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Voice over WiFi – Deployment recommendations and best practices

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Agenda

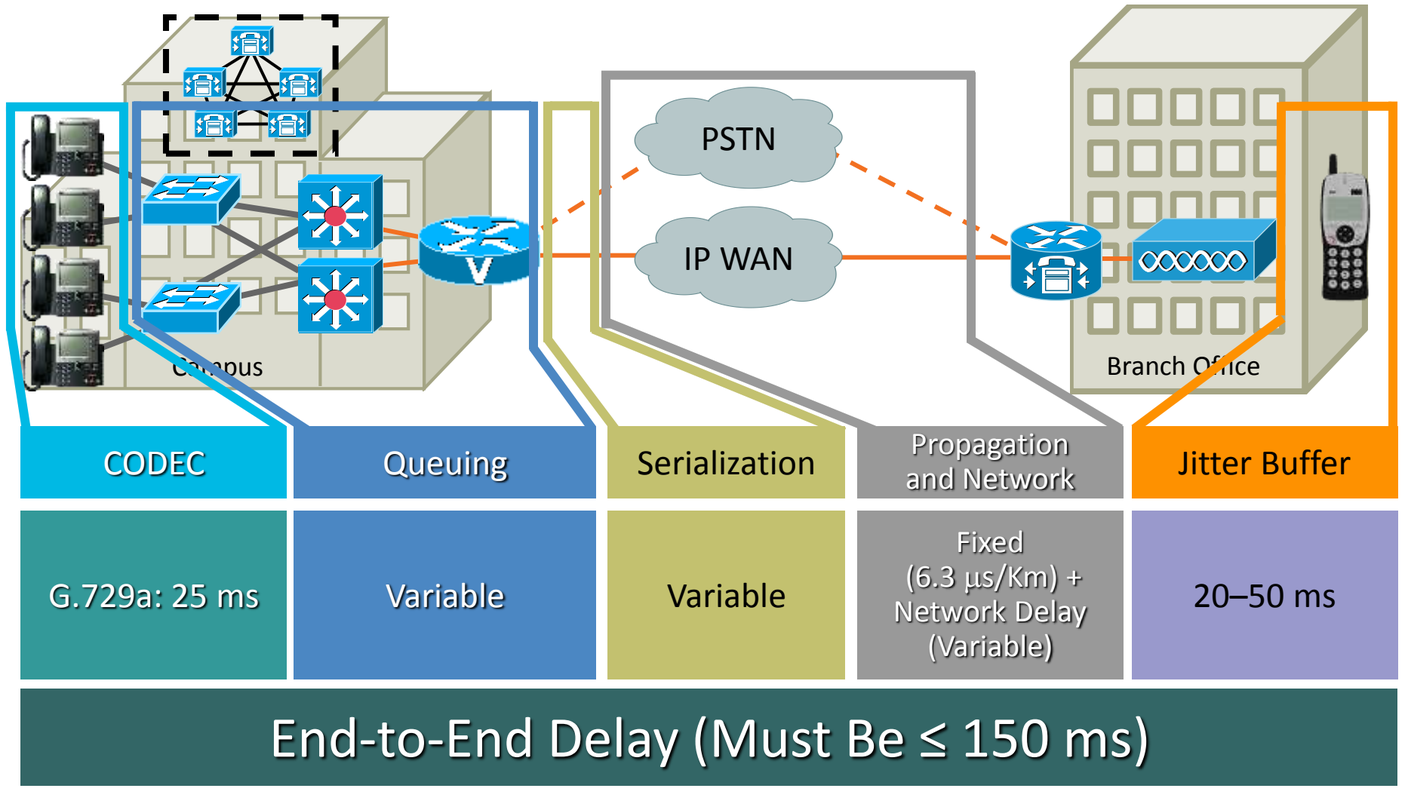
Voice over WiFi – Deployment recommendations and best practices

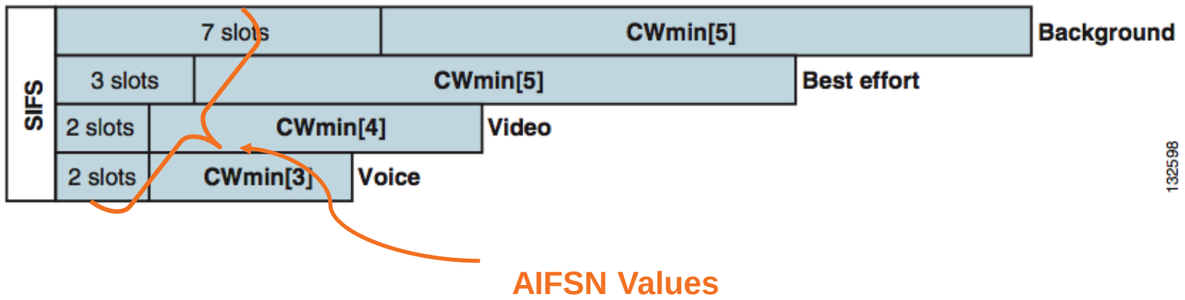
- Voice over WiFi 101
- VoWiFi RF Design
- VoWiFi Configuration
- What you should know
- Summary

Agenda

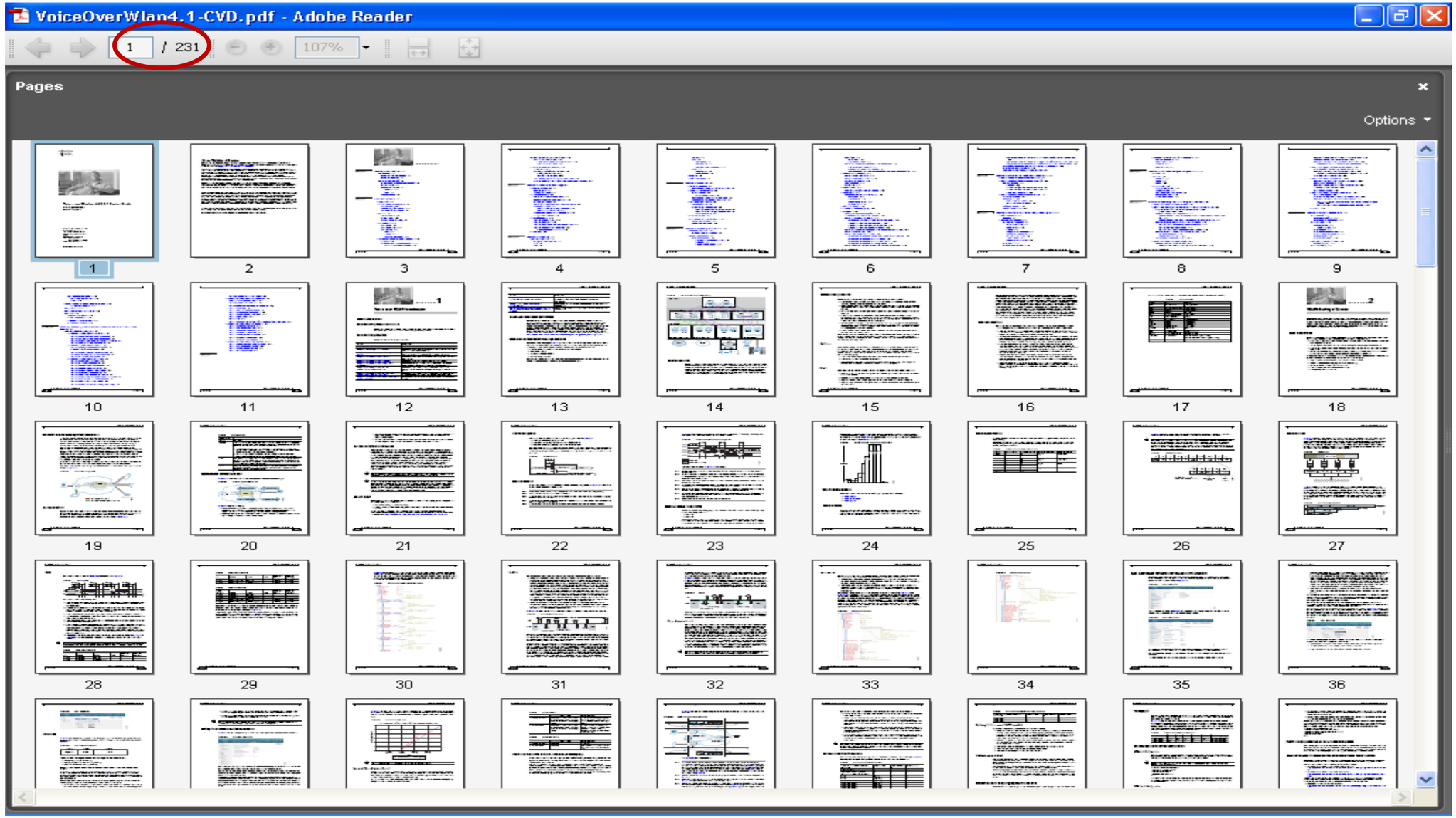
What Will Not Be Covered

- Collaboration Manager configurations
- Voice protocols comparison
- WMM and QoS in detail
- Voice Gateways…





Cisco Validated Voice over Wireless Design Guide



http://www.cisco.com/en/US/docs/solutions/Enterprise/Mobility/vowlan/41dg/vowlandg.pdf

Agenda

- Voice over WiFi – Deployment recommendations and best practices
  - **Voice over WiFi 101**
  - VoWiFi RF Design
  - VoWiFi Configuration
  - What you should know
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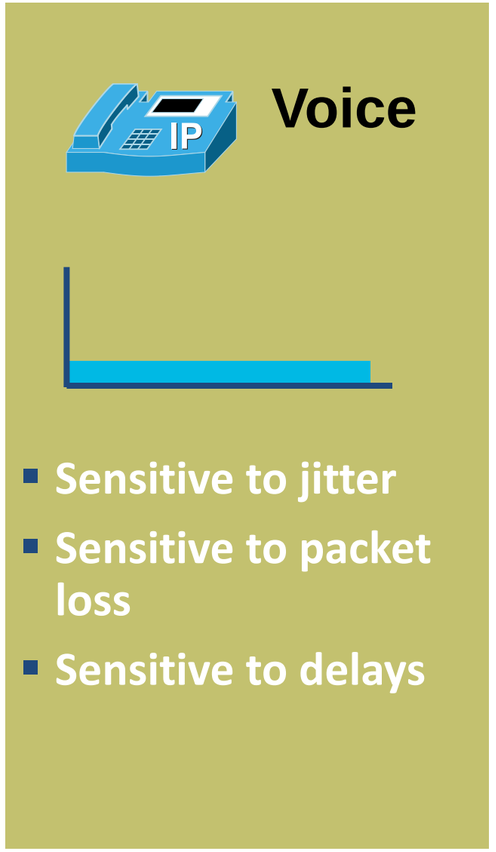
VoWiFi 101

Key Concepts

- Voice over WLAN would be similar to any other VoIP technology with the added issues of a wireless medium
  - Signaling: SCCP/SIP
  - Voice transport: RTP
- Wireless adds some important differences
  - Media is shared
  - Physical coverage is an issue
  - Security concerns
  - Battery life
  - Roaming



VoWiFi 101

Wireless as Media

- WiFi is unlicensed spectrum so has to operate on lower power
  - Coverage is lower than other radio technologies
- As the transmit media is shared we can expect:
  - Interference (other WiFi)
  - Noise
  - Capacity issues
- Access points have a limited area they can cover
  - Power restrictions
  - Antenna used
  - Physical environment

VoWiFi 101

Wireless as Media

- Voice is one of the most critical applications to have over Wireless
- Users have high expectations for voice, derived from GSM, Home wireless phones, and fixed line “real-life experience”
- The main objective on a VoWiFi project, is to provide end users with a service level as close as possible to what they expect
- Wireless Networks are mostly designed for data services, so it is usually not possible to “ just drop” voice on top, and expect any positive results





VoWiFi 101

Wireless as Media

- Voice has very strict requirements as an “application”
  - Packet Error Rate (PER) <=1%
  - As low jitter as possible, less than 100ms
  - Retries should be < 20%
  - This translates to coverage needs

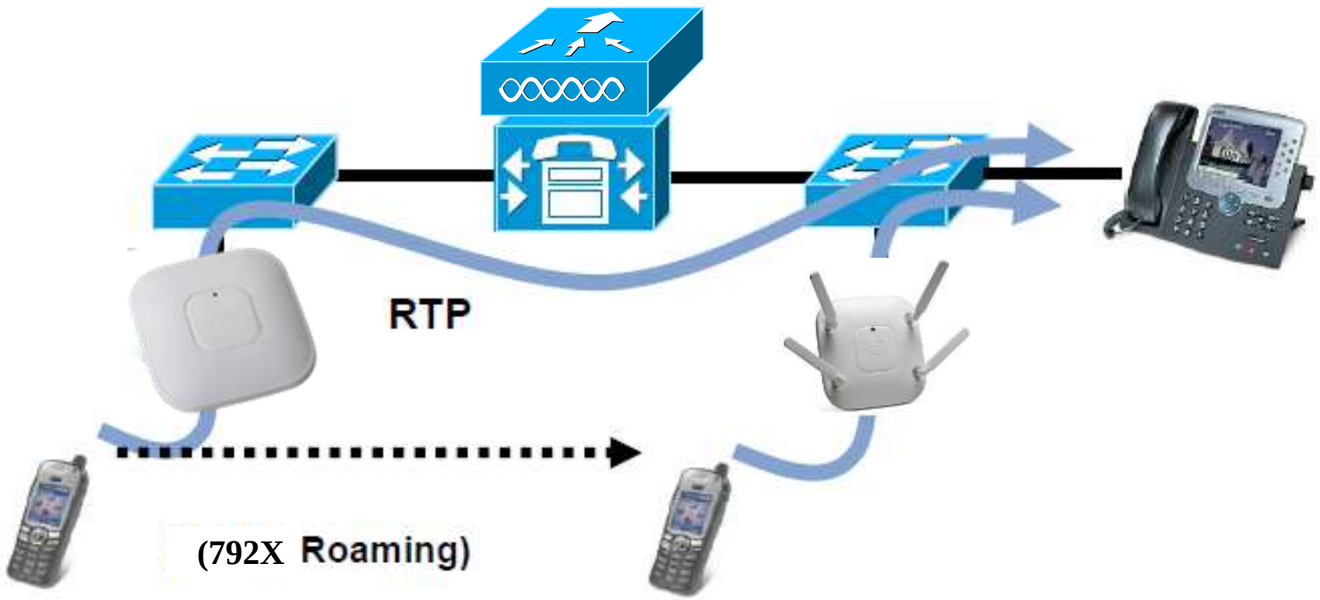
- Normally data services can tolerate loss of connectivity or high packet loss. Users will not accept a clipping voice, or unidirectional voice flow.

