
TOMORROW
starts here.
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High Density WiFi for Large Public Venues

BRKSPM-2013

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Solutions Architect, Cisco Advanced Services

#clmel

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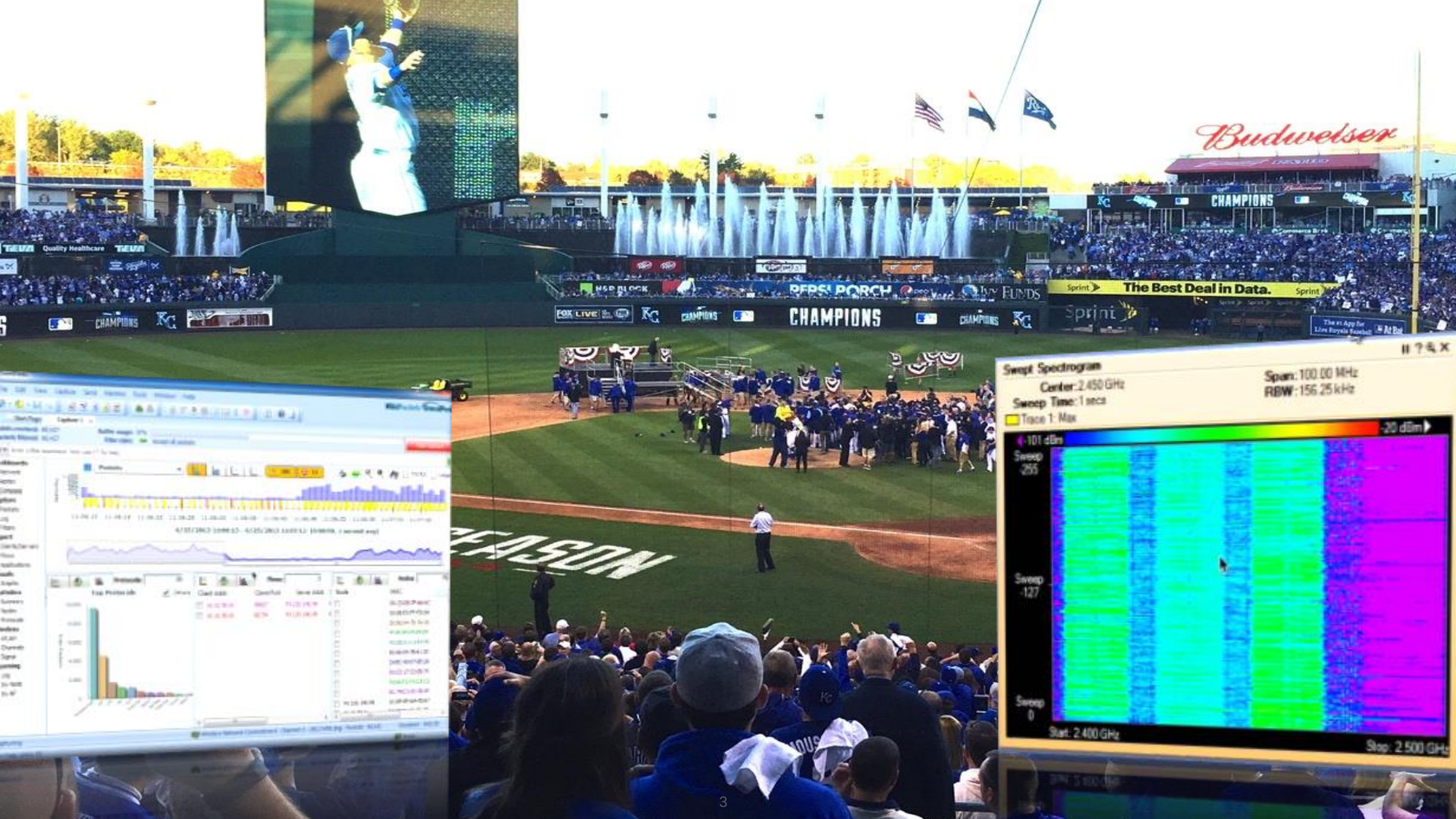
Budweiser
CHAMPIONS
The Best Deal in Data.
Swept Spectrogram
Center: 2.450 GHz
Sweep Time: 1 secs
Trace 1: Max
Span: 100.00 MHz
RBW: 156.25 kHz
-20 dBm
Start: 2.400 GHz
Stop: 2.500 GHz

Agenda

- Designing WLANs for High Client Densities
- HD Wi-Fi Configuration Tips
- Enemies of High Density Wi-Fi
- HD Wi-Fi Engineering Toolkit

Designing RF for High Client Densities

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Design for These 3 Key RF Relationships

AP to Client

- How clients hear AP's

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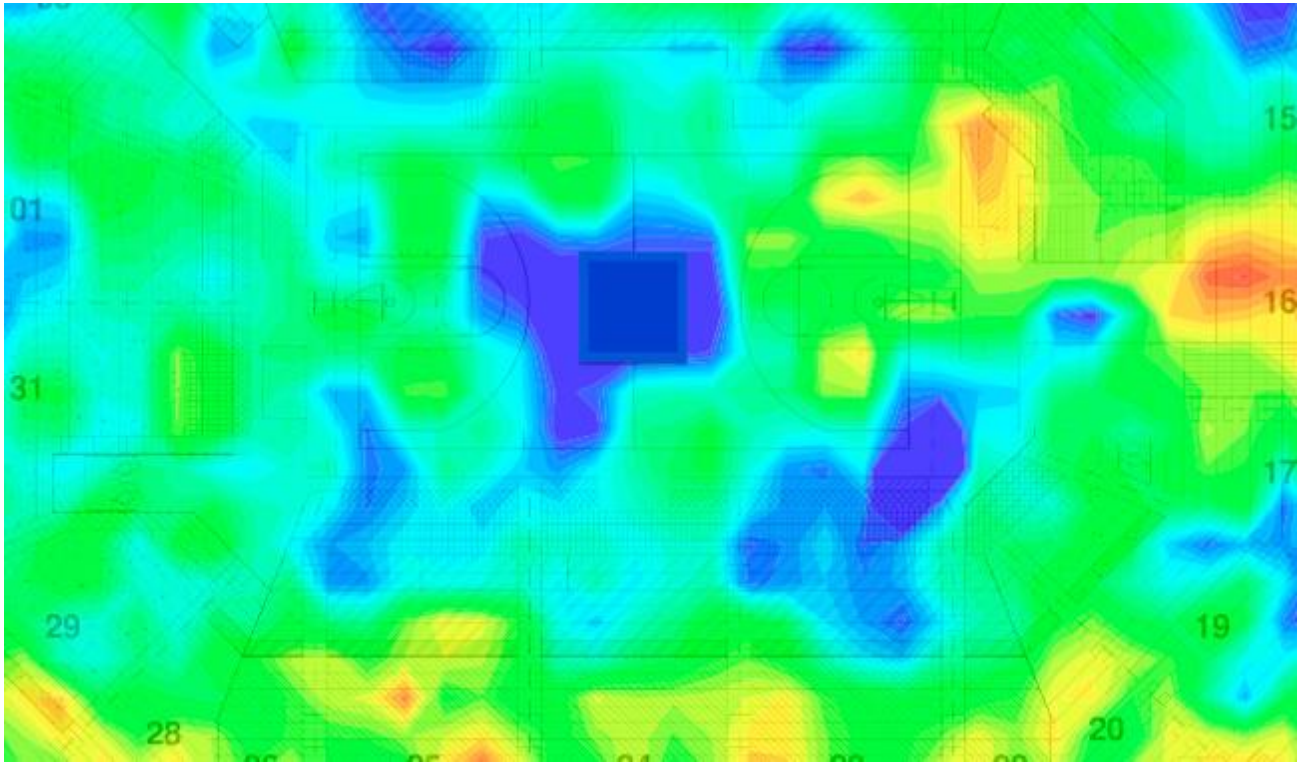
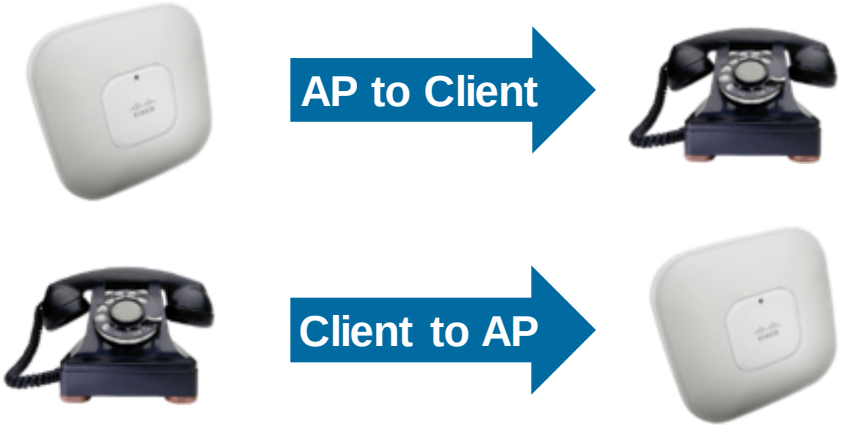
How Clients Hear AP's

Site Survey



Design for These 3 Key RF Relationships



- How clients hear AP's
- How AP's hear clients

How AP's Hear Clients

From WLC: "show client detail"

```
(Cisco Controller) >show client detail 0c:30:21:00:1c:36
Client MAC Address.............................. 0c:30:21:00:1c:36
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Client Statistics:
      Number of Bytes Received.................... 10389
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      Number of Interim-Update Sent............... 0
      Number of EAP Id Request Msg Timeouts....... 0
      Number of EAP Request Msg Timeouts.......... 0
      Number of EAP Key Msg Timeouts.............. 0
      Number of Data Retries...................... 59
      Number of RTS Retries....................... 0
      Number of Duplicate Received Packets........ 0
      Number of Decrypt Failed Packets............ 0
      Number of Mic Failured Packets.............. 0
      Number of Mic Missing Packets............... 0
      Number of RA Packets Dropped................ 0
      Number of Policy Errors..................... 0
      Radio Signal Strength Indicator............. -70 dBm
      Signal to Noise Ratio....................... 23 dB
Nearby AP Statistics:
      BAR-AP6-4B-S111(slot 0)
        antenna0: 47 secs ago..................... -73 dBm
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```
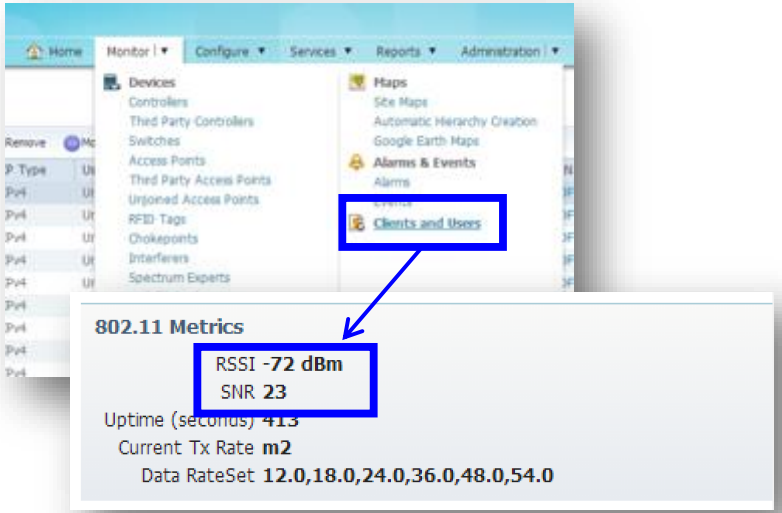

From Prime Infrastructure: Monitor -> Clients and Users



From Autonomous AP: "**show dot11 association all-client**"

How AP's Hear Clients

Or better yet, on AP CLI:

Telnet/SSH to AP and use "Show Controller <D0 | D1>" for immediate client RSSI readings of ALL clients associated to the specified radio

