Title

Root cause audio issues during a voice readiness assessment.

Brief

During a paid-for readiness assessment of a customer WLAN for voice support there were large audio gaps, longer than should be experienced even with slow roams. Protocol Analysis was used to determine the cause.

This was a brand-new healthcare building being assessed ready for opening. There were almost no other clients associated to the WLAN at the time of testing.

Diagnosis

The first step was to graph the audio streams to look for unusual behaviour. I used Wireshark Display Filters to see:

- Upstream QoS Data – Black line
- Downstream QoS Data – Blue Line
- Upstream Retries – Red Bars
- Probe Requests – Green Bars

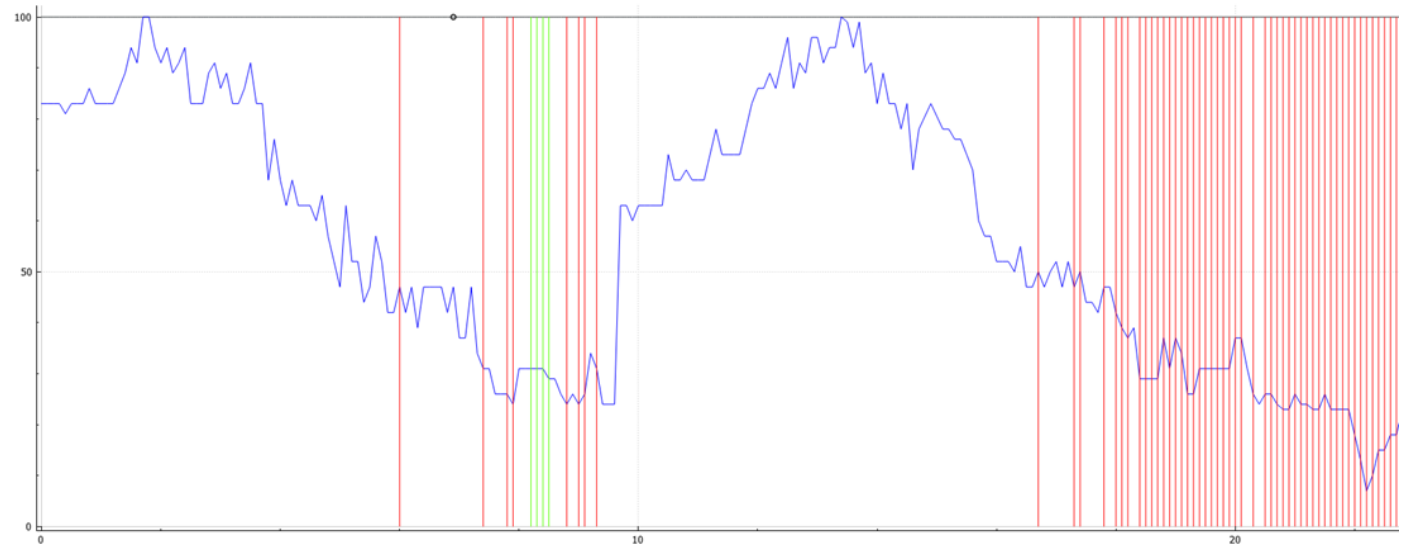
Note: It is important to use the Transmitter Address (TA) and Receiver Address (RA) as the Source/Destination Address can be different to the station that actually sent or is receiving the frame.

Note: I have captured Wireshark filters used in the screenshots.

The X Axis represents time passing and the Y axis represents signal quality.

Figure 1 shows us that the voice conversation was working well for the first ~17 seconds. Very few retries (red bars), downstream signal (blue line) decreasing and increasing as I move from AP to AP, and probes (green bars) when signal gets low enough to warrant a roam.

