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The bridge to possible

Catalyst Wireless
Optimize your wireless network for real time and mobile clients

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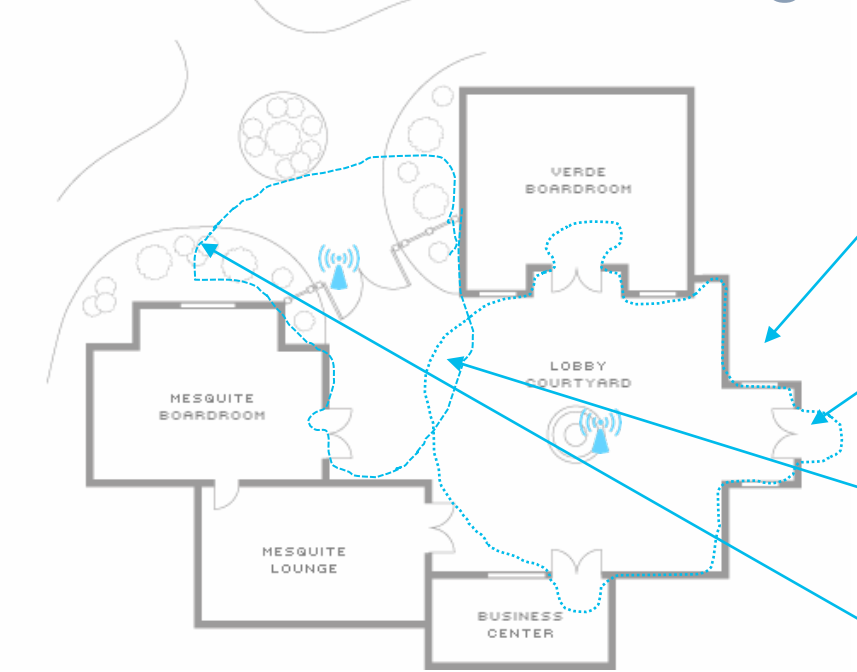
BRKEWN-2051

Agenda

- Introduction – the ideal Wi-Fi Coverage
- Taking Care of AP Power
- Taking Care of the Roaming Edge
- Taking Care of the Wi-Fi Domain Edge
- Maximizing Efficiency in the Cell
- Conclusion

The Ideal Wi-Fi Coverage



AP cell is not available here, where signal would be too weak for any client

Signal starts here, where STA can connect with good *goodput*

AP cell overlap is ‘optimal’: the STA still has good signal, but can find a better next best AP

AP cell stops where *goodput* stops

Take Care of Power

Use the Same Power as your Clients

AP at default (max) power

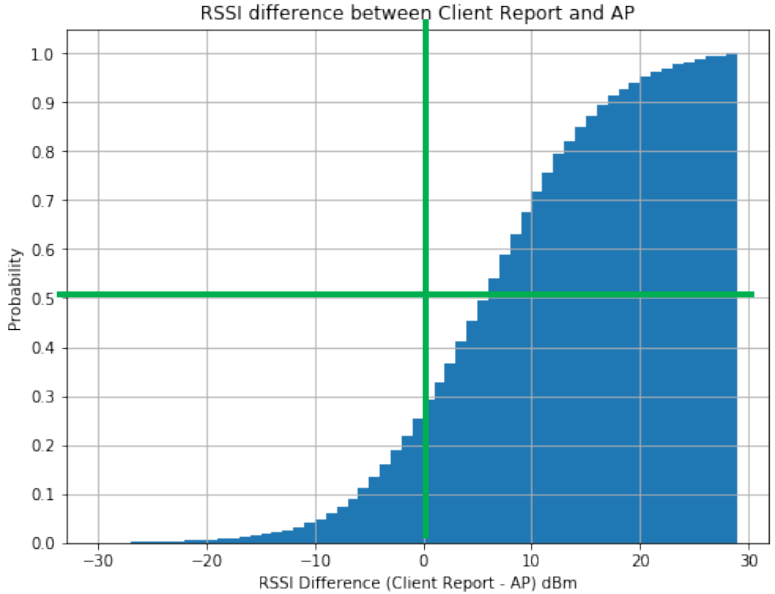
This is the AP 'signal' (at phone level)

I see you at -56

This is the phone 'signal' (at AP level)

I see you at -62

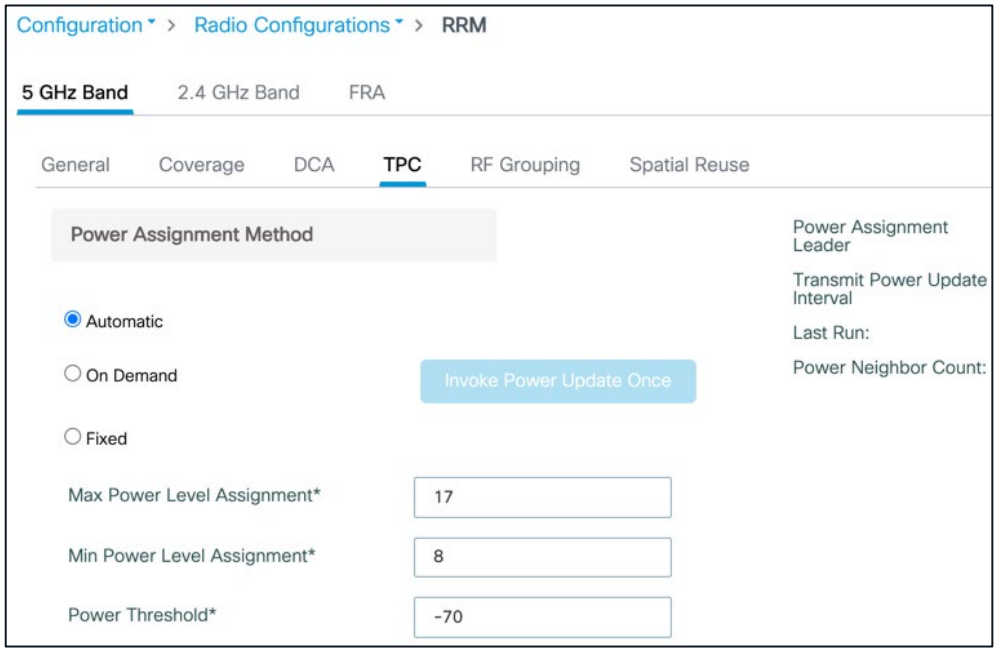
AP vs client average view



Most smartphones operate at 11 to 14 dBm, so should your APs

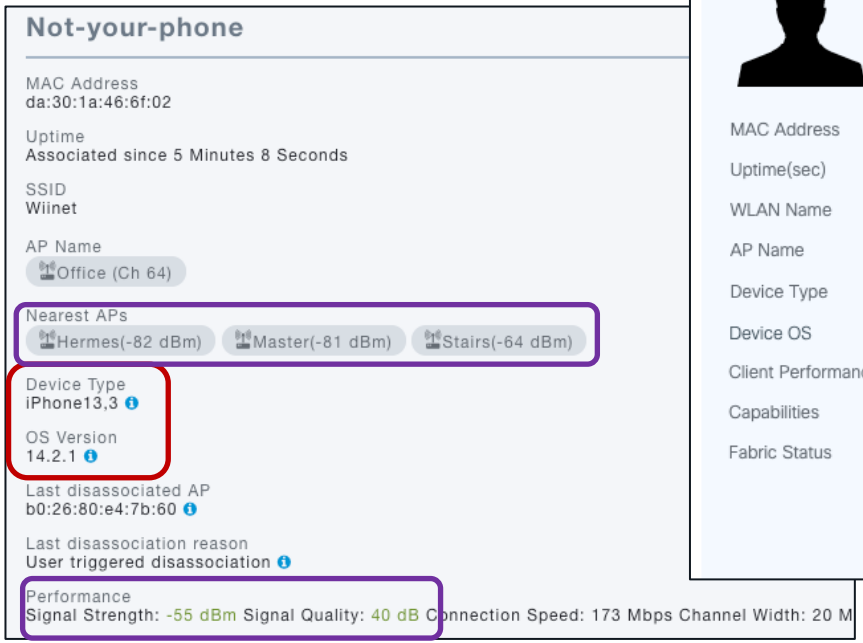
Set the AP Power Boundaries

- You can add a 3dB margin if you are unsure
  - Some APs may be in high density environments, others may have to cover large areas
  - Stricter boundaries, before deployment, is easier than post-deployment adjustments
- This step implies that you know your clients

