



Managing the mobile device wave: Best Practices

BRKEWN-2019



Session Objectives

- At the end of the session, the participants should be able to:

- Define High Client Density

- 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 educate end customers and 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, AP's
- Practical application

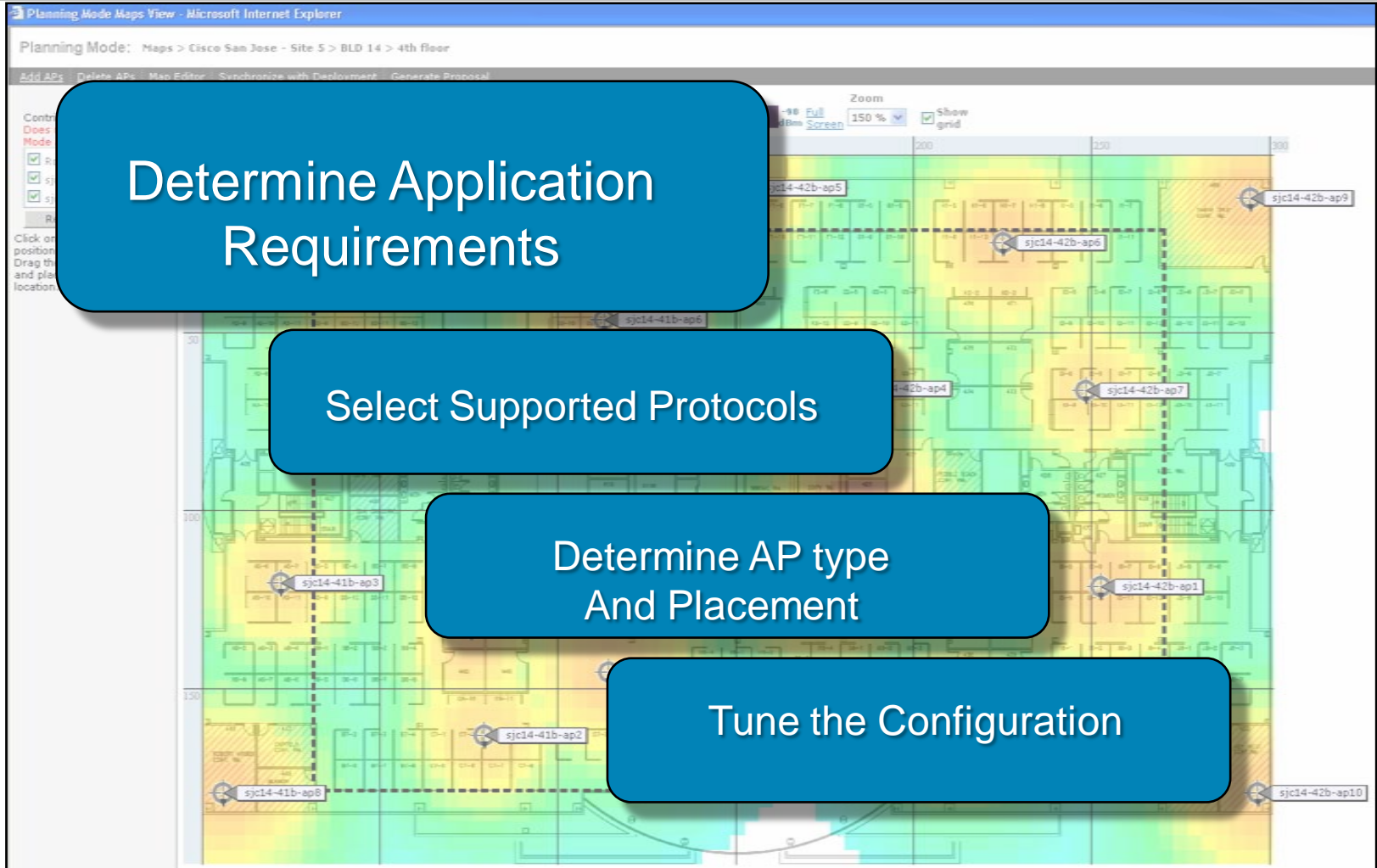
What Will Not be Covered

- Specific Applications and their Performance
- Wired side considerations and resource requirements
 - Security Services
 - Application server performance

Why High Client Density?

- Mobility has rapidly changed how we use and what we expect of wireless network resources
- Wireless is fast becoming the preferred option in edge technology and in a lot of cases the only practical one
- The need to provide high performance wireless connectivity to large dense groups of clients exists today in auditoriums, classrooms, lecture halls, sporting arena's
- The same principles are becoming increasingly necessary in traditional coverage models due to the explosion of 2.4 GHz smart devices and increasing connection counts per seat
- 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 Ethernet, is a shared medium
- Aggregate throughput is the total bandwidth shared by all users in a cell
- Generally, 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?

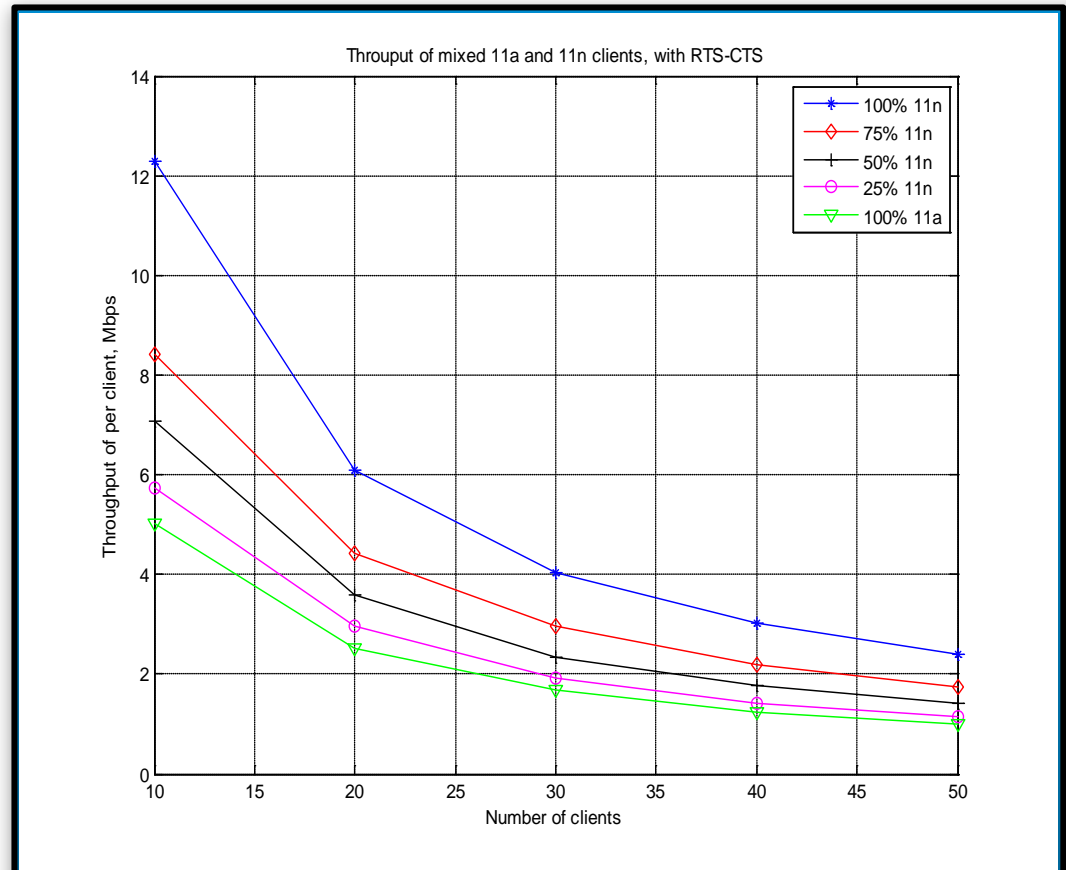
On average, what amount of per user throughput do you need to provide?

Per-User Application Throughput examples

Technology	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

What about HT20 rates?

- What is your expected mix of HT20 to legacy clients?
 - Few have the luxury of establishing and maintaining a fixed ratio – be sure
- The delta between 100% 802.11n clients and 100% legacy 802.11a clients is a 312% increase/decrease
- A 50/50 mix however drops that advantage to 34% increase
- As user density increases the spread narrows



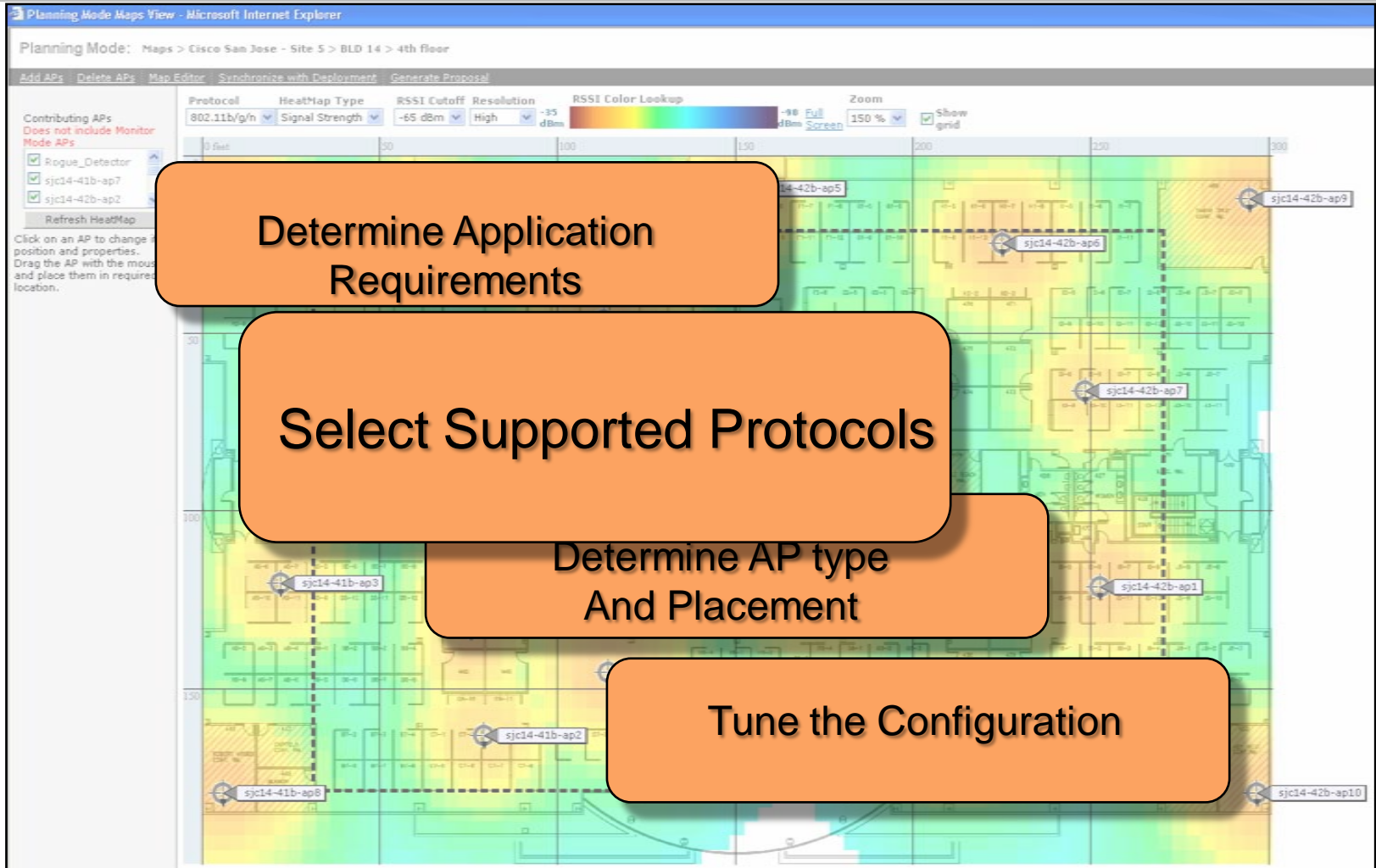
How Much Bandwidth is Required?

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

Design Steps



Channel Throughput by Protocol

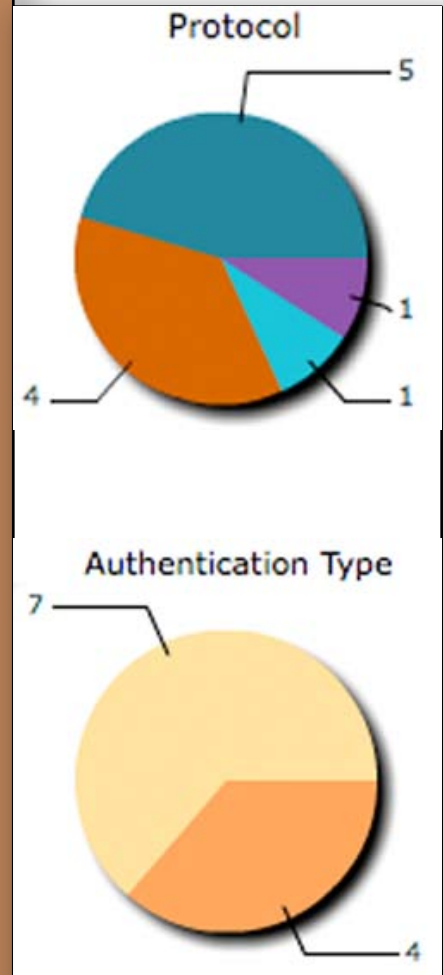
Protocol	Throughput (Mbps)
802.11b	7.2
802.11b/g mix	13
802.11g	25
802.11a	25
802.11n (HT20 2ss MCS15)	70*

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

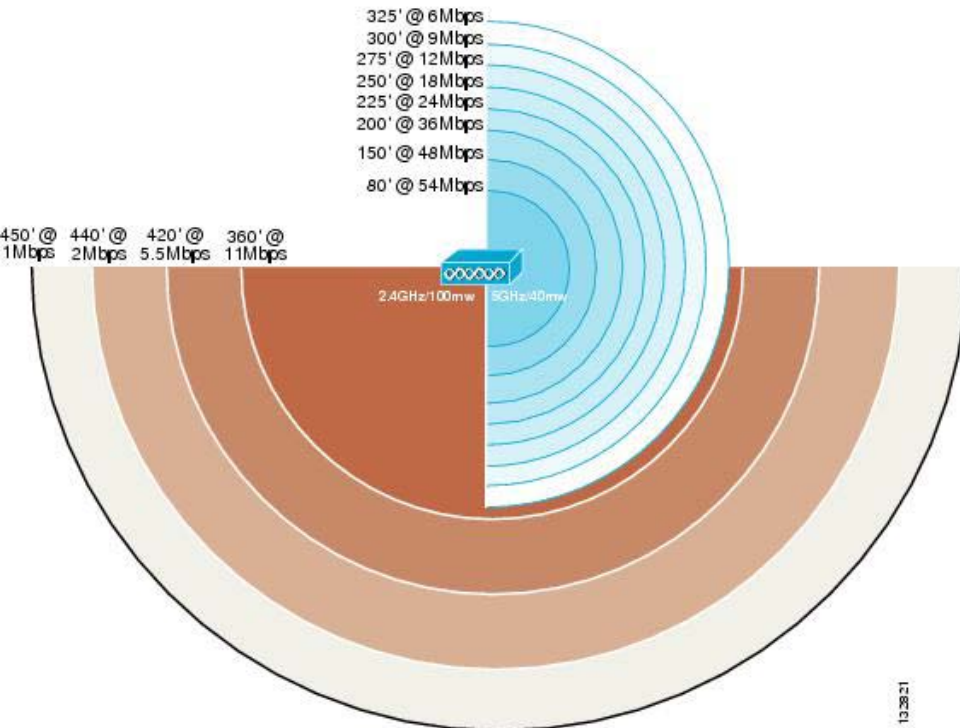
* Two spatial streams – note most PDA's are SISO (MCS 7) 35 Mbps max

Points to Consider

- 3 non-overlapping channels in 2.4 GHz
4 possible in EU/J with 1,5,9,13 – 14
- 12-21 non-overlapping channels in 5 GHz (check your regulatory domain)
- Not all clients will be able to use DFS channels or 802.11n – 100-140 least supported
- 802.11n AP's will buy a lot of advantage for legacy a/g clients
- In general – treat 802.11n clients as a bonus and **Do Not** count on the number that will be able to use it unless you have certain knowledge of their presence
- 5 GHz will be critical to supporting High Density



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 Utilization – is the aggregate of every radio on the channel that can be heard above -85 dBm – this means clients too.