However, at ~18 seconds the upstream retries (red bars) start increasing until they are constant. The downstream signal strength (blue line) keeps dropping lower and lower, and the client keeps transmitting constantly (black line along top). But you do not see any probe requests (green bars) from the client to initiate a roam.



abled	Graph Name	Display Filter	Color	Style	Y Axis	Y Field	SMA Period
☐	A	(wlan.fc.type_subtype == 0x0008) and (wlan.bssid == 00:f2:8b:15:86:2e)		Line	MIN(Y Field)	wlan_radio.snr	None
☑	Up QoS Data	(wlan.ta == [redacted]:32:57:1c) && (wlan.fc.type_subtype == 0x0028)		Line	MAX(Y Field)	wlan_radio.signal_percentage	None
☑	Down Qos Data	(wlan.ra == [redacted]:32:57:1c) && (wlan.fc.type_subtype == 0x0028)		Line	MAX(Y Field)	wlan_radio.signal_percentage	None
☑	Client Probes	(wlan.ta == [redacted]:32:57:1c) && (wlan.fc.type_subtype == 0x0004)		Impulse	MAX(Y Field)	wlan_radio.signal_percentage	None
☑	Up QoS Retry	(wlan.ta == [redacted]:32:57:1c) && (wlan.fc.type_subtype == 0x0028) && (wlan.fc.retry == 1)		Impulse	MAX(Y Field)	wlan_radio.signal_percentage	None

Figure 1 - Data Stream Graph

The client uses Beacon strength to determine its connection quality, so now I needed to verify beacon strength of the BSSID. Figure 2 shows that at 19 seconds the client (00:09:ef:32:57:1c) was transmitting its data frames to (therefore associated to) BSSID 00:fe:c8:fe:98:1e.

(wlan.ta == [redacted]:32:57:1c) && (wlan.fc.type_subtype == 0x0028)

Frame	AbTime	Time	Delta	Source	Destination	BSSID	Info
16134	13:19:37.…	19.012	0.017	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16153	13:19:37.…	19.031	0.018	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16154	13:19:37.…	19.031	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16155	13:19:37.…	19.032	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16166	13:19:37.…	19.049	0.016	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16180	13:19:37.…	19.066	0.017	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16181	13:19:37.…	19.067	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16196	13:19:37.…	19.084	0.017	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16197	13:19:37.…	19.085	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16198	13:19:37.…	19.085	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16199	13:19:37.…	19.085	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,
16200	13:19:37.…	19.086	0.000	[redacted]_32:57:1c	[redacted]_32:57:45	00:fe:c8:fe:98:1e	QoS Data,

Figure 2 - Associated BSSID

Figure 3 below shows the Beacons for the BSSID throughout most of the capture. Industry standard has the beacons sent every 100 Time Units (TU) or 102.4 milliseconds, so a client will receive roughly 10 per second. The voice client averages the signal from the last 10 beacons to monitor its connection quality. Figure 3 demonstrates several pieces of information, highlighted and numbered.

1. Beacons from the SSID are coming in every ~100ms as expected. The signal strength is low but it is good enough to be pass CCA thresholds, and the client has not yet roamed to this AP. The strength goes up as I approach the AP.
2. The timing changes here and the sequence number jumps 6 instead of the usual 3 digits. Looks like it missed a beacon which is not unusual. Beacons are not acknowledged or resent so a collision at either the transmitter or receiver can mean they get missed occasionally.
3. Timing returns more or less to normal although a few beacons are still missing. The signal strength is still good. This inconsistency is concerning.
4. Beacon timing is extremely inconsistent with large gaps between beacons. Many clients use the regularity and consistency of beacons to determine and maintain their connection, so this is not compatible with a functional WLAN.
   The signal strength is high, so these beacons are not being missed because of attenuation or corruption.
5. It was ~19 seconds that downstream retries increased to an unsupportable level. You can see that ZERO beacons were captured between 15 and 20 seconds. When a beacon did come in at 20.022 seconds you can see the signal of the AP has dropped to -78dBm which is not compatible with a satisfactory voice stream and explains why retries have increased.

(wlan.fc.type_subtype == 0x0008) and (wlan.bssid == 00:fe:c8:fe:98:1e)

