only L2 header)
802.11 + Radio (Radiotap)
802.11 + PPI (Per Packet Information)

Bandwidth	HT-(Offset-1)	20MHz(Offset0)	HT+(Offset+1)
Selected Channels	Primary Ch 5＋ Ext. Ch 1 Ch1+5(p)(40MHz)	Primary Ch 5 Ch5(20MHz)	Primary Ch 5＋ Ext. Ch 9 Ch 5(p)+9 (40MHz)





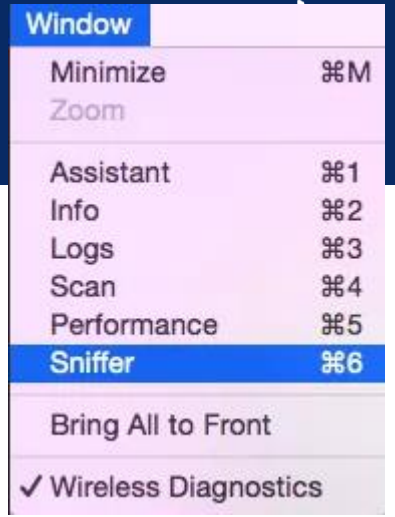


FCS settings	All frame	Capture frames FCS is valid	Capture frames FCS is invalid

Linux

1. Browse WikiDevi wikidevi.com and choose good device with Linux monitor mode support
2. insmod to install driver, lsusb / lspci to check device and ifconfig / iwconfig
3. airmon-ng check kill
   airmon-ng start wlan*
   to start monitor mode

macOS



- Choose MacBook pro (with monitor mode support)
- 1. Command + Space to open spotlight
  2. type Wireless Diagnostics to open Wireless Diagnostics Tool
  3. choose Sniffer in windows menu
  4. choose channel and bandwidth to start capturing
  5. You may need to enter admin pass
  6. press Stop to stop capture
  7. filename.WCAP file is the trace file
- You can open WCAP file in Wireshark and Wireshark itself can capture packets

We still need windows environments

- Windows10 PCs are still major in Japanese enterprise network, so we have to use Windows in wireless debugging and troubleshooting.
- But the time stopped at 2005 of AirPcapNX age, with IEEE802.11n 40MHz capturing, though Linux has many monitor mode driver with IEEE802.11ac with 80MHz (thank you very much, aircrack-ng !)
- Let’s talking about wireless capturing in Windows environment.

AirPcap discontinued, then ?

- My lovely AirPcaps are go away, then what are the alternatives ?
- Off course Air magnet, Omnipeek, and other enterprise solutions in Windows at expensive price tag.
- AcrylicWiFi is a nice product, but there are some driver issues.
- EyePA is one of the best alternatives

Eye P.A. (Eye Packet Analyzer)

Eye P.A. was just a wireless packet visualization software

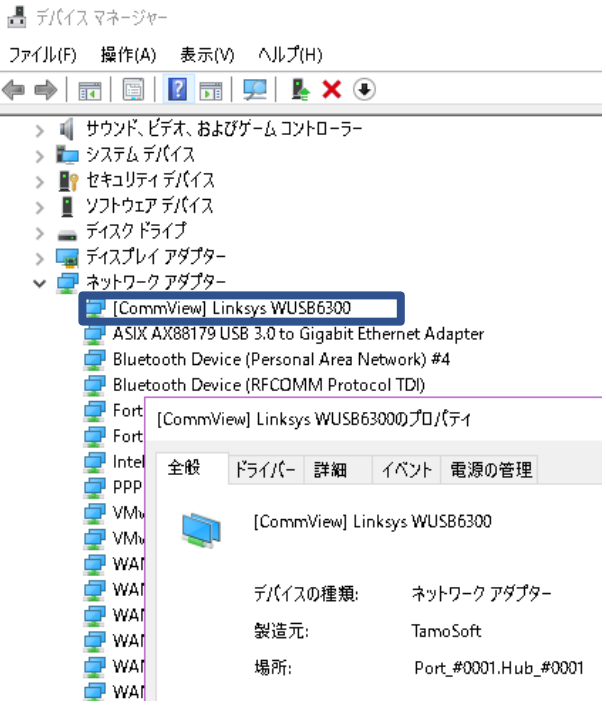
But packet capture function is added at version 2 with compatible monitor mode driver.

In version 2.0.1.2 EyePA uses Tarlogic NDIS Monitor driver, as known as Tamosoft TamoGraph

Compatible Adapters

- Supported adapter:
  Linksys WUSB6300 (recommended), ASUS USB-AC56, ASUS USB-AC68, ALFA Network AWUS1900, Amped Wireless ACA1 EnGenius EUB1200AC, D-Link DWA-182 rev C1, D-Link DWA-192, TRENDnet TEW-805UB, TP-LINK Archer T4U v2, TP-LINK Archer T4UH v2, Edimax EW-7822UAC, Edimax EW-7833UAC and AirPcap NX/TX

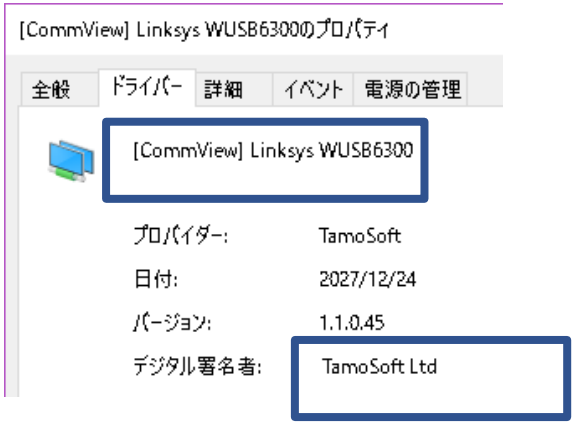
Linksys WUSB6300 IEEE802.11abgn+ac



Chipset Realtek RTL8812AU

abgn+ac, 2x2:2

[CommView] Linksys WUSB6300



Linksys WUSB6300

Manuf/OEM/ODM SerComm

FCC approval date: 19 June 2013
(Est.) initial retail price (in USD): $69.99
UPC: 745883598403 (UPC DB, On eBay)
Country of manuf.: China

Amazon image

ASIN
B00EDOG8NC (, On Amazon, On CCC)
On Newegg

Interface: USB

USB 3.0
Connector: Male A
Form factor tags: dongle

ID: 13b1:003f
Windows: USB\VID_13B1&PID_003F

FCC ID: Q87-WUSB6300
Industry Canada ID: 3839A-WUSB6300

WI1 chip1: Realtek RTL8812AU

Additional chips
5GHz Power Amplifier IC;Skyworks;SE5022T;SiGe, 5022T, AC242;2;
SPDT Switch w/ LNA;Skyworks;SKY85601;SKY, 85601, 229CU;2;;16-pin QFN;2.5 mm x 2.5mm;

Probable Linux driver
Realtek's vendor driver (8812au)
available on Edimax's site (from the 7822UAC's prod. pg)
md5: fda86443df638abd9f50a9997090d58e
slightly modified version (additional USB IDs added)
md5: 2e345f43f5fa50ca1137655b5a5bc9ab
also, abperiasamy's 8812au repo on GitHub which is patched for newer kernels
USB ID not yet observed in any mainline kernel / this list
(see also passys)

Windows driver
see Realtek's website

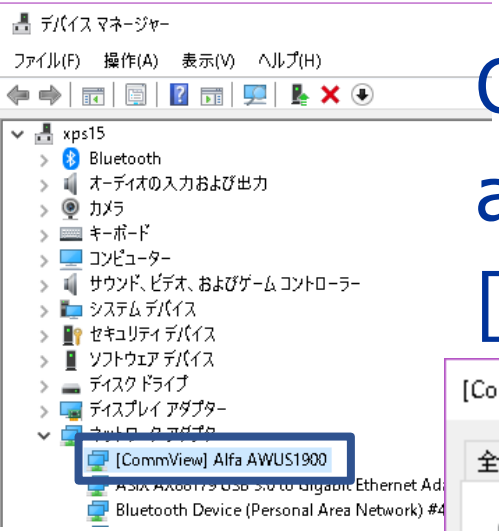
Antenna connector: none

abgn+ac, 2x2:2

Flags: DFS

OUI: C8:D7:19 (7 E, 9 W, 2012)

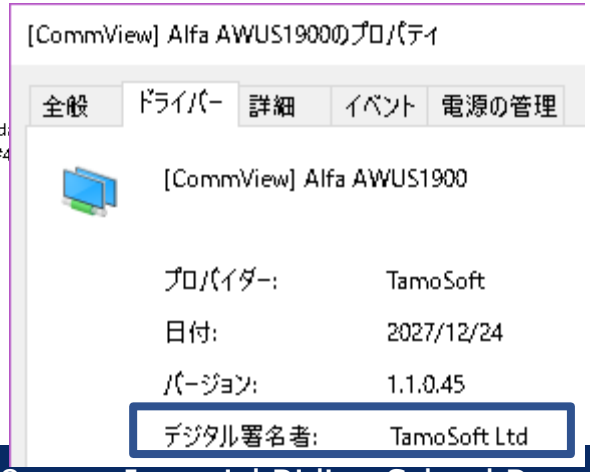
ALFA Network AWUS 1900 IEEE802.11abgn+ac



Chipset Realtek RTL88**14**AU

abgn+ac, **4x4:3**

[CommView] Alfa AWUS1900



ALFA Network AWUS1900

FCC approval date: 28 June 2017
UPC: 4718050305209 (UPC DB, On eBay)
Country of manuf.: Taiwan

Amazon image

ASIN
B01MZD7Z76 (, On **Amazon**, On **CCC**)

Interface: USB

USB 3.0
Connector: Female Micro-B
Form factor tags: corded (modular) adapter

ID: 0bda:8813 (1 addl. devices)
Windows: **USB¥VID_0BDA&PID_8813**

FCC ID: 2AB8788814

WI1 chip1: Realtek RTL8814AU

Probable Linux driver
See this driver @ **Edimax**
USB ID not yet observed in any mainline kernel / this list
(see also passys)

Windows driver
see **Realtek's website**

Antenna connector: RP-SMA

abgn+ac, 4x4:3

Flags: 256QAM

OUI: 00:C0:CA (5 E, 25 W, 2010)

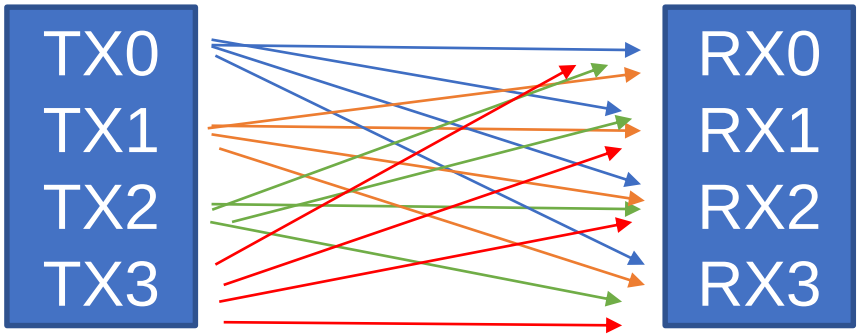
What is 2x2:2, 4x4:3 mean ?

Number of Transmitters

Number of Receivers

- Linksys WUSB6300 2x2:2
- ALFA Network AWUS1900 4x4:3

TxR:S



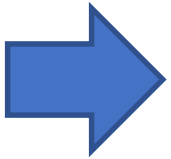
Number of Spatial Streams

It can send multiple streams at a time ?