```
KCR-6AO-OFC-394#show controller d1
<snip>
                  RxPkts KBytes  Dup Dec Mic Txc   TxPkts   KBytes   Retr  RSSI SNR
1ce6.2bb5.e294       158      23    0   0   0   0      122       30      4    63  34
<snip>
```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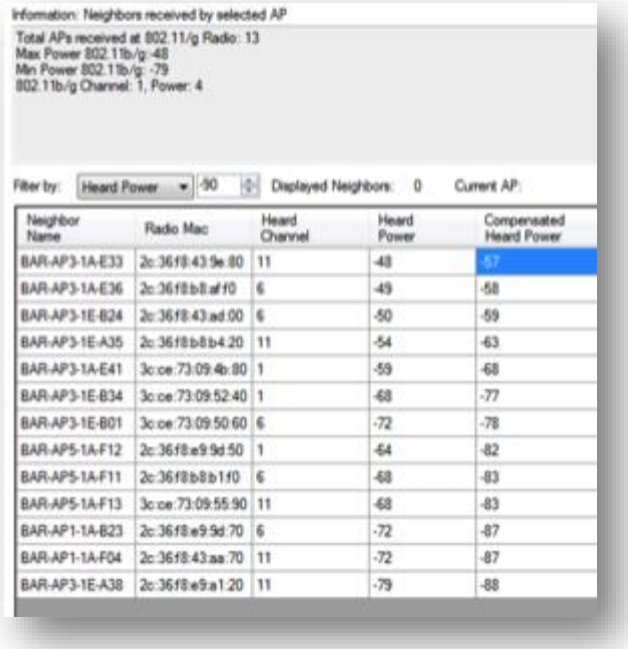
Design for These 3 Key RF Relationships

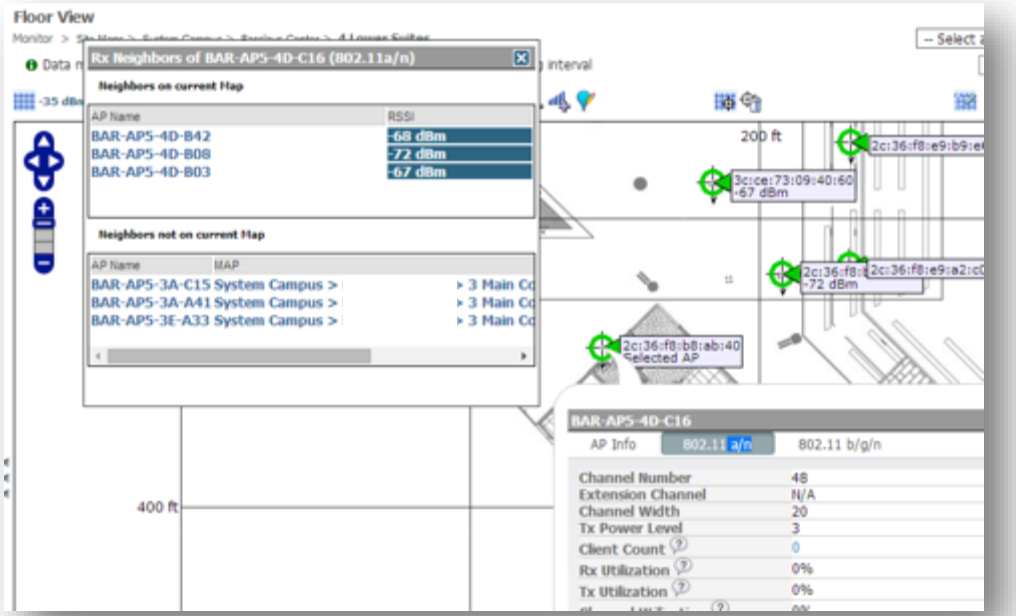
- How clients hear AP's
- How AP's hear clients
- How AP's hear each other

How AP's Hear Each Other

WLC Config Analyser (WLCCA)



Prime Infrastructure Maps



https://supportforums.cisco.com/document/7711/wlc-config-analyzer

Applying the 3 Key RF Relationships

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It All Starts with Layer 1: RF Design

Antenna Selection:

Decide which antenna is right for the job.

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It All Starts with Layer 1: RF Design

Antenna Selection:

Decide which antenna is right for the job.

Consider:

- Density of clients to be served
- Available mounting assets
  - Within ~20m of furthest client
  - Reasonable range 15-23m

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It All Starts with Layer 1: RF Design

Antenna Selection:

Decide which antenna is right for the job.

Antenna Placement:

Where will this antenna provide the best throughput and most reliable service?

Consider:

- Density of clients to be served
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Decide which antenna is right for the job.

Consider:

- Density of clients to be served
- Available mounting assets
  - Within ~20m of furthest client
  - Reasonable range 15-23m

Antenna Placement:

Where will this antenna provide the best throughput and most reliable service?

Consider:

- Line of sight
- Isolation from ambient RF
- Angle of incidence to client devices

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Antenna Selection

Photo	Name/Part No.	Beam	Use Case
	**Dual-Band Stadium Antenna** **3702p + AIR-ANT2513P4M-N**	**2.4/5GHz** 30°/30° Az 30°/30° Elev	Primary overhead coverage (i.e. seating areas)

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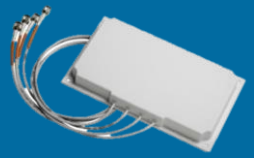	**Dual-Band Patch Antenna** **3702e/p + AIR-ANT2566P4W-R**	105°/125° Az 70°/60° Elev	Augmentation and short-distance HD coverage (<15m to client)

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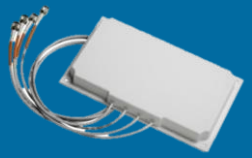	**Dual-Band Patch Antenna** **3702e/p + AIR-ANT2566P4W-R**	105°/125° Az 70°/60° Elev	Augmentation and short-distance HD coverage (<15m to client)
	**Integrated or External Omni** **3702i *or* 3702e + AIR-ANT2524V4C-R**	Omni Az 69°/60° Elev	Low density, Back-of-house

Antenna Placement: What **Not** To Do

Seating Area Coverage: Challenging Areas

Avoid long shots like this

Just Say "NO" to through-concrete placements

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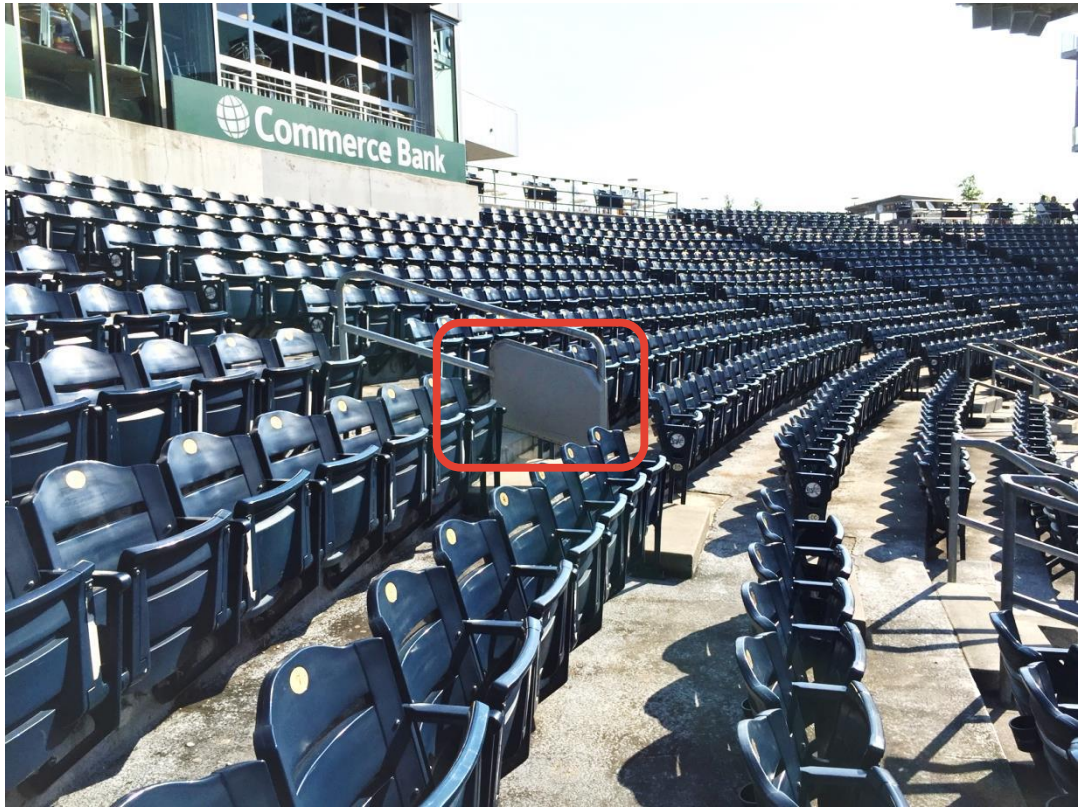
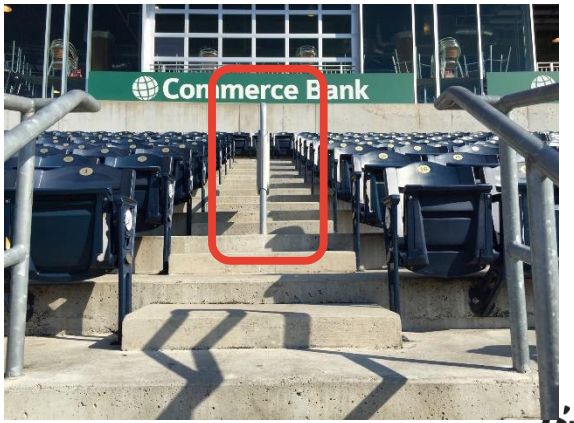
Creative AP/Antenna Mount Examples





Creative AP/Antenna Mount Examples

Seating Area Coverage: Challenging Areas

- Creative options may be required for low seating rows
  - Handrails
  - Front walls (aimed away from playing surface)
- Ensure compliance with minimum distances to bodies - >20cm
- Stick to directional antennas (AIR-ANT-2566NP-R patch)

Antenna Placement

Seating Area Coverage

- Wi-Fi is a 2-way street!
  - Clients need to hear our transmissions, but we need to hear their transmissions too
  - Most smartphones are 1SS – no diversity
- Consider **angle of incidence**
  - Ideal placement: above the targeted seats, aimed downward and/or away from field/pitch
- “Seats Per AP” is only part of the story
- Ideal max distance 23m from furthest client
  - Target 12m-15m for best results

Antenna Placement

High Density in Press/Media Areas and Conference Halls

- Omnis are not ideal for open areas where high capacity is needed
- Create smaller cells with directional antennas mounted above, aimed directly downward
- Understand RRM implications of this type of design

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Core HD WiFi Design Principles

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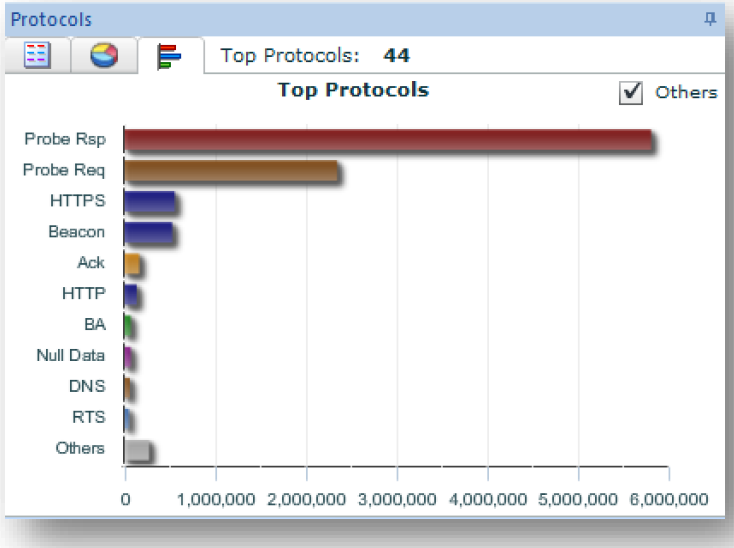
Maximising the Spectrum

Avoiding Excessive Management Traffic



- Always aim for 1 SSID
  - **Especially** in seating areas
- **More SSID's = Worse Performance**
- Why?
  - Each SSID requires a separate Beacon
  - Each SSID will beacon at the minimum mandatory data rate
- Each broadcast SSID will respond to null probe requests
  - **Exponential** amounts of airtime wasted