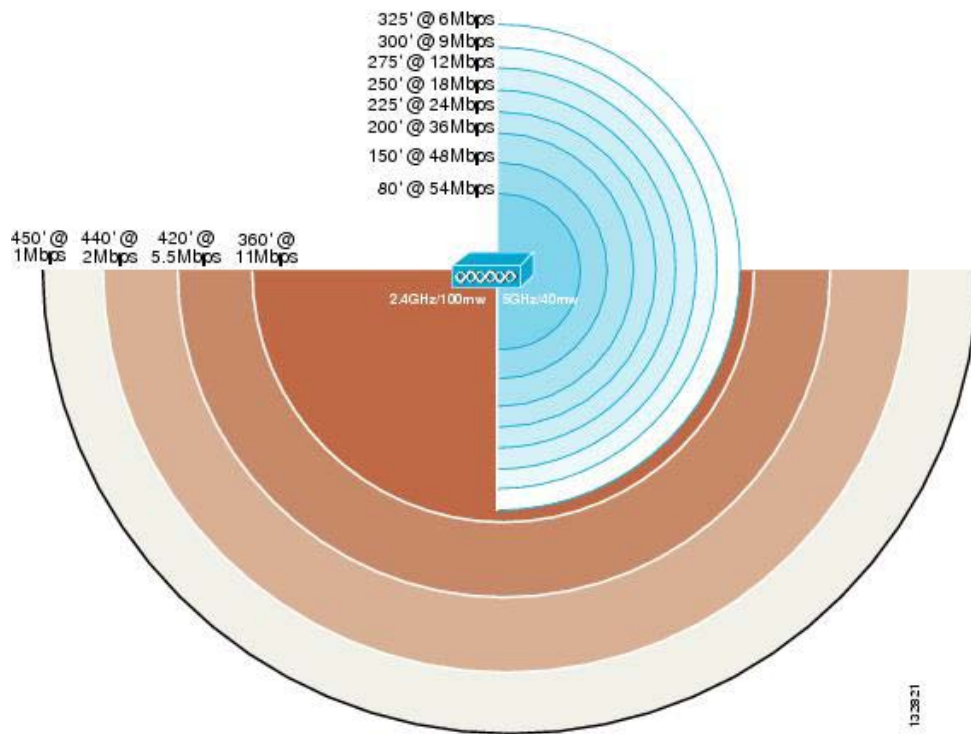
Channel Re-use

- The question is – how many channel's can I get in a room?
- Co-channel interference from Client Radios will be the single biggest obstacle- WHY?

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

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
- With 802.11n radios CCA is typically linked to Preamble/Start of packet
- Radios are better (mostly)
- CCA - is -85 dBm for 802.11b/g/a
- If you can hear it above that – 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 10-15 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 optimizing every aspect within our control

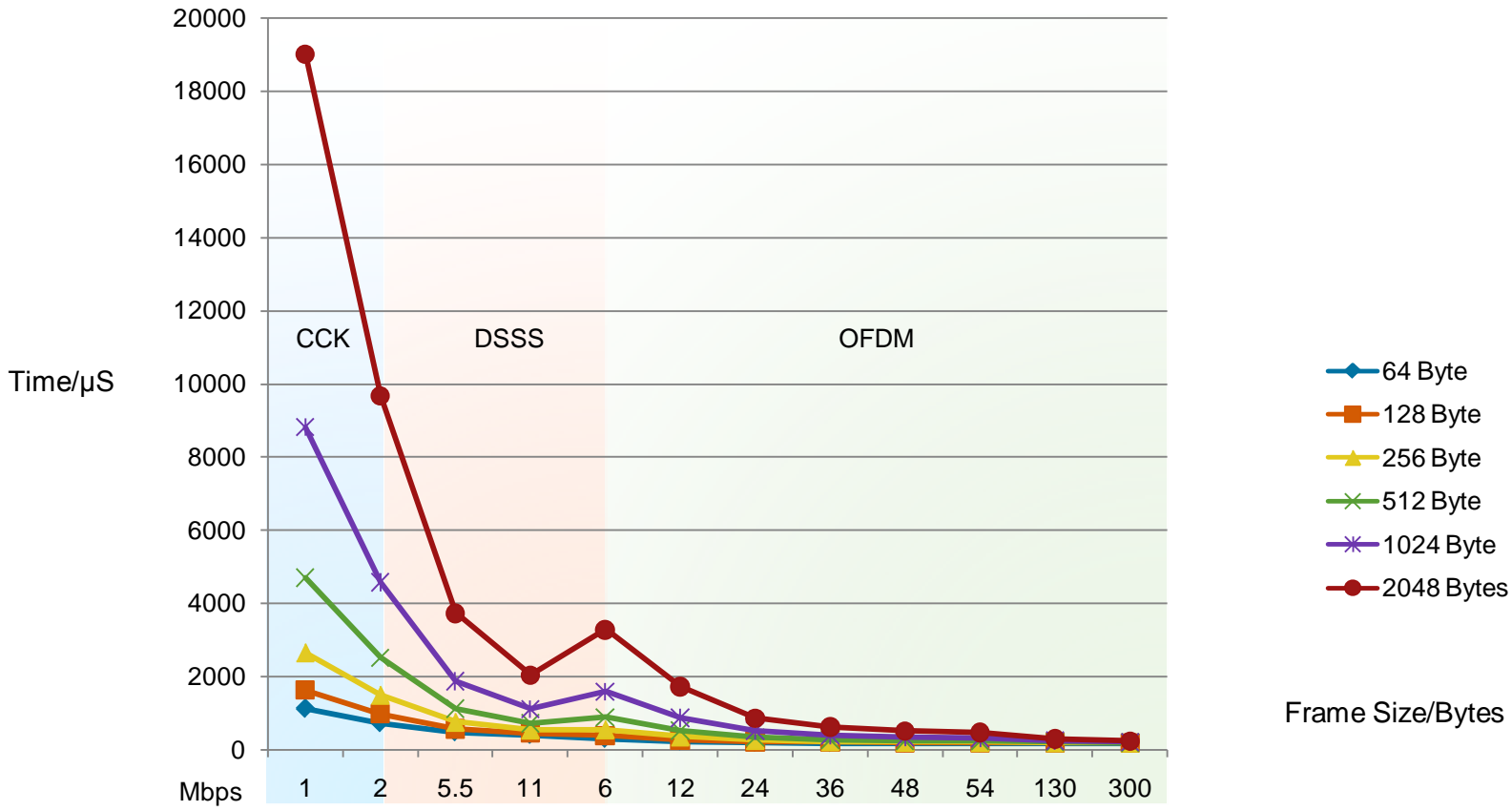
Channel Efficiency

- Range versus rate is something that we are generally working to maximize in a coverage design - However
- In High Density Design, the reverse is actually true – we want to minimize the propagation of a cell
- Minimizing 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
- Properly applied, this will maximize 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 utilization, 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

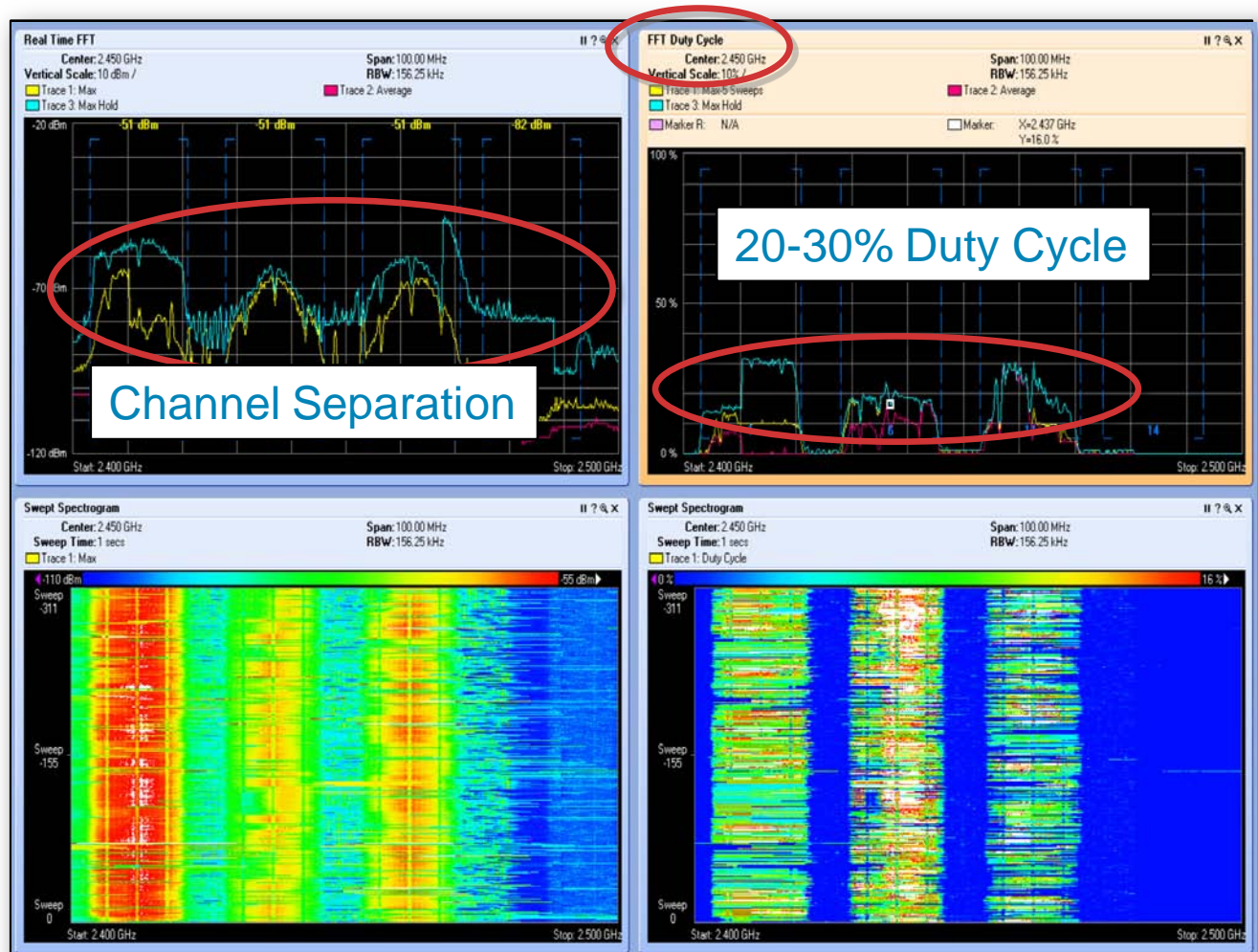
Understand Protocol Selection 802.11 b/g/a/n and Duty Cycle—Important? Why?



Spectrum is a Shared Finite Resource

Duty Cycle and Spectrum 802.11 b/g

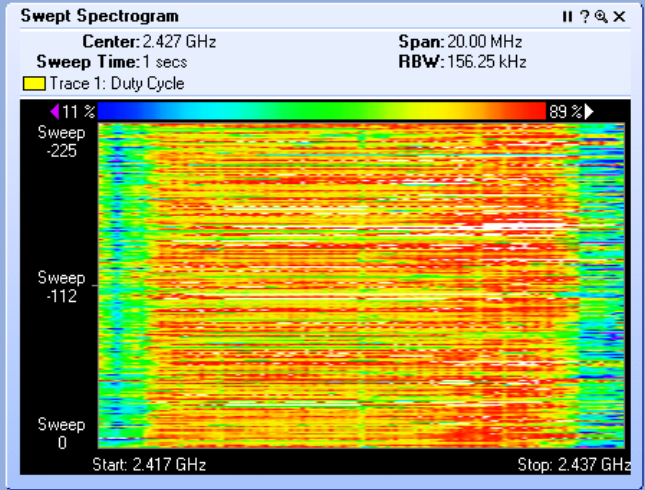
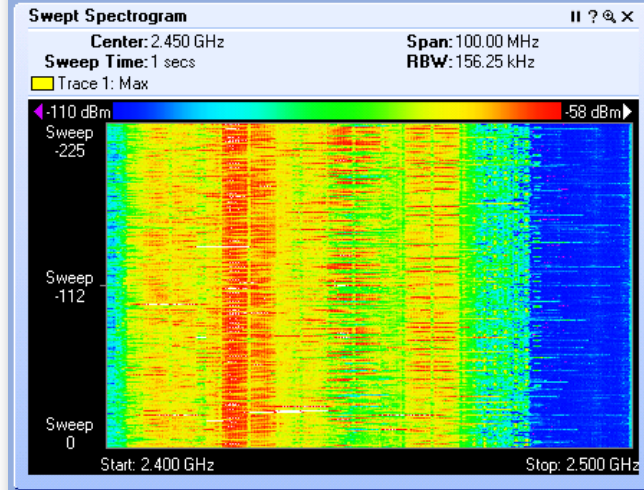
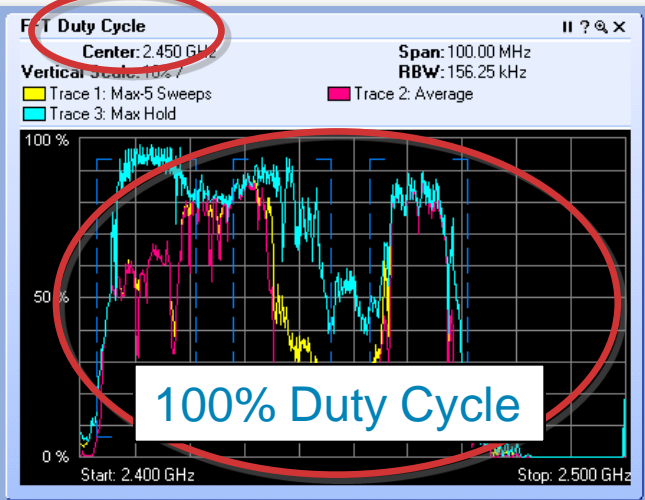
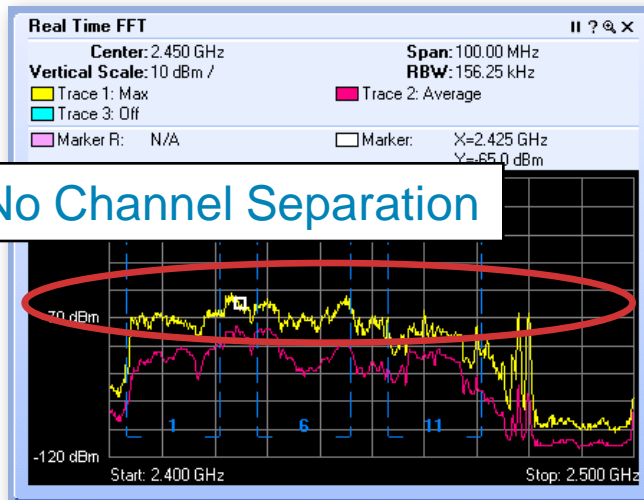
Healthy Network