Just a moment

AP is just a repeater, isn't it ?

- … I see 11ac can enlarge bandwidth to 160MHz
- But AP is just a half duplex repeater hub. Why AP can send multiple signals at a time ?



STBC (Space–time block coding) also as known as beam forming can send multiple channel signal at a time. So we can speed up double, triple, quadoruple in a connection.

Single user - MIMO (Multiple Input Multiple Output)

- In IEEE802.11a/b/g, a STA/AP has one antenna to transmit traffic and one to receive from others. So easy to calculate that 1 user 1 stream 20MHz.
- In 11ac, a STA/AP has many antenna to transmit and many antenna to receive. 11AC can also send many streams at a time (spatial stream) to send double, triple, and quadoruple to a single user because of STBC and beam forming technologies.
- So they can enlarge the bandwidth up to 160MHz.

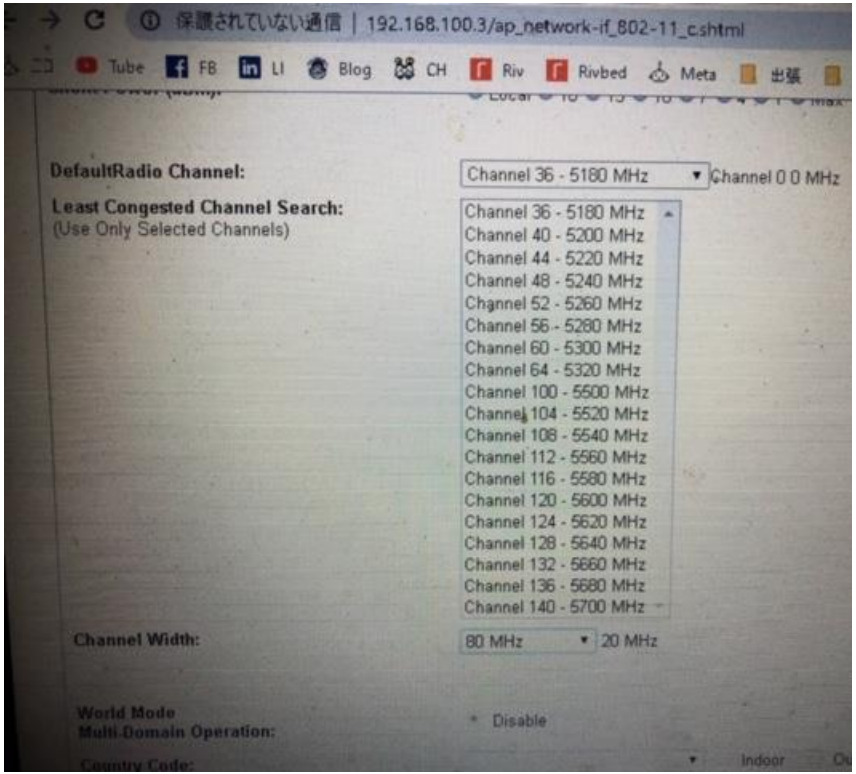
11ac capture in Windows

- Many AP supports MU-MIMO, but the capture side, we need to capture and filter a connetion between an AP and a STA. Single user MIMO with multiple Spatial Stream is the first step to capture 11ac traffic.
- We have to capture at good place (distance / direction) such as required RSSI is >= -45dBm
- Off course aircrack-ng (airmon-ng and others) and Linux is a good idea, but we want to capture in Windows environment !!

Cisco Aironet 1702i
IEEE802.11ac wave1 access point

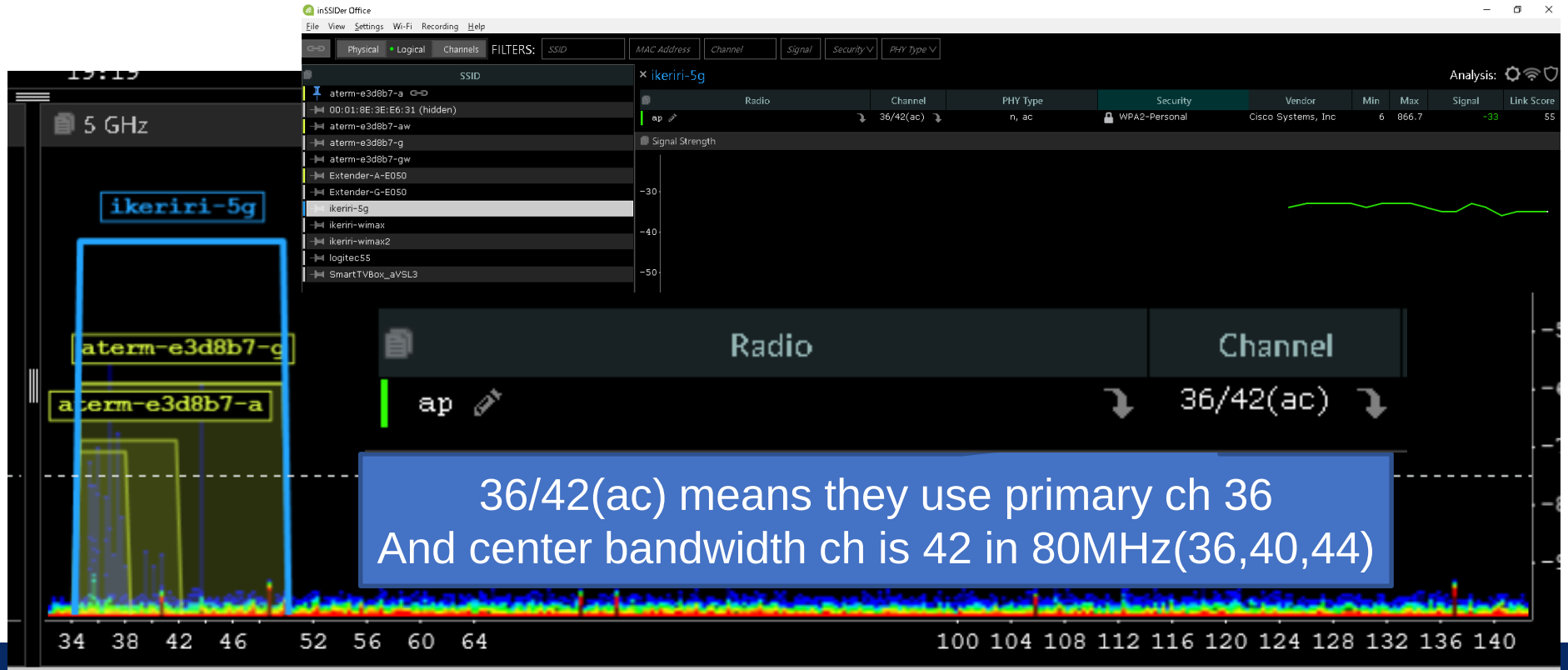
- 3x3:2 access point
  MU-MIMO and 2 spatial streams
- 802.11ac beam forming
- 20/40/80 MHz channel
- Max 867Mbps at 5GHz 80MHz bandwidth
- A-MPDU/A-MSDU are supported

Set up like this



- Set a fixed 80MHz bandwidth channel to 36
- Enable all MCS and beam forming, aggregation opt.
- SSID: ikeriri-5g
- WPA2-PSK passphrase: wireshark

Check the spectrum using InSSIDer Office



36/42(ac) means they use primary ch 36
And center bandwidth ch is 42 in 80MHz(36,40,44)

Rivet Networks Killer Wireless-AC 1535

At first I test Killer Wireless-AC 1535 in my Dell XPS (default), the WLAN card spec:
Qualcomm Atheros QCA6174A
Supports 20/40/80MHz at 5GHz
2x2:2 MU-MIMO,
Transmit Beamforming
High-density modulation (256-QAM)
low-density parity check (LDPC)
maximum ratio combining (MRC)
Rx space time block code (STBC) etc.
But…. It failed. (in later)

Rivet Networks Killer Wireless-AC 1535
Availability: now

FCC approval date: 28 May 2015
(Est.) release date: June 2015

Amazon image

ASIN
B01724QS3O (, On **Amazon**, On **CCC**)

Interface: NGFF

Connector: M.2
Form factor tags: 2230

ID: 168c:003e (14 addl. devices) **SS:** 1a56:1535
Windows:
PCI¥VEN_168C&DEV_003E&SUBSYS_15351A56

FCC ID: PPD-QCNFA364AH
Industry Canada ID: 4104A-QCNFA364A

WI1 chip1: Qualcomm Atheros QCA6174A

Probable Linux driver
ath10k
PCI ID first seen in kernel v4.0 (2015-04-12)
(see also passys)

Windows driver
Win 7/8.1/10
(**Bluetooth**)

Antenna connector: MHF4

abgn+ac, 2x2:2

Flags: MU-MIMO, bluetooth 4.1

OUI: 9C:B6:D0 (-, 1 W, 2015)

Intel Wireless-AC 9260NGW

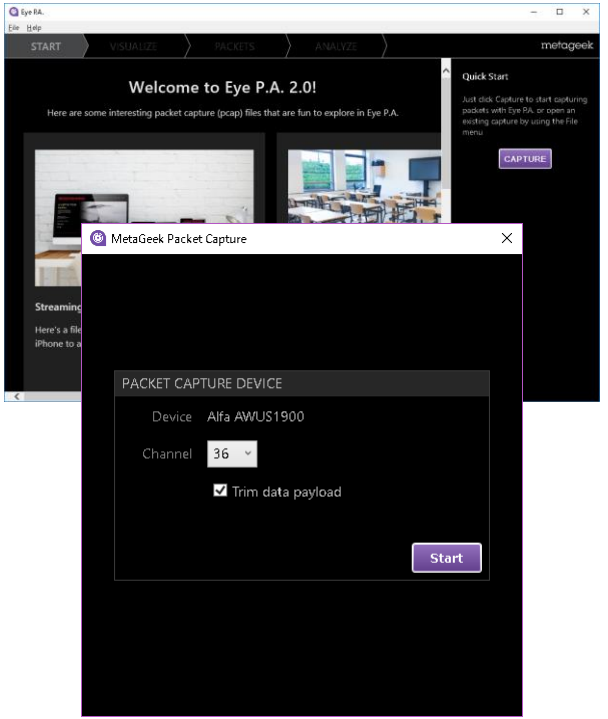
Then I changed the m.2 PCIe card from Killer 1535 to Intel Wireless-AC 9260NGW, the spec: Intel WCS9200 chipset Supports IEEE802.11ac w2 20/40/80/160MHz bandwidth

2x2:2 (common in laptop PC) MU-MIMO
5Ghz (160Mhz bandwidth) Max Speed1.7Gbps
May be this WLAN card is one of the newest and most advanced (result is later.)