Maximising the Spectrum

Integrate Existing WLANs

Maximising the Spectrum

Integrate Existing WLANs

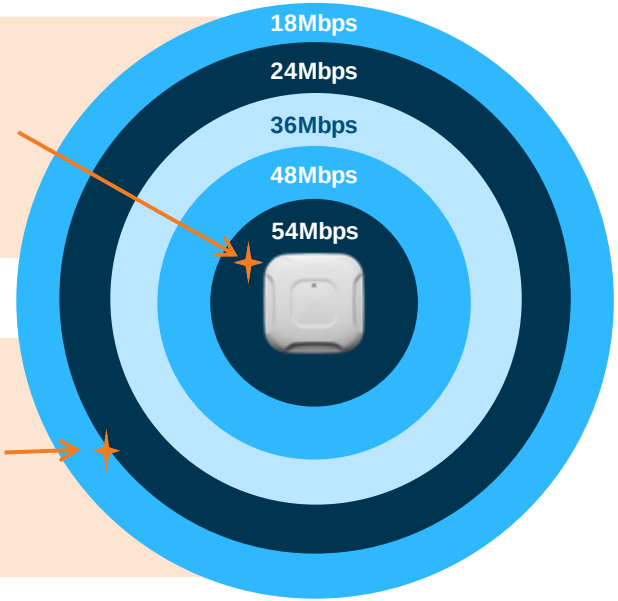
- Common to see various existing WiFi deployments in venues
- Efficient HD WLANs are deployed holistically – one infrastructure
- Benefits?
  - Configuration consistency
  - Airtime efficiency
  - Legacy management traffic that once chewed up 30-40% of airtime typically drops to < 1% of airtime

Maximising the Spectrum

PHY Rate Tuning: Why PHY Rates Matter

Client near AP:
Higher PHY Rate
More Efficient
(high signal-to-noise ratio)

Client far from AP:
Lower PHY Rate
Less Efficient
(lower signal-to-noise ratio)

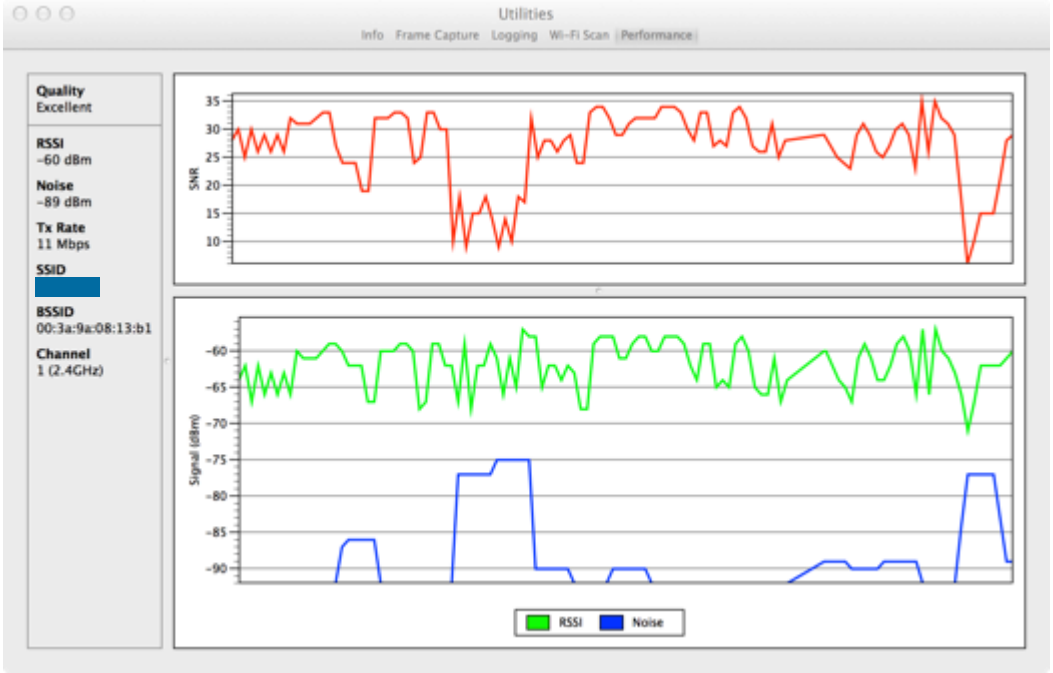


- How fast can we talk?
  - Signal (RSSI) and Noise are key factors
- As client moves further from AP or as noise worsens, client rate-shifts downward
- Lower rate, more airtime consumed
- Position AP's and antennas to allow elimination of low rates (i.e., <18mbps)
- Eliminate 802.11b rates

Maximising the Spectrum

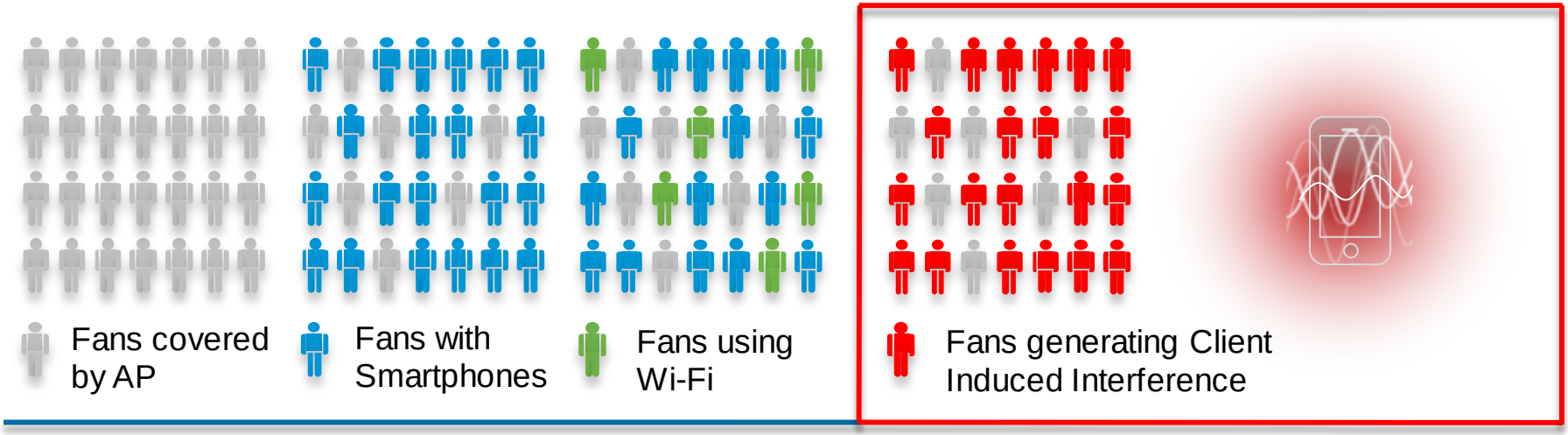
RSSI vs. SNR

- Check your noise floor in each band during peak usage
  - Packet captures with a NIC that you trust (MacBook Pro, etc.)
  - Fluke AirCheck
  - Spectrum Expert
  - Metageek Chanalyzer for Clean Air



Maximising the Spectrum

Client Induced Interference



Common Assumptions

- 75% of fans will have a Smartphone
- 30% of Smartphone users will utilise Wi-Fi
- **But what is everyone else doing?**

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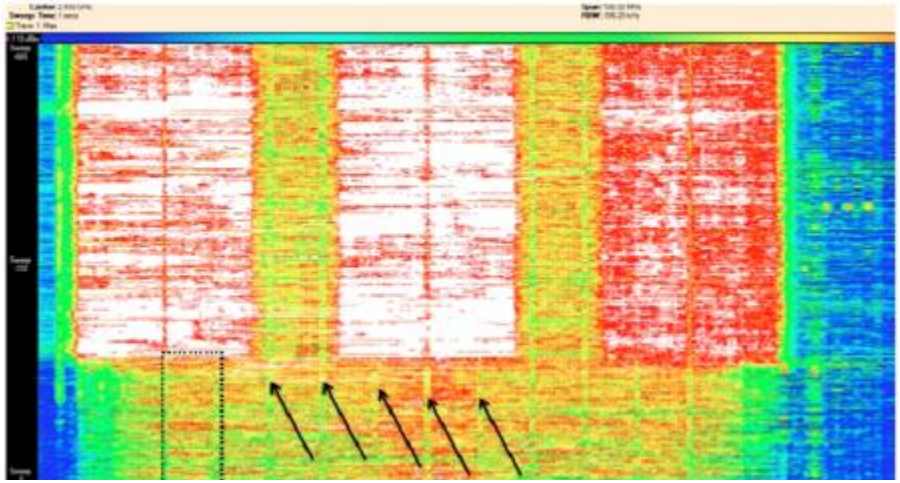
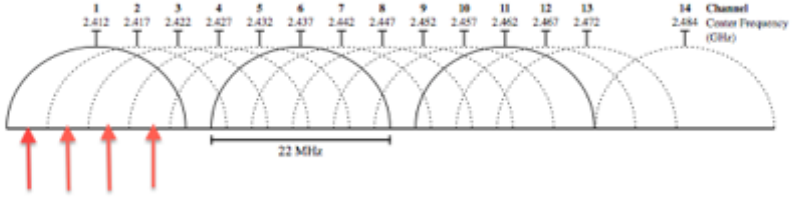
Maximising the Spectrum

Client Induced Interference (Cont'd)





- Client-induced interference: especially damaging on 2.4GHz but also impacts 5GHz via ACI (Adjacent Channel Interference)
- Probe requests sent on *all* channels
  - Many frames on overlapping channels, **driving noise floor to be higher/worse**
- Getting these devices on your network can help
  - Probe frequency diminishes significantly on an associated device

Maximising the Spectrum

Ease-of-Use & Client Induced Interference

- Ask yourself - how difficult is it to get on your WiFi network?
- Ease-of-use directly impacts airtime efficiency
- Low take rate = lots of probe request noise (1mb, max power, all channels)
  - Results in **Client Induced Interference**
- Design for seamless end-user experience
  - Captive portals for T&C: necessary?
- **A device on the network is far less damaging than a device off the network!**
- Device classification guide:
  - http://www.cisco.com/c/en/us/td/docs/wireless/controller/technotes/8-0/device_classification_guide.html

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Maximising the Spectrum

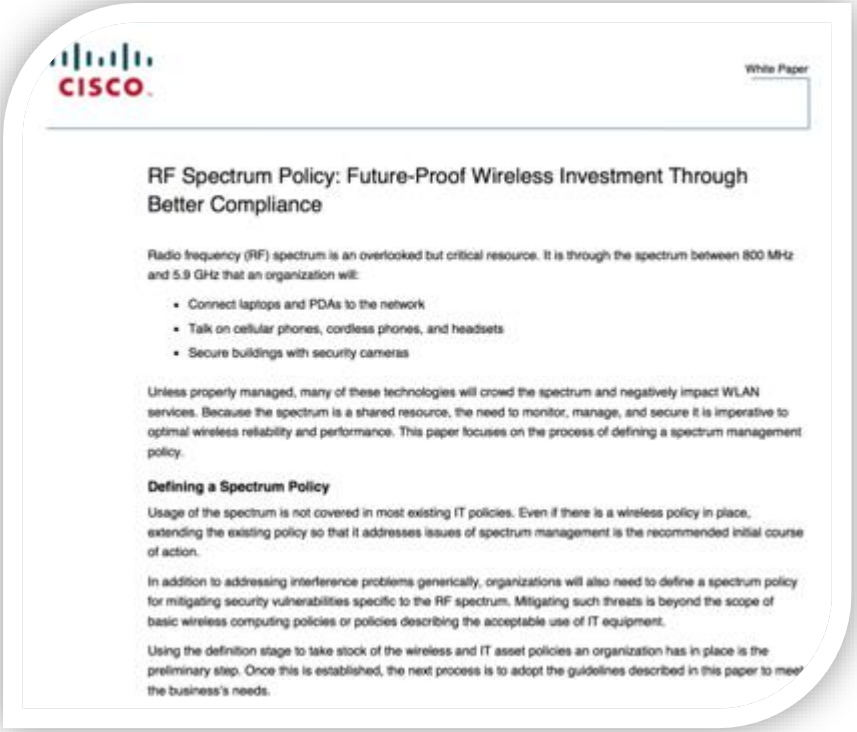
Ease-of-Use & Client Induced Interference

	Radios				Standards						Location			
	2.4 GHz	5 GHz	11n	11ac	11r	11k	11u	11v	11w	DFS Channels	Probing Frequency	Roaming Behavior	mDNS	Sleep Mode Behavior
iPhone 5s/i8.0	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	30 minutes	AP signal is < 20 dB	Discovery: Bluetooth + Network Mirroring: Network Wi-Fi Direct	Probes with the real MAC for 20 minutes, then sends probes alternating between the real and changing fake MAC with a 135 s cycle.
iPhone 5/i7.0/7.1	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	30 minutes	AP signal is < 20 dB	Discovery: Bluetooth + Network Mirroring: Network	Probes broadcast every 30 minutes.
iPhone 6/6+ i8.0 (8.0.0, 8.0.1, 8.0.2)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes[1]	Yes	Probes fast when signal AP is weak, probes every 30 minutes when AP signal is strong	Roams when AP signal is below 20 dB, panic probe unless helped with 802.11k	Discovery:Bluetooth + Network Mirroring:Network Wi-Fi Direct	Probes with real MAC 135 to 1350 s, no probes for about 140 s, then 2 to 6 probes with locally administered random

Maximising the Spectrum

Develop and Enforce an RF Policy

- Employ an effective RF policy to manage non Wi-Fi interference as it occurs
  - http://www.cisco.com/en/US/prod/collateral/wireless/ps9391/ps9393/prod_white_paper0900aecd8073bef9.html



White Paper

RF Spectrum Policy: Future-Proof Wireless Investment Through Better Compliance

Radio frequency (RF) spectrum is an overlooked but critical resource. It is through the spectrum between 800 MHz and 5.9 GHz that an organization will:

- Connect laptops and PDAs to the network
- Talk on cellular phones, cordless phones, and headsets
- Secure buildings with security cameras

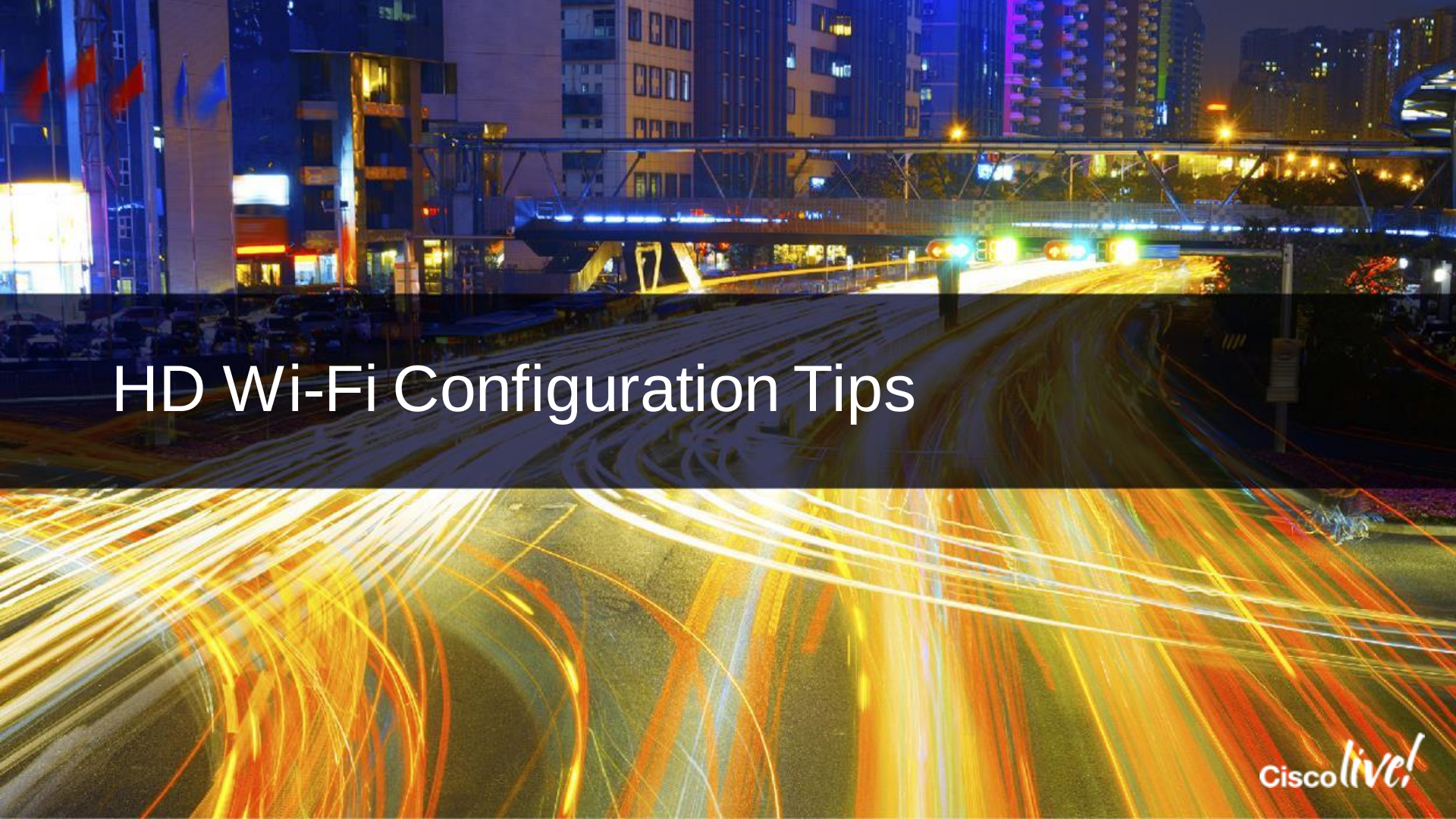