- In general it is better to prevent a call, than to place a call over a congested media
  - This is where “Call Admission Control” takes place

VoWiFi 101

Roaming

- Roaming means that the Phone has to find a new AP before the current parent quality has gone below what is needed to maintain good voice
  - Has to be Secure
  - Not too aggressive, but not conservative
  - May use multiple triggers: Beacon, retries, packet loss, RSSI, SNR, QBSS



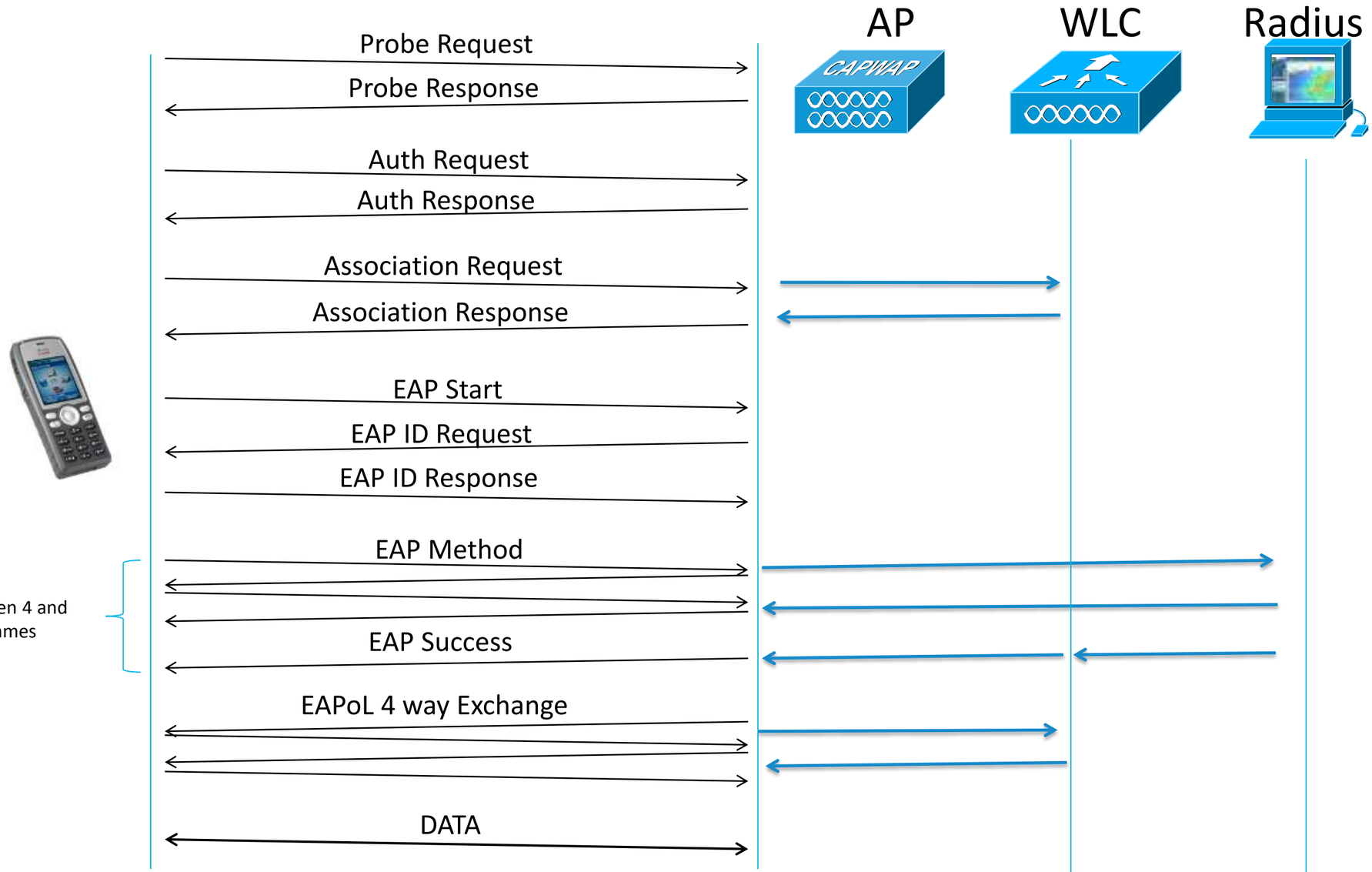
VoWiFi 101

Secure Roaming

- How to accept a new client association quickly in a secure way?
- Each roam may need full reauthentication
  - Key caching mechanisms are needed: CCKM, PMKID, Sticky key caching, 802.11r
- A key caching will remove the need for a complete 802.1x, which is slow
- Voice requirement: max 150ms of traffic drop, 300ms at most

