



You make **possible**



Оптимизация беспроводной сети для работы с мобильными клиентами

Смартфонами, планшетами и т.д.

Платов Виктор, консультант по технологии Wi-Fi

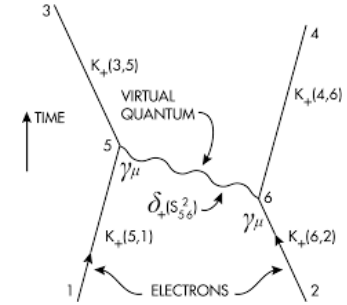
CCIE# 24288 CWNE #283



Agenda

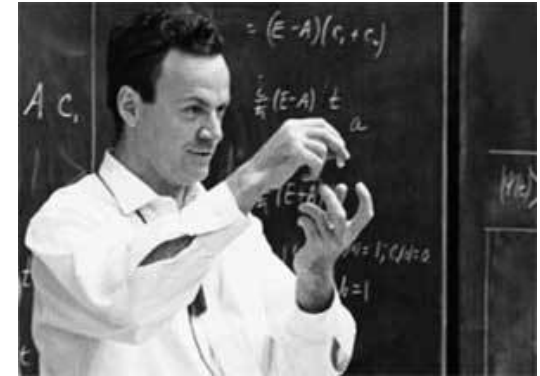
- Introduction
- Getting Connected – build your first cell
 - AP selection behavior – best practices
- Optimizing Roaming
 - Cell position and overlaps (band steering, analytics on WLC/DNAC, 11k/v)
- Optimizing Application Performances
 - E.g. webex (QoS path STA – AP/WLC-GW, w/without FL RFC 8325, DNAC policy / monitoring with Assurance app 360, path trace)
- Conclusion

Ask Questions ☺



*I would rather have questions that
can't be answered than answers that
can't be questioned*

Richard Feynman

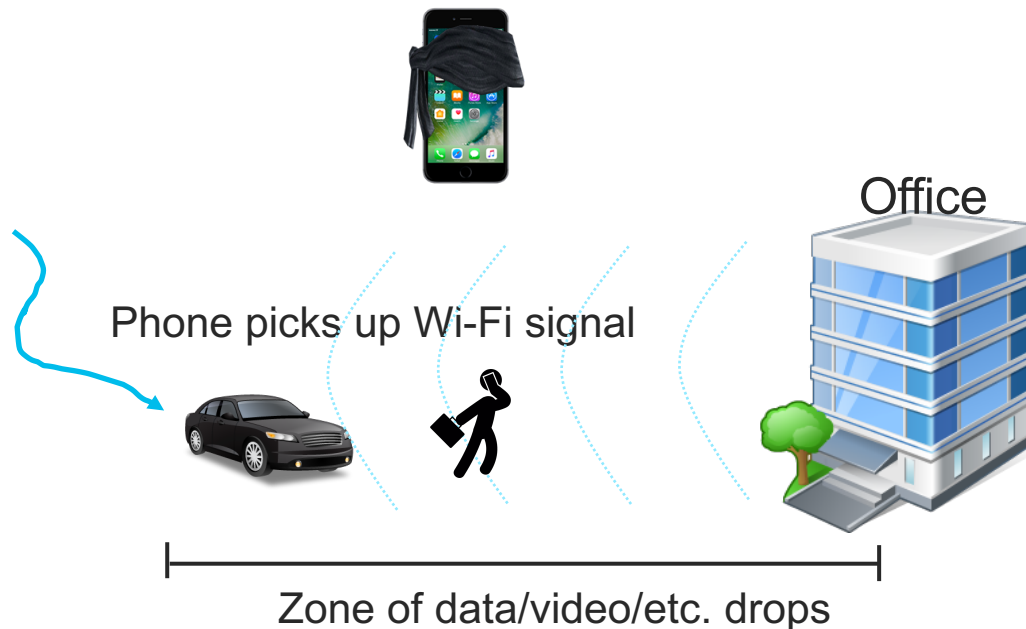


Building your First Cell



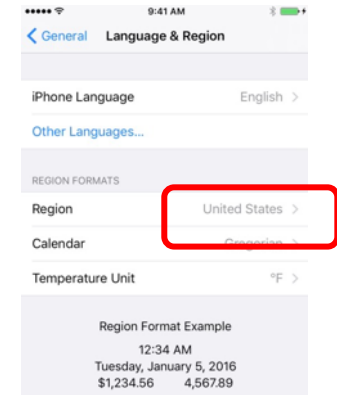
Walking into Wi-Fi

- Phone tries to prefer Wi-Fi
 - May connect, fail, then drop back to LTE
 - Your Webex call will suffer -> limit the transition zone
- Probe only the broadcast
 - Unless older than Android 5.2 and iOS 8
- 2 probes at 20 ms interval on each channel



DFS Channel Exceptions

- Scanned channels are based on country config
- All country channels are scanned (5 GHz and 2.4 GHz)
- Channels 100 – 140 are DFS -> cannot probe directly Listen...



If 802.11 frame detected → channel is safe to use → send probe requests

You may wait up to 100 ms... or 60 s!

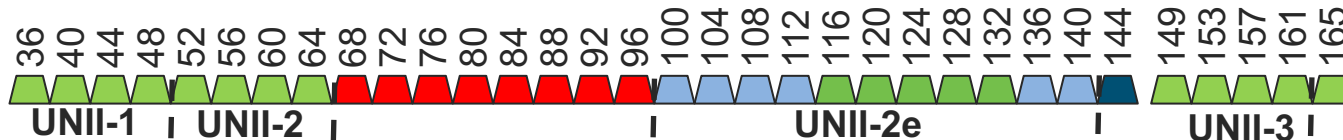
To avoid time waste, iOS/Samsung scans all other channels first, then 100 – 140

E.g. (US, A Domain) 36, 40, 44, 48, 52, 56, 60, 64, 149, 153, 157, 161, 165, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Repeat 5 times, then scan 100, 104, 108, 112, 118, 120, 124, 128, 132, 136, 140

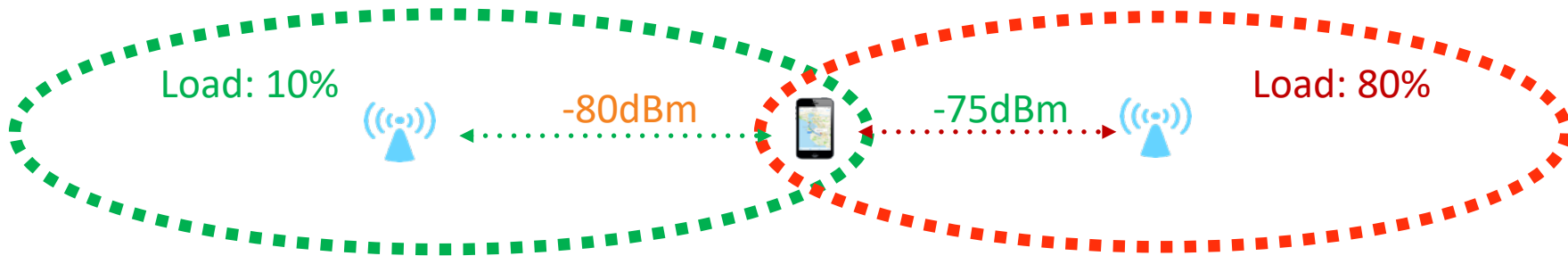
Refresh only every 6 scan cycles

Your phone/tablet may take up to one minute to detect an AP on channel 100 – 140



AP Arbitration Logic

- Apple iOS 10 and later: strongest signal and best throughput potential



(APs with 100% load are also discarded)

On first connection, a phone you see at -82 dBm (AP viewpoint) will try to join

AP Arbitration Logic

- Android 9 (e.g. Samsung) and after: strongest signal

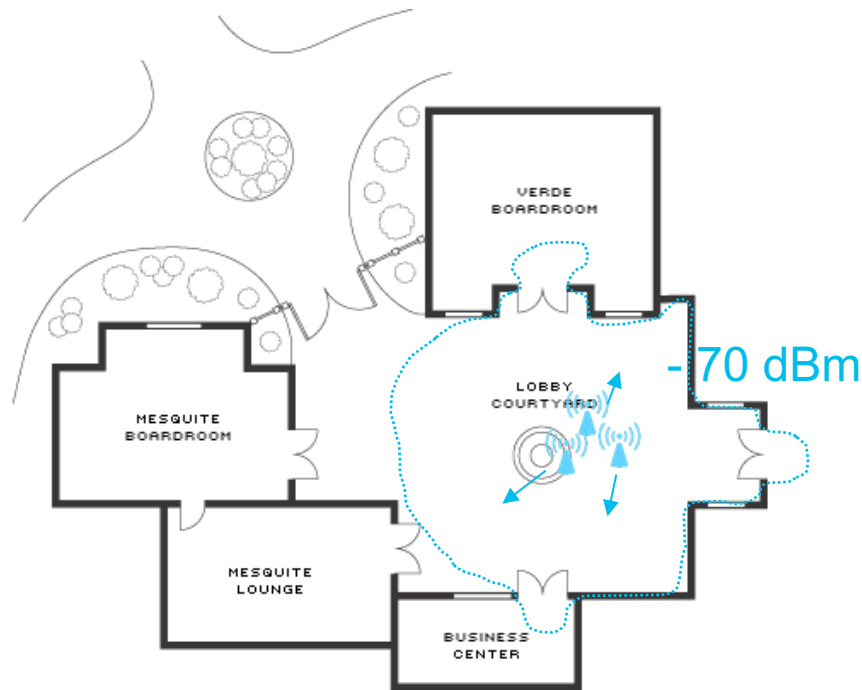


Phone would choose AP B

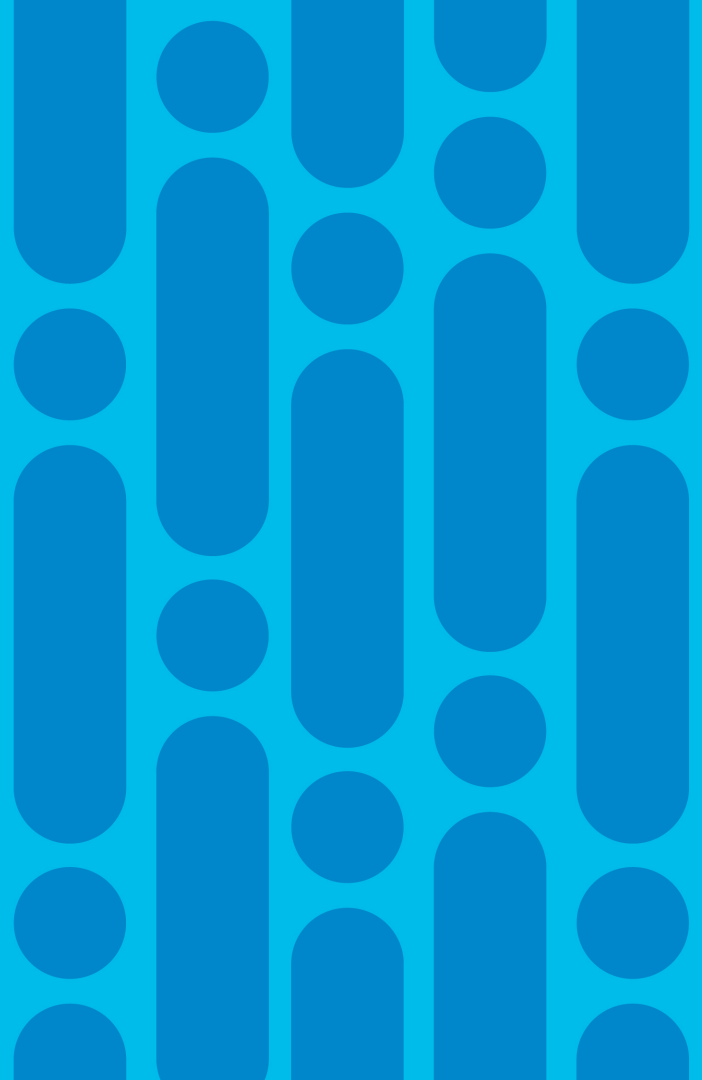
- Strong signal does not equate to “good AP”
- Phone has a further intelligent WiFi arbitration mechanism

Impact on Your Network Design

1. Make sure that at least one AP is available at > -70 dBm at entrance points
2. Minimize the -82 to -75 dBm zone
3. You can add APs for high density
4. Avoid DFS channels if low density
 - With high density, DFS channels are okay, as active channels will be probed
 - 40 MHz channels may force you to DFS



Optimizing Roaming



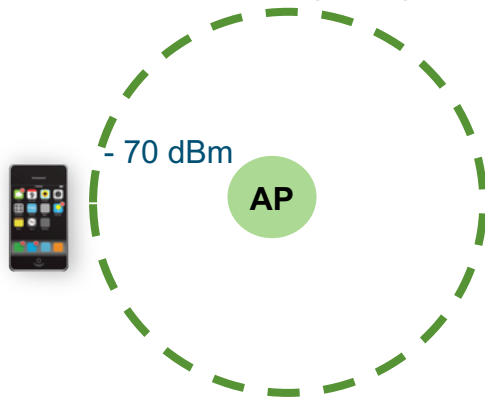
You are now Connected

- Your phone / tablet will continue to probe:
 - At regular intervals (e.g. 327 seconds)
 - And if the AP signal falls below roaming threshold
- Phone probes the broadcast and your associated SSID



Phone Roaming Logic

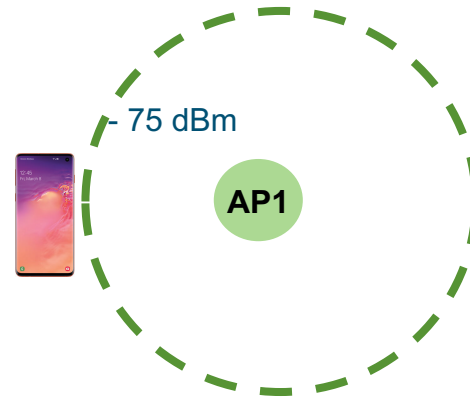
Apple (iOS)



If current AP signal is below -70 dBm

- Scan, join AP with 8 dB better than current AP
- (if client is not sending data, only join if new AP is 12 dB better than current AP)
- If 2 APs or more are better than -65 dBm, prefer the 5GHz AP
- <https://support.apple.com/en-us/HT203068>

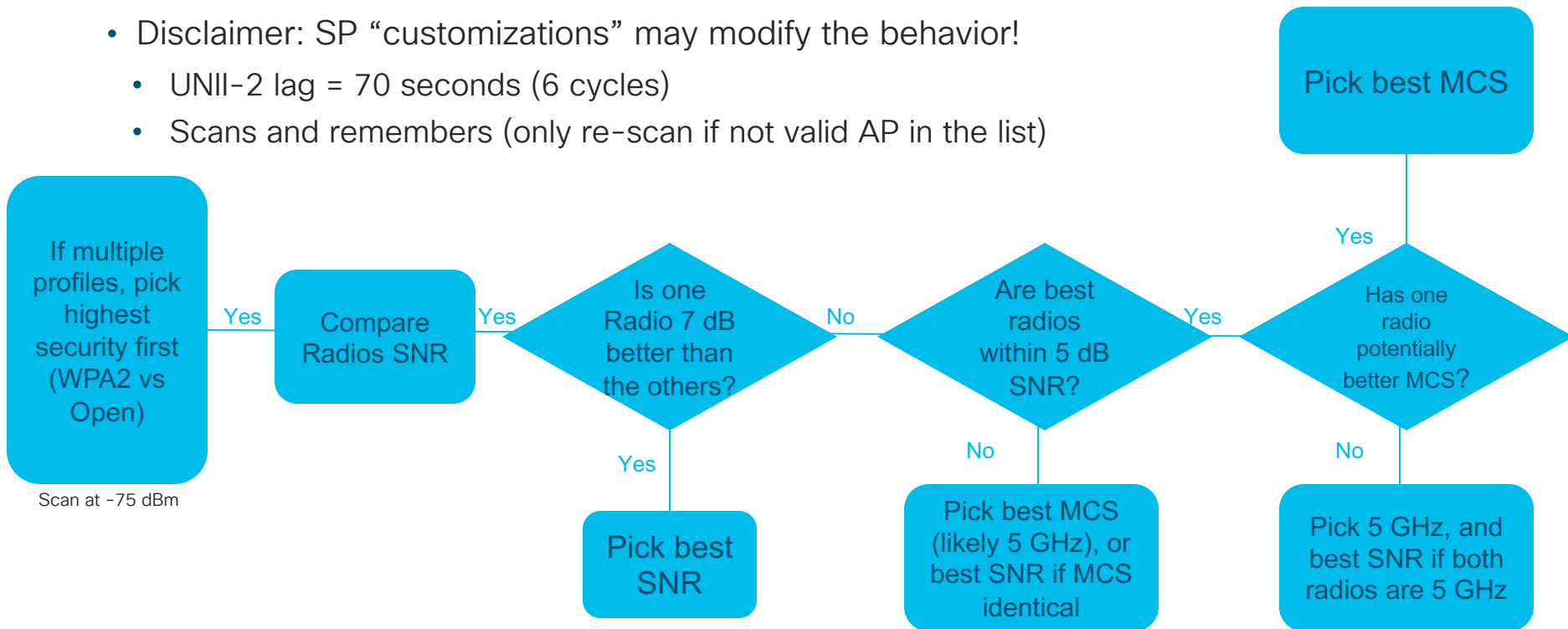
Samsung (Android)



