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RF Design for the Mobile Device Explosion

BRKEWN-2019

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Session Objectives

- At the end of the session, the participants should be able to:
  - Define High Client Density – and why this is important
  - Understand how to define the mobile application requirements in terms of bandwidth/client
  - Understand throughput characteristics of available wireless protocols (802.11b,g,a,n)
  - Understand the RF challenges that come with High Client Density
  - Understand the available mitigation strategies that can be employed and how/when to apply them
  - Use the knowledge gained to produce successful wireless deployments

What Will Be Covered

- Introduction – Challenge Statement
- Key Design Criteria and Concepts
  - RF Basics in Dense Environments
  - Balancing Signal Against Interference
- Available Design Elements
  - Wireless Protocols/Capabilities
  - Features - RRM, ClientLink, BandSelect, Antenna Selection, APs
- Practical Application and experience

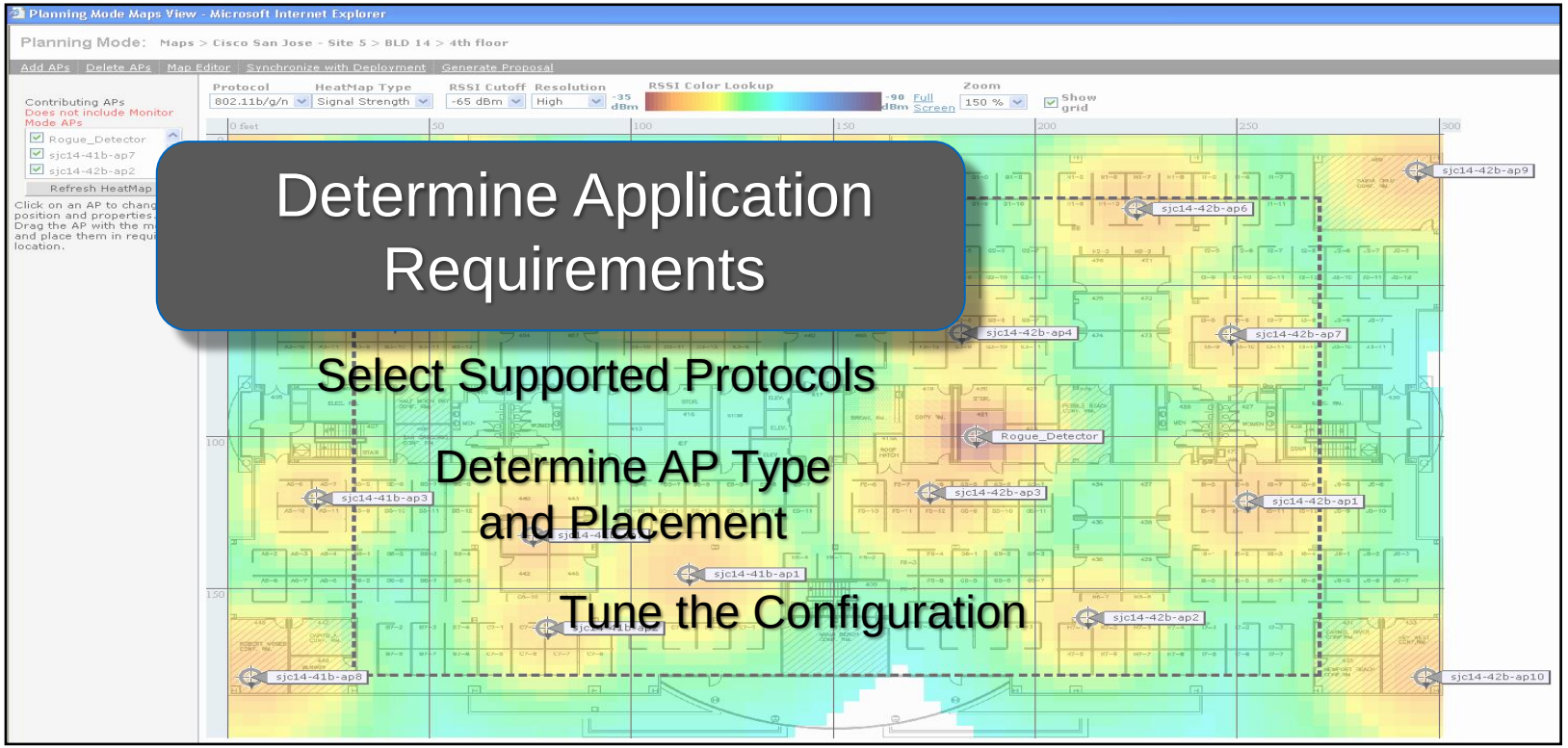
What Will Not Be Covered

- Specific Applications and Their Performance
- Wired Side Considerations and Resource Requirements
  - Security Services
  - Application Server Performance

Why High Client Density?

- Wireless is the preferred option in edge technology and in a lot of cases the only practical one
- High performance wireless connectivity for large dense groups of clients started with stadiums and auditoriums – but has reached every network - someplace
- The explosion of 2.4 GHz smart devices and increasing connection counts per seat are everywhere – spectrum is precious
- Application demands are increasing in this medium
- Even with the fantastic advances - wireless is still a shared Half Duplex medium and requires efficient spectrum use to succeed.

Design Steps



Aggregate and Per-User Throughput

- 802.11, like wired 802.3 Ethernet, it is a shared medium – **No AIR Switching!** (well at least until 802.11ac Wave 2)
- Aggregate throughput is the total bandwidth shared by all users in a cell
- The larger the cell, the more users in the cell
  - Greater per user throughput means smaller cells and more access points for a given area
- How many users per access point?
  - What's the aggregate throughput of the access point?
  - On average, what amount of per user throughput do you need to provide?
  - What is the Coverage Density

Per-User Application Throughput Examples

Protocol	Data Rate (Mbps)	Aggregate Throughput (Mbps)	Example User Count	Average per User Throughput
802.11b	11	7.2	10	720Kbps
802.11b	11	7.2	20	360Kbps
802.11b	11	7.2	30	240Kbps
802.11b/g	54	13	10	1.3Mbps
802.11b/g	54	13	20	650Kbps
802.11b/g	54	13	30	430Kbps
802.11a	54	25	10	2.5Mbps
802.11a	54	25	20	1.25Mbps
802.11a	54	25	30	833Kbps
802.11n MCS7	72 (400 nS GI)	35	10	3.5 Mbps
802.11n MCS7	72 (400 nS GI)	35	20	1.75 Mbps
802.11n MCS7	72 (400 nS GI)	35	30	1.16 Mbps

Just say No.

How Much Bandwidth is Required?

Often, less than you'd think

- It is most likely that you won't be supporting just one application
- Design for the highest bandwidth demand that you intend to support
  - What you really need here is the minimum acceptable throughput that the application will require
  - It is advisable to measure this yourself on multiple platforms - manufacturer/supplier numbers are good – but Trust and Verify is always a better career bet.
- Multiply this number by the number of connections/seats that you need to support
- This is the aggregate bandwidth you will require in your space

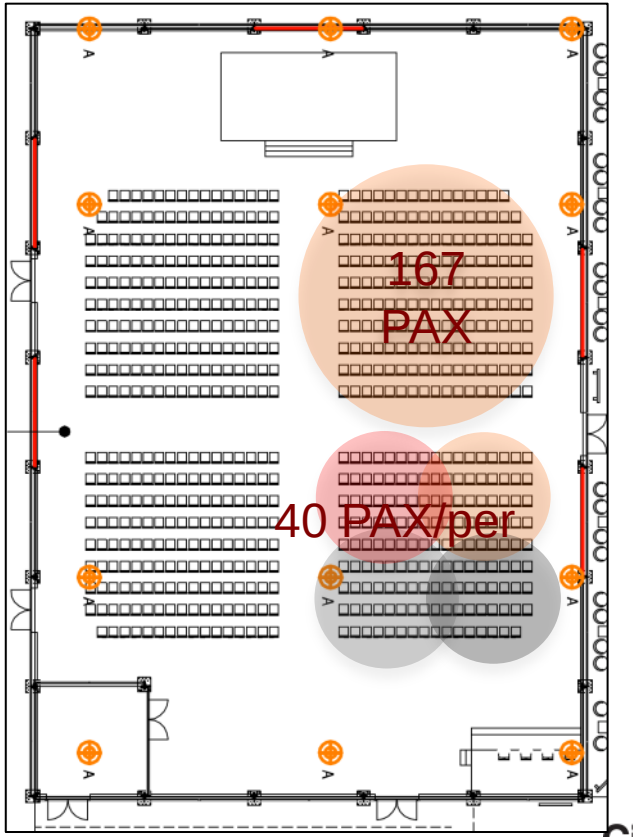
Application – By Use Case	Throughput – Nominal
Web - Casual	500 Kbps
Web - Instructional	1 Mbps
Audio - Casual	100 Kbps
Audio - instructional	1 Mbps
Video - Casual	1 Mbps
Video - Instructional	2-4 Mbps
Printing	1 Mbps
File Sharing - Casual	1 Mbps
File Sharing - Instructional	2-8 Mbps
Online Testing	2-4 Mbps
Device Backups	10-50 Mbps

QoE – Quality of Experience

- User Value Measurement – did the user find value in the service?
- Subjective
- Value is a moving target – and varies by test point
- Objective is Ookla – speedtest.net
- Differs from Quality of Service and SLA's
- What is the goal of providing Wi-Fi coverage?
- Realistic expectation's

Bigger Cells, More Users

- The Cell is the unit of bandwidth
- Manage the per user bandwidth by managing the size of the Cell



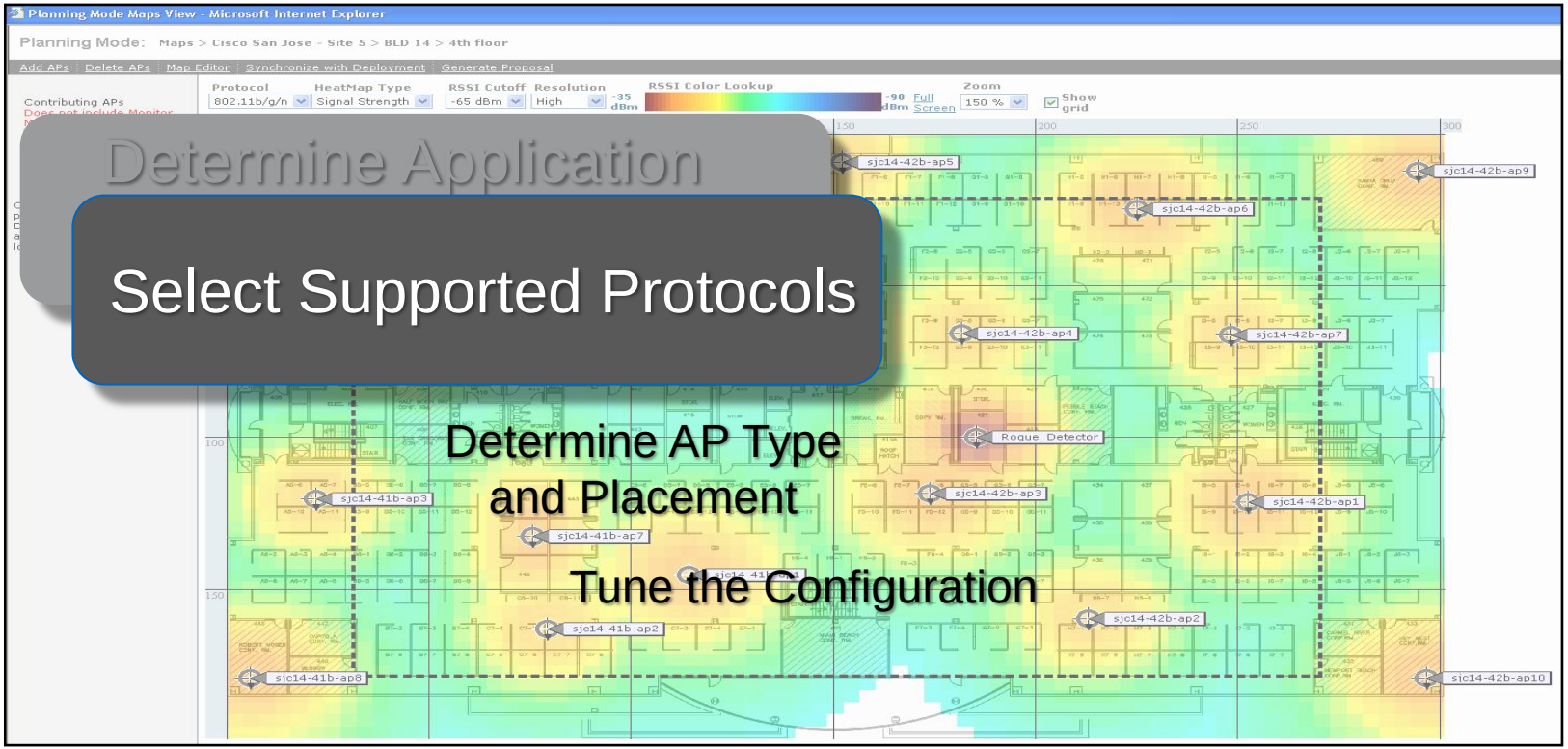
Take-up Rate – and Oversubscription for Wireless

- Successful QoE Wi-Fi drives more adoption

- Take-up Rates are on the increase in covered venues
  - Sporting event – 20-30% now 30-40%
  - Lecture Hall – University – 100%
  - Key Note – 30-50%
  - Small Theater 20-40%

- Event Driven –
  - CiscoLive, MWC, CTIA, Symposium, SuperBowl, Sporting venues

Design Steps



Channel Throughput by Protocol

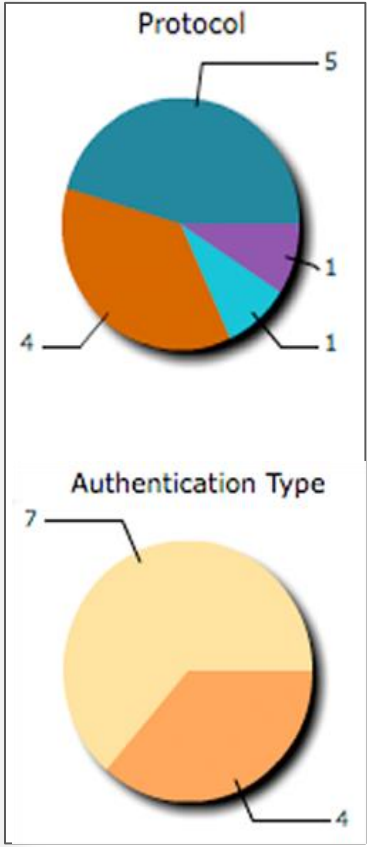
Protocol	Throughput (Mbps)
802.11b	7.2
802.11b/g mix	13
802.11g	25
802.11a	25
802.11n (HT20 1ss MCS7)	35
802.11n (HT20 2ss MCS15)	70*

- If your application requires 3 Mbps then you can get 2 concurrent seats on 802.11b or 4 seats on b/g mix
- 6 concurrent seats on a pure 802.11g channel – or 802.11a
- This assumes that the channel is performing at peak efficiency

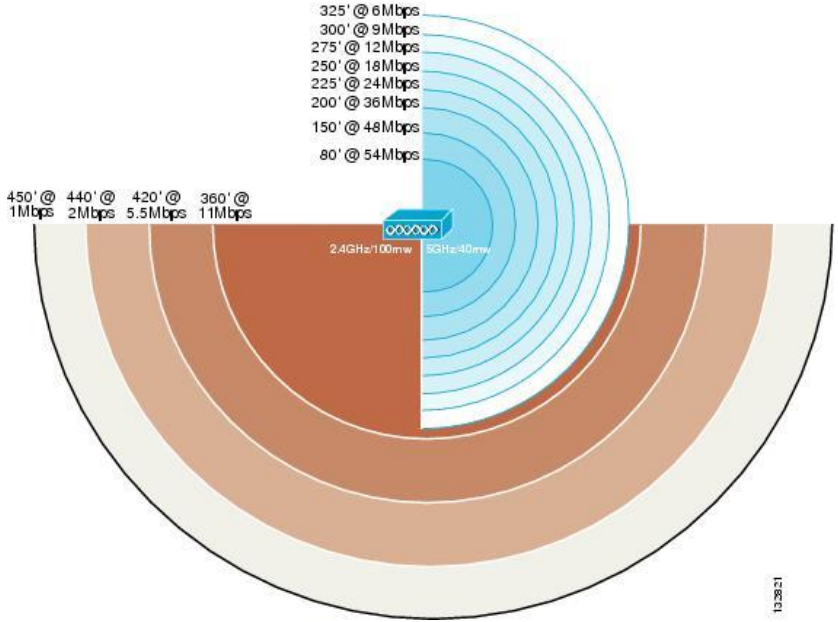
* Two spatial streams – note most PDA's are SISO (MCS 7) 35 Mbps max

Points to Consider

- 3 non-overlapping channels in 2.4 GHz
  - That's 1 (one) 100 Mbps FastEthernet interface!
- 13-21 non-overlapping channels in 5GHz in ANZ
- -N = 13ch, -Z = 21ch
- 5 GHz is critical to supporting High Density
- 5 GHz device support on the rise
- Trend is towards faster refresh



Cell Size – By Protocol / Speed



Assuming 10% PER

Speed	Required SNR	AP Sensitivity
1	0	-91
2	3	-91
5.5	6	-91
6	2	-87
11	9	-88
12	6	-86
24	11	-85
36	13	-85
48	17	-78
54	19	-77

Channel Utilisation – Is the Aggregate of Every Radio on the Channel That Can Be Heard Above -85 dBm – This Means Clients Too

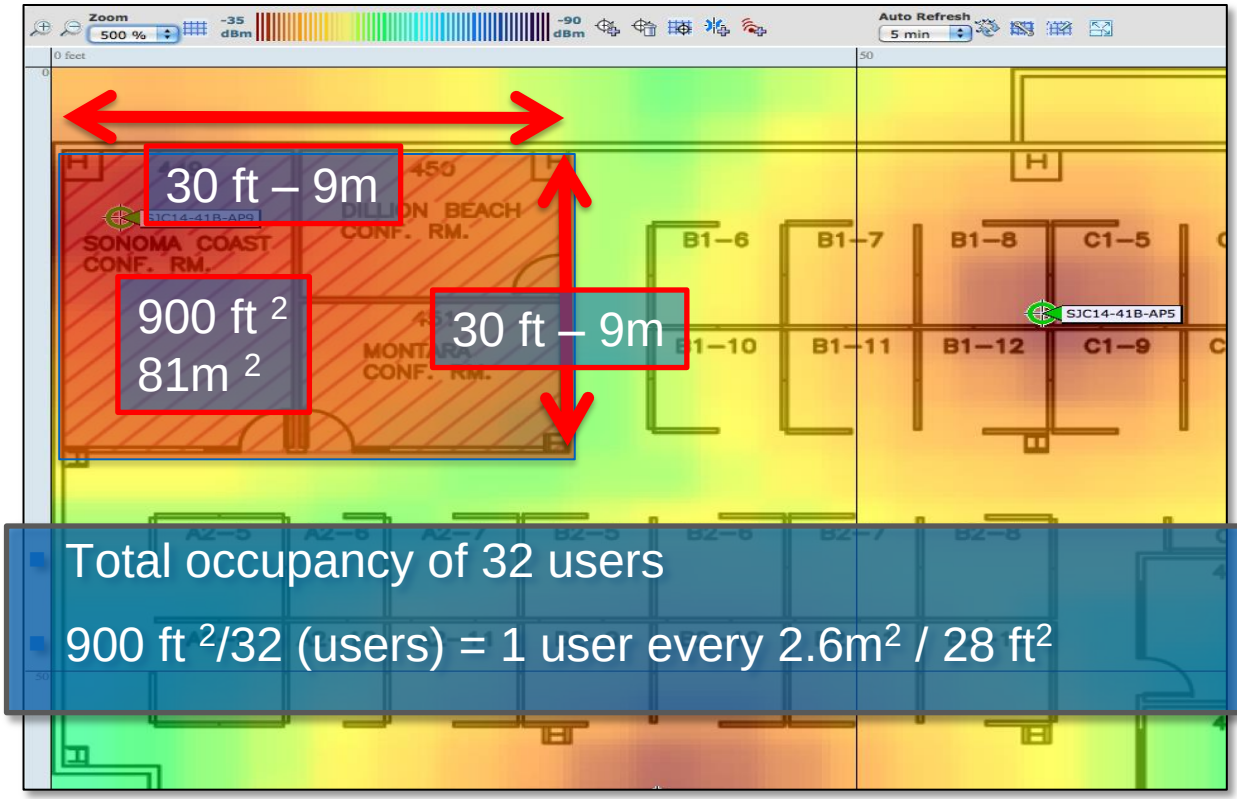
Channel Re-Use

- The question is – how many channel's can I get in a room?
- Co-channel and Adjacent Channel interference from Client Radios is what is important
- Speeds determine the impact

