고밀도, 하이모빌리티 WiFi의 설계방안과 사례연구

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TAMING THE BEAST: Dispatches from the front lines of HD WIFI
Agenda

- Cisco High Density WLAN
- 802.11r Fast Transition
- WLAN RF Design Fundamental
- Physical AP Placement Tips
- Configuration Best Practices
- Enemies of HD Wi-Fi
- Case Study: Big Game
Why High Density Wi-Fi?

- Wireless has become the preferred access technology -- and in many cases the only practical one.
- The need for high density started with stadiums and auditoriums -- but has reached every network.
- The explosion of smart devices and increasing connection counts per seat are everywhere.
- Application demands are increasing.
- Even with advances - wireless is still a shared half-duplex medium and requires efficient use to succeed.

2 to 3 devices per user
What are Some Typical Challenges?

- Interference from other WiFi networks in the venue
- Interference from non-WiFi systems operating in the same band
- Co-channel interference: Many APs in the venue, but effectively no more capacity

- Clients operating at low data rates (ex. 802.11b) pull down the performance of the network
- Clients mistakenly choose a 2.4 GHz radio (louder signal) instead of 5 GHz (less load)

- Sticky Clients: Clients mistakenly stay on the same AP, even when person has moved from one end of the venue to another

- Limitations on mounting assets. Hard to put APs where you want them

- Probe storms: 2.4 GHz clients probe on all 11 overlapping channels

- Ad Hoc Viruses: Clients forming bogus ad hoc networks such as “Free Public Wi-Fi”
Solid RF Design

- Constrain RF
  - Directional Antennas, Down-Tilt

- Good RF Layout/Design
  - Channels, Tx Power

- Eliminate Interference
  - Rogues and Non-Wi-Fi Interference

Basic Tuning

- Minimize SSIDs

- Disable Low Data Rates
  - Helps with Sticky Clients, Improves capacity

- Band Select
  - Push dual-band clients to 5 GHz

- RF Profiles

Advanced

- Rx-SOP Tuning
  - Greatly improves capacity by reducing co-channel impact
  - Also reduces sticky clients

- Optimized Multicast Video
Cisco High Density Experiences

- Spectrum Intelligence
- Optimizes Wireless Client Performance
- Multi-Client Performance
- Cell Size Efficiency
Client Link 3.0

- ClientLink uses multiple transmit antennas to focus transmissions in the direction of the client.
- In the mixed-client networks, optimizes overall network capacity by helping ensure that 802.11a/g/n and 802.11ac clients operate at the best possible rates, especially when they are near cell boundaries.
- Client agnostic since Multiple Antennas Design Work for All Clients.

256QAM - Is it achievable?

- 256QAM is really difficult to achieve – especially m9
- ClientLink 3.0 helps the 3700 achieve 256QAM
  - With the 3700, I’ve seen m9 at 23 meter with a 1ss client and 10 meter with a 3ss client
- AP3700 has a significant 256QAM advantage over competition
- Let’s test this -
  - Use a MacBook Pro (3ss) and record the data rate in 40+ locations in a cubicle environment while running traffic to the client.

<table>
<thead>
<tr>
<th>Modulation</th>
<th>MCS</th>
<th>PHY Rate (3 Spatial Stream)</th>
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<tr>
<td>64QAM</td>
<td>m7</td>
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<td>256QAM</td>
<td>m8</td>
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<tr>
<td>256QAM</td>
<td>m9</td>
<td>1300 Mbps</td>
</tr>
</tbody>
</table>
256QAM Heat Map: Cisco 3702i vs. Competition

- ClientLink 3.0 helps the 3700 achieve 256 QAM with m9 rate
- AP 3700 has a significant 256 QAM advantage over the competition 11ac AP
- The Test:
  Use a MacBook Pro (3ss) and record the data rate in 40+ locations in a cubicle environment while running traffic to the client.