- Android behavior depends on vendor, above is Samsung S8 and later
- If current AP signal is below -75 dBm **OR** if beacon loss > 2 seconds, **OR** if (RSSI lower than -65 dBm and CU > 70%)
- Scan*, join AP with signal 10 dBm better than current AP
- Samsung uses the 'short scan' (remembered channels first)
- <https://support.samsungknox.com/hc/en-us/articles/115013403768-Enhanced-Roaming-Algorithm>

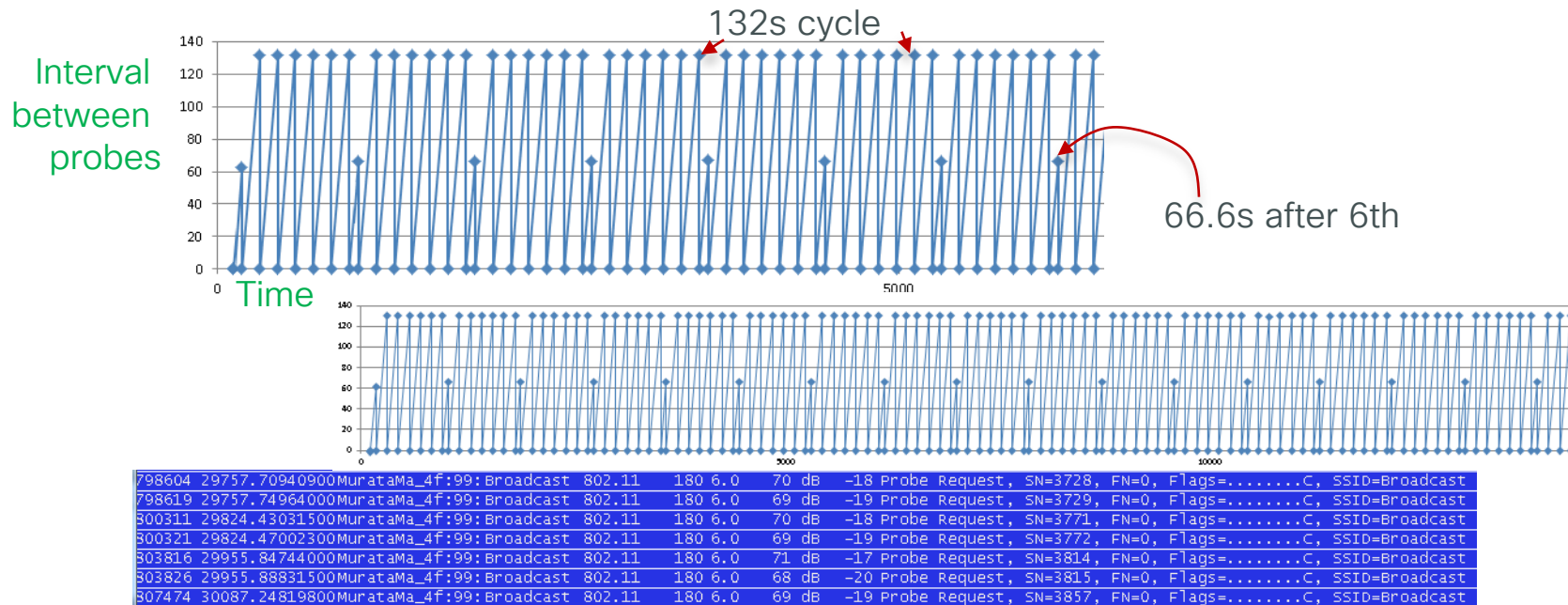
Samsung AP Arbitration Behavior

- Disclaimer: SP “customizations” may modify the behavior!
 - UNII-2 lag = 70 seconds (6 cycles)
 - Scans and remembers (only re-scan if not valid AP in the list)



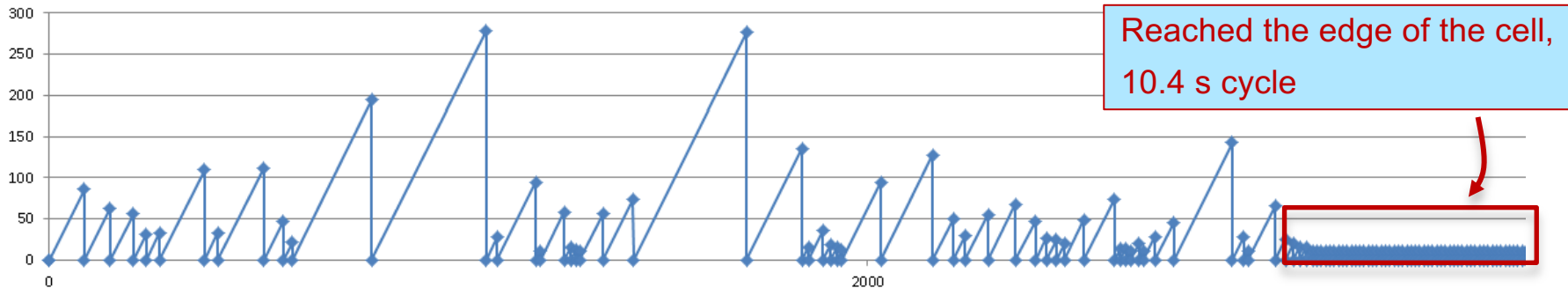
Other Android? Use Probe as Happiness Index

- Samsung S10 when idle and not associated (baseline)



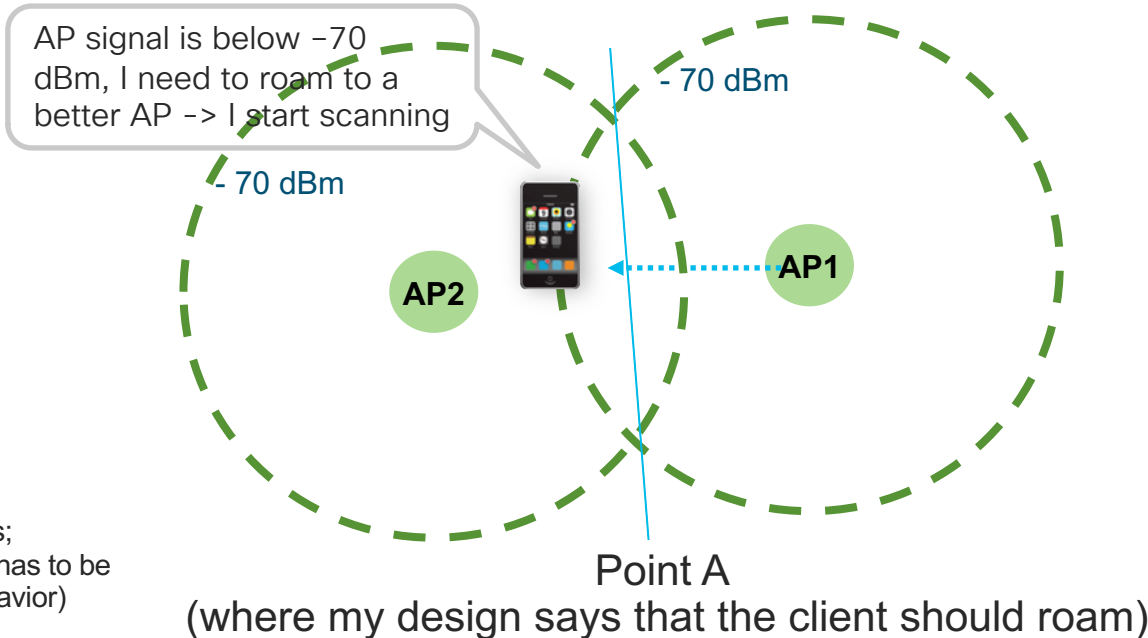
Determining Android Probing Behavior

- Try to determine when your BYOD gets to the edge of the cell (from its perspective): at that time, it will start probing repeatedly to find the next AP
- When at the edge of the cell, and idle (or moving with AP signal at low level), phone settles to a 10.4 s cycle
- When you observe this kind of behavior change, you know that there is the edge of your cell



How to Make a Phone Roam

- Phones do not scan 'because you move' (no accelerometer trigger)
- When data rate drops, or AP signal falls below -70 | -75 dBm RSSI*, phone scans and tries to roam.



- * -70 dBm iPhone, -75 dBm iPad, -75 dBm most Androids;
- (any packet from the AP, beacon or data is used; signal has to be below threshold for more than one second to trigger behavior)

The Authoritarian way - Optimized (“Smart”) Roaming

Without Smart Roaming

Weak Wi-Fi
Signal

-85dB

-80dB

Client Stickiness
Causes Poor
User Experience

Consistent User
Experience

Cisco “Smart Roaming”

-80dB

-80dB

Efficient Cell
Usage

3G or 4G

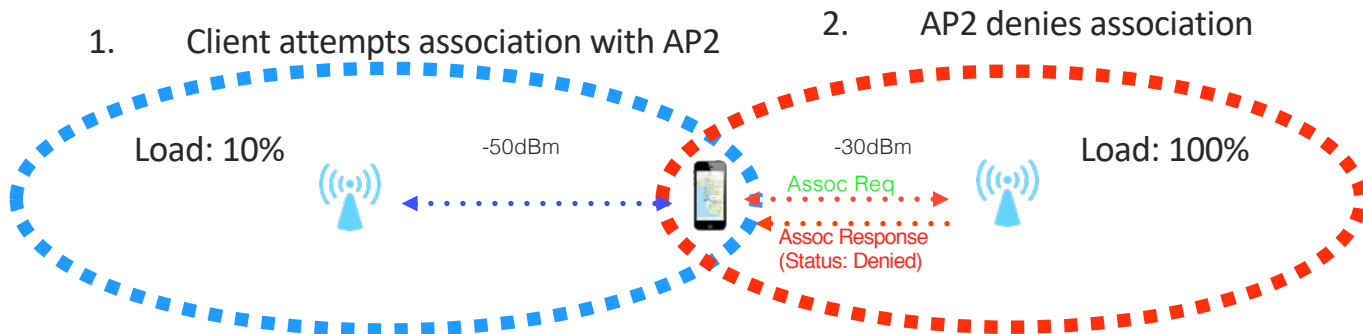
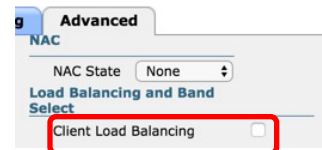
iOS and Aggressive Load balancing

- To steer clients to other available APs or bands, AP2 denies association
 - No standards compliant reason for denial
 - No information about neighboring Access Points
- If AP is the best signal... iPhone / iPad tries again...
- After 5 attempts, SSID (not 'BSSID') is blacklisted
 - This behavior is specific to iOS

WLANs > Edit 'Mynet'

< Back

Apply

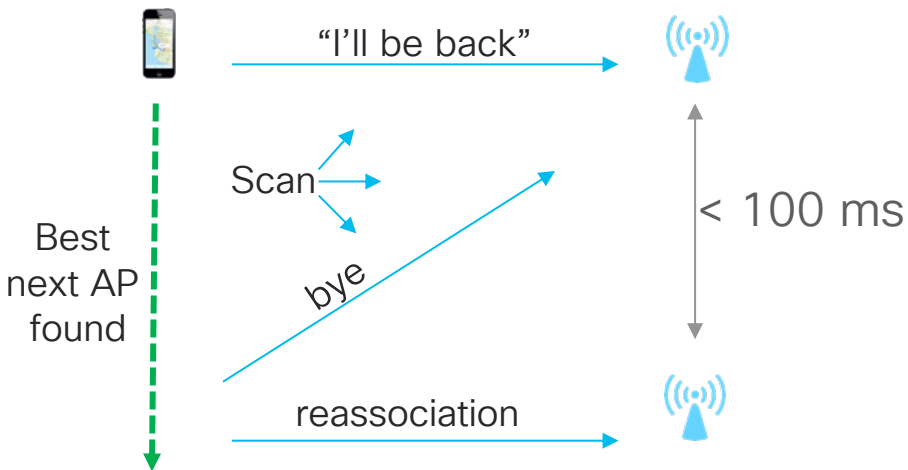


Do not use Client Load Balancing with phones... 802.11v can help

Roaming Scenarios

Your goal is to minimize your Webex real time flow interruptions

Weaker signal, need to roam...



Seamless roaming scenario

CAN
YOU
HEAR
ME



Can't talk to AP!

- No response, multiple retries, rate shifts...
- AP kicked me out

Panic scan!

AP found! Reassociation....

Failure! Bad AP / connection failed

Panic scan! ...



Many
seconds



"We like support calls" scenario

The Subtle Way: 802.11k (and 802.11v)

- Let's start with 802.11k

What could
my next AP be?

Here are the
best 6 for you

802.11k neighbor list

```
▶ 802.11 radio information
▶ IEEE 802.11 Action, Flags: .....C
▼ IEEE 802.11 wireless LAN management frame
  ▼ Fixed parameters
    Category code: Radio Measurement (5)
    Action code: Neighbor Report Response (5)
    Dialog token: 100
  ▼ Tagged parameters (30 bytes)
    ▼ Tag: Neighbor Report
      Tag Number: Neighbor Report (52)
      Tag length: 13
      BSSID: CiscoInc_db:df:7d (a8:0c:0d:db:df:7d)
      ▶ BSSID Information: 0x000002f7
      Operating Class: 0
      Channel Number: 40 (iterative measurements on that Channel Number)
      PHY Type: 0x07
    ▼ Tag: Neighbor Report
      Tag Number: Neighbor Report (52)
      Tag length: 13
      BSSID: CiscoInc_b4:46:cd (08:cc:68:b4:46:cd)
      ▶ BSSID Information: 0x000002f7
      Operating Class: 0
      Channel Number: 100 (iterative measurements on that Channel Number)
      PHY Type: 0x07
```

```
▶ 802.11 radio information
▶ IEEE 802.11 Action, Flags: .....C
▼ IEEE 802.11 wireless LAN management frame
  ▼ Fixed parameters
    Category code: Radio Measurement (5)
    Action code: Neighbor Report Request (4)
    Dialog token: 100
  ▶ Tagged parameters (13 bytes)
```

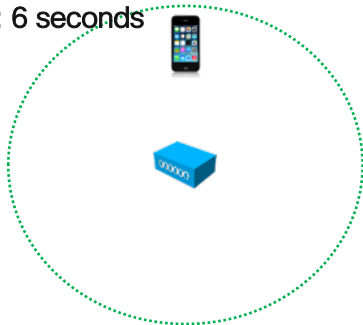
The Subtle Way: 802.11k (and 802.11v)

- Let's start with 802.11k

-70 dBm, I need to roam and scan:

ch 36, 40, 44, 48, 52, 56, 60, 64,
149, 153, 157, 161, 165, then 100,
104, 108, 112, 116, 120, 124, 128,
132, 136, 140

Total score: 6 seconds



Without 802.11k

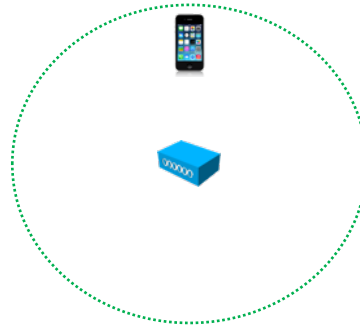
-70 dBm, I need to roam and scan:

scan shortlist ch 40, 48, 157.

Found usable AP? yes -> roam

Total score: 200 ms

No usable AP found? -> full scan



With 802.11k

802.11v: Send your BYOD to the Next (Best) Cell

- 802.11k vs 802.11v BSS Transition Management

What could
my next AP be?



Here are the
best 6 for you



802.11k neighbor list

Need to roam, what AP do
you recommend?



Try this one



802.11v Solicited request

Want to join your cell



Nah, load too high, go there
instead



802.11v Unsolicited request

Your RSSI / rates are too
low, roam to there instead



802.11v Unsolicited
Optimized Roaming request

802.11v: Cisco vs Other Guys

- We understand how iOS and Samsung devices think, other guys do not

Need to roam, what AP do
you recommend?

Love it, thanks!

Try this one



Need to roam, what AP do
you recommend?