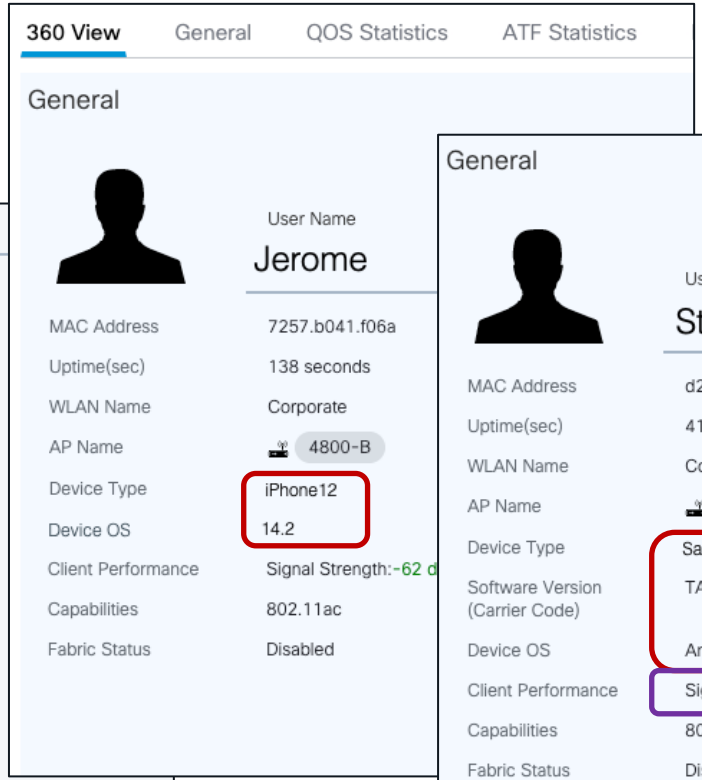


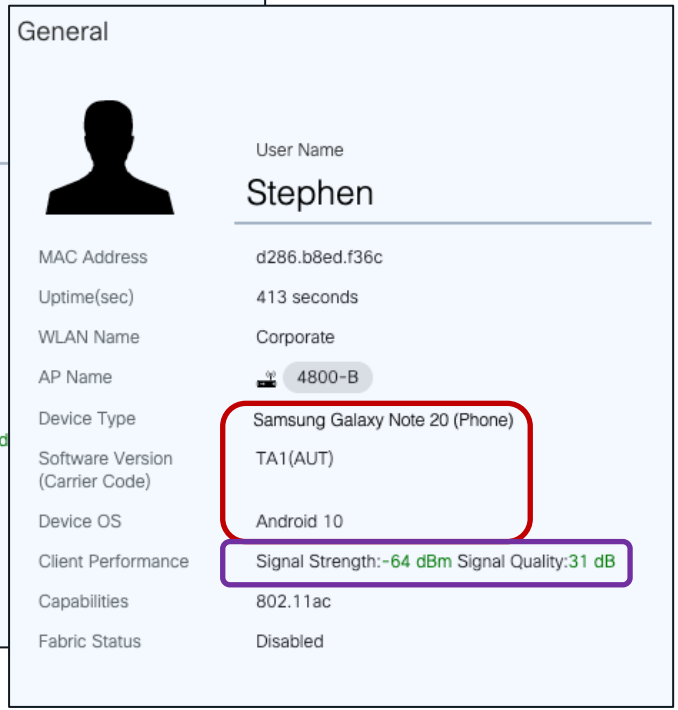
Check Your Clients in WLC/DNAC

AireOS



IOS-XE





Reciprocal Exchanges ("Knowing Each Other")

(Apple iOS exchange after association – same would happen with Samsung or Intel)

```
18.331689   Cisco_61:14:8e      62:61:8b:ba:57:f6   Association Response, SN=1462, FN=0, Flags=........C
18.354630   62:61:8b:ba:57:f6   Cisco_61:14:8e      Null function (No data), SN=695, FN=0, Flags=.......TC
18.354636   62:61:8b:ba:57:f6   Cisco_61:14:8e      Action, SN=696, FN=0, Flags=........C, SSID=Open
18.354903   62:61:8b:ba:57:f6   Cisco_61:14:8e      Action, SN=697, FN=0, Flags=........C
18.355961   Cisco_61:14:8e      62:61:8b:ba:57:f6   Action, SN=5, FN=0, Flags=........C
```

What is the neighborhood like?

```
IEEE 802.11 Wireless Management
▼ Fixed parameters
    Category code: Radio Measurement (5)
    Action code: Neighbor Report Request (4)
```

Meet the neighbors

```
IEEE 802.11 Wireless Management
▼ Fixed parameters
    Category code: Radio Measurement (5)
    Action code: Neighbor Report Response (5)
    Dialog token: 172
▼ Tagged parameters (30 bytes)
  ▼ Tag: Neighbor Report
      Tag Number: Neighbor Report (52)
      Tag length: 13
      BSSID: Cisco_d8:b7:4e (00:a2:ee:d8:b7:4e)
    ▶ BSSID Information: 0x000002f7
      Operating Class: 125
      Channel Number: 157 (iterative measurements on that Channel Number)
      PHY Type: 0x07
  ▼ Tag: Neighbor Report
      Tag Number: Neighbor Report (52)
      Tag length: 13
      BSSID: Cisco_d8:b7:41 (00:a2:ee:d8:b7:41)
    ▶ BSSID Information: 0x000002e7
      Operating Class: 118
```

```
IEEE 802.11 Wireless Management
▼ Fixed parameters
    Category code: Radio Measurement (5)
    Action code: Radio Measurement Report (1)
    Dialog token: 0
▼ Tagged parameters (31 bytes)
  ▼ Tag: Measurement Report
      Tag Number: Measurement Report (39)
      Tag length: 29
      Measurement Token: 0x71
    ▶ Measurement Report Mode: 0x00
    ▼ Measurement Report Type: Beacon Report (0x05)
        Operating Class: 243
        Measurement Channel Number: 48 (iterative measurements on t
        Measurement Start Time: 0x0a04eb099b07fc6f
        Measurement Duration: 0xb981
      ▶ Reported Frame Information: 0x00
        Received Channel Power Indicator (RCPI): 206 (P = -7.0 dBm)
```

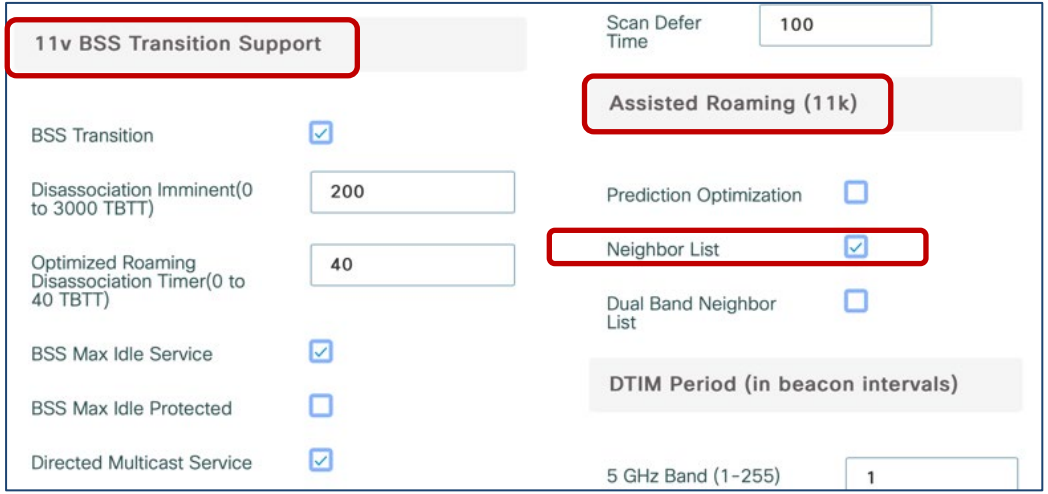
This is how I saw the world

Activating Exchanges

For Apple or Samsung, no action needed
For others, enable individually 802.11k,v
Or enable MBO

- Enables 802.11k/v/w

There are no downsides to
802.11k/v
Test PMF/802.11w before deployment

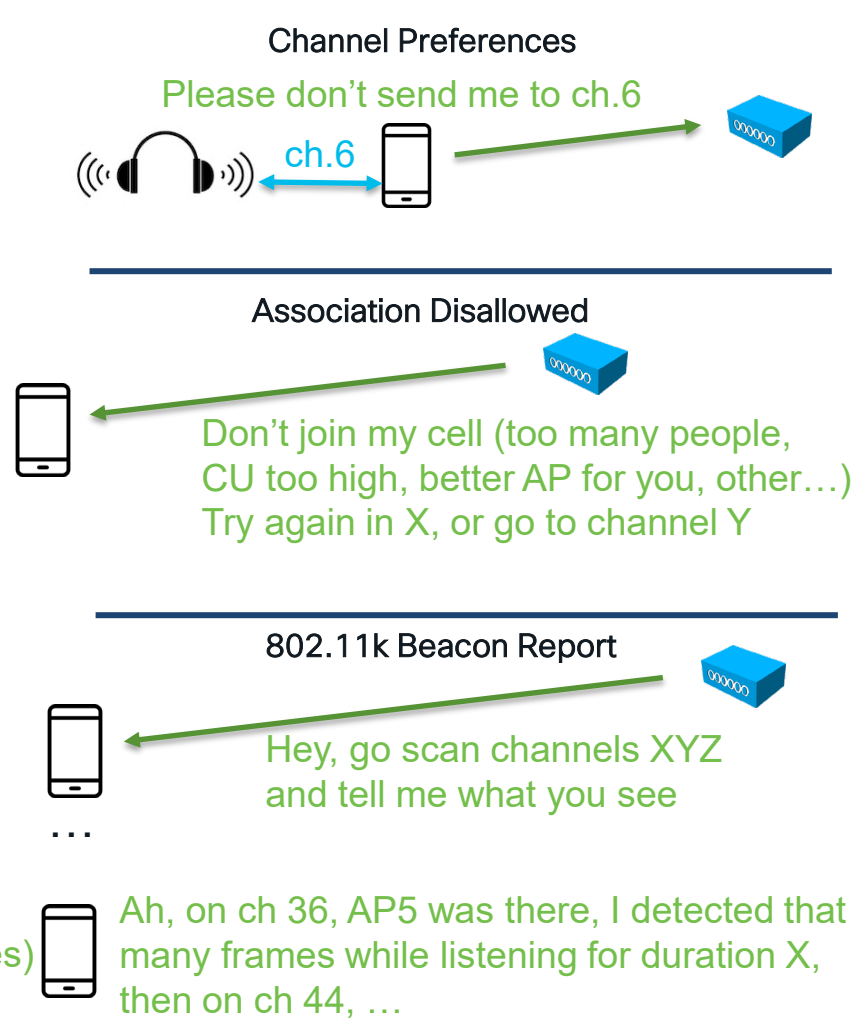



```
C9800#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
C9800(config)#wlan Corporate
C9800(config-wlan)#shut
C9800(config-wlan)#security pmf optional
C9800(config-wlan)#mbo
C9800(config-wlan)#no shut
```

Wi-Fi Aware (aka MBO)

Optimized Multiband Operations (Wi-Fi Alliance)

- At association: channel preferences (STA), association disallowed (AP)
- During the session: 802.11v (BTM), including ‘go to LTE’ variant, 802.11k reports
- Supported by all recent Samsung Galaxy / Notes clients
- In eWLC 16.12 and AireOS 16.10



Clients and Report Operations

Use your Samsung Clients to create a client RF map

- C9800#wireless client mac-address a6b0.839d.d11b scan-report ?
  once One-time request for a scan report (beacon measurement report) from a wireless client
  periodic Periodically request a scan report (beacon measurement report) from a wireless client
  C9800#wireless client mac-address a6b0.839d.d11b scan-report once mode ?
  active (1) Request client to actively measure beacons with probing
  passive (0) Request client to passively measure beacons without probing
  table (2) Request client to report its stored beacon measurements that it has already received
- C9800#wireless client mac-address a6b0.839d.d11b scan-report once mode active bssid all ssid all operating-class ?