Intel Dual Band Wireless-AC 9260 **(9260NGW)**
FCC approval date: 24 July 2017
Interface: NGFF
Connector: M.2 **Form factor tags:** 2230
FCC ID: PD99260NG **Industry Canada ID:** 1000M-9260NG
WI1 chip1: Intel WCS9200
Probable Linux driver iwlwifi, k3.10+ (in backports) (see also passys)
Antenna connector: MHF4
abgn+ac, 2x2:2
Flags: Wave2, MU-MIMO, VHT160, DFS, Bluetooth 5.0
OUI: none specified

Capture test with EyePA

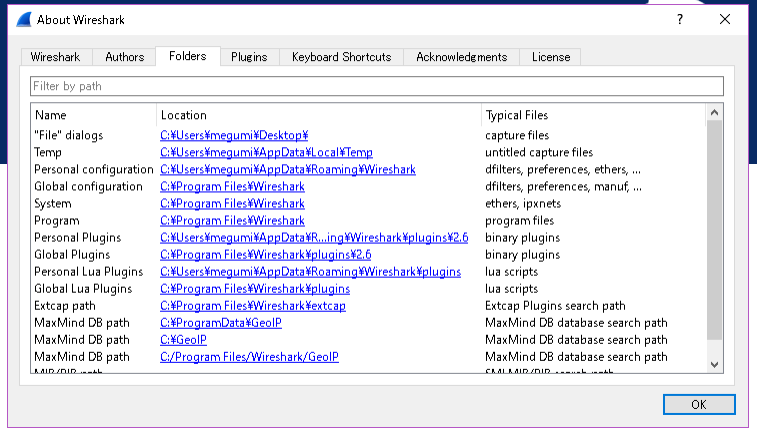
1. Plug in Linksys WUSB6300 or ALFA AWUS1900 (may be other Realtek)
2. Start up EyePA and capture at 36CH without trimming data packet (need Administrator right)
3. Connect at SSID:ikeriri-5g (Passphrase:wireshark)
4. Ping at 1.1.1.1 or somewhere
5. Stop capture and check the pcap file



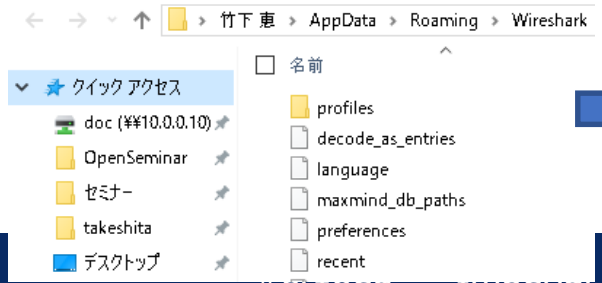
Capture Result of 5GHz 80MHz 11ac channel using EyePA

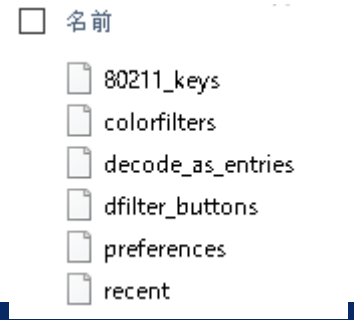
Capture Hardware / STA (AP: Cisco Aironet 1702i 5GHz 80MHz 36CH)		Rivet Networks Killer Wireless-AC 1535 2x2:2(80MHz)	Intel Wireless-AC 9260NGW 2x2:2(160MHz)
LINKSYS WUSB6300 2x2:2	Management frames	OK	OK
	Data frames	NG	NG
ALFA network AWUS1900 4x4:3	Management frames	OK	OK
	Data frames	NG	OK (only 802.11-common field without VHT PHY info)

Open trace file 80mhz.pcapng



- Download supplemental file at http://www.ikeriri.ne.jp/sharkfest/
- Open 80Mhz.pcap
- Download 11ac.zip to extract and copy your personal configuration profile directory of Wireshark (Customized Wireshark setting, columns, coloring rules, ieee802.11keys and more)



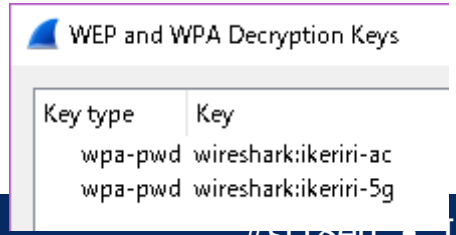


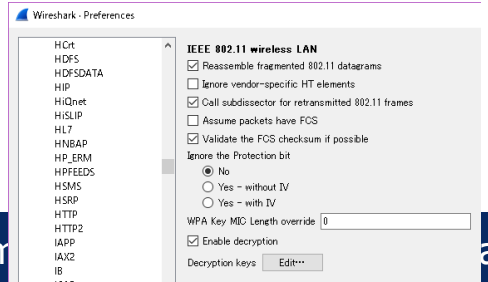
Customizing Wireshark for dissecting 11ac (1)

- We will use PPI header for more PHY information
- Add fields as column, wlan_radio.signal_dbm (Signal), wlan_radio.data_rate (Rate), wlan_radio.channel (Ch) and wlan.fc.type_subtype (type/subtype)

No.	Time	Char	Signal (dBm)	Rate (Mbps)	Type/Subtype	Source	Destination	Protocol	Length	Info
6	5.104000	36	-43dBm	6	Association R…	IntelCor_a7:a1:b6	Cisco_70:18:d0	802.11	278	Assoc
7	5.120000	36	-39dBm	6	Association R…	Cisco_70:18:d0	IntelCor_a7:a1:b6	802.11	239	Assoc

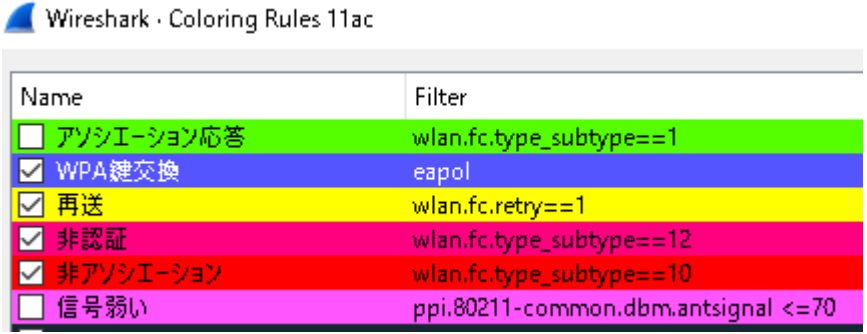
- Add SSID and WPA2PSK passphrase into decryption key settings of 802.11 protocol in Wireshark preference



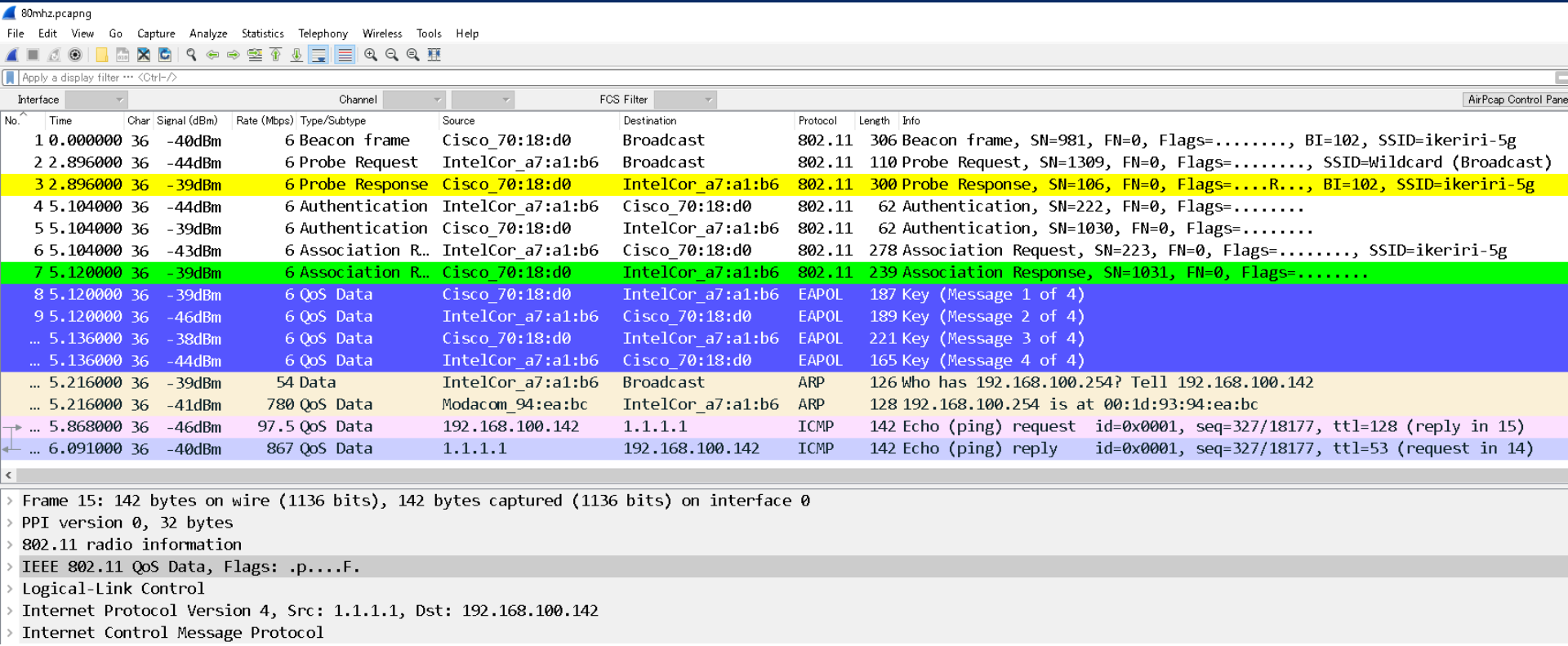


Customizing Wireshark for dissecting 11ac (2)

- Create your own coloring rules, filter button, display filter and capture filter and so on.
- In this time
  Association Response (Green)
  EAPOL key exchange (Blue)
  CSMA/CA retransmit (Yellow)
  Deauthentication / Disassociation (Red)
  Weak Signal under -70dBm (Pink) note: we need -45dBm
- Let's apply 11ac profile to see trace file