ClientLink 3.0 YouTube video:
- http://www.youtube.com/watch?v=0q_shbSpOIA
Clean Air

- Provides continual, system-wide discovery without performance impact
- Accurately identifies source, location, and scope of interference
- Takes automatic action to avoid current and future interference, with full history reporting
- Cisco AP 3700 provides complete visibility over 80 MHz 11ac spectrum
Spectrum Intelligence

- Dedicated hardware chipset for monitoring spectrum
- Identifies interferer signatures by penetrating beyond Layer 1 (Records pseudo MAC address to avoid duplication)
- Quick and Accurate Interference Detection to Reduce False Positives
- Aggregation of all alarms/alerts on Prime level to monitor health of entire network
With 802.11ac, the total bandwidth available to clients is increased to 1.3Gbps, but this is still a shared medium technology.

An efficient packet scheduler designed for the needs of 802.11ac is needed to keep up with client counts of 60+ per radio.

Cisco’s AP3700 provides on-radio caching technology which leverages additional RAM for per-client queuing techniques.
How do we provide optimized roaming experience?

- **Low RSSI Check**: Offers access to clients with the strongest signal.
- **Disable Lower Data Rates**: Reduces cell bleeding and increases efficiency by lowering the duty cycle.
- **RX-SOP (RX-Self Optimization)**: Eliminates sticky clients by forcing clients with dropping signal strength to move quickly between adjacent cells.
- **Moves Clients with dropping signal strength to available cellular network/Wi-Fi network**.
Disable Mandatory Lower Data Rates

Without Disabling Lower Data Rates

- 6Mbps
- 9Mbps
- 12Mbps
- 18Mbps
- 24Mbps

I can hear beacons from the AP, so I can associate with it & reduce the overall performance.

Disabling Lower Data Rates

- 24Mbps

Cell Size reduction increase efficiency and lowers duty cycle.

I cannot hear beacons from the AP, so now I am forced to search for a AP with a stronger signal.
Low RSSI Check

Without Low RSSI Check

My “Association Request” will Receive “Association Response” SUCCESS

With Low RSSI Check Set to -80dBm (Default)

“Association Response” SUCCESS is restricted to clients within CELL range better than -80dBm

My “Association Request” will Receive “Association Response” REJECT – Poor Channel
Rx-SOP

- Rx-SOP is radio’s receiver sensitivity – How well AP can hear clients
- Decreasing Rx-SOP to lower level (-95 dBm), increases cell size
- Raising Rx-SOP to higher level (-75 dBm), reduces the cell size, which provides much better spatial re-use
- Smaller cell size and efficient re-use of spectrum is key in the High Density

Higher Rx-Sop Threshold = Smaller Cell Size = Better spectrum re-use
Introducing Cisco “Optimized Roaming”

Today’s Solution
- Weak Wi-Fi Signal
- Overall Drop In Cell Performance
- Client Stickiness Causes Poor User Experience

Cisco “Optimized Roaming”
- Consistent User Experience
- Efficient Cell Usage

-80dB
-80dB

3G or 4G
Seamless roaming across Wi-Fi and/or Cellular network

~10 x Faster transition to available stronger network

Always ON device with very minute downtime

“Optimized Roam” is Agnostic of Mobile Device & OS Type
802.11r Fast Transition
What is 11r?

- An IEEE standard which defines a new concept of roaming
- The WLAN client uses scanning or neighbor reports to discover APs available for transition.
- Handshake with the new AP is done even before the client roams
- More secure due to 3 levels of key hierarchy
- Standard defines 2 methods of roaming – Over-the-air and Over-the-DS
- The Association-Response Frame is expanded therefore older client drivers may not understand the 11r response frame. Therefore in some customer sites to have 11r roaming may require an additional SSID.
Fast Transition 802.11r Roaming Comparison

The Action Frames are new to 802.11r and the Association Frames are modified.

Pairwise Master Key ID (PMKID) Roam is 10 Packets Long.