MCS Index 1/2/3 Spatial Stream	Modulation	Minimum Sensitivity 20 MHz	Required SNR (dB)
0/8/16	BPSK 1/2	-82	1
1/9/17	QPSK 1/2	-79	4
2/10/18	QPSK 3/4	-77	6.5
3/11/19	16 QAM 1/2	-74	9.75
4/12/20	16 QAM 3/4	-70	13
5/13/21	64 QAM 2/3	-66	17.25
6/14/22	64 QAM 3/4	-65	18.75
7/15/23	64 QAM 5/6	-64	19.75

*Assuming 10% PER

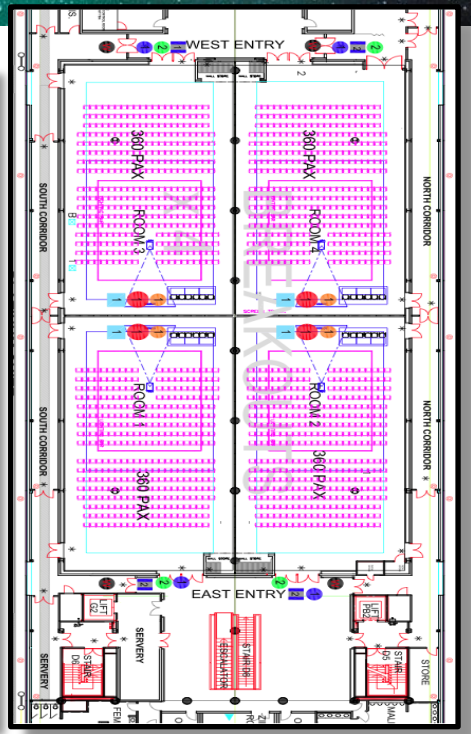
“Normal” Enterprise Planning



- Total occupancy of 32 users
- 900 ft ^{2}/32 (users) = 1 user every 2.6m^2 / 28 ft^2

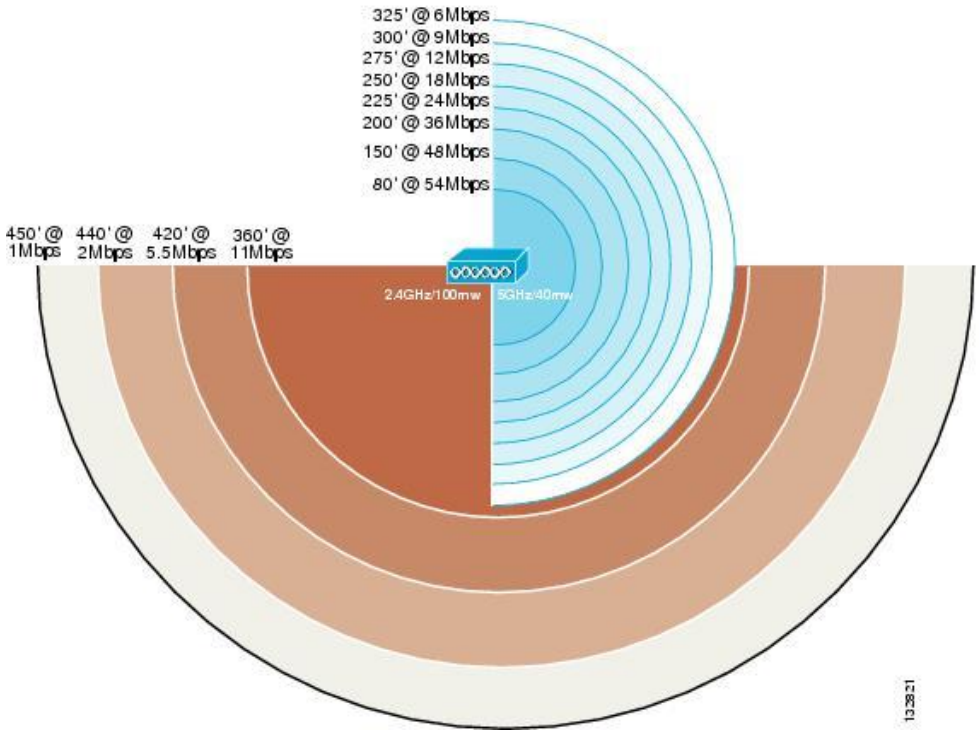
High Density Clients

- Contrast “normal” with these assumptions
- If sitting in a theater style seat, place your hand on the back of the seat in front of you – that’s about 1m
- The average seat width is ~50cm
- So – lets assume 1m x 1m or 1m ^{2}
- In the user seating – that’s 1 device per 1m^2



The “New Normal” Is More than 1 Device/Mac per User

Data Rate and Performance Variance



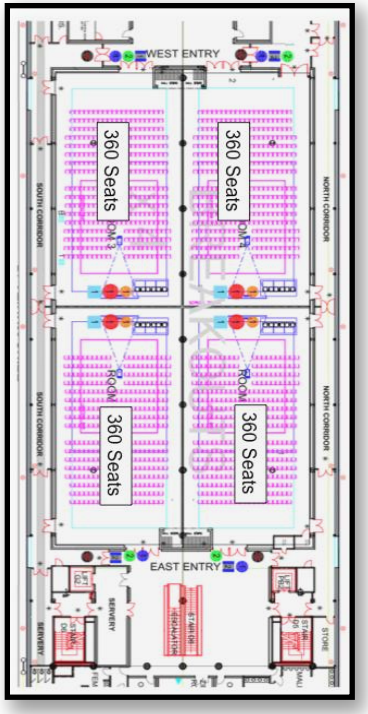
- Data rates decrease with the increase of distance from the radio source and client power will increase
- Individual throughput (performance) varies with the number of users
- Performance degrades with radio interference from other sources
- Critical deployment design goal is to achieve high data rate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

What is CCA?

- 802.11 is CSMA/CA – collision avoidance
- CCA is Clear Channel Assessment – and is the listen before talk component of Collision Avoidance
  - ED-Energy Detect
  - Preamble - requires modem
- With 802.11n radios CCA is typically linked to Preamble/Start of packet
- Radios are better (mostly)
- CCA - is -65 and SOP is -85 dBm for 802.11b/g/a/n
- If you can hear it above these levels – you are sharing the spectrum

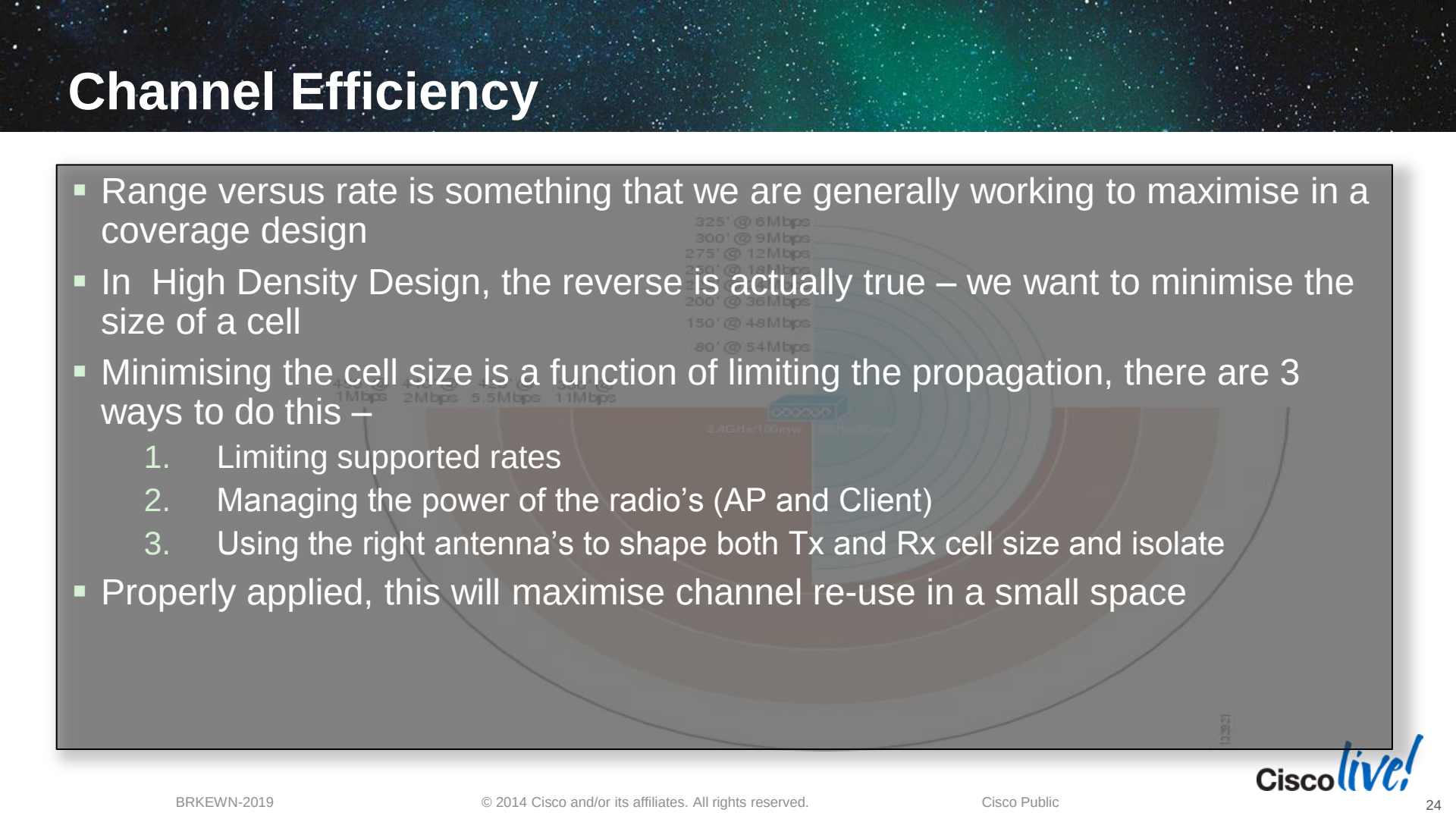
Cell Isolation

- In a High Density Client environment, the AP's will have the best view of the room often line of site to the client (in overhead mounting)
- Client devices will be embedded with the users and result in a 8-10 dB attenuation. This serves to reduce the overall interference radius of the clients.
- Difficult to predict the radio dynamics affecting the client unless direct measurements can be taken when space is filled.
- Very possible to focus on the AP and it's view of the world and improve downlink performance.
- The object is to make the network resilient by optimising every aspect within our control



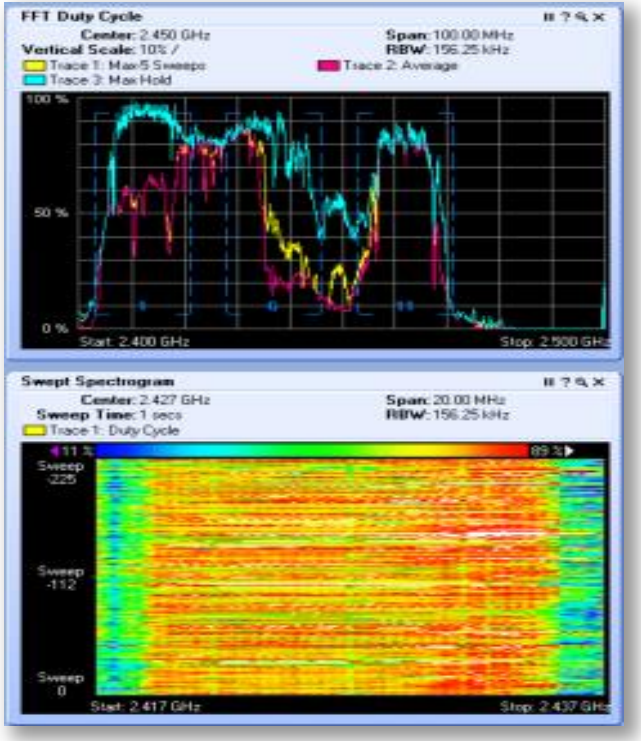
Channel Efficiency

- Range versus rate is something that we are generally working to maximise in a coverage design
- In High Density Design, the reverse is actually true – we want to minimise the size of a cell
- Minimising the cell size is a function of limiting the propagation, there are 3 ways to do this –
  1. Limiting supported rates
  2. Managing the power of the radio's (AP and Client)
  3. Using the right antenna's to shape both Tx and Rx cell size and isolate
- Properly applied, this will maximise channel re-use in a small space

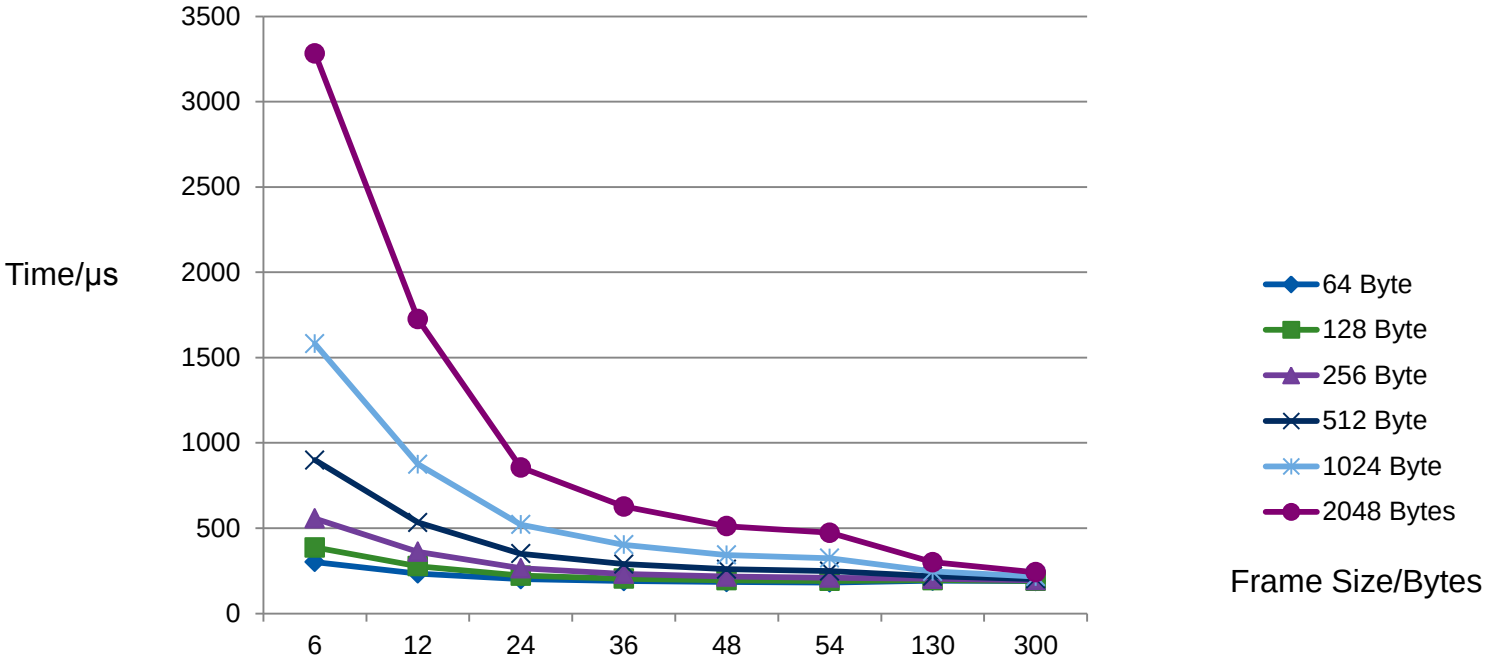


Duty Cycle – and Spectrum Capacity

- Duty Cycle is the on time of a given transmitter
- It is measured as percentage of total time available, this relates directly to channel utilisation, but is only part of the story – protocol overhead is the full story
- 802.11 can only do essentially two things to recover in a challenging RF environment
  - Retransmit a Frame – Turn the radio on again to send information that has already been sent once = Increased Duty Cycle
  - Rate shift to a slower speed that can be supported – If retries are excessive, then the link will be rate shifted to a slower speed in an attempt to gain reliability
- Both of these will increase Duty Cycle and make the problem worse if it is a dense network



Understanding Protocol Selection in 802.11



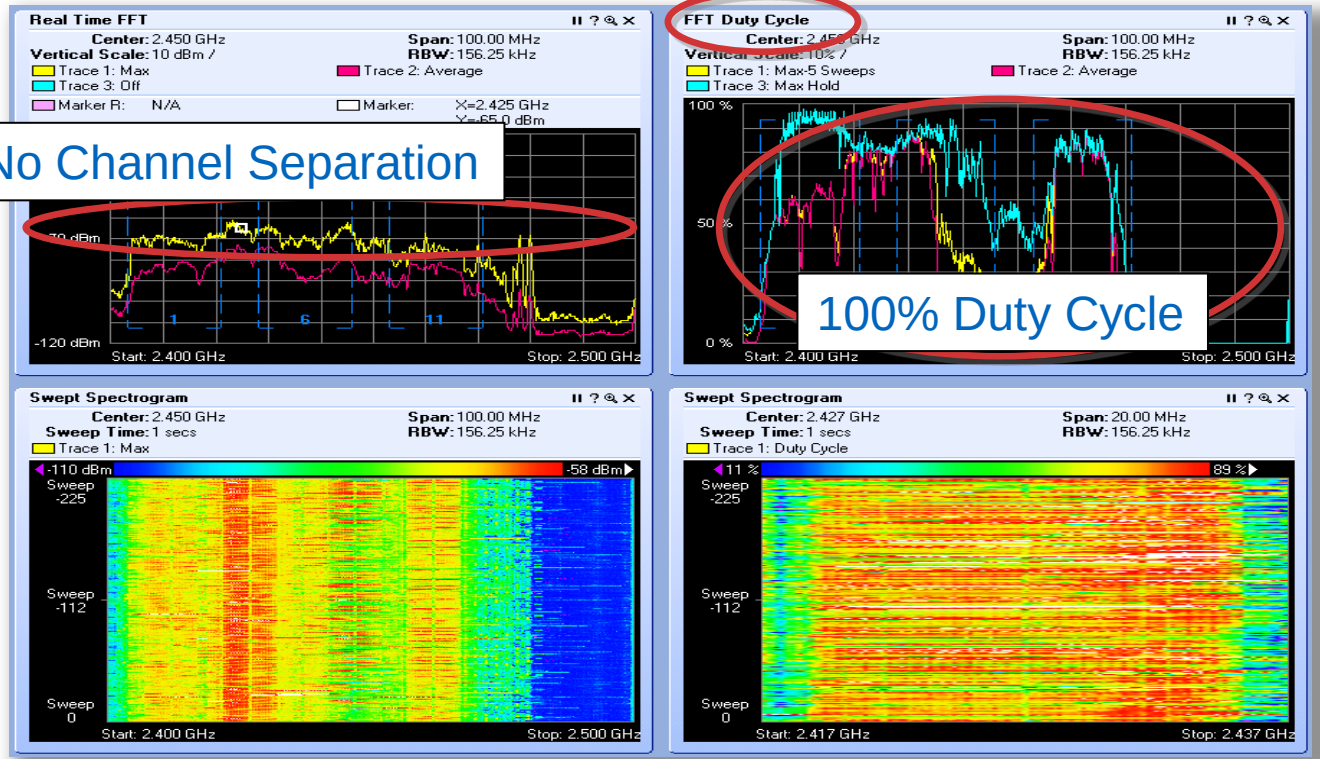
Spectrum Is a Shared Finite Resource

Duty Cycle and Spectrum 802.11 b/g

Healthy Network

Duty Cycle and Spectrum 802.11 b/g

Unhealthy Network

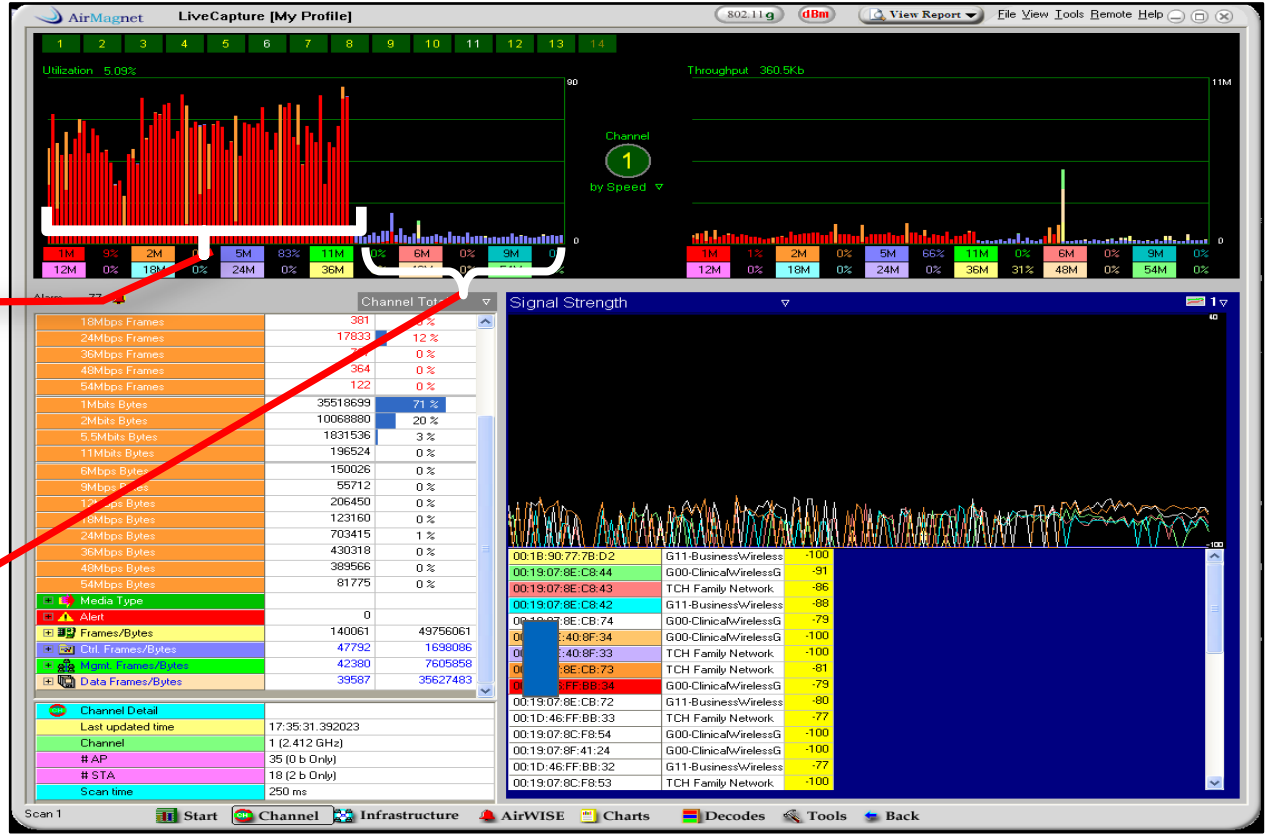


Channel Utilisation - What Made the Difference?