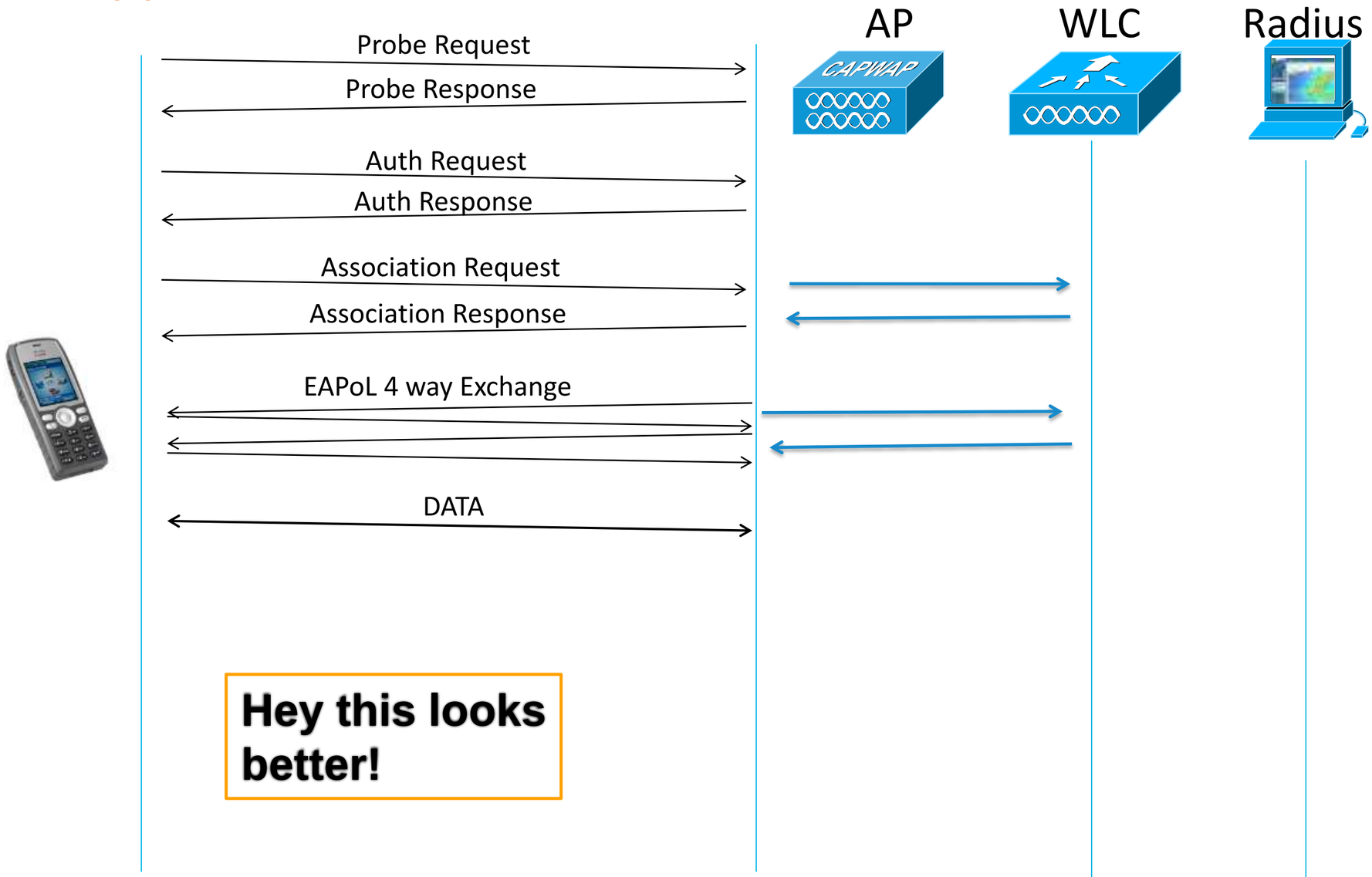
VoWiFi 101

Association + 802.1x



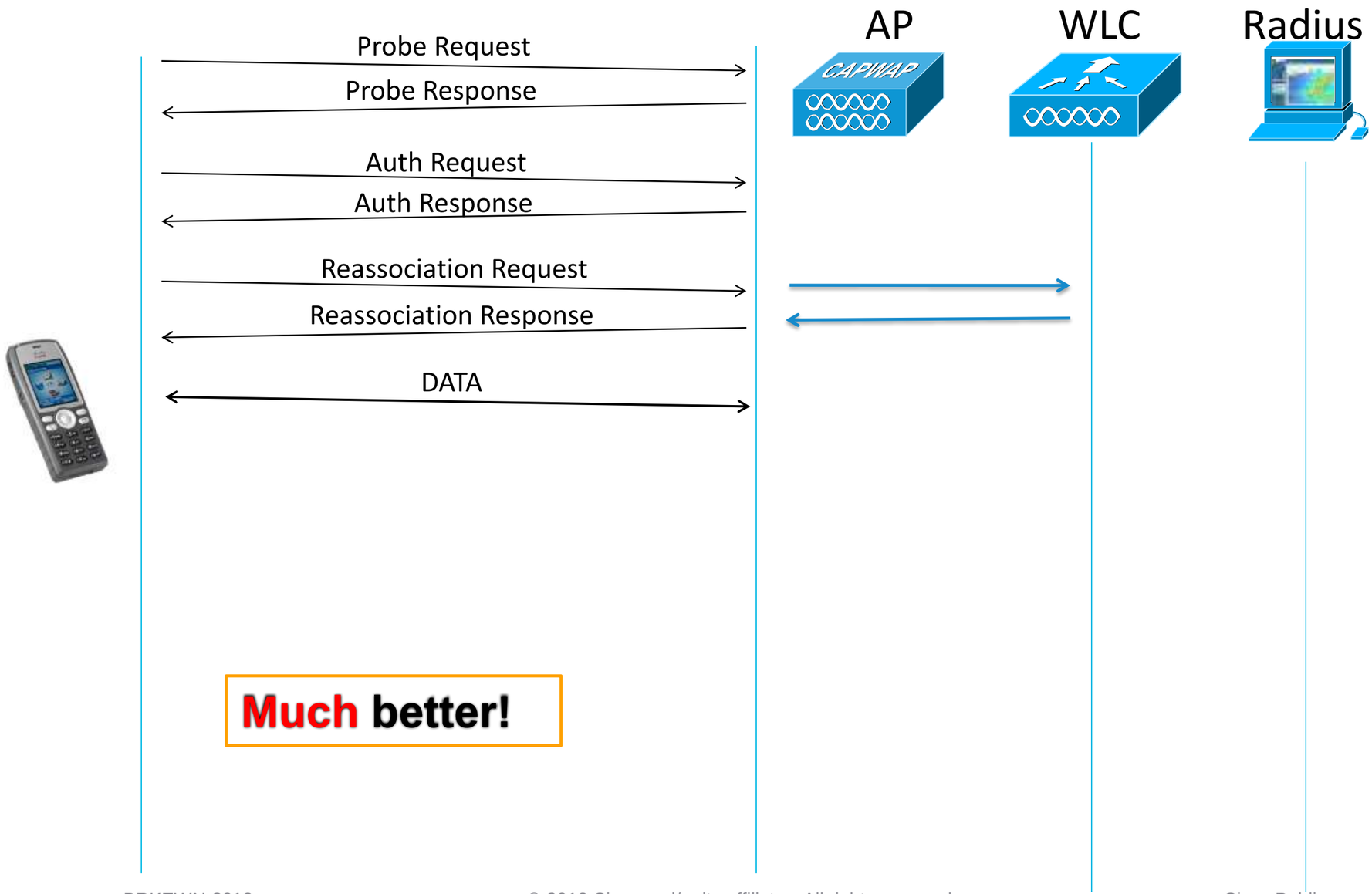
VoWiFi 101

WPA(2)-PSK



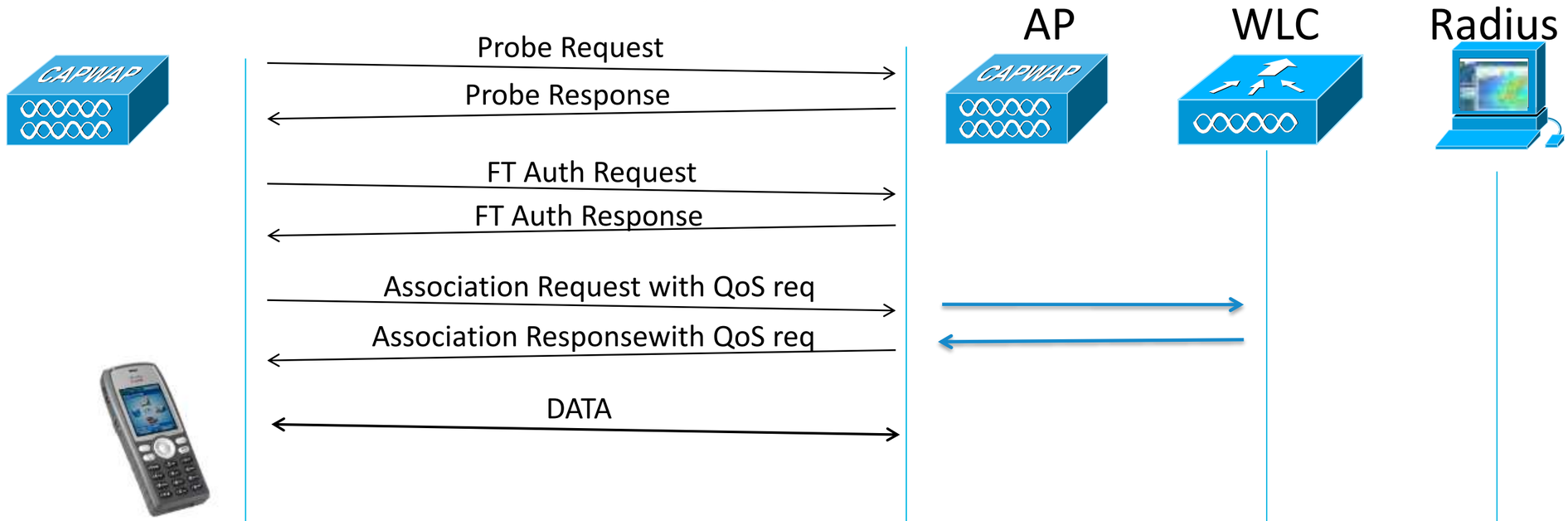
VoWiFi 101

CCKM



VoWiFi 101

802.11r – “Fast Transition” (FT)

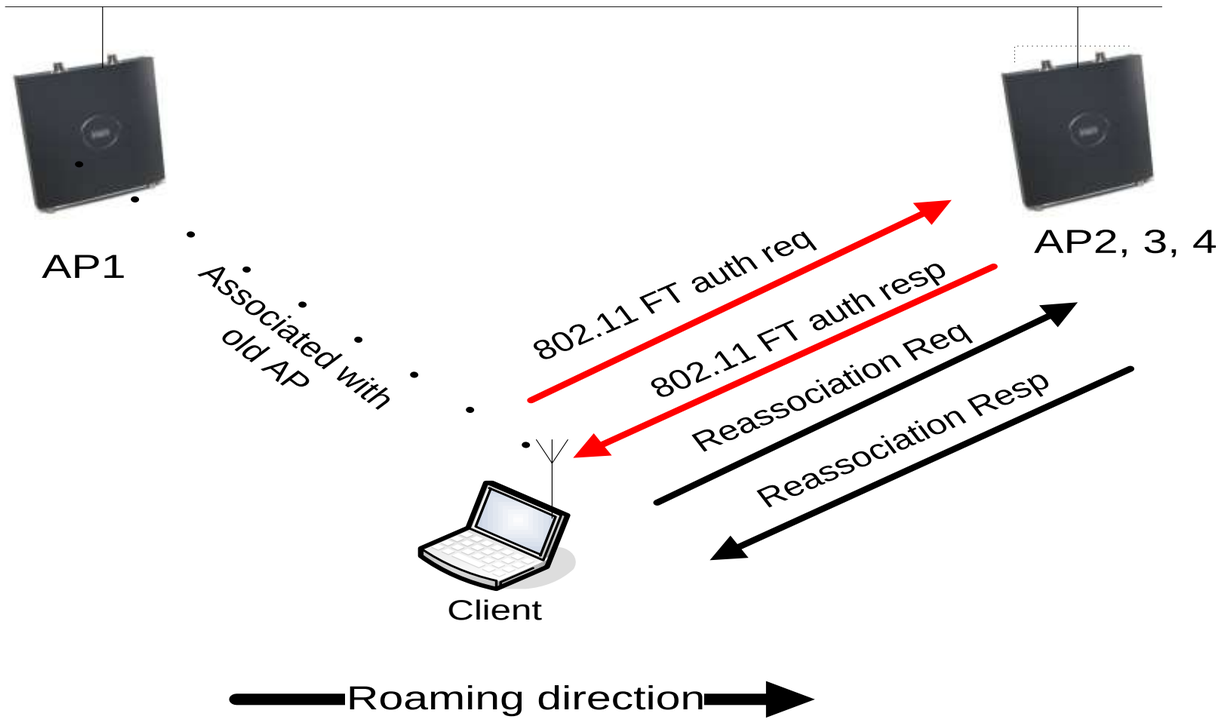


802.11r Action Packet exchange occurs before the Roam. Therefore the Roam is 2 packets long. This is a standardized method, but it has some backward compatibility drawbacks, as Action Frames are new and Association Frames are modified.

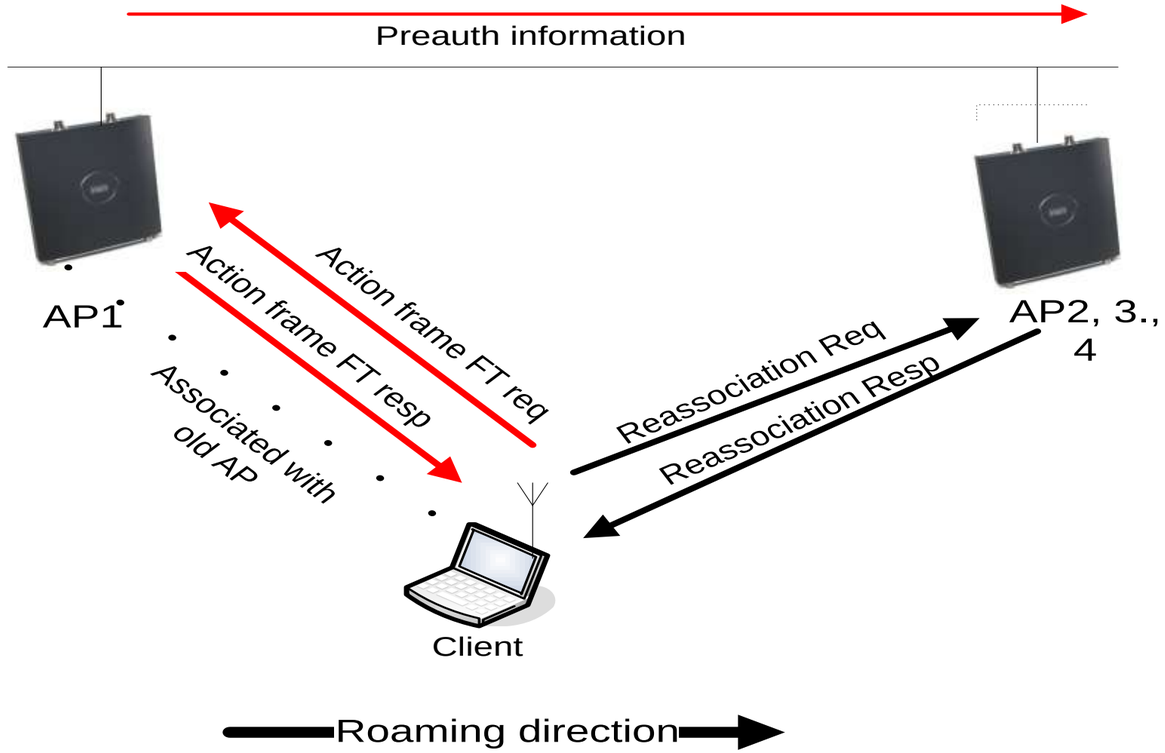
VoWiFi 101

802.11r – Pre-authenticated secure roam (by SSID/WLAN)

802.11r Over the Air roaming



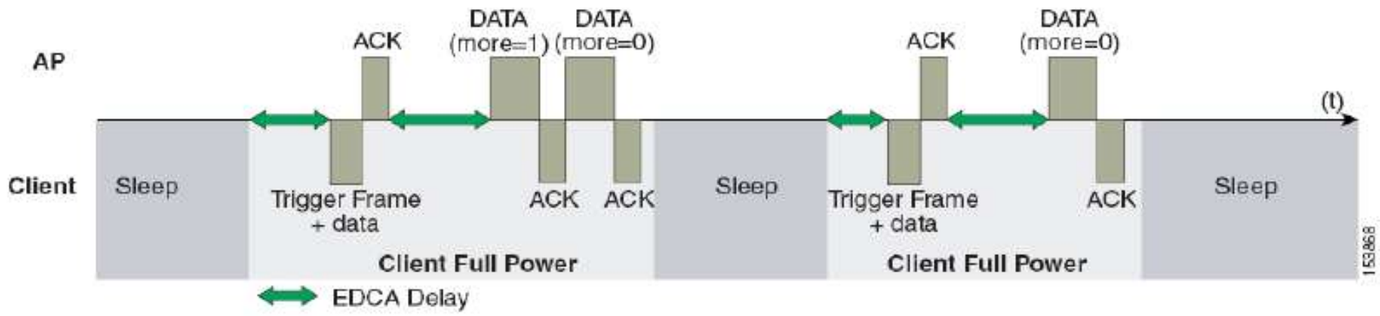
802.11r Over the DS roaming



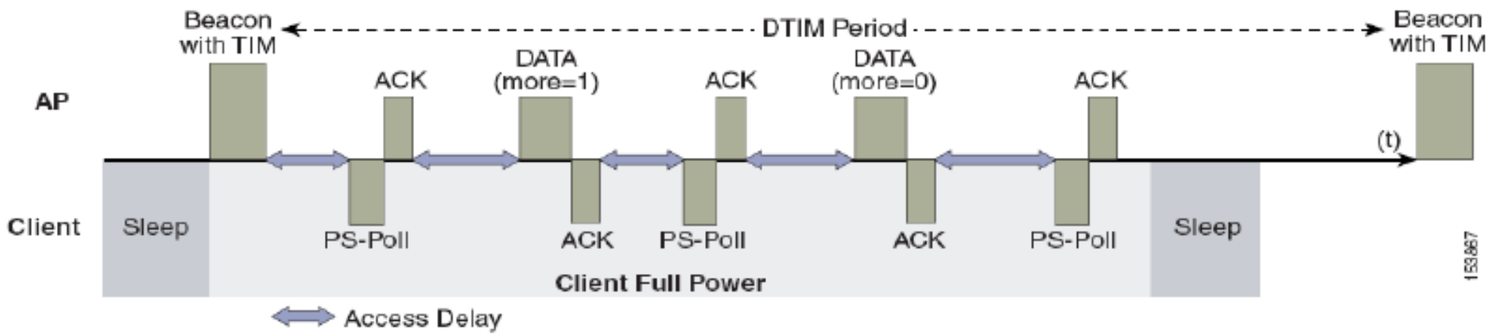
VoWiFi 101

Power Save

- Devices are battery operated, so they must have power saving mechanisms
  - U-APSD



  - PSP/Legacy



For IOS devices, you have to support MCS0 data rate, as the OS is dropping the data rate to MCS0 to save power, but not checking if that rate is supported before doing it.

VoWiFi 101

Top Ten Recommendations

1. QoS and Availability on your wired network is your foundation
2. Security requirements for voice applications are different than from data
3. Start with user consultation and education
4. Address VoWiFi availability requirements in planning and design
5. Maximize your WLAN Capacity by using the 5GHz spectrum
6. Choose the right VoWLAN handset, based on user requirement and features, and availability in Cisco Compatible Extension Program
7. Follow the VoWLAN handset guidance in planning and design
8. Use Radio Resource Management for deployment, monitoring, and troubleshooting your WLAN
9. Perform a post installation site-survey to confirm you have met your VoWiFi goals
10. Plan for the future and the addition of more services such as Location

Agenda

- Voice over WiFi – Deployment recommendations and best practices
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VoWiFi RF Design

What Should Be Covered

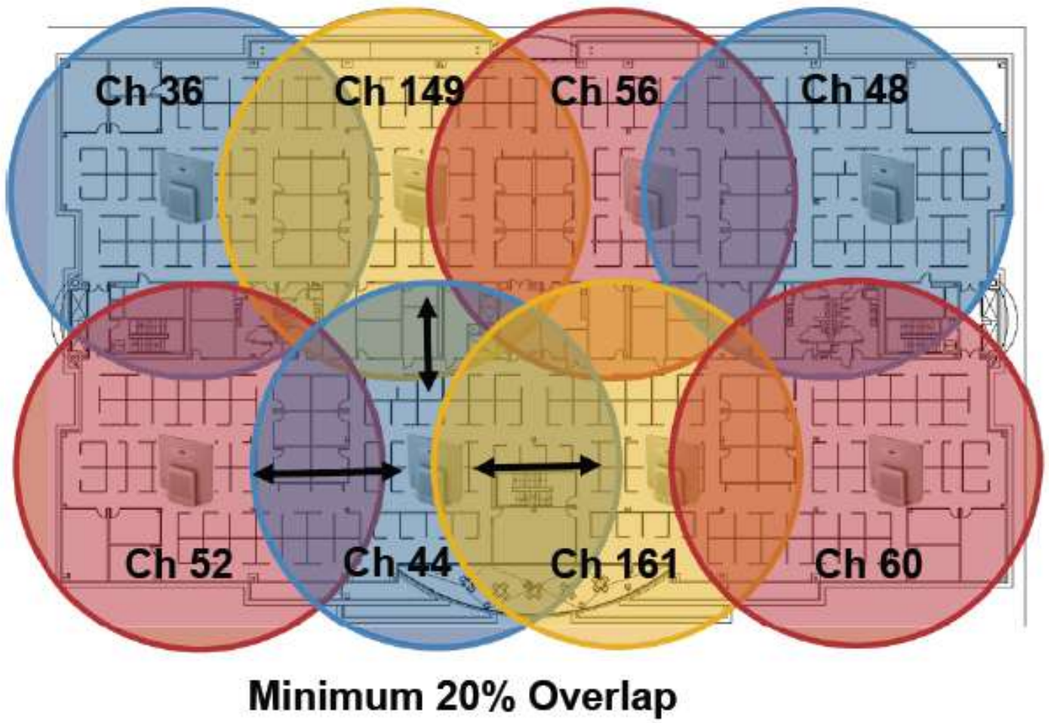
- In order to determine if VoWiFi can be deployed, the environment must be evaluated to ensure the following items meet Cisco guidelines.