Active: best option, go scan those channels

Passive: less RF invasive, but most time consuming

Table: good… only if the client scanned within the last 11 seconds

Clients and Report Operations

- C9800#wireless client mac-address a6b0.839d.d11b scan-report once mode active bssid all ssid all operating-class ?
- <1-255> Request beacon measurements from one specific operating class. Validated Operating Classes: 81,82,115,118,121,124.
- network Request beacon measurements for all Cisco network channels in set of six operating classes. Set of Operating Classes: {81,82,115,118,121,124}.
- <0-65535> msec
- default Default maximum measurement duration for client to measure beacons (passive = 112 msec, active = 200 msec, table = 0 msec)
- C9800#wireless client mac-address a6b0.839d.d11b scan-report once mode active bssid all ssid all operating-class 81 channel all delay none duration default
- C9800#show wireless client mac-address a6b0.839d.d11b detail
- C9800#debug wireless client mac-address a6b0.839d.d11b

Class	Channels
81	1,2,3,4,5 6,7,8,9,10 11,12,13
82	14
115	36,40, 44,48
118	52,56, 60,64
121	100,104,108, 112,116,120, 124,128,132, 136,140,144
124	149,153, 157,161

Clients and Report Operations

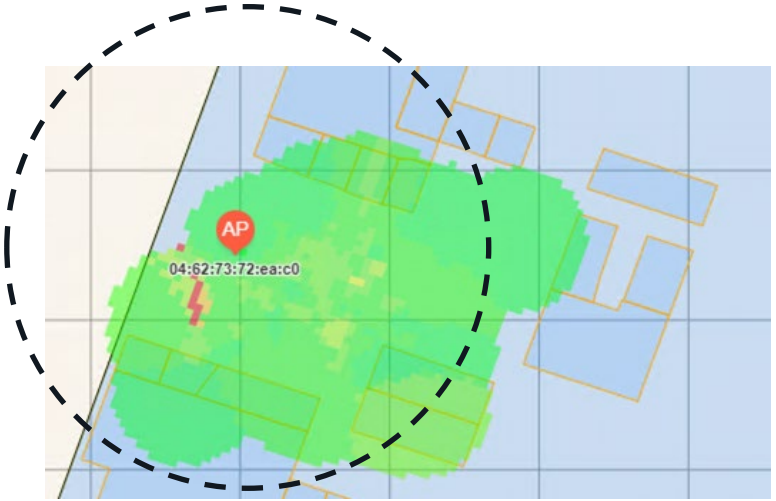
target channel

```
a6:b0:83:9d:d1:1b          Broadcast          Probe Request, SN=2076, FN=0, Flags=........C, SSID=Open
```

Back on main AP channel

```
   101  3.900671    a6:b0:83:9d:d1:1b    Cisco_61:14:8e    Action, SN=2138, FN=0, Flags=........C, BI=100, SSID=Open,
   107  4.105056    a6:b0:83:9d:d1:1b    Cisco_61:14:8e    Null function (No data), SN=2139, FN=0, Flags=...P...TC
```

```
▼ Tagged parameters (687 bytes)
  ▼ Tag: Measurement Report
      Tag Number: Measurement Report (39)
      Tag length: 251
      Measurement Token: 0x01
    ▶ Measurement Report Mode: 0x00
    ▼ Measurement Report Type: Beacon Report (0x05)
        Operating Class: 124
        Measurement Channel Number: 149 (iterative measurements on that Channel Number)
        Measurement Start Time: 0x00000002e2ea0a5c
        Measurement Duration: 0x0064
      ▶ Reported Frame Information: 0x00
        Received Channel Power Indicator (RCPI): 62 (P = -79.0 dBm)
        Received Signal to Noise Indicator (RSNI): 16.0 dB
        BSSID Being Reported: Cisco_61:14:81 (f4:db:e6:61:14:81)
        Antenna ID: 0x00
        Parent Timing Synchronization Function (TSF): 0x00000000
      ▶ SubElement ID: Reported Frame Body (1)
      ▶ SubElement ID: Reported Frame Body Fragment ID (2)
  ▼ Tag: Measurement Report
      Tag Number: Measurement Report (39)
      Tag length: 89
      Measurement Token: 0x01
    ▶ Measurement Report Mode: 0x00
    ▼ Measurement Report Type: Beacon Report (0x05)
        Operating Class: 124
        Measurement Channel Number: 149 (iterative measurements on that Channel Number)
```



If you like scripting, build your own client maps

Take Care of Roaming Edge

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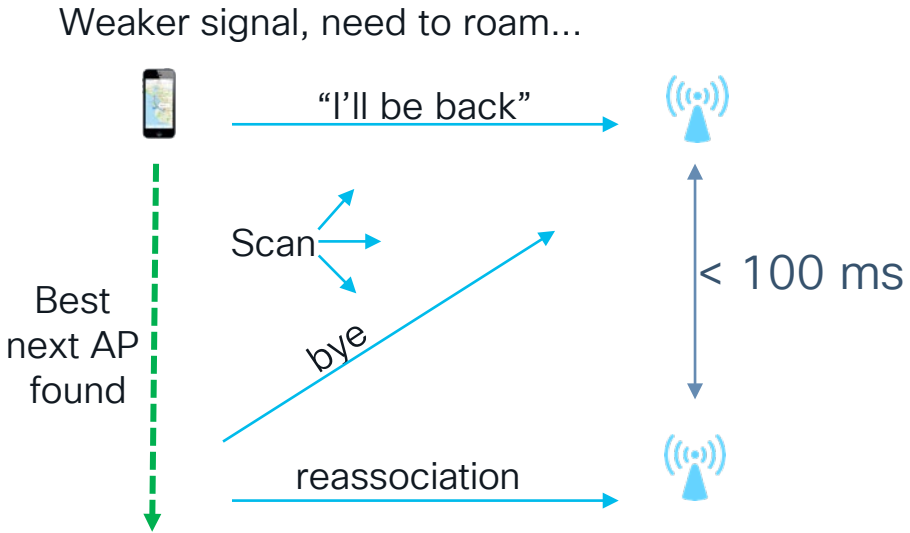
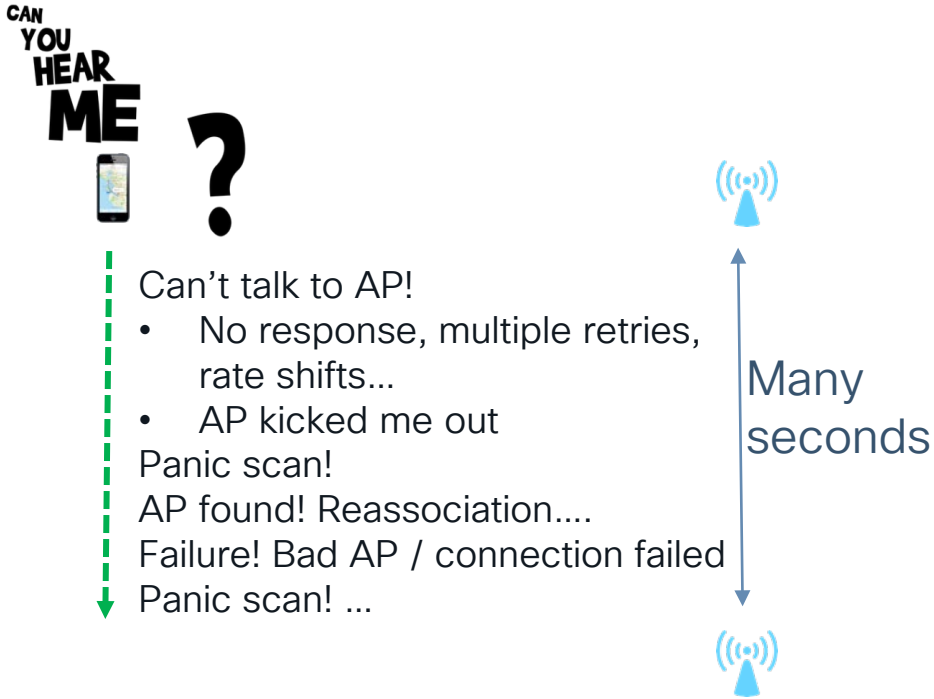
Roaming Scenarios