That is NOT a good AP!
(ignore and full scan)

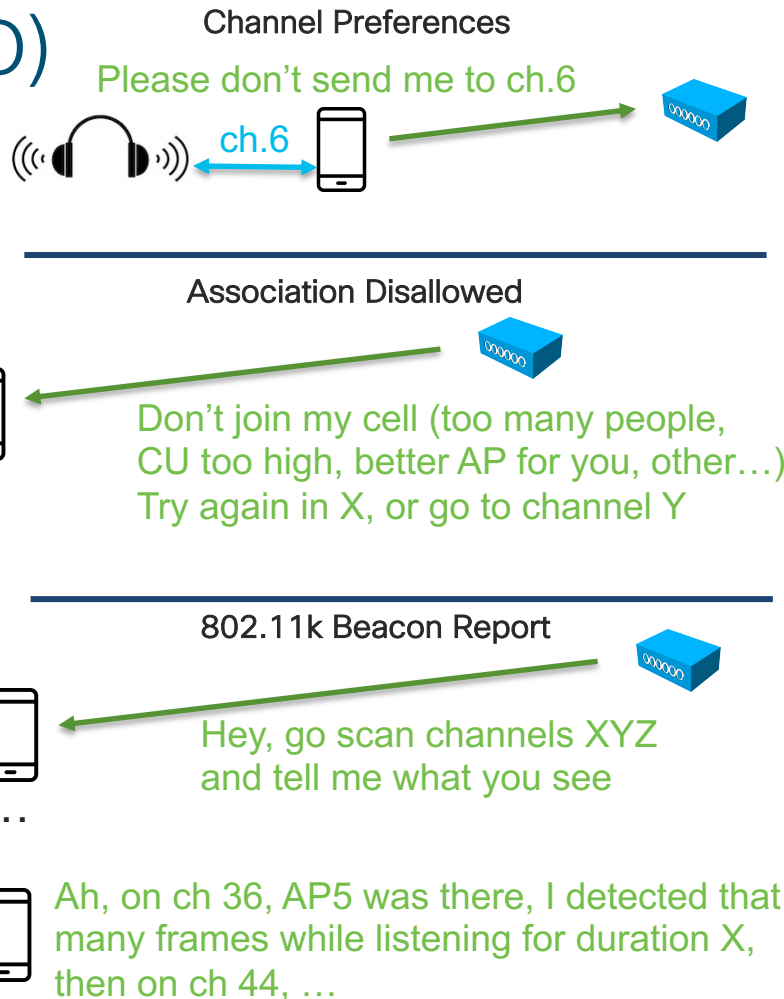
Try this one



Wi-Fi Agile Multiband (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



Where this Happens

Enable individually 802.11k,v
Or enable MBO

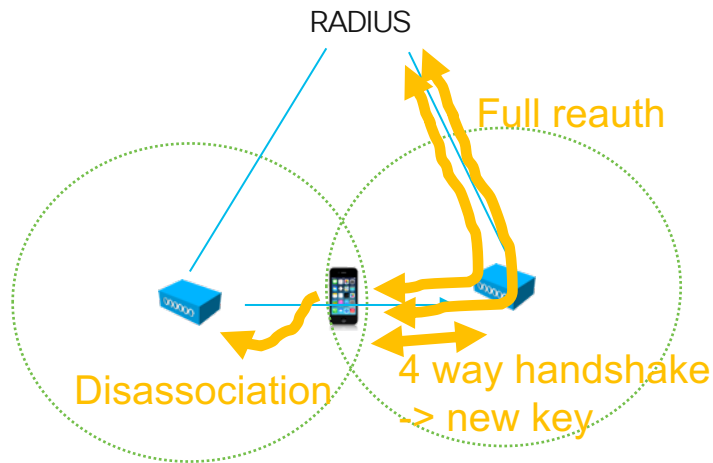
- Enables 802.11k/v/w

There is no downsides to
802.11k/v

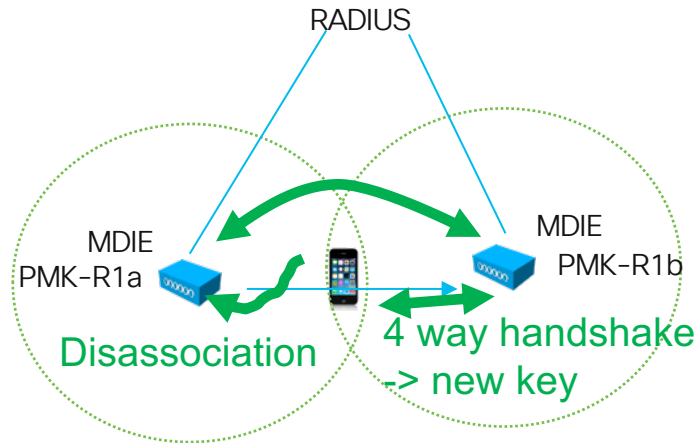
Test PMF/802.11w
before deployment

The screenshot displays the 'WLANs > Edit 'none'' configuration page. The 'General' tab is selected, showing the 'MBO State' checkbox, which is highlighted with a red box. Below it, the 'Off Channel Scanning Defer' section includes a 'Scan Defer Priority' row with checkboxes 0 through 7, where 4, 5, and 6 are checked. The '11v BSS Transition Support' section is also highlighted with a red box, containing checkboxes for 'BSS Transition' (checked), 'Disassociation Imminent(0 to 3000 TBTT)' (200), 'Optimized Roaming Disassociation Timer(0 to 40 TBTT)' (40), 'BSS Max Idle Service' (checked), 'BSS Max Idle Protected' (unchecked), and 'Directed Multicast Service' (checked). The 'Assisted Roaming (11k)' section is highlighted with a red box, showing 'Prediction Optimization' (unchecked), 'Neighbor List' (checked), and 'Dual Band Neighbor List' (unchecked). The 'DTIM Period (in beacon intervals)' is set to 1. The '11k' section at the bottom is highlighted with a red box, showing 'Neighbor List' (checked/Enabled), 'Neighbor List Dual Band' (unchecked/Enabled), and 'Assisted Roaming Prediction Optimization' (unchecked/Enabled). The 'Advanced' tab is also visible, showing 'KIS based CAC Policy' (unchecked), 'Radius Client Profiling' (unchecked), 'Local Client Profiling' (unchecked), 'PMIP' (unchecked), 'PMIP Mobility Type' (unchecked), 'PMIP NAI Type' (Hex), 'PMIP Profile' (Non), 'PMIP Realm' (Non), 'Universal AP Admin Support' (unchecked), and '11v BSS Transition Support' (checked/Enabled). The 'Universal AP Admin' is set to Non.

802.11r: Fast BSS Transition (AKA Fast Roaming)



Standard WPA2 (802.1x)
Score: up to 6 seconds



802.11r (FT)
Score: less than 100 ms

Cisco-Apple Optimized Roaming

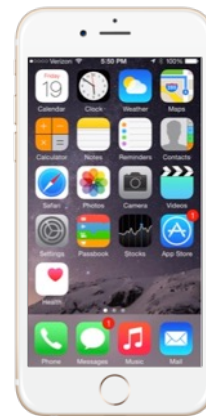


Legacy client **cannot** join the same SSID where 11r is enabled



Non-Cisco-AP

Legacy client that does not support 11r/k/v **can** join the same SSID



I recognize that you are an Apple device
11r is enabled for you

Association

802.11k, 802.11v are on by default



Cisco-AP

Do you Need Adaptive 802.11r?

Use Adaptive FT if:

- ✓ You have a large population of iOS clients
- ✓ Your Security is WPA2/WPA3
- ✓ You need fast roaming
- ✓ You cannot enable FT

Enterprise-class phones support 802.11r, hybrid works 'often'

Auth Key Mgmt

Fast Transition	Enabled
Over the DS	<input type="checkbox"/>
Reassociation Timeout	20

802.1x	<input checked="" type="checkbox"/>
PSK	<input type="checkbox"/>
CCKM	<input type="checkbox"/>
FT + 802.1x	<input checked="" type="checkbox"/>
FT + PSK	<input type="checkbox"/>
802.1x-SHA256	<input type="checkbox"/>
PSK-SHA256	<input type="checkbox"/>

WLANs > Edit 'none'

General Security QoS Policy-Mapping

Security Type Enterprise

MAC Filtering ☐

WPA2+WPA3 Parameters

Policy ☒ WPA2 ☐ WPA3

Encryption Cipher ☒ CCMP128(AES) ☐ CCM

Fast Transition

Fast Transition ☒ Adaptive

Over the DS ☒

Reassociation Timeout 20 Seconds

Protected Management Frame

General Security Advanced

Layer2 Layer3 AAA

Layer 2 Security Mode WPA + WPA2

MAC Filtering ☐

Protected Management Frame

PMF Disabled

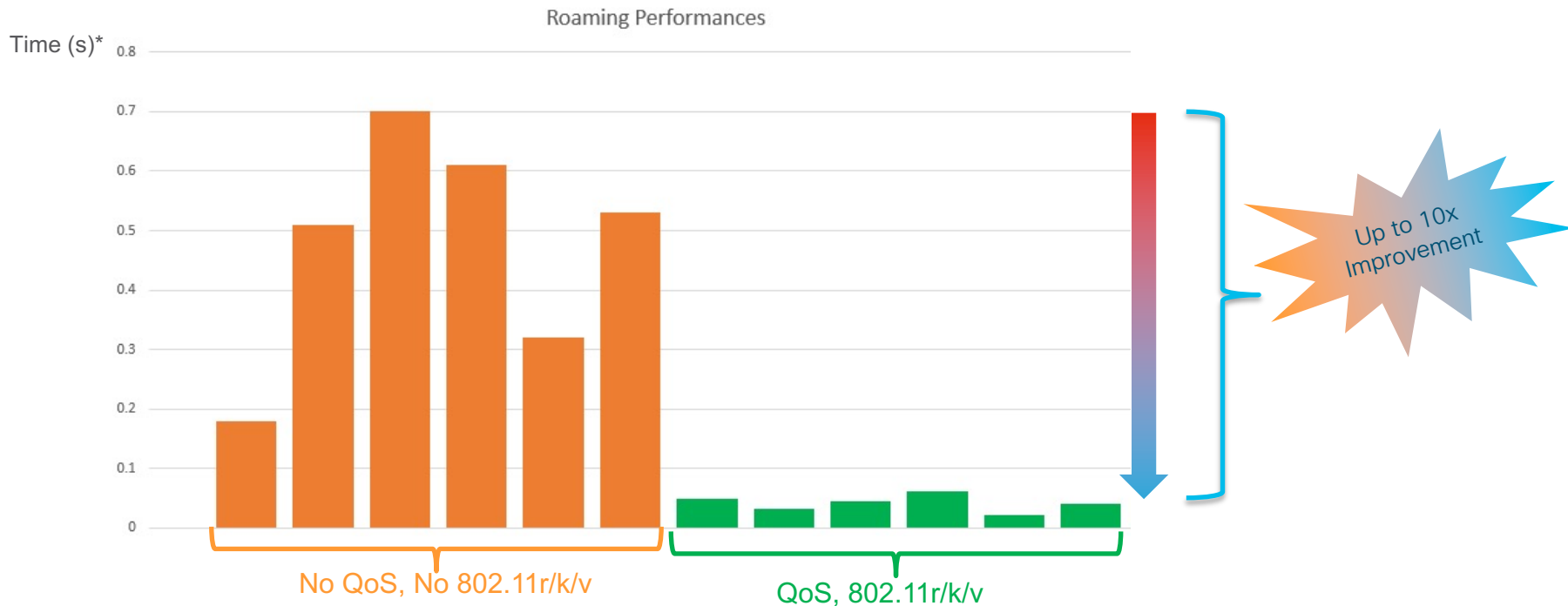
Fast Transition Adaptive Enabled

Over the DS

Reassociation Timeout Adaptive Enabled

Roaming Performance :

10x Better end-user Browsing and App Experience



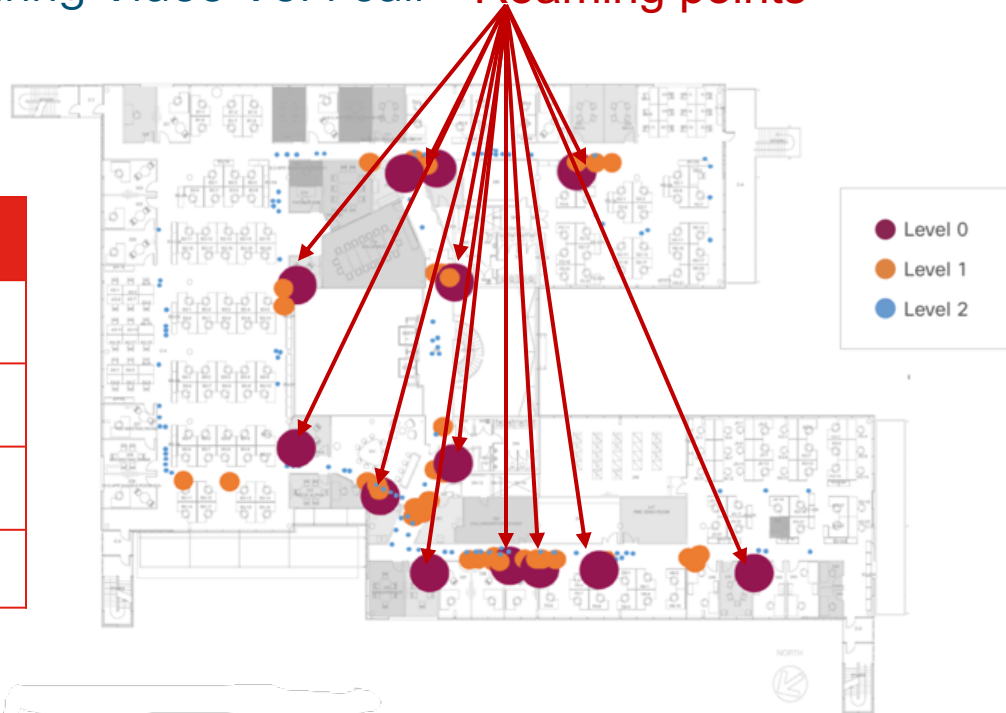
*Time Interval between last packet on previous AP, and first packet on next AP

An Example – Cisco Bedfont Lakes

Support requests – Wi-Fi issues during Video VoFi call

Roaming points

Incident level	(Before upgrade) Count over 1 week
Level 0 (productivity Crusher) - Call disconnected -	13
Level 1 (Productivity Inhibitor) - Audio & video gaps -	36
Level 2 (Minor Annoyance) - Audi glitch or light pixelization-	131
Total	180



1. Determine coverage gaps
2. If coverage is satisfactory, look at SW config

An Example – Cisco Bedfont Lakes

Support requests – Wi-Fi issues during Video VoFi call

Incident level	(Before upgrade) Count over 1 week	(After upgrade) Count over 1 week	Change (%)
Level 0 (productivity Crusher) - Call disconnected -	13	0	- 100%
Level 1 (Productivity Inhibitor) - Audio & video gaps -	36	8	- 78%
Level 2 (Minor Annoyance) - Audi glitch or light pixelization-	131	96	- 27%
Total	180	104	-42 %

An Example – Cisco Bedfont Lakes

Support requests – Wi-Fi issues during Video VoFi call

Before the Software Upgrade



After the Software Upgrade



<https://www.cisco.com/c/dam/en/us/products/collateral/wireless/cisco-on-cisco-so-r4.pdf>

What About the Other Clients?

- Some client support 802.11r (Enterprise Class), most do not support 802.11k / v

- 802.11r: search the Wi-Fi Alliance web site – Voice Enterprise certified devices must support 802.11r

The screenshot shows the Wi-Fi Alliance Product Finder website. The URL is www.wi-fi.org/product-finder-results?sort_by=default&sort_order=desc&capabilities=6. The page displays "Your Search Results (356)" and includes a sidebar with navigation options: Keyword Search, Brand, Categories, and Featured Capabilities. The Featured Capabilities section lists various certifications, with "Voice-Enterprise (356)" selected. The main content area shows a grid of product cards for Alcatel-Lucent, Bitatek, Lenbrook, NEC, and HTC, each displaying product details and certification status.

Product Finder
Your Search Results (356) Start new search

Sort By: Best Match

Clear all filters

Keyword Search

Brand

Categories

Featured Capabilities

- ☐ Wi-Fi Vantage™ (21)
- ☐ Wi-Fi CERTIFIED WiGig™ (0)
- ☐ Wi-Fi CERTIFIED™ ac (with wave 2 features) (32)
- ☐ Wi-Fi Aware™ (0)
- ☐ Passpoint™ (278)
- ☐ Miracast® (243)
- ☐ Wi-Fi Direct® (330)
- ☐ Wi-Fi CERTIFIED™ ac (255)
- ☒ Voice-Enterprise (356)
- ☐ Wi-Fi Protected Setup™ (332)

Show Advanced Filters

Product Details:

- Alcatel-Lucent:** Product Name: Lightradio 9764 MCO ... Model Number: AP-9764 Brand: Alcatel-Lucent Category: Routers Last Certified Date: 2013-12-18
- Bitatek:** Product Name: Frey Model Number: M1 Brand: Bitatek Co., Ltd. Category: Other Last Certified Date: 2016-09-22
- Lenbrook:** Product Name: Node2 Model Number: N110 Brand: Lenbrook Industries Ltd. Category: Gaming, Media & Music Last Certified Date: 2015-03-10
- NEC:** Product Name: PK-WL026 Model Number: PK-WL026 Brand: NEC Corporation Category: Routers Last Certified Date: 2014-05-14
- htc:** Product Name: OPJA30000 Model Number: OPJA30000 Brand: HTC Corporation Category: Phones Last Certified Date: 2015-02-09
- htc:** Product Name: OPJA20000 Model Number: OPJA20000 Brand: HTC Corporation Category: Phones Last Certified Date: 2015-02-09

What About the Other Clients?