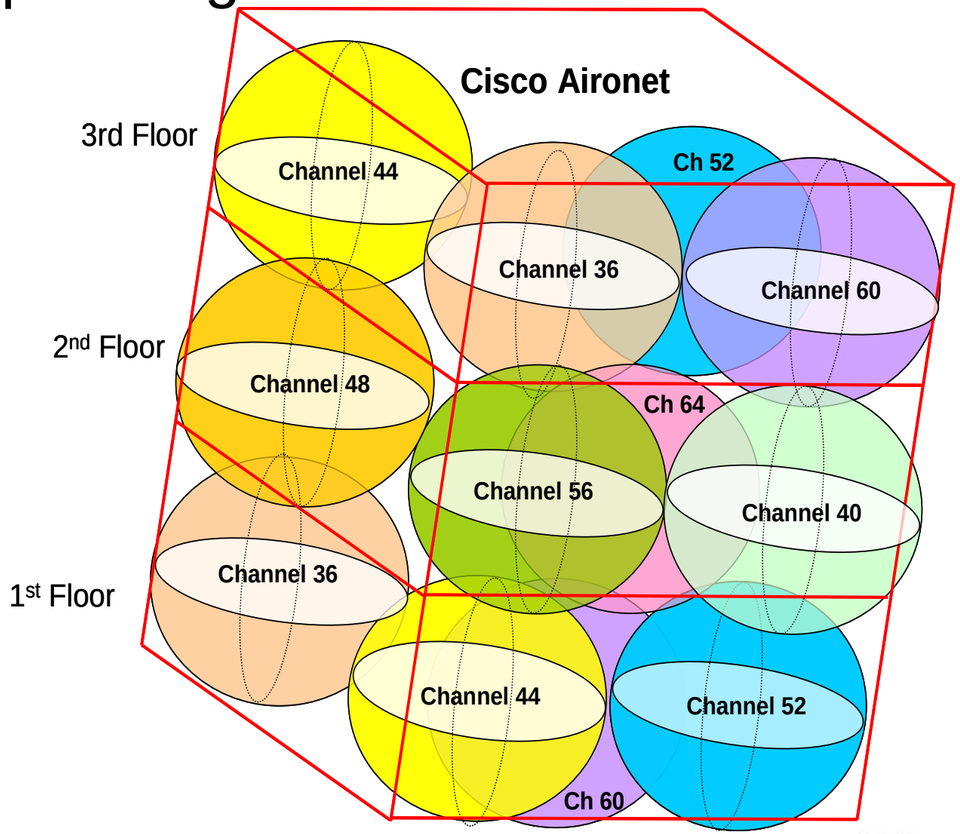
- Many different tools and applications can be used to evaluate these items in order to certify the deployment.
  - Signal
  - Channel Utilization
  - Noise
  - Packet Loss / Delay
  - Retries
  - Multipath

VoWiFi RF Design

Coverage

- The cell edge should be designed to -67 dBm, where there is a 20-30% overlap of adjacent access points at that signal level.
- This ensures the phone always has adequate signal and can roam seamlessly.

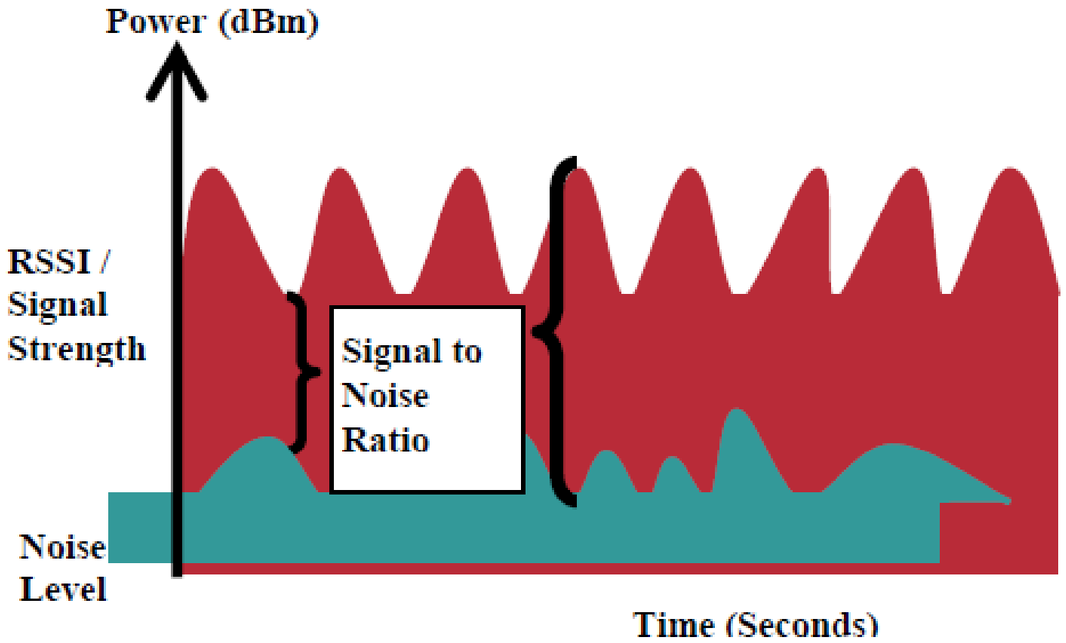




VoWiFi RF Design

Channel Utilization and Noise

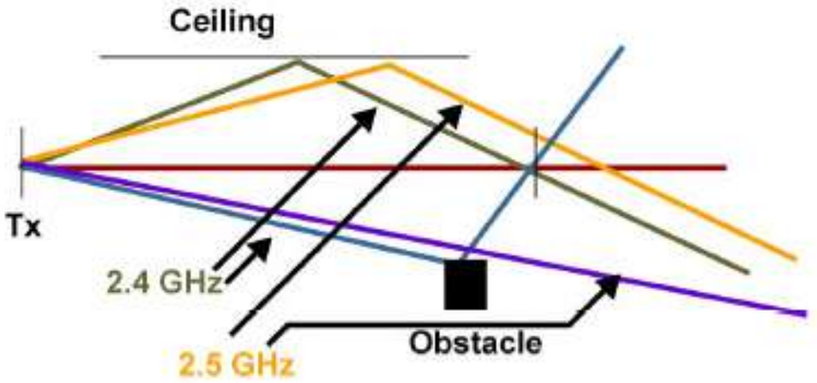
- Channel Utilization levels should be kept under 50%.
- You can check it using a spectrum analyzer like SpectrumExpert or Fluke AirCheck
- If using a Cisco phone, this is provided via the QoS Basic Service Set (QBSS), which equates to a value around 105.
- Noise levels should not exceed -92 dBm, which allows for a Signal to Noise Ratio (SNR) of 25 dB where a -67 dBm signal should be maintained.



VoWiFi RF Design

What Should or Should Not Be Done

- Highly reflective environments
- Multipath distortion/fade is a consideration
- 802.11b most prone
- 802.11g/a better
- 802.11n much better
- Things that reflect RF:
  - Irregular metal surfaces
  - Large glass enclosures/walls
  - Lots of polished stone



VoWiFi RF Design

What Should or Should Not Be Done

- Multipath. Multipath should be kept minimal as this can create nulls and reduce signal levels.

- Temptation is to mount on beams or ceiling rails
- This reflects transmitted as well as received packets
- Dramatic reduction in SNR due to high-strength, multipath signals