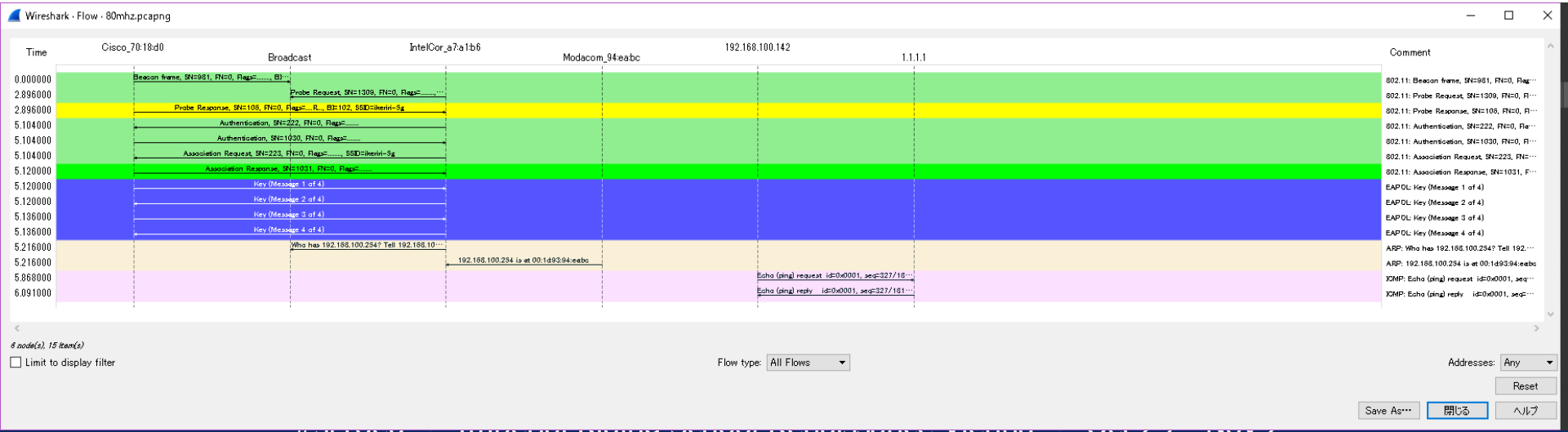


Looks nice with 11ac profile

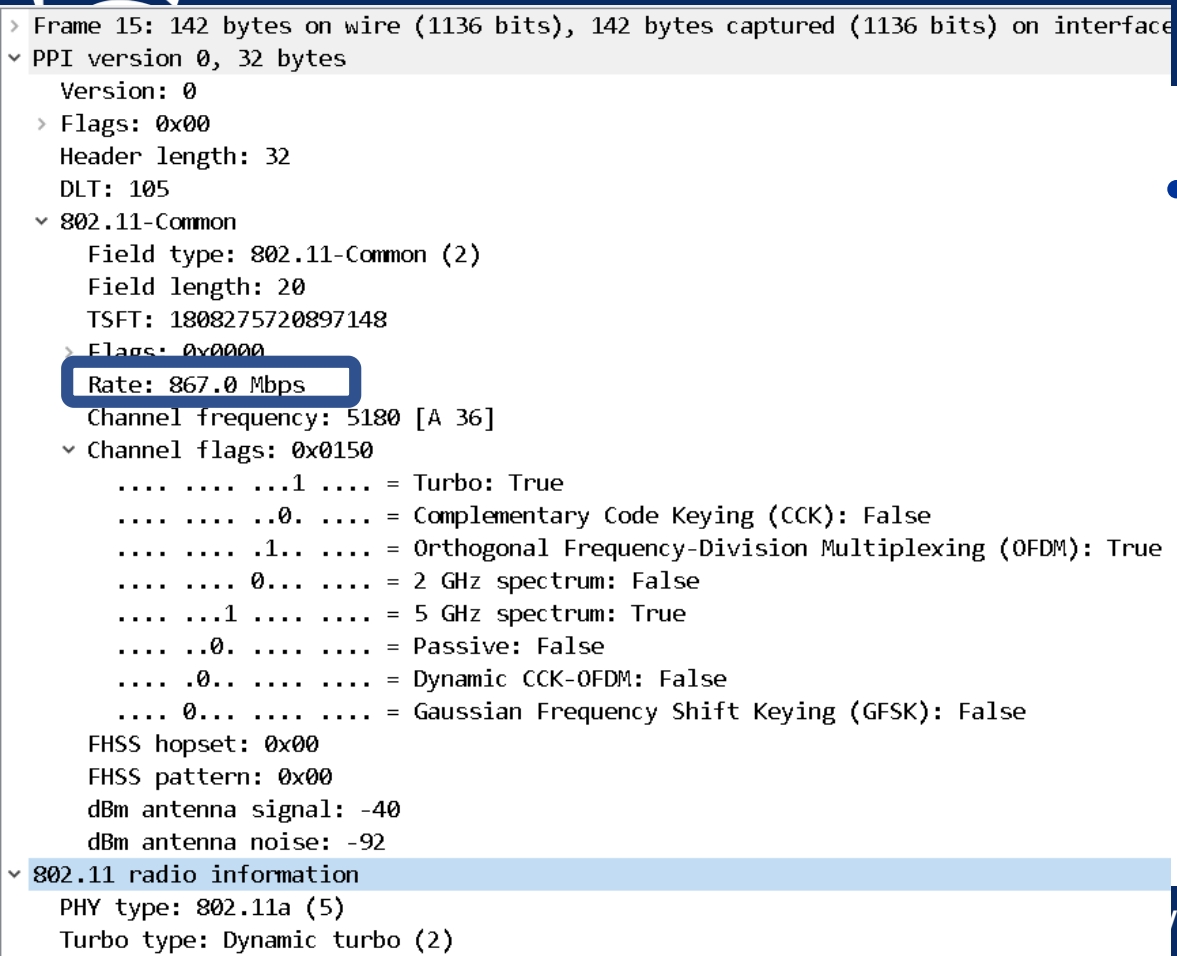


Visualize packet with Flow Graph

- You can also create Flow Graph from Statistics to visualize the sequence of 11ac from link up, wpa2 4 way handshake, and icmp (ping) request/response



Check speed of #15 packet



- Look inside of packet detail pane of #15 frame, and check Rate is 867Mbps,maximum rate of 80MHz bandwidth (2 spatial streams)

Check MCS index of 11ac

We need to check MCS (modulation code set) table to specify MCS number, modulation, coding, bandwidth, Data rate with short/long guard interval, minimum SNR and required RSSI

802.11ac - VHT MCS, SNR and RSSI

VHT MCS	Modulation	Coding	20MHz				40MHz				80MHz				160MHz			
			Data Rate		Min.		Data Rate		Min.		Data Rate		Min.		Data Rate		Min.	
			800ns	400ns	SNR	RSSI	800ns	400ns	SNR	RSSI	800ns	400ns	SNR	RSSI	800ns	400ns	SNR	RSSI
1 Spatial Stream																		
0	BPSK	1/2	6.5	7.2	2	-82	13.5	15	5	-79	29.3	32.5	8	-76	58.5	65	11	-73
1	QPSK	1/2	13	14.4	5	-79	27	30	8	-76	58.5	65	11	-73	117	130	14	-70
2	QPSK	3/4	19.5	21.7	9	-77	40.5	45	12	-74	87.8	97.5	15	-71	175.5	195	18	-68
3	16-QAM	1/2	26	28.9	11	-74	54	60	14	-71	117	130	17	-68	234	260	20	-65
4	16-QAM	3/4	39	43.3	15	-70	81	90	18	-67	175.5	195	21	-64	351	390	24	-61
5	64-QAM	2/3	52	57.8	18	-66	108	120	21	-63	234	260	24	-60	468	520	27	-57
6	64-QAM	3/4	58.5	65	20	-65	121.5	135	23	-62	263.3	292.5	26	-59	526.5	585	29	-56
7	64-QAM	5/6	65	72.2	25	-64	135	150	28	-61	292.5	325	31	-58	585	650	34	-55
8	256-QAM	3/4	78	86.7	29	-59	162	180	32	-56	351	390	35	-53	702	780	38	-50
9	256-QAM	5/6			31	-57	180	200	34	-54	390	433.3	37	-51	780	866.7	40	-48
2 Spatial Streams																		
0	BPSK	1/2	13	14.4	2	-82	27	30	5	-79	58.5	65	8	-76	117	130	11	-73
1	QPSK	1/2	26	28.9	5	-79	54	60	8	-76	117	130	11	-73	234	260	14	-70
2	QPSK	3/4	39	43.3	9	-77	81	90	12	-74	175.5	195	15	-71	351	390	18	-68
3	16-QAM	1/2	52	57.8	11	-74	108	120	14	-71	234	260	17	-68	468	520	20	-65
4	16-QAM	3/4	78	86.7	15	-70	162	180	18	-67	351	390	21	-64	702	780	24	-61
5	64-QAM	2/3	104	115.6	18	-66	216	240	21	-63	468	520	24	-60	936	1040	27	-57
6	64-QAM	3/4	117	130.3	20	-65	243	270	23	-62	526.5	585	26	-59	1053	1170	29	-56
7	64-QAM	5/6	130	144.4	25	-64	270	300	28	-61	585	650	31	-58	1170	1300	34	-55
8	256-QAM	3/4	156	173.3	29	-59	324	360	32	-56	702	780	35	-53	1404	1560	38	-50
9	256-QAM	5/6			31	-57	360	400	34	-54	780	866.7	37	-51	1560	1733.3	40	-48
3 Spatial Streams																		
0	BPSK	1/2	19.5	21.7	2	-82	40.5	45	5	-79	87.8	97.5	8	-76	175.5	195	11	-73
1	QPSK	1/2	39	43.3	5	-79	81	90	8	-76	175.5	195	11	-73	351	390	14	-70
2	QPSK	3/4	58.5	65	9	-77	121.5	135	12	-74	263.3	292.5	15	-71	526.5	585	18	-68
3	16-QAM	1/2	78	86.7	11	-74	162	180	14	-71	351	390	17	-68	702	780	20	-65
4	16-QAM	3/4	117	130	15	-70	243	270	18	-67	526.5	585	21	-64	1053	1170	24	-61
5	64-QAM	2/3	156	173.3	18	-66	324	360	21	-63	702	780	24	-60	1404	1560	27	-57
6	64-QAM	3/4	175.5	195	20	-65	364.5	405	23	-62			26	-59	1579.5	1755	29	-56
7	64-QAM	5/6	195	216.7	25	-64	405	450	28	-61	877.5	975	31	-58	1755	1950	34	-55
8	256-QAM	3/4	234	260	29	-59	486	540	32	-56	1053	1170	35	-53	2106	2340	38	-50
9	256-QAM	5/6	260	288.9	31	-57	540	600	34	-54	1170	1300	37	-51			40	-48

(https://www.wlanpros.com/mcs-index-charts/)

2 special streams , 80MHz 867Mbps

802.11ac - VHT MCS, SNR and RSSI

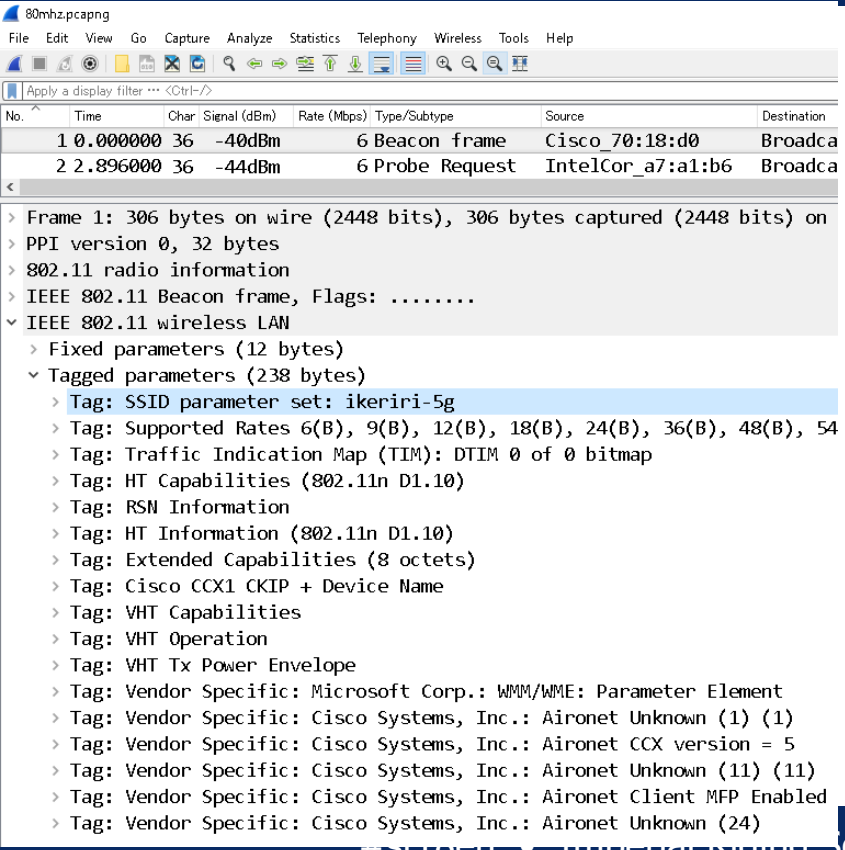
VHT MCS	Modulation	Coding	20MHz				40MHz				80MHz			
			Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI
			800ns	400ns			800ns	400ns			800ns	400ns		
2 Spatial Streams														
0	BPSK	1/2	13	14.4	2	-82	27	30	5	-79	58.5	65	8	-76
1	QPSK	1/2	26	28.9	5	-79	54	60	8	-76	117	130	11	-73
2	QPSK	3/4	39	43.3	9	-77	81	90	12	-74	175.5	195	15	-71
3	16-QAM	1/2	52	57.8	11	-74	108	120	14	-71	234	260	17	-68
4	16-QAM	3/4	78	86.7	15	-70	162	180	18	-67	351	390	21	-64
5	64-QAM	2/3	104	115.6	18	-66	216	240	21	-63	468	520	24	-60
6	64-QAM	3/4	117	130.3	20	-65	243	270	23	-62	526.5	585	26	-59
7	64-QAM	5/6	130	144.4	25	-64	270	300	28	-61	585	650	31	-58
8	256-QAM	3/4	156	173.3	29	-59	324	360	32	-56	702	780	35	-53
9	256-QAM	5/6			31	-57	360	400	34	-54	780	866.7	37	-51