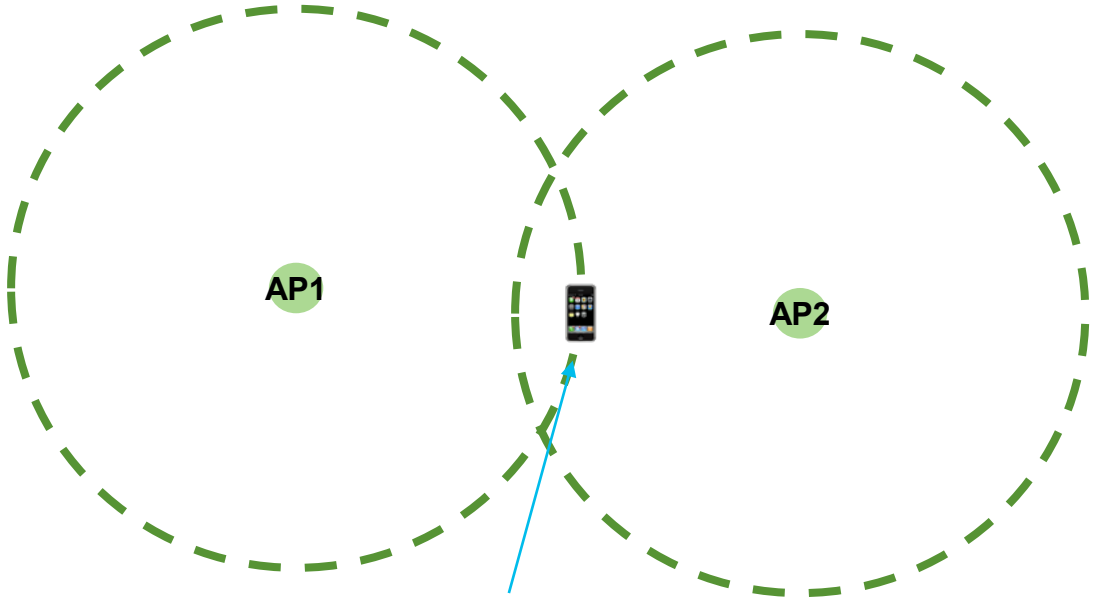


Seamless roaming scenario



“We like support calls” scenario

Optimal Cell Edge



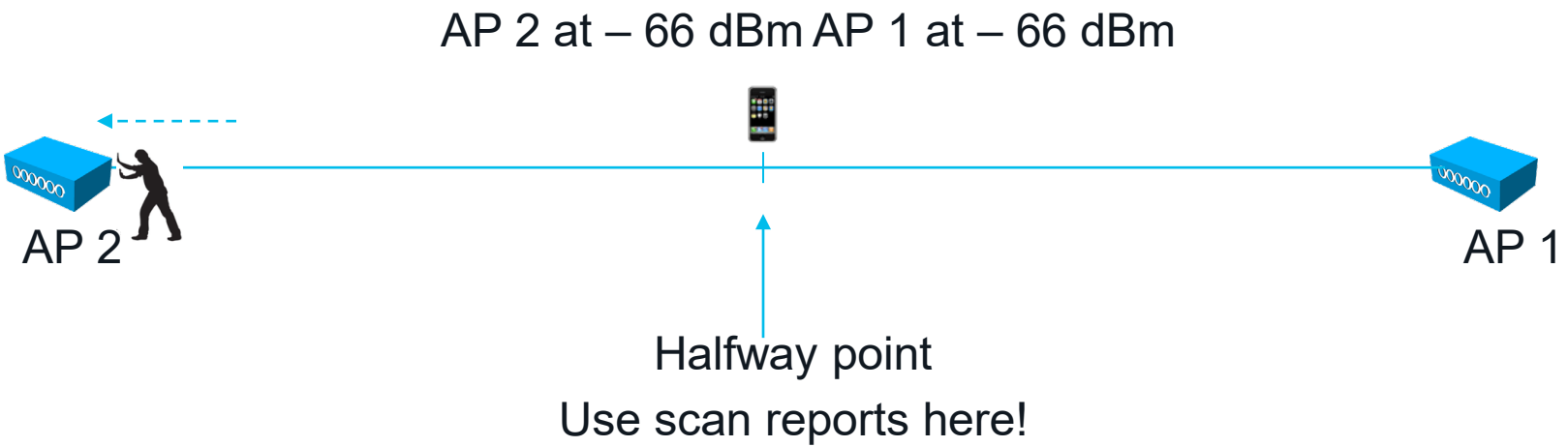
At the point where AP1 signal is -70 dBm, AP2 signal is -62 dBm

That's a -66 dBm edge

- iPhones start scanning at -70 dBm, jumps to next AP if 8 dB better (w/ active traffic)
- Samsung, Intel start scanning at -75 dBm, need 6 to 8 dB more to jump

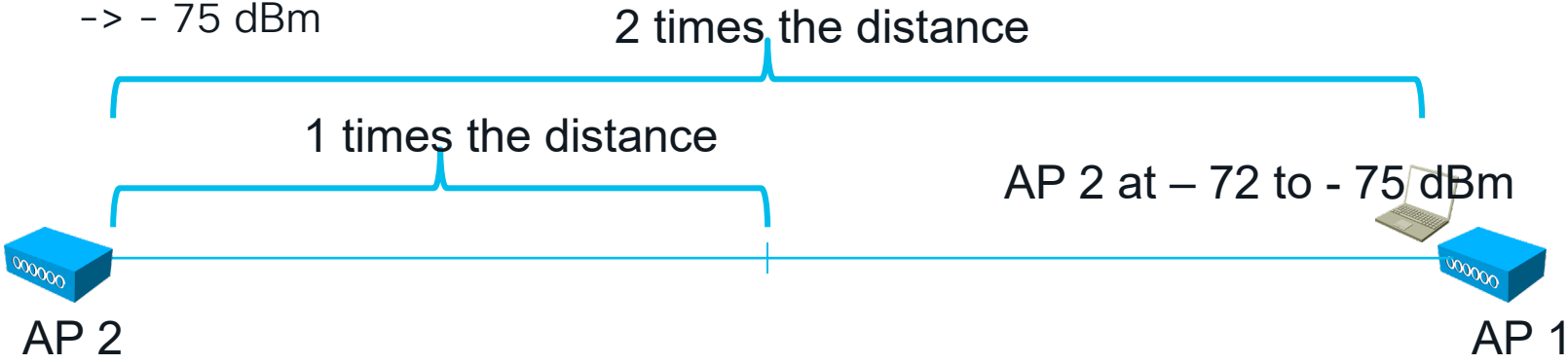
The – 72 dBm Rule

- So if you stand at the "-66 dBm border"…
  - Move away from AP 1 until you get – 66 dBm
  - Then push AP 2 in the other direction until you also hear it at – 66 dBm



The – 72 dBm Rule

- Go back to AP 1
  - AP2 should be at "– 66 – 6" = -72 dBm. Add 2-3dB loss if there is a plaster wall -> - 75 dBm



How Much is -66 dBm in MCS?

Why “It depends” is the only answer – Minstrel algorithm

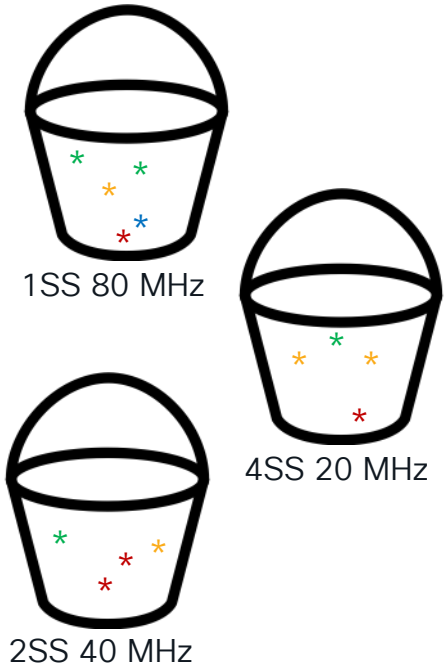
- Your clients use an adaptive algorithm to pick the best rate in real time
  - You can’t tell what rate will be picked at -66 dBm
- Most algorithm derive/improve from Minstrel, let’s use it as an illustration
- Start: Organize rates rates in groups
  - (MCS 0 to 9 – 1 SS 20 MHz, MCS 0 to 9 – 1 SS 40 MHz, etc.
  - same for 2 SS, 3 SS etc.)
  - Trim off groups not supported by the AP
  - Optional: from each group, pick rates compatible with initial signal budget
  - Compute the transmission time for each selected rate
  - Transmit at the rate that provides smallest transmission time

Minstrel-VHT – Picking a Better Rate

Conditions change, and so should rates (even at same signal level)

1. At regular intervals (e.g. 100 ms), Minstrel enters a sampling period (SP)
2. During SP, pick a ‘random’* rate in a group
3. Try the rate, within the max retry limit for this group (e.g. 3)
4. If the rate results in higher throughput** than previous rate, rank the rate up
5. Repeat until the end of the sampling period
6. Retain 3 rates: highest throughput, second highest throughput, highest probability (least loss/retries)

(*more on this in 2 slides, **more on this on next slide)



Minstrel-VHT – "Throughput"?

Throughput is the largest number of data payload bytes transmitted per unit of time (e.g. per second)

- Minstrel uses FLR (Frame Loss Rate, i.e. number of successful frames over total attempts over a sliding window)
- Minstrel also uses EWNA (Exponential Weighted Moving Average)
  - Statistical technique to put more weight on recent measurements
  - Choose a weight factor $0 < \lambda \leq 1$ (e.g. 0.8)
  - For the current sampling window: Window Throughput (for this rate) = λ FLR $_{\text{this window}}$
  - Then: Previous window throughput = $(1-\lambda)$ (FLR $_{\text{previous window}}$)
  - Then: "window before" throughput = $(1-\lambda)$ (FLR $_{\text{previous window}}$)^2
  - Then $(1-\lambda)$ (FLR $_{\text{previous window}}$)^3 etc.