Unless properly managed, many of these technologies will crowd the spectrum and negatively impact WLAN services. Because the spectrum is a shared resource, the need to monitor, manage, and secure it is imperative to optimal wireless reliability and performance. This paper focuses on the process of defining a spectrum management policy.

Defining a Spectrum Policy

Usage of the spectrum is not covered in most existing IT policies. Even if there is a wireless policy in place, extending the existing policy so that it addresses issues of spectrum management is the recommended initial course of action.

In addition to addressing interference problems generically, organizations will also need to define a spectrum policy for mitigating security vulnerabilities specific to the RF spectrum. Mitigating such threats is beyond the scope of basic wireless computing policies or policies describing the acceptable use of IT equipment.

Using the definition stage to take stock of the wireless and IT asset policies an organization has in place is the preliminary step. Once this is established, the next process is to adopt the guidelines described in this paper to meet the business's needs.



HD Wi-Fi Configuration Tips

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HD Features and Configurations

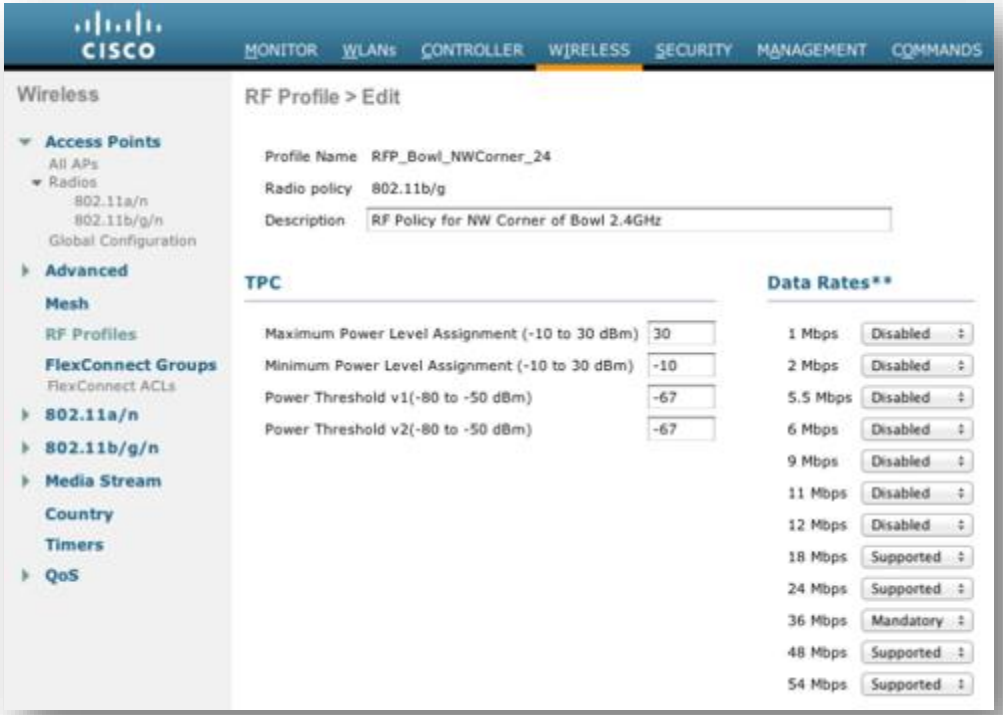
- RF Profiles for granular RF control
- Dynamic Channel Allocation (DCA) Per RF Profile
- Device Profiling & AVC
- RX-SOP threshold configuration and tuning
- Other HDX Features
- Tips & Tricks on Transmit Power Control (TPC)

HD Config Tip: Use RF Profiles for Fine-Tuning

- **RF Profiles** provide granular control of RF parameters – especially useful in High Density WiFi
  - Long vs. short seating section sizes
  - High vs. low ceilings in conference halls and theatres
  - Accommodate existing devices without impacting the entire network – i.e., enable 11b rates only where needed

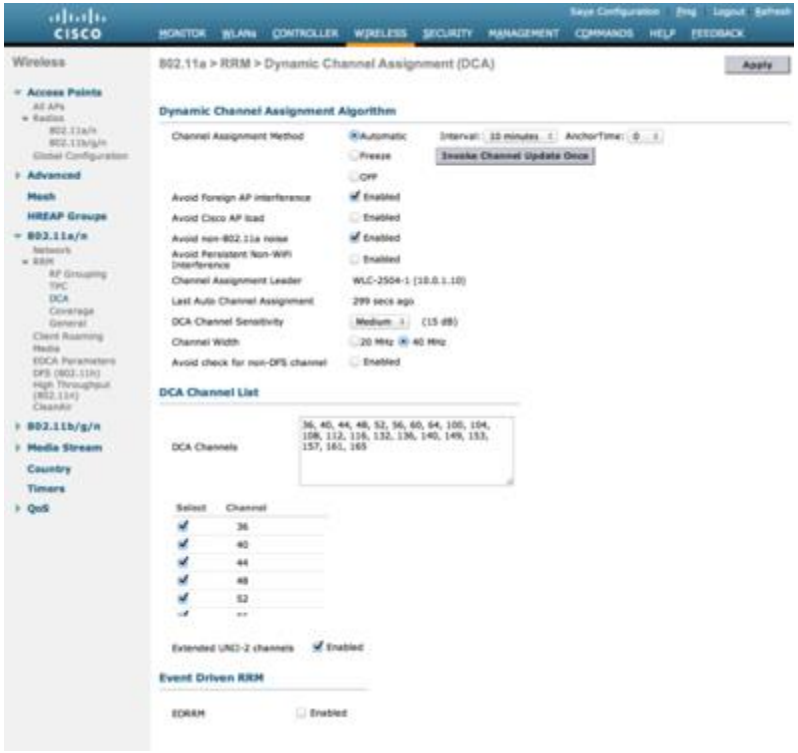
HD Config Tip: RF Profiles

- Provides granular administrative control over:
  - TPC
  - Mandatory, Supported, and Disabled PHY Rates
- RF Profiles are separate for 2.4 GHz or 5GHz bands
  - Profiles are applied to AP Groups
  - All AP's in the group will assume these RF Profile settings
- More capabilities in 7.4, 7.6, etc



HD Config Tip: DCA per RF Profiles in HD

- Allows better granularity when planning 5GHz channel allocation
- Consider eliminating DFS channels for Access Points that serve Business Critical applications
- Allows you to assign indoor-only channels appropriately but without need for static channels

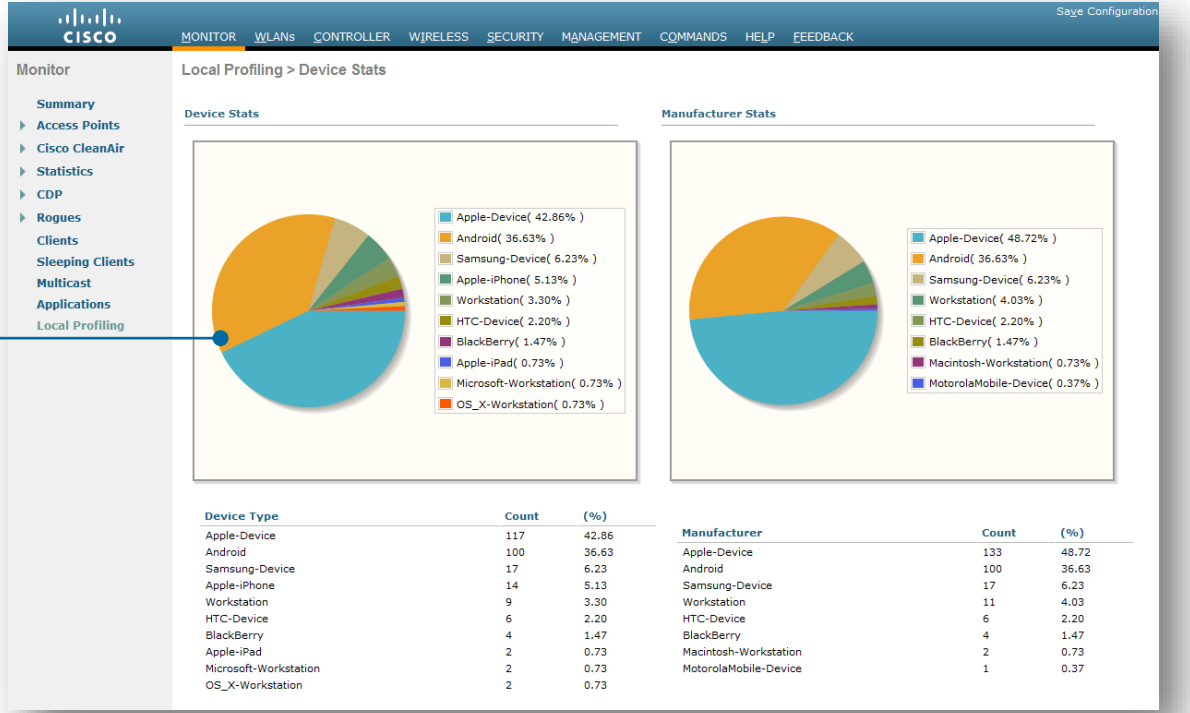


WLC 7.5+: Device Profiling

Who's online?

Which device types do you care about?

Monitor this data to get a better idea.

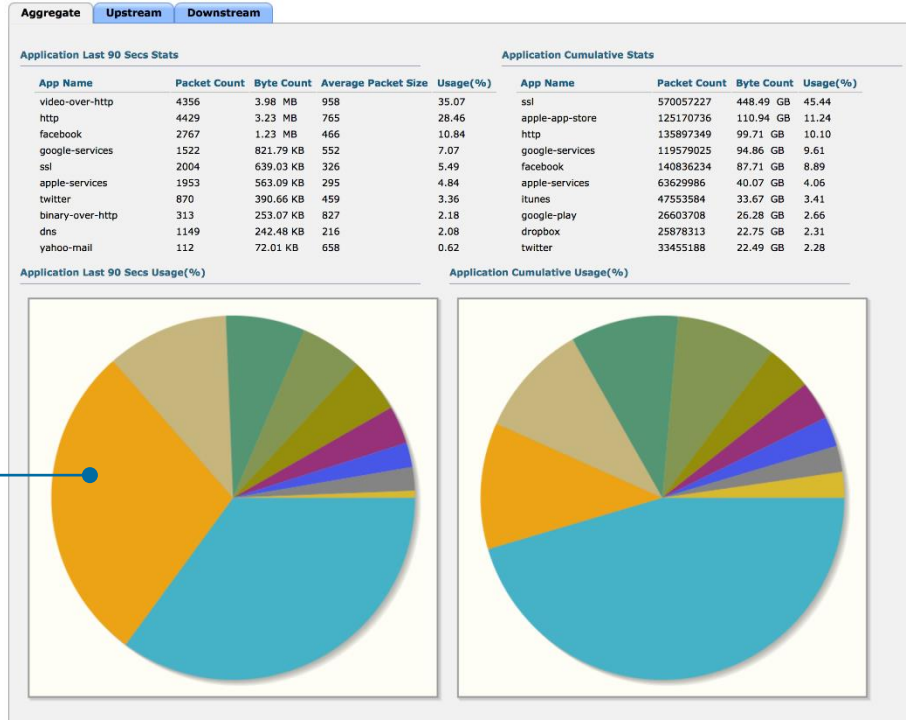


http://www.cisco.com/c/en/us/td/docs/wireless/controller/technotes/7-5/NativeProfiling75.html

WLC 7.4+: Application Visibility Control

How is my network being used?

Netflix? Software updates? Facebook? Use **AVC** to advance your network intelligence



http://www.cisco.com/c/en/us/support/docs/wireless/5500-series-wireless-controllers/115756-avc-guide-00.html

Receive Sensitivity Threshold (RX-SOP)

- RX-SOP can be **beneficial if optimised cautiously** but also **very dangerous if not optimised properly**
  - Fine line between 1) significant performance improvements and 2) under-serving clients at the cell edge
- Doesn't impact the actual RF energy on the channel, but does impact our sensitivity to it
- Reduces RX sensitivity of the AP to a pre-determined power level
  - I.e., ignore everything coming into the radio at lower than -80
- Must **be careful** not to "deafen" the AP to the point that it can't hear TX from a valid client's radio
- Antenna placement is key

Tuning RX-SOP Thresholds

- Pre-configured thresholds as of WLC v8.0 (GUI) – low, medium, high
- Custom thresholds (CLI Only) – per RF Profile
  - *config 802.11b rx-sop threshold*
  - *config rf-profile rx-sop threshold <value> <rf-profile>*
  - *show 802.11b extended* (to verify)
  - **NOTE – on 8.0+ watch for involuntary reset of custom thresholds when performing other config tasks on RF profile; bug under investigation*
- For either scenario: understand how the network sees the client at the **furthest reach of your intended cell**
  - Leave at least 10dB cushion (i.e. body in front of client etc)
  - Example: if you hear your furthest client at -71, try -81
  - Use methods described on slides titled **"How AP's Hear Clients"**
- Start conservative, go only more aggressive if your data supports it

Refresher: How AP's Hear Clients

From WLC: "show client detail"