MCS 9, Short GI 400ns, Min SNR 37db, RSSI -51dBm

We can capture data frame of 80MHz, MCS9, 2SS

- This time we can capture 80MHz MCS9 2SS data frame (only 802.11-common without VHT PHY info) in Windows environment
- Because capture hardware AWUS1900 4x4:3 and capture driver just write out 802.11-common fields in PPI header (I hope to add more PHY info)
- Anyway we can caputure 867Mbps frames !

Check Very High Throughput information in beacon frame



Select #1 packet to extract IEEE802.11 wireless LAN header > Tagged parameters > VHT Capabilities header

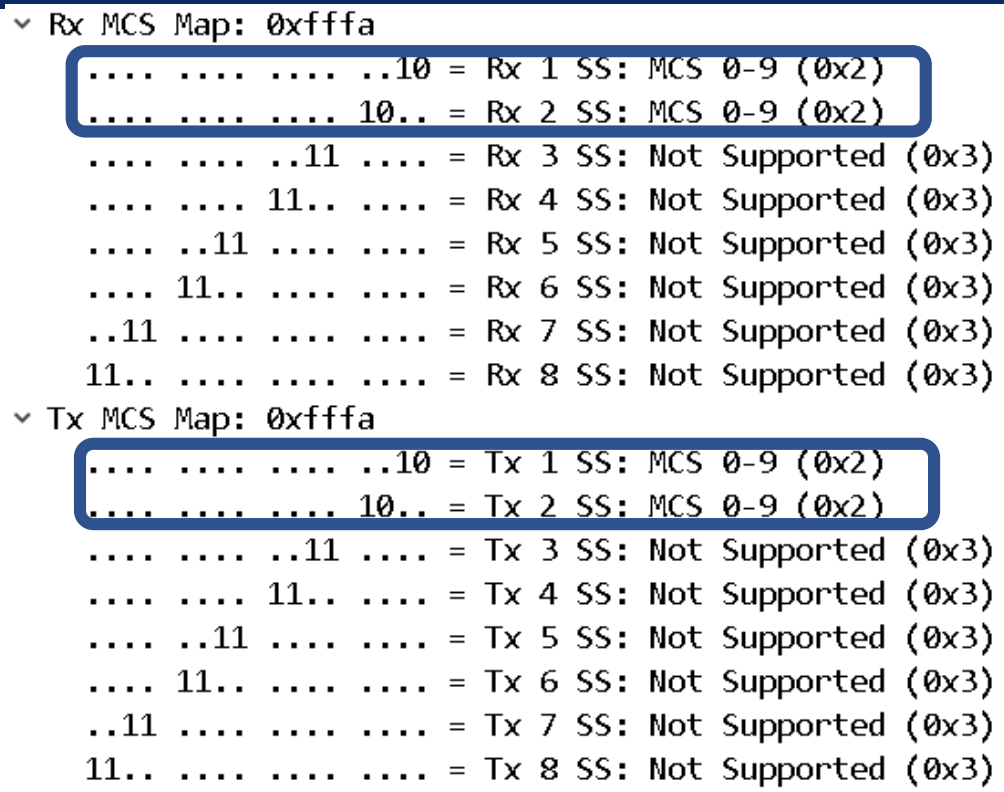
Check the each field of VHT Capabilities

VHT Capabilities shows AP spec

Extract VHT Capabilities > VHT Capabilities Info

```
VHT Capabilities Info: 0x0f8259b2
   .... .... .... .... .... .... .... ..10 = Maximum MPDU Length: 11 454 (0x2)
   .... .... .... .... .... .... .... 00.. = Supported Channel Width Set: Neither 160MHz nor 80+80 supported (0x0)
   .... .... .... .... .... .... ...1 .... = Rx LDPC: Supported
   .... .... .... .... .... .... ..1. .... = Short GI for 80MHz/TVHT_MODE_4C: Supported
   .... .... .... .... .... .... .0.. .... = Short GI for 160MHz and 80+80MHz: Not supported
   .... .... .... .... .... .... 1... .... = Tx STBC: Supported
   .... .... .... .... .... .001 .... .... = Rx STBC: 1 Spatial Stream Supported (0x1)
   .... .... .... .... .... 1... .... .... = SU Beamformer Capable: Supported
   .... .... .... .... ...1 .... .... .... = SU Beamformee Capable: Supported
   .... .... .... .... 010. .... .... .... = Beamformee STS Capability: 3 (0x2)
   .... .... .... .010 .... .... .... .... = Number of Sounding Dimensions: 3 (0x2)
   .... .... .... 0... .... .... .... .... = MU Beamformer Capable: Not supported
   .... .... ...0 .... .... .... .... .... = MU Beamformee Capable: Not supported
   .... .... ..0. .... .... .... .... .... = TXOP PS: Not supported
   .... .... .0.. .... .... .... .... .... = +HTC-VHT Capable: Not supported
   .... ..11 1... .... .... .... .... .... = Max A-MPDU Length Exponent: 1 048 575 (0x7)
   .... 11.. .... .... .... .... .... .... = VHT Link Adaptation: Both (can provide unsolicited feedback and respon
   ...0 .... .... .... .... .... .... .... = Rx Antenna Pattern Consistency: Not supported
   ..0. .... .... .... .... .... .... .... = Tx Antenna Pattern Consistency: Not supported
   00.. .... .... .... .... .... .... .... = Extended NSS BW Support: 0x0
```

Rx/Tx MCS Map



Extract VHT Capabilities > Rx/Tx MCS Map
This AP can use 1 or 2 spatial streams with MCS 0-9 in sending and receiving frame.

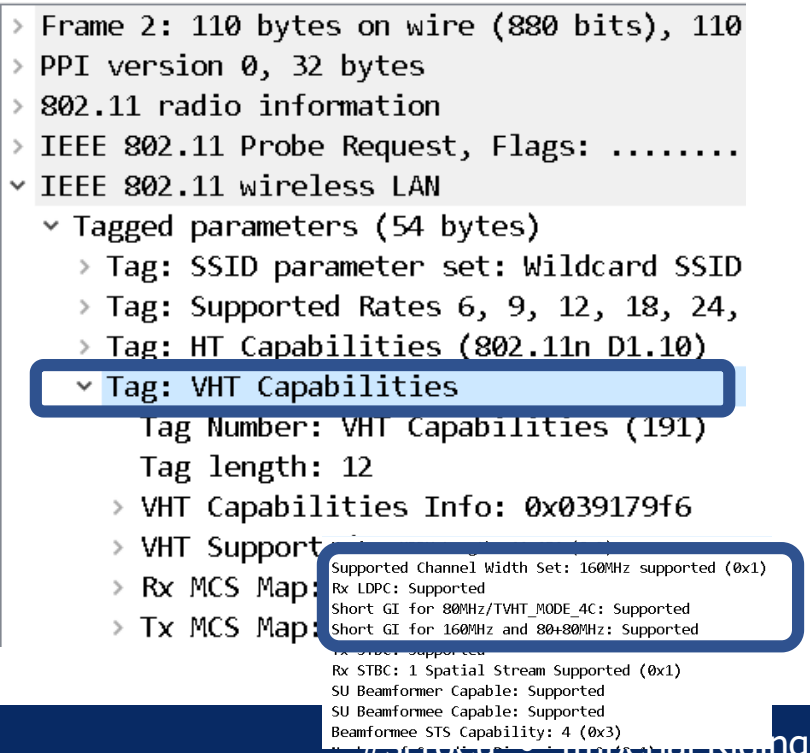
MCS number table

VHT MCS	Modulation	Coding
0	BPSK	1/2
1	QPSK	1/2
2	QPSK	3/4
3	16-QAM	1/2
4	16-QAM	3/4
5	64-QAM	2/3
6	64-QAM	3/4
7	64-QAM	5/6
8	256-QAM	3/4
9	256-QAM	5/6

- 11ac MCS number is simple to understand, in any bandwidth and streams, the MCS number indicates the same Modulation and Coding.
- 256QAM Modulation and 5/6 coding are used in MCS9 in AC (just 1 symbol sends 256 value = 2^8 8bits and send 5bits then add 1 error correction bit)

STA's Probe Request and AP's Probe Response

Select #2/3 frames and extract IEEE802.11 wireless LAN



> Tagged parameters

> VHT capabilities

Intel card send 11ac spec information

This STA can use 160MHz bandwidth as well as 80+80 (optional) bandwidth, but AP cannot.

STA's Association Request and AP's Association Response

Select #6/7 frames and extract IEEE802.11 wireless LAN

```
Maximum MPDU Length: 11 454 (0x2)
Supported Channel Width Set: Neither 160MHz nor 80+80 supported
Rx LDPC: Supported
Short GI for 80MHz/TVHT_MODE_4C: Supported
Short GI for 160MHz and 80+80MHz: Not supported
Tx STBC: Supported
Rx STBC: 1 Spatial Stream Supported (0x1)
SU Beamformer Capable: Supported
SU Beamformee Capable: Supported
Beamformee STS Capability: 3 (0x2)
Number of Sounding Dimensions: 2 (0x1)
MU Beamformer Capable: Not supported
MU Beamformee Capable: Not supported
TXOP PS: Not supported
+HTC-VHT Capable: Not supported
Max A-MPDU Length Exponent: 1 048 575 (0x7)
VHT Link Adaptation: No Feedback (0x0)
Rx Antenna Pattern Consistency: Not supported
Tx Antenna Pattern Consistency: Not supported
Extended NSS BW Support: 0x0
```

> Tagged parameters

> VHT capabilities

STA says 160MHz or 80+80MHz but AP choose 80MHz bandwidth to associate.