- Some client support 802.11r (Enterprise Class), most do not support 802.11k / v

- 802.11v: Mike Albano maintains a list of clients, with announced 11v support

Secure <https://sites.google.com/a/mikealbano.com/clients/home>

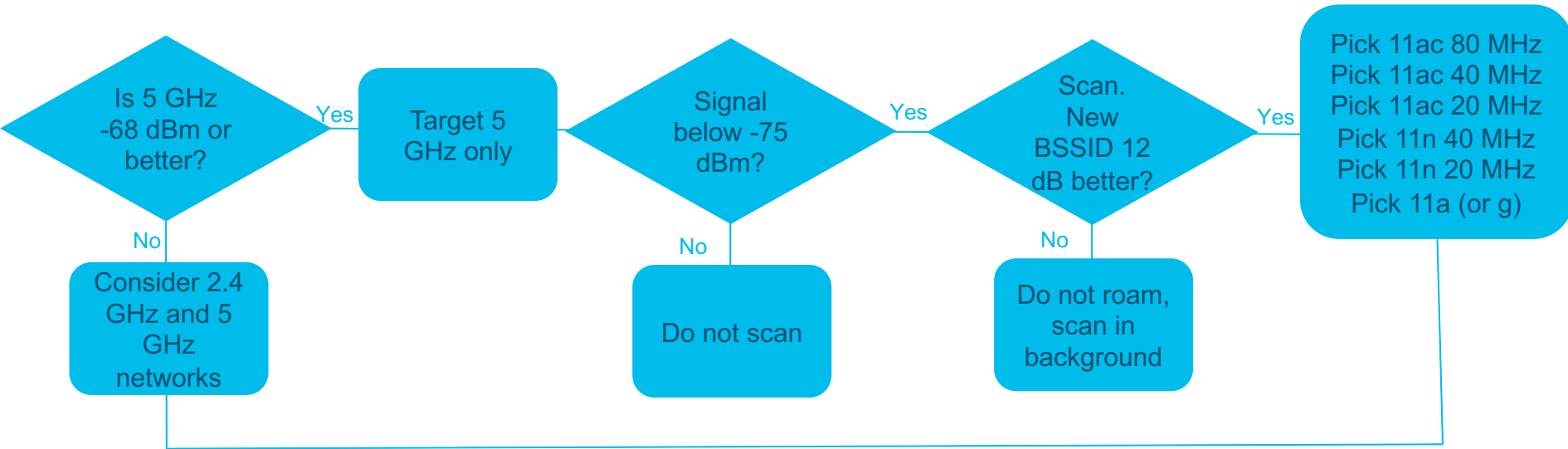
Edimax AC1200 USB
Google Home
Google Pixel
HP EliteBook Folio
HP zBook 15inch
HTC One
HTC One(M8)
Intel 6235
Intel 7265
Intel 7260
Intel 6300-Ultimate
Intel 8265
iMac 5K
iMac (Mid 2007)

Frog News US News EDCS - Eng:EAG:W... WNBU Project list WNBU code download Imported From Firefox

	124	128	132	136	140	144	149	153	157	161	165	SS	.11	MU-MIMO	Max Tx	.11v	.11w
Edimax AC1200 USB	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	2	n		11	N	
Google Home	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	2	n		15		
Google Pixel	N	N	N	N	N	N	Y	Y	Y	Y	Y	1	ac		30	Y	
HP EliteBook Folio	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	2	ac		7		
HP zBook 15inch	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	1	n		13		
HTC One	N	N	N	N	N	N	Y	Y	Y	Y	Y	1	n				
HTC One(M8)	N	N	N	N	N	N	Y	Y	Y	Y	Y	1	n				
Intel 6235	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						
Intel 7265	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						
Intel 7260	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						
Intel 6300-Ultimate	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						
Intel 8265	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y						
iMac 5K	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	2	ac	N	19	Y	
iMac (Mid 2007)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	2	ac	N	19	Y	

What About the Other Clients?

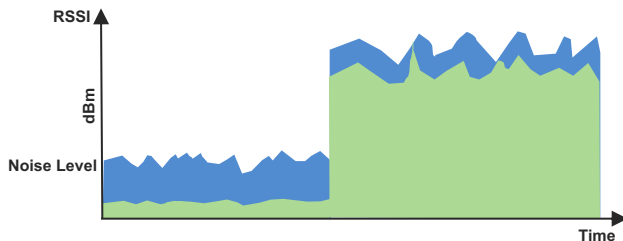
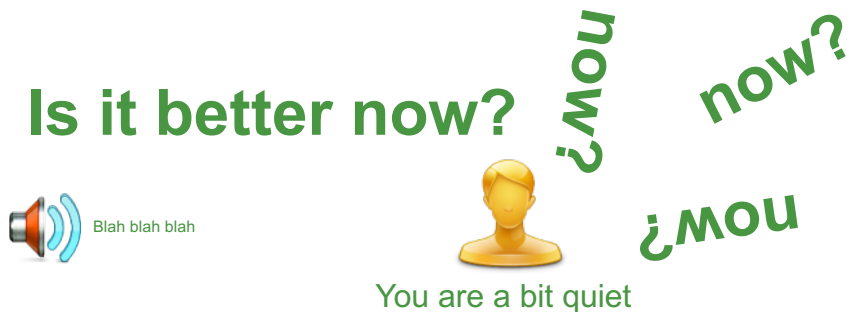
- Mac OS Roaming Logic (<https://support.apple.com/en-us/HT206207>)
- No 11v/k/r support





Optimizing Cell Overlap

Higher Power Does not Always Mean Better Signal

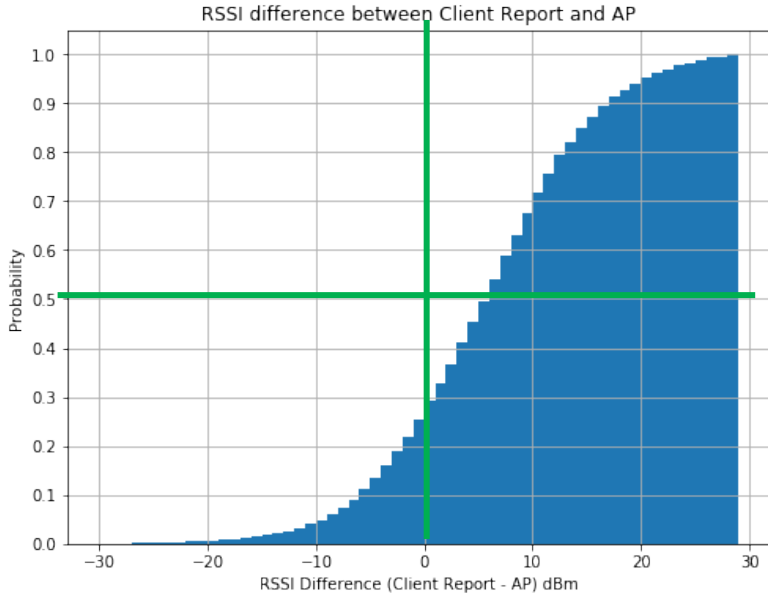


Aim for:

- Noise level ≤ -92 dBm
- RSSI ≥ 67 dBm
- > 25 dB or better SNR
- Channel Utilization under 50%.

The “View from my Hand” is Different from the “View from the Ceiling”

- 6 month report from network ‘designed from the ceiling’
 - AP power set with “AP to AP” in mind(max ‘level 1’)
- RSSI seen by the AP is lower than that seen by Client (likely due to lower transmit power of Client)
- RSSI difference is significant.
 - 50 percent of time the RSSI is about 6 dB. Median is 6 dB with a std of 10 dB.



I see you at -62

AP1

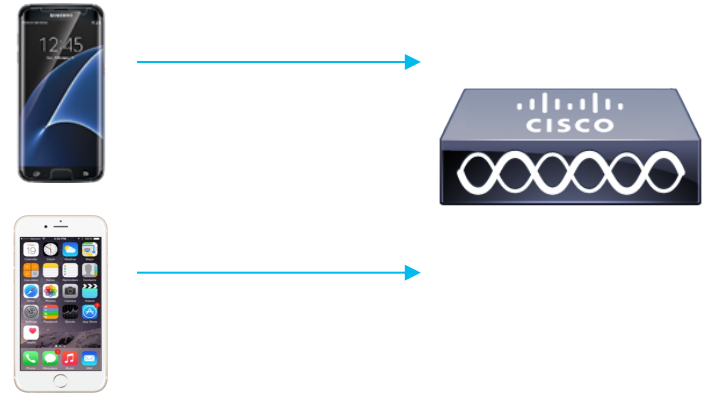


I see you at -56

How do We Know the View from the Client?

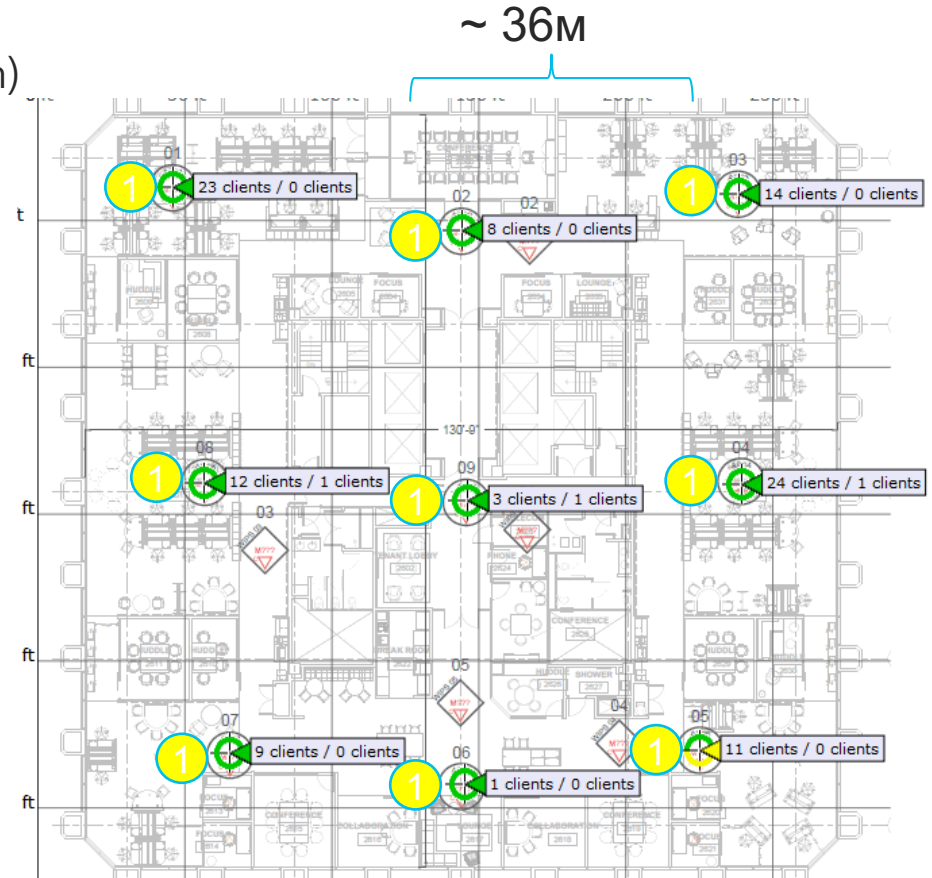
Unique Cisco partnership

- At association, client sends us HW, OS details
- Upon disconnection, also sends us non-802.11 disconnect reasons
- iOS also sends us 11k view at each roam
- Samsung supports dynamic 11k queries



Imagine This Scenario

- (based on an actual customer situation)
- Customer moved to first Wi-Fi only building (including voice and video)
- DISASTER! Wi-Fi was Terrible!!
- Investigation revealed all APs at max power (power level 1)
- Covering ~700 sq. m. per AP (230 sq. m. per AP is recommended)
- They needed 3x as many APs!



If AP Signal is Strong, Client Uses High Data Rate

- Client power can be low, noise at the AP high, HW specs may be different...



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



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

Can Power Really Damage Cell Conditions?

- Bad design example: Client @ 12 dBm, AP @20 dBm

17	0.039879000	172.31.255.101	172.31.255.103	UDP	1420	34	-35 55 dB	54.0	Source port: 50857	Destination port: search-agent
18	0.040266000	172.31.255.101	172.31.255.103	UDP	1420	34	-35 55 dB	54.0	Source port: 50857	Destination port: search-agent
19	0.040648000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
20	0.041938000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
21	0.042217000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	36.0	Source port: 50857	Destination port: search-agent
22	0.043444000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	12.0	Source port: 50857	Destination port: search-agent
23	0.043445000	Cisco_Oa:04:2e (RA)		802.11	40		-45 45 dB	12.0	Acknowledgement, Flags=.....C	
24	0.043850000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
25	0.044245000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
26	0.044641000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent
27	0.045023000	172.31.255.101	172.31.255.103	UDP	1420	34	-35 55 dB	54.0	Source port: 50857	Destination port: search-agent
28	0.045750000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	36.0	Source port: 50857	Destination port: search-agent
29	0.046223000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	36.0	Source port: 50857	Destination port: search-agent
30	0.047450000	172.31.255.101	172.31.255.103	UDP	1420	34	-29 61 dB	12.0	Source port: 50857	Destination port: search-agent
31	0.047450000	Cisco_Oa:04:2e (RA)		802.11	40		-47 43 dB	12.0	Acknowledgement, Flags=.....C	
32	0.047963000	172.31.255.101	172.31.255.103	UDP	1420	34	-34 56 dB	54.0	Source port: 50857	Destination port: search-agent

Frame 29: 1420 bytes on wire (11360 bits), 1420 bytes captured (11360 bits) on interface 0

Radiotap Header v0, Length 26

IEEE 802.11 QoS Data, Flags:R.F.C

Type/Subtype: QoS Data (0x28)

Frame Control: 0x0A88 (Normal)

Version: 0

Type: Data frame (2)

Subtype: 8

Flags: 0xA

....1..10 = DS status: Frame from DS to a STA via AP(To DS: 0 From DS: 1) (0x02)

....0.. = More Fragments: This is the last fragment

....1.. = Retry: Frame is being retransmitted

...0.... = PWR MGT: STA will stay up

..0.... = More Data: No data buffered

.0.... = Protected flag: Data is not protected

0.... = Order flag: Not strictly ordered

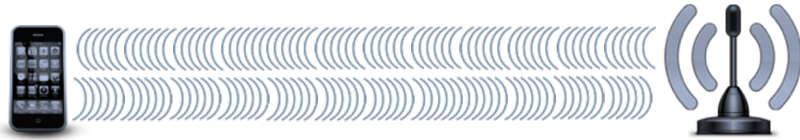
Based on Rx AP signal, BYOD thinks 54 Mbps rate is okay...

But client message is too weak, and AP does not ACK until rate falls to 12 mbps

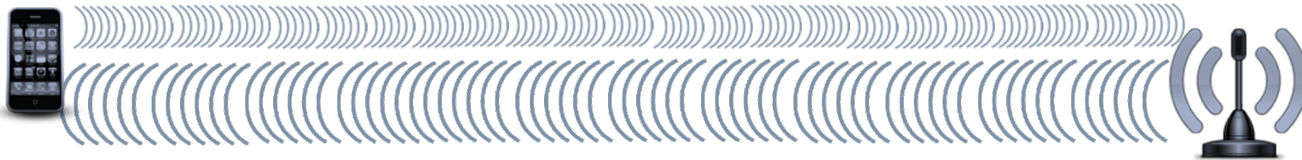
Each message takes 8 times more to be transmitted
(including EIFS and retries)

So, what is the right Power?