Minimize Reflections When Choosing Locations

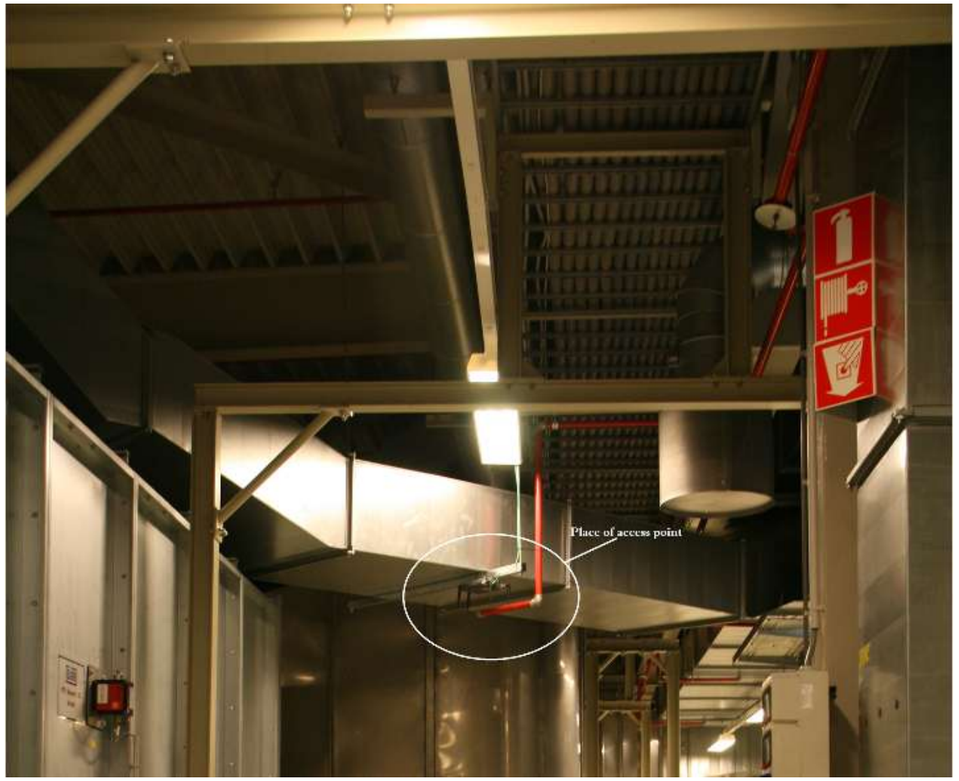
VoWiFi RF Design

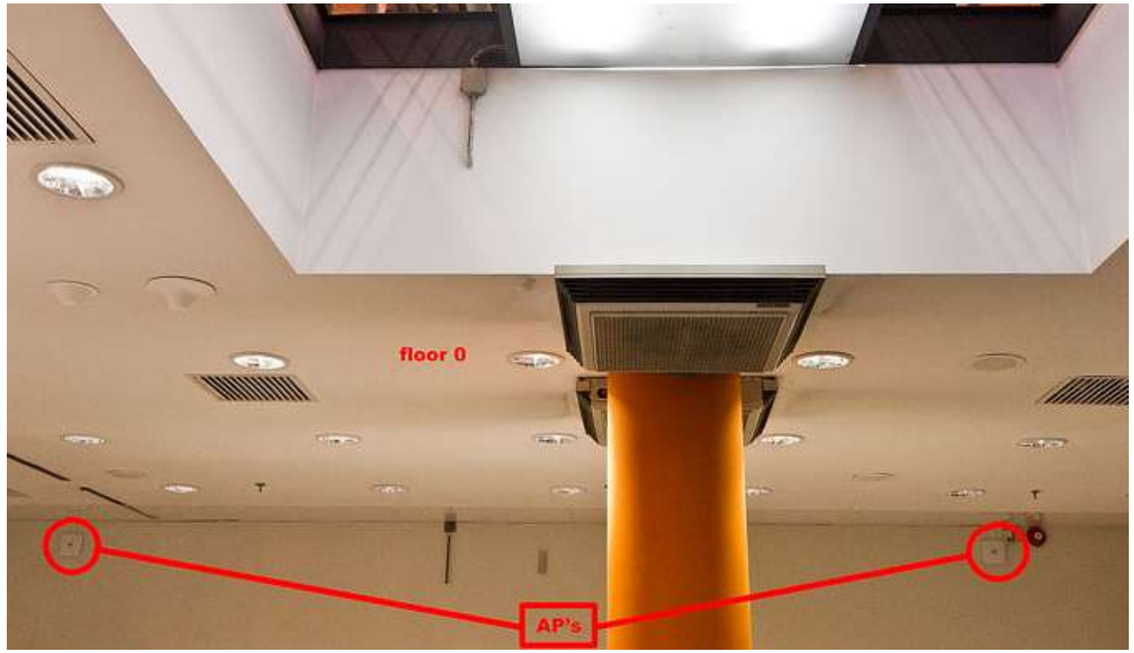
What Should or Should Not Be Done

Mount the box and antennas downward Please

VoWiFi RF Design

More Examples





VoWiFi RF Design

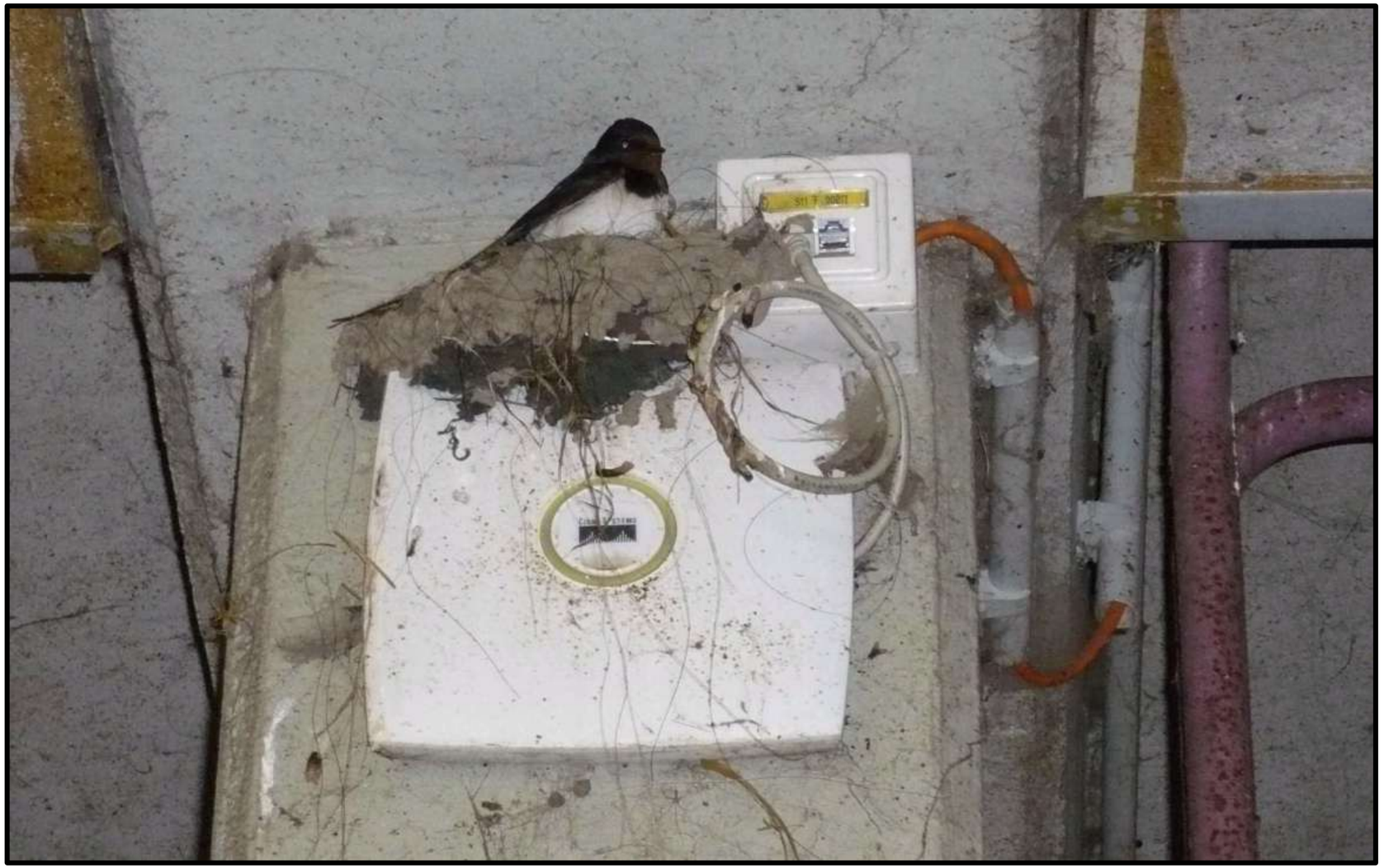
More Examples

Ceiling mount AP up against pipe

A little ICE to keep the packets cool

VoWiFi RF Design

More Examples



VoWiFi RF Design

A Few Tips

- Every site is unique, do not assume two installations would be the same
- Think of the AP coverage area as a “reading light”: you want to illuminate where the devices will be. Avoid long run AP placement
- Use the appropriate equipment for the need: 1130/1140/2600i/3500i/3600i for carpeted areas, 1240/1260/2600e/3500e/3600e for specific applications, antenna orientations
- Work on a primary assumption of 1 AP every 17 meters for Voice deployments
- Avoid using the APs with internal antennas in vertical placements. RF planning is more difficult
- Validate that the coverage is “as expected” after installation

VoWiFi RF Design

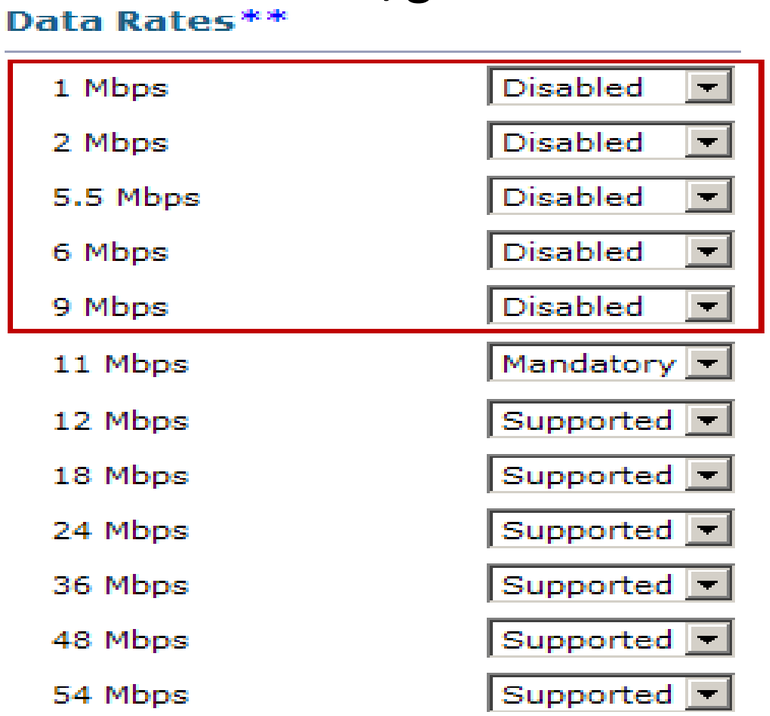
A Few More Tips

- Use 5 GHz whenever possible (a lot of smartphones were 2.4 GHz only, but we are getting there)
- Try to isolate sources of interference, rogues, etc, as part of initial survey
- More needed in 2.4 → Clean Air provides continuous monitoring of possible common interferers
- For high ceiling: do not use omni antennas on high placed APs. Either move APs closer to clients, or use patch/directional
- Always do the design for APs at power level 3, so there is power budget available (yes, all APs exist now with autonomous IOS versions for Site Survey)
- Always allow diversity on AP, or MIMO if 11n

The Data Rate Influence on CAC Bandwidth

- The denser the deployment of indoor APs, the higher the first required data rate (recommendation from Cisco)
- If the AP deployment is not dense, the lower data rates may be necessary to provide coverage
- With the G711 codec and the overhead of the 802.11 protocol, the cell throughput does not increase at data rates above **24Mbps**

Tuned 802.11b/g Data Rates:



VoWiFi RF Design

Coverage Areas

- A huge percentage of problems come from incorrectly defined coverage areas
- Coverage areas: where the voice service should be offered
- Typical errors: “not needed in the bathrooms”, “not in the elevators”, “not in the stairs”, “not in the outdoor smoking area”
- Talk to end-users. Think what they will need and when

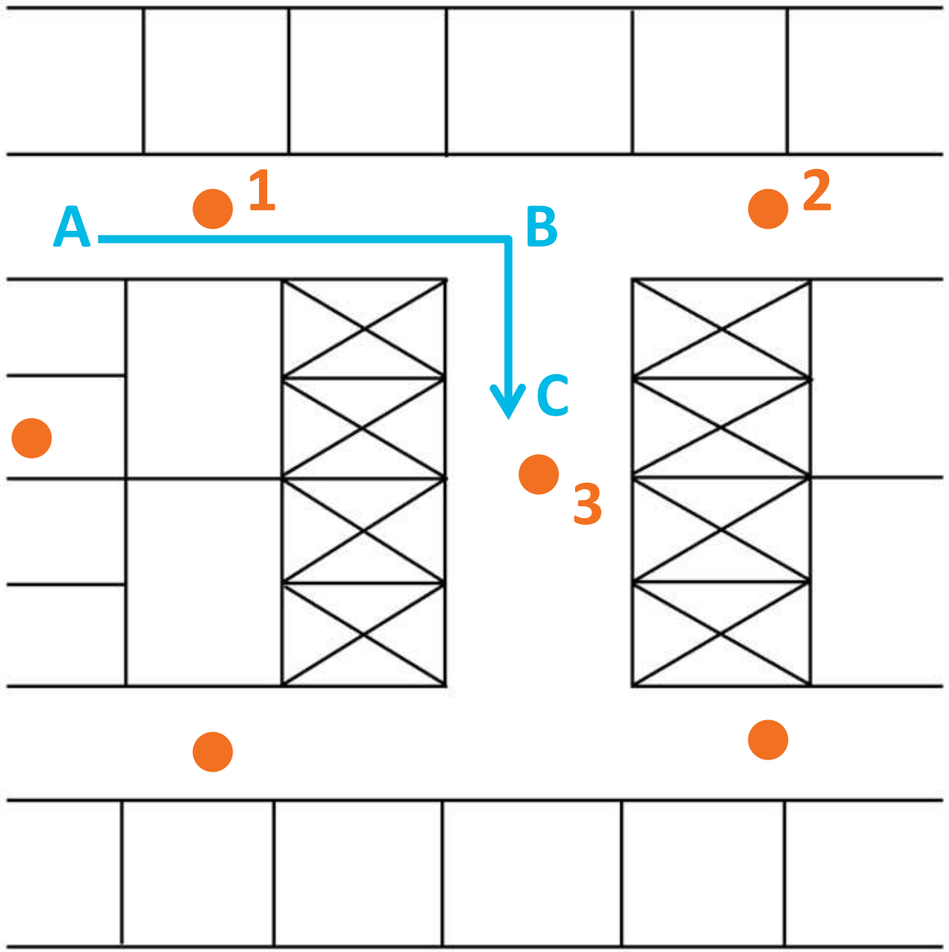
VoWiFi RF Design

The “Transition” AP

- Cell overlap coverage is not always the only concern
- Roaming can fail if the client device does not have enough time to properly scan for neighboring access points
  - Imagine turning the corner around a metal or high attenuation barrier – the RF environment changes very rapidly
- Challenging RF obstacles need to be considered during AP placement
- A “Transition” AP that is placed at the intersection of hallways can alleviate some scenarios

VoWiFi RF Design

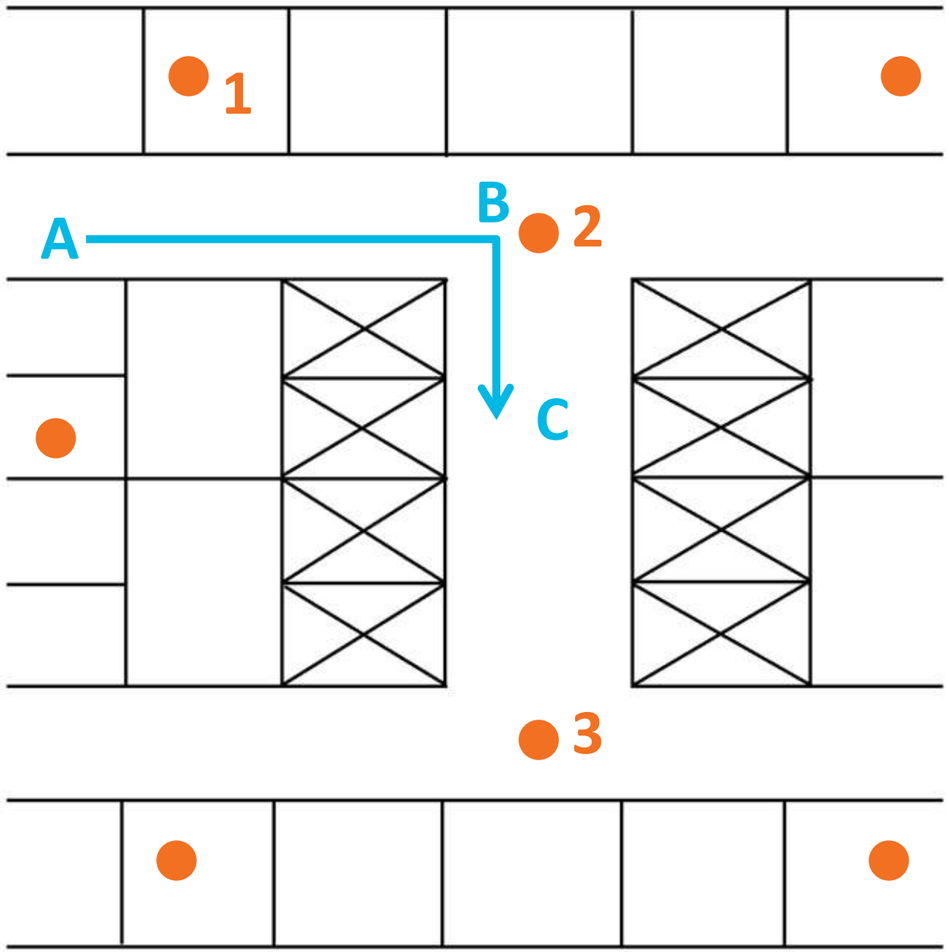
Scanning Problems



- At point A the phone is connected to AP 1
- At point 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 point 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