160MHz MCS8/9 2SS in Wave 2

- 11ac has option specifications a.k.a. wave 2 160MHz or 80+80 MHz bandwidth, MCS 8 or 9, 256QAM, and 4 spatial streams
- In actual 80+80MHz is compli -cated so many AP uses 160MHz (sometimes called as VHT160) and many laptop supports 2 spatial streams
- Finally the throughput is reached at 1.7Gbps

2 special streams 160MHz 1733Mbps

802.11ac - VHT MCS, SNR and RSSI

VHT MCS	Modulation	Coding	20MHz				40MHz				80MHz				160MHz			
			Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI
			800ns	400ns			800ns	400ns			800ns	400ns			800ns	400ns		
2 Spatial Streams																		
0	BPSK	1/2	13	14.4	2	-82	27	30	5	-79	58.5	65	8	-76	117	130	11	-73
1	QPSK	1/2	26	28.9	5	-79	54	60	8	-76	117	130	11	-73	234	260	14	-70
2	QPSK	3/4	39	43.3	9	-77	81	90	12	-74	175.5	195	15	-71	351	390	18	-68
3	16-QAM	1/2	52	57.8	11	-74	108	120	14	-71	234	260	17	-68	468	520	20	-65
4	16-QAM	3/4	78	86.7	15	-70	162	180	18	-67	351	390	21	-64	702	780	24	-61
5	64-QAM	2/3	104	115.6	18	-66	216	240	21	-63	468	520	24	-60	936	1040	27	-57
6	64-QAM	3/4	117	130.3	20	-65	243	270	23	-62	526.5	585	26	-59	1053	1170	29	-56
7	64-QAM	5/6	130	144.4	25	-64	270	300	28	-61	585	650	31	-58	1170	1300	34	-55
8	256-QAM	3/4	156	173.3	29	-59	324	360	32	-56	702	780	35	-53	1404	[illegible]	38	-50
9	256-QAM	5/6			31	-57	360	400	34	-54	780	866.7	37	-51	1560	1733.3	40	-48

MCS 9, Short GI, Min SNR 40db, required RSSI -48dBm

The laptop logical speed can be reached at 1.7Gbps

Netgear R7800 Nighthawk X4S

Netgear R7800 -100NAS (v2)
Availability: now

Manuf/OEM/ODM Delta Networks

FCC approval date: 04 November 2015
(Est.) release date: 04 January 2016
Country of manuf.: China
Series: AC2600

Amazon image

ASIN
B0192911RA (, On Amazon, On CCC)
On Newegg

Type: wireless router

FCC ID: PY315100319
PCB ID: 2976495801

Power: 12 VDC, 3.5 A
Connector type: barrel

CPU1: Qualcomm IPQ8065 (1.7 GHz, 2 cores)
FLA1: 128 MiB (Micron MT29F1G08ABBEAH4:E)
RAM1: 512 MiB (Nanya NT5CC128M16IP-DI × 2)

Expansion IFs: USB 3.0, eSATA
USB ports: 2
SATA ports: 1
Serial: yes

WI1 chip1: Qualcomm Atheros QCA9984
WI1 802dot11 protocols: an+ac
WI1 MIMO config: 4x4:4
WI1 antenna connector: U.FL
WI2 chip1: Qualcomm Atheros QCA9984
WI2 802dot11 protocols: bgn
WI2 MIMO config: 4x4:4
WI2 antenna connector: U.FL

ETH chip1: Qualcomm IPQ8065
Switch: Qualcomm Atheros QCA8337
LAN speed: 10/100/1000
LAN ports: 4
WAN speed: 10/100/1000
WAN ports: 1

abgn+ac

Additional chips
2.4GHz Power Amplifier Module;Skyworks;SE2623L;;4;
5GHz Power Amplifier Module;RFMD;RFPA5542;;4;

Stock bootloader: U-Boot

Stock FW OS: Linux

Third party firmware supported: DD-WRT (Kong-AC) • (List), LEDE Project • (List)

Flags: Wave2, MU-MIMO, VHT160, DFS

Default IP address: http://www.routerlogin.net
the IP http://www.routerlogin.net is used by 3 additional devices
of which 3 are **Netgear** devices
Default login user: admin
Default login password: password
admin:password credentials used by 381 additional devices
of which 274 are **Netgear** devices

802dot11 OUI: none specified

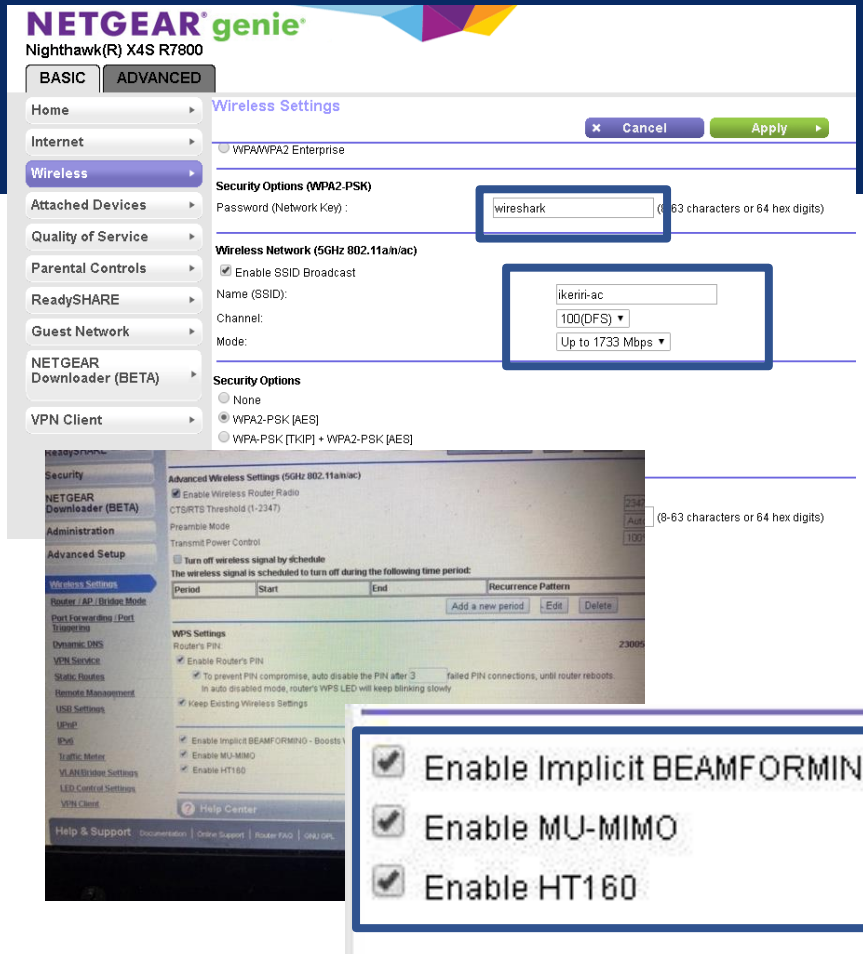
I tried Netgear R7800 Nighthawk X4S, supports abgn+ac, wave2, MU-MIMO, VHT160, DFS.
5GHz chipset is Qualcomm Atheros QCA9984 (4x4:4)

There are open source firmware but it is prohibited in Japan (radio law...)

Netgear R7800 Nighthawk X4S and Intel Wireless-AC 9260NGW

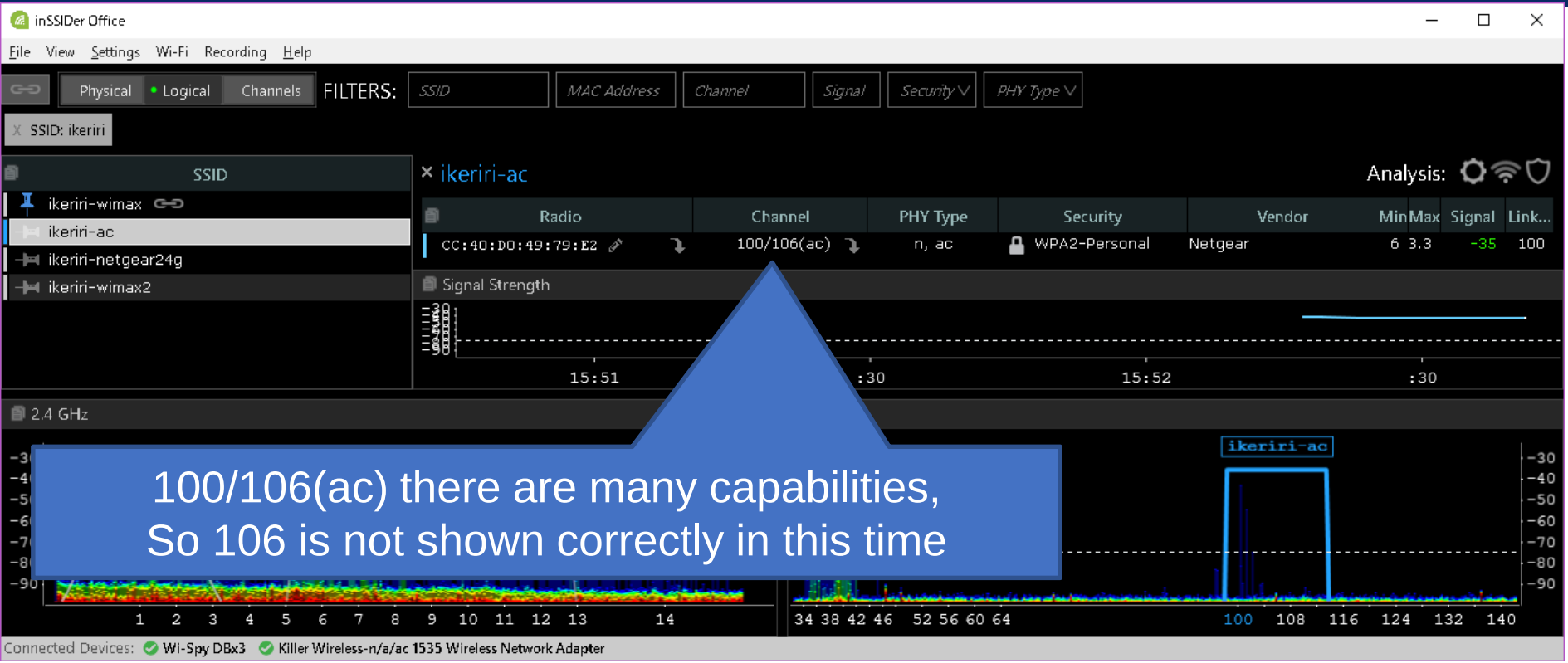
- In November 2018, there are a few combination of AP and STA to get 1.7Gbps
- Also we cannot always get maximum logical speed because of RSSI, SNR, other radio signal, etc.
- 80+80Mhz bandwidth settings may not work (if supported)