```
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      Number of EAP Request Msg Timeouts.......... 0
      Number of EAP Key Msg Timeouts.............. 0
      Number of Data Retries...................... 59
      Number of RTS Retries....................... 0
      Number of Duplicate Received Packets........ 0
      Number of Decrypt Failed Packets............ 0
      Number of Mic Failured Packets.............. 0
      Number of Mic Missing Packets............... 0
      Number of RA Packets Dropped................ 0
      Number of Policy Errors..................... 0
      Radio Signal Strength Indicator............. -70 dBm
      Signal to Noise Ratio....................... 23 dB
Nearby AP Statistics:
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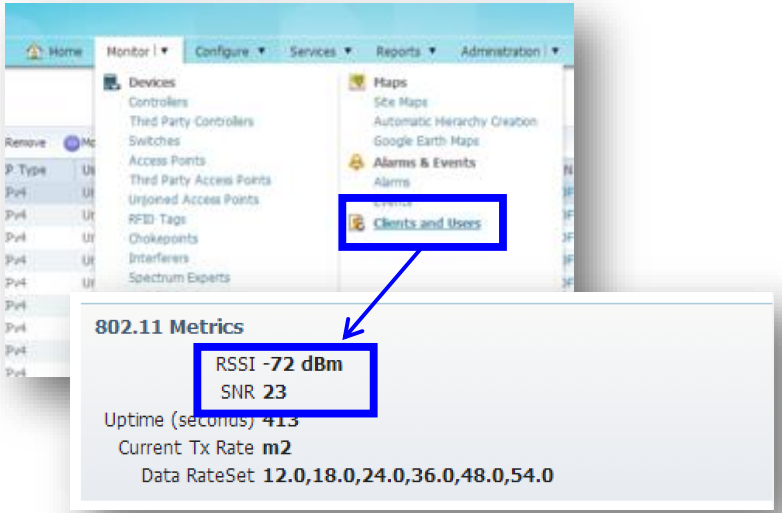