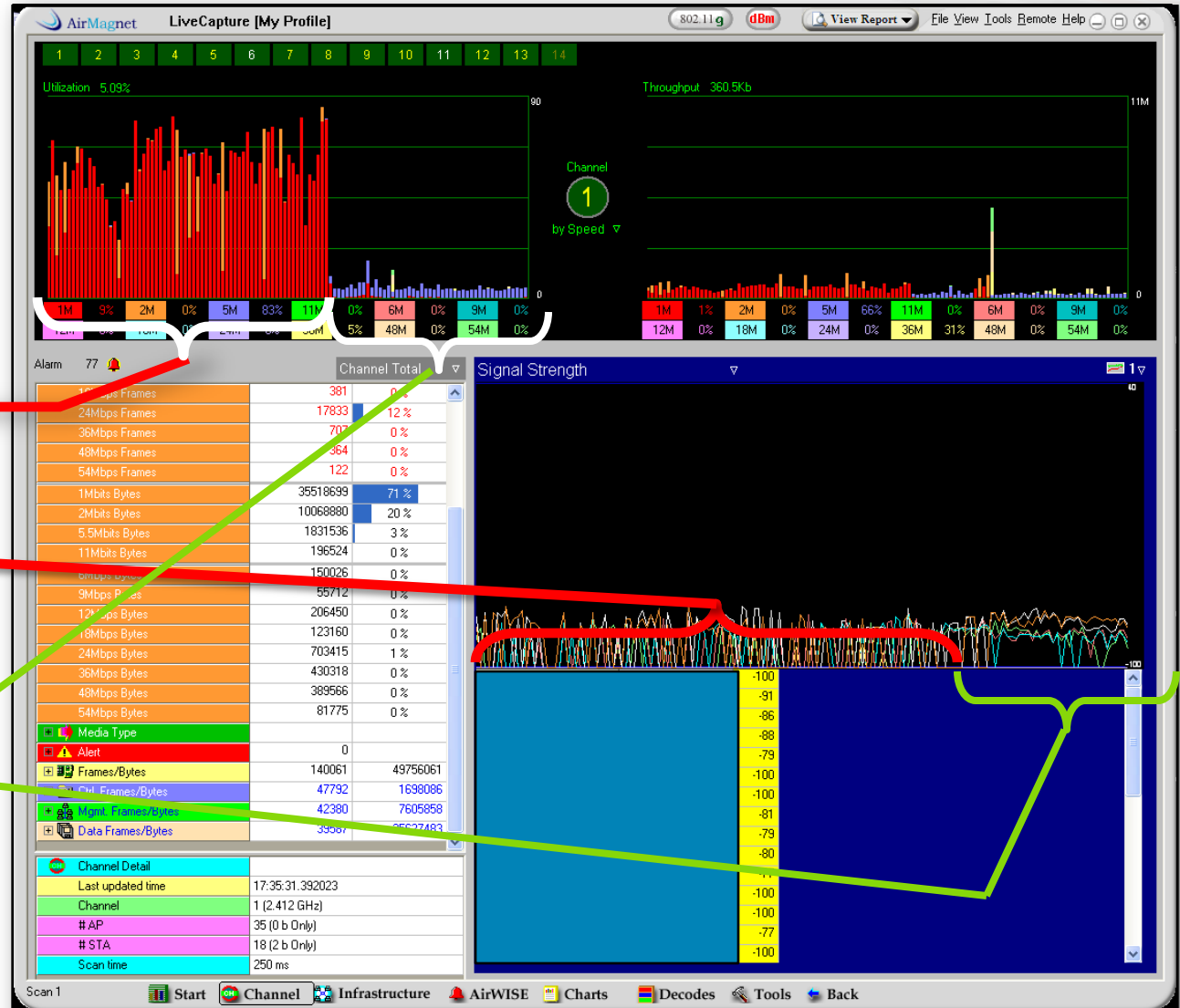
Duty Cycle and Spectrum 802.11 b/g

Un-Healthy Network

No Channel Separation



Channel Utilization— What Made the Difference?



What Made This Dramatic Change?
Before

5% After

Every SSID Counts!

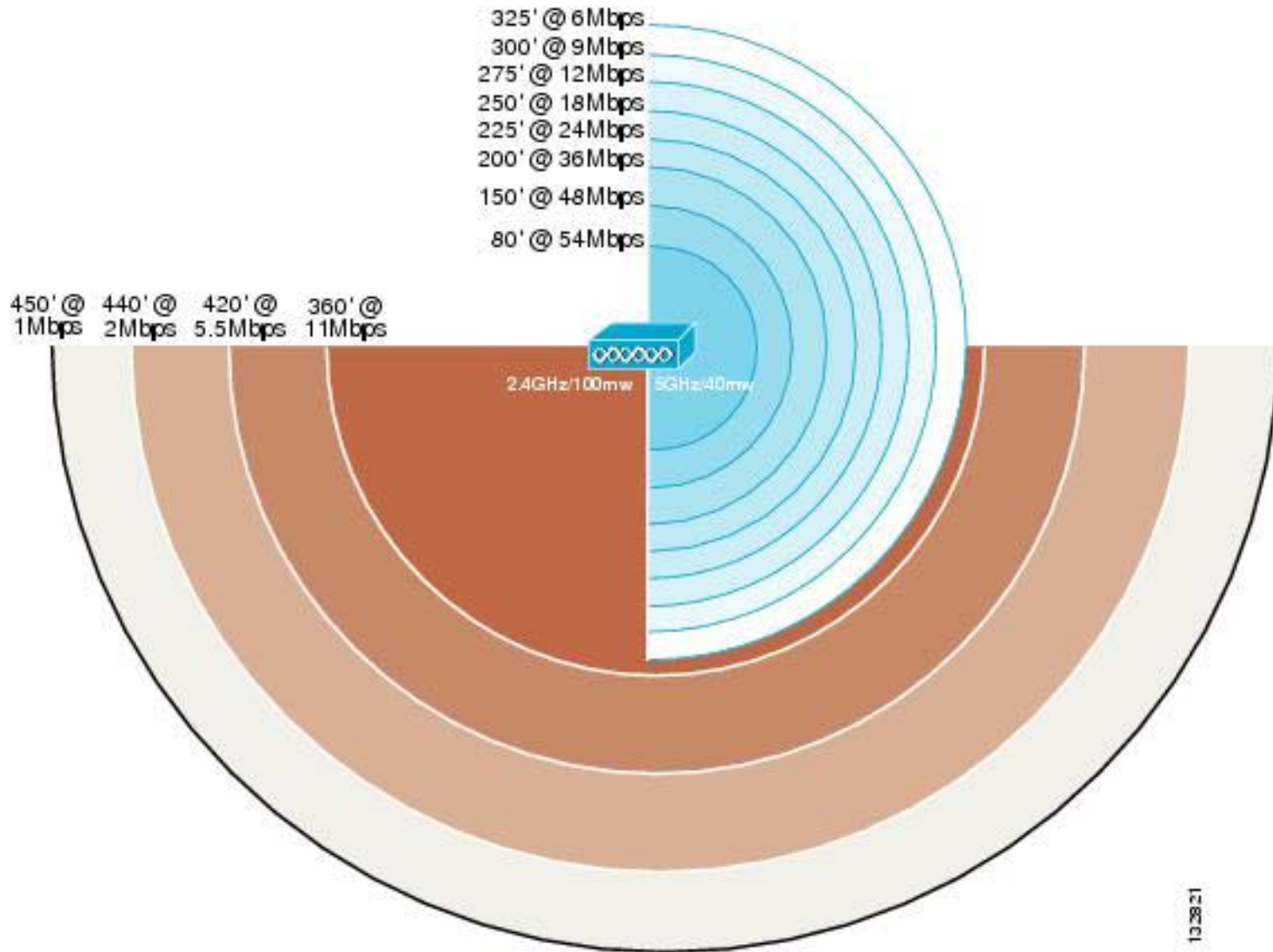
- Each SSID requires a separate Beacon
- Each SSID will advertise at the minimum mandatory data rate
- Disabled – not available to a client
- Supported – available to an associated client
- Mandatory – Client must support in order to associate

Data Rates**

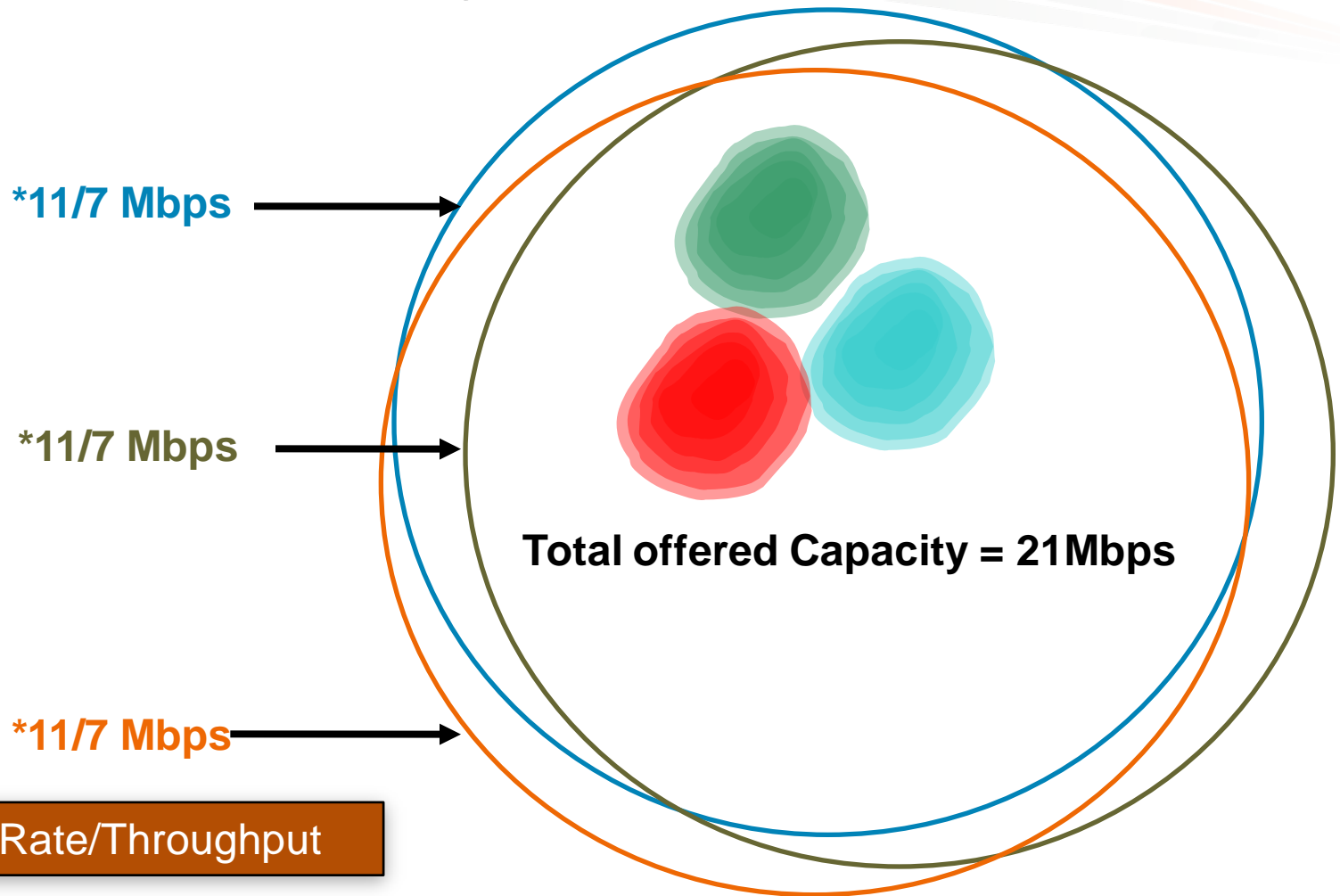
1 Mbps	Disabled
2 Mbps	Disabled
5.5 Mbps	Disabled
6 Mbps	Disabled
9 Mbps	Disabled
11 Mbps	Disabled
12 Mbps	Supported
18 Mbps	Supported
24 Mbps	Mandatory
36 Mbps	Supported
48 Mbps	Supported
54 Mbps	Supported

Data Rate – Cell Size

Controlling Cell Size

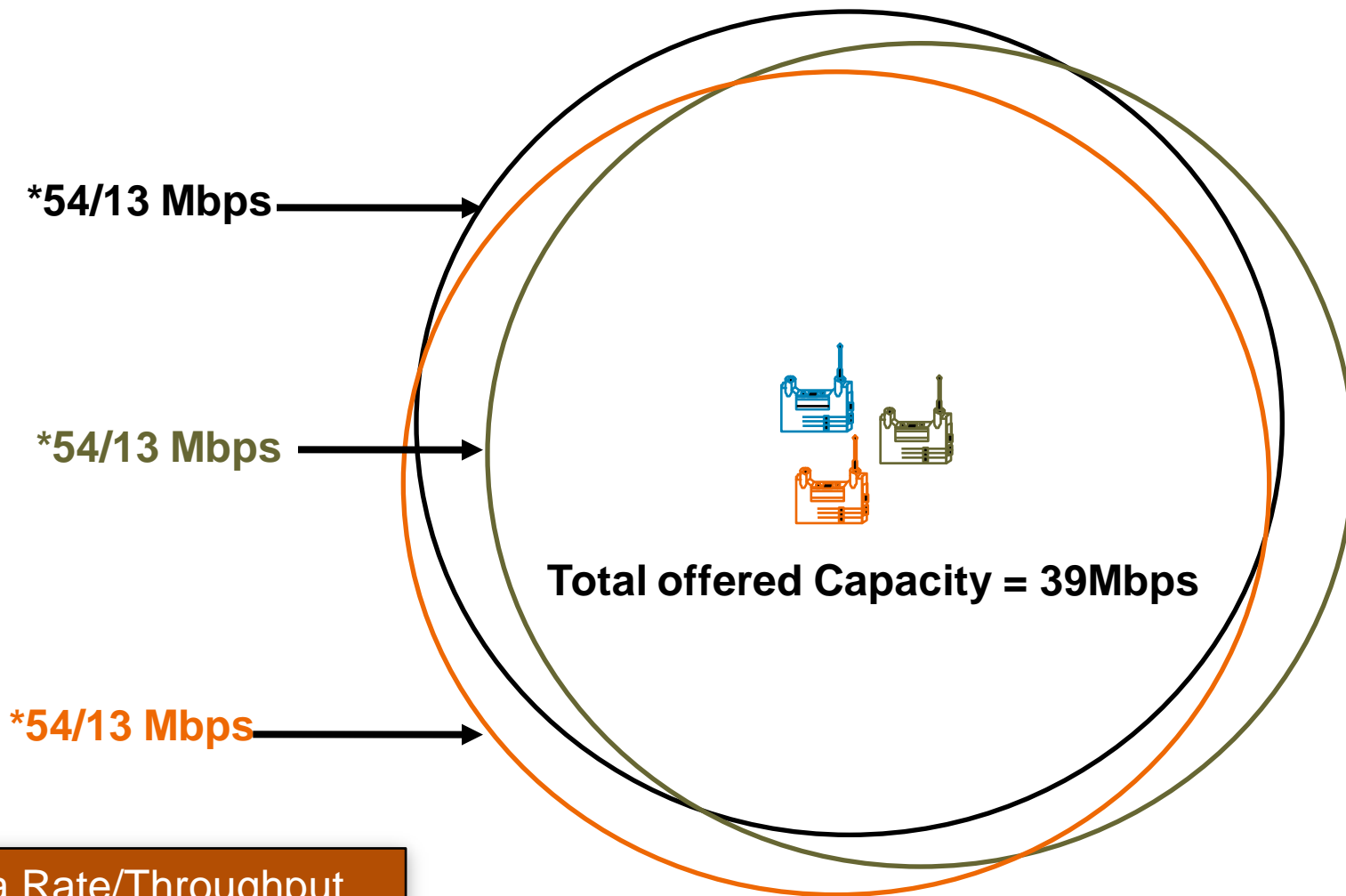


802.11b Scalability



What if we added 3 more AP's to this coverage area?