802.11r Action Packet Exchange Occurs Before the Roam. Therefore the Roam is 2 Packets Long.
802.11r Over the Air roaming

802.11r Over the DS roaming

Does This guarantee that an 11r Client is Going to Roam in 80ms?
### 802.11r Mixed-mode support

<table>
<thead>
<tr>
<th>Make/NIC model</th>
<th>Driver Version</th>
<th>Support</th>
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<tbody>
<tr>
<td>iPad</td>
<td>iOS 6</td>
<td>✔️</td>
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<tr>
<td>iPad Air</td>
<td>iOS 7.0</td>
<td>✔️</td>
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<td>iPhone</td>
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<td>Samsung Galaxy S4</td>
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<td>Windows 8</td>
<td>Intel 14.2.1.2</td>
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<td>Windows 7</td>
<td>Intel 14.1.1.3 (05/01/2011)</td>
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<td></td>
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<td>Cisco 9971</td>
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<td>Netgear</td>
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<td>ADU</td>
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</tr>
<tr>
<td>Juniper Odyssey</td>
<td></td>
<td>✗</td>
</tr>
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</table>

**BYOD Device (Android, iPhone) with latest S/W can support 11r Mixed-Mode**

**Most of Win XP machine does not support 11r Mixed-mode**

**802.11r support is also varied by 802.1x supplicant**
802.11r Summary

- Industry Standard **Fastest** Roaming protocol, under 802.1x/EAP environment
- When client roams between APs
  - Skip AAA server re-authentication
  - Skip EAP Key exchange
  - Can Further reduce delay by Pre-authentication over Wired connection
- Reduce Roaming Delay from >1 sec. to <100 msec
- Supported by Modern OS & Device – Windows 8, Samsung Galaxy S4 or newer, Apple iOS 6+ with iPhone 4s or newer
- May require separate SSID for Windows XP or for none-11r Mixed mode supported device
- Fundamental requirement for WMM-VE
Cell Size – Higher Power ≠ Larger Coverage

- Higher power does not always mean higher SNR...