Minstrel-VHT – "Throughput"?

Minstrel throughput example with EWNA/FLR

- Let's decide that λ = 0.8
- This window (t) FLR 10%
- (t-1) window FLR 40%
- (t-2) window FLR 80%
- Throughput:

$(0.8)(0.1) + (1-0.8)(0.4) + (1-0.8)(0.8^2)$

= 0.288 EWNA

- Suppose the other way round
- This window (t) FLR 80%
- (t-1) window FLR 40%
- (t-2) window FLR 10%
- Throughput:

$(0.8)(0.8) + (1-0.8)(0.4) + (1-0.8)(0.1^2)$

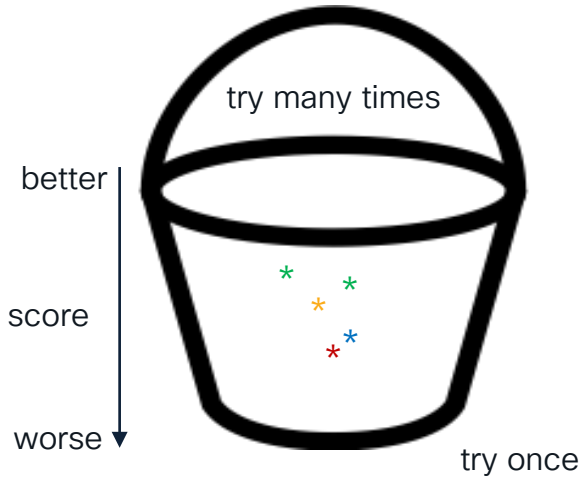
= 0.722 EWNA

Minstrel remembers the past, but the past becomes less important as it is farther
(good life lesson)

Minstrel-VHT – “Throughput”?

- Minstrel then sorts rates: faster (max bytes/sec) on top, with throughput as weight
- Next sampling period will try all rates (not really ‘minstrel-spirit’ anymore), but more frequently ‘top rates’ than slow or high-loss rates

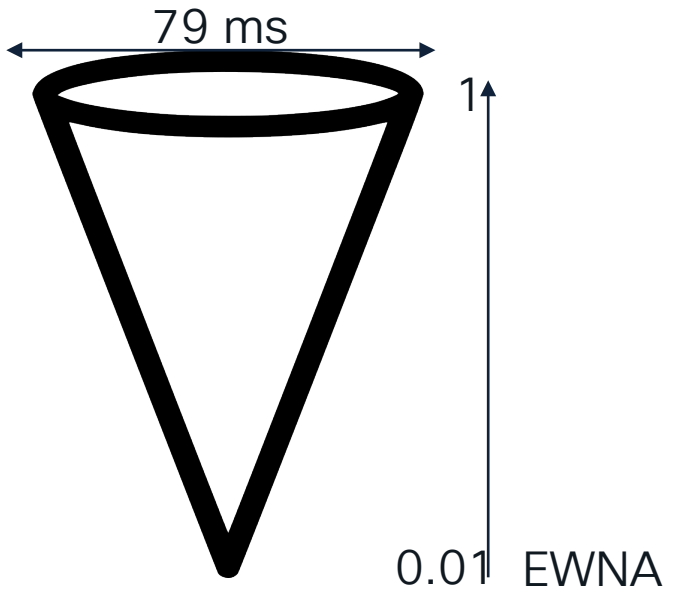
time to transmit n bytes x *EWNA* = *throughput score*



Minstrel-VHT – Retry Chain

Now we have our rates, we just need to act when transmission fails

- Minstrel defines for each rate (r) a max retry count (c)
  - The count is affected by the historical FLR/EWNA for that rate
  - The retry score assigns a retry time (percentage of max 79.2 ms)
  - The number of retries depends then on the data rate
  - (I'll retry more a rate that has been highly successful in the past)



Minstrel-VHT – Retry Chain

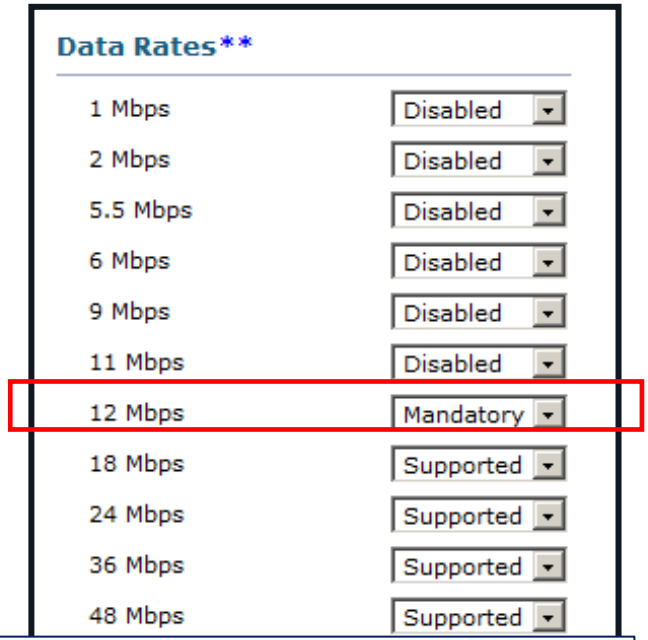
Now we have our rates, we just need to act when transmission fails

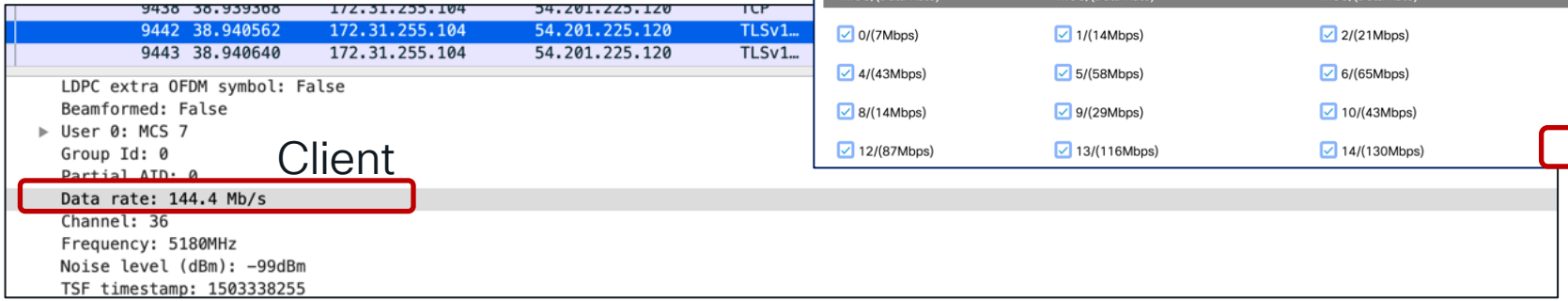
- The logic is as follows:(in non-sampling windows):
  1. Use best rate,
  2. If transmission fails, retry for (c_1)
  3. Switch to second best rate if fails > c_1
  4. Retry second best rate for c_2
  5. Switch to highest probability rate
  6. Empty buffer and t=100ms, , then enter sampling window

RF and MCS

Conclusion: Worry about signal, not about MCS

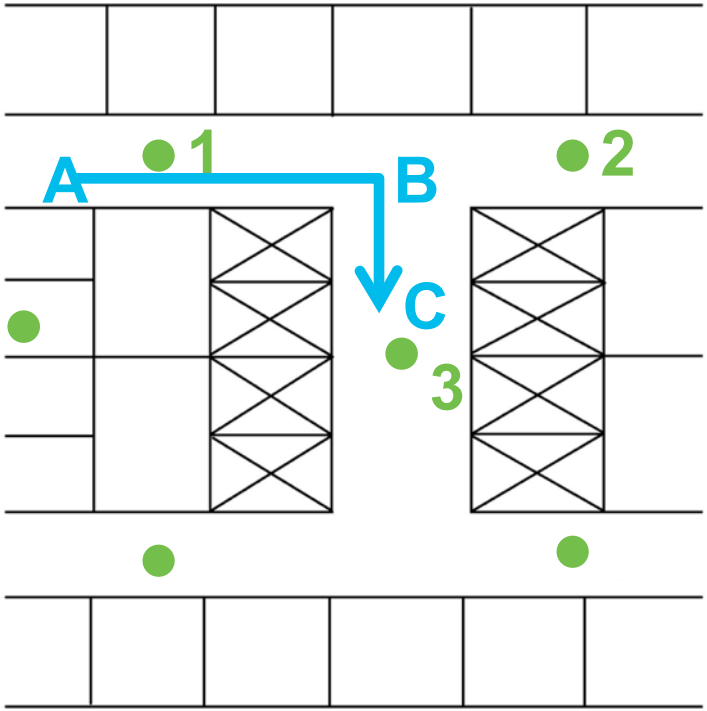
- Disable legacy low rates to limit the beacon spread to your cell geometry, do not touch the low MCSs
  - The client does not check if the AP uses the MCS the client uses