80% ~

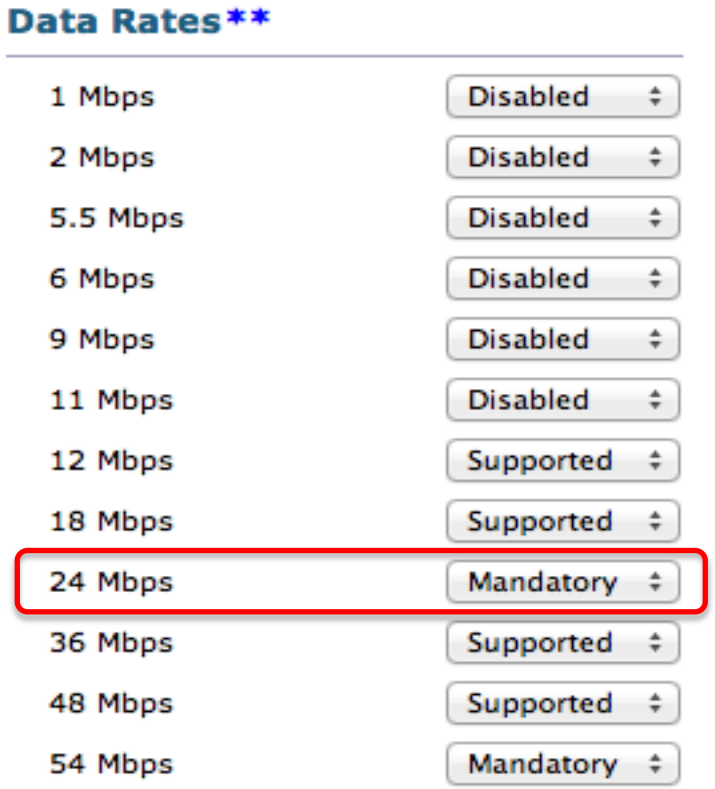
What changed?

5% After

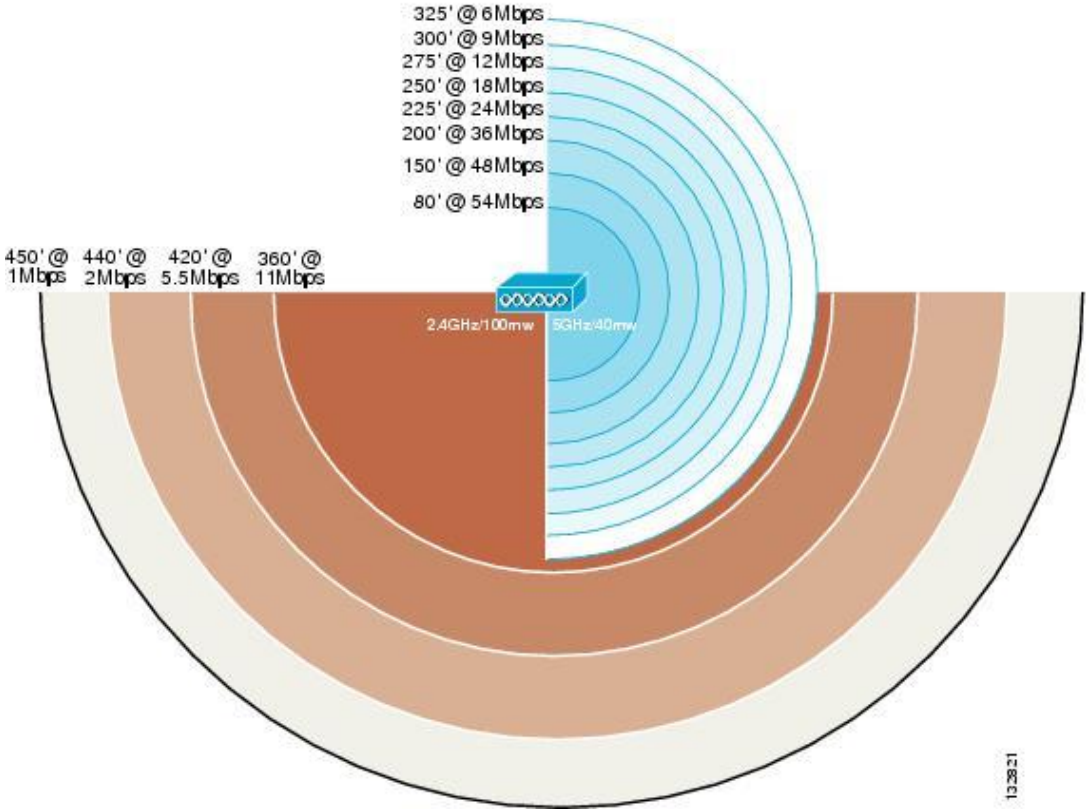


Every SSID Counts!

- 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 Existing **associated client**
- Mandatory – Client must support to **associate**
- Lowest mandatory rate is beacon rate
- Highest mandatory rate is default mcast rate



Data Rate – Controlling Cell Size



802.11a Scalability – ANZ 5GHz Has 21 Channels

*54/25 Mbps
*54/25 Mbps
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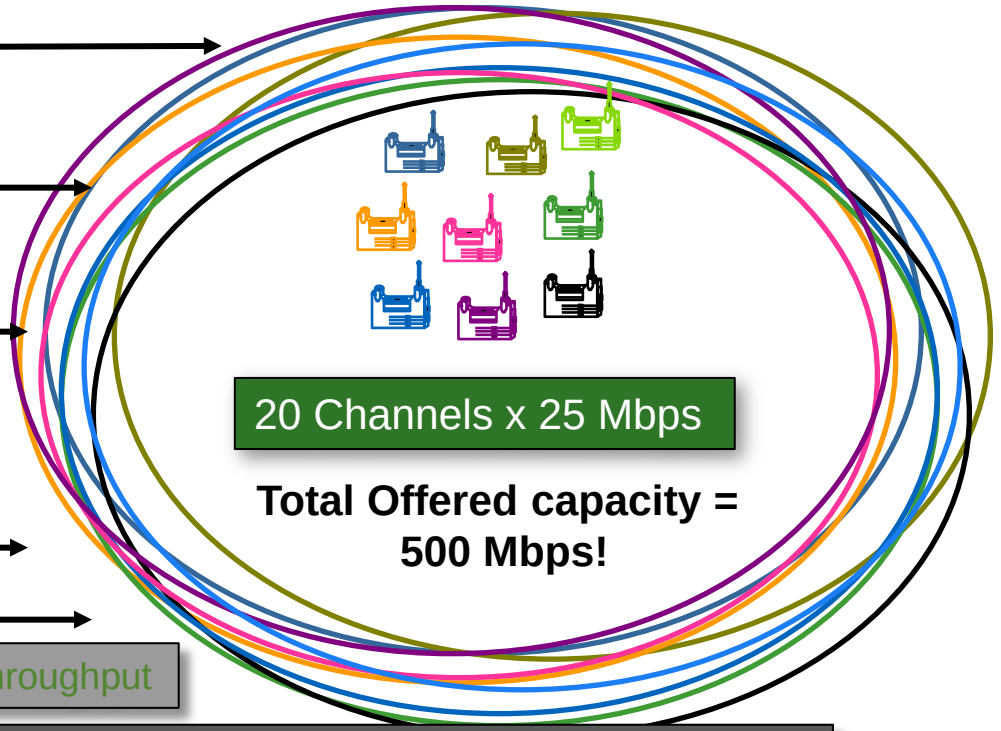


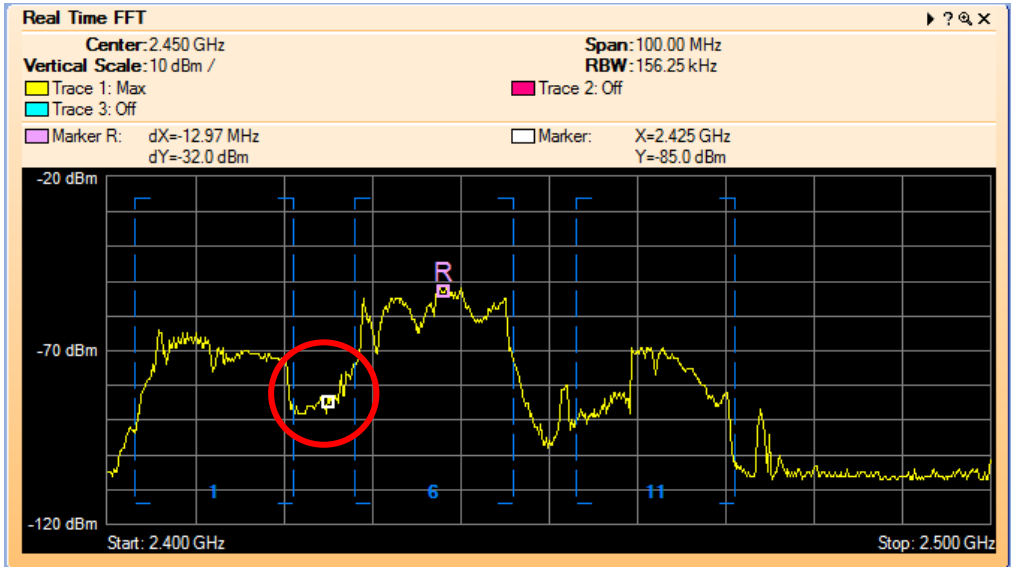
20 Channels x 25 Mbps

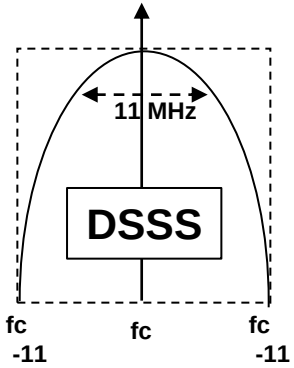
Total Offered capacity = 500 Mbps!

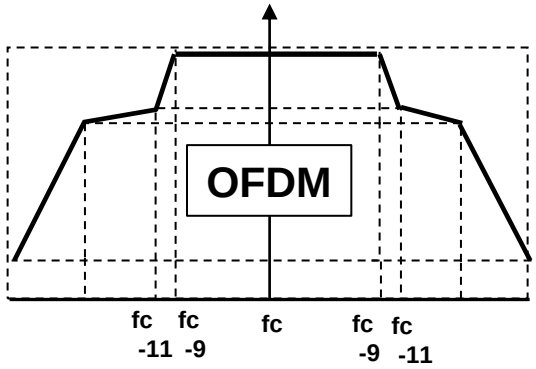
* Data Rate/Throughput

What About 11n? 9-Bonded Channels

Spectral Mask





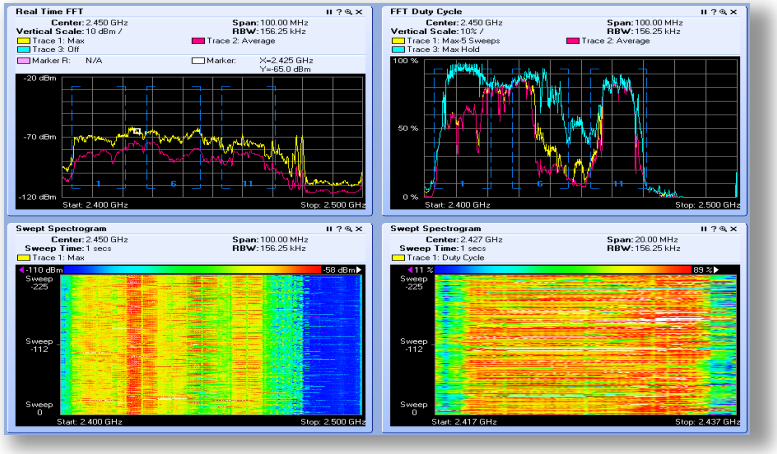


Capacity

- Aggregate Capacity is throughput multiplied by available, non-overlapping channels
  - 802.11b and 802.11g operate in the same band, use the same three channels
  - Any 802.11g capacity increase is from throughput alone
- 802.11a currently provides 4 to 21 channels in most of the world
  - While throughput might be similar to 802.11g, channels are not, neither then is capacity
- In theory, access points set to non-overlapping channels may be co-located to provide all available capacity in a single coverage area
  - More commonly, it's an expression of total throughput across a network or facility

Efficiency – What we CAN, and CAN'T control

- CAN
  - HD RF design (AP Placement and selection)
  - HD Configuration
  - Proper Hardware Selection
  - Proper wired Infrastructure
  - Bandwidth Policy
  - Spectrum Policies
  - Education



- CAN'T
  - Client device selection
  - Client device behaviour
  - Spectrum Availability
  - If it really works

"Ultimately – the Boss is Physics"

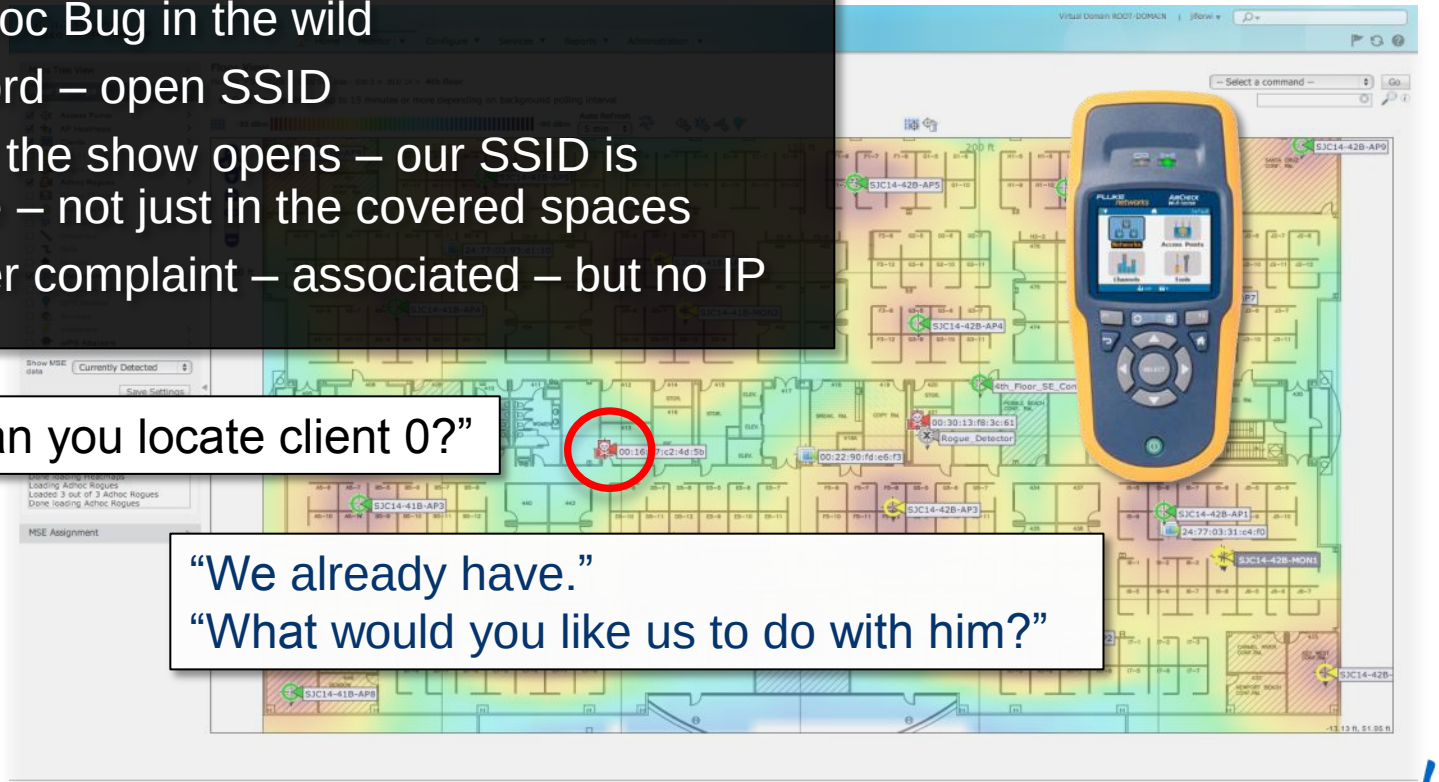
Spectrum Policy

A. have one
B. Need one
C. What's a Spectrum Policy Gareth?
D. All the above

Answer:

No Spectrum Policy

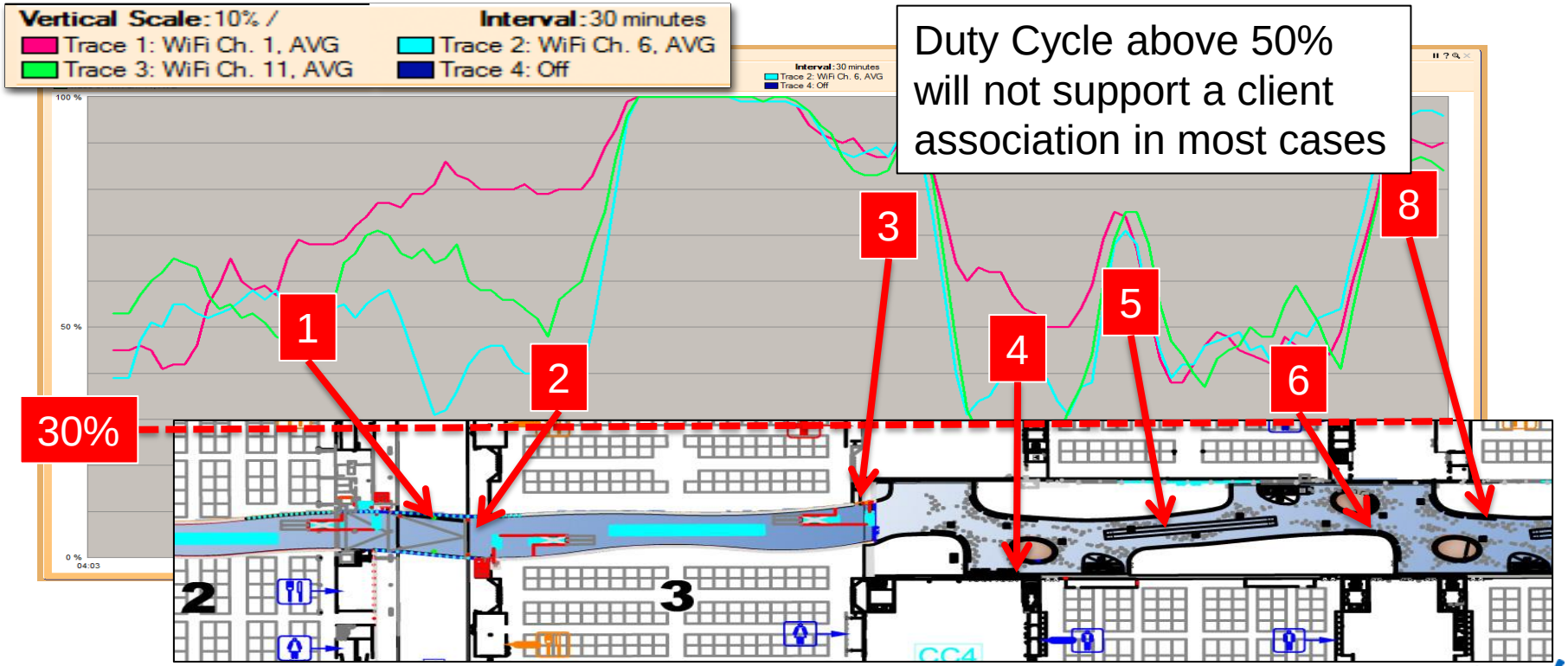
- CiscoLive London 2010
- iPhone adhoc Bug in the wild
- NO password – open SSID
- Hours after the show opens – our SSID is everywhere – not just in the covered spaces
- #1 customer complaint – associated – but no IP address



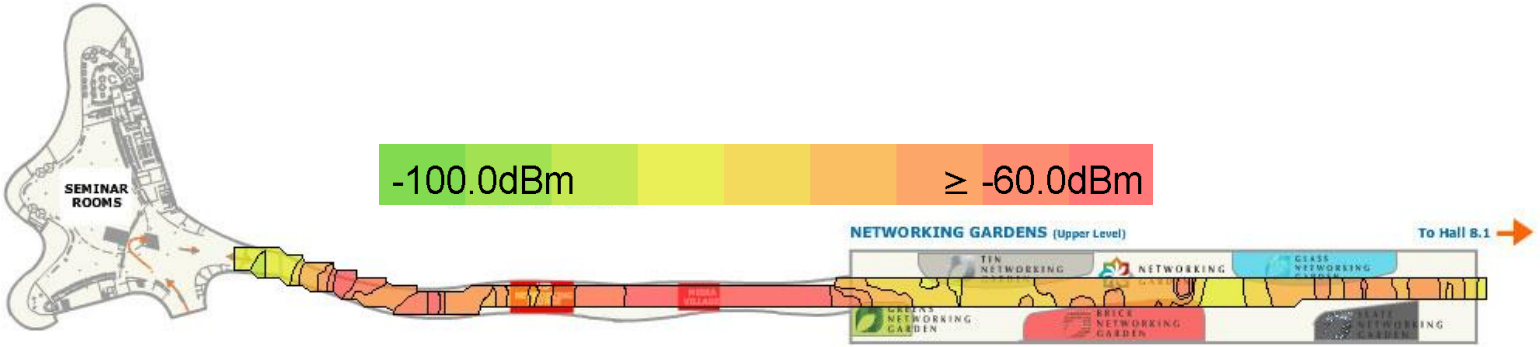
"Can you locate client 0?"