	Frame	Time	Delta	Source	Destination	BSSID	RSSI	Rate	Ch	Info
	4072	4.669	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-79 dBm	6.0	48	Beacon frame, SN=950,
	4143	4.773	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-77 dBm	6.0	48	Beacon frame, SN=953,
	4222	4.878	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-79 dBm	6.0	48	Beacon frame, SN=956,
1.	4300	4.982	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-73 dBm	6.0	48	Beacon frame, SN=959,
	4382	5.087	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-73 dBm	6.0	48	Beacon frame, SN=962,
	4458	5.191	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-75 dBm	6.0	48	Beacon frame, SN=965,
	4534	5.296	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=968,
	4620	5.400	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=971,
2.	4780	5.609	0.208	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-72 dBm	6.0	48	Beacon frame, SN=977,
	4861	5.713	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-70 dBm	6.0	48	Beacon frame, SN=980,
	4943	5.818	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=983,
	5194	6.131	0.313	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=992,
3.	5269	6.236	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=995,
	5353	6.340	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-73 dBm	6.0	48	Beacon frame, SN=998,
	5508	6.549	0.208	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-69 dBm	6.0	48	Beacon frame, SN=1004,
	5603	6.653	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=1007,
	5895	6.967	0.313	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-71 dBm	6.0	48	Beacon frame, SN=1016,
	6365	7.489	0.522	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-67 dBm	6.0	48	Beacon frame, SN=1031,
	6881	8.011	0.521	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-67 dBm	6.0	48	Beacon frame, SN=1046,
	6966	8.116	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-65 dBm	6.0	48	Beacon frame, SN=1049,
	7046	8.220	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-67 dBm	6.0	48	Beacon frame, SN=1052,
	7328	8.533	0.313	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-67 dBm	6.0	48	Beacon frame, SN=1061,
4.	8142	9.473	0.940	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-68 dBm	6.0	48	Beacon frame, SN=1086,
	8718	10.100	0.626	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-67 dBm	6.0	48	Beacon frame, SN=1107,
	8806	10.205	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-67 dBm	6.0	48	Beacon frame, SN=1110,
	8976	10.413	0.208	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-68 dBm	6.0	48	Beacon frame, SN=1116,
	11354	13.338	2.924	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-52 dBm	6.0	48	Beacon frame, SN=1201,
	11431	13.442	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-53 dBm	6.0	48	Beacon frame, SN=1204,
5.	12314	14.487	1.044	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-56 dBm	6.0	48	Beacon frame, SN=1234,
	17060	20.022	5.535	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-78 dBm	6.0	48	Beacon frame, SN=1396,
	19497	22.216	2.193	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-84 dBm	6.0	48	Beacon frame, SN=1460,
	21456	23.678	1.462	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-83 dBm	6.0	48	Beacon frame, SN=1502,
	22922	24.513	0.835	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-87 dBm	6.0	48	Beacon frame, SN=1525,
	23048	24.618	0.104	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-85 dBm	6.0	48	Beacon frame, SN=1528,
	32614	37.360	12.742	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-82 dBm	6.0	48	Beacon frame, SN=1895,

Figure 3 - Beacon frames

Next I looked at what could be causing the drastic beacon loss. To see if my equipment was to blame I looked at other downstream data. Figure 4 shows that the equipment was successfully capturing all other voice frames (based on sequence number) around the time of the 14 second beacon, both before and after it when you should see other beacon events. However the timing of the voice frames is wrong – they should arrive every 17-20ms consistently. These downstream voice frames are coming from the AP, so could this AP buffers be overloaded?

((wlan.ra == [redacted]:32:57:1c) && (wlan.fc.type_subtype == 0x0028) && (wlan.fc.retry == 0)) or ((wlan.fc.type_subtype == 0x0008) and (wlan.bssid == 00:fe:c8:fe:98:1e))