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<table>
<thead>
<tr>
<th>Speed</th>
<th>Required SNR</th>
<th>AP Sensitivity</th>
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<tr>
<td>1</td>
<td>0</td>
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<tr>
<td>54</td>
<td>19</td>
<td>-77</td>
</tr>
</tbody>
</table>
```

This for data, for voice, add 25 dB to SNR
Cell Size – Depends on Protocol and Rates

- Data rates decrease with the increase of distance from the radio source and client power will increase
- Individual throughput (performance) varies with the number of users
- Performance degrades with radio interference from other sources
- Critical deployment design goal is to achieve high data rate at cell boundary
  - High signal AND low noise
Moving Away From the AP Degrades Performances

Spectrum is a Shared Finite Resource
2.4-GHz Network Design

- Conclusion: try to design small cells, with clever overlap...
The cell useful size is different from the AP footprint… And clients do not make it easier…
Designing for Efficient RF Relationships

- How clients hear AP’s
- How AP’s hear clients
- How AP’s hear each other
Channel Coverage Sizing Recommendations

- Coverage must be designed for your Client Devices
- Not all clients are created equal !!!
  1. Live call test with the actual client to determine its coverage
- Removing legacy DSSS data rates and slower OFDM data rates from the WL C configuration equals:
  1. Less Co-Channel Interference
  2. Better throughput in the cell
  3. More usage of ClientLink and MRC
  4. Smaller coverage cells
- Smaller Coverage Cell Sizes equals:
  1. More cells in a given coverage area
  2. More cells equals more call with better voice and video quality
Bad AP Placement: AP around corner

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

- 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
Radiation Pattern and Environment

- Radiation patterns provided by vendors are lab values
  - Do not take into account environmental impact
- Example: dipole antenna in lab environment (left), and positioned below a metallic plate (right)
- Position the antenna carefully to obtain a radiation pattern similar to the example provided by the vendor
Avoid Reflections

- Highly reflective environments
- Multipath distortion/fade is a consideration
- Legacy SISO technologies (802.11a/b/g) are most prone
- 802.11n improvements with MIMO
- Devices are susceptible
- Things that reflect RF
  - Irregular metal surfaces
  - Large glass enclosures/walls
  - Lots of polished stone
RF Design – More Bad Examples

Mount horizontally… and not behind a metallic pipe

A little ICE to keep the packets cool

Mmm…
Every SSID Counts!

- Each SSID requires a separate Beacon
- Each SSID will advertise at the minimum mandatory data rate
- Disabled – not available to a client
- Supported – available to an associated client
- Mandatory – Client must support in order to associate
- Lowest mandatory rate is beacon rate
- Highest mandatory rate is default Mcast rate

BAD EXAMPLE! (good example in 2 slides)
Channel Utilization—What Made the Difference?

60% Before

5% After
Channel Design – Use the tools

- Disable low, unused rates (802.11b)
- Let RRM control channel and power levels
- If you can, use 3600/3700 APs, with ClientLink and BandSelect:
  - BandSelect to push 5 GHz-able to the 5 GHz band
  - ClientLink to provide better throughput for 802.11a/g/n clients
Cisco BandSelect Technology

- Automatic Band Steering and Selection For 5GHz Capable Devices

**BEFORE**
All clients crowd the 2.4GHz spectrum lowering performance

**AFTER**
5GHz capable clients are automatically moved to cleaner 5GHz spectrum
Configuring Band Select

- Enabled on a per WLAN basis (disabled by default)

WLANs > Edit 'Open31'

### General
- P2P Blocking Action: Disabled
- Client Exclusion: Enabled
- Maximum Allowed Clients: 0
- Static IP Tunneling: Disabled
- Maximum Allowed Clients Per AP Radio: 200
- Clear HotSpot Configuration: Enabled
- Client user idle timeout (15-100000): 300
- Client user idle threshold (0-1000000): 0

### QoS
- Scan Defer Priority: 0, 1, 2, 3, 4, 5, 6, 7
- Scan Defer Time(msecs): 100

### Policy-Mapping

### Advanced

#### Management Frame Protection (MFP)
- MFP Client Protection: Optional

#### DTIM Period (in beacon intervals)
- 802.11a/n (1 - 255): 1
- 802.11b/g/n (1 - 255): 1

#### NAC
- NAC State: None

#### Load Balancing and Band Select
- Client Load Balancing: Off
- Client Band Select: Off

#### Passive Client
- Passive Client: Off
BandSelect – Test Before Full Deployment

- Caveat – Possible Increased Roaming Delay

- No Delay
- Some Delay (1.5s)
- Possible Delay
Physical AP Placement Tips