"We already have."
"What would you like us to do with him?"

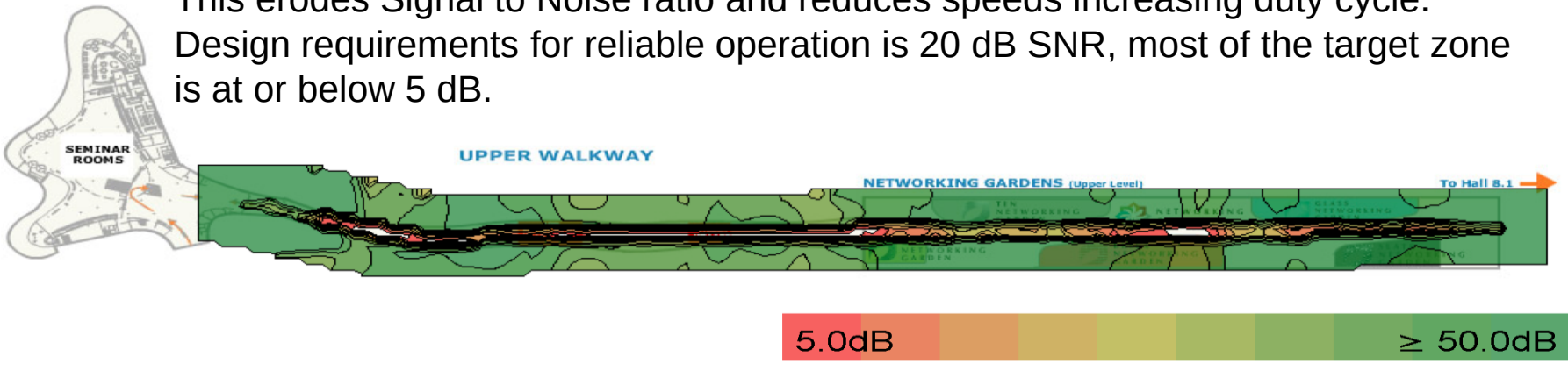
RF Duty Cycle above 30% = Intermittent Connectivity



Noise Floor and SNR



Average Noise Floor, -75 would be considered minimal. The noise floor is Ambient Noise from all Wi-Fi sources. Over the target area generally it is above -60 dBm. This erodes Signal to Noise ratio and reduces speeds increasing duty cycle. Design requirements for reliable operation is 20 dB SNR, most of the target zone is at or below 5 dB.

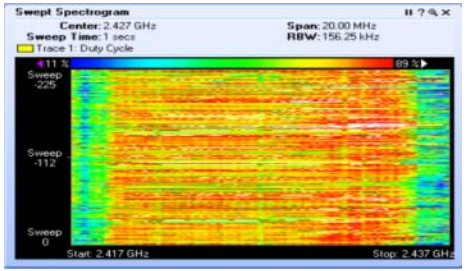


Location 6

Channel	Total (average %)	Total (last %)	802.11 (average %)	802.11 (last %)	Non-802.11 (average %)	Non-802.11 (last %)	Access Point Count
1 (2.412GHz)	68	75	62	73	6	2	14
2 (2.417GHz)	24	25	23	24	1	1	1
3 (2.422GHz)	19	18	18	16	1	2	1
4 (2.427GHz)	14	4	13	4	1	0	0
5 (2.432GHz)	27	52	25	48	2	4	0
6 (2.437GHz)	64	70	62	68	2	2	14
7 (2.442GHz)	29	28	28	27	1	1	0
8 (2.447GHz)	20	11	17	10	3	1	1
9 (2.452GHz)	11	15	11	14	0	1	1
10 (2.457GHz)	24	5	23	4	1	1	0
11 (2.462GHz)	51	69	47	67	4	2	12
12 (2.467GHz)	30	42	27	40	3	2	0
13 (2.472GHz)	15	36	12	33	3	3	3

Spectrum Policy's are Venue/Vertical Specific

- What's the user base? Is there a vendor solutions exhibition?
  - CiscoLive, Mobile World Congress – vendor booths – have a lot of Wi-Fi
  - The last meeting of the ANZAAB* – not so much
  - Sporting Events
  - University Lecture Hall/Campus
  - Enterprise – Carpeted Office, Manufacturing, Healthcare
- Wireless Vendor Exhibition –
- Person in the booth generally hands on technical
- Likely has no idea how the Wi-Fi is configured
  1. Turn on Wi-Fi
  2. Determine it does not work
  3. Crank up the power
  4. Select different channel
  5. Select 40 MHz channel in 2.4
  6. Complain



What's Required in a Spectrum Policy

- Anything you want – but make it reasonable, and remember that this is an education effort – so don't start with an advanced class
- Implementing the policy means every participant is notified and agrees – generally provided as part of the vendor kit – and is signed for acknowledgement
- If you implement a policy – Be prepared to staff the policy
  - Help vendors comply – have people on the floor locating offender's, and working with them to solve issues
  - Have to start with the worst – and work backwards
  - It is an education Process
  - There needs to be stated remedies for violators

Setting the Expectation
…and getting Acknowledgement

WI-FI POLICY

- Over the past 2 years, we've successfully introduced some changes to the wifi networks within the halls to create a better experience for the exhibitors that wish to install their own private Wi-Fi networks in their stands. We will be keeping this successful policy for MWC2013, which encompasses the following:

  – You will not be able to use the public Wi-Fi network within any Exhibition Hall at MWC2013

    In previous years, exhibitors and attendees alike have had the opportunity to purchase daily passes to use the public Wi-Fi network with the exhibition halls to access the internet, but at this years event, as at the last event, this public network will be turned off to give the exhibitors who install their own Wi-Fi networks within their stands a better experience for conducting demos and for general internet usage.

  – If you wish to install a Wi-Fi network within your stand, you are permitted to do so, as in previous years. You can purchase bandwidth, then either install your own Access Point(s) or you can rent Access Points from Fira de Barcelona and have them install and support a Wireless network for you.

  – We will be using advanced 'mitigation' software to monitor access points that have not been disclosed in the Wi-Fi submission form and have the ability to cancel their signal and disable the access points. This is a last resort effort after contact with the stand has been made.

  – Public Wi-Fi will still be available for attendees in 'Hot Spot' areas around the venue. These areas will be marked with a Wi-Fi Hotspot logo, so look for these at the show. A password will be clearly advertised on the logo's around the venue for access to the public Wi-Fi service.

Wi-Fi is a Shared Spectrum

- Successful user communities can – and DO create self policing band plans
- Your Venue – Your Spectrum – Your Guests
- Community resource – name/shame may work
- Education, expectation, shared experience – not over night
- NFL, MLB, NBA, Airport Authorities, Medical Facilities/Healthcare all have stated policies

"If your Going to Boil a Frog, Start with Cold water"

BandSelect

Access Point Assisted 5 GHz Band Selection

Challenge

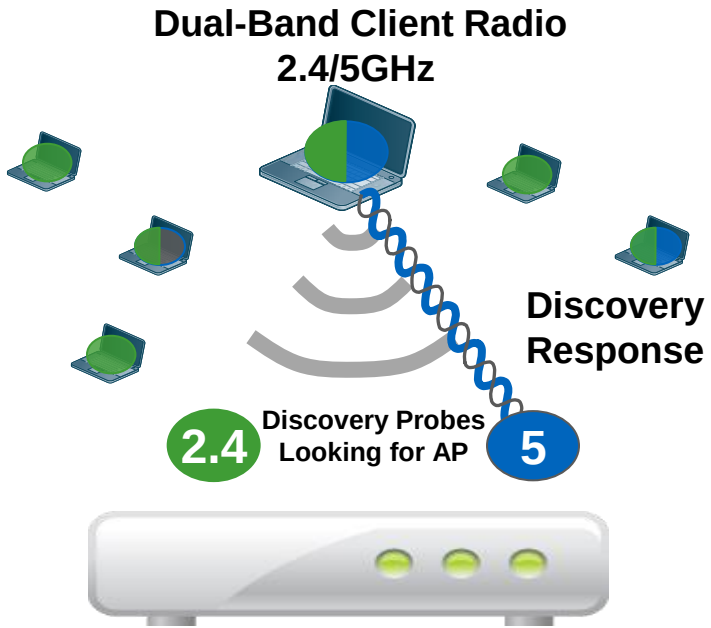
Dual-Band Clients Persistently Connect to 2.4GHz

- 2.4GHz may have 802.11b/g clients causing contention
- 2.4GHz is prone to interference

Solution

BandSelect Directs Clients to 5GHz, Optimising RF Usage

- Better usage of the higher capacity 5GHz band
- Frees up 2.4GHz for single band clients

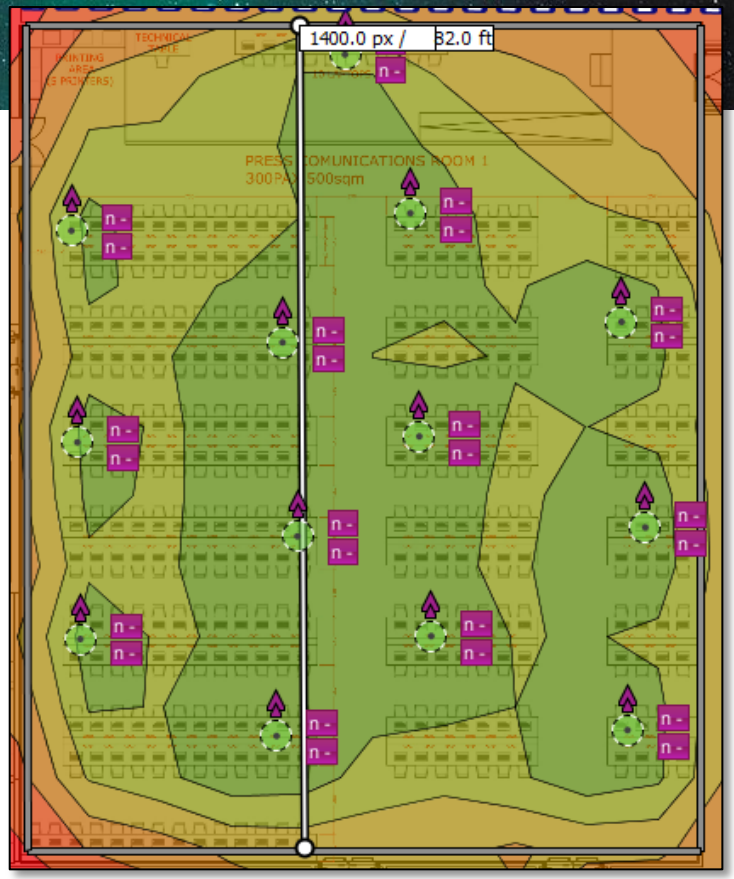


Optimise RF Utilisation by Moving 5GHz Capable Clients out of the Congested 2.4GHz Channels

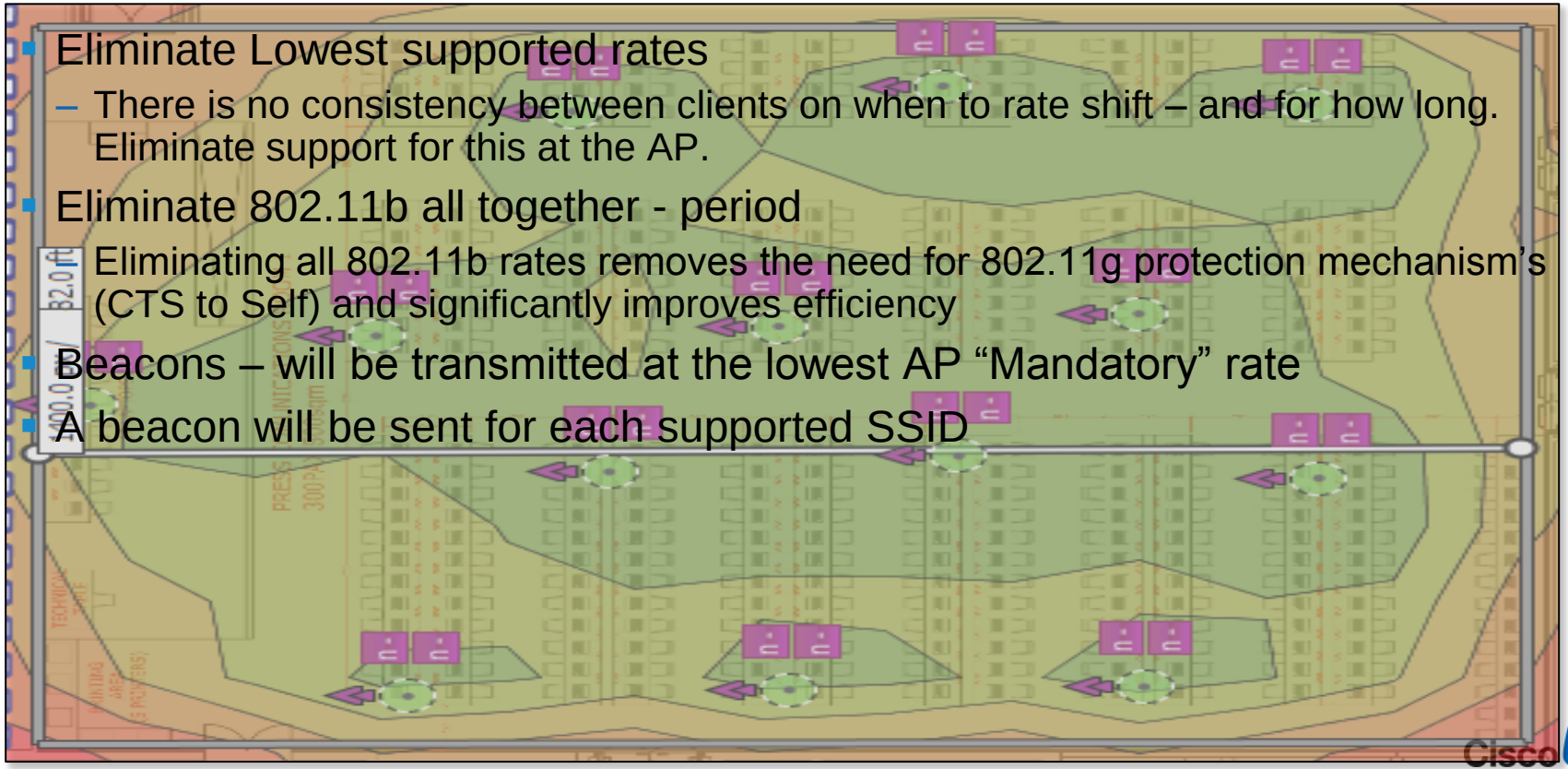
High Density Deployment

- 13 x 3602i AP's
- 5K ft ^{2}
- 300 Seats
- Wired connections at each station
- 5 total 2.4 GHz channels

"Wow, the wireless is actually faster than the wired"
First tweet from the pressroom

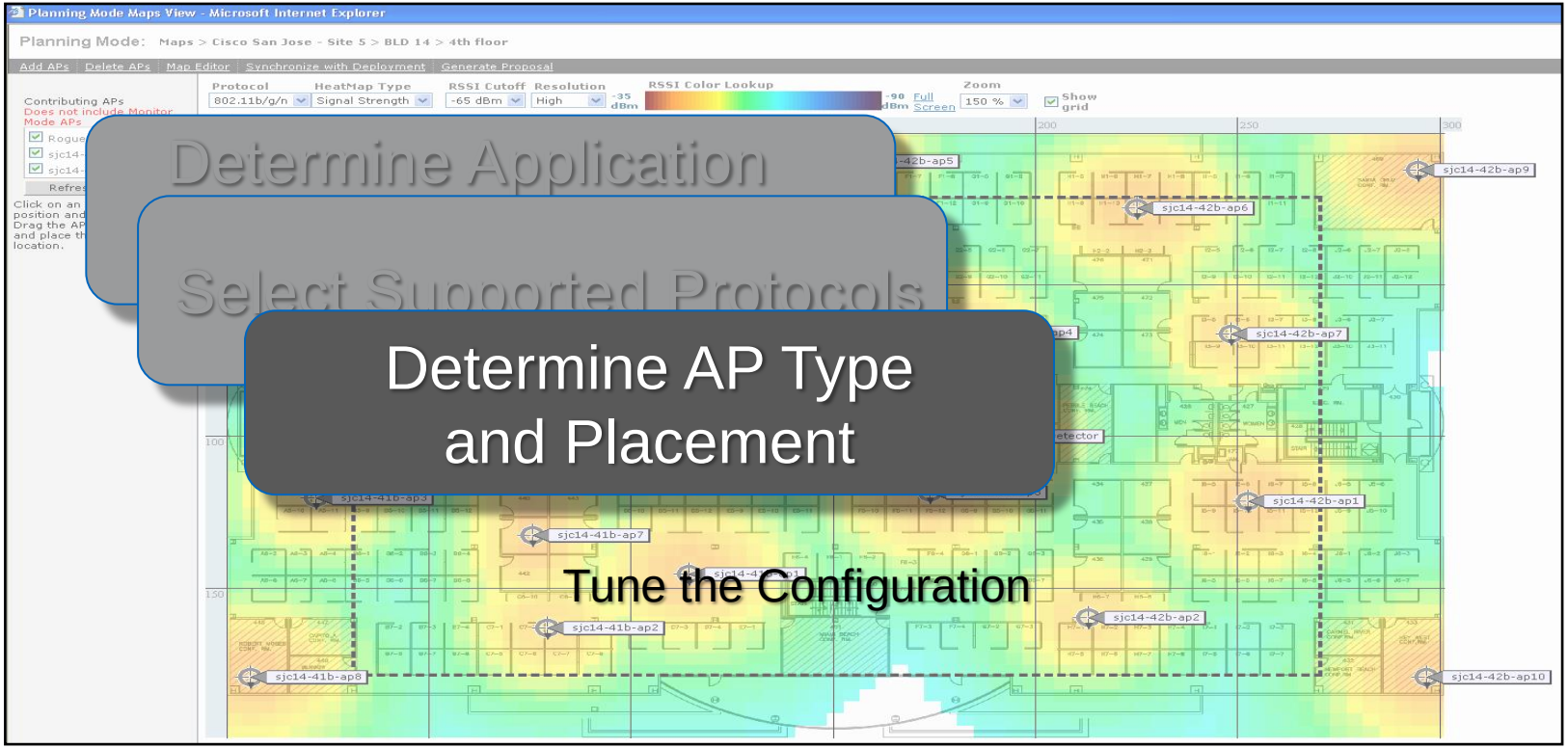


2.4 GHz Efficiency



- Eliminate Lowest supported rates
  - There is no consistency between clients on when to rate shift – and for how long. Eliminate support for this at the AP.
- Eliminate 802.11b all together - period
  - Eliminating all 802.11b rates removes the need for 802.11g protection mechanism's (CTS to Self) and significantly improves efficiency
- Beacons – will be transmitted at the lowest AP "Mandatory" rate
- A beacon will be sent for each supported SSID