802.11b/g mixed Scalability



802.11a Scalability – US 5 GHz has 21 Indoor Channels

*54/25 Mbps

*54/25 Mbps

*54/25 Mbps

*54/25 Mbps

*54/25 Mbps

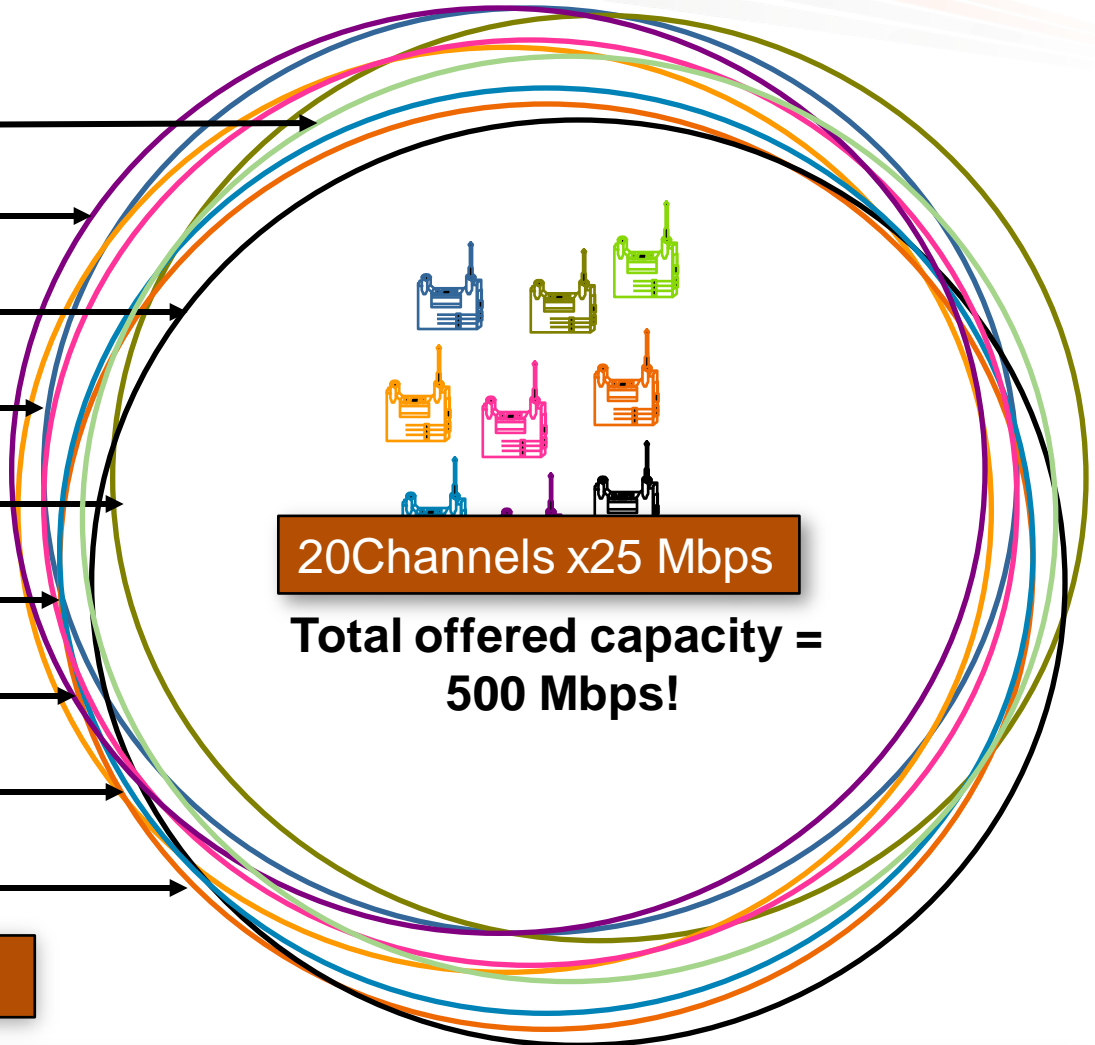
*54/25 Mbps

*54/25 Mbps

*54/25 Mbps

*54/25 Mbps

* Data Rate/Throughput



What about 11n? 9-banded channels

Capacity

- 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 12 to 23 channels in most of the world

While throughput might be similar to 802.11g, channels are not, neither then is capacity

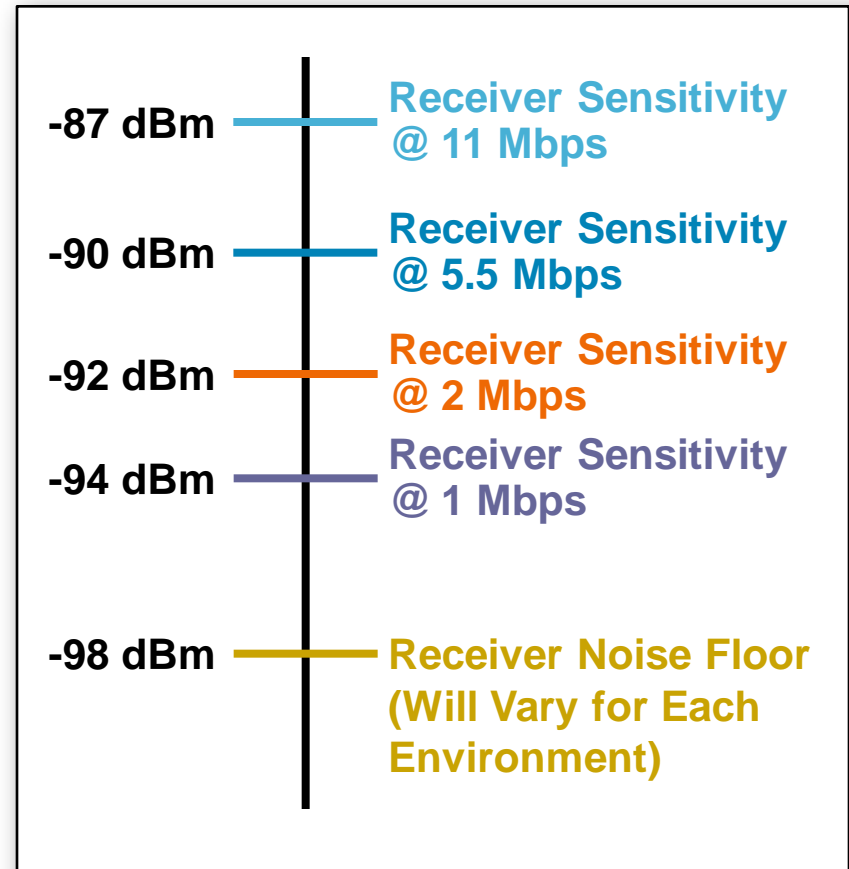
- In theory, access points set to non-overlapping channels may be co-located to provide all available capacity in a single coverage area

More commonly, it's an expression of total throughput across a network or facility

Receiver Sensitivity

Example for 2.4GHz Direct Sequence

- Indication of the ability of the receiver to decode the desired signal
- The minimum received signal level, in the absence of interference, at which the desired signal can be decoded with a particular Bit Error Rate (BER)
- Typically expressed in dBm
- The more negative the value, the better
- Function of the data rate: the higher the data rate, the higher the receiver sensitivity required



BandSelect

Access Point Assisted 5 GHz Band Selection

Challenge

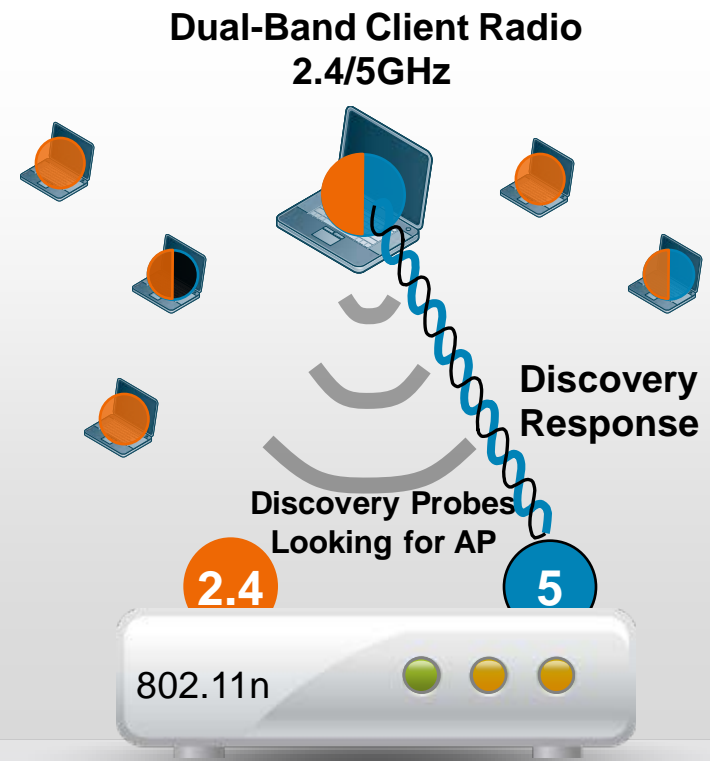
Dual-Band clients persistently connect to 2.4 GHz

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

Solution

BandSelect directs clients to 5 GHz optimizing RF usage

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



Optimized RF Utilization by Moving 5 GHz Capable Client Out of the Congested 2.4 GHz Channels

BandSelect

Configuration – Per-SSID Override Cont'd

The screenshot shows the Cisco WLAN configuration interface. The top navigation bar includes the Cisco logo and links for Save Configuration, Ping, Logout, and Refresh. Below the navigation bar, the main menu includes MONITOR, WLANs (highlighted), CONTROLLER, WIRELESS, SECURITY, MANAGEMENT, COMMANDS, HELP, and FEEDBACK. The left sidebar shows the WLANs configuration tree with 'Advanced' selected. The main content area is titled 'WLANs > Edit' and contains several tabs: General, Security, QoS, and Advanced (selected). The Advanced tab is divided into several sections: Coverage Hole Detection, DHCP Server, DHCP Addr. Assignment, Management Frame Protection (MFP), DTIM Period (in beacon intervals), NAC, and Load Balancing and Band Select. The Load Balancing and Band Select section is highlighted with a red box and contains two options: Client Load Balancing and Client Band Select, both of which are currently disabled.

Save Configuration | Ping | Logout | Refresh

MONITOR **WLANs** CONTROLLER WIRELESS SECURITY MANAGEMENT COMMANDS HELP FEEDBACK

WLANs

WLANs > Edit < Back Apply

General Security QoS **Advanced**

Coverage Hole Detection Enabled

Enable Session Timeout

Aironet IE Enabled

Diagnostic Channel Enabled

IPv6 Enable

Override Interface ACL

P2P Blocking Action

Client Exclusion Enabled

Media Session Snooping

DHCP Server Override

DHCP Addr. Assignment Required

Management Frame Protection (MFP)

Infrastructure MFP Protection (Global MFP Disabled)

MFP Client Protection

DTIM Period (in beacon intervals)

802.11a/n (1 - 255)

802.11b/g/n (1 - 255)

NAC

State Enabled

Load Balancing and Band Select

Client Load Balancing

Client Band Select

Off Channel Scanning Defer

Scan Defer Priority	0	1	2	3	4	5	6	7
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

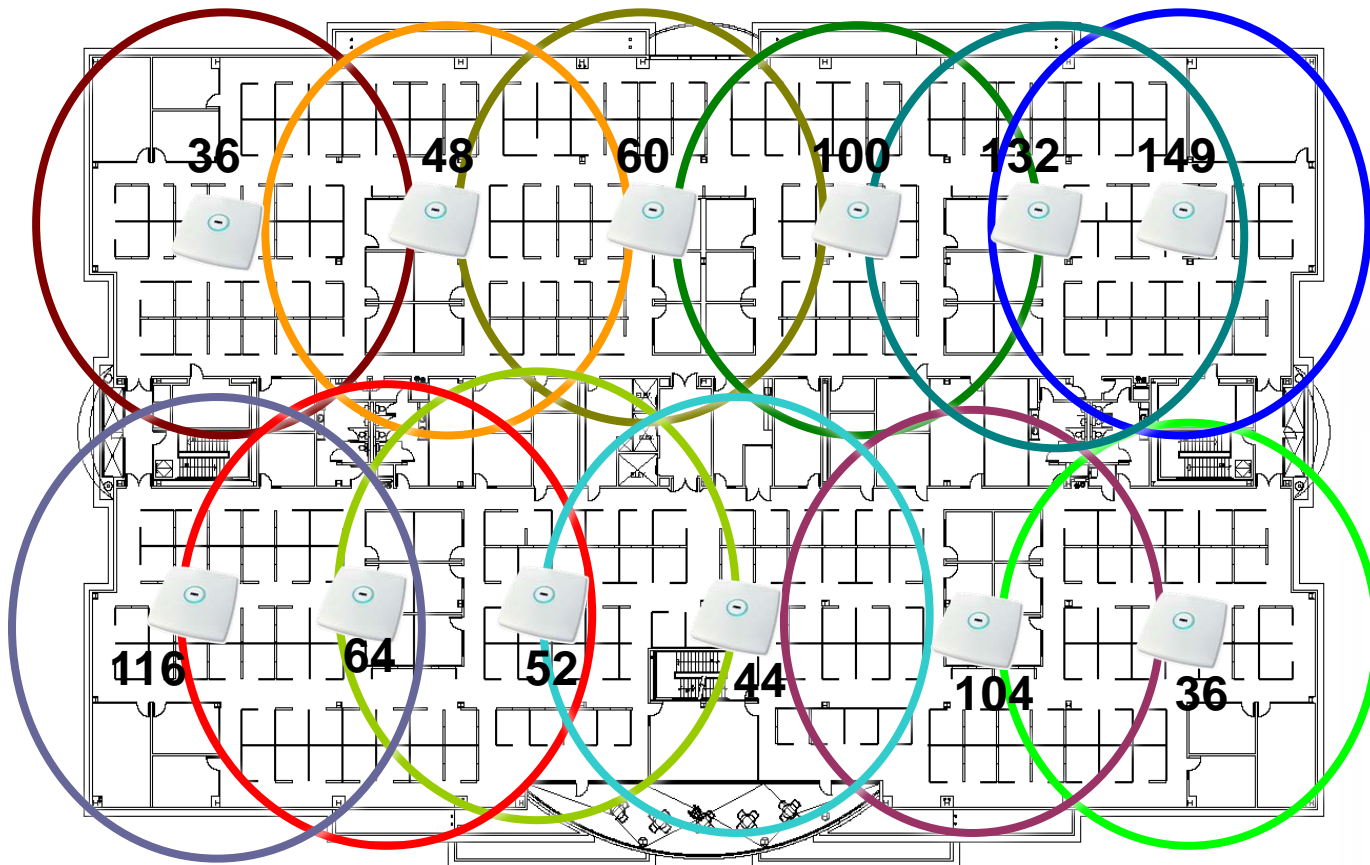
Scan Defer Time (msecs)

HREAP

High Density Deployment

- High Density 5GHz office deployment

5GHz does not have the overlap or collision domain issues of 2.4GHz. 12 AP's on 1 floor



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.