From Autonomous AP: "**show dot11 association all-client**"

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Refresher: How AP's Hear Clients

Or better yet, on AP CLI:

Telnet/SSH to AP and use "Show Controller <D0 | D1>" for immediate client RSSI readings of ALL clients associated to the specified radio

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                  RxPkts KBytes  Dup Dec Mic Txc   TxPkts  KBytes  Retry RSSI SNR
1ce6.2bb5.e294       158     23    0   0   0   0      122      30     43   63  34
<snip>
```


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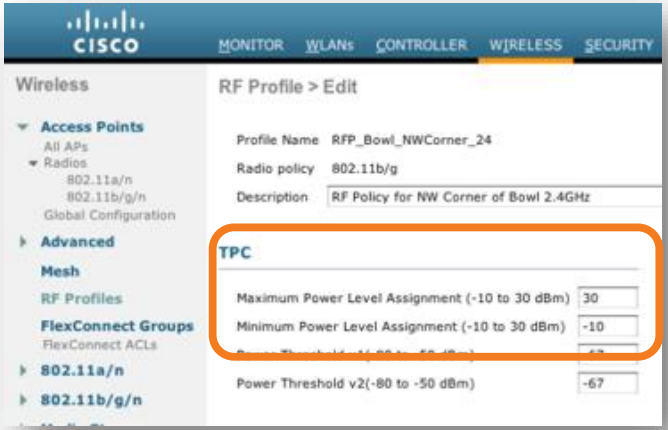
TPC Min/Max for High Density Environments

- Min/Max Power Levels – not everything is as it seems
- Tx power tables differ by:
  - AP model
  - Configured antenna gain (i.e., even if you set antenna type via Prime Infrastructure)
  - Channel (i.e. UNII1/2,2e/3)
- Show Controller (at AP CLI) is your friend
  - Best way to see **exactly** what your power/channel capabilities and configurations are **in dBm**
- **Use "show controller" at AP to see exactly what TX power is in use**

TPC Min/Max in Profiles – to the rescue in HD

- **TPC Min/Max** (global OR per RF Profile) allow you to set actual limits on dBm levels to avoid ambiguity of the relative "Power Levels"
- **TPC Min –** lower power limit specified for a given radio. RRM will never adjust power *below* this level.
  - Prevents installations from cooling down when venues are empty – can be 10 dB difference in perceived signal at the floor
- **TPC Max –** upper power limit specified for a given radio. RRM will never adjust power *above* this level.
  - Set to prevent UNii3 and UNii2 cells from being overly large or small.
  - Pick max power level supported in UNii1 +1 dB and apply to all.
- Produces even cells – matching design goals



Enemies of HD Wi-Fi

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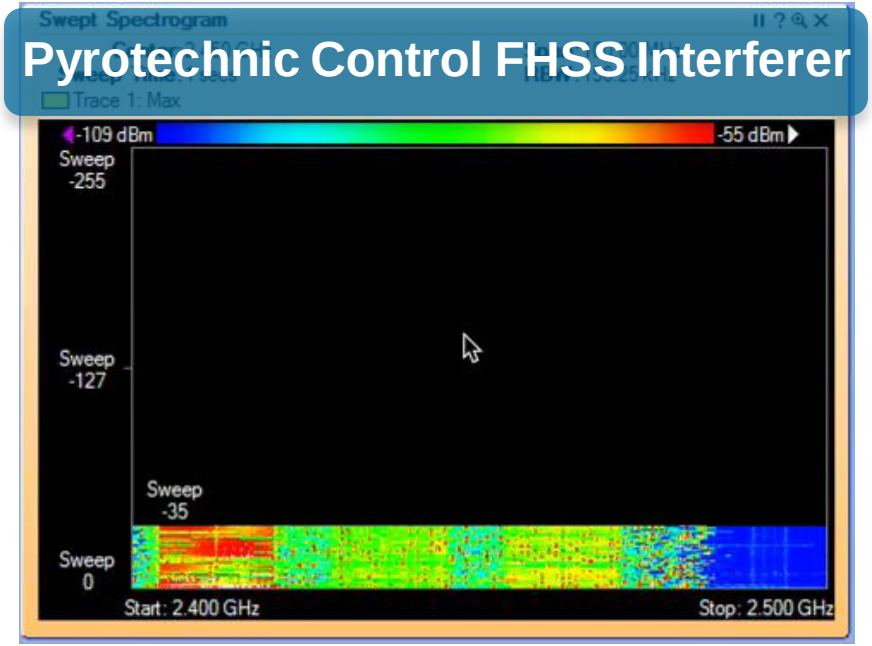
The Classics: Rogue APs

- DSL modems – least loaded channel on 2.4ghz (especially press/media)
- MiFi's, Eye-Fi's, and **hotspot-enabled smartphones**
- Low PHY rates, max power
- Often on overlapping channels due to least-congested channel selection
- Causes exponential load on the air due to probe requests/responses and beacons

Looks like it belongs… but it doesn't

The Classics: Non-WiFi Interferers

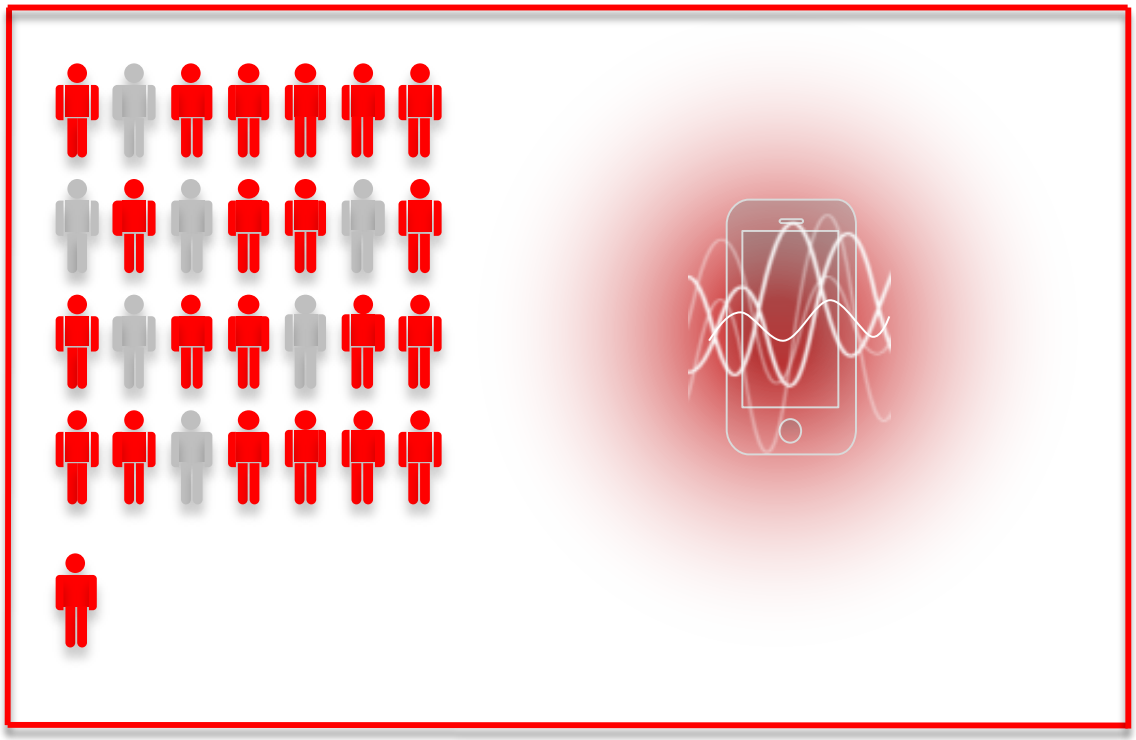


Pyrotechnic Control FHSS Interferer

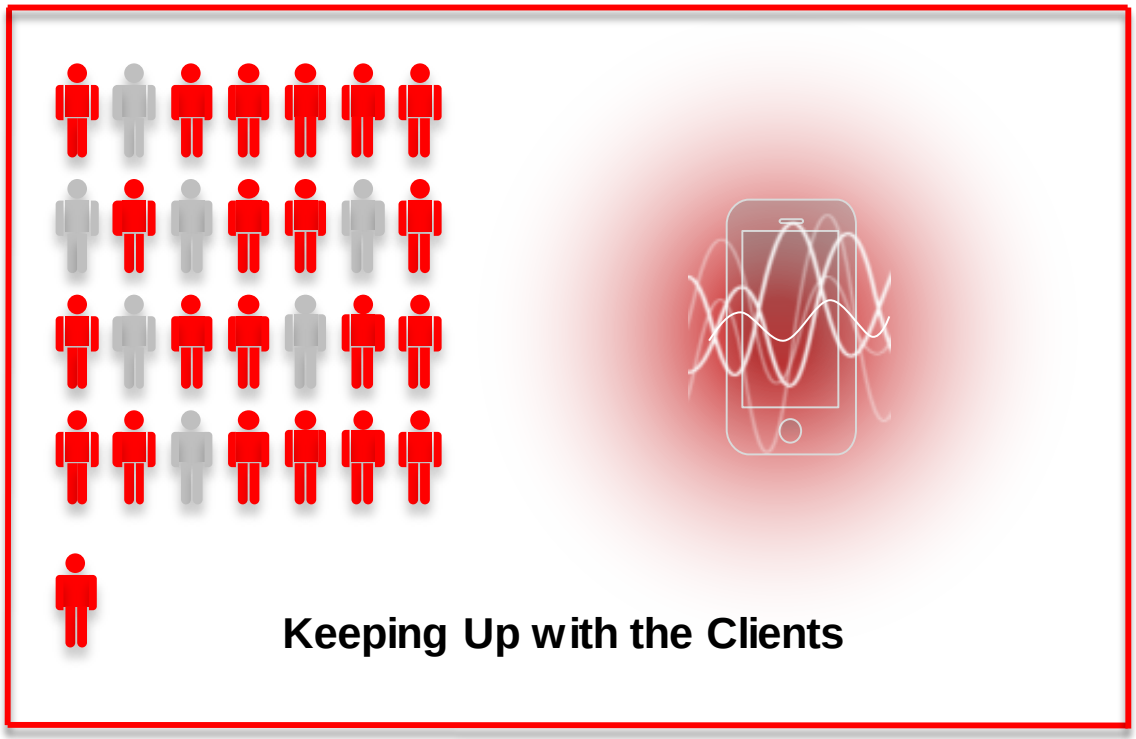
- Video cameras, wireless audio (Coachcomm, Zaxcom), lighting, pyro, and cryo systems, etc.
- Ever look at a Fluke meter and see zero AP's where you'd expect to see dozens? Non-WiFi Interferers often drown out 802.11 altogether.