Design Steps



Selection of APs

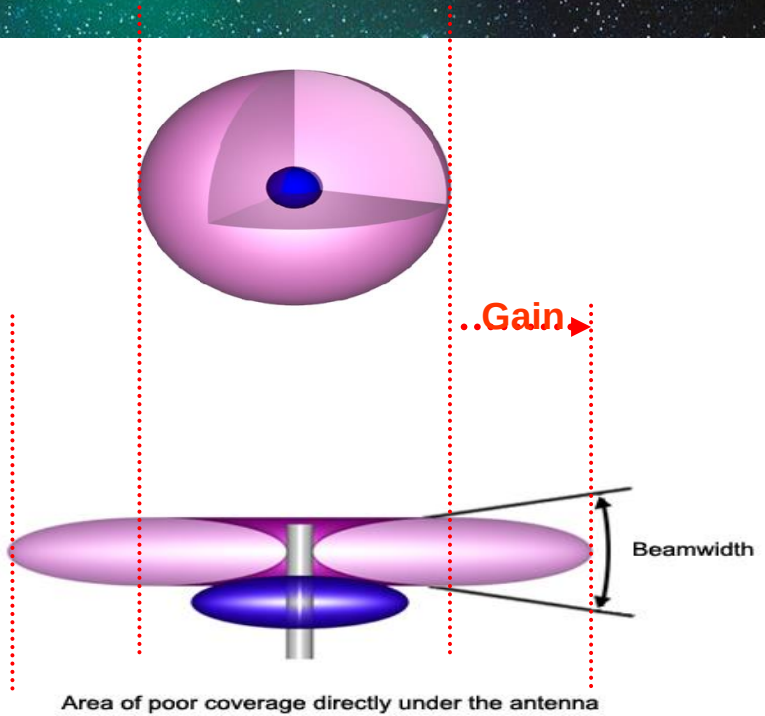
- The type of AP you select will have a large impact on the amount of data that you successfully deliver
- 802.11n AP's provide improved performance for legacy clients
- 802.11n Clients get a huge benefit – and relieve a lot of stress on bandwidth for legacy clients (130 mbps connections for 802.11n HT20 MCS 15)
- Depending on density requirements – standard omni antenna may suffice
- Higher Density = More Complexity = More Engineering Required = Better Overall QoE

Antenna Theory and Antenna Gain

- A theoretical isotropic antenna has a perfect 360º vertical and horizontal beamwidth (it puts the i in dBi)
- This is a reference for all antenna
- Gain is equal in all directions
- The reception of good signals and interference is the same in all directions

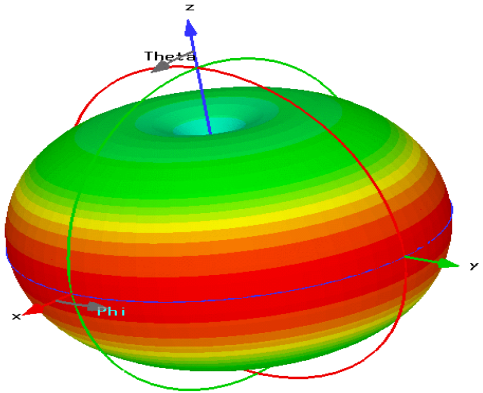
High Gain Omni-Directional Antenna:

- More coverage area on the horizontal elevation
- Energy level directly above or below the antenna will become lower

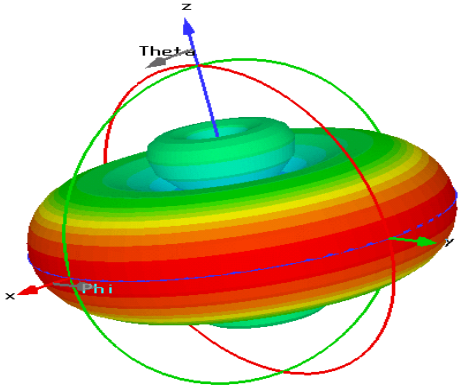


There Is No Increase in Transmitted Energy with the Higher Gain

Antenna Radiation Patterns

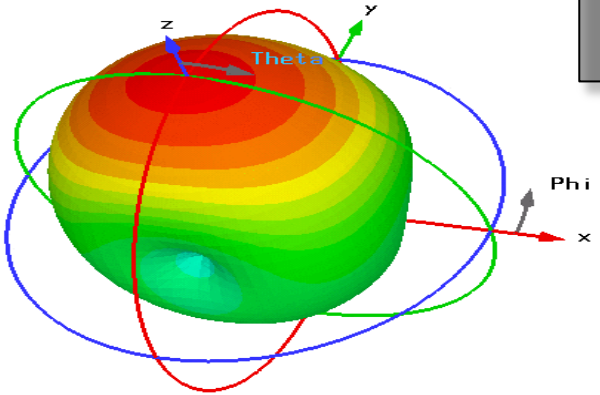


Dipole

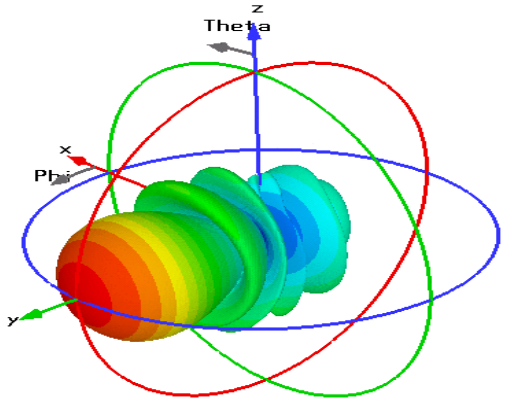


Omni

Antenna Choice Plays a Critical Part in Design for Proper Coverage

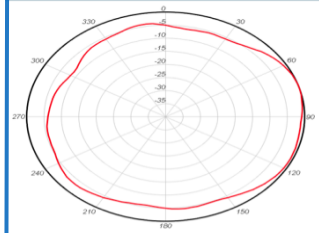
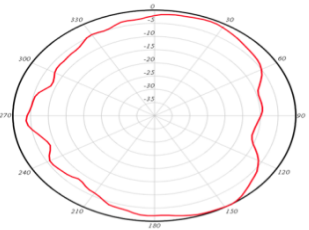
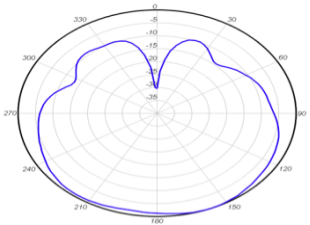
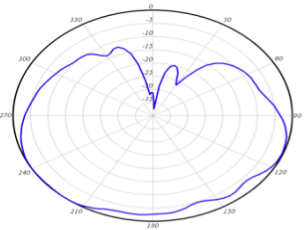


Patch



Yagi

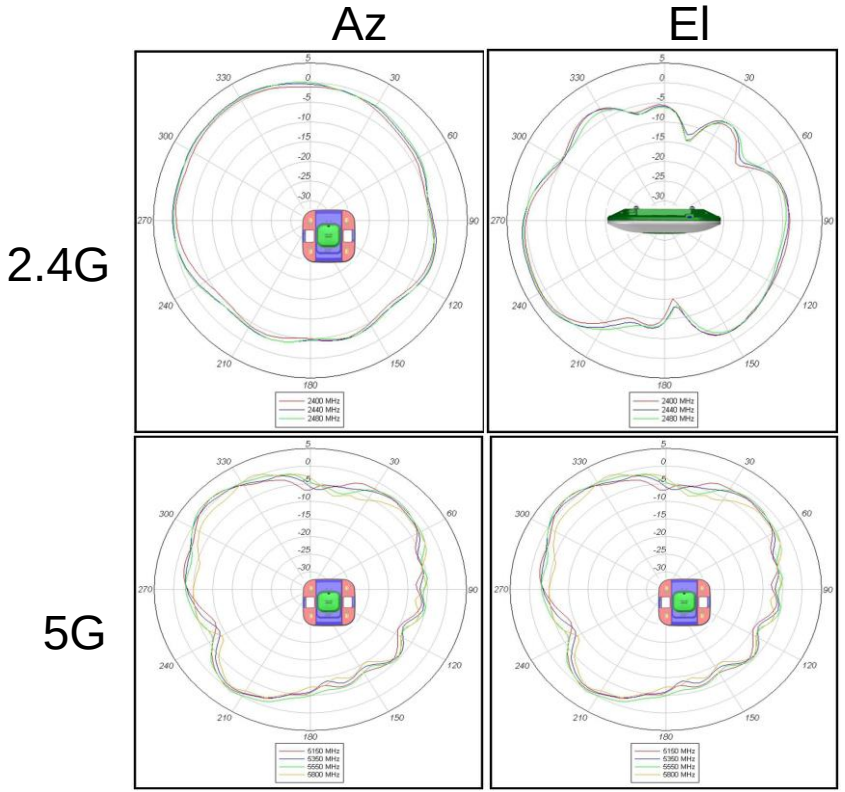
Cisco 1040, 1140, 3500i Antennas

2.4 GHz, 4 dBi Azimuth Plane Radiation Pattern	5 GHz, 3 dBi Azimuth Plane Radiation Pattern	2.4 GHz, 4 dBi Elevation Plane Radiation Pattern	5 GHz, 3 dBi Elevation Plane Radiation Pattern
			

Frequency Range	• 2.4–2.5GHz • 5.15–5.85 GHz
Gain	• 2.4 GHz: 4 dBi • 5 GHz: 3 dBi
Polarization	Linear, Vertical
Azimuth 3dB Beamwidth	Omnidirectional
Elevations 3dB Beamwidth	2.4 GHz = 120 degrees, 5 GHz = 120 degrees
Antenna Connector	Integrated
Mounting	Integrated
Antenna Type	Omnidirectional

AP-3602i Antenna Patterns for 2.4/5 GHz

AP 3600 Dual Resonant integrated antenna performance Specifications		
Parameter	**Minimum**	**Nominal Value**
Antenna Type		Dual-Resonant Inverted F
Operating Frequency Range		2400-2484 MHz
		5150-5850 MHz
Nominal Input Impedence		50Ω
VSWR		2400-2484 MHz 2:1
		5150-5850 MHz 2:1
Peak Gain	1 dBi	2.4 GHz band 2 dBi
	2 dBi	5 GHz band 4 dBi
Polarization		Linear
Elevation Plane 3-dB Beamwidth	60˚	2.4 GHz band 150˚
	40˚	5 GHz band 50˚
Azimuth plane Ripple	5 dB	2.4 GHz band 7 dB
	8 dB	5 GHz band 12 dB

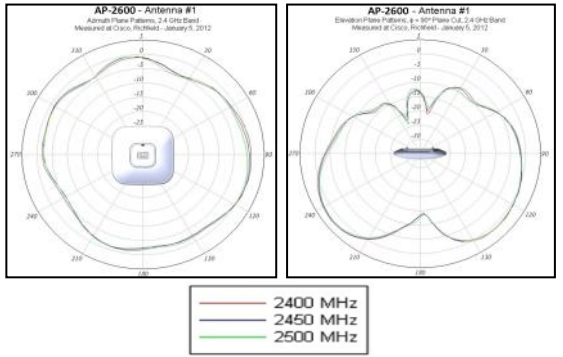


AP-2602i Antenna Patterns for 2.4/5 GHz

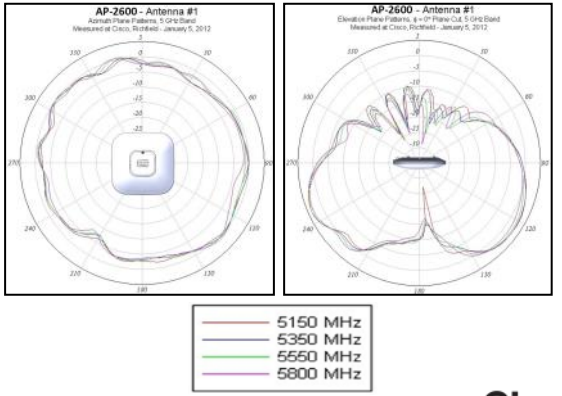
AP-2600 Dual-Resonant Integrated Antenna Performance Specifications		
Parameter	**Minimum**	**Nominal Value**
Antenna Type		Omnidirectional
Operating Frequency Range		2400 - 2484 MHz
		5150 - 5850 MHz
Nominal Input Impedance		50 Ω
Peak Gain	2.5 dBi	2.4 GHz Band: 4 dBi
	3.0 dBi	5 GHz Band: 4 dBi
Elevation Plane 3-dB Beamwidth	40°	2.4 GHz Band: 150°
	40°	5 GHz Band: 50°

Az El

2.4G



5G



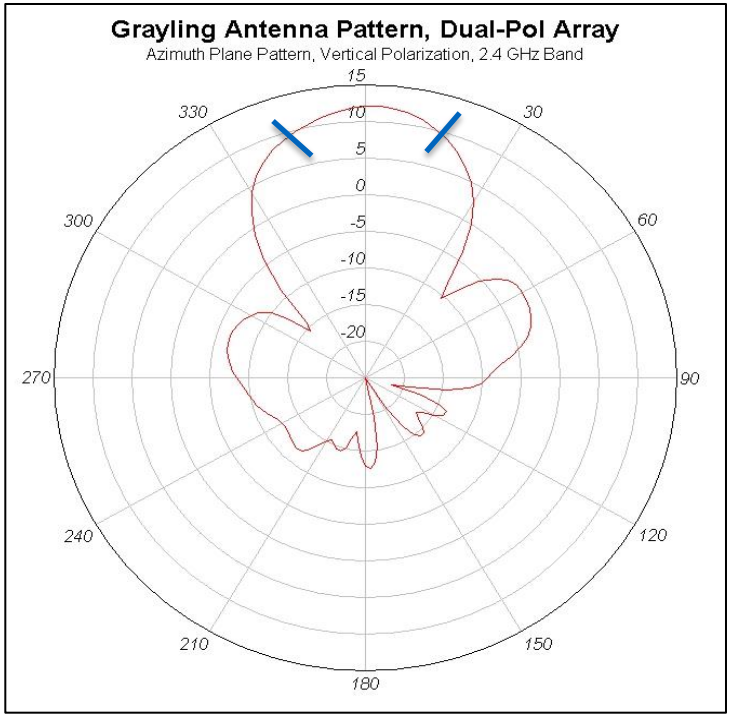
Directional Antenna Options

Product ID	Description H/E Plane		Gain
AIR-ANT2460NP-R	2.4 GHz 80° /75° MIMO directional patch		6 dBi
AIR-ANT5160NP-R	5 GHz 65° /65° MIMO directional patch		6 dBi
AIR-ANT2410Y-R	2.4 GHz 55°/47° single element yagi (1 piece, 3 required)		10 dBi
AIR-ANT25137NP-R	Dual-band 2.4 GHz 36°/36° 5 GHz 55°/48° MIMO directional patch		13/7 dBi
AIR-ANT2566P4W-R	Dual-Band 2.4 GHz 105°/70° 5 GHz 125°/60° 4 element Dual band MIMO		6/6 dBi

Stadium Antenna Specifications

2.4 GHz Patterns (AIR-ANT25137NP-R=)

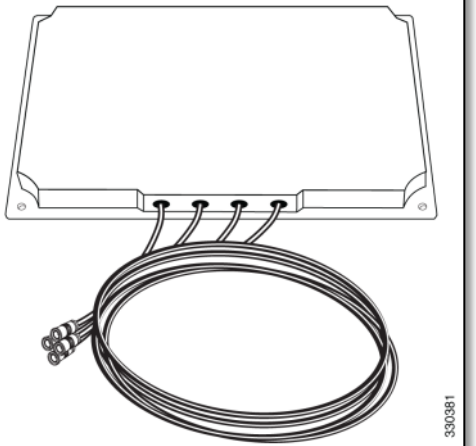
Electrical Parameters	
Antenna Type	MIMO Patch Array
Operating Frequency Range	2400 - 2500 MHz
VSWR	1.7:1
Peak Gain	13 dBi
Polarisation	Cable A = Horizontal
	Cable B = Vertical
	Cable C = Vertical
Azimuth Plane 3-dB Beamwidth	36 degrees
Elevation Plane 3-dB Beamwidth	36 degrees
Front-to-Back Ratio	13 dBi
1st Sidelobe Level	-12 dBc



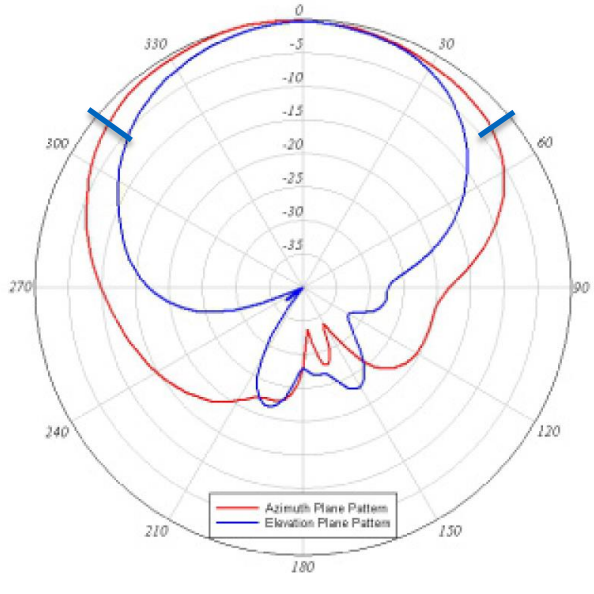
4 Element MIMO Directional Patch

2.4 GHz Patterns (AIR-ANT2566P4W-R)

Antenna type	4-element dual-band MIMO
Operating frequency range	2400 to 2484 MHz
	5150–5850 MHz
VSWR	2:1 or less
Gain	6 dBi in both bands
Polarization	Linear, vertical
Azimuth Plane 3-dB Beamwidth	2.4 GHz band: 105°
	5 GHz band: 125°
Elevation Plane 3-dB Beamwidth	2.4 GHz band: 70°
	5 GHz band: 60°
Length	6.3 in. (16 cm)
Width	11 in. (27.9 cm)
Depth	1.2 in. (3.05 cm)
Weight	1.4 lbs
Cable length and type	3 ft. (91.4 cm) plenum rated
Connector	RP-TNC
Environment	Indoor/outdoor
Operating temperature range	-22° to 158° F
	-30° to 70° C

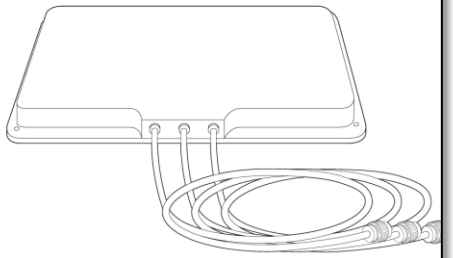


Azimuth and Elevation Radiation Patterns
Left Antenna - 2.4 GHz Band

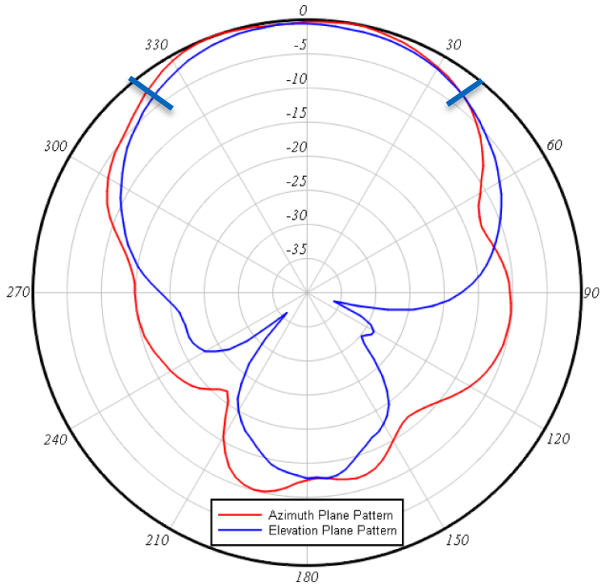


AIR-ANT2460NP-R – 2.4GHz MIMO Patch

Antenna type	3-element MIMO patch
Operating frequency range	2400–2484 MHz
VSWR	2:1 or less
Peak gain	6-dBi
Polarization	Linear, vertical
Azimuth plane 3D beamwidth	80°
Elevation plane 3D beamwidth	75°
Front-to-back ratio	10-dB
Length	5.8 in. (14.7 cm)
Width	11.25 in. (28.57 cm)
Depth	1.13 in. (2.87 cm)
Cable length and type	3-ft(91.4 cm), plenum rated
Connector	RP-TNC
Environment	Indoor/Outdoor
Operating temperature	-22° F to 158° F (-30° C to 70° C)