Antenna Placement
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
Maximize the Spectrum
Avoiding Excessive Management Traffic

- Always aim for 1 SSID
  - Especially in seating areas

- 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
Maximize the Spectrum
Integrate Legacy WLANs

- Efficient HD WLANs are deployed holistically – one infrastructure

Benefits?
- Provide consistent configuration management
- Improve airtime efficiency throughout the venue
- Legacy management traffic that once chewed up 30-40% of airtime typically drops to < 1% of airtime
- Allows greater airtime availability
Maximize the Spectrum
Leveraging PHY Rate Tuning

- Size your cells to allow elimination of low rates (i.e., <12mbps)
- Eliminate 11b rates
- Recommend NOT disabling any MCS rates due to interoperability issues with some clients
  - Disabling MCS rates, especially 0-7, can cause significant client issues
1mb Data Rates & Client Performance

iPerf Test #1: Client (first-generation iPad) connected at 1mb data rate

iPerf Test #2: Client (first-generation iPad) connected at 24mb data rate

The 24mb PHY connection resulted in 17x as much data being moved across the Wi-Fi network in the same amount of time.
Client-Induced Interference: What is it?

Common Assumptions
• 75% of fans will have a Smartphone
• 30% of Smartphone users will utilize Wi-Fi
• But what is everyone else doing?
Client-Induced Interference
What does it look like and how can we mitigate?

- Client-induced interference: damaging on 2.4GHz
- 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
Maximizing 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
- A device on the network is far less damaging than a device off the network!
Maximizing the Spectrum
Client Induced Interference: 2.4GHz Probing Behavior

For example:

iPhone 5s – iOS v7.0.3
Unassociated:
• Sends 4 probe requests per “learned” network, per channel every 3-6 seconds on channels 1 – 11

Associated:
• Very few probe requests for any network on any channel – almost no client induced interference at all!
Develop an RF Policy

Employ an effective RF policy to manage non Wi-Fi interference as it occurs

Understand Your Clients

- Identify your target client device types and their key specs
- Test them for yourself!
- Most smartphone radios will have much poorer sensitivity than your survey kit’s NIC
  - On average in our testing, 10dB worse!
- Understand popular clients in your market
- Recognize device behavior changes in software updates
Know Your Noise Floor

- **RSSI vs. SNR**

- **Clients have varying sensitivity to noise**

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

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**Sample receiver sensitivity table for CB21AG NIC**

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>2.4 GHz Min RSSI</th>
<th>2.4 GHz Min SNR</th>
<th>5 GHz Min RSSI</th>
<th>5 GHz Min RSSI</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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**Sample sensitivity table for MCS rates**

<table>
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<th>Data Rate</th>
<th>2.4 GHz Min RSSI</th>
<th>2.4 GHz Min SNR</th>
<th>5 GHz Min RSSI</th>
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<td>115.6:240</td>
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<td>130:270</td>
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<td>144:300</td>
<td>-64</td>
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<td>-61</td>
<td>32</td>
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</table>

*Data is intended to be an example only.*

*Rx sensitivity capabilities will vary based upon the receiver in use.*
Stadium Wi-Fi Configuration Best Practices
Use RF Profiles for Fine-Tuning

- Stadiums are not “one size fits all” from an RF perspective
- Tuning control must be granular
  - Long vs. short seating sections, etc.
  - Accommodate specific devices – 11b rates only where needed
- Before WLC v7.2: Physical Controller Groups
- v7.2+: RF Profiles
Config Tip: RF Profiles

- Provides granular administrative control over:
  - Min/Max TPC values
  - TPC Thresholds
  - Mandatory, Supported, and Disabled PHY Rates (per band)

- 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
Understanding RRM: Using WLCCA

- Don’t assume that RRM is broken just because it doesn’t look “right”
- Use the WLCCA to identify and understand neighbor relationships
- Often exposes unintended consequences of the physical installation
Optimizing RRM: TPC

- Calculates Tx power on a per-AP, per-radio basis for every member of the RF group
- Calculations run at 10-minute intervals
- TPC updates are iterative