- Mitigation: remove them altogether or change frequency if possible

But What is Our Biggest Challenge?

But What is Our Biggest Challenge?



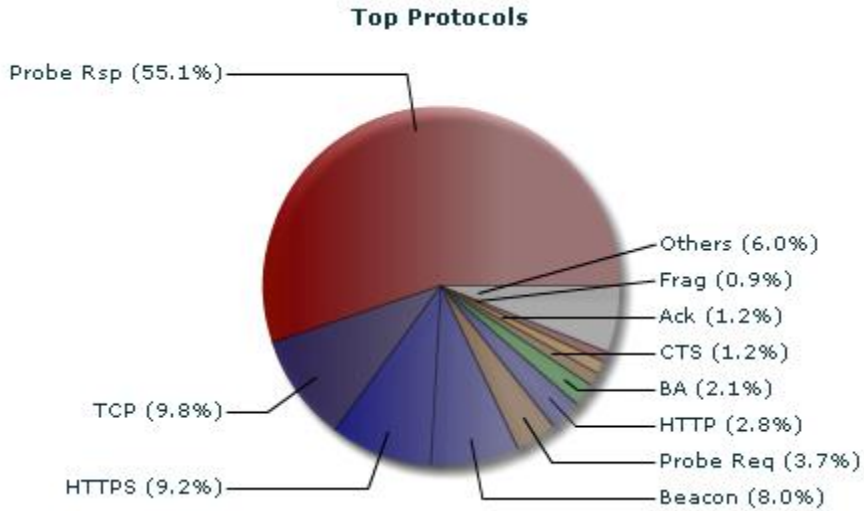
But What is Our Biggest Challenge?



- Probe requests (on-channel contention)
- Probe requests (off-channel noise and ACI)
- 1SS, no diversity
- Media discovery protocols
- Suboptimal roaming in HD

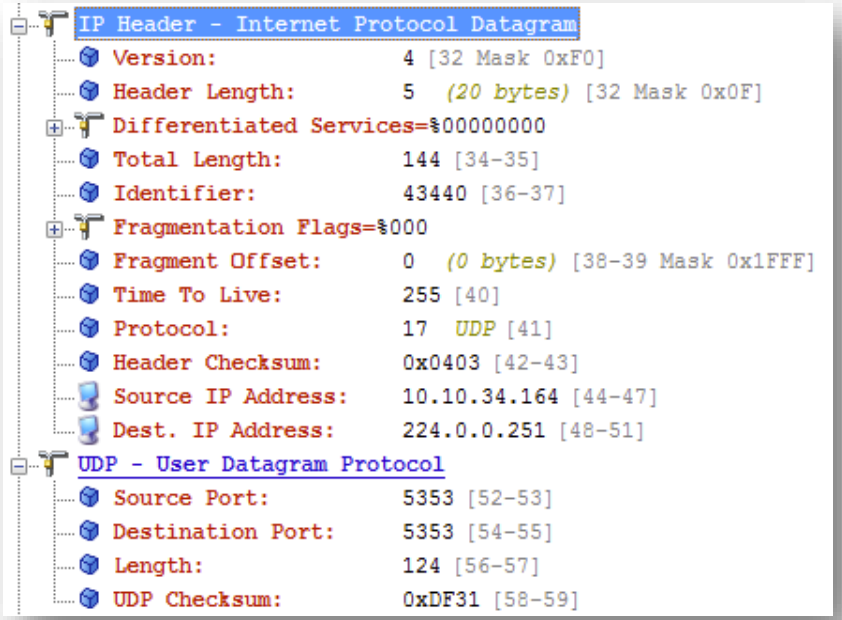
Probe Requests and Responses

- Often #1 frame types observed in HD packet captures
- Especially in smaller enclosed venues
- Why?
  - Venue is packed with omni-antenna equipped smartphones probing at 1mbps (55k-60k devices in a 85k seat stadium)
  - Result: we hear probe requests from client devices far outside our own cell



Client Chatter

- Clients often talk much more than necessary in HD environments
- Beyond the usual probes, etc
- Often related to new types of media transmission/discovery
- IPv4: mDNS (Bonjour: UDP/5353)
- IPv4: SSDP (UDP/1900)
- IPv6: mDNS, Link-Local Multicast



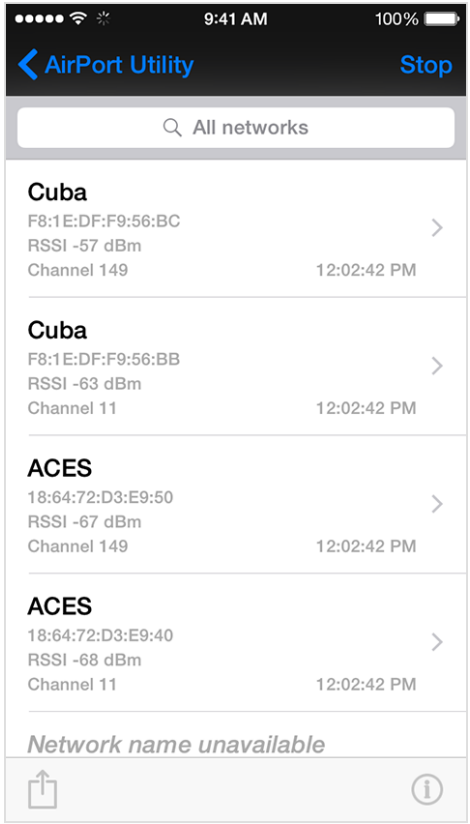
mDNS Packet Example

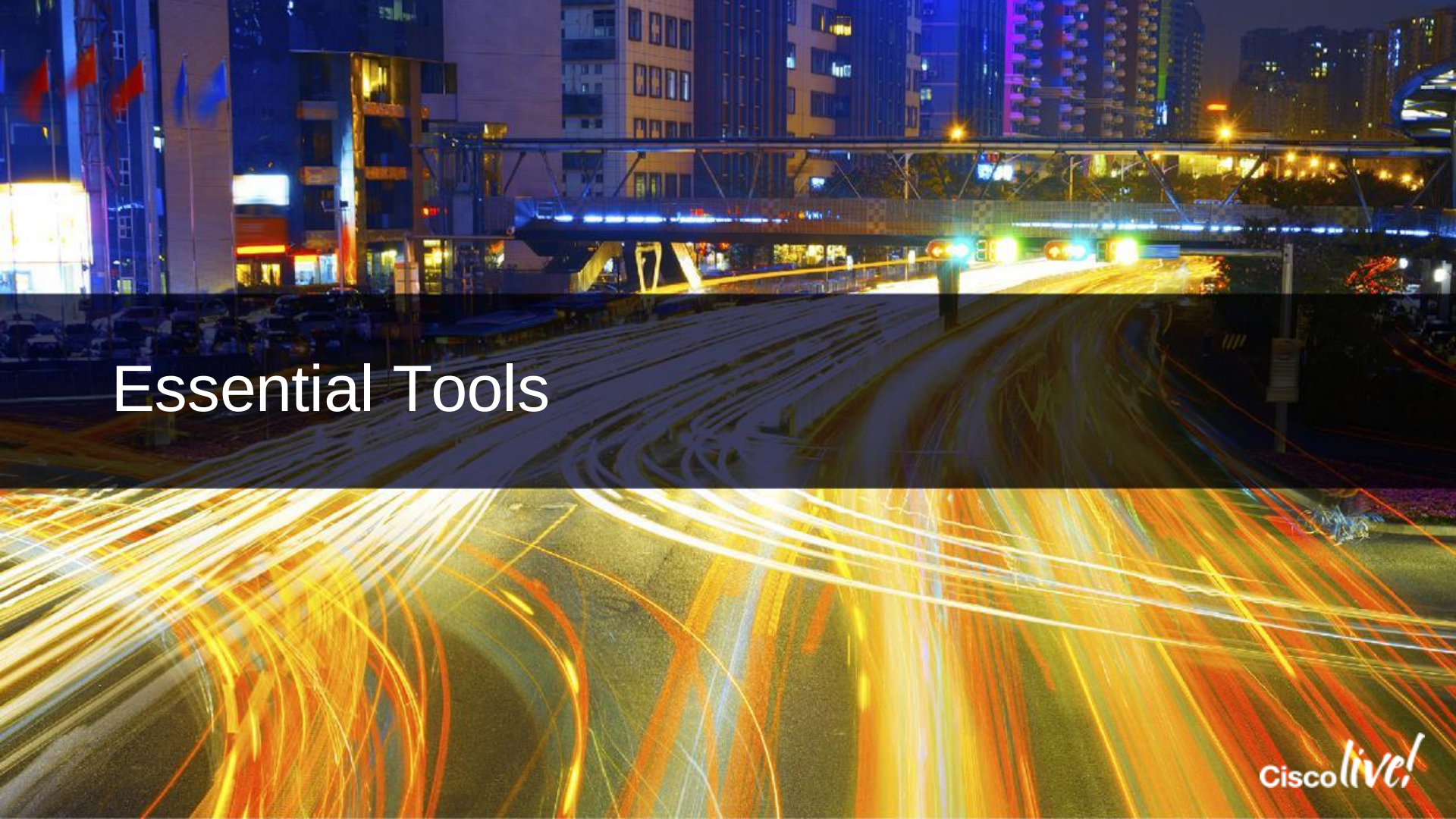
Smartphone Roaming

- Battery life is king for most smartphone manufacturers
- Probing behaviours generally follow suit
- Many phones won't go looking for a "better" AP unless things are REALLY bad (low RSSI/SNR)

Apple iOS8 Roaming Details

- Apple has published official details on iOS 8 roaming behaviour
  - http://support.apple.com/en-us/HT6463
- Includes tips on how to take measurements directly from iOS 8 devices!
  - *Tip: Download Airport Utility from the iOS App Store*

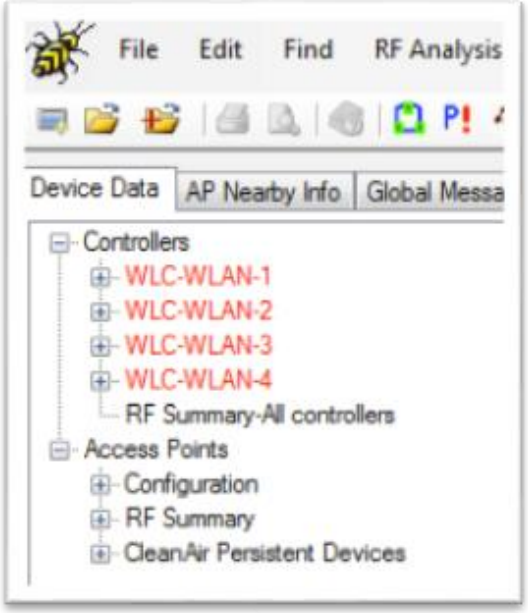



Essential Tools

Data-Gathering Tools

WLC Config Analyser (WLCCA)

- The WLC Config Analyser (WLCCA) is an extremely valuable tool when tuning large venues
- WLCCA helps us determine:
  - **Configuration consistency** across multiple WLC's
  - **RF Problem Finder** – determine likely "problem" RF areas
  - **AP Neighbours** – how do AP's hear each other? Too well, not well enough?
  - Additional views of **CleanAir data**
  - RRM overview with the RF Summary



Download at https://supportforums.cisco.com/docs/DOC-1373

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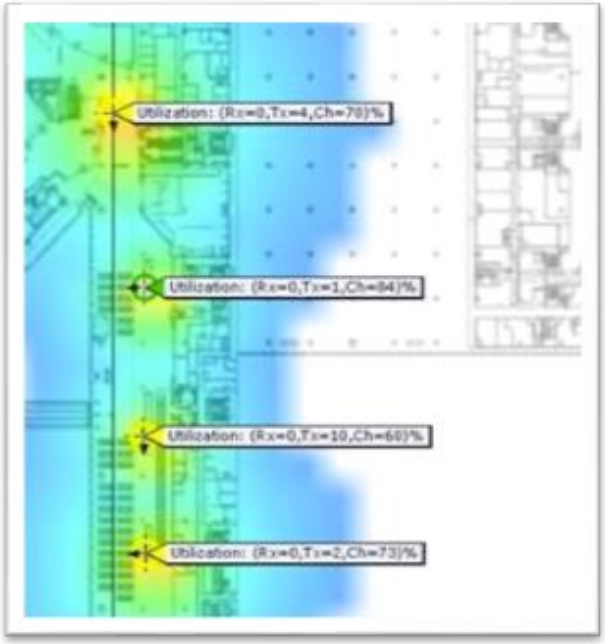
Data-Gathering Tools

Cisco Prime Infrastructure and MSE

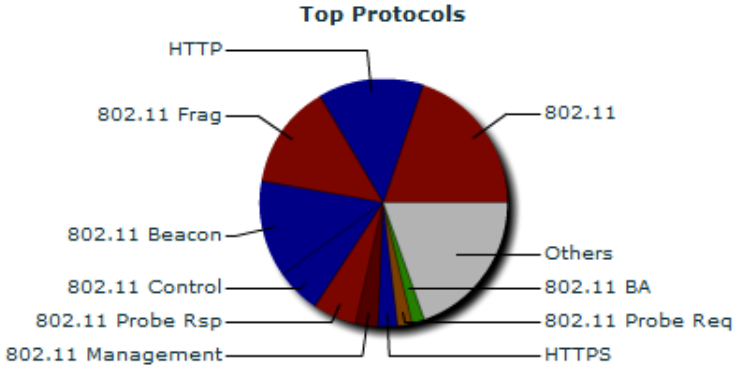


- Up-to-date CPI placement maps are helpful in tuning
- Use these maps in conjunction with WLCCA
- Allows for easy area overview comparisons of AP channels, CU, and power levels
- Easy reference point for number of Associated Clients per radio

Data-Gathering Tools

OmniPeek and Wireshark

- OmniPeek/Wireshark