VoWiFi RF Design

Transition AP Placement



- 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

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VoWiFi Configuration

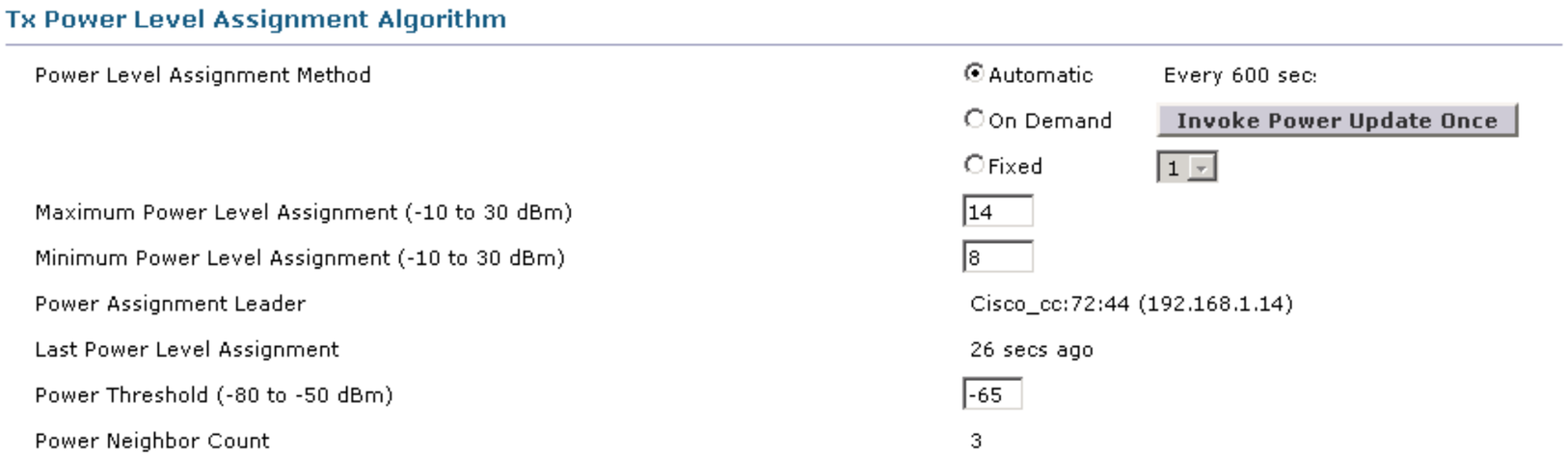
Use Design Guide

- Disabled
  - DHCP required
  - P2P blocking
  - MFP client
  - Band select
  - Load balancing
  - Low data rates
- Optional
  - Client Exclusion
- Enabled
  - Aironet extensions
  - DTPC
  - Platinum + 802.1p “6”
  - Long session timeout
  - Fast roaming (CCKM/Open/PSK)
  - WMM (allowed/required)
  - DTIM “2”
  - AES
  - EDCA for Voice or mixed
  - CAC

VoWiFi Configuration

RRM Advanced Settings

- Use long DCA period: 8/12/24 hours to prevent frequent channel changes
- Set the Maximum Power Level to match your clients
- Set the Minimum Power Level to avoid pico-cell issues
- Power Threshold can be increased to increase overall power assignments, or decreased to reduce power assignments
  - Default value is -70, remember it is a negative number!



VoWiFi Configuration

Channel and Power Levels

- UNII-1 Channels are intended for indoor use, typically have lower max transmit power of 14 dB*
- UNII-2 Channels require use of DFS (Dynamic Frequency Selection), typically have max transmit power of 17 dB*
- UNII-3 Channels do not require DFS, and have a max transmit power of 17 dB*

*Maximum transmit power may vary by AP model

Channel ID	36	40	44	48	52	56	60	64	100	104	108	112	116	120	124	128	132	136	140	149	153	157	161
Center Freq. MHz	5180	5200	5220	5240	5260	5280	5300	5320	5500	5520	5540	5560	5580	5600	5620	5640	5660	5680	5700	5745	5765	5785	5805
Band	UNII-1				UNII-2															UNNII-3			

VoWiFi Configuration

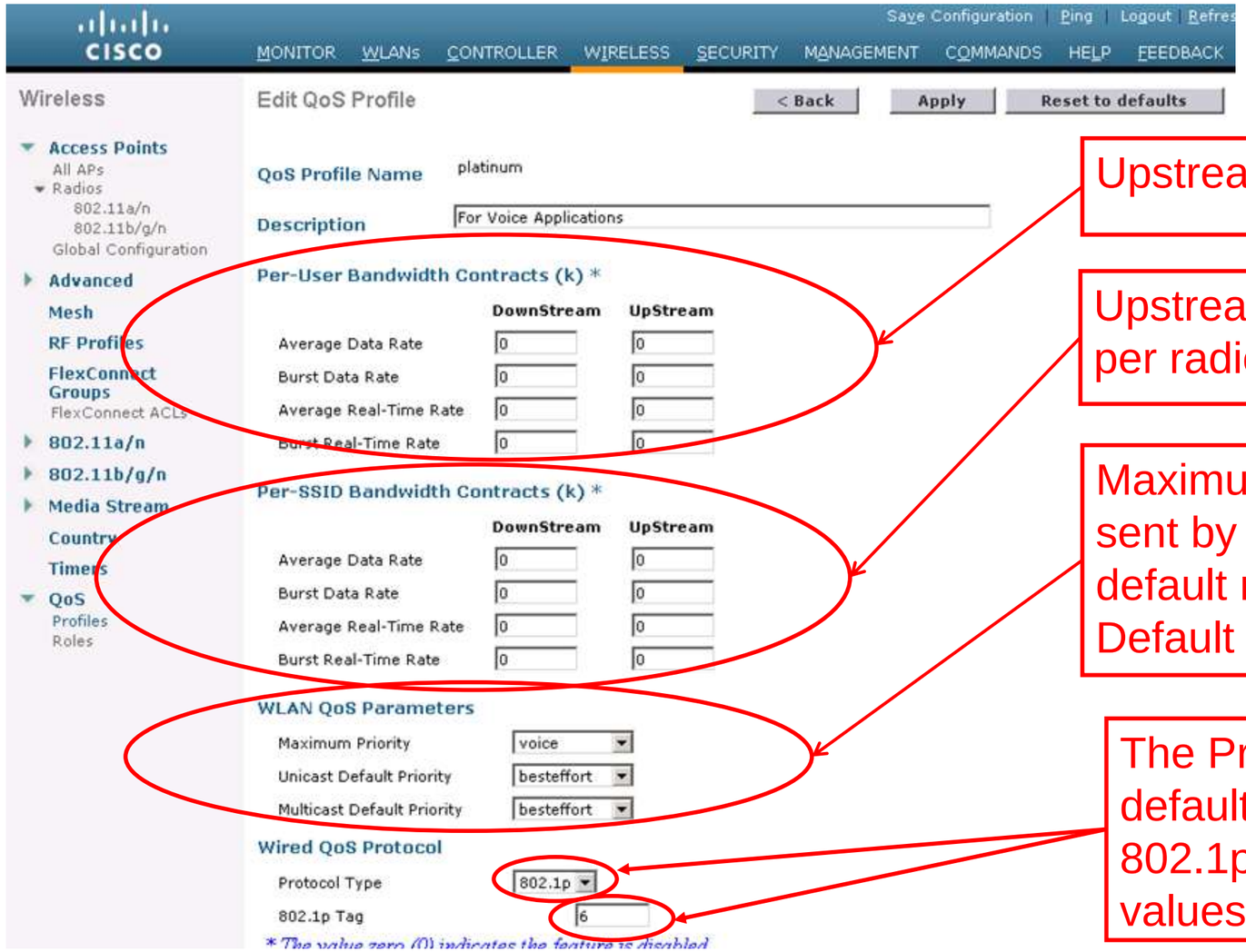
DSCP and COS

- Trust DSCP on APs
- Trust COS on WLC trunks
  - NB: COS value requires 802.1q tag, so it will not work for the native vlan!
- Set 802.1p Wired Protocol to 6 for the Platinum QoS Profile
- Ensure cos-dscp map on switched network is properly defined
  - COS 3 to DSCP 24 (CS3) for SCCP traffic
  - COS 5 to DSCP 46 (EF) for RTP traffic
  - mls qos map cos-dscp 0 8 16 24 32 46 48 56

Traffic Type	DSCP	802.1p	WMM UP
Voice (RTP)	EF (46)	5	6
Call Control (SCCP)	CS3 (24)	3	4

Classification
Marking/Mutation
Shaping/Policing
Queueing
Bandwidth Allocation
Trust

How to enable QoS for Voice?



Upstream per- user contracts added in 7.3.

Upstream and downstream per- SSID (per AP per radio) contracts added in 7.3.

Maximum Priority is the maximum marking which can be sent by a WMM client. Unicast Default Priority is the default marking of non-WMM client traffic. Multicast Default Priority is for multicast traffic.

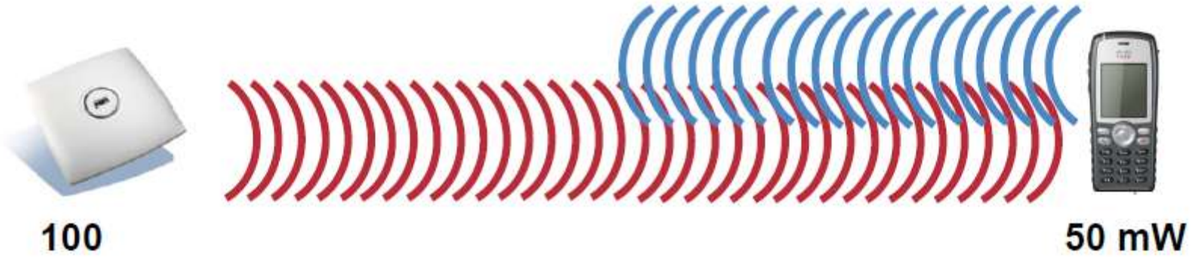
The Protocol Type has two options: None & 802.1p. By default it is set to None. If the Protocol Type is set to 802.1p, then the 802.1p tag can be modified. Valid values are from 0 to 7.

*NOTE: Modification of QoS profile marking that will be used by the AP

VoWiFi Configuration

DTPC

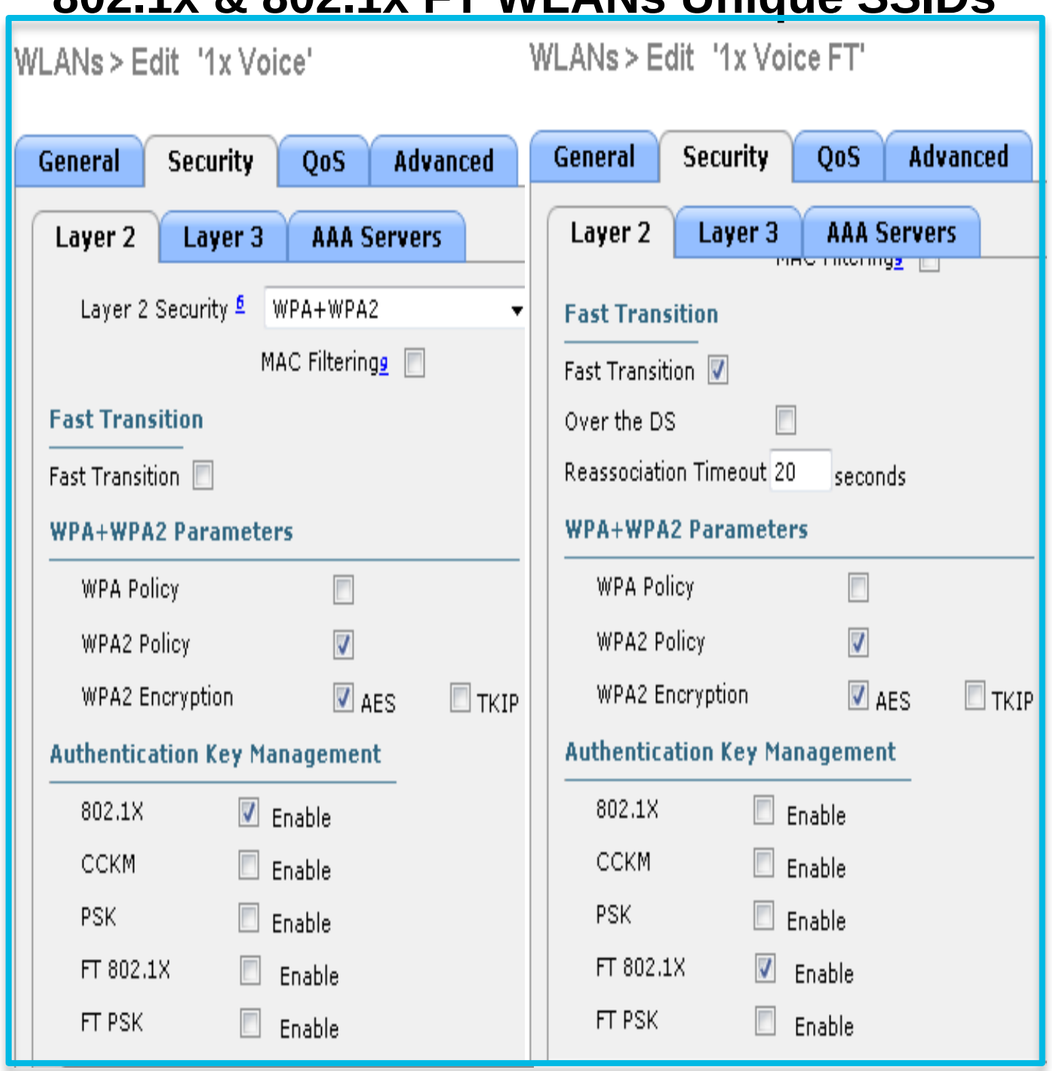
- Mismatched transmit powers on AP and client can cause one-way audio and poor performance
- 792x phone has max tx power of 40 mW (16 dBm)
- Most Smartphones have max tx power of
- AP 2.4 GHz can be up to 100 mW (20 dBm)
- AP 5.0 GHz can be up to 50 mW (17 dBm) (varies by channel)
- Other benefits include reduced co-channel interference radius and power saving on clients
- Requires CCXv2



If implementing 802.11r today:

Multiple WLANs for Multiple Authentication types, Each with a Unique SSID

802.1x & 802.1x FT WLANs Unique SSIDs



WLAN ID	Type	Profile Name	WLAN SSID	Status	Security Policies
6	WLAN	1x Voice	1Voice	Enabled	[WPA2][Auth(802.1X)]
7	WLAN	1x Voice FT	1VoiceFT	Enabled	[WPA2][Auth(FT 802.1X)]
8	WLAN	PSK Voice	pskVoice	Enabled	[WPA2][Auth(PSK)]
9	WLAN	PSK Voice FT	pskVoiceFT	Enabled	[WPA2][Auth(FT-PSK)]

PSK & PSK FT WLANs With Unique SSIDs

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802.11r (Fast Transition) and client devices

It can get a little complex…

- An iPhone with iOS 6.0 can authenticate to a WLAN with and without “FT”.
- A non-6.0 iOS client can’t associate.
- Both iPhone 4 models will take the 6.0iOS upgrade.
- But iPhone 4 does **not** do 11r.
- The iPhone 4s does 11r

(The iPhone 5 also).