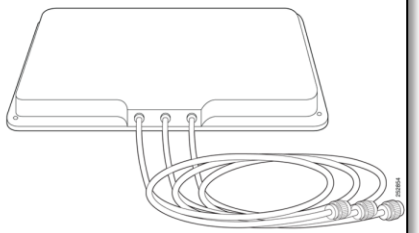


Left Antenna Azimuth and Elevation Radiation Patterns

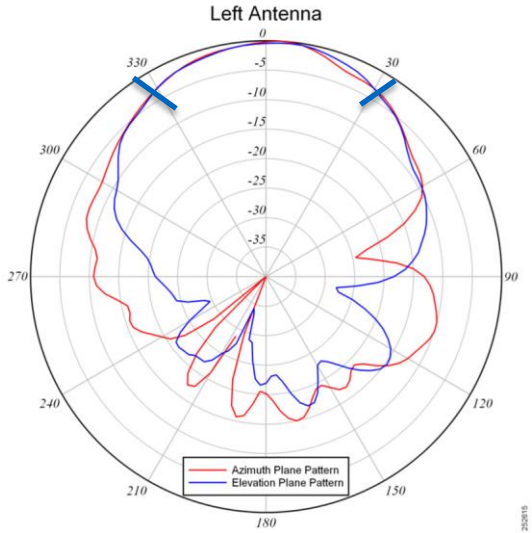


AIR-ANT5160NP-R 5 GHz MIMO Patch

Antenna type	3-element MIMO patch	See Figure 1.
Operating frequency range	5150–5850 MHz	
VSWR	2:1 or less	
Gain	6-dBi	
Polarization	Linear, vertical	
Elevation Plane Beamwidth	65°	
Azimuth Plane Beamwidth	65°	
Front-to-back ratio	>15 dB	
Length	4 in. (10.16 cm)	
Width	7 in. (17.78 cm)	
Depth	1 in. (2.54 cm)	
Cable length and type	3 ft. (91.4 cm) plenum rated	
Connector	RP-TNC	
Environment	Indoor/outdoor	
Operating temperature	-22° to 158° (-30° to 70°)	



Azimuth and Elevation Radiation Patterns



CiscoLive London 2012

- 28 x 3502i AP's
- 25 with 2.4GHz enabled
- 18 Mbps first Mandatory data rate
- 4500 seats – 20-30 % take-up
- We call this Carpet Bombing

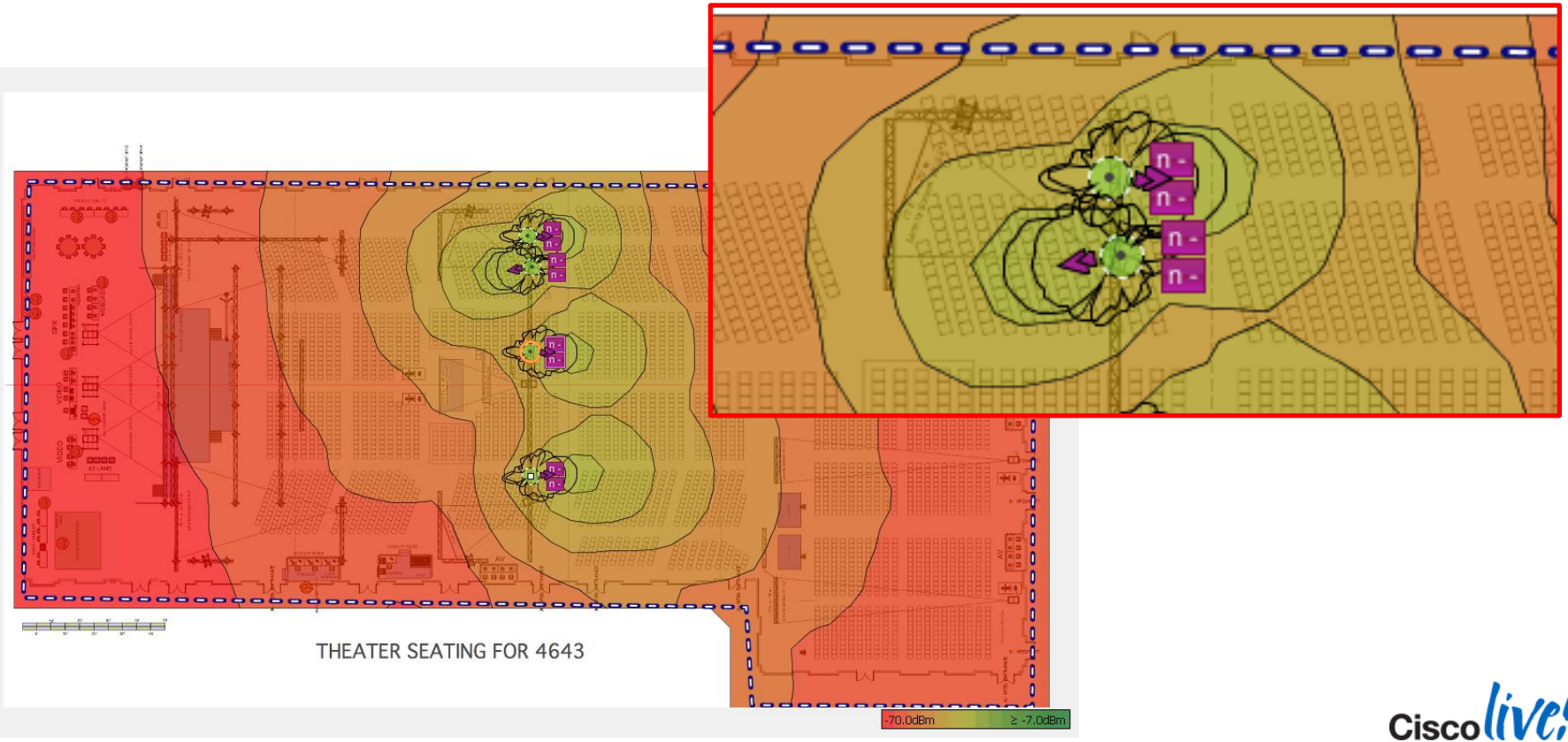
- AP's spaced ~10m apart
- Even coverage
- Placed centre mass

CiscoLive London 2013

- 22 x 3502P's mounted overhead
- 22 with 2.4Ghz enabled
- 24 Mbps first mandatory data rate
- 4500 seats – 30-40% take-up expected
- Everybody was a hero

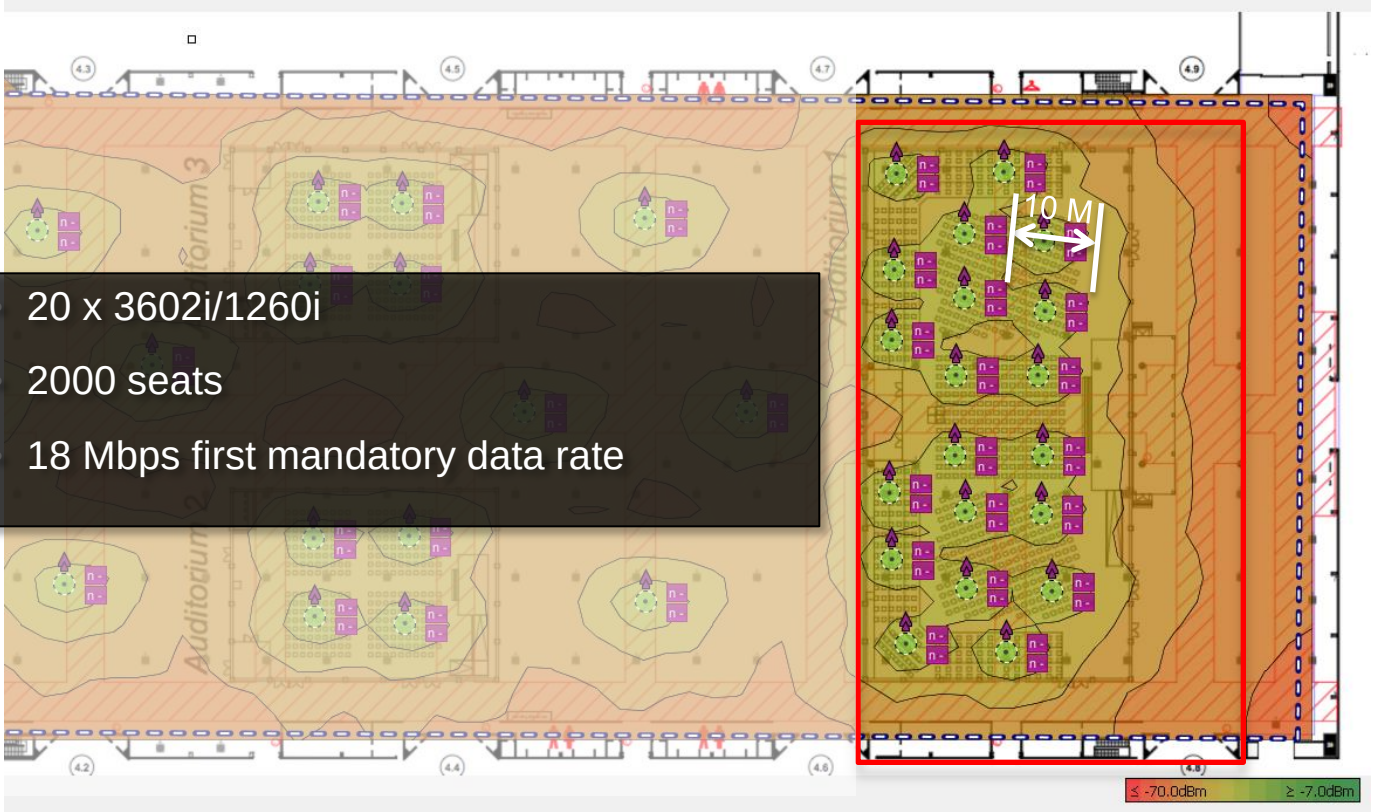
- Used AIR-ANT25137NP-R=
- Rail height was 12m (38 ft)
- No closer than 10m, no farther than 30m

Front to Back Ratio – is Good



Theatre-Auditorium

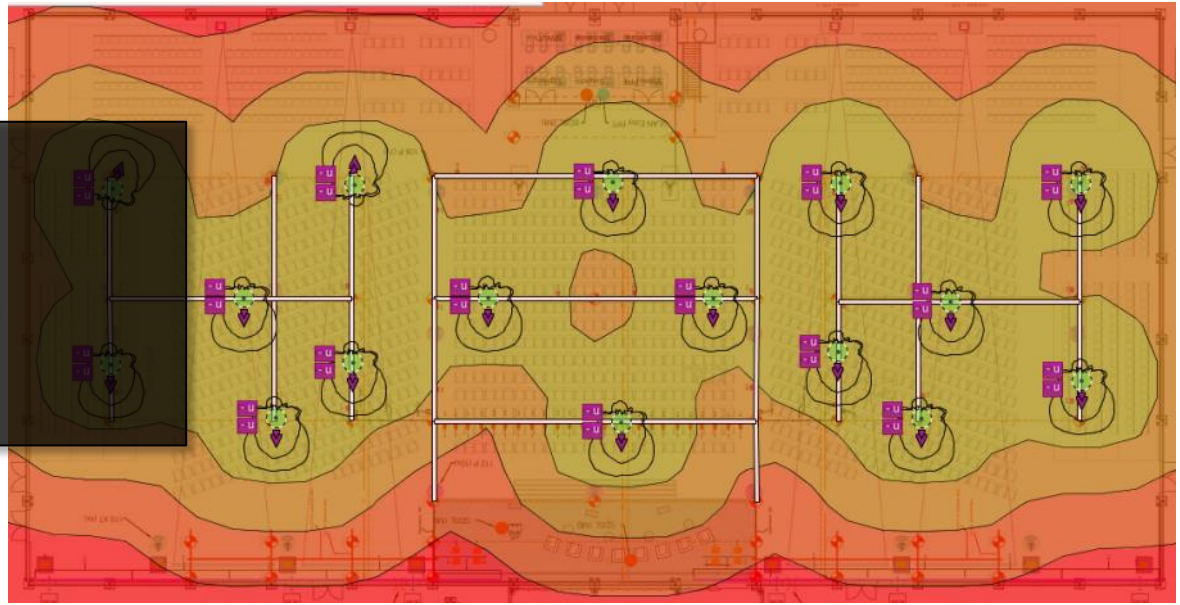
High Density Coverage



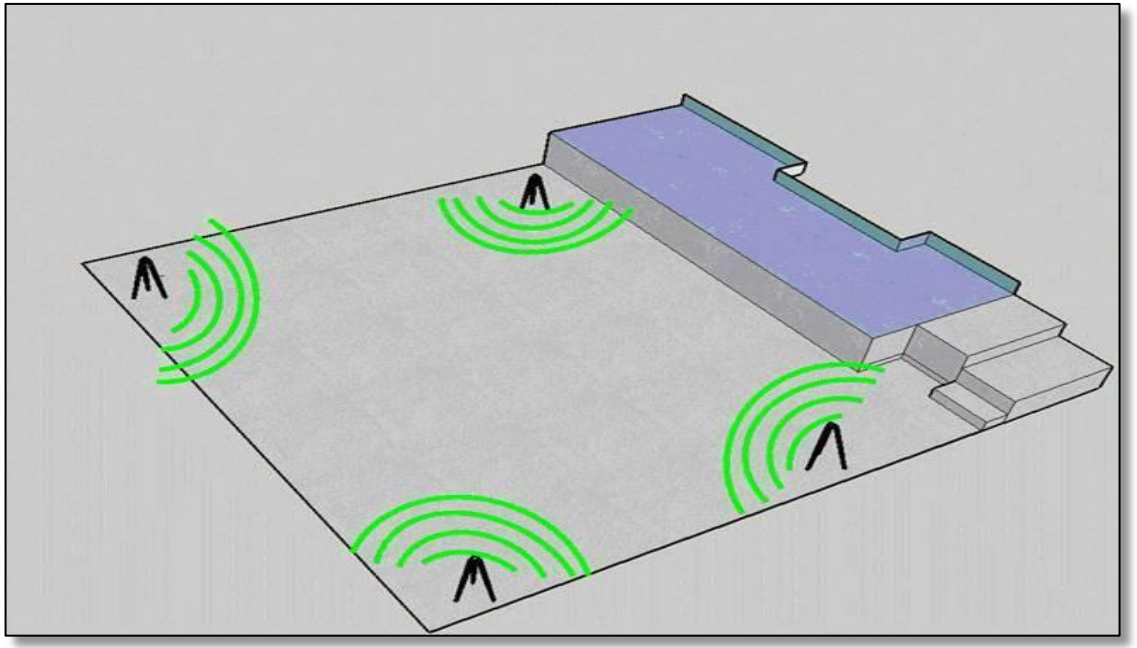
- 20 x 3602i/1260i
- 2000 seats
- 18 Mbps first mandatory data rate

MWC-2013 Auditorium 1

- 16 x 3502e
- 2000 seats
- 24 Mbps first mandatory data rate
- 55% take rate



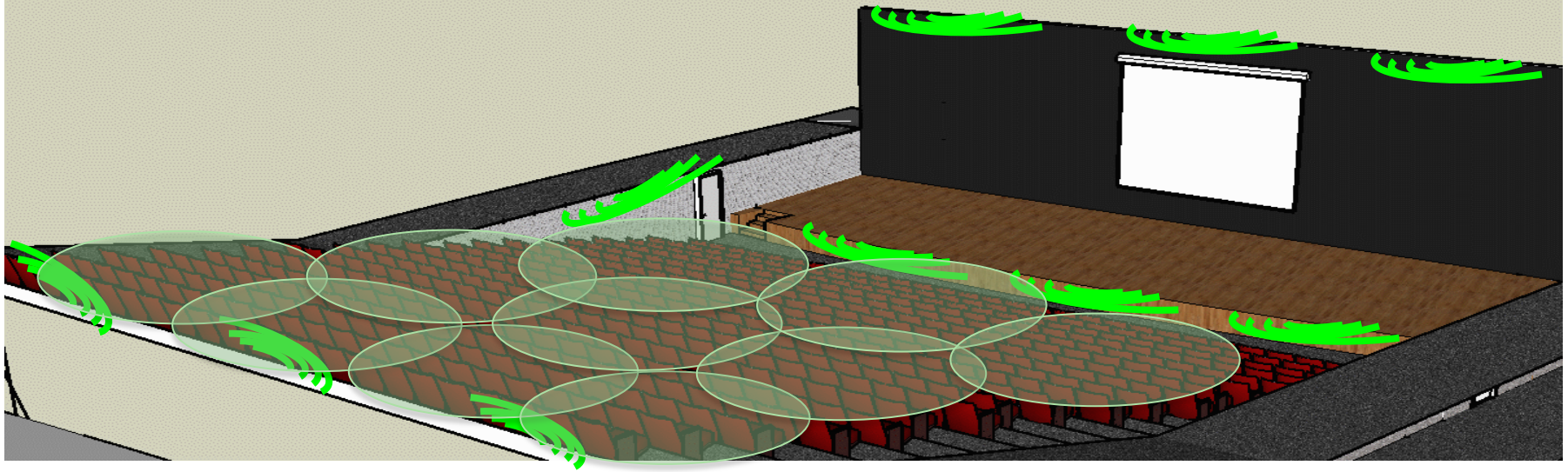
Theatre – Auditorium
Casual Coverage



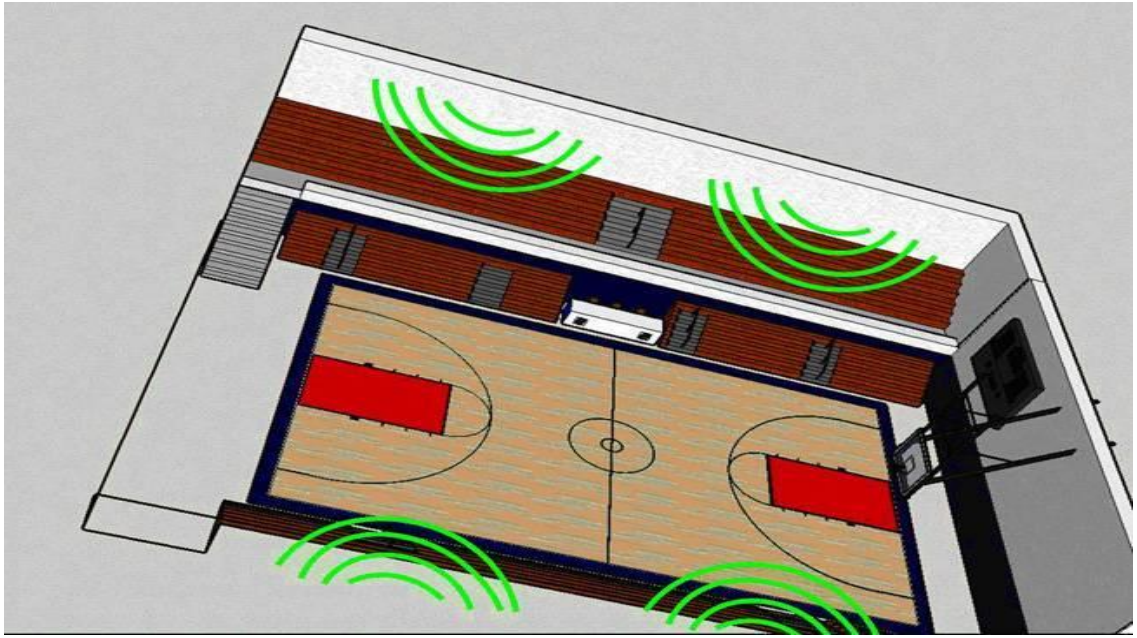
- Use Tripods and Omnis to mount APs
- Illuminating from the corners encourages cell separation
- Antennas pointed up!