Frame	Time	Delta	Source	Destination	BSSID	RSSI	Rate	Ch	Info
12098	14.218	0.017	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-58 dBm	24.0	48	QoS Data, SN=221,
12202	14.383	0.164	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-60 dBm	24.0	48	QoS Data, SN=222,
12207	14.385	0.002	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-60 dBm	24.0	48	QoS Data, SN=223,
12211	14.386	0.000	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-60 dBm	24.0	48	QoS Data, SN=224,
12221	14.387	0.001	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-59 dBm	24.0	48	QoS Data, SN=225,
12226	14.388	0.000	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-61 dBm	24.0	48	QoS Data, SN=226,
12231	14.390	0.001	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-59 dBm	24.0	48	QoS Data, SN=227,
12236	14.391	0.000	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-57 dBm	24.0	48	QoS Data, SN=228,
12240	14.392	0.001	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-59 dBm	24.0	48	QoS Data, SN=229,
12246	14.398	0.006	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-57 dBm	24.0	48	QoS Data, SN=230,
12263	14.416	0.017	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-59 dBm	24.0	48	QoS Data, SN=231,
12279	14.434	0.018	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-61 dBm	24.0	48	QoS Data, SN=232,
12302	14.472	0.037	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-59 dBm	24.0	48	QoS Data, SN=233,
12314	14.487	0.015	Cisco_fe:98:1e	Broadcast	00:fe:c8:fe:98:1e	-56 dBm	6.0	48	Beacon frame, SN=
12335	14.507	0.019	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-57 dBm	24.0	48	QoS Data, SN=235,
12362	14.529	0.022	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-57 dBm	24.0	48	QoS Data, SN=236,
12462	14.678	0.149	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-63 dBm	24.0	48	QoS Data, SN=237,
12470	14.687	0.008	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-63 dBm	24.0	48	QoS Data, SN=238,
12474	14.688	0.001	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-62 dBm	24.0	48	QoS Data, SN=239,
12480	14.689	0.001	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-63 dBm	24.0	48	QoS Data, SN=240,
12487	14.691	0.001	[redacted]_32:57:45	[redacted]_32:57:1c	00:fe:c8:fe:98:1e	-63 dBm	24.0	48	QoS Data, SN=241,

Figure 4 - Downstream data

Next I wanted to check if the airwaves were saturated. Figure 5 shows the QBSS data from the associated AP beacon at that 14 second mark – my voice client is the only one associated and utilisation is very low.

```
> Frame 12314: 292 bytes on wire (2336 bits), 292 bytes captured (2336 bits)
> 802.11 radio information
> IEEE 802.11 Beacon frame, Flags: ........C
v IEEE 802.11 Wireless Management
  > Fixed parameters (12 bytes)
  v Tagged parameters (252 bytes)
    > Tag: SSID parameter set: [redacted]_Voice
    > Tag: Supported Rates 6(B), 9, 12(B), 18, 24(B), 36, 48, 54, [Mbit/sec]
    > Tag: Traffic Indication Map (TIM): DTIM 1 of 1 bitmap
    > Tag: Country Information: Country Code GB, Environment Any
    v Tag: QBSS Load Element 802.11e CCA Version
        Tag Number: QBSS Load Element (11)
        Tag length: 5
        QBSS Version: 2
        Station Count: 1
        Channel Utilization: 8 (3%)
        Available Admission Capacity: 23437 (749984 us/s)
    > 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: Cisco Systems, Inc.: Aironet DTPC Powerlevel 14dBm
    > Tag: VHT Capabilities
    > Tag: VHT Operation
    > Tag: VHT Tx Power Envelope
    > Tag: Vendor Specific: Microsoft Corp.: WMM/WME: Parameter Element
    > Tag: Vendor Specific: Cisco Systems, Inc.: Aironet Unknown (1) (1)
    > Tag: Vendor Specific: Cisco Systems, Inc.: Aironet CCX version = 5
    > Tag: Vendor Specific: Cisco Systems, Inc.: Aironet Unknown (11) (11)
    > Tag: Vendor Specific: Cisco Systems, Inc.: Aironet Client MFP Enabled
```

Figure 5 - QBSS Info

Unfortunately, I am unable to open the spectrum analysis data I captured for this event as I no longer have a license for the software used to capture it. It showed no signs of 5GHz interference in the area.

Summary

Using Protocol Analysis I had demonstrated what caused the audio issue I was experiencing during my assessment. There were two causes found:

1. The access point was not behaving consistently or as per the 802.11 standard. The AP was rebooted by the customer and subsequent associations behaved correctly. Not a very satisfactory explanation but a resolution to the issue none the less. The paid-for assessment took place on a single day/visit and therefore this issue could have re-appeared after some operational time. Technical Support and the customer had access to my findings to aid future troubleshooting if required.

2. The voice client did not handle the unexpected behaviour appropriately. As the client averaged the last 10 beacon frames to determine its connection quality it was working with out of date data due to the absence of beacons. It thought the connection quality was still acceptable because the last 10 beacons it had received averaged out to an acceptable signal strength. The client behaviour was updated in a later software version to account for missing beacons from the associated BSSID as a trigger for a roam event.