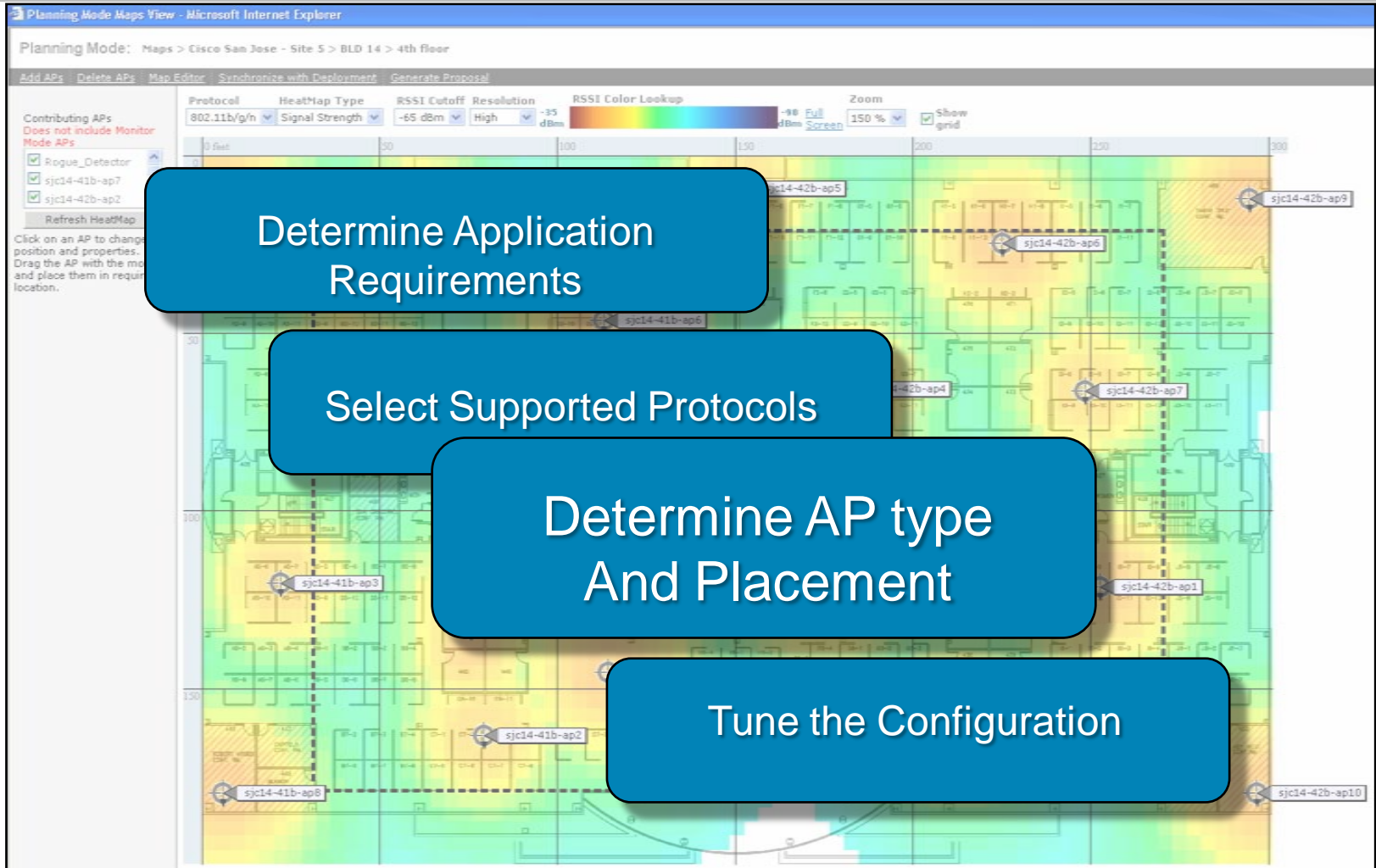
- Eliminate 802.11b all together if possible

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

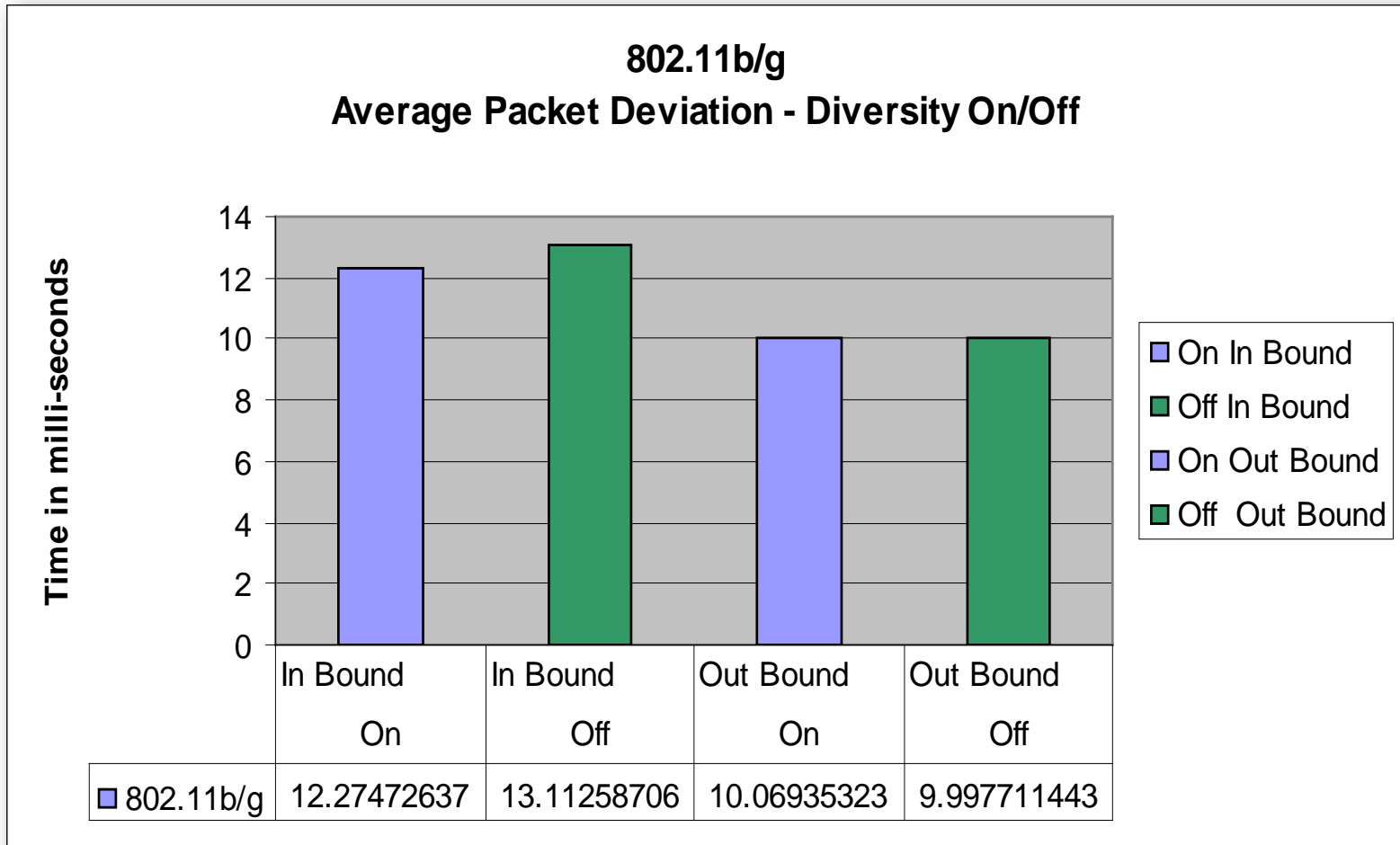
Design Steps



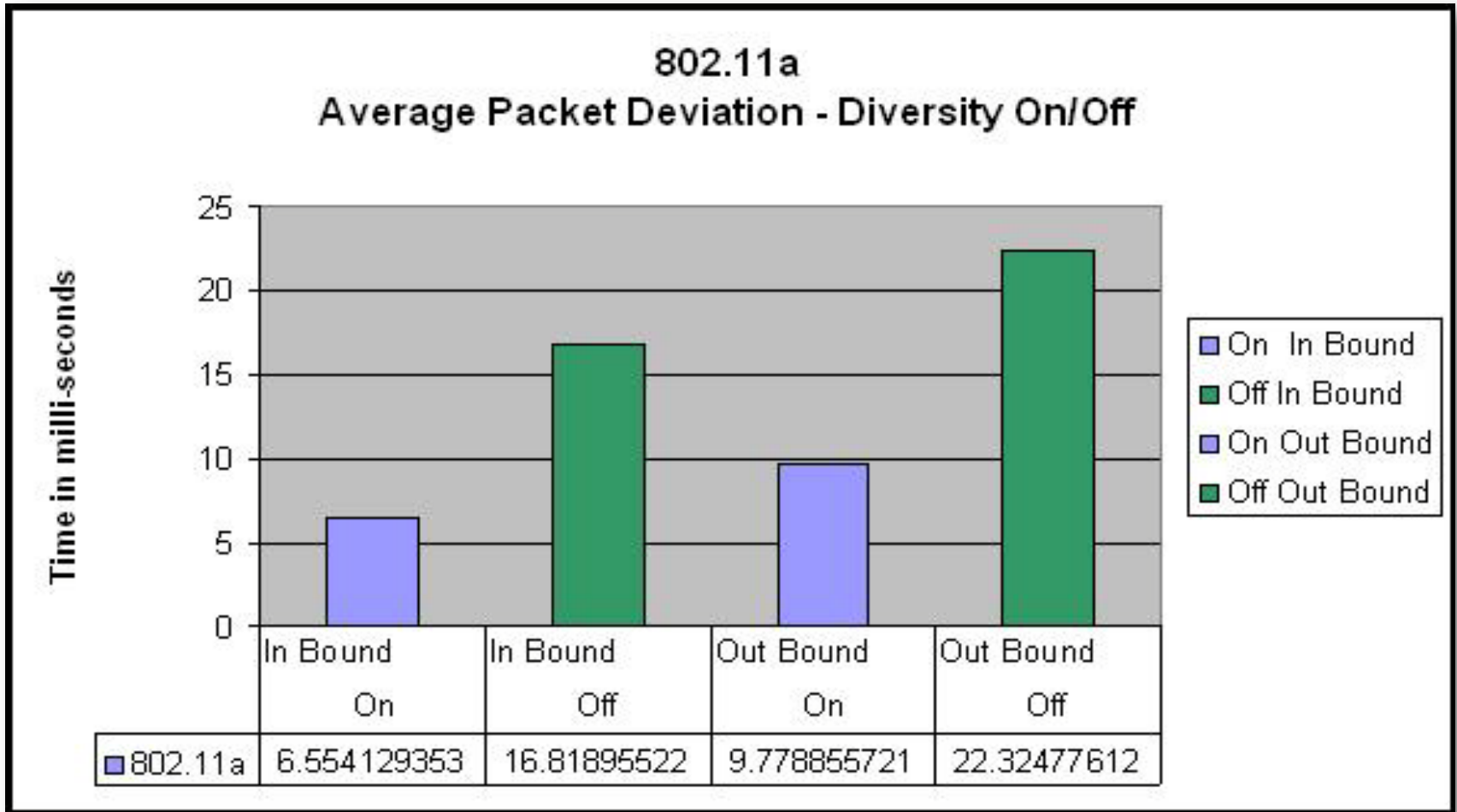
Selection of AP's

- The type of AP you select will have a large impact on the amount of data that you successfully deliver
- Any AP that you consider should at a minimum have diversity antennae's
- 802.11n AP's in general provide improved performance for legacy clients
- 802.11n Clients get a huge benefit – and relieve a lot of stress on bandwidth for legacy clients (140 mbps connections for 802.11n in 20 MHz)
- In all cases – Stock Omni antenna's are the recommended approach

Diversity On/Off 11b/g



802.11a Diversity

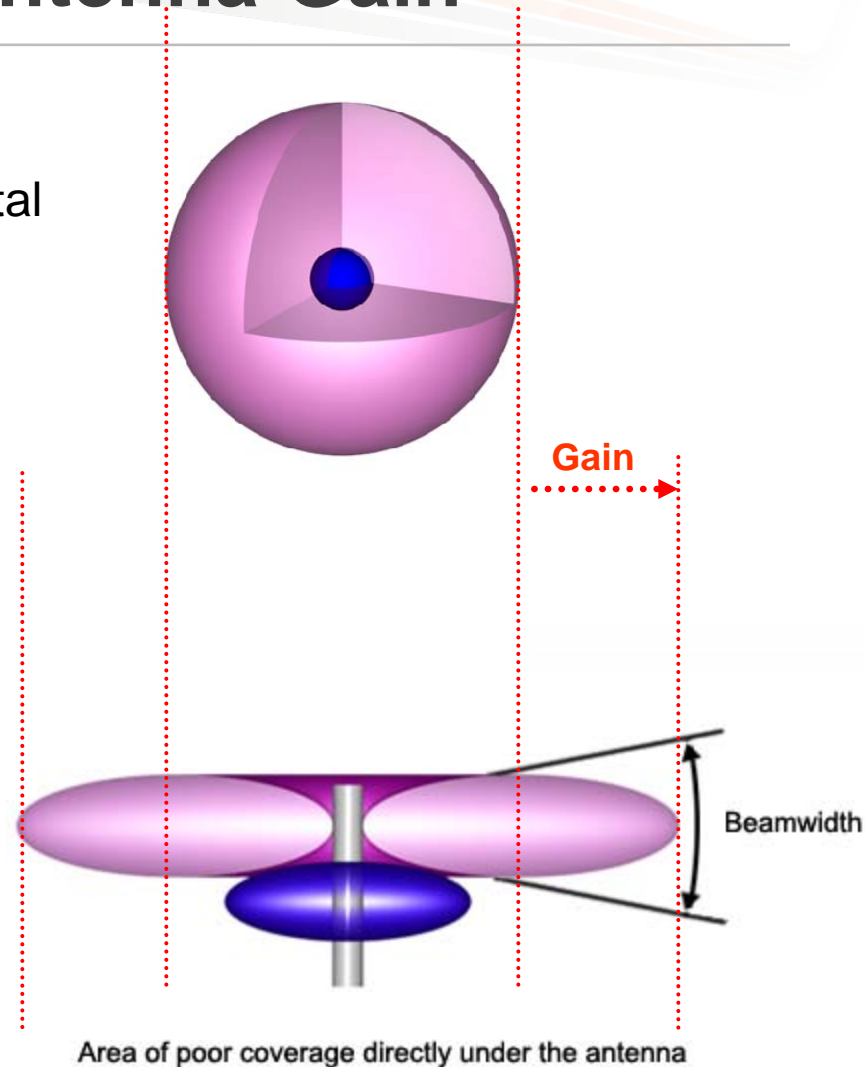


Antenna Theory and Antenna Gain

- A theoretical isotropic antenna has a perfect 360° vertical and horizontal beamwidth
- This is a reference for **all** antennae
- Gain is equal in all directions
- The reception of good signals and interference is the same in all directions

High Gain Omni-directional Antennae:

- 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

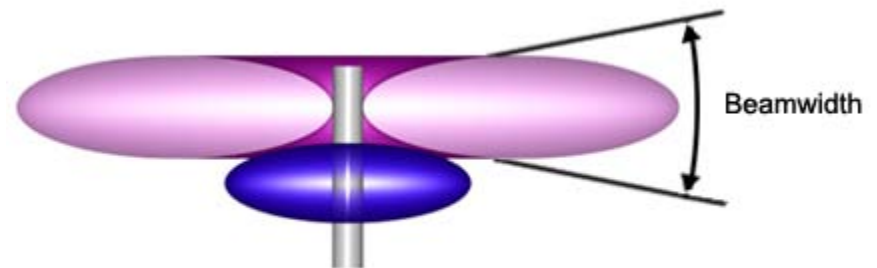
Higher Gain AP Antenna's Provide Better Reception of Client Signals

- Even if the client has a lower transmit power than the AP
- Even if the client has a lower gain antenna than the AP
- Because the signal is focused to a certain coverage area

The signal received at the radio will have better signal strength because of the gain of the AP antenna

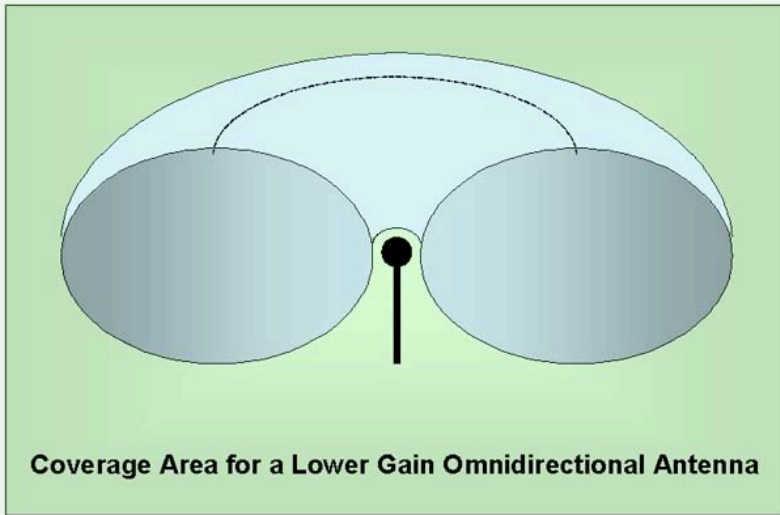
In most cases the SNR will be better because the radio will not hear the signals that are not coming from the direction not covered by the antenna