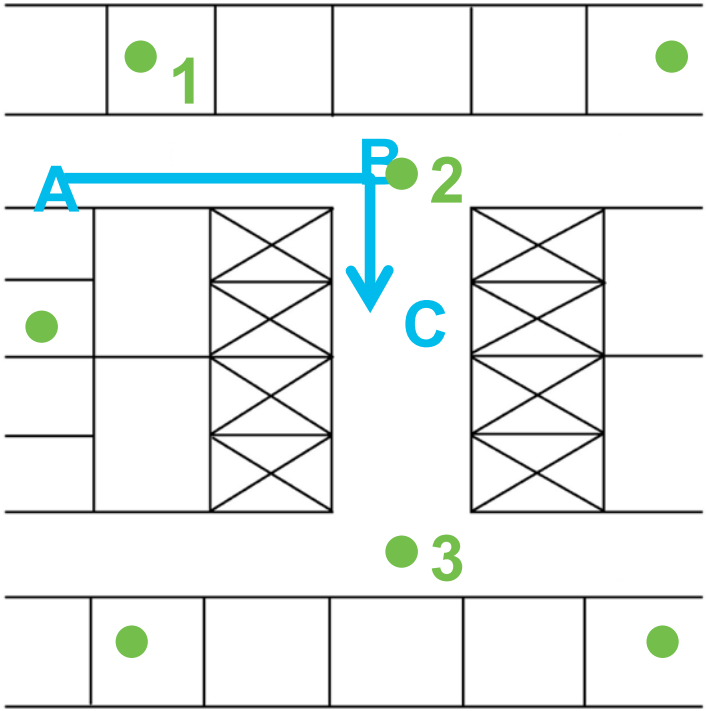
Client

Strategically Position Your Transition APs



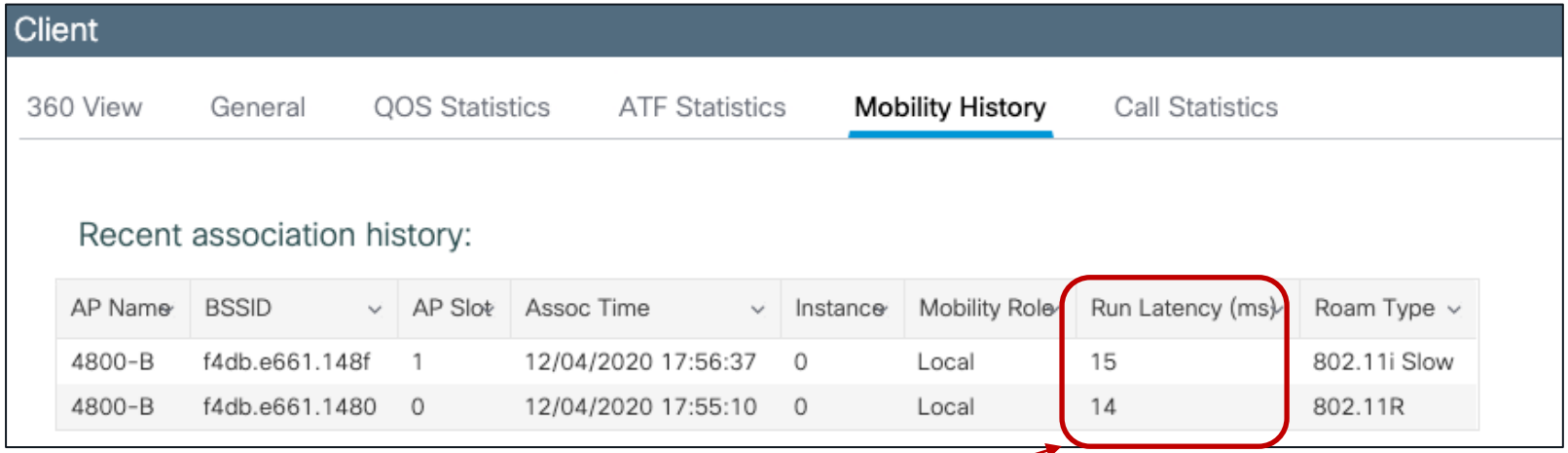
- At “A” the phone is connected to AP 1
- At “B” the phone has AP 2 in the neighbor list, AP 3 has not yet been scanned due to the RF shadow caused by the elevator bank
- At “C” the phone needs to roam, but AP 2 is the only AP in the neighbor list
- The phone then needs to rescan and connect to AP 3
  - 200 B frame @ 54 Mbps is sent in 3.7 µs
  - 200 B frame @ 24 Mbps is sent in 8.3 µs
  - Rate shifting from 54 Mbps to 24 Mbps can waste 1100 µs

Strategically Position Your Transition APs



- At point A the phone is connected to AP 1
- At point B the phone has AP 2 in the neighbor list as it was able to scan it while moving down the hall
- At point C the phone needs to roam and successfully selects AP 2
- The phone has sufficient time to scan for AP 3 ahead of time

Verify on your WLC



If this is more than 50 ms, roaming is suboptimal
If this is more than 100 ms, you need to rethink your design (AP positions, cell overlap)

At the Edge of the Wi-Fi Domain

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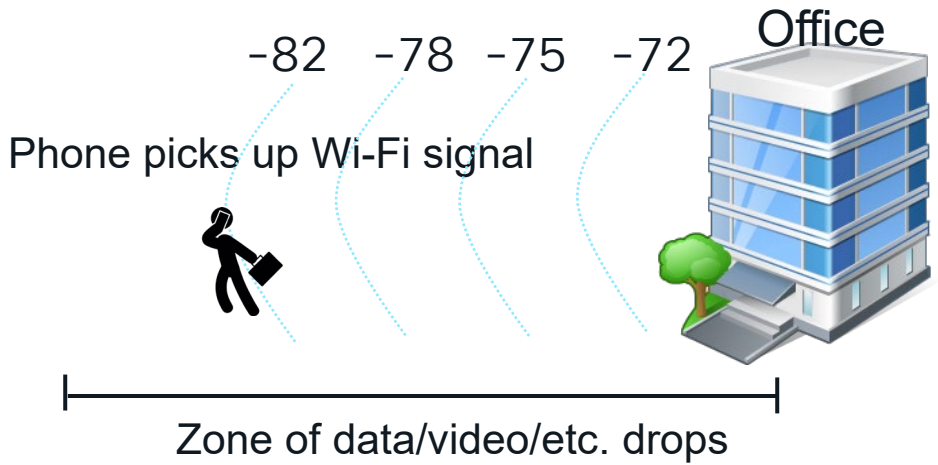
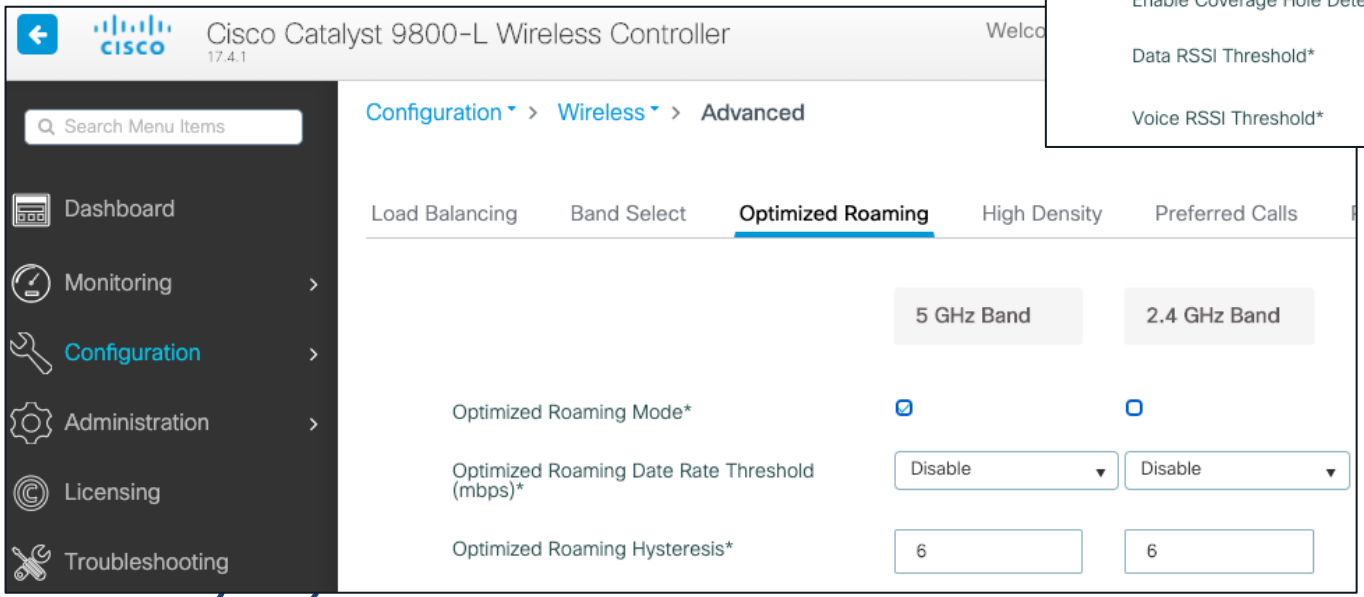
Walking Away From Wi-Fi

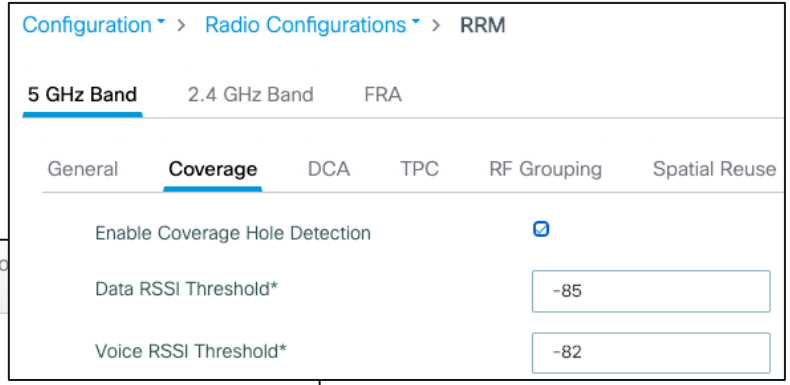
- Phone tries to prefer Wi-Fi
  - Jumps to a better AP if available
  - Otherwise, prefers Wi-Fi as long as Wi-Fi is in range