- Use TPC Thresholds & Min/Max for power level tuning
  - TPC Thresholds for general adjustments
  - Finer adjustments can be made with Min/Max if needed
  - RF Profiles provide granular control

When tuning, be sure you know which WLC is your group leader
Optimizing RRM: DCA

- Exercise caution when setting DCA lists for 5GHz
- Watch DFS frequencies
- Consider eliminating DFS channels for Ticketing AP’s
  - But – DCA lists must be set per WLC
- One possible strategy: on pre-production network, enable DFS channels and watch NCS for DFS events
Enemies of HD Wi-Fi
Rogue APs

- Press/media are prime instigators
- For a recent major sports event, many dedicated DSL modems were installed at the last minute, all of which had 2.4GHz WiFi turned on by default
- MiFi's, Eye-Fi’s, and hotspot-enable smartphones are everywhere
- Low PHY rates, max power
- Often on overlapping channels due to least-congested channel selection
- Causes exponential OTA traffic due to probe requests/responses and beacons

Looks like it belongs… but it doesn’t
Adhoc Rogues

- Adhoc rogues – even in 2014, still a significant problem
  - Beacons, probe requests, probe responses all occupy airtime
  - Users perpetuate the issue by attempting to connect
  - Examples: "MEDIA" SSID in press are a at Recent Big Football Game; FPW still very prevalent

- Mitigation: user education and ease-of-use
Non-WiFi Interferers

- 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
Probe Requests & Responses

- Often #1 frame types in HD
- Especially in smaller enclosed venues
  - NBA, NHL, etc.
- Why?
  - Stadium is full of mini AP’s with omni antennas (smartphones) probing at 1mbps
  - Our radios are high quality and ultra sensitive
  - We hear probe requests from client devices far outside our own cell
- Responses can be streamlined to some degree through tuning
Bad Client Behavior

- Pro tip: profile new OS and hardware behavior
- Clients sometimes do things they shouldn’t
- Example: Virtual NAV abuse
  - Does this client device really need to reserve 11,330 microseconds of channel time to Tx a CTS frame? Probably not
Client Chatter

- IPv4: mDNS (Bonjour)
  - In packet captures, look for UDP packets to destination 224.0.0.251 on UDP/5353
  - iOS devices primarily responsible – but some frames also observed from Android devices

- IPv6: mDNS, Link-Local Multicast
  - In packet captures, look for DHCPv6 and ICMPv6 advertisements
  - Android devices primarily responsible – but also some frames from iOS devices

![mDNS Packet Example]
At one sports event in 2012, Multicast DNS (mDNS/Bonjour) lookups from iOS devices made up **22.5% of all packets** captured on channels 1, 6, and 11 during halftime.

UDP Multicast to 224.0.0.251 on UDP/5353
- **SSDP** (automated discovery protocol) discovery frames have grown quickly in prevalence as Digital Living Network Alliance (DLNA) services are implemented on more smartphone OS platforms.
- Appears as multicast traffic to 239.255.255.250 on UDP/1900
Client Chatter: IPv6

- Smartphone OS’s are increasingly chatty with IPv6 discovery/broadcast messages
- DHCPv6
  - Common destination address is ff02::1:2 (all nodes on the local network segment)
- ICMPv6 Nadv
  - Common destination address is ff02::1 (all DHCP servers and relays on local site)
- Check MAC header – if exit from DS, you didn’t hear this directly from the client device and the WLAN is propagating it
Client Chatter: Mitigation

- IPv6
  - Use WLC ACL’s if necessary
  - If no valid need for IPv6, turn it off
    - IPv6 “killswitch” is available in 7.3+
    - WLC CLI: “config ipv6 disable”
  - Consider VLAN ACL’s on switched infrastructure to block propagation of IPv6 advertisements from wired side

- mDNS, SSDP
  - Use WLC ACL’s
  - See the Cisco Wireless LAN Apple Bonjour Deployment Guide for more info
Case Studies: Data to Drive Your Decisions
Case Study: 5GHz Adoption Rates

- Total Unique Clients: 28,801
- Total Potential Clients (MSE Probing Clients detected): 55,000
- 54% of unique clients connected at 5GHz (11n)
- Legacy A/G clients dwindling rapidly

Note: Devices which connected to both 2.4 and 5GHz appear once for each protocol.
# Case Study: Top Over-The-Air Protocols

## Top Protocols

- **Probe Resp**: 802.11 Management Probe Response, 1,903 packets, 407,461 bytes
- **Adc**: 802.11 Control Acknowledgment, 742 packets, 10,388 bytes
- **Beacon**: 802.11 Management Beacon, 651 packets, 130,778 bytes
- **ICMPv6 NdAdv**: Internet Control Message Protocol - Neighbor Advertisement, 605 packets, 71,934 bytes
- **Probe Req**: 802.11 Management Probe Request, 599 packets, 66,241 bytes
- **ARP Request**: ARP Request, 337 packets, 26,274 bytes
- **CTS**: 802.11 Control Clear to Send, 98 packets, 1,372 bytes