- In short: **equal to your worst client max power**
 - E.g. you design for 5 GHz, worst client max is at 12-14 dBm, set your AP power to 14 dBm



- Otherwise, you get this:



Hand and Phone Position Affect Signal

Object in Signal Path	Signal Attenuation Through Object
Plasterboard wall	3 dB
Glass wall with metal frame	6 dB
Cinderblock wall	4 dB
Office window	3 dB
Metal door	6 dB
Metal door in brick wall	12 dB
Phone and body position	3 - 6 dB
Phone near field absorption	Up to 15 dB

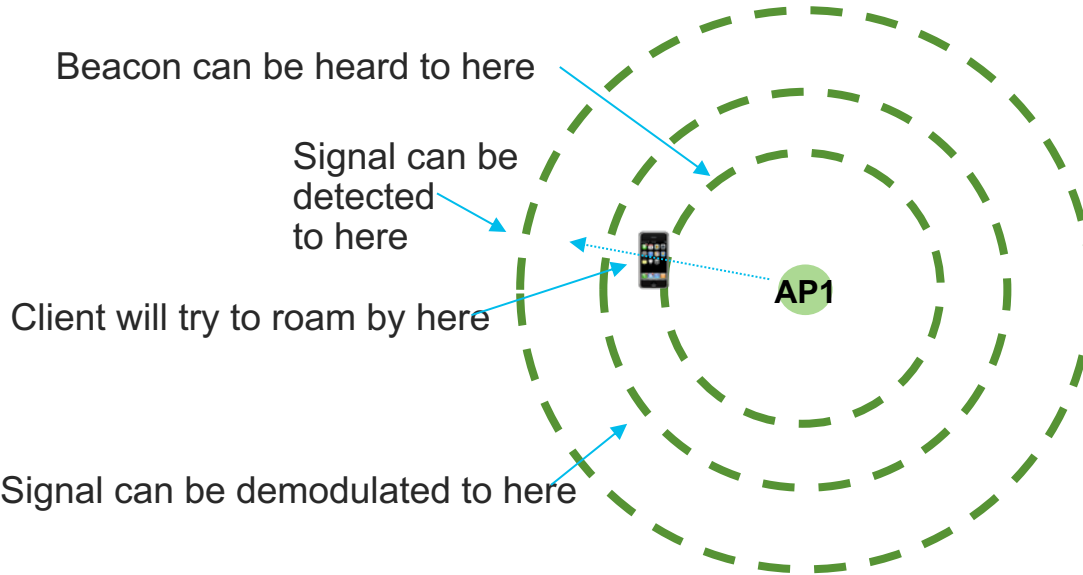


There can be a 20 dB difference between these photos



Power and Roaming

- First Mandatory Data Rate is used for beacon transmission
- Can be used to modulate cell useful area
- But iOS and Samsung will roam if more than 20 beacons lost



Data Rates**	
1 Mbps	Disabled
2 Mbps	Disabled
5.5 Mbps	Disabled
6 Mbps	Disabled
9 Mbps	Disabled
11 Mbps	Disabled
12 Mbps	Mandatory
18 Mbps	Supported
24 Mbps	Supported
36 Mbps	Supported
48 Mbps	Supported
54 Mbps	Supported

Do not Waste your Time Disabling 802.11n/ac/ax Rates

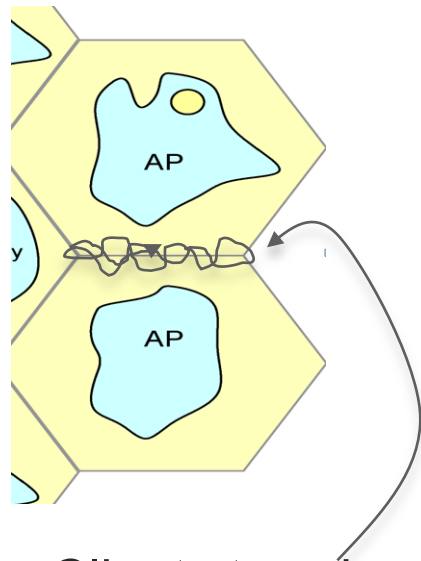
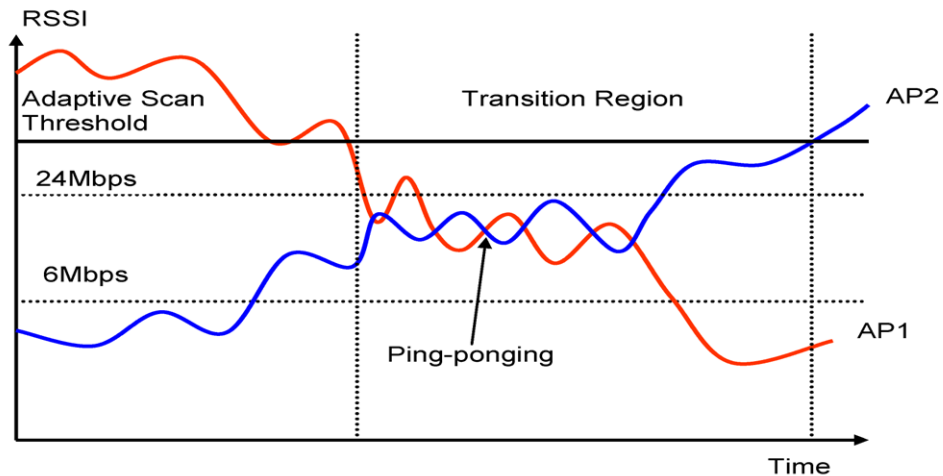
- 6, 12, 24 Mbps were 'default mandatory' and tested because they represented different modulations (BPSK, QPSK, QAM)
 - There is no mandate for MCSs
 - Your client may send at MCS disabled on your WLC
 - All you are doing is creating asymmetry

MCS/(Data Rate)	MCS/(Data Rate)	MCS/(Data Rate)	MCS/(Data Rate)
<input checked="" type="checkbox"/> 0/(7Mbps)	<input checked="" type="checkbox"/> 1/(14Mbps)	<input checked="" type="checkbox"/> 2/(21Mbps)	<input checked="" type="checkbox"/> 3/(29Mbps)
<input checked="" type="checkbox"/> 4/(43Mbps)	<input checked="" type="checkbox"/> 5/(58Mbps)	<input checked="" type="checkbox"/> 6/(65Mbps)	<input checked="" type="checkbox"/> 7/(72Mbps)
<input checked="" type="checkbox"/> 8/(14Mbps)	<input checked="" type="checkbox"/> 9/(29Mbps)	<input checked="" type="checkbox"/> 10/(43Mbps)	<input checked="" type="checkbox"/> 11/(58Mbps)
<input checked="" type="checkbox"/> 12/(87Mbps)	<input checked="" type="checkbox"/> 13/(116Mbps)	<input checked="" type="checkbox"/> 14/(130Mbps)	<input type="checkbox"/> 15/(144Mbps)

9438	38.939308	172.31.255.104	54.201.225.120	TCP	134	53078 → 443 [ACK] Seq=644 ACK=3333
9442	38.940562	172.31.255.104	54.201.225.120	TLSv1...	334	7 144.444,144.444 Application Data, Application Data
9443	38.940640	172.31.255.104	54.201.225.120	TLSv1...	528	7 144.444,144.444 Application Data, Application Data
LDPC extra OFDM symbol: False						
Beamformed: False						
▶ User 0: MCS 7						
Group Id: 0						
Partial AID: 0						
Data rate: 144.4 Mb/s						
Channel: 36						
Frequency: 5180MHz						
Noise level (dBm): -99dBm						
TSF timestamp: 1503338255						

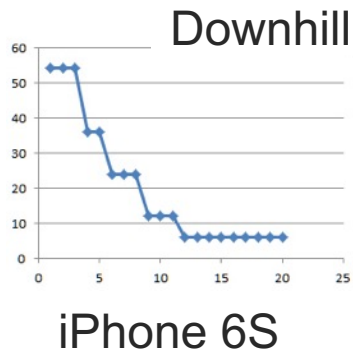
Client

Avoid Ping Pong Zones

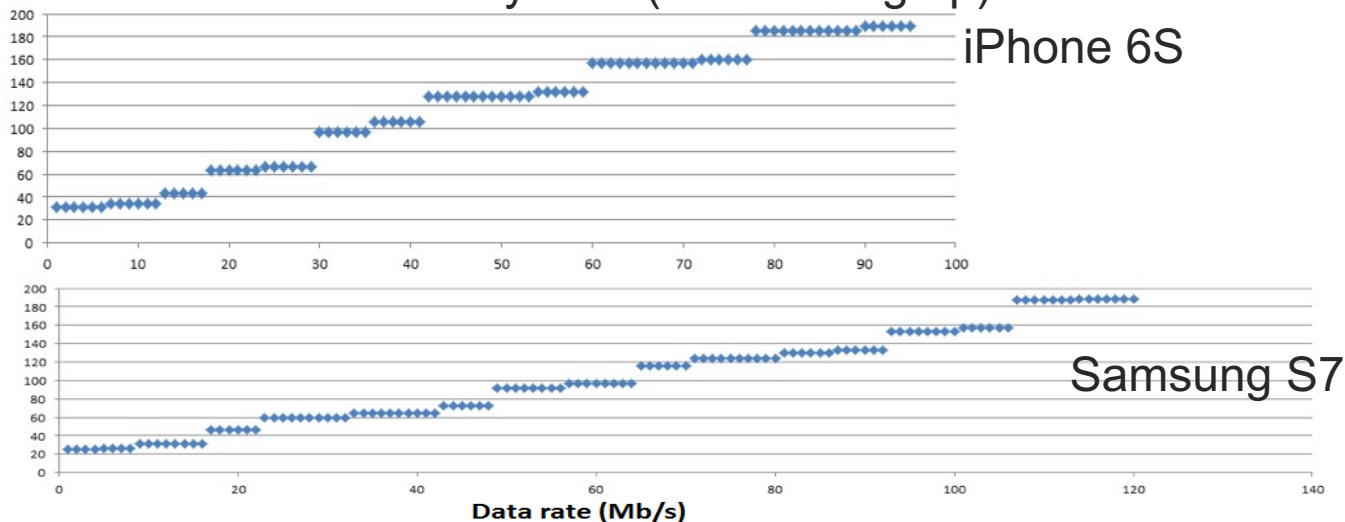


Ping-pong effect occurs when a wireless client is at the edge of two cells and hops between them.

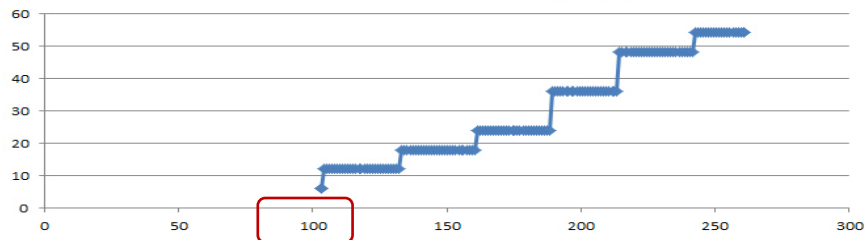
Rate Shifting Performance Evaluation



Recovery time (rate shifting up)

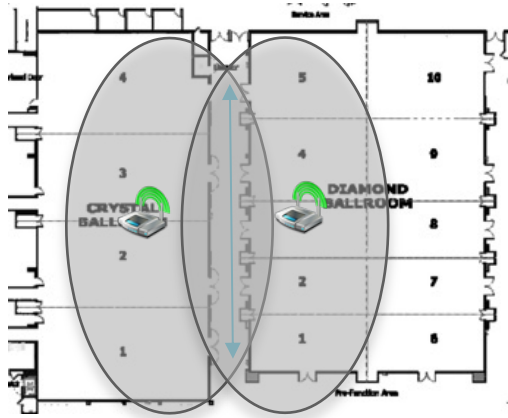


Worse
(cheap Android brand)



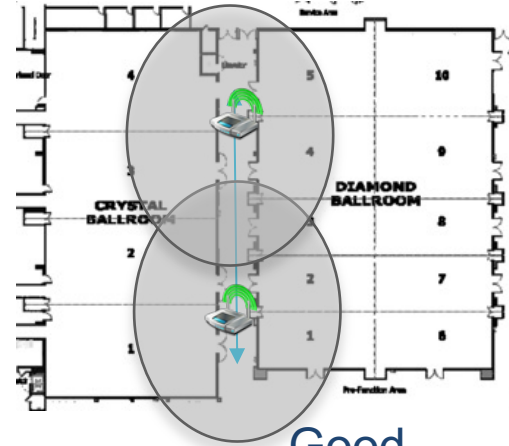
Impact on Your Network Design

- Set your AP power to 11 to 14 dBm
 - When your AP signal is at -62 dBm / - 67 dBm on the phone, another AP should be in range
 - Make sure that your first allowed rate is mandatory / beacon rate
- Don't hide the SSID
- Avoid Designs with sudden signal degradation (Ping Pong syndrome)



Bad

↕ Outside space where people on a call pace back and forth



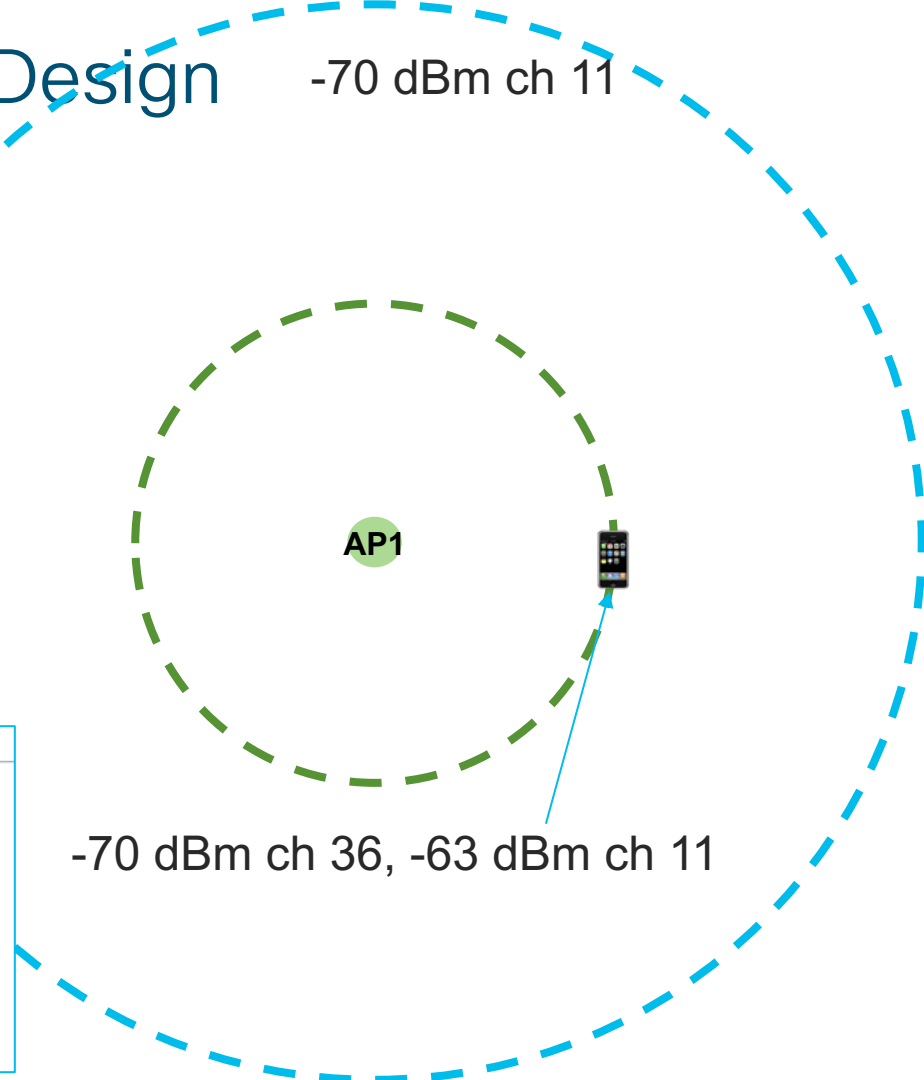
Good

Impact on your Network Design

- 2.4 GHz vs 5 GHz issue
- AP1 power level 1 for 5 GHz
- AP1 power level 1 for 2.4 GHz
- Solution: make sure that AP power on 2.4 GHz is at least 2 levels below AP power on 5 GHz (e.g. 5 GHz -> level 3, 2.4 GHz -> level 5)
- RRM “should” do it for you if your design is right and RRM config correct

Tx Power Level Assignment Algorithm

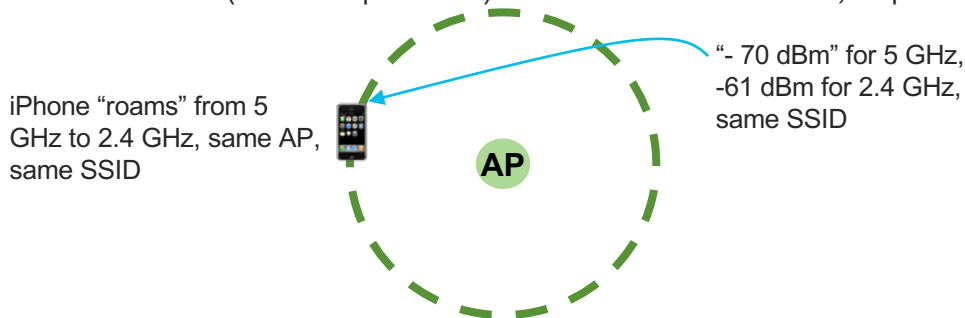
Power Level Assignment Method	<input checked="" type="radio"/> Automatic <input type="radio"/> On Demand <input type="radio"/> Fixed	Every 600 secs <input type="button" value="Invoke Power Update Once"/> <input type="text" value="1"/>
Maximum Power Level Assignment (-10 to 30 dBm)	<input type="text" value="14"/>	
Minimum Power Level Assignment (-10 to 30 dBm)	<input type="text" value="-10"/>	
Power Assignment Leader	WLC40 (172.31.255.40)	
Last Power Level Assignment	150 secs ago	
Power Threshold (-80 to -50 dBm)	<input type="text" value="-70"/>	
Channel Aware	<input type="checkbox"/> Enabled	
Power Neighbor Count	3	



Impact on your Network Design

Design your 5 GHz / 2.4 GHz overlap wisely:

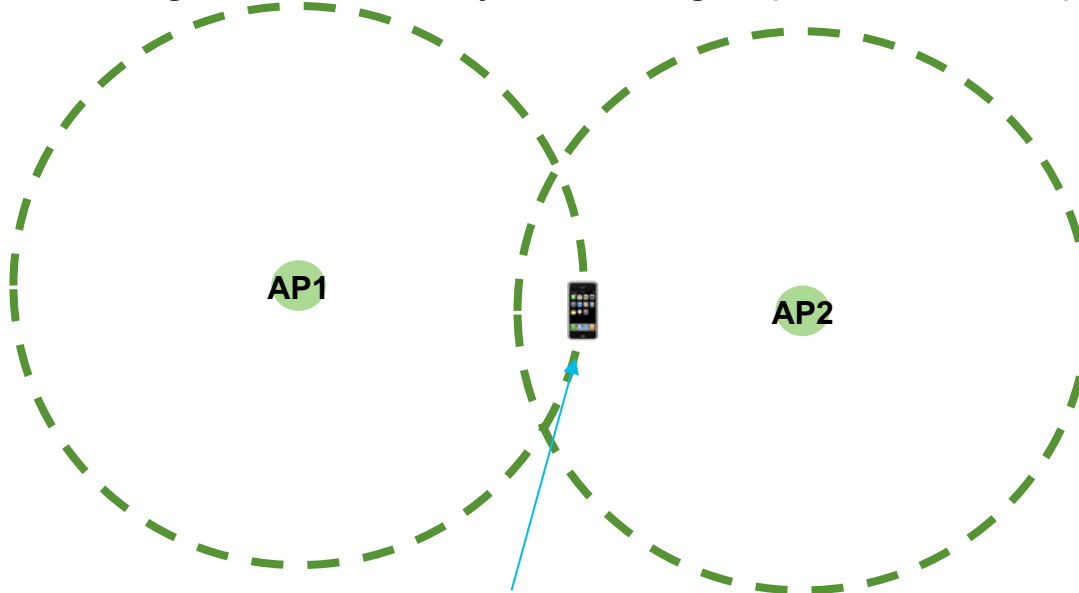
- 2.4 GHz signal, at same distance from the AP, is commonly 7 dB better than 5 GHz signal
- IOS is “supposed to” roam to next BSSID only if its signal is at least 8 dB better than previous one (this in theory avoid the 5 GHz to 2.4 GHz poor roaming behavior)
- BUT measurement sensitivity uncertainty in mass silicon is 3 to 4 dB*
- To limit roaming, limit the SSID to one band (5 GHz if possible). With dual-band SSIDs, expect frequent 5 GHz -> 2.4 GHz roams



* This means that your iPhone can show -70 dBm for the AP, while my iPhone at exact same position can show between -66 and -74. Measure next day on your iPhone and you may also see anything between -66 and -74

Impact on your Network Design

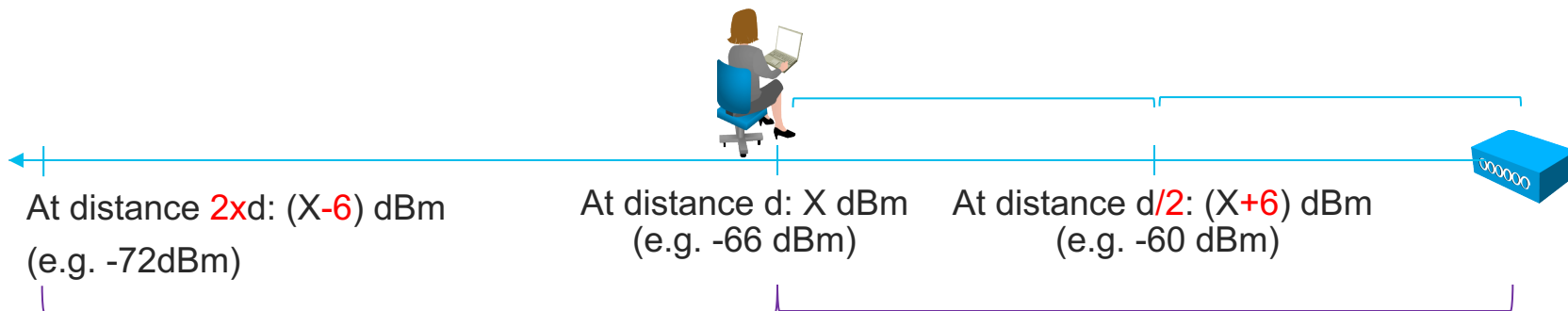
If you can, design for 5 GHz only, and design optimized overlaps



At the point where AP1 signal is -70 dBm, AP2 signal is -62 dBm
That's a -66 dBm edge

How To Design Your Overlap

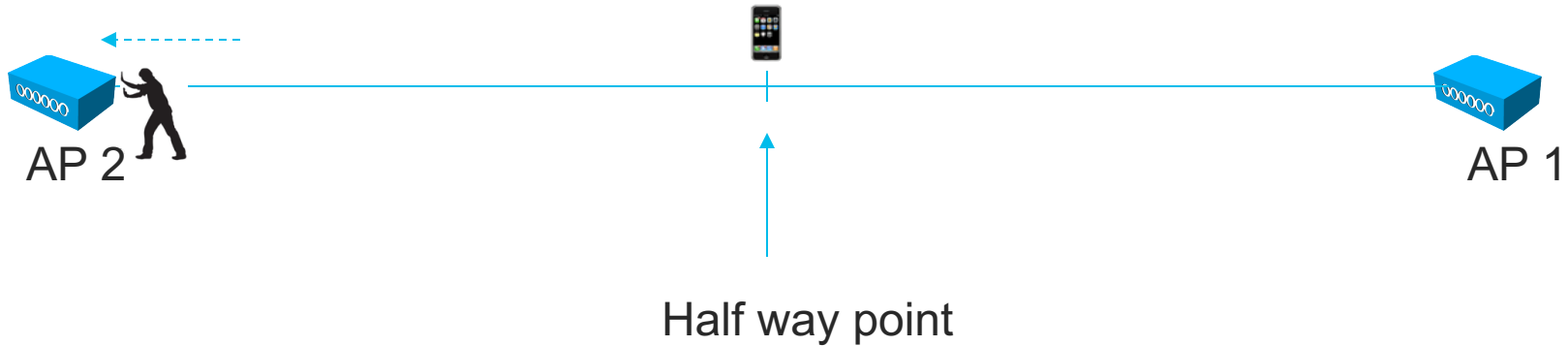
- First trick to know:
 - Twice the distance = -6 dB
 - Half the distance = + 6dB



The – 72 dBm Rule

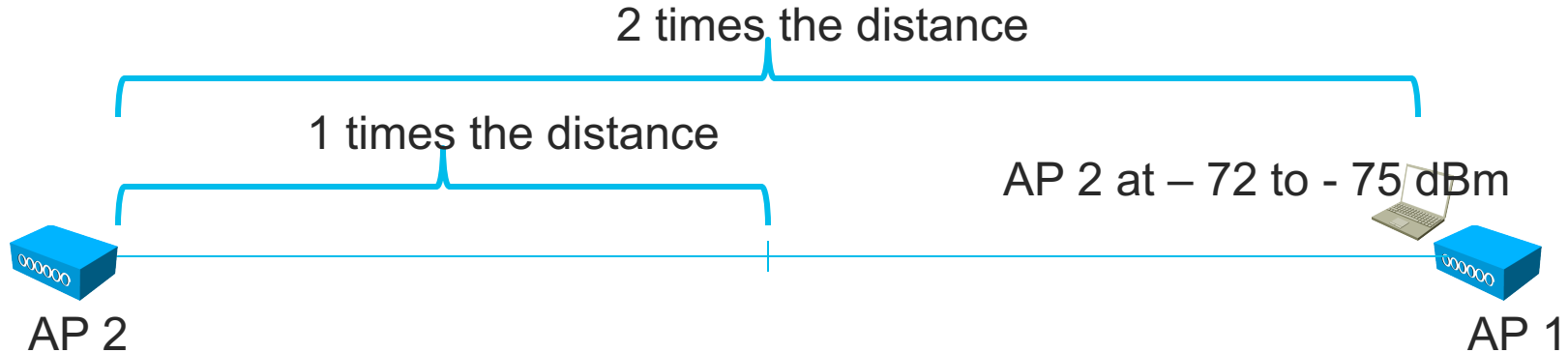
- So if you stand at the “–66 dBm border”...
 - Move away from AP 1 until you get – 66 dBm
 - Then pull AP 2 in the other direction until you also hear it at – 66 dBm

AP 2 at – 66 dBm AP 1 at – 66 dBm



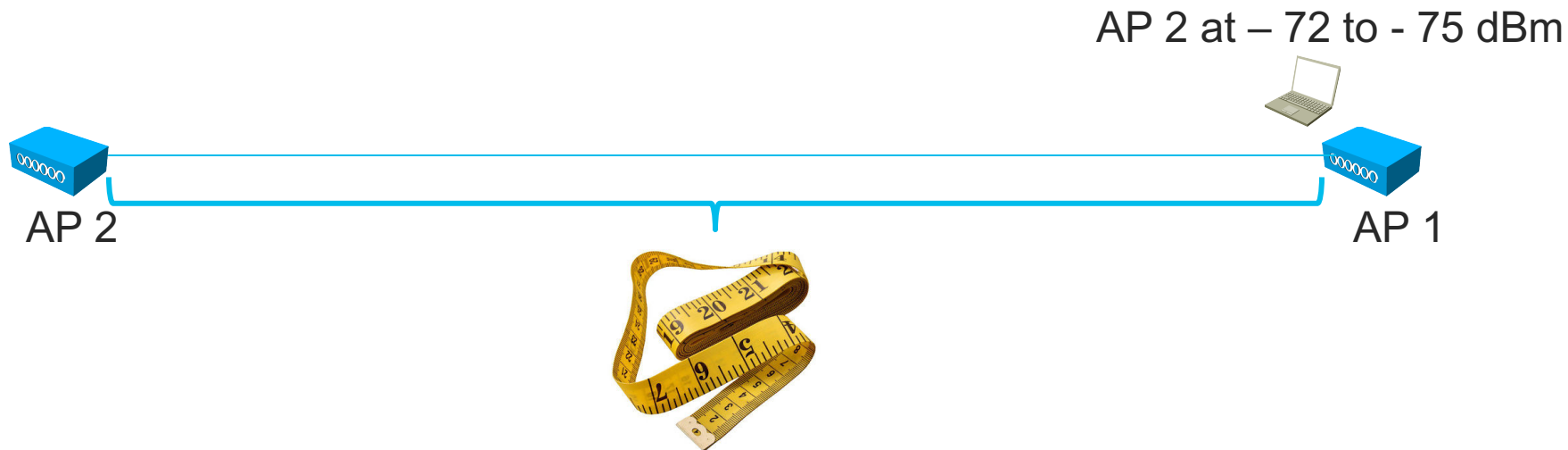
The - 72 dBm Rule

- 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

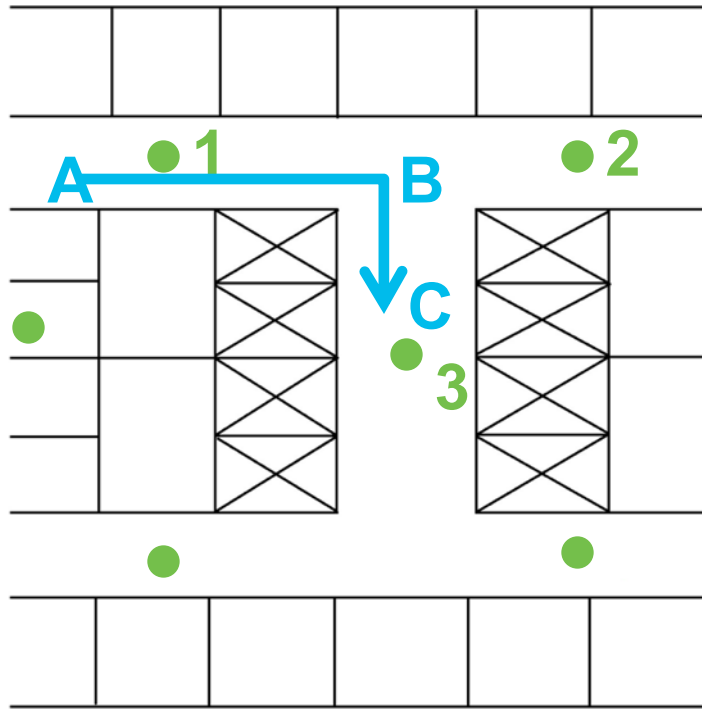


The - 72 dBm Rule

- Measure
 - This is your average AP to AP distance for this environment

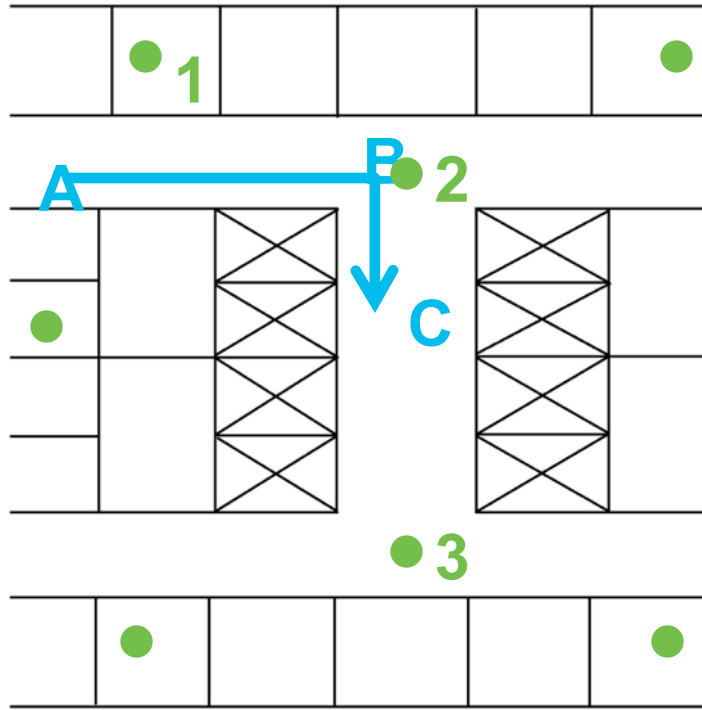


Strategically Position Your Transition APs



- 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 μ s
 - 200 B frame @ 24 Mbps is sent in 8.3 μ s
 - Rate shifting from 54 Mbps to 24 Mbps can waste 1100 μ s

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

Optimizing for Real-Time Applications



QoS – Consistency is Key

PROPOSED STANDARD

Internet Engineering Task Force (IETF)
Request for Comments: 8325
Category: Standards Track
ISSN: 2070-1721

T. Szigeti
J. Henry
Cisco Systems
F. Baker
February 2018

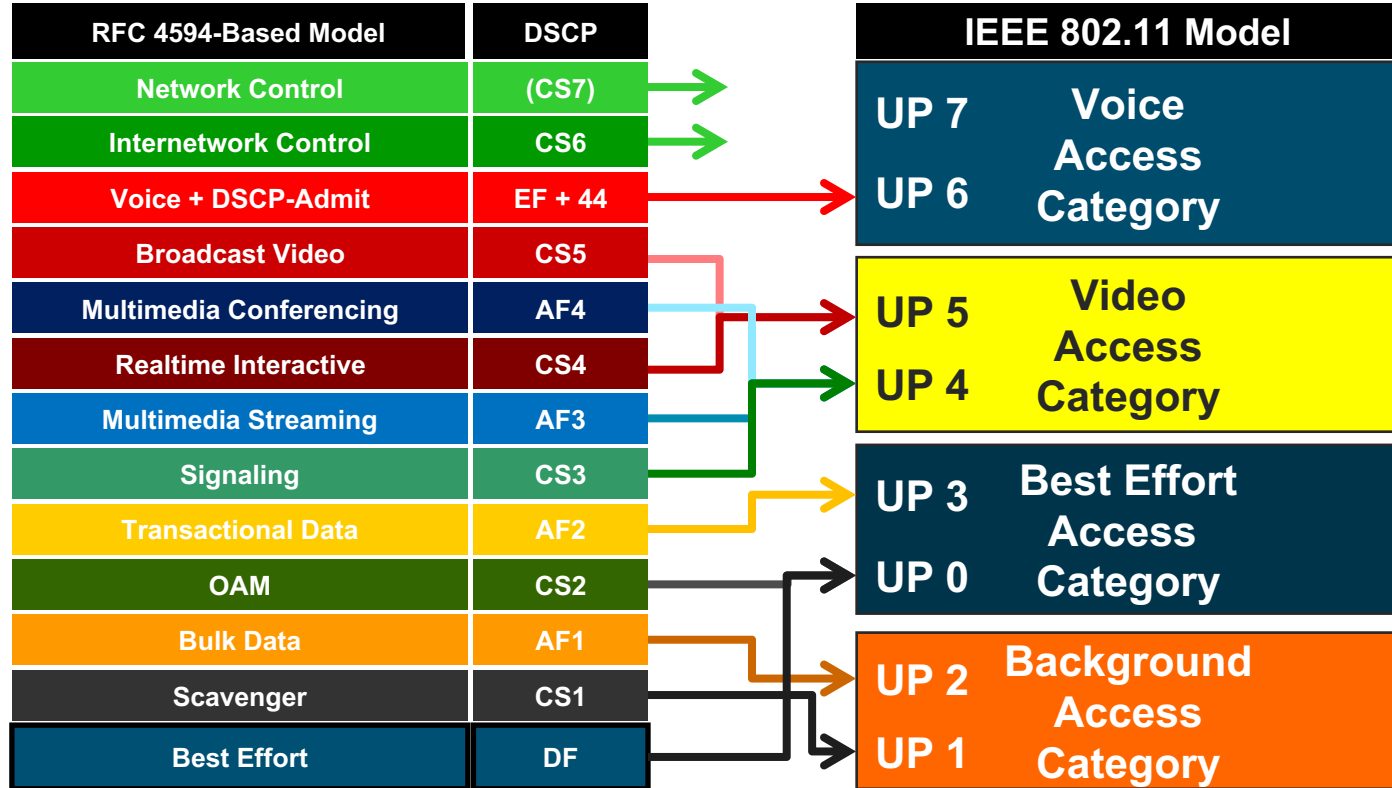
Mapping Diffserv to IEEE 802.11

Abstract

As Internet traffic is increasingly sourced from and destined to wireless endpoints, it is crucial that Quality of Service (QoS) be aligned between wired and wireless networks; however, this is not always the case by default. This document specifies a set of mappings from Differentiated Services Code Point (DSCP) to IEEE 802.11 User Priority (UP) to reconcile the marking recommendations offered by the IETF and the IEEE so as to maintain consistent QoS treatment between wired and IEEE 802.11 wireless networks.