  - For packet captures of the WLAN, including beacons and other management traffic
  - Helpful for troubleshooting of problems at the source
- OP-specific features we like:
  - Shows breakdown by data rates – very helpful for determining cause of high CU
  - Can do multi-channel aggregation – all three 2.4GHz channels at once (3 NICs) – "Triple Blendy"



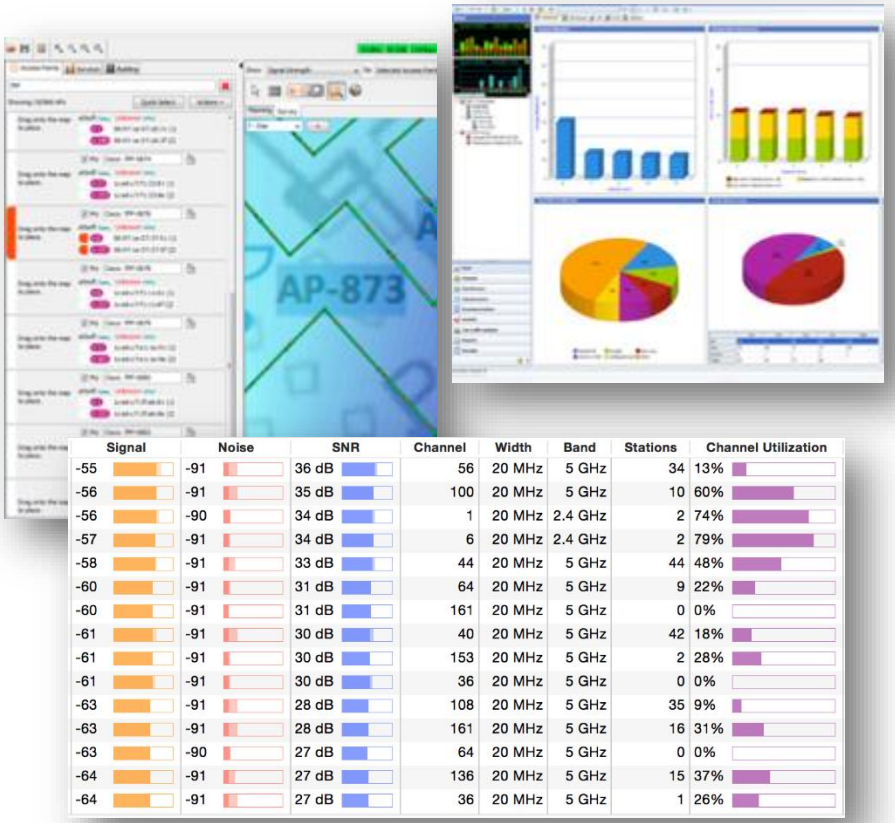
Packets

vg. Signal	Cur. Noise	Avg. Noise	1 Mbits/s Pack...	2 Mbits/s Pack...
24	0	19	7,600	227
19	2	12	0	1
32	73	13	0	0
21	2	20	4,540	243
17	0	10	0	0
72	0	17	0	0
21	0	15	13,000	196
11	2	3	0	0
33	0	5	2	0

Data-Gathering Tools

Site Survey Tools

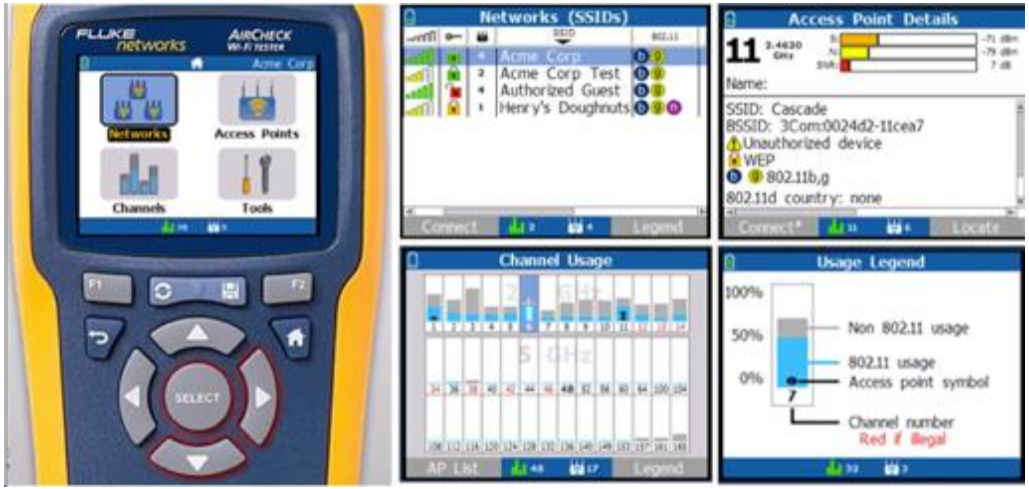
- Ekahau Site Survey Pro
  - Design & Verify
  - Determine **differences in coverage** that occur as a result of tuning changes
- Airmagnet WiFi Analyser Pro
  - Provides **in-depth 802.11- based protocol analysis**
  - Realtime tool, useful during events
- WiFi Explorer App
  - https://itunes.apple.com/us/app/wifi-explorer/id494803304?mt=12



Data-Gathering Tools

Fluke AirCheck

- For quick coverage and cell size checks, use a mobile device (i.e. Fluke AirCheck)
  - This **does not replace a site survey** but can allow for more immediate discovery of obvious concerns with the installation – disconnected antennas, for example.



Data-Gathering Tools

Metageek Chanalyzer Pro with Cisco CleanAir

- Layer 1
- Provides a view of real energy on a channel
- Identify interferers of all types
- Critical part of the “big picture”

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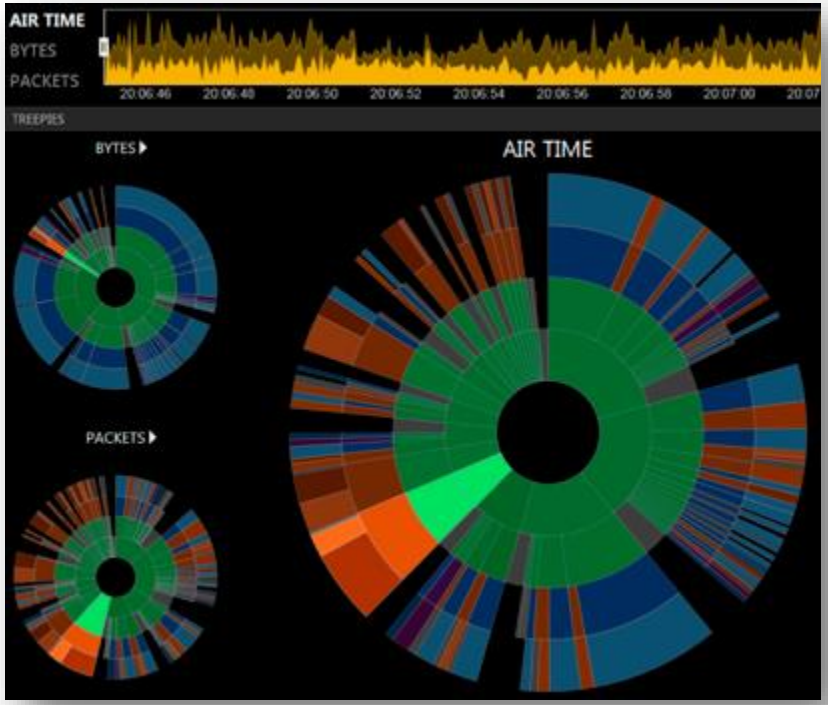
Data-Gathering Tools

MetaGeek Eye P.A., InSSIDer



Purpose-built tools can help build narrative around the data you collect

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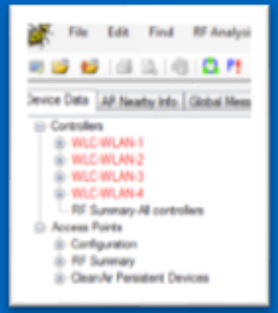
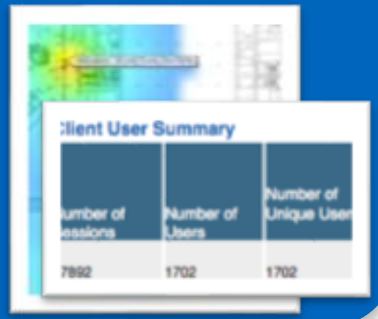
Data-Gathering Tools

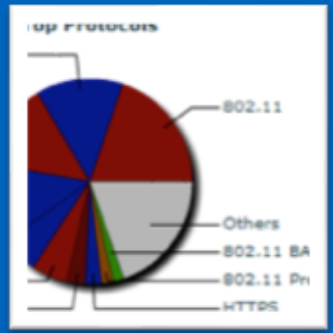
WLCCA



Prime & MSE

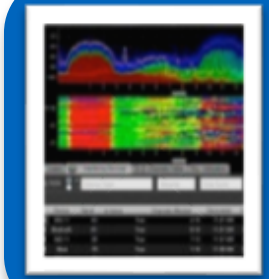


OmniPeek and/or Wireshark

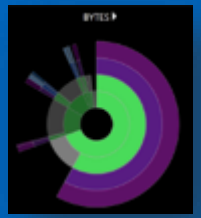


Survey & Analysis

Fluke AirCheck



Metageek Chanalyzer & CleanAir



MetaGeek EyePA

+ YOUR BRAIN

= SUCCESS

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Key Takeaways

- Design the RF environment with **appropriate antennas and sensible physical placements**
- Employ **HD-focused WLC feature configurations** such as RF Profiles for more flexible and robust designs
- **Understand the key outside factors** that may impact a live HD WLAN, including enemies of performance
- Get comfortable with Wi-Fi analysis and optimisation tools to **make informed, data-driven decisions**


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