- So, which one is it?

Do an internet search to find the Model if unsure.

7.3 Controllers Compared

Scalability-Numbers based on SW-Release 7.3	vWLC	2504	WLCM2	5508	WiSM2	7500	8500
Maximum # of APs	200	50	10/50	500	1000	6000	6000
Maximum # of Clients	3000	500	500	7000	15000	64 000	64 000
Maximum # of FlexConnect-Groups	100	20	20	20	100	2000	2000
Maximum # of APs per FlexConnect-Group	100	25	25	25	50	100	100
Maximum # of Rogue APs	800	2000	2000	2000	4000	24 000	24 000
Maximum # of Rogue Clients	1500	2500	2000	2500	5000	32 000	32 000
Maximum # of RFID-Tags	3000	500	500	5000	10 000	50 000	50 000
Maximum # of APs per RRM-Group	1000	500	500	1000	2000	6000	6000
Maximum # of AP-Groups	200	50	30	500	500	6000	6000
Maximum # of VLANs	512	16	16	512	512	4095	4’095
Maximum # of WLANs	512	16	16	512	512	512	512
Maximum Throughput non-DTLS (FlexConnect: Central-Switching)	500 Mbps	500 Mbps	500Mbps	7 Gpbs	16 Gbps	1 Gbps	10 Gbps
Maximum Throughput DTLS (FlexConnect: Central-Switching)	not supported	500 Mbps	not supported	5 Gbps	9 Gbps	1 Gbps	5 Gbps
Min. SW-Version	7.3	7.0	7.0	6.0	7.0	7.0	7.3

APs supporting Voice over Wifi well:

For Your Reference

Aironet a/b/g

1242

1130

Recommended

Aironet nG1

3500
2x3:2
$1395

1260
1140
2x3:2
$995

1040
2x2:2
$795

Aironet nG2

3600
4x4:3
$1495

New

2600
3x4:3
$1095

AVAILABLE NOW

Soon

1600
3x3:2
$695

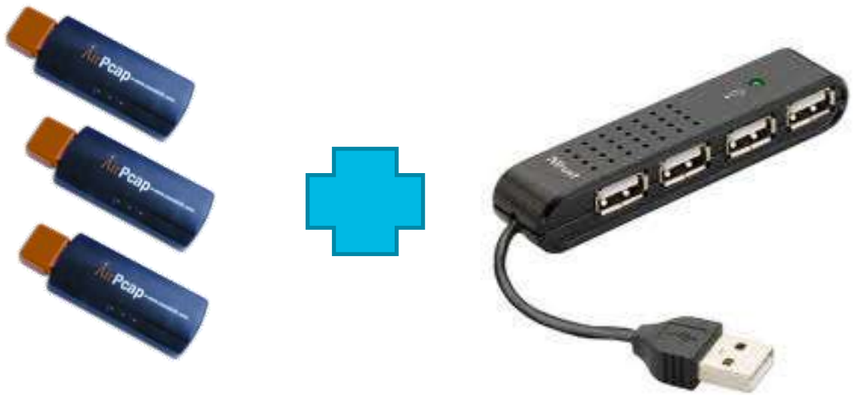
December 2012

Cisco live!

Troubleshooting Tools

Wireless Captures, RF Analysis, Configuration Analysis

- Wireless sniffer
  - Omnipeek/AirPcap
  - Mac with OS X 10.6 and above
  - Windows 7 with Netmon 3.4
  - Multichannel, for roaming issues
  - AP in Sniffer mode



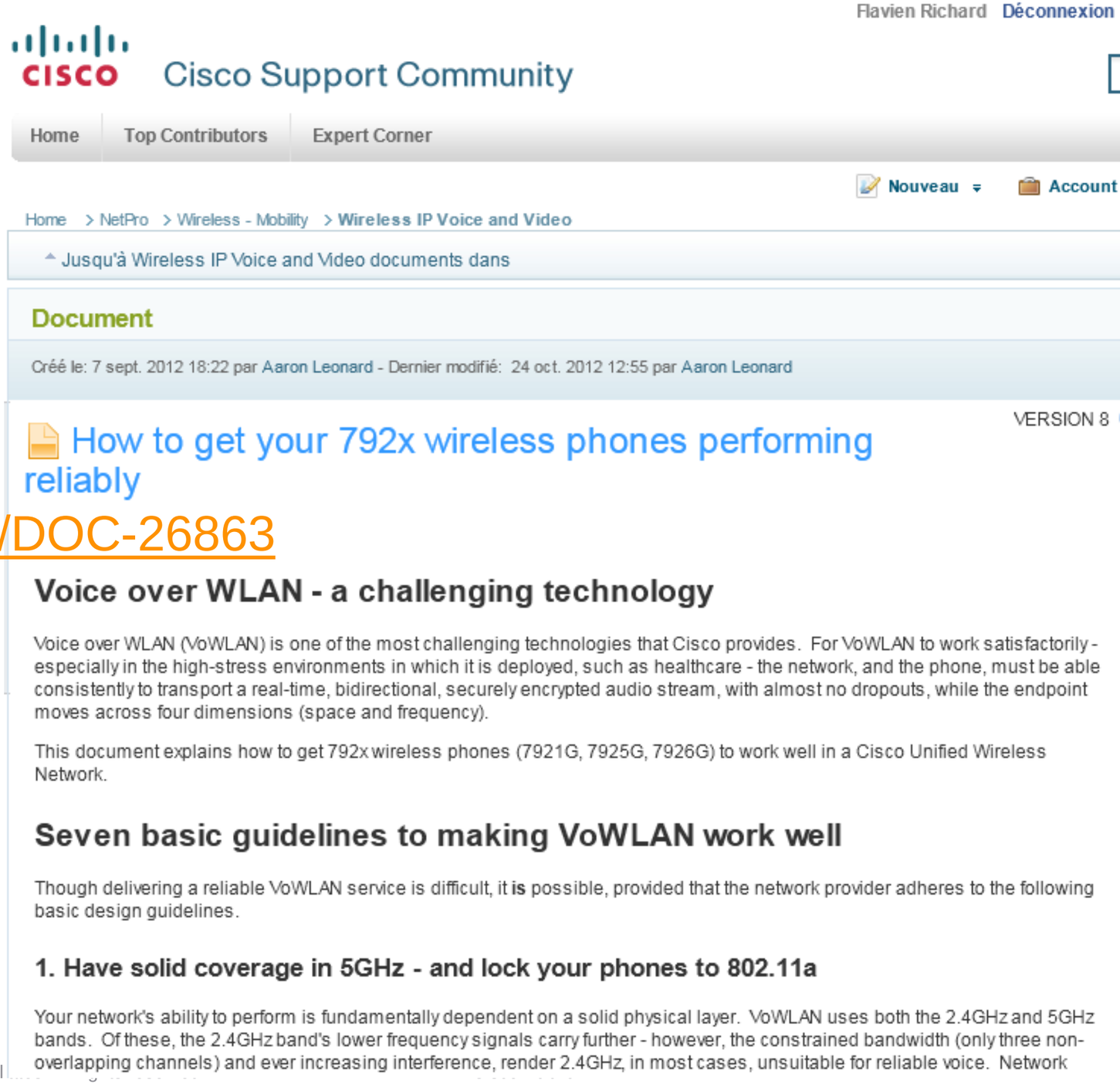
- L1 analysis: SpectrumExpert, 3500/3600 Ap, etc
- WLCCA (WLC Configuration Analyzer) – TAC support
- NCS / Cisco Prime Infrastructure for Historical view and « Client Troubleshooting tool »

Support Community

How to get your 792x wireless phones performing reliably)

https://supportforums.cisco.com/docs/DOC-26863

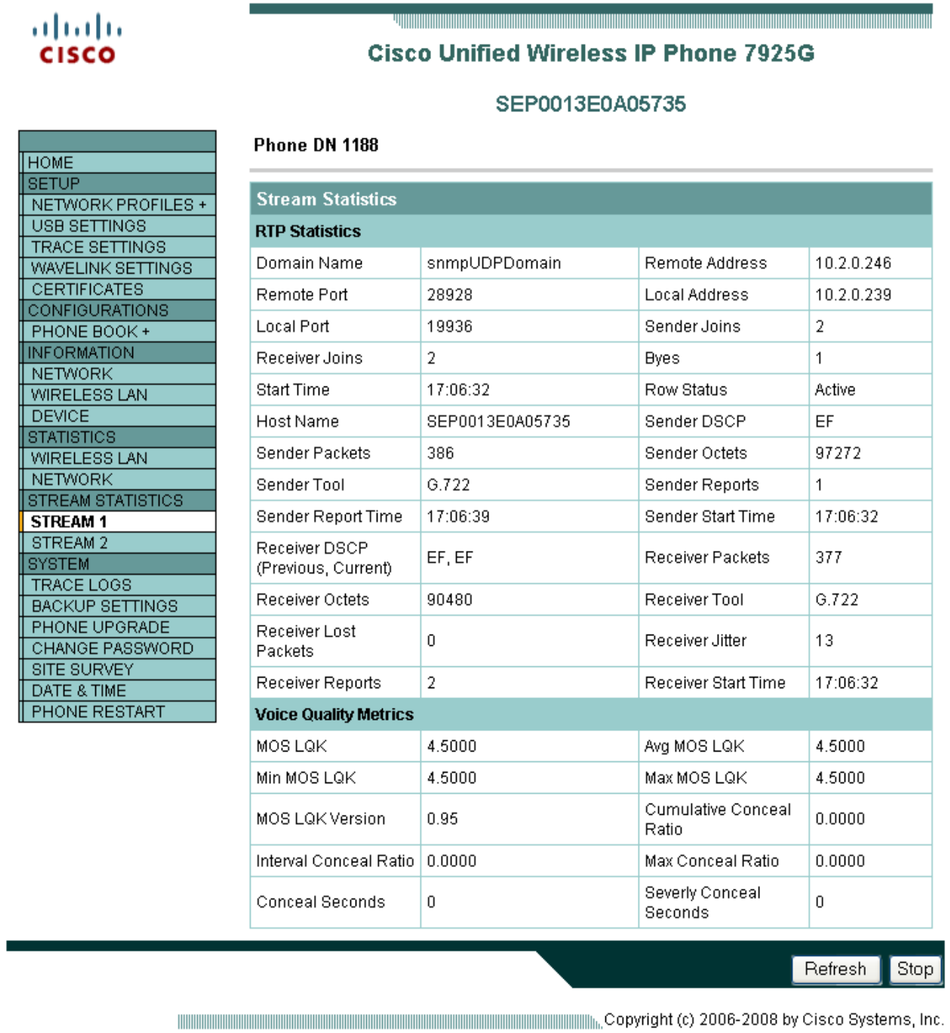
Please upgrade all Cisco wireless IP Phones to code version 1.4.3



Data Analysis on a Cisco Wireless IP Phone

Packet Loss and Delay

- Per voice guidelines, PER should not exceed 1% packet loss.
- If there is > 1% packet loss, then voice quality can be degraded significantly.
- All Cisco IP Phones have the ability to display “receiver lost packets” as well as the total # of receiver packets in the stream (call) statistics.
- Simply divide the receiver lost packets by the total # of receiver packets.
- Jitter should also be kept at a minimum (< 100 ms).