Set up like this



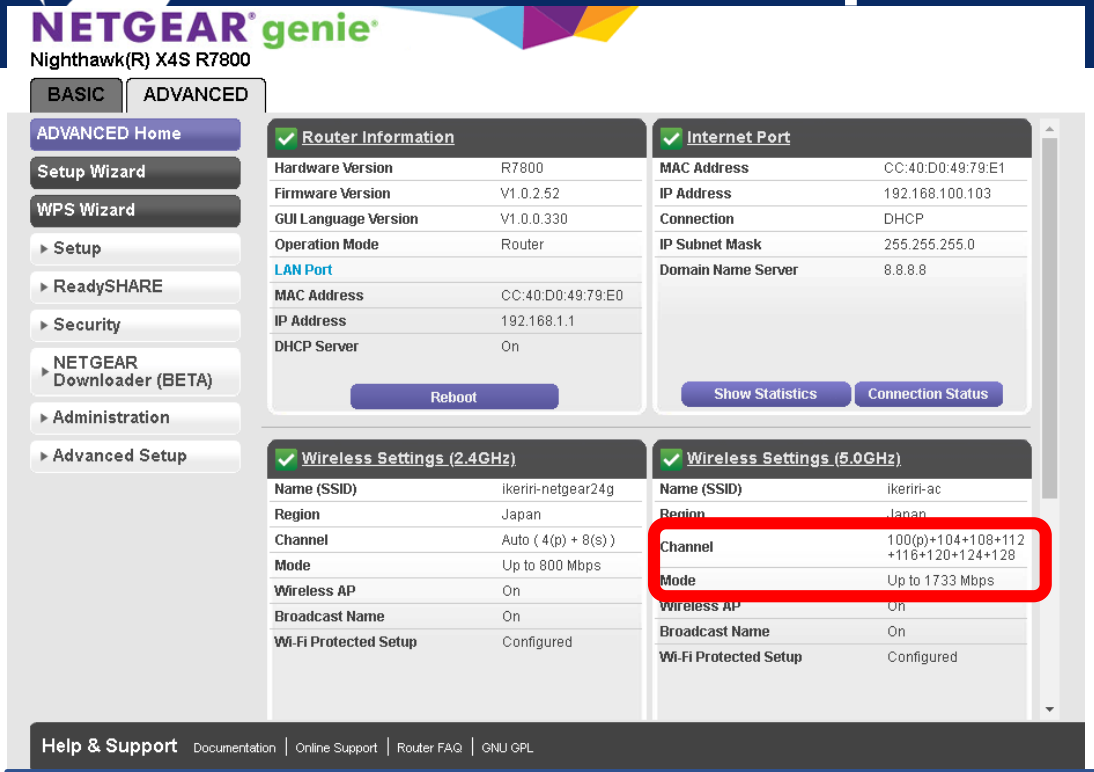
- SSID: ikeriri-ac
- WPA2-PSK passphrase:wireshark
- Set channel (100) and mode as up to 1733Mbps
- Enable HT160 (important)
- Enable Implicit BEAMFORMING
- Enable MU-MIMO

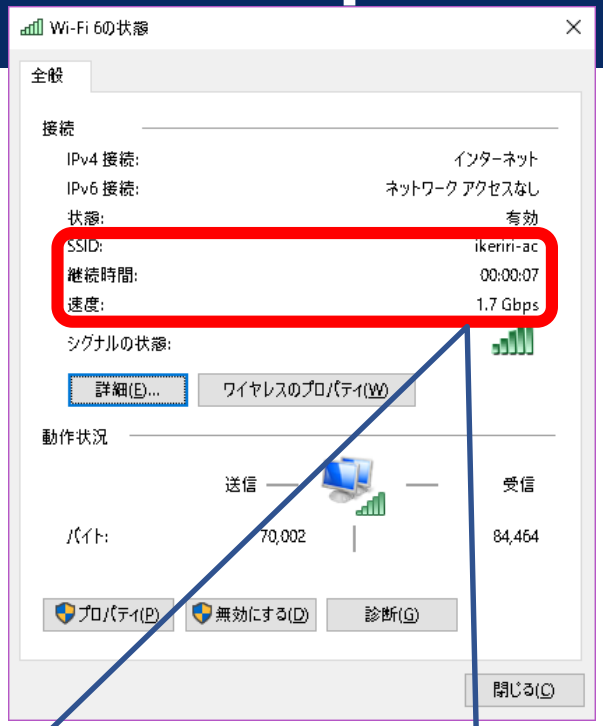
Check the spectrum using InSSIDer Office



100/106(ac) there are many capabilities,
So 106 is not shown correctly in this time

Linked up at 1.7Gbps





MCS 9, Short GI, Min SNR 40db, required RSSI -48dBm

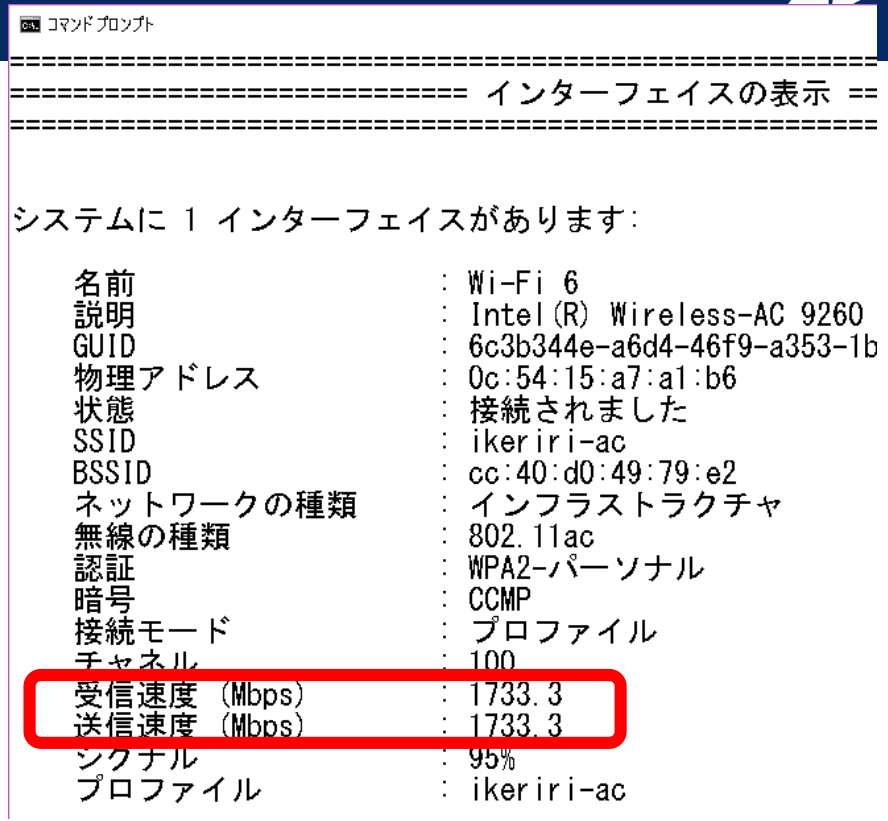
netsh wlan sh all

Open command prompt to type “netsh wlan sh all”

You may find receive rate and send rate is 1733.3Mbps

(some info is written in Japanese)

OK, let’s start capturing ! Wait, VHT160 is not supported by ALFA Realtek RTL8814AU…



Open 160Mhz.pcapng in Wireshark

There are no icmp frame, but we can utilize them !

160Mhz.pcapng

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ··· <Ctrl-/> Expression···

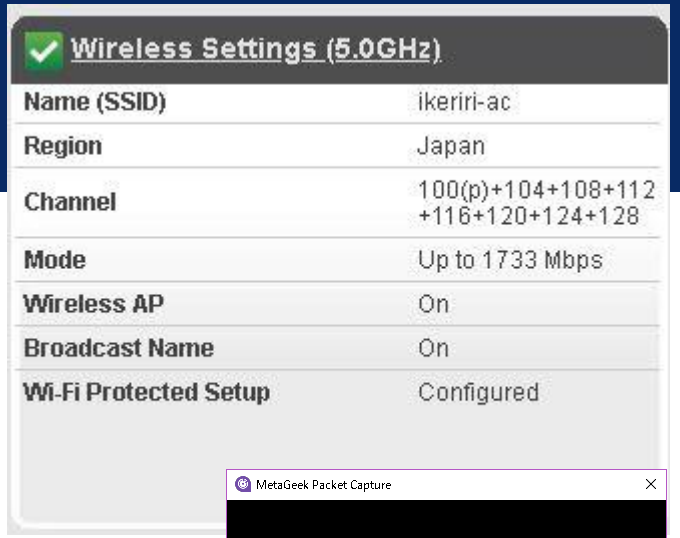
No.	Time	Signal (dBm)	Rate (Mbps)	Type/Subtype	Source	Destination	Protocol	Length	Info
1	0.000000	-28dBm	6	Beacon frame	Netgear_49:79:e2	Broadcast	802.11	368	Beacon frame, SN=2588, FN=0, Flags=........, BI=100, SSID=ikeriri-ac
2	4.649000	-37dBm	6	Probe Request	IntelCor_a7:a1:b6	Broadcast	802.11	110	Probe Request, SN=163, FN=0, Flags=........, SSID=Wildcard (Broadcast)
3	4.649000	-27dBm	6	Probe Response	Netgear_49:79:e2	IntelCor_a7:a1:b6	802.11	469	Probe Response, SN=47, FN=0, Flags=........, BI=100, SSID=ikeriri-ac
4	8.805000	-37dBm	6	Authentication	IntelCor_a7:a1:b6	Netgear_49:79:e2	802.11	62	Authentication, SN=16, FN=0, Flags=........
5	8.805000	-29dBm	6	Authentication	Netgear_49:79:e2	IntelCor_a7:a1:b6	802.11	62	Authentication, SN=49, FN=0, Flags=........
6	8.805000	-37dBm	6	Association R…	IntelCor_a7:a1:b6	Netgear_49:79:e2	802.11	232	Association Request, SN=17, FN=0, Flags=........, SSID=ikeriri-ac
7	8.805000	-28dBm	6	Association R…	Netgear_49:79:e2	IntelCor_a7:a1:b6	802.11	229	Association Response, SN=50, FN=0, Flags=........
8	8.825000	-27dBm	6	QoS Data	Netgear_49:79:e2	IntelCor_a7:a1:b6	EAPOL	165	Key (Message 1 of 4)
9	8.825000	-37dBm	6	QoS Data	IntelCor_a7:a1:b6	Netgear_49:79:e2	EAPOL	189	Key (Message 2 of 4)
10	8.856000	-28dBm	6	QoS Data	Netgear_49:79:e2	IntelCor_a7:a1:b6	EAPOL	221	Key (Message 3 of 4)
11	8.856000	-38dBm	6	QoS Data	IntelCor_a7:a1:b6	Netgear_49:79:e2	EAPOL	165	Key (Message 4 of 4)
12	8.906000	-72dBm	54	QoS Data	0.0.0.0	255.255.255.255	DHCP	426	DHCP Request - Transaction ID 0x3daae13d

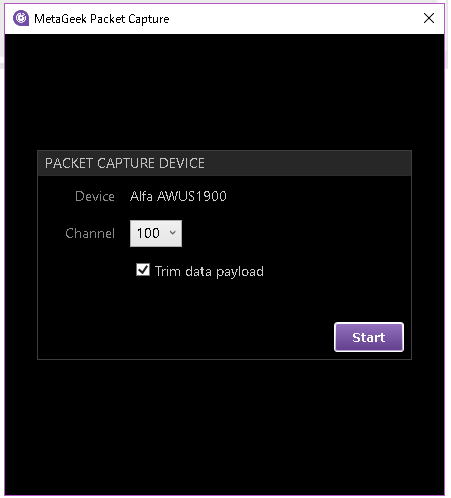
```
> Frame 1: 368 bytes on wire (2944 bits), 368 bytes captured (2944 bits) on interface 0
> PPI version 0, 32 bytes
> 802.11 radio information
> IEEE 802.11 Beacon frame, Flags: ........
> IEEE 802.11 wireless LAN
```

```
0000  00 00 20 00 69 00 00 00  02 00 14 00 8c 00 00 00   ·· ·i··· ········
0010  0f 96 0e 00 00 00 0c 00  7c 15 50 01 00 00 e4 a0   ········ |·P·····
0020  80 00 00 00 ff ff ff ff  ff ff cc 40 d0 49 79 e2   ········ ···@·Iy·
```