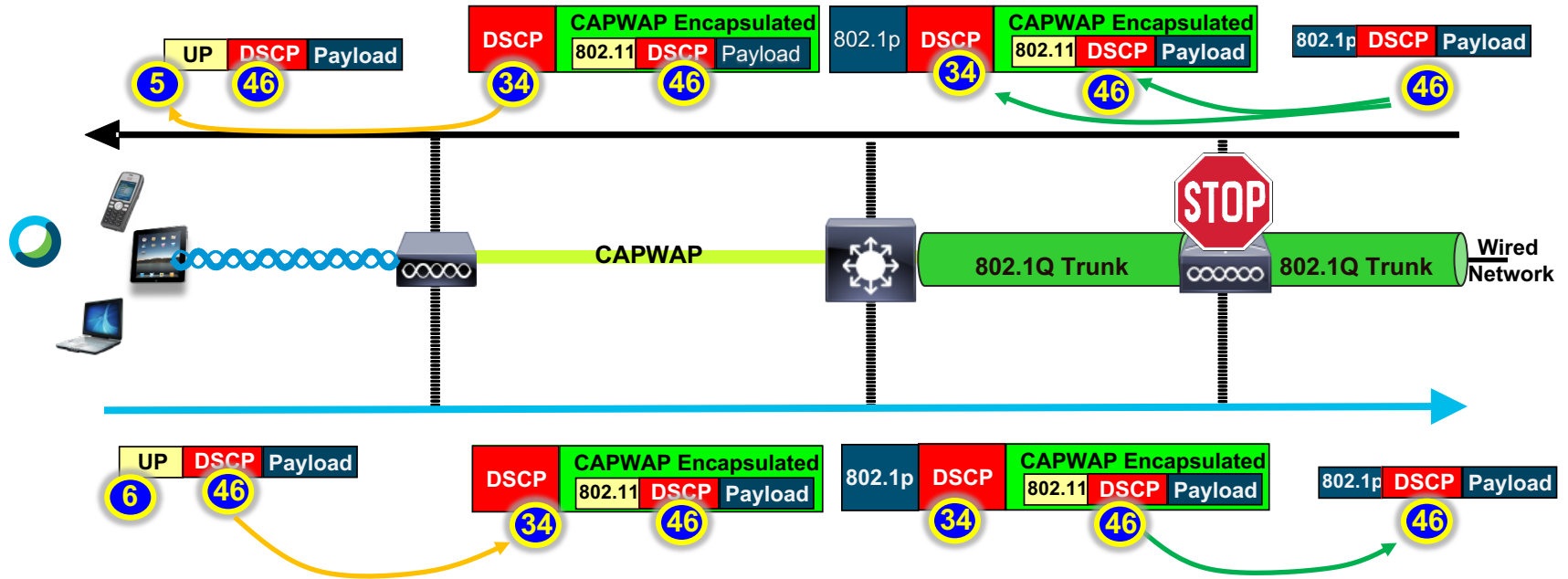
RFC 8325

- ✓ Apple
- ✓ Samsung/Google
- ✓ Microsoft

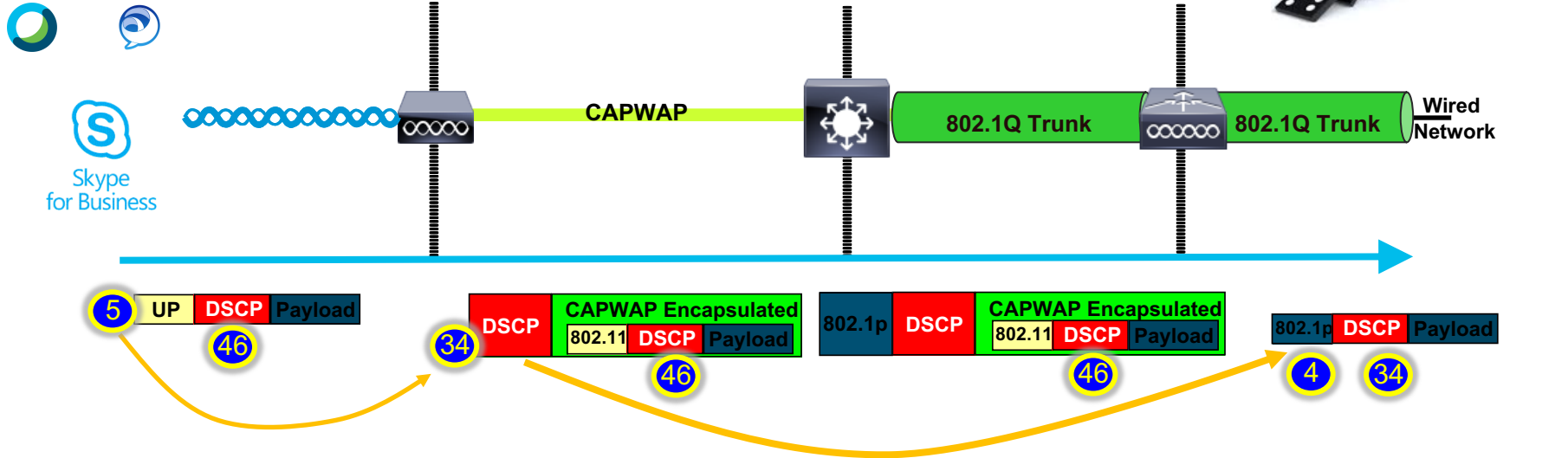


You can set QoS ceilings

Example: Effect of "Gold" Profile



Default UP to DSCP Mapping Problems



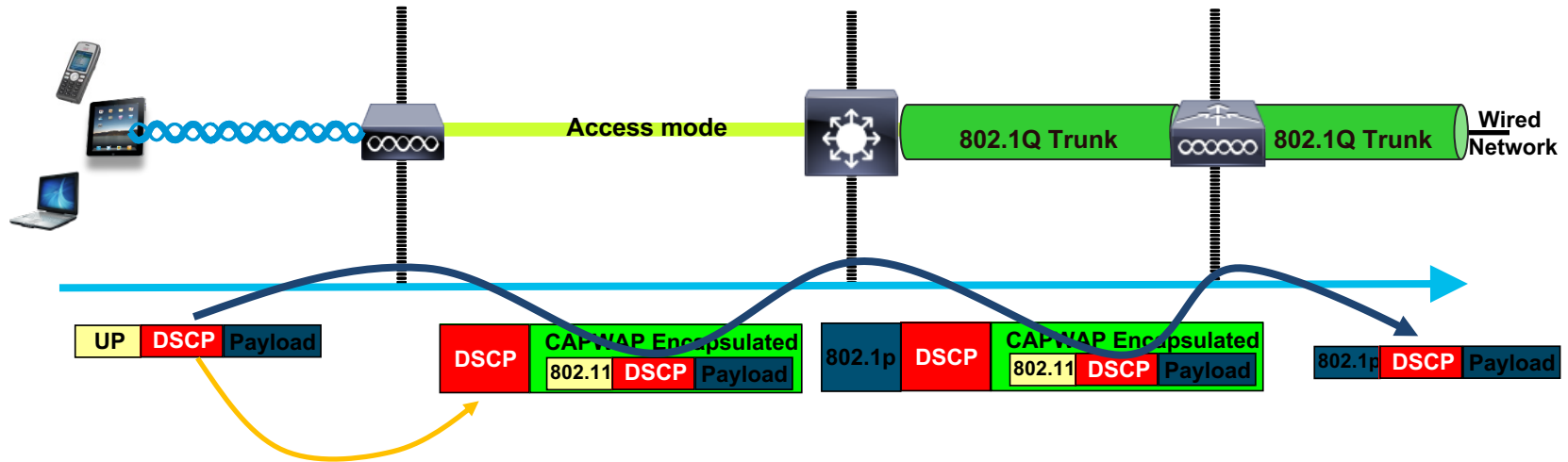
Voice Client Marked 46 (EF) UP = 5 Demoted to 34 (AF41)

Video Client Marked 34 (AF41) UP = 4 Demoted to 26 (AF31)

Signaling Client Marked 24 (CS3) UP = 3 Demoted to 18 (AF21)

Use DSCP When you Can

- This approach greatly simplifies QoS design and removes unexpected mapping behaviors
 - Does not apply if your STAs can't mark DSCP



Configure the QoS Profile Page

Edit Policy Profile

General Access Policies **QoS and AVC**

Auto QoS: None

QoS SSID Policy

Egress: platinum

Ingress: platinum-up

QoS Client Policy

Egress: Search or Select

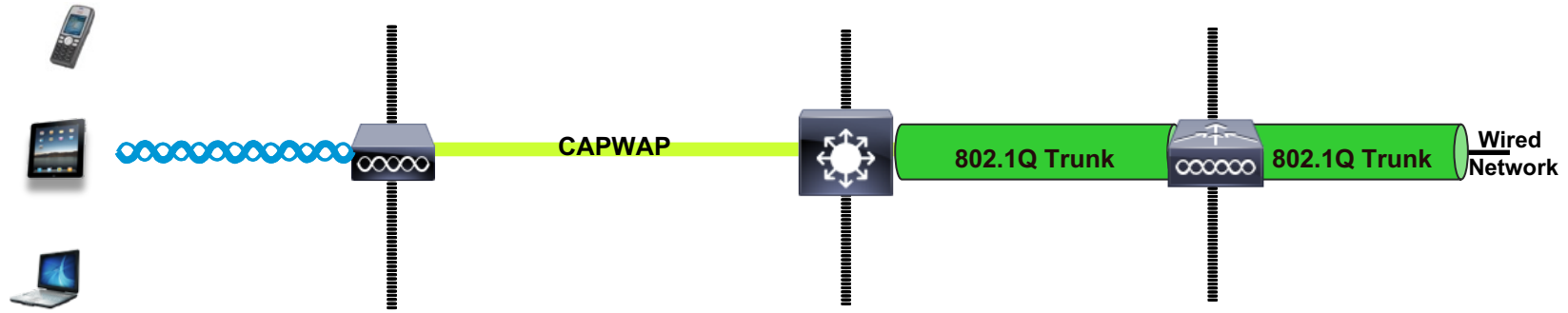
Ingress: Search or Select

Use Platinum for most corporate WLANs where voice is expected

Use best effort, or background, for guest WLANs

Profile Name	Max Downstream DSCP Value	Max Upstream DSCP Value
Platinum / Voice	46 (EF)	46 (EF)
Gold / Video	34 (AF41)	34 (AF41)
Silver / Best Effort	0 (CS0)	18 (AF21)
Bronze / Background	10 (AF11)	10 (AF11)

Infrastructure QoS and Client QoS



“Not much we can do”
here

We do a lot here

QoS Partnerships

- Windows: use Group Policies
- Samsung: natively implements RC 8325
- iOS: use Fastlane

2015

Endpoint/Client	Voice (EF)	Video (AF41/42)	Control (CS3)
WMM Convention	6	4, 5	4
Audio (iOS)	5	5	0
Audio (Samsung)	5	5	0
Audio (OSX)	5	5	0
Audio (Windows 10)	5	4	3

2019

Endpoint/Client	Voice (EF)	Video (AF41/42)	Control (CS3)
WMM Convention	6	4, 5	4
Audio (iOS)	6	5	5
Audio (Samsung)	6	5	5
Audio (OSX)	6	5	5
Audio (Windows 10)	6	5	5

Most vendors have adopted RFC 8325, but you need to activate marking
STA cannot know if the network supports QoS

Fastlane – Who Does What



Application Developer

- Marks app flows appropriately based upon Apple APIs in iOS 10 / Mac OS 10.13
- Makes new app version available on AppStore



Network Administrator

- Upgrades Cisco WLAN Software to version 8.3.x
- Accepts most Cisco configuration defaults
- Enables Fastlane on target SSIDs



Mobile Device Manager

- (Optional) Creates and deploy an iOS QoS profile to whitelist only mission-critical applications

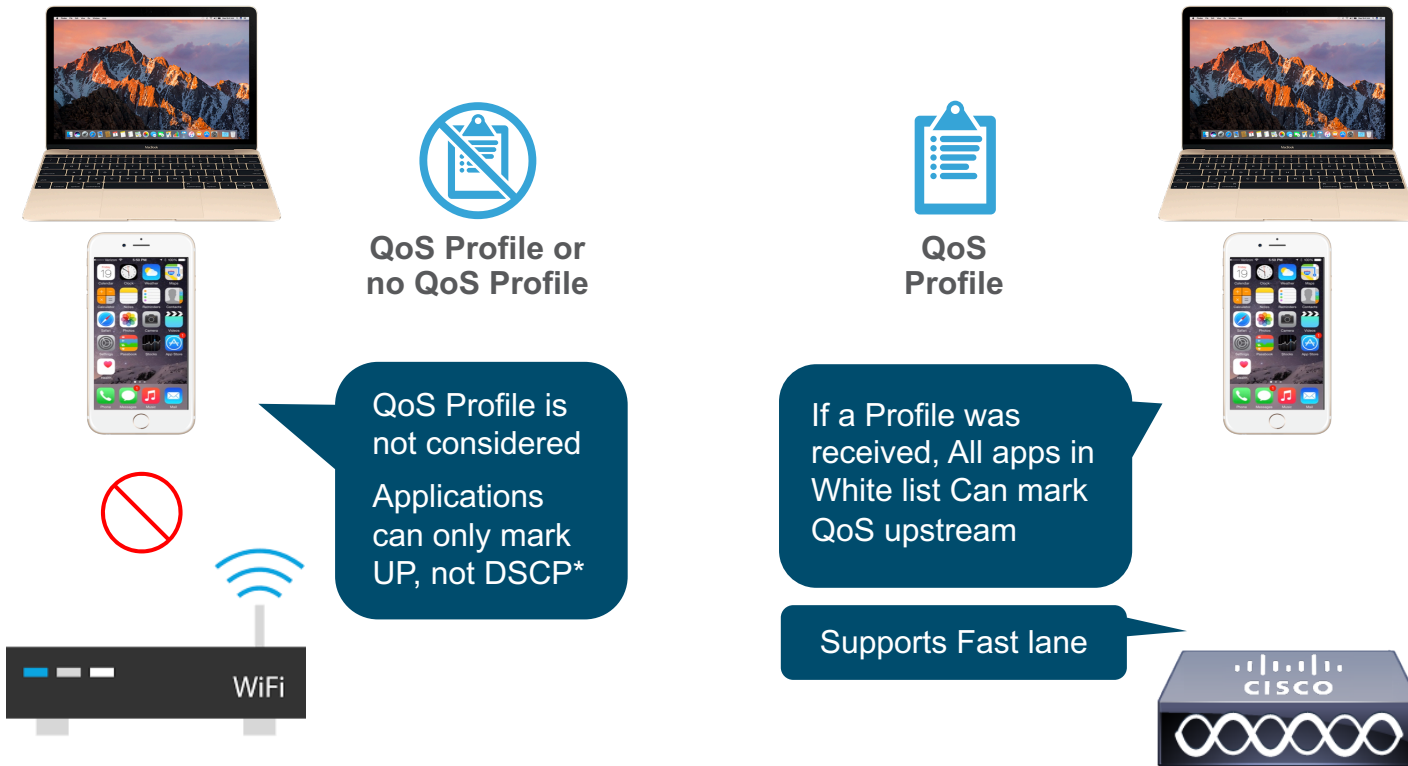


End User

- Downloads iOS 10 (or above) on iPhone and iPad, Mac OS 10.13 (or above) from AppStore
- Accepts all defaults
- (Optional) Receives the QoS profile

Cisco WLAN Network and Apple equipment with iOS 10, Mac OS 10.13 and above recognize each other; QOS marking is trusted end-to-end

Fast Lane only applies to Cisco-Apple Deployments



Fast Lane enables network administrator to prioritize applications per your environment