Theatre – Lecture Hall

Overhead Is Optimal, but Using Directional Antennas Can Get You Where You Need to Be – 460 Seats 11 APs/Channels



Small Sporting Event

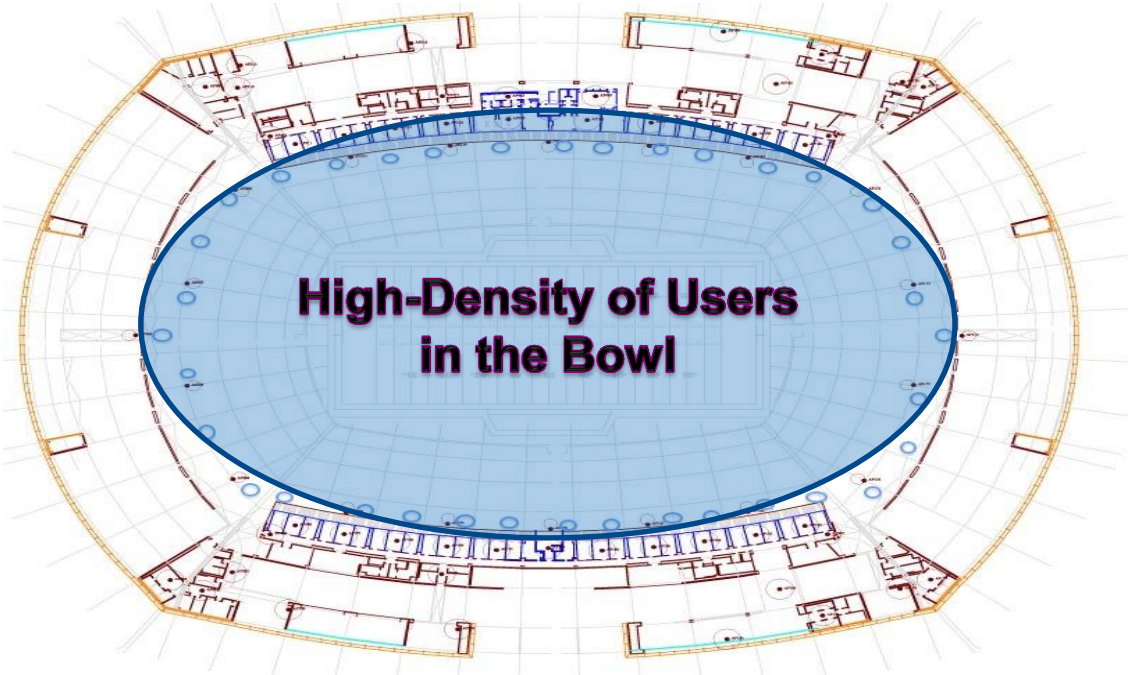


- Illuminating from the sides focuses energy near users
- If illuminating from the centre out is an option - better
- The centre is not likely to need much connectivity
- Omni, Patch, or wall mounted antennas

Large Venue High Density

20K Seats and Up

- ✓ Divide the coverage area into cells to support the application and anticipated number of application users
- ✓ Use APs with Directional Antennas to create WLAN cells within the seating areas
- ✓ Use down-tilt to control the vertical RF beam width
- ✓ Design and Install for both 2.4 GHz and 5 GHz support
- ✓ If dual-band APs are used, verify if PoE+ switches are required to power the AP



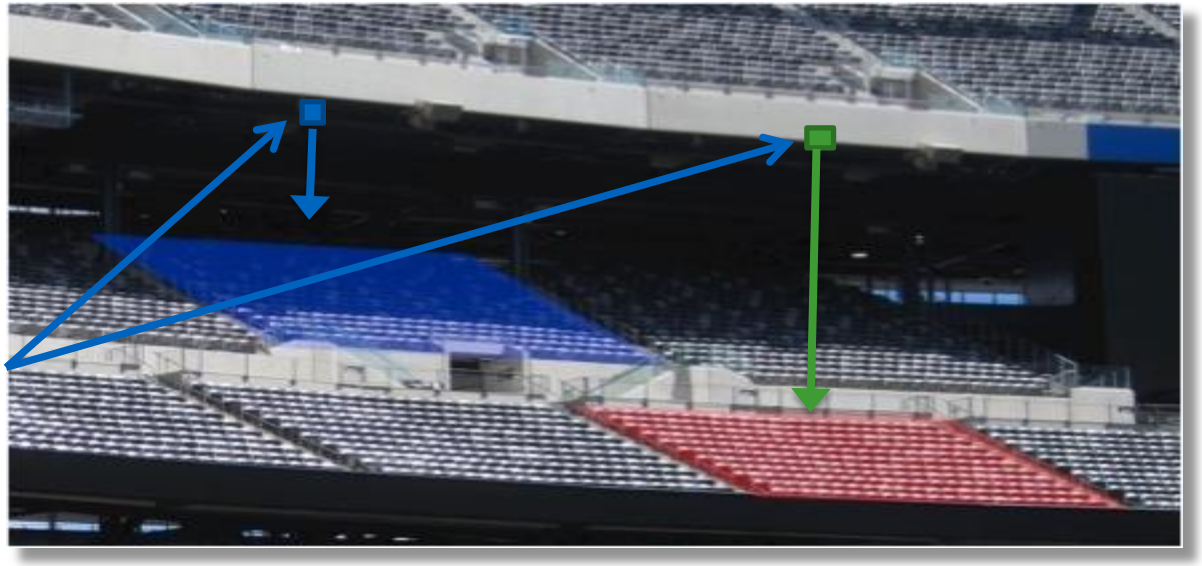
Note: Where APs May Be Physically Mounted in the Stadium Also Effects Capacity Design

Example: Single Tier

- 480 Seats (blue)
- 322 Seats (red)

- One AP per section

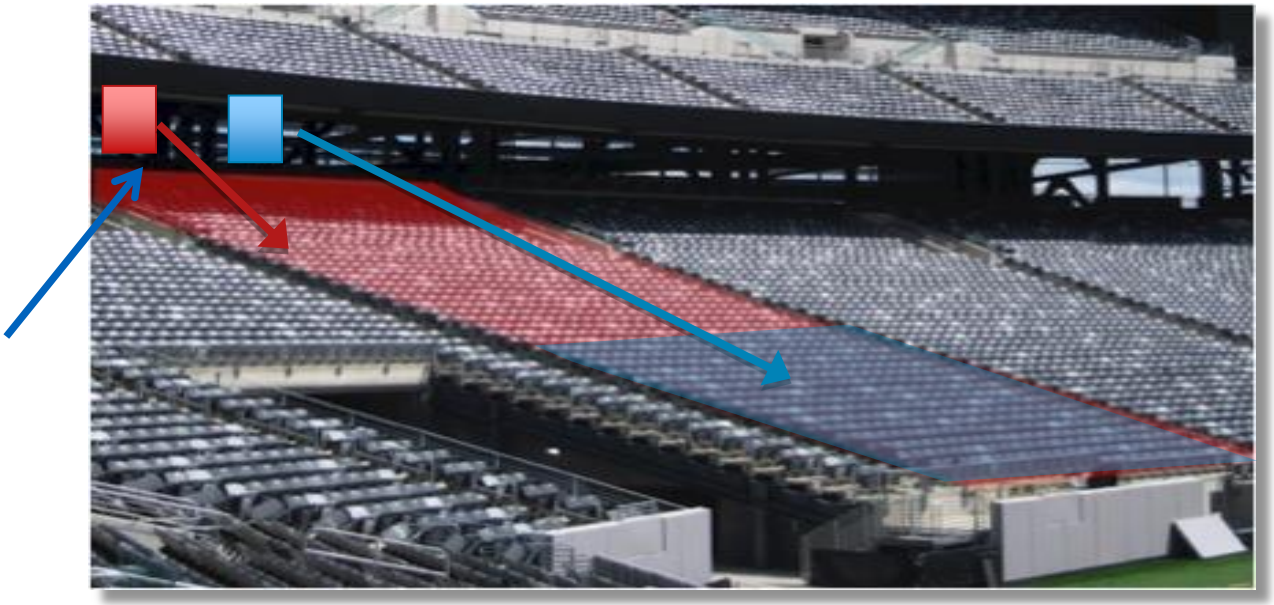
  Dividing Up the Coverage Area Depends on Where AP/Antennas May Be Mounted



Example: There is Such a Thing as Too Aggressive

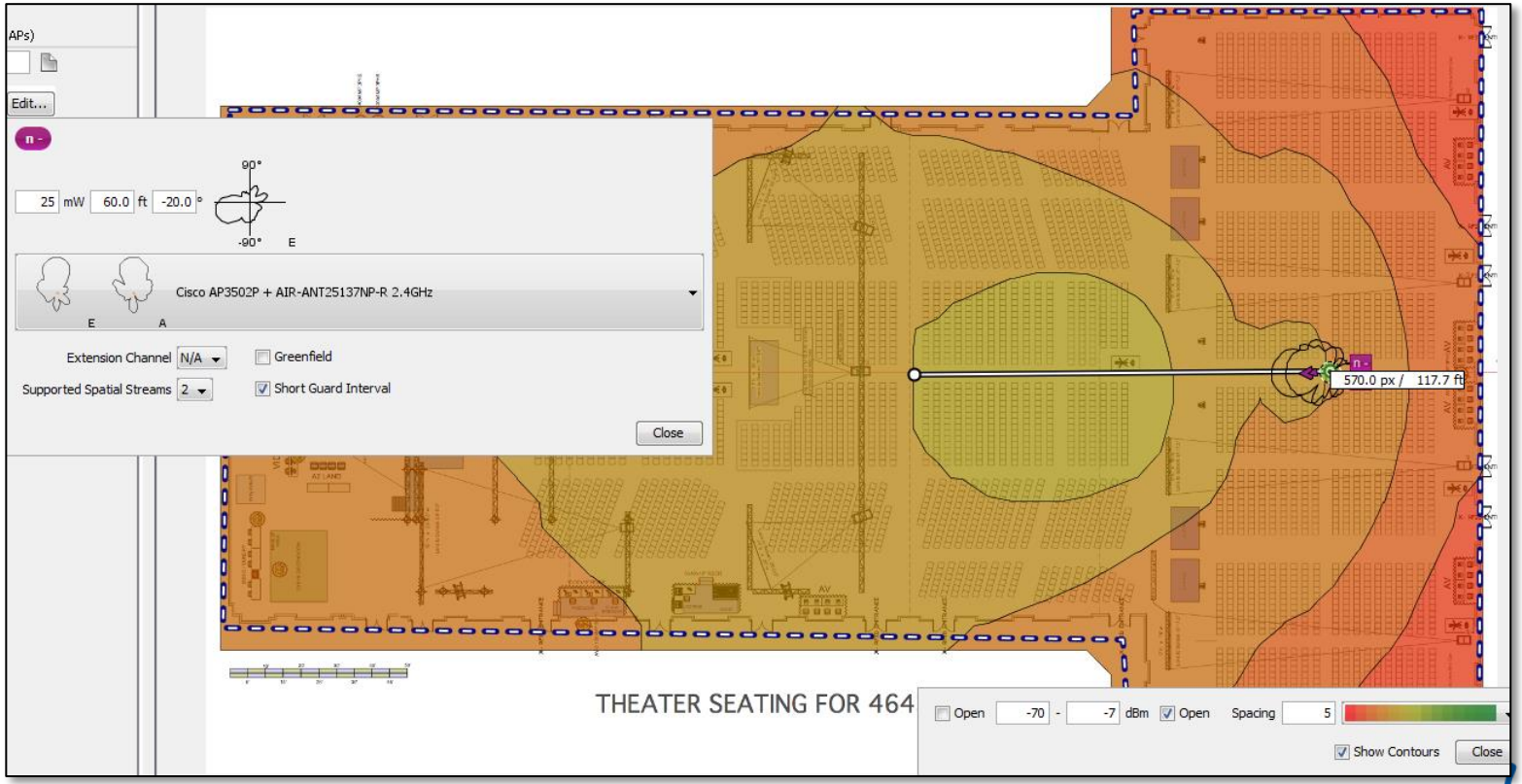
- 1020 Seats
- 29m Deep
- 14m Wide

Seating sections in the lower bowl are Served by a different AP



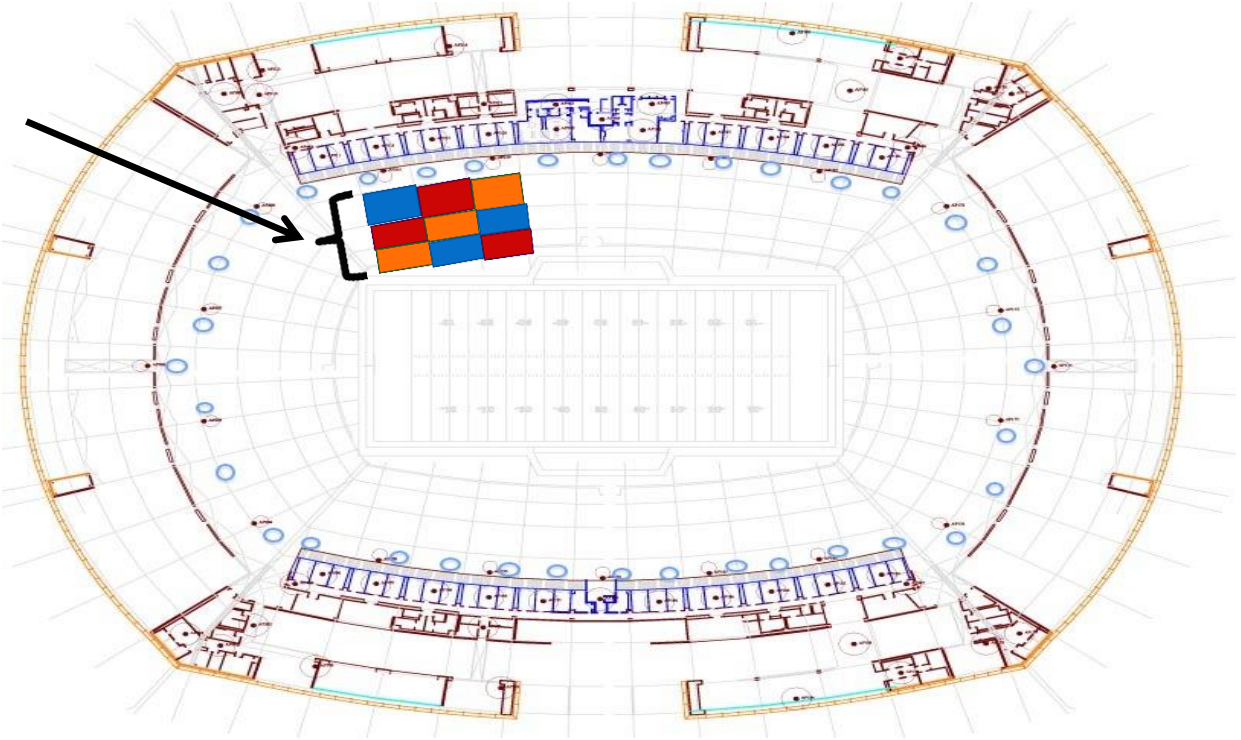
The Mighty Stadium Antenna (Grayling)

AIR-ANT25137-NP-R

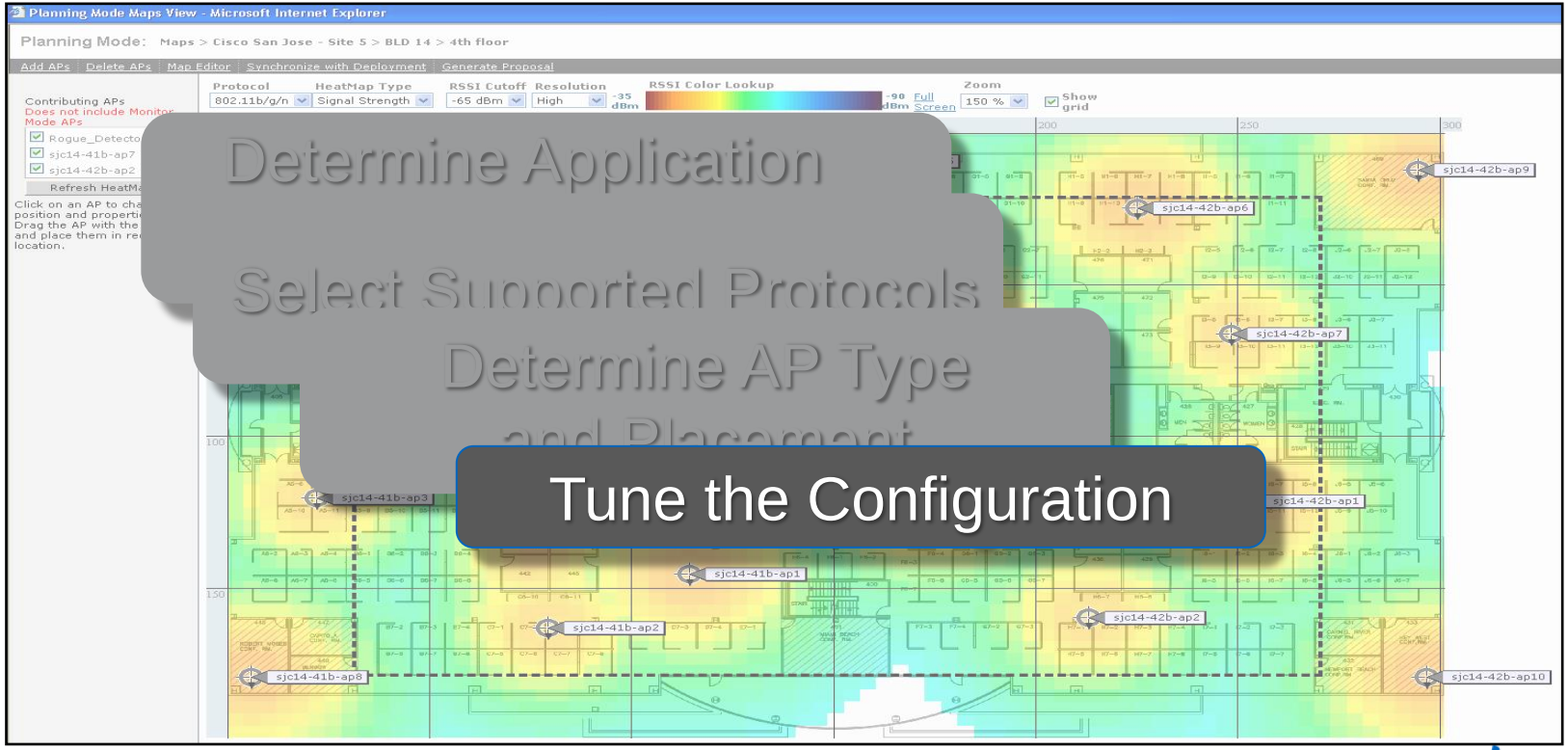


Bowl Seating RF Cell Footprint

- Overlapping cells should use non-overlapping channels (shown is the use of the 3 non-overlapping channels in the 2.4 GHz domain)
- Use Radio Resource Management (RRM) to automatically set the AP channel and power
- Sub-dividing fan seating with an AP/Directional Antenna depends on where APs can be mounted and pointed



Design Steps



Managing the Resulting RF

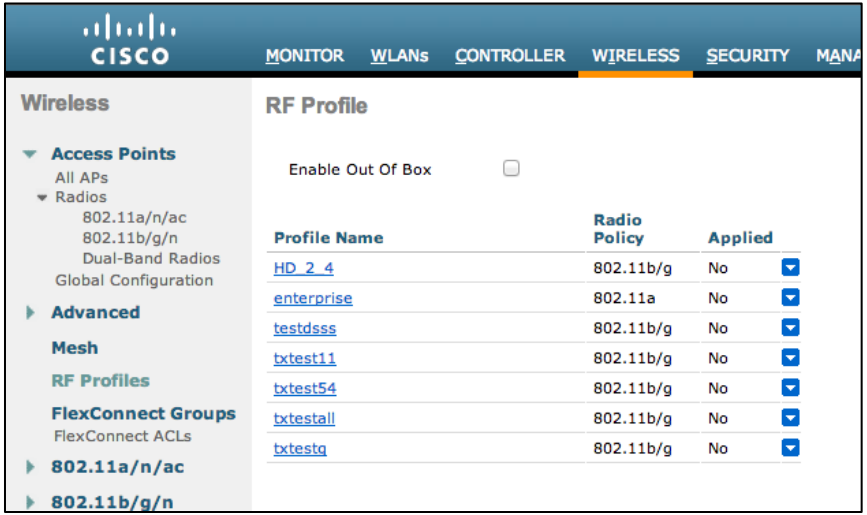
- Use RRM? Oh you betcha ! - RRM profiles available since 7.2!
- DCA will establish and maintain channel plan with changing interference levels – this is a good thing
  - DCA Channel sensitivity = LOW (20 dB)
  - Ensure you run a start-up – AFTER all AP's are in place
    - (Cisco Controller) >config 802.11b/a channel global restart
- TPC Threshold to adjust power levels to the floor
- TPC Min/Max – always set min – prevents cool down in empty room and maintains power levels for a ready network
- Minimise cell foot print by eliminating lower data rates
- Tune RX-SOP as needed – be very very careful – a little goes a long way