- Reception gain has the same coverage characteristics as transmission gain

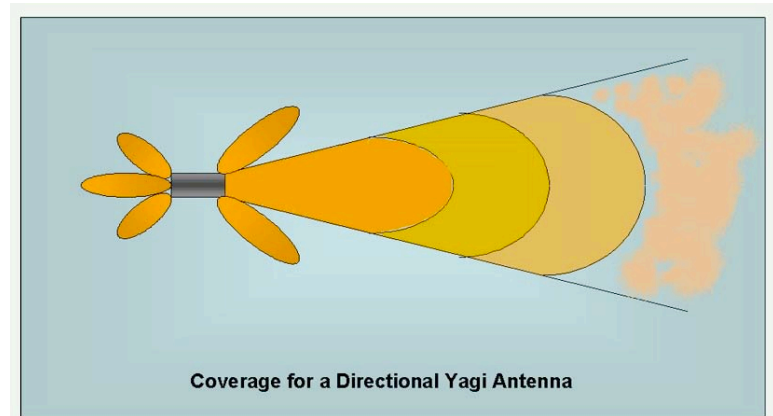
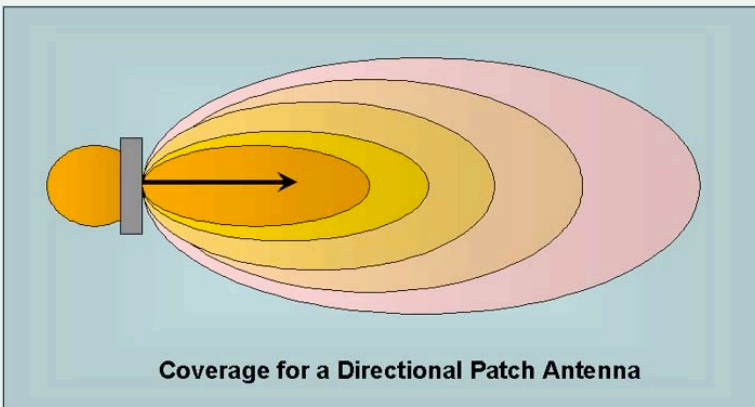


Area of poor coverage directly under the antenna









Antenna Radiation Patterns



- Antenna choice plays a critical part in design for proper coverage



Antenna Options

Product ID	Description		Gain	F/B	A/E
AIR-ANT2452V-R=	2.4 GHz 5.2 dBi Diversity pillar mount ant,RP-TNC Connectors		5.2 dBi	N/A	Omni
AIR-ANT2451NV-R=	2.4 GHz 3 dBi/5 GHz 4 dBi 802.11n dual band omni antenna		3 dBi/4 dBi	N/A	Omni
AIR-ANT2460NP-R=	2.4 GHz 6 dBi 802.11n directional antenna		6 dBi	10 dB	80/75
AIR-ANT5160NP-R=	5 GHz 6 dBi 802.11n directional antenna		6 dBi	>15 dB	65/65
AIR-ANT2422SDW-R=	2.4 GHz 2.2 dBi Short white dipole antenna, Qty 1		2.2 dBi	N/A	Omni
AIR-ANT5135SDW-R=	5 GHz 3.5 dBi Short white dipole antenna, Qty. 1		3.5 dBi	N/A	Omni
AIR-ANT2440NV-R=	2.4 GHz 4 dBi 802.11n Omni wall mount antenna		4 dBi	N/A	Omni
AIR-ANT5140NV-R=	5 GHz 4 dBi 802.11n Omni wall mount antenna		4 dBi	N/A	Omni

Ruggedized 11n Enterprise AP's



Ceiling mount AP placement



AP1140 Series

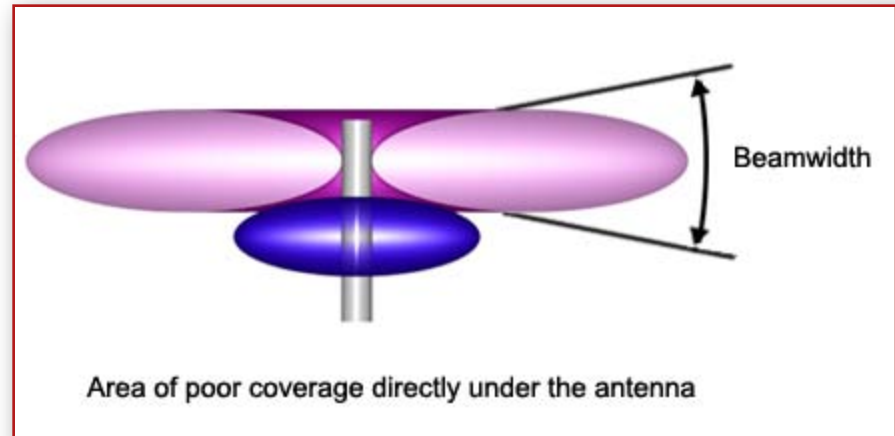
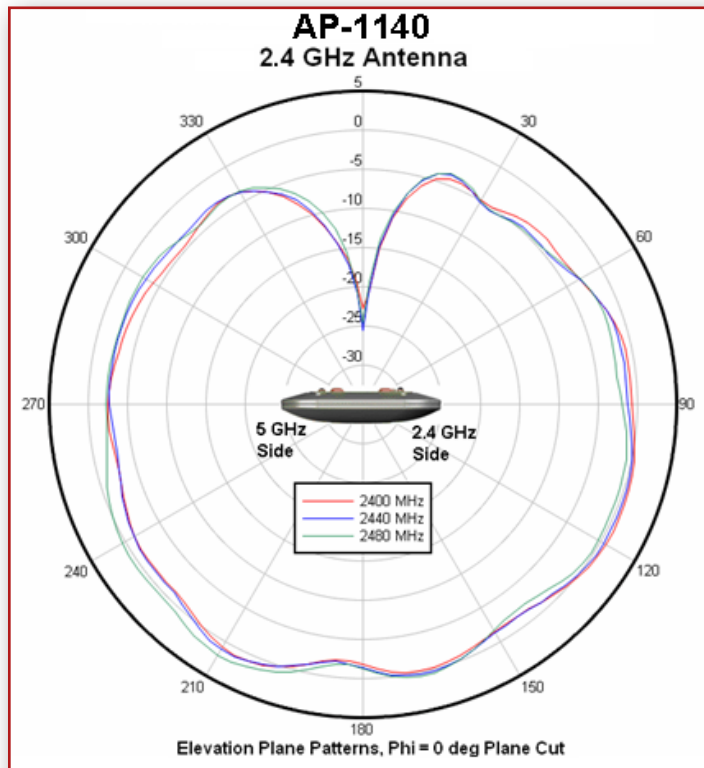
AP3500 Series



The design of the diversity omni 2.4 and 5 GHz antennas in the AP1140 and 3500 are optimized for ceiling mounting

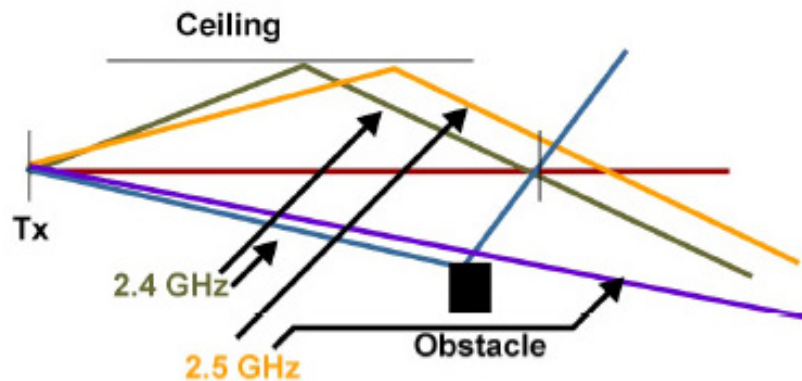
Modern Omni Antenna Behavior

Basic Omni design – and caveat



Modern Cisco 802.11n AP elevation –
A lot goes into the antenna design – RF Matters!

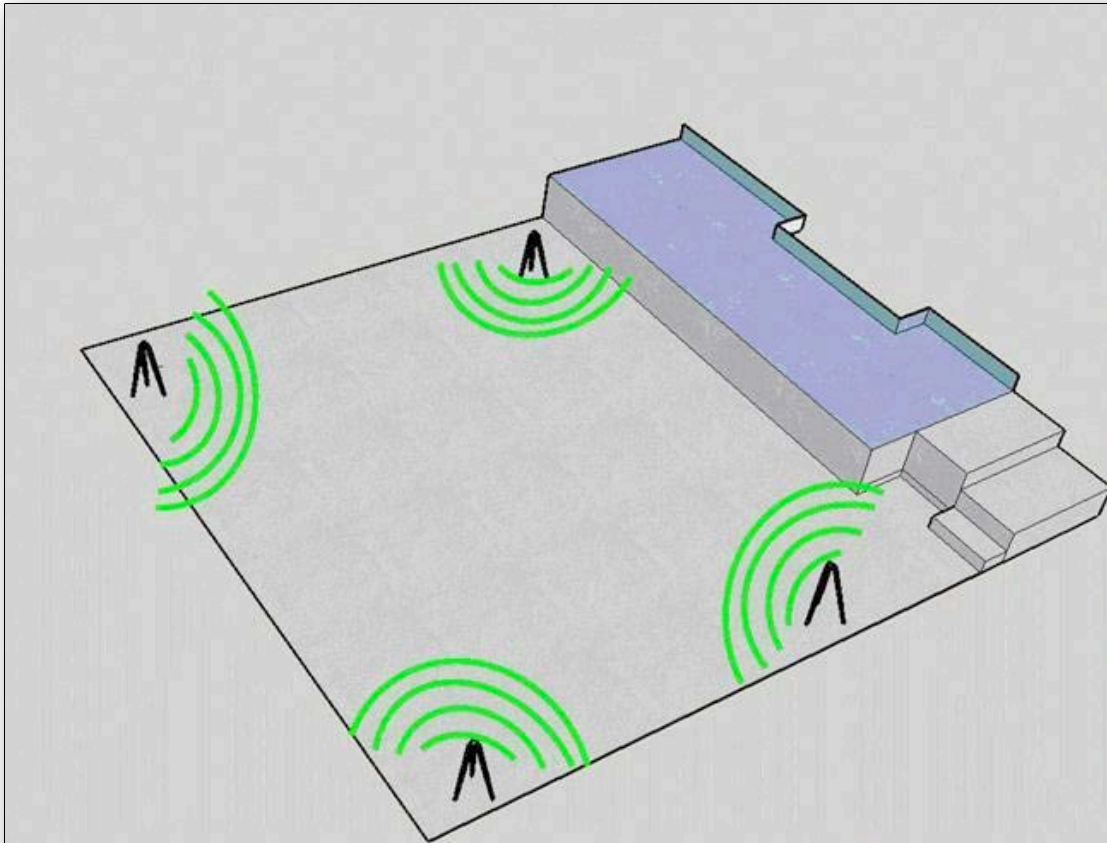
AP Placement Considerations—Multipath



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



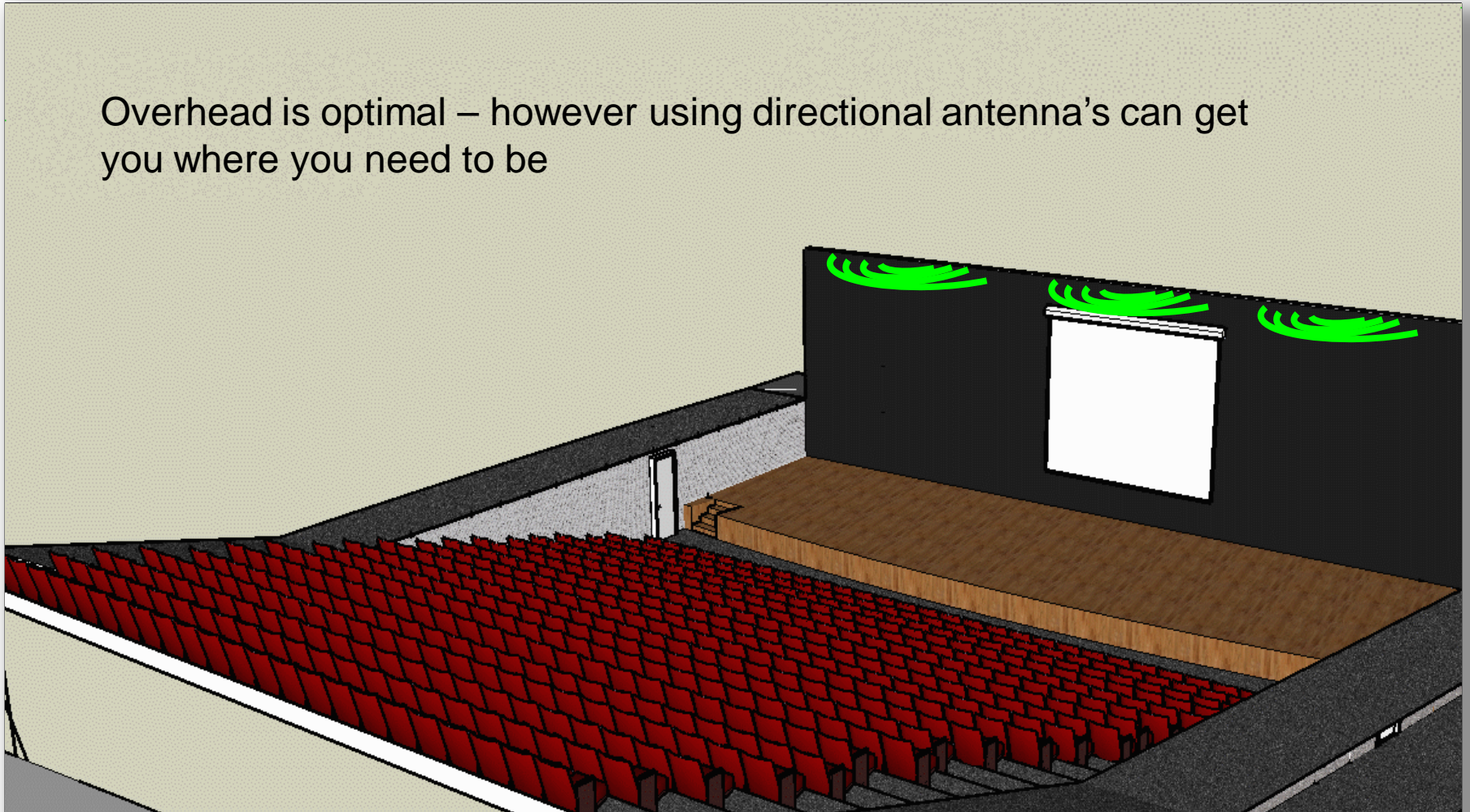
Theater - Auditorium



- Use Tripods and Omni's to mount AP's
- Illuminating from the corners encourages cell separation
- Antennae's pointed up!