Supports
Fast lane



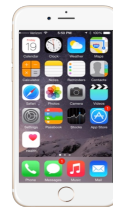
Admin can provision Apple IOS device with a QoS profile*
Applications in whitelist get QoS marking**
Other applications get BE/BK

Supports
Fast lane



My profile for
this environment:
Minecraft = Real-time-
interactive
Viber = BE

My profile for
this environment:
Minecraft = BE
Viber = Voice



Supports Fast lane

Supports Fast lane

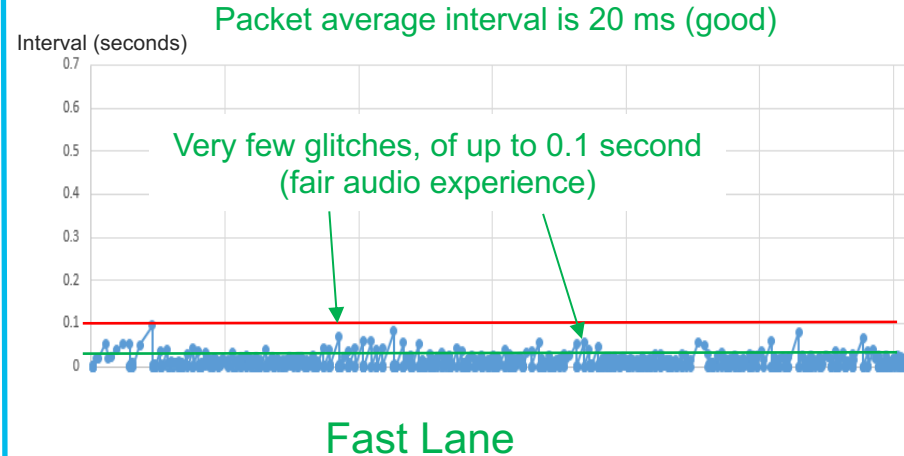
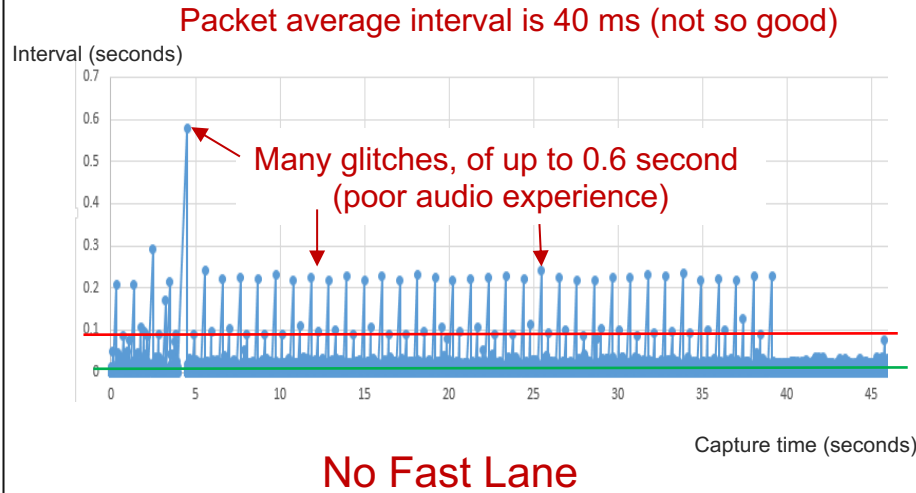


Configure AVC to Ensure Marking Consistency

AVC provides traffic visibility... and ensures that marking stays consistent in both directions

QoS Prioritization is Critical in Congested Scenarios

- In a congested environment, one voice packet is sent every 20 ms
- We measure the actual interval between voice packets in the upstream direction



Impact on Your Network Design

- Enable QoS (your clients use it!)
- Platinum for corporate WLANs, Best effort or Background for guests
- Trust DSCP (CoS, 802.1p are things of the past)
- Use AVC as needed to ensure consistent marking

Addressing Issues



Client Analytics – In Depth Client View

DNAC

Cisco DNA Center

Client Health

Client 360

24 Hours: Oct 02, 1:09 pm – Oct 03, 1:09 pm

10/10 Galaxy-S10e

Device: Samsung Galaxy S10e OS: Android 9 MAC: 10-98:C3:7B:AF:4E IPv4: 12.1.0.7 IPv6: fe80:0:0:0:6200:353d:8832:fa41 VLAN ID: 12 Status: Connected Last seen: Oct 3, 2019 1:07:00 pm
Connected Network Device: AP7872.5DED.D23C SSID: samsung-analytics Last Known Location: -- View All Details

C9800

Detail Information Oct 3, 2019 1:09 pm

Device Info Connectivity RF

Information

Device Type	Samsung Galaxy S10e
Operating System	Android 9
Firmware Version	SD7
Sales Code	TMB
Country Code	US
User Name	Unknown Wireless User
Host Name	Galaxy-S10e
MAC Address	10:98:C3:7B:AF:4E
IPv4 Address	12.1.0.7
IPv6 Address	fe80:0:0:0:6200:353d:8832:fa41
Status	CONNECTED

Connection Information

Band	5 GHz
Spatial Streams	2
Channel Width	20 MHz
WMM	Supported
U-APSD	Disabled

Welcome Cisco

Client

360 View General QoS Statistics ATF Statistics Mobility History Call Statistics

General

User Name
N/A

MAC Address
1098:c37b:af4e

Uptime(sec)
14 seconds

WLAN Name
nbangalo-sa-open

AP Name
AP4C77.6D9E.61B2

Device Type
Samsung Galaxy S10e(Phone)

Software Version
(Carrier Code)
SD7(TMB)

Device OS
Android 9

Client Performance
Signal Strength:-28 dBm Signal Quality:55 dB

Capabilities
HTTP

Fabric Status
Disabled

Last Disconnect Reason
User initiated disconnection - Device was switched to airplane mode

Top Applications

No data available

OK

DNAC Client Troubleshooting

Network
Time Travel

Real-Time
Client Event
Viewer

Session
Duration

Start and Stop Full Packet
Capture for AP4800

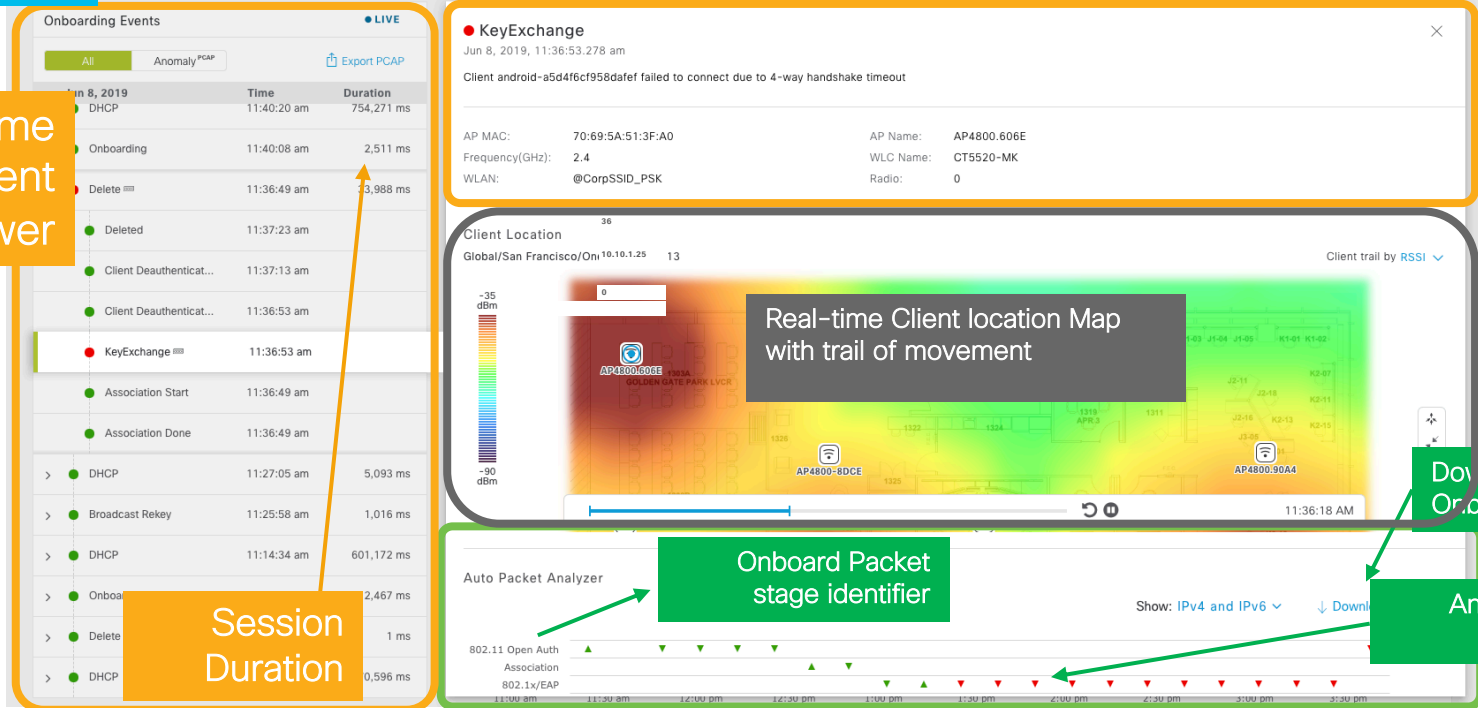
Real-Time
Live Mode

Run Data Packet Capture

Download

Start Live Capture

Client Capture: android-a5d4f6cf958dafef

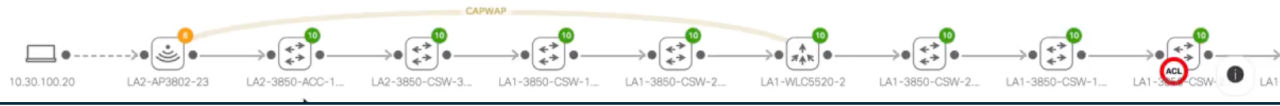


DNAC Application Health and Path Trace

Path Trace

To find the location of an issue, perform a path trace between two nodes in your network – a source device and a destination device.

10.30.100.20 (port: not specified) → 10.30.120.10 (port: 9100) [protocol: tcp] Apr 6, 2018 4:38 pm



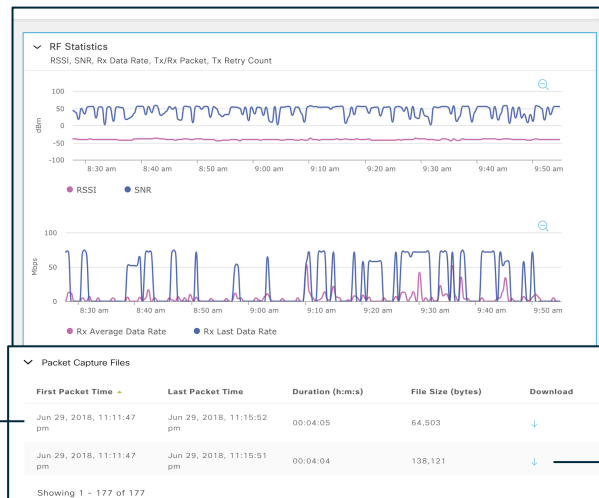
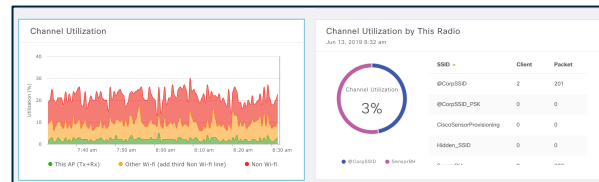
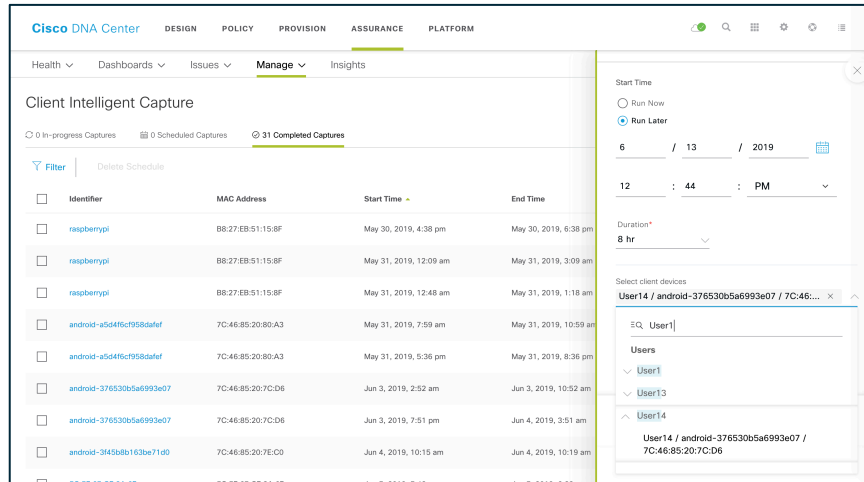
Path trace: visibility into path, and each hop performance and configuration

Name	Domain Name	Health		Destination	Average Throughput (Mbps)	Average Bandwidth Utilization (%)	Traffic Class	Packet Loss (%)		Latency (ms)		Application Delay (ms)	
		Most Recent	Last 24 Hours					Max	Average	Max	Average	Max	Average
All Applications				Multiple	0.48	0.66							
ssh	--	1	View	02/27 1:40 pm	02/27 6:30 pm	02/27 11:15 pm		100	11	62670	3996	859	13

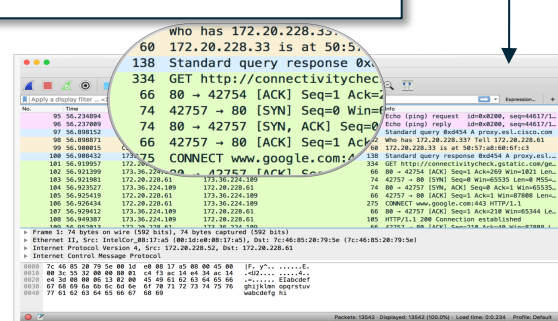
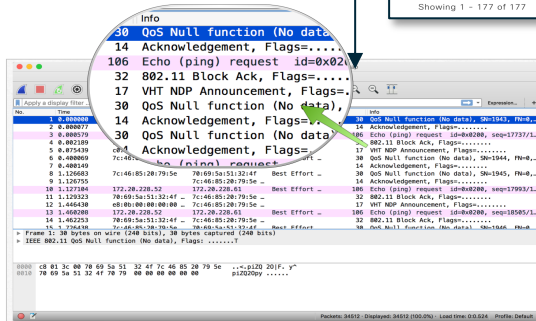
Application Experience: per user, per application metrics



Intelligent Capture Operation



- From C9800 or DNAC
- Provides per client, per AP RF metrics
- Wireless pcap, wired pcap



You Did Your Best, But Good Design Cannot Compensate For Everything

5.1.4 Windows 7 and Windows 8 considerations for Lync and Skype


Applications running on Windows 7 and Windows 8 (Classic API) have access to a set of controls to improve real-time media streaming. Settings for Windows 8 Modern applications are different and are discussed later in more detail.

Windows 7 and Windows 8 Classic (x86 only): Real-time communication applications have an option to set the network into a "streaming" mode. This setting directs the Wi-Fi NIC driver to suppress background scanning for the duration of a call and also provides improved results for stationary usage. If the user is moving during a call, however, the WAP association remains sticky until the wireless signal becomes too low and disconnects, forcing a full scan and reassociation to the nearest WAP, which usually results in an audible glitch. Note that this streaming mode is separate from any DSCP (and resulting WMM) settings. The implementations between Lync and Skype differ in the following ways:

- Lync 2013 (and Lync 2010) on Windows 7 and 8 (Classic) set this streaming mode flag (not configurable).
- DSCP and WMM settings are implemented by using a QoS policy for Lync, and are usually implemented through a domain-wide policy (GPO).
- Skype clients do not use the streaming mode setting.

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 issue with IPAD Last Reply 1 hour 8 min ago.	20	0	0	7	Leo Laohoo

Cisco + Partners Releases Summary

- AireOS 8.3+, any C9800, for FastLane and iOS roaming optimizations (“aligned” 11k/11v support, Adaptive 11r)
- AireOS 8.5+, any C9800, for iOS “knowing each other”, 11k report, “why I left the cell”
- iOS 10+, MacOS 14.13+, Samsung S8+ for RFC 8325 QoS
- AireOS 8.10, C9800 16.12 for aligned MBO support, Samsung 11k reports query
- C9800 17.1 for Samsung “knowing each other”, 11k report, Auto 11r, “why I left the cell”
- Continuous alignment for 802.11ax (1.4 times the other vendors speed with S10 and our APs!), WPA3 and other mainstream features
- And many more features to come this year...

Summary

- Remember – 70 dBm, 11 / 14 dBm, limit the -75/80+ dBm zone
- Avoid hidden SSIDs, DFS channels (except in HD), aggressive load balancing, “smart” roaming
- Think “roaming path”, “next AP” should always be in view
- Position your APs so that “view from the ceiling = view from the ground”
- Enable 11k/r/v, 5 GHz-only SSIDs if you can
- If you build for iOS, Android and other BYODs are likely to perform well too



Thank you





You make **possible**