- **ARP Response**: ARP Response, 69 packets, 4,415 bytes
- **Null Data**: 802.11 Null Data, 61 packets, 1,708 bytes
- **SNAP**: SNAP, 45 packets, 3,600 bytes
- **HTTPS**: Secure HTTP Protocol, 45 packets, 5,483 bytes
- **BA**: 802.11 Block ACK, 29 packets, 928 bytes
- **QoS Null Data**: 802.11 QoS Null Data, 27 packets, 810 bytes
- **DHCP**: Dynamic Host Configuration Protocol, 26 packets, 9,516 bytes
- **Action**: 802.11 Management Action, 19 packets, 703 bytes
- **Encrypted Data**: 802.11 Encrypted Data, 18 packets, 2,204 bytes
- **PS-Poll**: 802.11 Control Power-Save Poll, 18 packets, 360 bytes
- **DHCPv6**: Dynamic Host Configuration Protocol v6, 12 packets, 2,150 bytes
- **Auth**: 802.11 Management Authentication, 6 packets, 215 bytes
- **ICMPv6**: Internet Control Message Protocol Version 6, 4 packets, 432 bytes
- **IGMP**: Internet Group Management Protocol, 3 packets, 192 bytes
- **Reassoc Resp**: 802.11 Management Reassociation Response, 3 packets, 366 bytes
- **LSAP**: LSAP, 3 packets, 114 bytes
- **CFE**: 802.11 Control Contention-Free End, 2 packets, 40 bytes
- **RTS**: 802.11 Control Request to Send, 1 packet, 20 bytes

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Case Study: Rogue APs

From a recent large sporting event:

- **964** Total detected rogue AP’s at -70dBm or higher, including:
  - 200+ MiFi portable hotspots
  - 10+ GoPro live-streaming cameras
  - 30+ Eye-Fi SD Cards
Case Study: Adhoc Rogues

From a large sporting event in 2013:

- Adhoc Rogues
  - **2,752** total detected adhoc rogues, including:
    - “Free Public WiFi”: 1,563
    - “MEDIA”: 595
- “MEDIA” adhoc wildfire ignited & thrived in the Press area
  - Publicize your networks
Case Study: Creation vs. Consumption

From a recent large sporting event:

<table>
<thead>
<tr>
<th></th>
<th>Aggregate WiFi Traffic (GBytes)</th>
<th>Upstream (Out of the Stadium) (Gbytes)</th>
<th>Downstream (Into Stadium) (Gbytes)</th>
<th>Peak WiFi Throughput IN (Mbps)</th>
<th>Peak WiFi Throughput OUT (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>369.9 GB</td>
<td>144.6</td>
<td>225.3</td>
<td>75</td>
<td>42</td>
</tr>
<tr>
<td>2013</td>
<td>1.125 TB</td>
<td>683.4</td>
<td>441.5</td>
<td>185.16</td>
<td>396.09</td>
</tr>
</tbody>
</table>
Case Study: MWC 2014

- 2.4 GHz/5 GHz (40/60 %) 2.5-5 Band
- 85/15 % IPv4/v6
- 50 % Dual stack devices

- IPv4
- IPv6
- S.Stack
- D.Stack

- 85k Registered
- 60k Daily Assist
- 22k Daily Connect

- 6,000 Flows/s(pk.)
- 2,73M Sessions(T)
- 90M DNS Cache hits

- 0.1% 19,1 TB Exchanged
- 15 GB Hadoop DB

- 200 DHCP Queries/s (pk.)
- 1,2 Gbps (pk.)
- 350k NAT(pk.)
- 4 NAT dev

- 220/AP Users (pk.)
- 20/AP Users (avg)
Essential Tools
Data-Gathering Tools

WLCCA
Data-Gathering Tools
WLC Config Analyzer (WLCCA)

- The WLC Config Analyzer (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 Neighbors** – 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
Data-Gathering Tools
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

- **WLCCA**
- **Prime & MSE**
- **OmniPeek and/or Wireshark**
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:
  - 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”
Data-Gathering Tools

WLCCA
Prime & MSE
OmniPeek and/or Wireshark
Survey & Analysis
Data-Gathering Tools
AirMagnet Survey & WiFi Analyzer Pro

- Ekahau Site Survey Pro
  - Design & Verify
  - Determine **differences in coverage** that occur as a result of tuning changes

- Airmagnet WiFi Analyzer Pro
  - Provides **in-depth 802.11-based protocol analysis**
  - Realtime tool, useful during events
Data-Gathering Tools

- **WLCCA**
- **Prime & MSE**
- **OmniPeek and/or Wireshark**
- **Survey & Analysis**

**Fluke AirCheck**
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

WLCCCA
Prime & MSE
OmniPeek and/or Wireshark
Survey & Analysis

Fluke AirCheck
Metageek Chanalyzer & CleanAir
Data-Gathering Tools
Metageek Chanalyzer Pro with Cisco CleanAir

- Provides a view of real energy on a channel
- Identify interferers of all types
- Critical part of the “big picture” during live events
Data-Gathering Tools

- **WLCCA**
- **Prime & MSE**
- **OmniPeek and/or Wireshark**
- **Survey & Analysis**

**Tools:**
- WLCCA
- Prime & MSE
- OmniPeek and/or Wireshark
- Survey & Analysis

**Equipment:**
- Fluke AirCheck
- Metageek Chanalyzer & CleanAir
- MetaGeek EyePA
Packet captures are great but what’s the real story being told?
Data-Gathering Tools

WLCCA

Prime NCS & MSE

OmniPeek and/or Wireshark

Survey & Analysis

Fluke AirCheck

Metageek Chanalyzer & CleanAir

MetaGeek EyePA

YOUR BRAIN = SUCCESS
- 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 optimization tools to make informed, data-driven decisions