160Mhz.pcapng Packets: 12 · Displayed: 12 (100.0%) Profile: 11ac

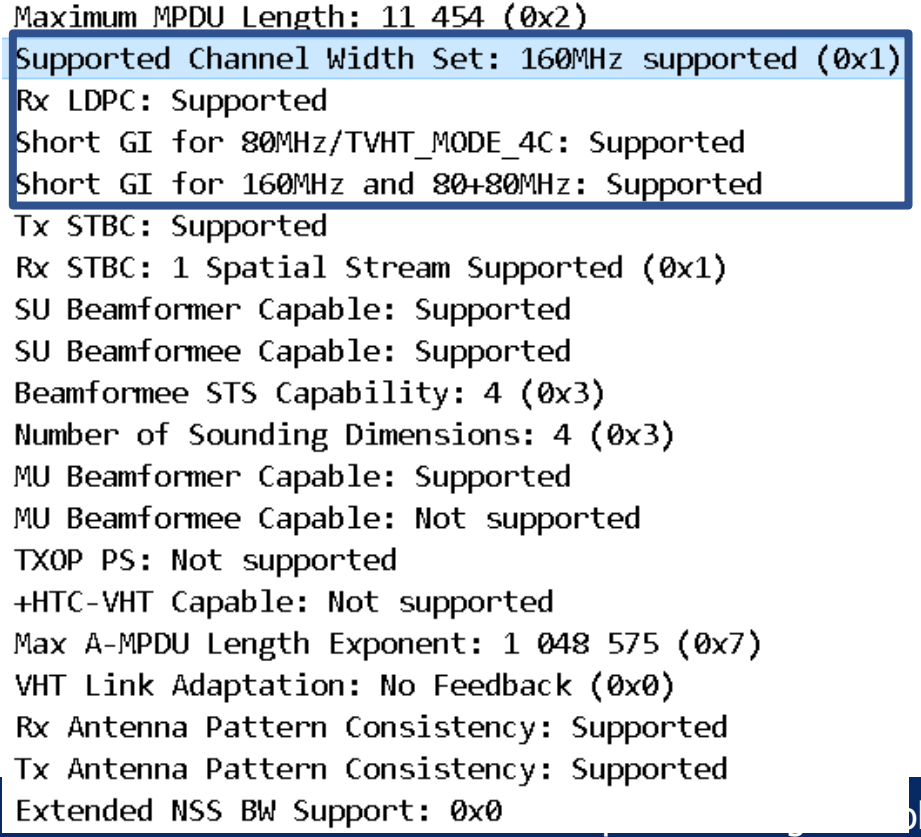
Open 160Mhz.pcap





- We can capture beacon, probe request / response, authentication, association request / response, wpa2-psk 4way handshake, and few data frames that sent in a low rate because capture hardware and capture driver do not support 160Mhz bandwidth…
- But we can capture all connection process, all 4way handshake, deauth, disassoc, and other management frames for analysis.
- We can debug and troubleshoot !

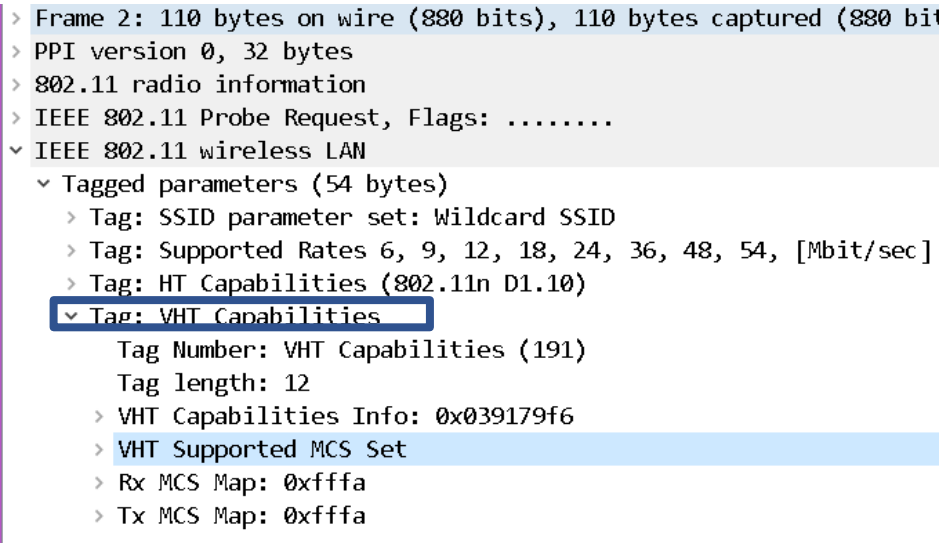
Select #1 beacon frame and extract VHT capabilities

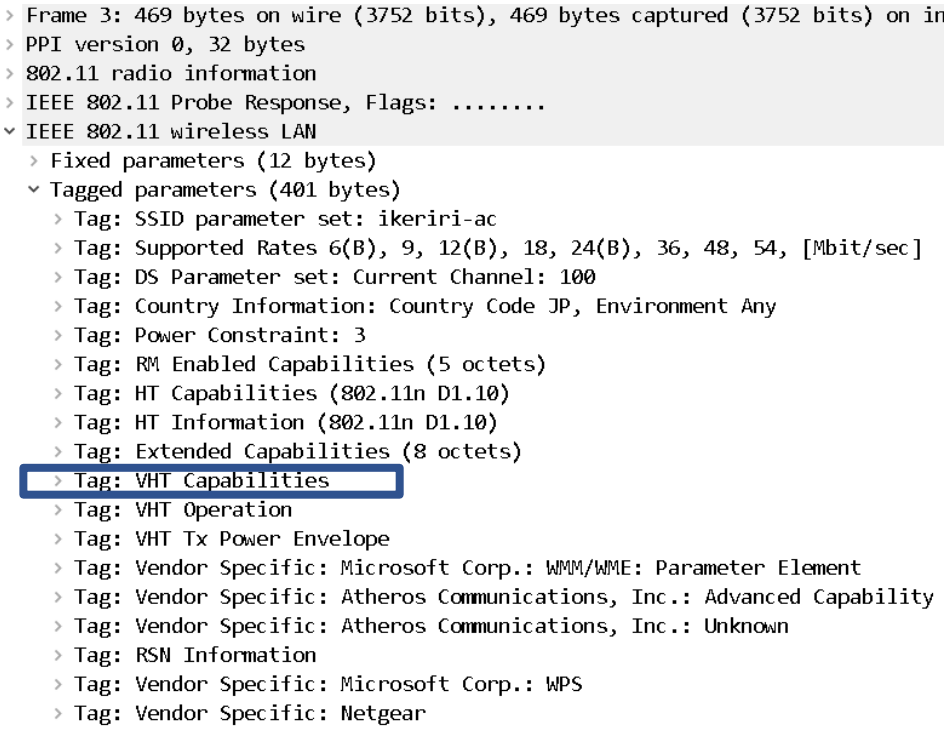


Select #1 frame and extract IEEE802.11 wireless LAN > Tagged parameters > VHT Capabilities > VHT Capabilities Info and check each field.

You can find both AP and STA support 160Mhz

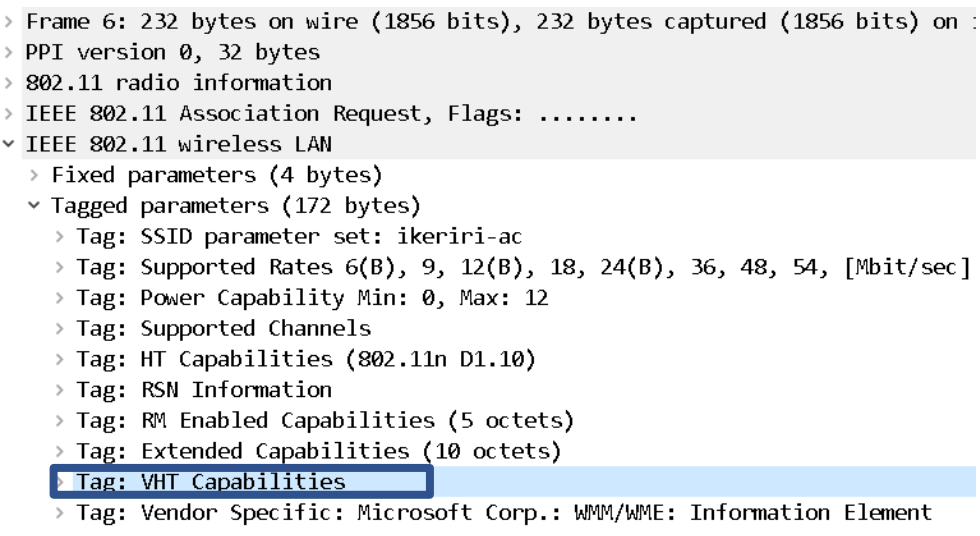
Select #2/3 probe request / probe response

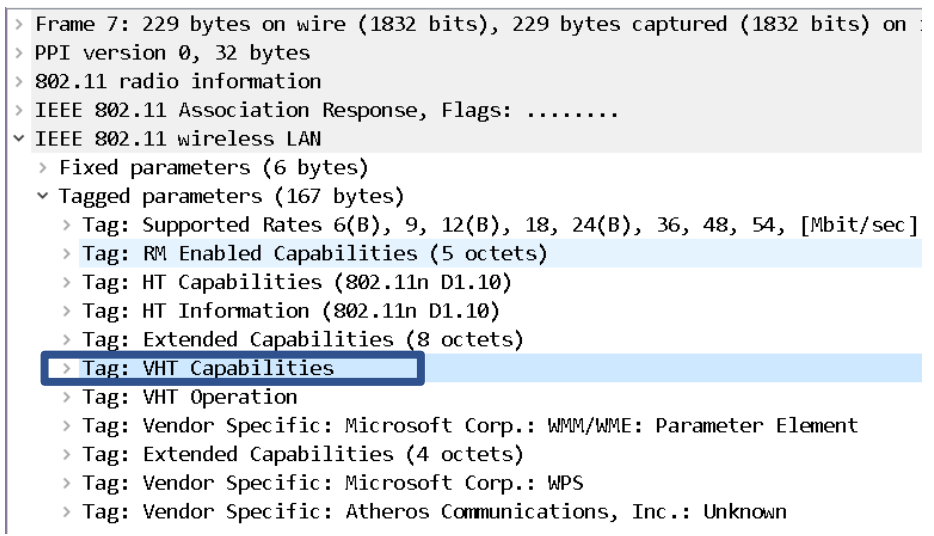




Check VHT Capabilities in probe request / response

Select #6/7 association request / association response frame





Check VHT Capabilities in association request / association response

We can **partly** debug and troubleshoot 160Mhz bandwidth

Unfortunately this time we can capture 80MHz data frame at 867Mbps, cannot capture 160MHz bandwidth. Other 160MHz bandwidth WLAN card such as Atheros may be used in windows environment in the future.

But we can still caputure and troubleshoot 160MHz bandwidth to look other compatible frames, such as management, control and 4way handshake frames.

Wireshark opens the door to dissect 11ac !

USE WIRESHARK

Thank you for attending !

どうもありがとうございました

Supplemental file

http://www.ikeriri.ne.jp/sharkfest

いけりり★ネットワークサービス

http://www.ikeriri.ne.jp