Cisco Unified Wireless IP Phone 7925G

SEP0013E0A05735

HOME
SETUP
NETWORK PROFILES +
USB SETTINGS
TRACE SETTINGS
WAVELINK SETTINGS
CERTIFICATES
CONFIGURATIONS
PHONE BOOK +
INFORMATION
NETWORK
WIRELESS LAN
DEVICE
STATISTICS
WIRELESS LAN
NETWORK
STREAM STATISTICS
STREAM 1
STREAM 2
SYSTEM
TRACE LOGS
BACKUP SETTINGS
PHONE UPGRADE
CHANGE PASSWORD
SITE SURVEY
DATE & TIME
PHONE RESTART

Phone DN 1188

Stream Statistics			
RTP Statistics			
Domain Name	snmpUDPDomain	Remote Address	10.2.0.246
Remote Port	28928	Local Address	10.2.0.239
Local Port	19936	Sender Joins	2
Receiver Joins	2	Byes	1
Start Time	17:06:32	Row Status	Active
Host Name	SEP0013E0A05735	Sender DSCP	EF
Sender Packets	386	Sender Octets	97272
Sender Tool	G.722	Sender Reports	1
Sender Report Time	17:06:39	Sender Start Time	17:06:32
Receiver DSCP (Previous, Current)	EF, EF	Receiver Packets	377
Receiver Octets	90480	Receiver Tool	G.722
Receiver Lost Packets	0	Receiver Jitter	13
Receiver Reports	2	Receiver Start Time	17:06:32
Voice Quality Metrics			
MOS LQK	4.5000	Avg MOS LQK	4.5000
Min MOS LQK	4.5000	Max MOS LQK	4.5000
MOS LQK Version	0.95	Cumulative Conceal Ratio	0.0000
Interval Conceal Ratio	0.0000	Max Conceal Ratio	0.0000
Conceal Seconds	0	Severly Conceal Seconds	0

Refresh Stop

Data Analysis

QoS Verification

- On the 792x phone, while on a call navigate to Settings > Status > Network Statistics
- Check that the “DataRcvVO” counter is incrementing
- Packet Capture


```
QoS Control Field:      %0000000000000110
                          -------- ........ AP PS Buffer State: 0
                          ........ 0....... A-MSDU: Not Present
                          ........ .00..... Ack: Normal Acknowledge
                          ........ ...0.... EOSP: Not End of Triggered Service Period
                          ........ ....x... Reserved
                          ........ .....110 UP: 6 - Voice
802.2:          D=0xAA SNAP S=0xAA SNAP C=0x03 Unnumbered Information
IP Header - Internet Protocol Datagram
  Version:                4
  Header Length:          5   (20 bytes)
  Differentiated Services:%10111000
                          1011 10.. Expedited Forwarding
                          .... ..00 Not-ECT
```

Wireless Multimedia (WMM) a Wi-Fi Alliance subset of 802.11e

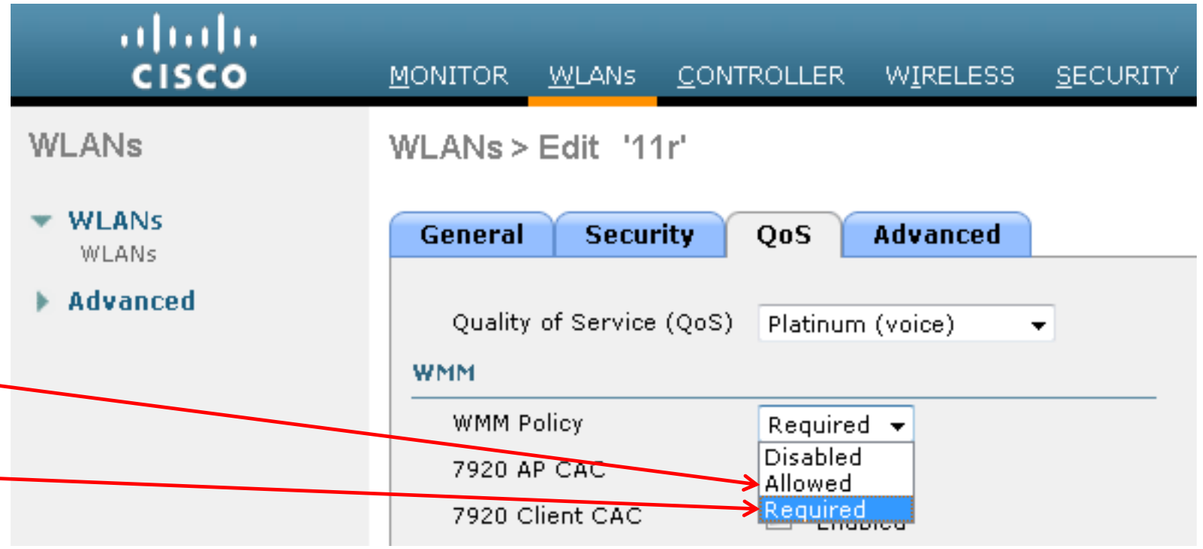
WLAN Configurations of WMM affect QoS Behaviors:

WMM Allowed

Non-WMM clients and WMM enabled Client can join the WLAN

WMM Required

Only WMM enabled Clients can join the WLAN



- WMM enabled Clients transmit all packets with WMM QoS Header
  - The Header QoS field contain
- Non-WMM Clients transmit no packets with WMM QoS Header
  - Non-WMM can not receive packets from the AP that have a WMM QoS Header
- All packets from and to Non-WMM Clients are sent with Best Effort Wi-Fi Channel Access, hence don't have QoS

FaceTime Voice Packet – With WMM Required

Packet	Transmitter	Source	Destination	BSSID	Protocol
141	F0:CB:A1:5F:BE:6A	192.168.0.10	192.168.0.2	Cisco:FC:3B:10	UDP
142	Cisco:FC:3B:10	192.168.0.10	192.168.0.2	Cisco:FC:3B:10	UDP
143	F0:CB:A1:5F:BE:6A	192.168.0.10	71.74.127.200	Cisco:FC:3B:10	UDP
144	A4:67:06:7C:BA:D7	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
145	A4:67:06:7C:BA:D7	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
146	A4:67:06:7C:BA:D7	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
147	A4:67:06:7C:BA:D7	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic

```
BSSID:                    00:21:1B:FC:3B:10  Cisco:FC:3B:10 [4-9]
Source:                   A4:67:06:7C:BA:D7 [10-15]
Destination:              F0:CB:A1:5F:BE:6A [16-21]
Seq Number:               2958 [22-23 Mask 0xFFF0]
Frag Number:              0 [22 Mask 0x0F]
QoS Control Field:        %0000000000000110 [24-25]
                          -------- ........ AP PS Buffer State: 0
                          ........ 0....... A-MSDU: Not Present
                          ........ .00..... Ack: Normal Acknowledge
                          ........ ...0.... EOSP: Not End of Triggered Service Period
                          ........ ....0110 UP: 6 - Voice
802.2 Logical Link Control (LLC) Header
Dest. SAP:                0xAA  SNAP [26]
Source SAP:               0xAA  SNAP [27]
Command:                  0x03  Unnumbered Information [28]
Vendor ID:                0x000000 [29-31]
Protocol Type:            0x0800  IP [32-33]
IP Header - Internet Protocol Datagram
Version:                  4 [34 Mask 0xF0]
Header Length:            5  (20 bytes) [34 Mask 0x0F]
Differentiated Services:  %11000000 [35]
                          0011 00.. Class Selector 6
                          .... ..00 Not-ECT
Total Length:             173 [36-37]
```

FaceTime Video Packet – With WMM Required

Packet	Transmitter	Source	Destination	BSSID	Protocol
222	A4:67:06:7C:BA:D7	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
223	Cisco:FC:3B:10	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
224	A4:67:06:7C:BA:D7	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
225	Cisco:FC:3B:10	192.168.0.2	192.168.0.10	Cisco:FC:3B:10	RTP Dynamic
226	F0:CB:A1:5F:BE:6A	192.168.0.10	71.74.127.200	Cisco:FC:3B:10	UDP

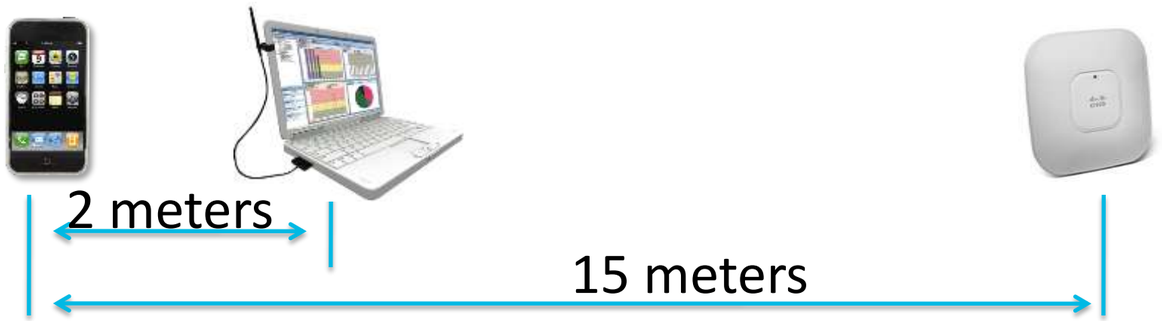
```
BSSID:                    00:21:1B:FC:3B:10  Cisco:FC:3B:10 [4-9]
Source:                   A4:67:06:7C:BA:D7 [10-15]
Destination:              F0:CB:A1:5F:BE:6A [16-21]
Seq Number:               1858 [22-23 Mask 0xFFF0]
Frag Number:              0 [22 Mask 0x0F]
QoS Control Field:        %0000000000000101 [24-25]
                             -------- ........ AP PS Buffer State: 0
                             ........ 0....... A-MSDU: Not Present
                             ........ .00..... Ack: Normal Acknowledge
                             ........ ...0.... EOSP: Not End of Triggered Service Period
                             ........ ....0101 UP: 5 - Video
802.2 Logical Link Control (LLC) Header
Dest. SAP:                0xAA  SNAP [26]
Source SAP:               0xAA  SNAP [27]
Command:                  0x03  Unnumbered Information [28]
Vendor ID:                0x000000 [29-31]
Protocol Type:            0x0800  IP [32-33]
IP Header - Internet Protocol Datagram
Version:                  4 [34 Mask 0xF0]
Header Length:            5  (20 bytes) [34 Mask 0x0F]
Differentiated Services:  %10000000 [35]
                             0010 00.. Class Selector 4
                             .... ..00 Not-ECT
Total Length:             1279 [36-37]
```

FaceTime Voice or video Packets - with WMM Allowed

Packet	Transmitter	Source	Destination	BSSID	Protocol
22	F0:CB:A1:5F:BE:6A	192.168.0.10	17.173.255.223	Cisco:FC:3B:10	UDP
23	F0:CB:A1:5F:BE:6A	192.168.0.10	192.168.0.2	Cisco:FC:3B:10	UDP
24	F0:CB:A1:5F:BE:6A	192.168.0.10	71.74.127.200	Cisco:FC:3B:10	UDP
25	F0:CB:A1:5F:BE:6A	192.168.0.10	71.74.127.200	Cisco:FC:3B:10	UDP

```
Duration:          44  Microseconds [2-3]
BSSID:             00:21:1B:FC:3B:10  Cisco:FC:3B:10 [4-9]
Source:            F0:CB:A1:5F:BE:6A [10-15]
Destination:       A4:67:06:7C:BA:D7 [16-21]
Seg Number:        12 [22-23 Mask 0xFFF0]
Frag Number:       0 [22 Mask 0x0F]
QoS Control Field: %0000000000000000 [24-25]
                   -------- ........ AP PS Buffer State: 0
                   ........ 0....... A-MSDU: Not Present
                   ........ .00..... Ack: Normal Acknowledge
                   ........ ...0.... EOSP: Not End of Triggered Service Period
                   ........ ....0000 UP: 0 - Best Effort
```

Differences in Receive sensitivity and Transmit power



	New iPad	Iphone-4s	Moto-Xoom	Galaxy S2	Galaxy Tab v2
					
Measured - best	-33 dBm	-39 dBm	-34 dBm	-31 dBm	-33 dBm
Pathloss	46 dB	46 dB	46 dB	46 dB	46 dB
RSSI	13 dBm	7 dBm	12 dBm	15 dBm	13 dBm

Conclusion: Do your coverage tests with the devices you will deploy!

iPhone 5 Spatial Streams and 40MHz bonding

- This iPhone 5 Association Request shows the phone supports 1 Spatial Stream

Source	Transmitter	Destination	BSSID	Fl...	Cha...	Si...	Data...	Size	Relative Time	Protocol
54:26:96:10:84:16		Cisco:96:73:62		#	6	-28	11.0	14	32.167658000	802.11 Ack
54:26:96:10:84:16	54:26:96:10:84:16	Cisco:96:73:62	Cisco:96:73:62	*	6	-30	11.0	170	32.168229000	802.11 Assoc Req
Cisco:96:73:62		54:26:96:10:84:16		#	6	-27	11.0	14	32.168234000	802.11 Ack

```
Tx and Rx MCS Set:                %0  Equal [96 Mask 0x40]
Tx Maximum Number Spatial Streams Supported:%00  1 Spatial Stream [96 Mask 0x30]
Tx Unequal Modulation:            %0  Not Supported [96 Mask 0x08]
Reserved:                         %0000000000000000000000000  b101-b127 [96-99 Mask 0x07FFFFFF]
HT Extended Capabilities Info:    %0000000000000000 [100-101]
                                  xxxx .... .... .... Reserved
                                  .... 0... .... .... Reverse Direction Responder: Not Supported
                                  .... .0.. .... .... +HTC Support: Not Supported
                                  .... ..00 .... .... MCS Feedback: STA Does Not Provide MCS Feedback
                                  .... .... xxxx x... Reserved
                                  .... .... .... .00. Transition Time: No Transition
                                  .... .... .... ...0 Transmitter Supports PCO: Not Supported
Tx Beam Forming Capability (TxBF):%00000000000000000000000000000000 [102-105]
                                  xxx. .... .... .... .... .... .... .... Reserved
                                  ...0 0... .... .... .... .... .... .... Channel Estimation Capability: 1 Space Time Stream
                                  .... .00. .... .... .... .... .... .... CSI Max Number of Rows: 1 Row of CSI
                                  .... ...0 0... .... .... .... .... .... Compressed BF Feedback Matrix: 1 TX Antenna Sounding
                                  .... .... .00. .... .... .... .... .... Uncompressed BF Feedback Matrix: 1 TX Antenna Sounding
                                  .... .... ...0 0... .... .... .... .... CSI Number of BF Antennas: 1 TX Antenna Sounding
```

Agenda

- Voice over WiFi – Deployment recommendations and best practices
  - Voice over WiFi 101
  - VoWiFi RF Design
  - VoWiFi Configuration
  - What you should also know
  - **Summary**

Summary

Key Take Aways

- RF: survey, survey, survey
- You can’t just drop voice on a WiFi deployment and expect it to work
- Involve the users and value their feedback
- Design with the least powerful client in mind
- Implement Fast Secure Roaming techniques
- Study the Cisco Validated Design Guide and review this presentation

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