Highly Recommend Version 7.2 or Greater

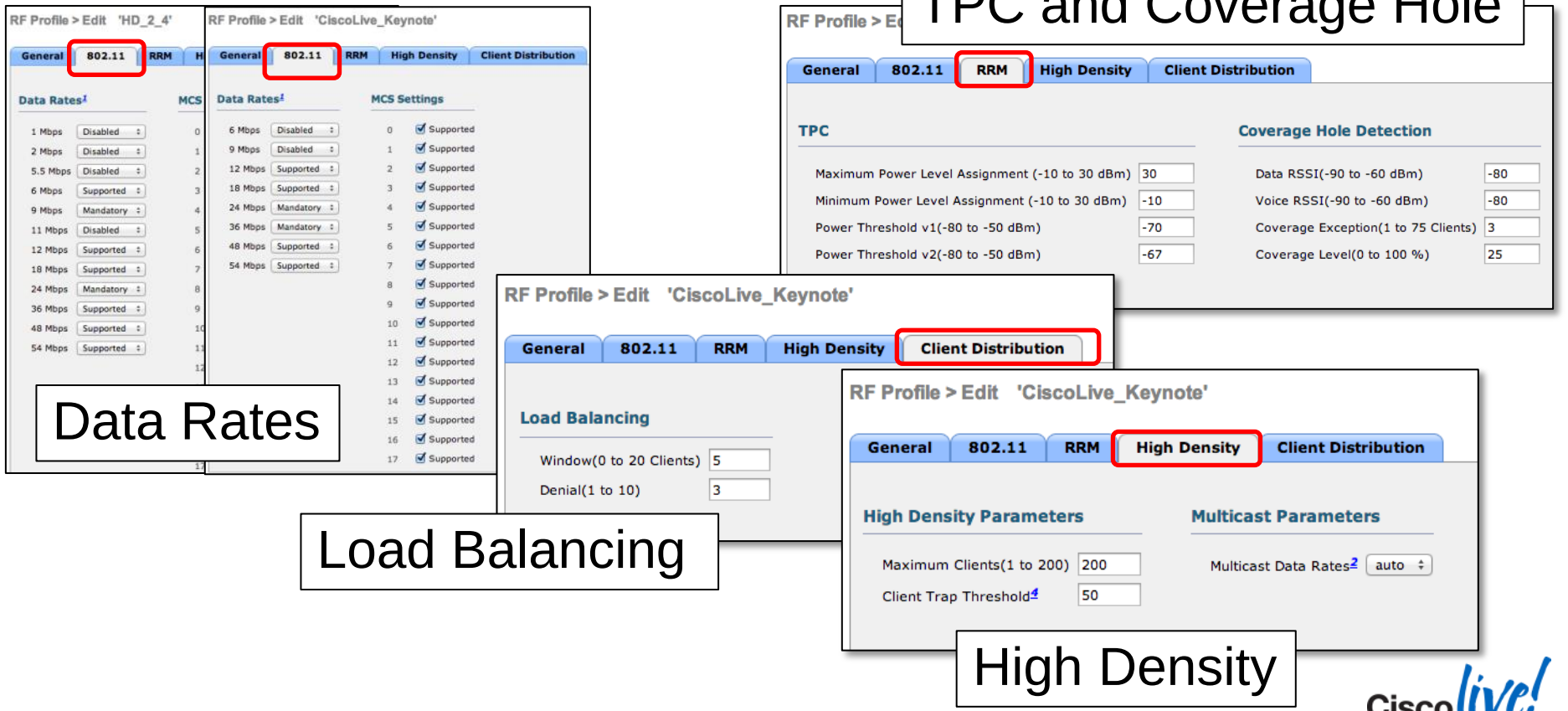
RF Profiles – RRM – Create

- RF Tuning parameters can be applied through profiles assigned in AP groups
- 2 Profiles per AP group – 1 each 2.4 and 5 GHz
- Profiles must be applied on ALL WLC's from which AP's will be assigned (same as AP Group)
- Permits control of granular groups of AP's
- We love it…

Wireless -> RF Profiles

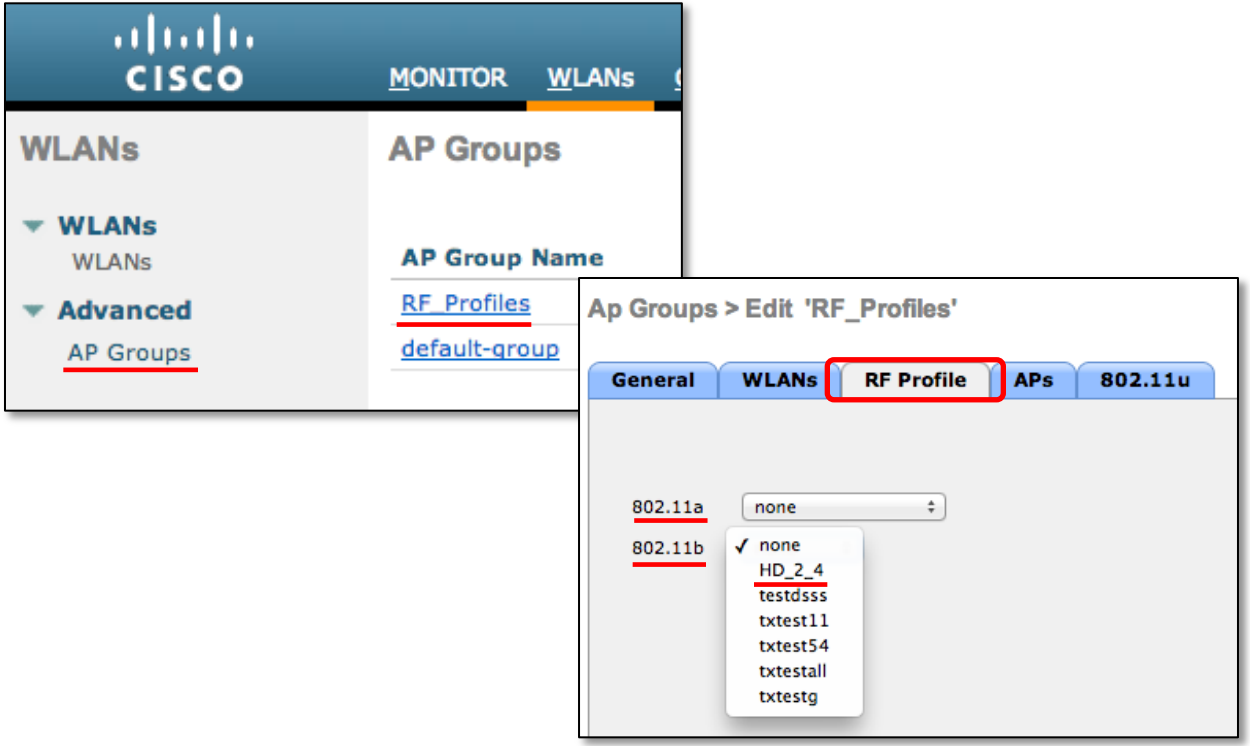


Profiles : Granular Control



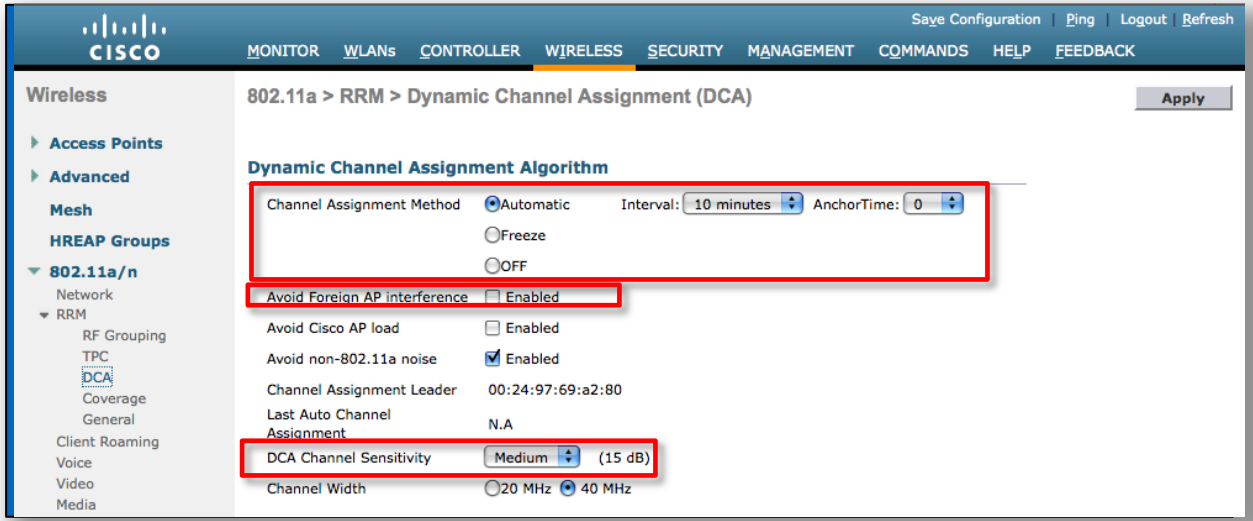
Profiles – Applied Through AP Groups

- Create Profiles
- Create or edit AP Groups
- Apply Profiles (2.4/5 Ghz) to AP groups
- Assign AP's



DCA Settings

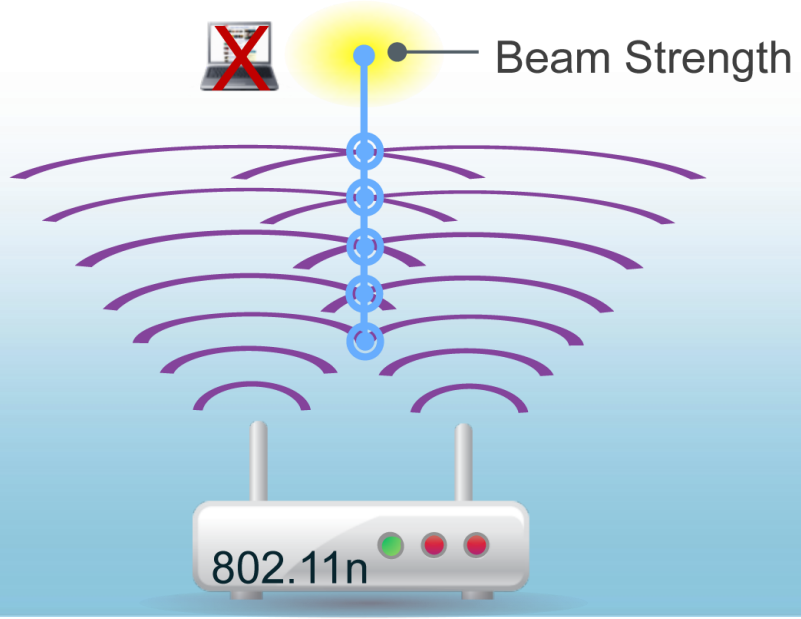
- Set DCA to Automatic
- Avoid Foreign AP interference
- Threshold for change can be managed by changing to low sensitivity – 20 dB improvement required for channel change
- Ensure DCA has run through startup



The Problem

Beam Strength not Directed to Client

802.11a/g (ClientLink)
802.11a/g/n (ClientLink 2.0)



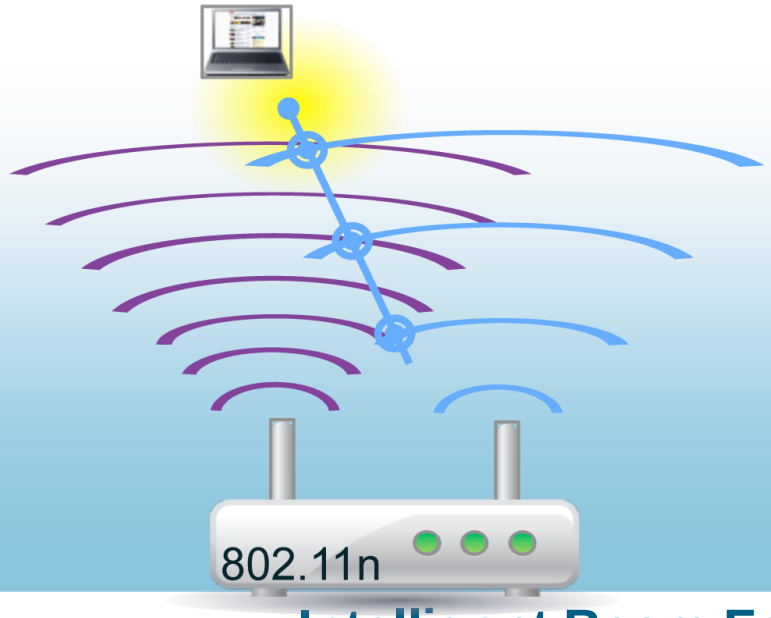
802.11a/g/n/ac Client Connection Not Optimised, Creates Coverage Hole/Rate Shifting

The Solution

Cisco Innovation: ClientLink 3.0

802.11a/g (ClientLink)

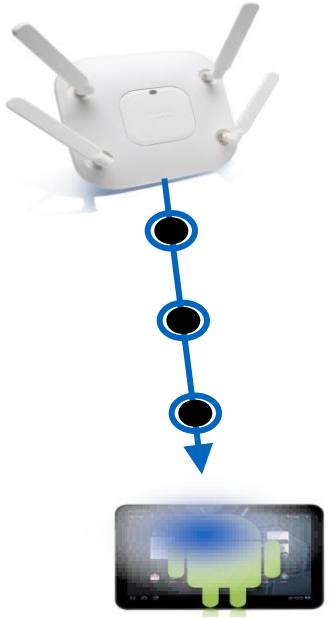
802.11a/g/n (ClientLink 2.0)

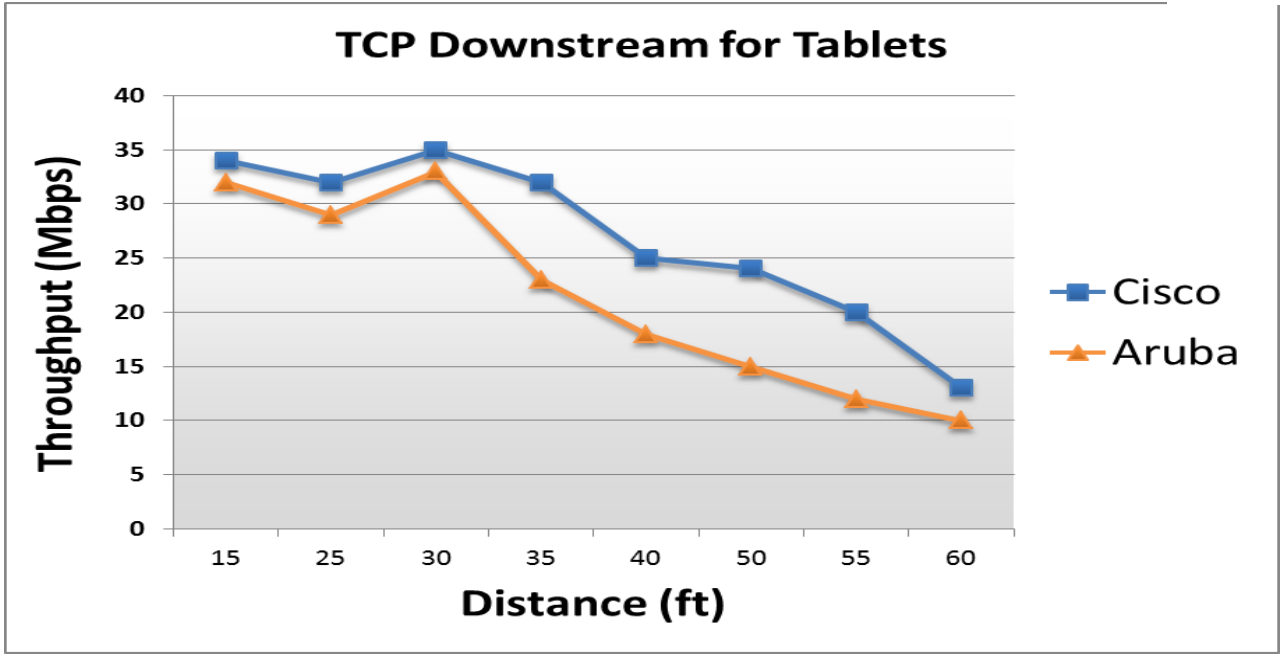


Intelligent Beam Forming Directs Signal to Improve Performance and Coverage for 802.11a/g/n/ac Devices

Cisco ClientLink 2.0

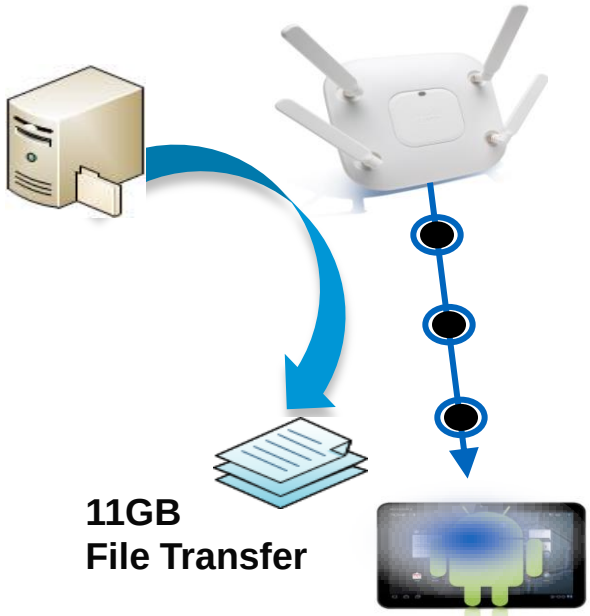
1SS Client Performance Miercom Results





- With a Motorola Xoom, one spatial stream client performance is an average of 32% better with Cisco 3600.

ClientLink 2.0 Battery Life Improvement Test

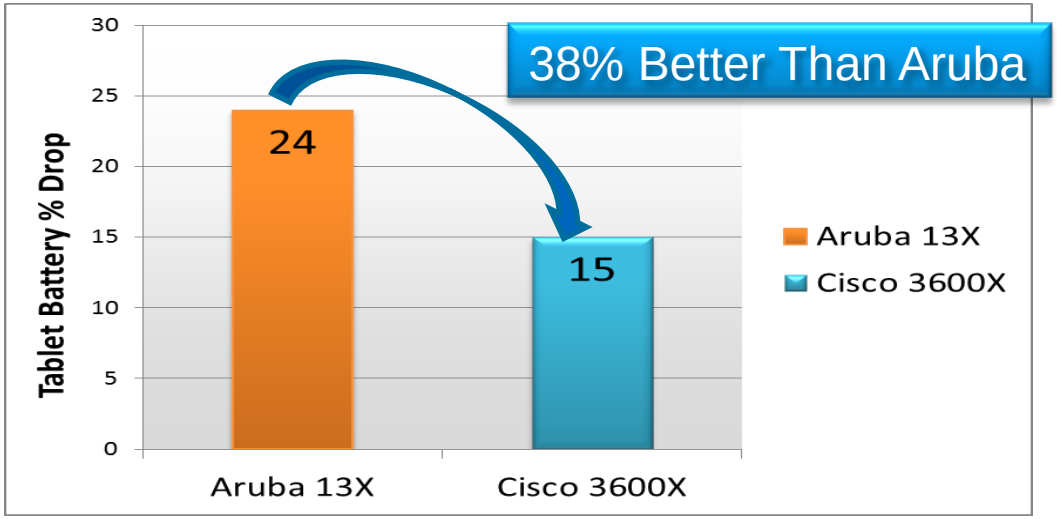


Total Time Taken

Total Battery Drop

- 10m Distance from Access Point to Motorola Xoom
- Download a file via FTP till complete and observe battery drop.

Battery Life Improvement Results



- Total GB tablet can download before hitting 100% battery drain

  Cisco = 73.33GB

  Aruba = 45.83GB

	Start Battery	End Battery	Total Battery Drop	Download Time
Cisco 3600e	75%	60%	15%	56 min
Aruba AP 134	75%	51%	24%	70 min

Load Balancing

Implementation

- The threshold to start load balancing is configured as a number of clients
- Association denied (Code 17) frames will be sent to clients who attempt to associate to loaded APs
- If the client does not join a different AP, the “loaded” AP will allow the client to associate after a number of retries (default is 3)
- Configured on a per-controller basis at a global level
  - Can be overridden for specific WLANs
- Data Rates correctly set will be far more deterministic

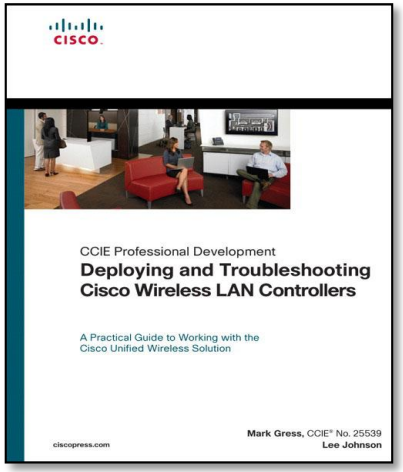
For your Reference

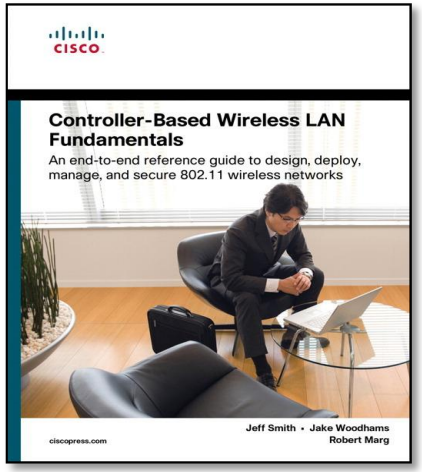
Cisco 802.11n Design and Deployment Guidelines:
http://www.cisco.com/en/US/solutions/collateral/ns340/ns394/ns348/ns767/white_paper_80211n_design_and_deployment_guidelines.html

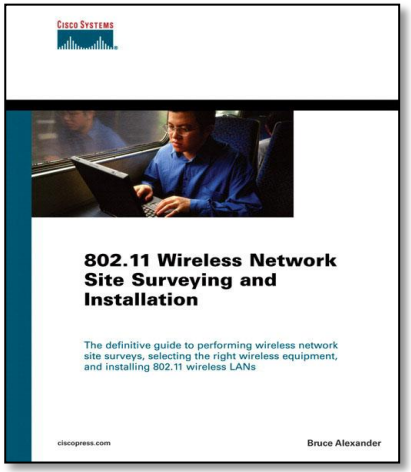
Cisco High Density Wireless LAN Design Guide:
http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps10981/design_guide_c07-693245_ps10315_Products_White_Paper.html

Cisco Clientlink 3.0 White Paper:
http://www.cisco.com/c/dam/en/us/products/collateral/wireless/aironet-3600-series/at_a_glance_c45-691984.pdf

Recommended Reading







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