Transition Method 1: “Optimized” Roaming

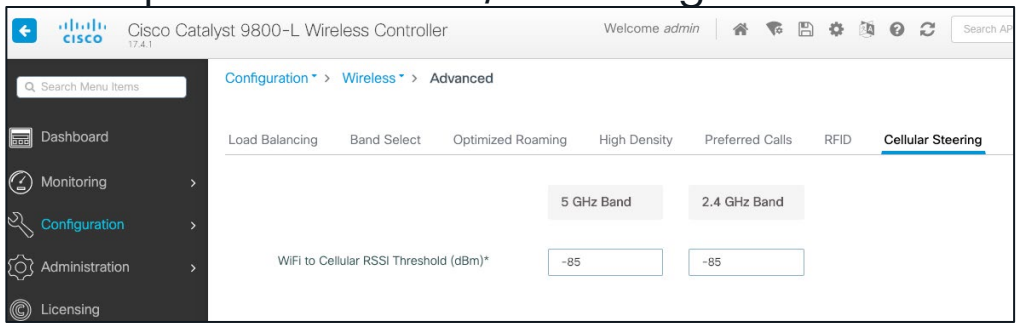
- Works in Combination with CHDM
- Use with caution

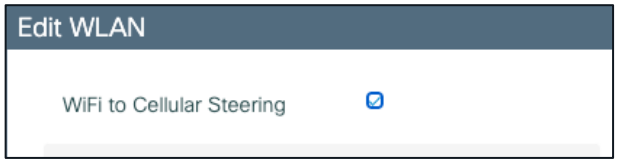


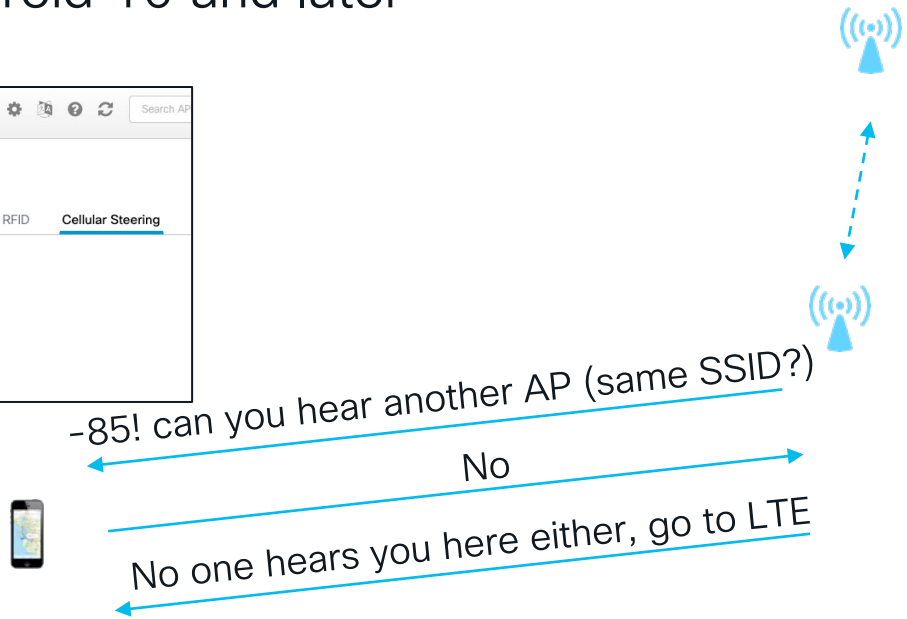


Transition Method 2: Wi-Fi to Cellular Steering

- Works with Samsung S8 / Android 10 and later
  - Specific to Cisco/Samsung



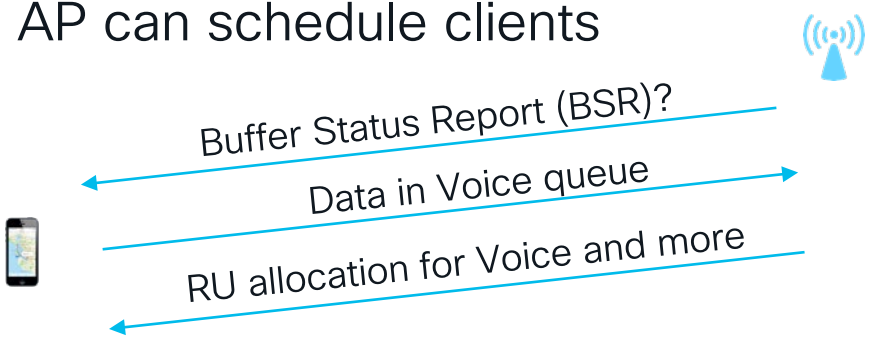




While in the Cell

802.11ax APs

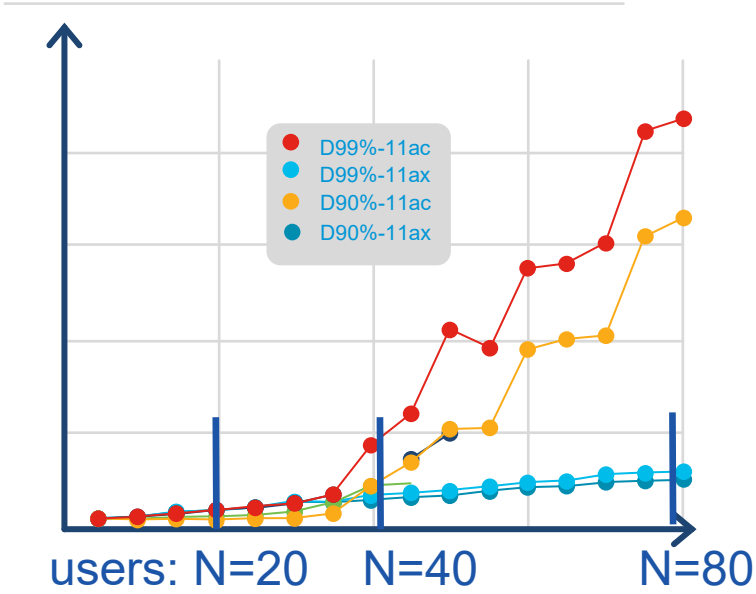
- It is hard to saturate a 5.83 Gbps, 8x8 uplink/downlink MU-MIMO with eight spatial streams
- But in case you thought you would…
- With OFDMA, UL-MU-MIMO, the AP can schedule clients



- Of course, if you overload your AP, as usual, some clients may suffer

FastLane Plus

- You may remember FastLane
  - With Apple iOS and MacOS (since 2015)
  - Activates a list of prioritized apps
- For 802.11ax, we developed FastLane plus
  - the (11ax iOS 14 and up) client tells us in advance what traffic is going to come up
  - Uses an Advanced Service Request (ASR) frame
    - This is where you love the AI A13/A14 chips
  - We pre-book resources, and allocate them as traffic flows



ASR Config CLI/GUI

To enable FastLane Plus, use the Advanced Service Request Function

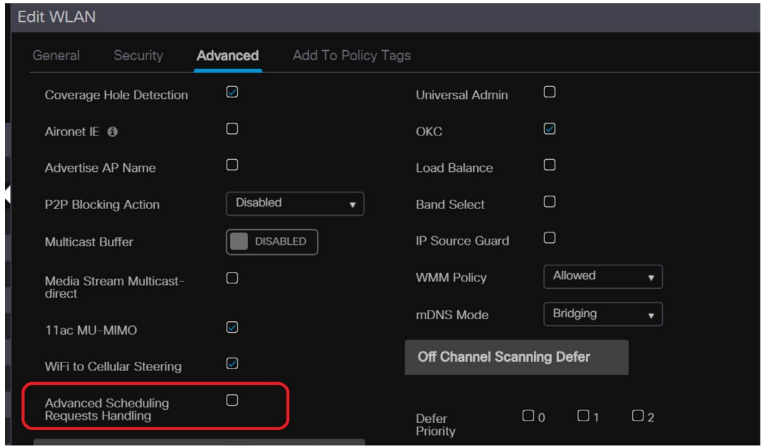
AireOS (8.10 MR4)

Command	Description
config wlan asr {enable | disable } <WLAN ID>	Enable or Disable ASR for a given WLAN
show wlan <wlan _id>	Display if ASR is enabled/disabled for a given WLAN