Theater – Lecture Hall

Overhead is optimal – however using directional antenna's can get you where you need to be



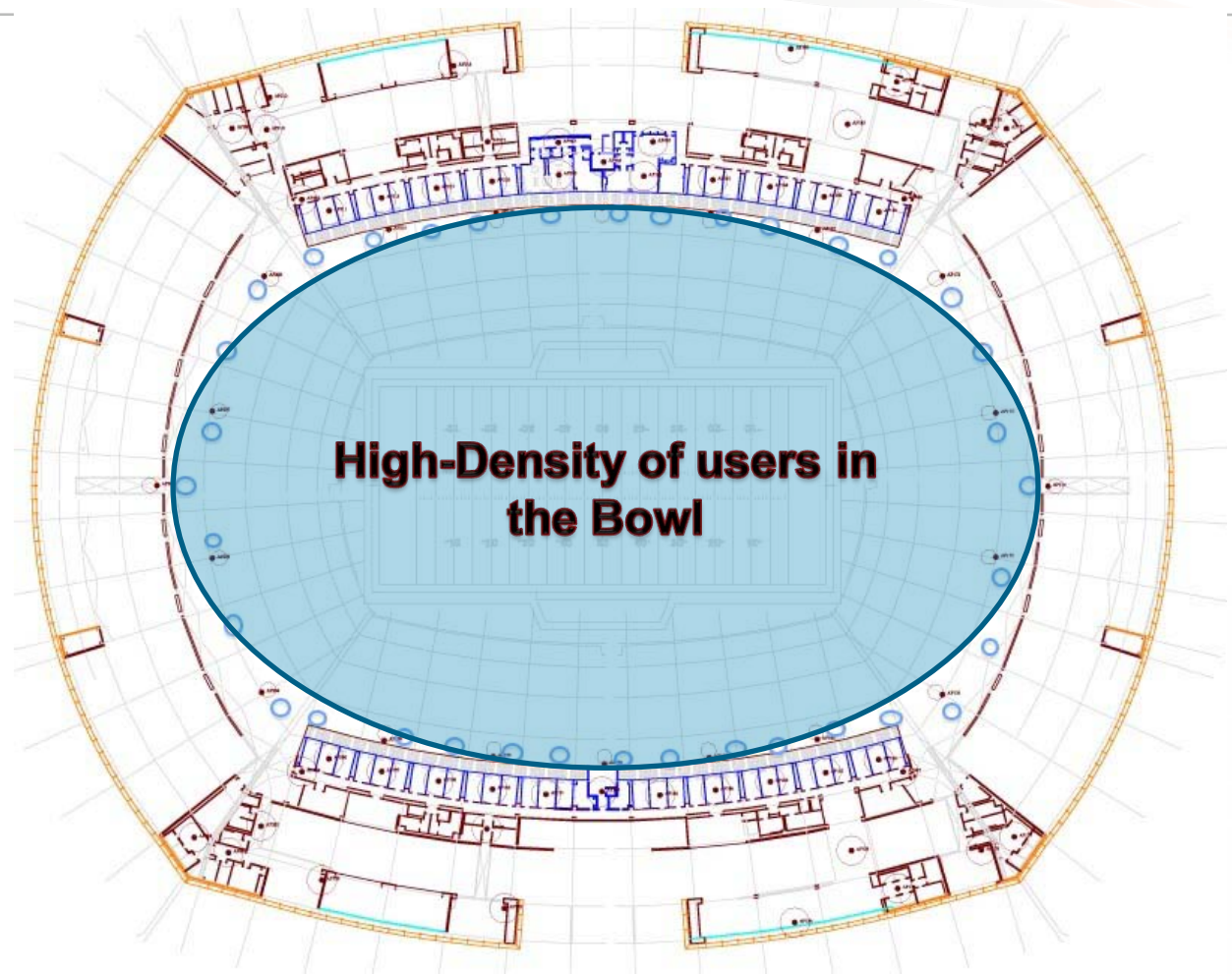
Small Sporting Event



- Illuminating from the sides focuses energy near users
- The center is not likely to need much connectivity
- Omni Patch, or wall mounted

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

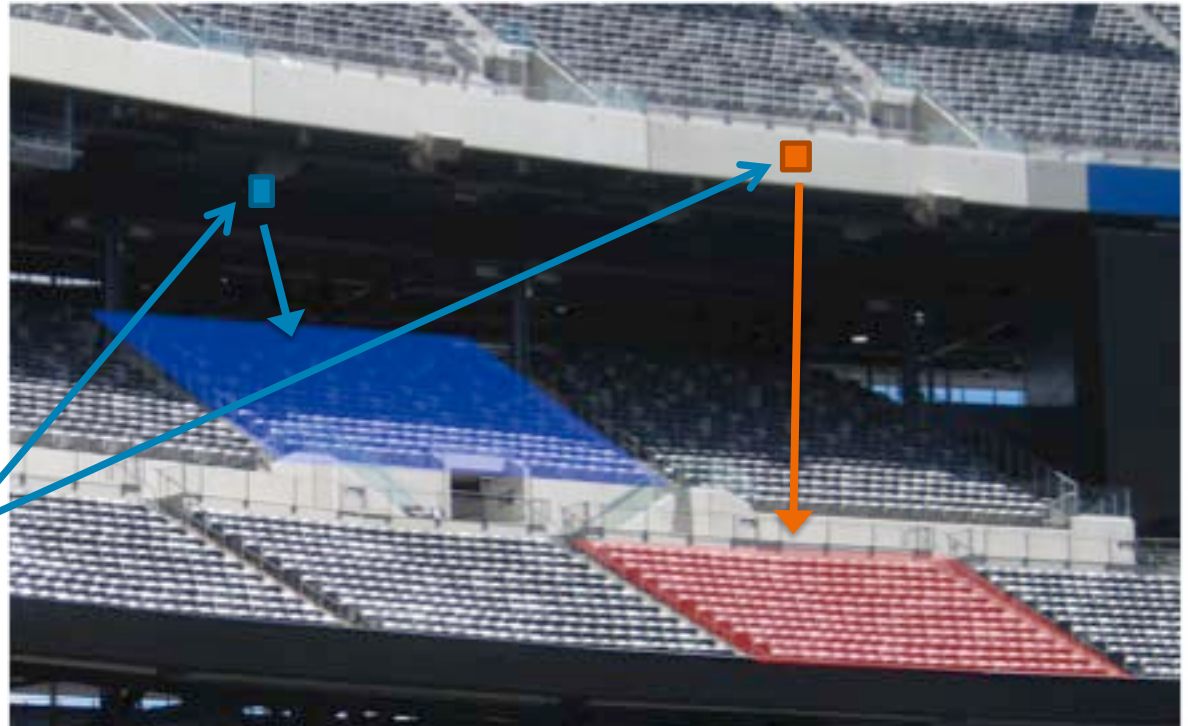


Note: Where APs may be physically mounted in the stadium also effects capacity design

Example: Single Tier

- 322 Seats (red)
- 480 Seats (blue)
- One AP per section

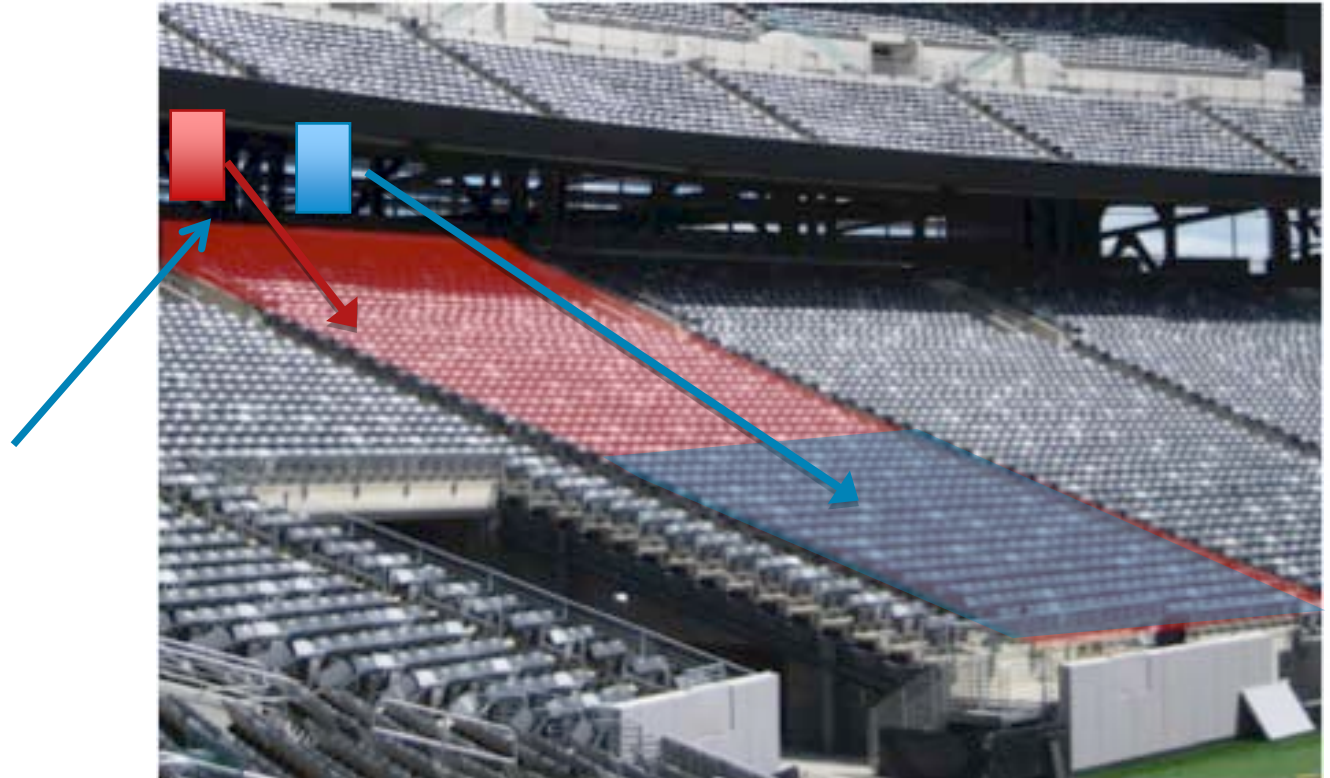
Dividing up the coverage area depends on where AP/Antennas may be mounted



Example: Two-Tiered RF Design

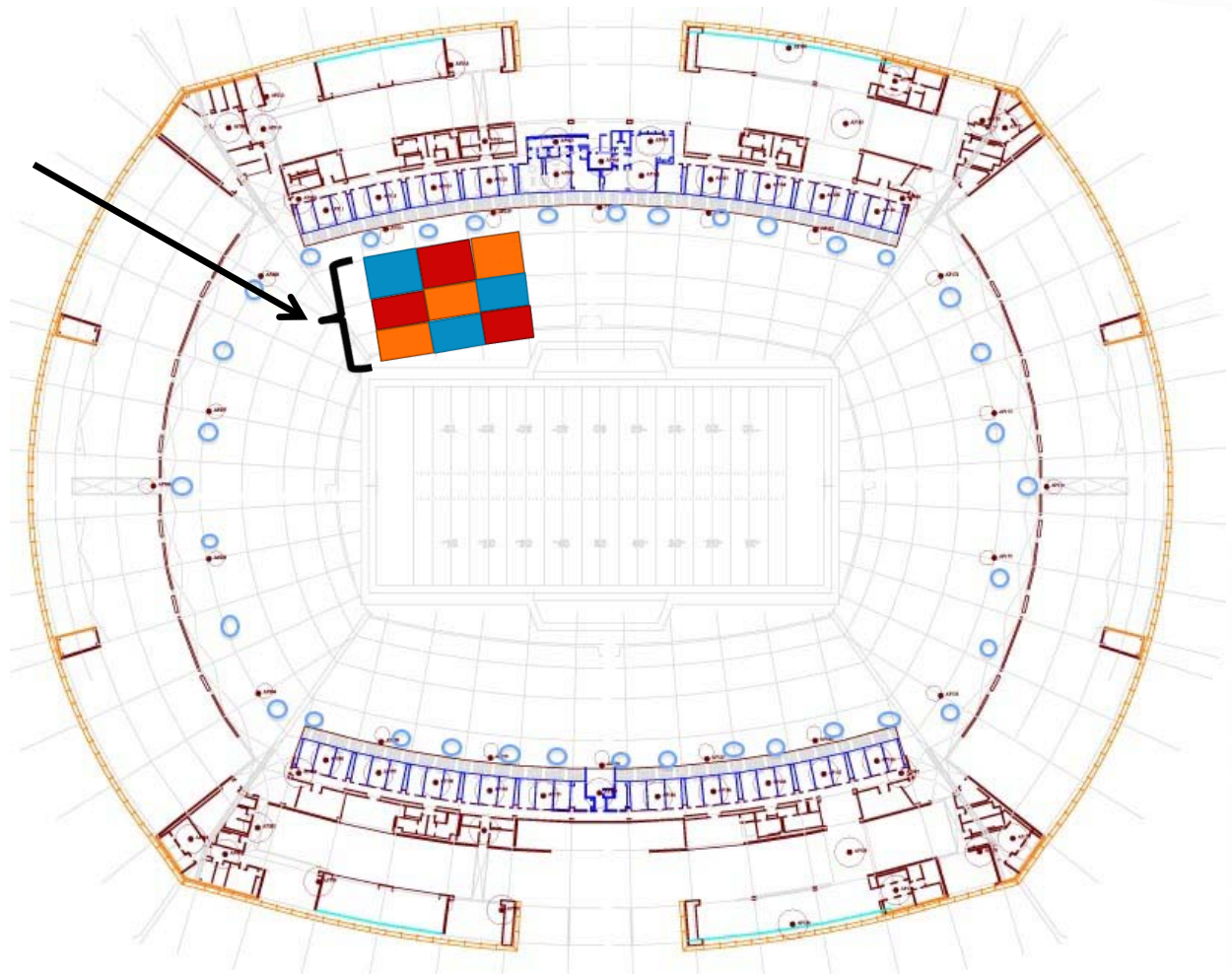
- 1020 Seats
- 96' Deep
- 47' Wide

Seating sections in the lower bowl are served by different AP

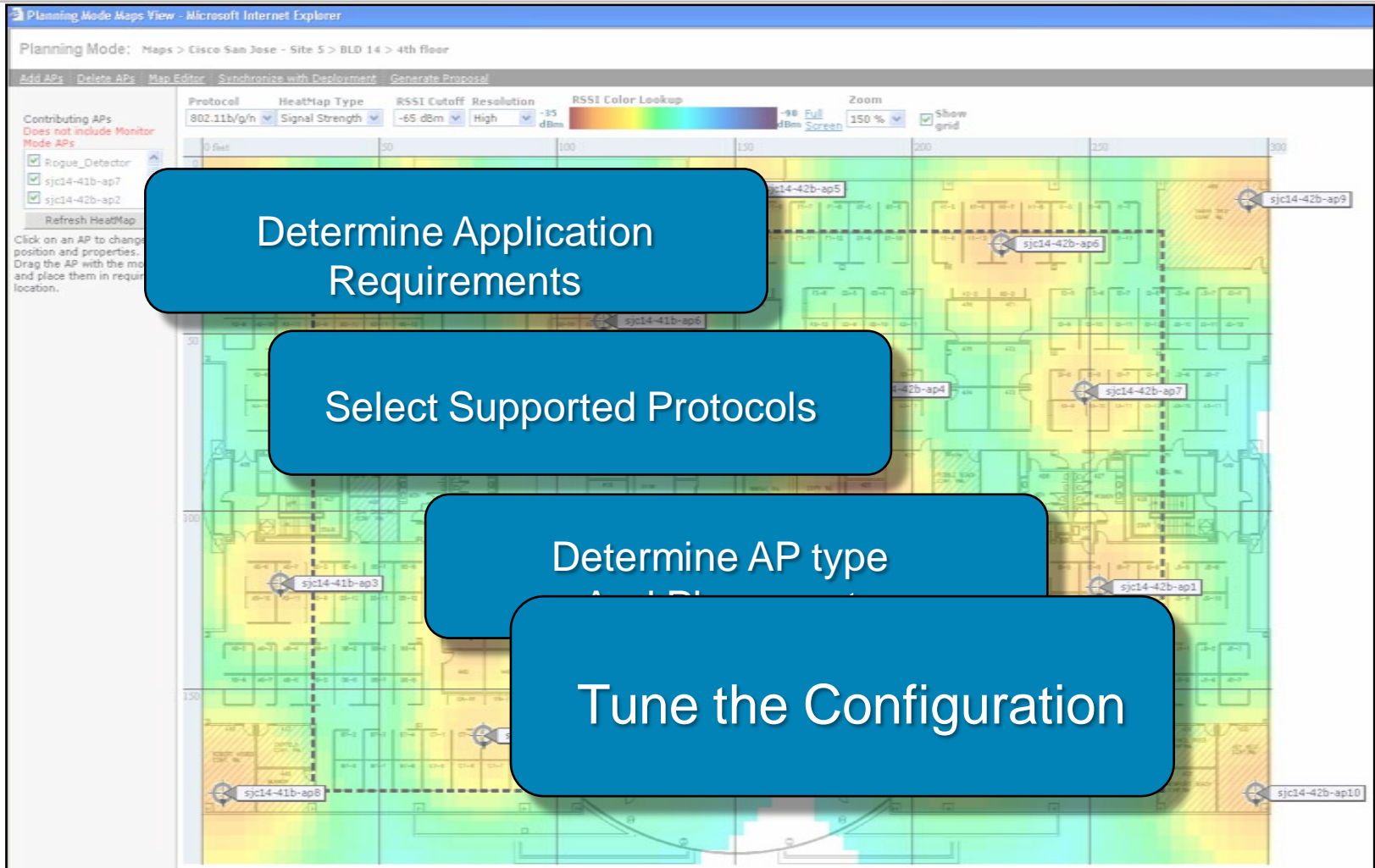


Bowl Seating RF Cell Footprint

- 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? YES!
- DCA will maintain channel plan with changing interference levels – this is a good thing
- TPC Threshold to adjust power levels to the floor
 - Set threshold higher for 5 GHz
 - Lower for 2.4 GHz
- Minimize cell foot print by eliminating lower data rates
- Maintain 20% cell overlap

Highly recommend versions 6.0 or greater

RRM Configurations – data rates

- 5 GHz – eliminate 6-9 Mbps
- 2.4 GHz – eliminate 1,2,5.5,6,9 Mbps
- Mandatory, Supported, Disabled – What's it all mean
- If you can, eliminate 11 Mbps – turns off 802.11b all together!