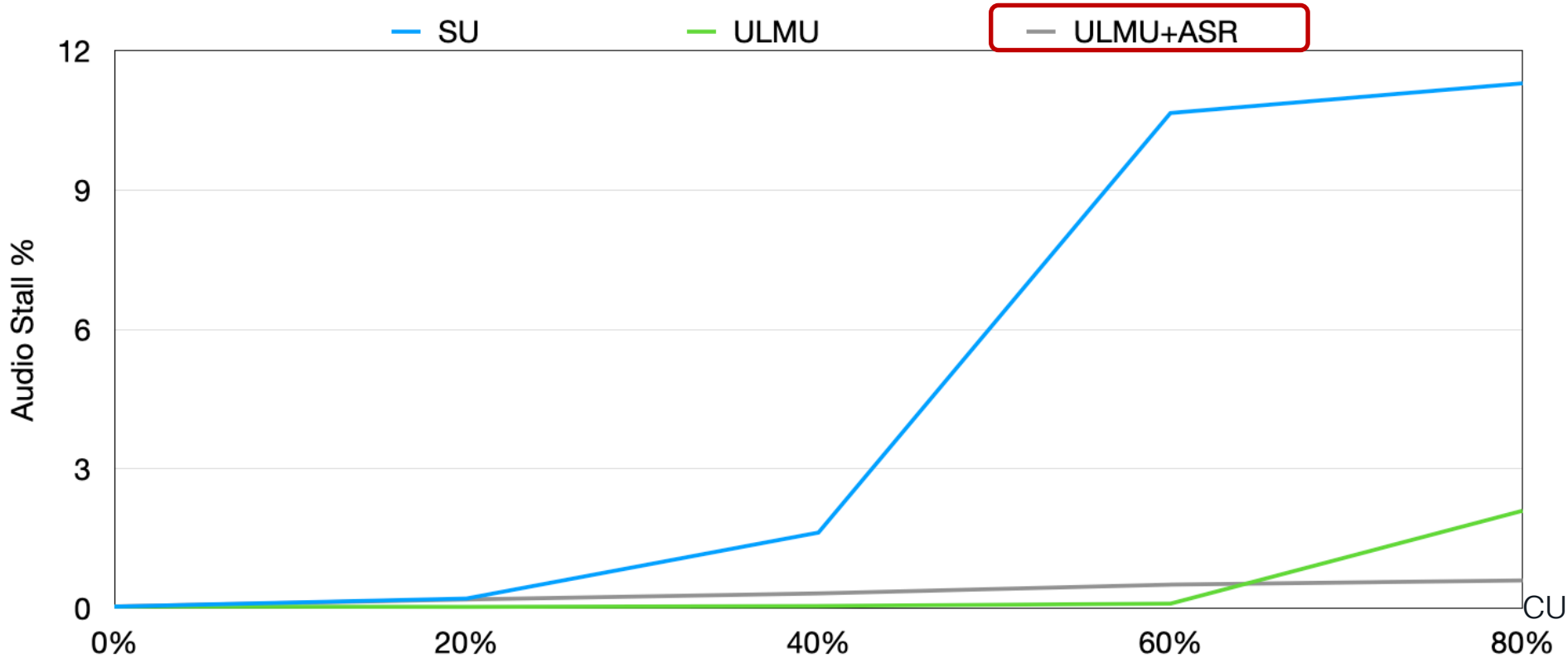
IOS-XE (17.4.1)

Command	Description
(config-wlan) scheduler asr (config-wlan) no scheduler asr	Enable or Disable ASR for a given WLAN
show wlan <wlan _id>	Display if ASR is enabled/disabled for a given WLAN

GUI in next IOS-XE release

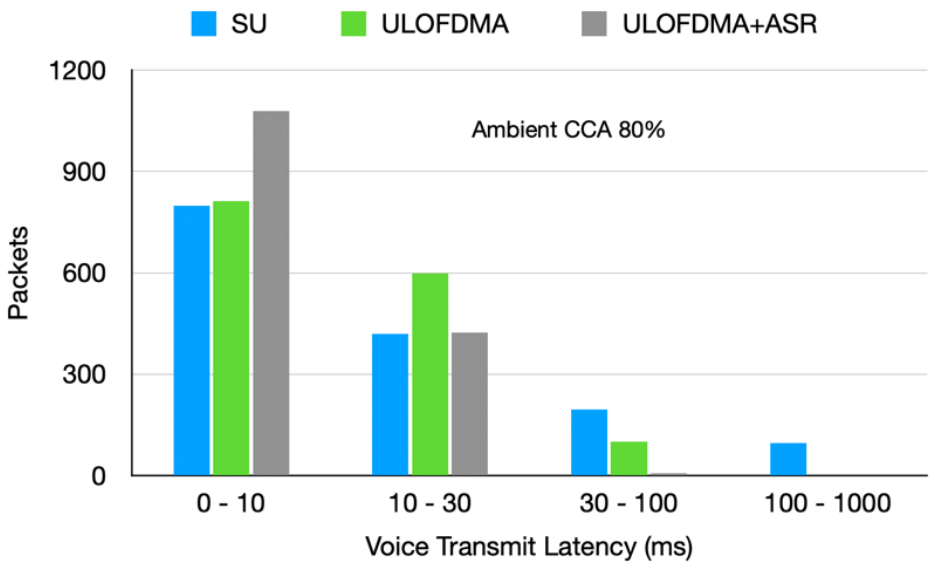


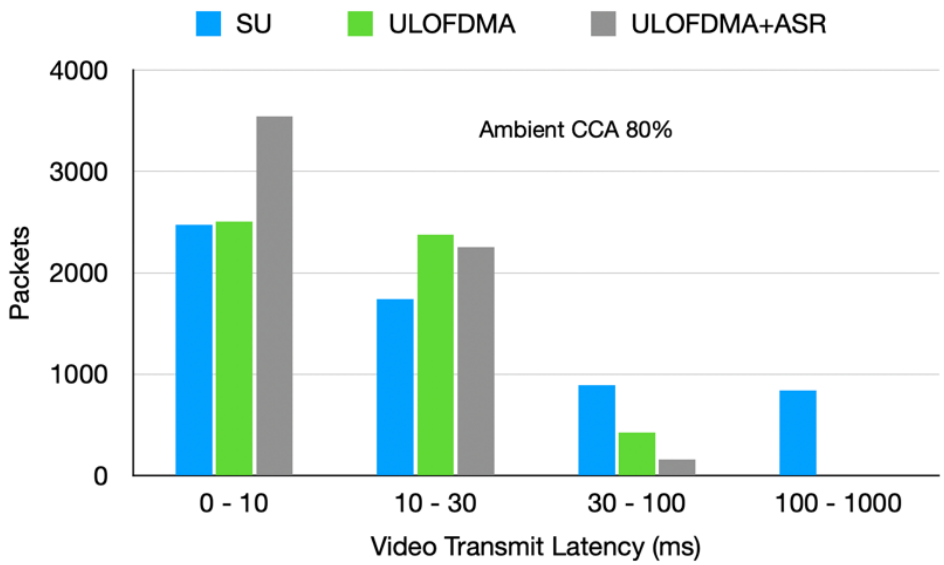
ASR Effect on Audio Stalls



No more robotic voices, no more “can you hear me?”

ASR Effect on Latency

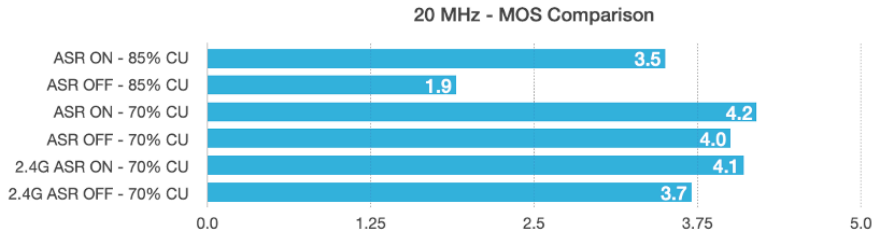




ASR Effect on MoS

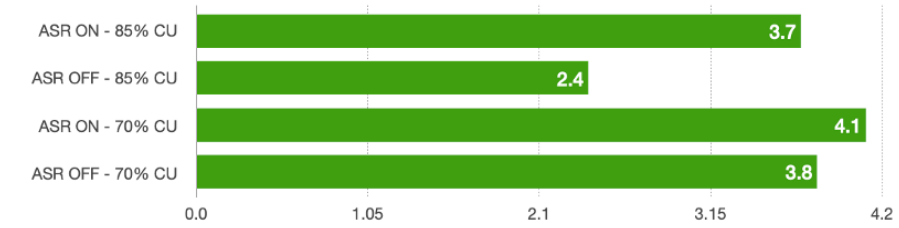
20 MHz MOS

ASR ON/OFF	MOS
ASR ON - 85% CU	3.5
ASR OFF - 85% CU	1.9
ASR ON - 70% CU	4.2
ASR OFF - 70% CU	4.0
2.4G ASR ON - 70% CU	4.1
2.4G ASR OFF - 70% CU	3.7



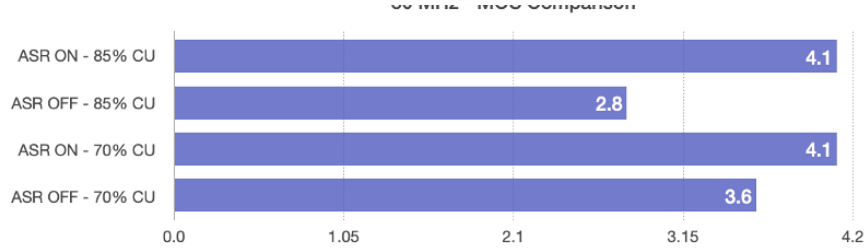
40 MHz MOS

ASR ON/OFF	MOS
ASR ON - 85% CU	3.7
ASR OFF - 85% CU	2.4
ASR ON - 70% CU	4.1
ASR OFF - 70% CU	3.8



80 MHz MOS

ASR ON/OFF	MOS
ASR ON - 85% CU	4.1
ASR OFF - 85% CU	2.8
ASR ON - 70% CU	4.1
ASR OFF - 70% CU	3.6



Skype audio, 16 calls

FastLane Plus Conclusions

- If you have iOS 14 devices in your 802.11ax enable ASR:
  - Consistent MOS score improvement for Voice and Video across bandwidths and at 70% & 85% congestion level.
  - Delay factor (ms) improvement for Video calls across bandwidths and at 70% & 85% congestion level.
  - Better UL latency numbers (negligible packets in higher latency bucket 40-100 ms or >100ms with ASR)

Conclusion

Recommendations Summary

- Position your APs to avoid signal bleeding on entrances
- Set AP power to client power (11/14 dBm?)
- Disable low legacy rates to match the cell size
- Ensure 8 dB overlap between cells
- We give you tools to know exactly how your client behaves and sees the network: use them as much as your network allows
  - client specs report,
  - leaving reason codes,
  - scan reports (802.11v, 802.11k, MBO),
  - ASR

The bridge to possible

Thank you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IT
UP
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