The image displays two screenshots of the Cisco RRM configuration interface, specifically the 'Data Rates' section for 802.11a and 802.11g. Both screenshots show a table of data rates with dropdown menus for each rate. The 802.11a screenshot shows rates from 6 Mbps to 54 Mbps, with 6, 9, and 12 Mbps set to 'Disabled', 18, 24, 36, and 48 Mbps set to 'Supported', and 54 Mbps set to 'Mandatory'. The 802.11g screenshot shows rates from 1 Mbps to 54 Mbps, with 1, 2, 5.5, 6, and 9 Mbps set to 'Disabled', and 11, 12, 18, 24, 36, 48, and 54 Mbps set to 'Supported'. A red box highlights the 'Data Rates' table in both screenshots.

802.11a Global Parameters - Data Rates**

Data Rate	Status
6 Mbps	Disabled
9 Mbps	Disabled
12 Mbps	Disabled
18 Mbps	Supported
24 Mbps	Mandatory
36 Mbps	Supported
48 Mbps	Supported
54 Mbps	Supported

802.11g Global Parameters - Data Rates**

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

DCA Settings

- Set DCA to Automatic
- Avoid Foreign AP interference
- Threshold for change can be managed buy changing to low sensitivity – 30 dBm improvement required for channel change
- Ensure DCA has run through startup

The screenshot shows the Cisco Wireless Controller configuration page for Dynamic Channel Assignment (DCA). The page is titled "802.11a > RRM > Dynamic Channel Assignment (DCA)" and includes an "Apply" button. The configuration is organized into sections:

- Dynamic Channel Assignment Algorithm:** This section is highlighted with a red box. It contains:
 - Channel Assignment Method: Automatic, Interval: 10 minutes, AnchorTime: 0
 - Freeze
 - OFF
- Avoid Foreign AP interference:** This setting is highlighted with a red box and is currently Enabled.
- Avoid Cisco AP load:** Enabled
- Avoid non-802.11a noise:** Enabled
- Channel Assignment Leader:** 00:24:97:69:a2:80
- Last Auto Channel Assignment:** N.A
- DCA Channel Sensitivity:** This setting is highlighted with a red box and is currently Medium (15 dB).
- Channel Width:** 20 MHz, 40 MHz

TPC Threshold

- 5 GHz can be run much hotter than 2.4 GHz – more channels
- Hotter 5 GHz signals will also encourage dual-band reluctant clients to prefer 5 GHz
- Power levels of 4-5 is generally what you will want for 5 GHz, 7 is acceptable for 2.4 GHz.
- Test your coverage – and adjust

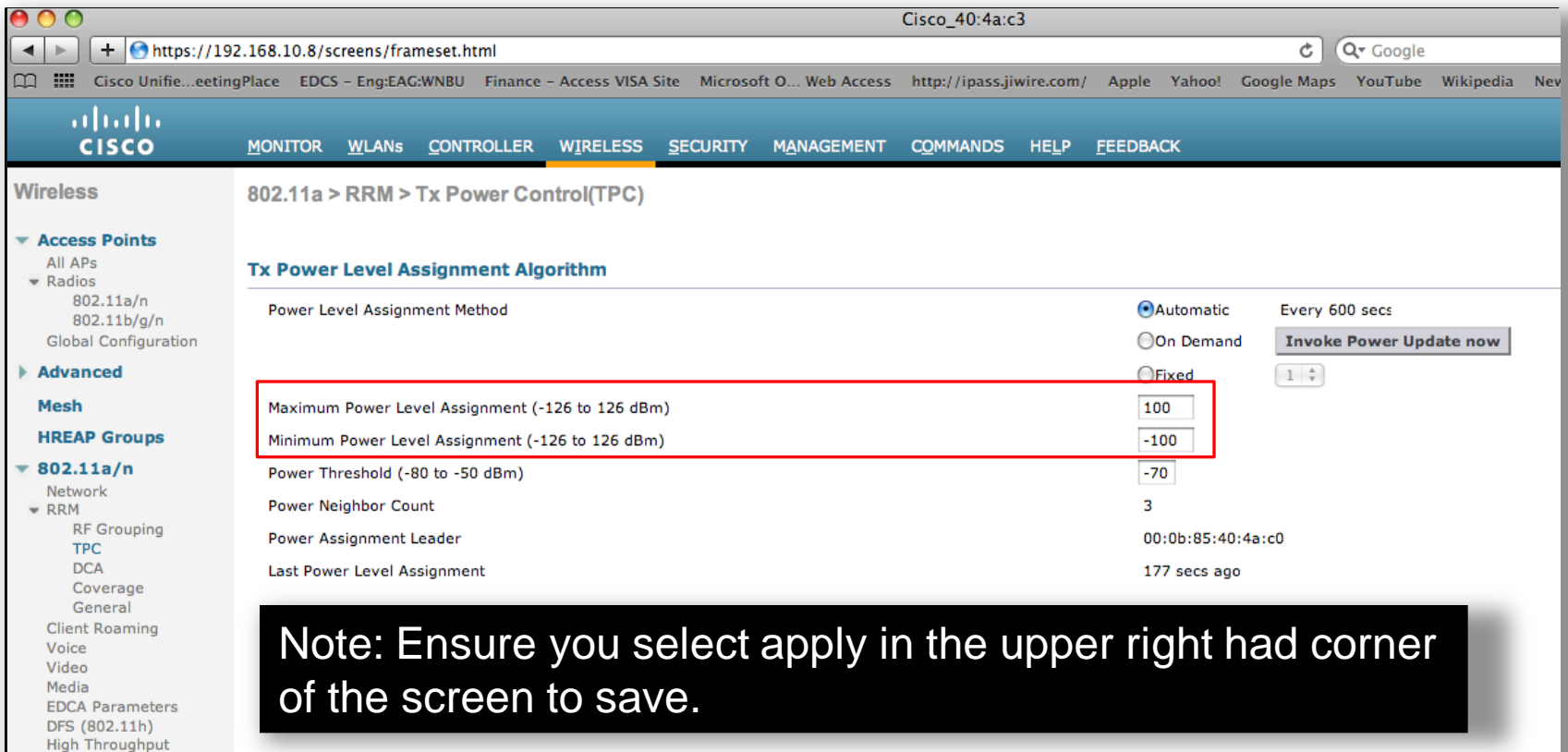
The screenshot shows the Cisco Wireless configuration interface for a specific WLAN (802.11a) under the RRM (Radio Resource Management) section. The page is titled "Tx Power Control (TPC)" and features a navigation menu on the left and a main configuration area on the right. The configuration area is titled "Tx Power Level Assignment Algorithm" and includes several settings:

Setting	Value
Power Level Assignment Method	<input checked="" type="radio"/> Automatic (Every 600 secs) <input type="radio"/> On Demand <input type="radio"/> Fixed (1)
Maximum Power Level Assignment (-126 to 126 dBm)	100
Minimum Power Level Assignment (-126 to 126 dBm)	-100
Power Threshold (-80 to -50 dBm)	-74
Power Neighbor Count	3
Power Assignment Leader	00:24:97:69:a2:80
Last Power Level Assignment	N.A

The "Power Threshold" setting is highlighted with a red box in the original image. The interface also includes a navigation menu on the left with options like "Access Points", "Advanced", "Mesh", "HREAP Groups", and "802.11a/n", and a top navigation bar with "MONITOR", "WLANS", "CONTROLLER", "WIRELESS", "SECURITY", "MANAGEMENT", "COMMANDS", "HELP", and "FEEDBACK".

TPC Min/Max power GUI configuration v. 6.1.n

- From the controller GUI select-
Wireless=>802.11a/b=>RRM-TPC



Wireless

802.11a > RRM > Tx Power Control(TPC)

Tx Power Level Assignment Algorithm

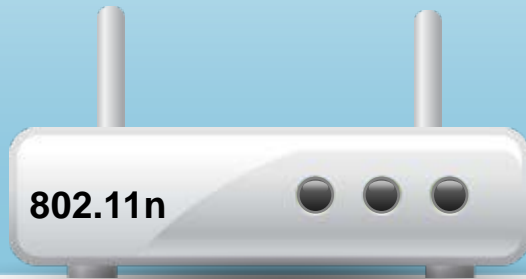
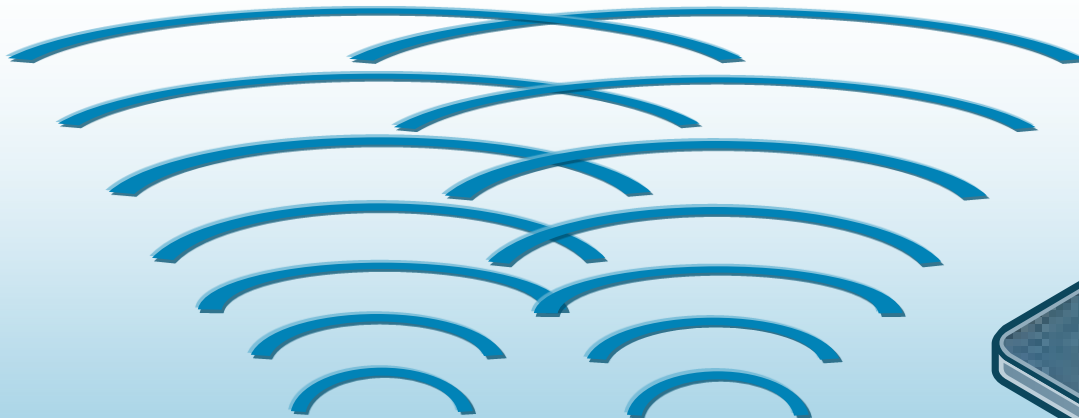
Power Level Assignment Method	<input checked="" type="radio"/> Automatic	Every 600 secs
	<input type="radio"/> On Demand	Invoke Power Update now
	<input type="radio"/> Fixed	<input type="text" value="1"/>
Maximum Power Level Assignment (-126 to 126 dBm)	<input type="text" value="100"/>	
Minimum Power Level Assignment (-126 to 126 dBm)	<input type="text" value="-100"/>	
Power Threshold (-80 to -50 dBm)	<input type="text" value="-70"/>	
Power Neighbor Count	<input type="text" value="3"/>	
Power Assignment Leader	<input type="text" value="00:0b:85:40:4a:c0"/>	
Last Power Level Assignment	<input type="text" value="177 secs ago"/>	

Note: Ensure you select apply in the upper right had corner of the screen to save.

Client Link - The Problem

Beam Strength Not Directed to Client

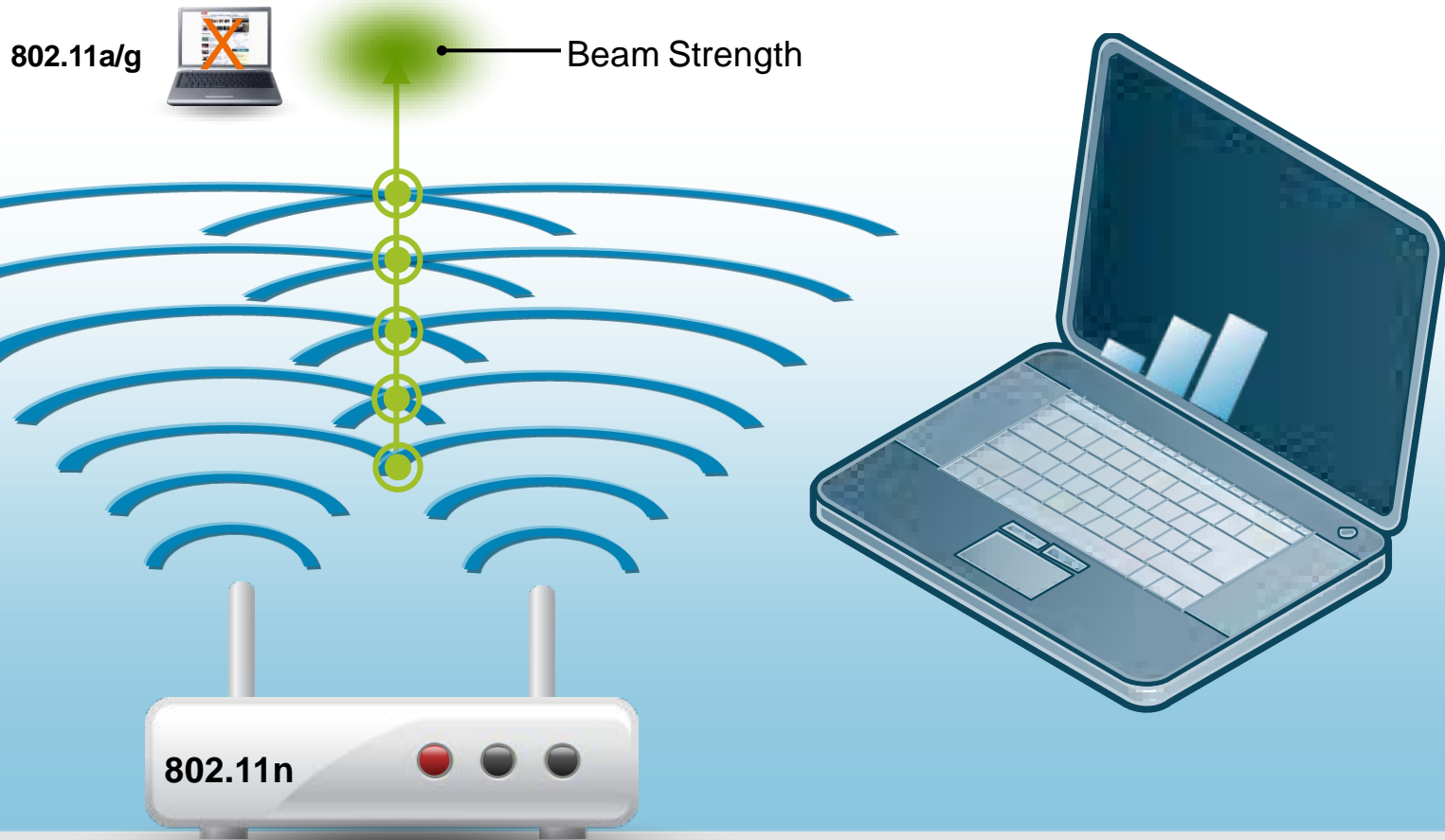
802.11a/g



**802.11a/g Client Connection Not Optimized,
Creates Coverage Hole**

The Problem

Beam Strength Not Directed to Client

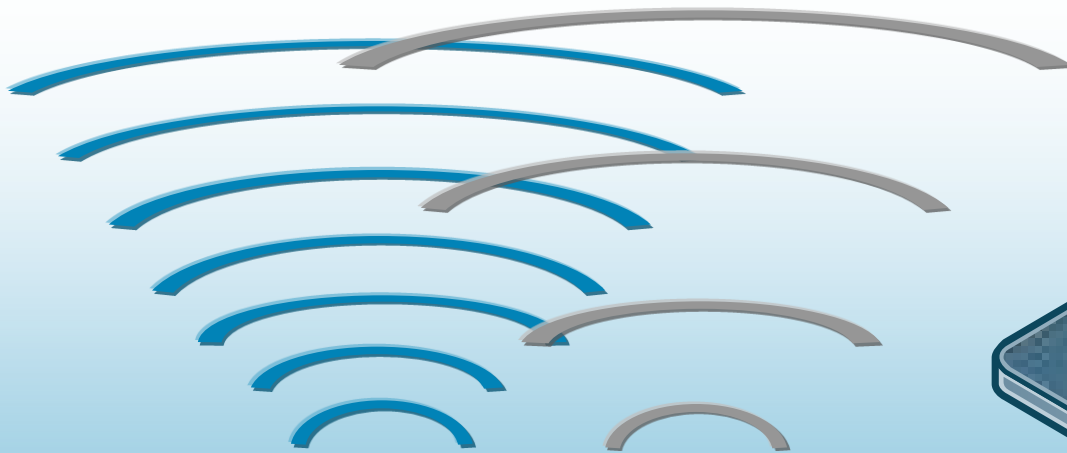


**802.11a/g Client Connection Not Optimized,
Creates Coverage Hole**

The Solution

Cisco Innovation: ClientLink

802.11a/g

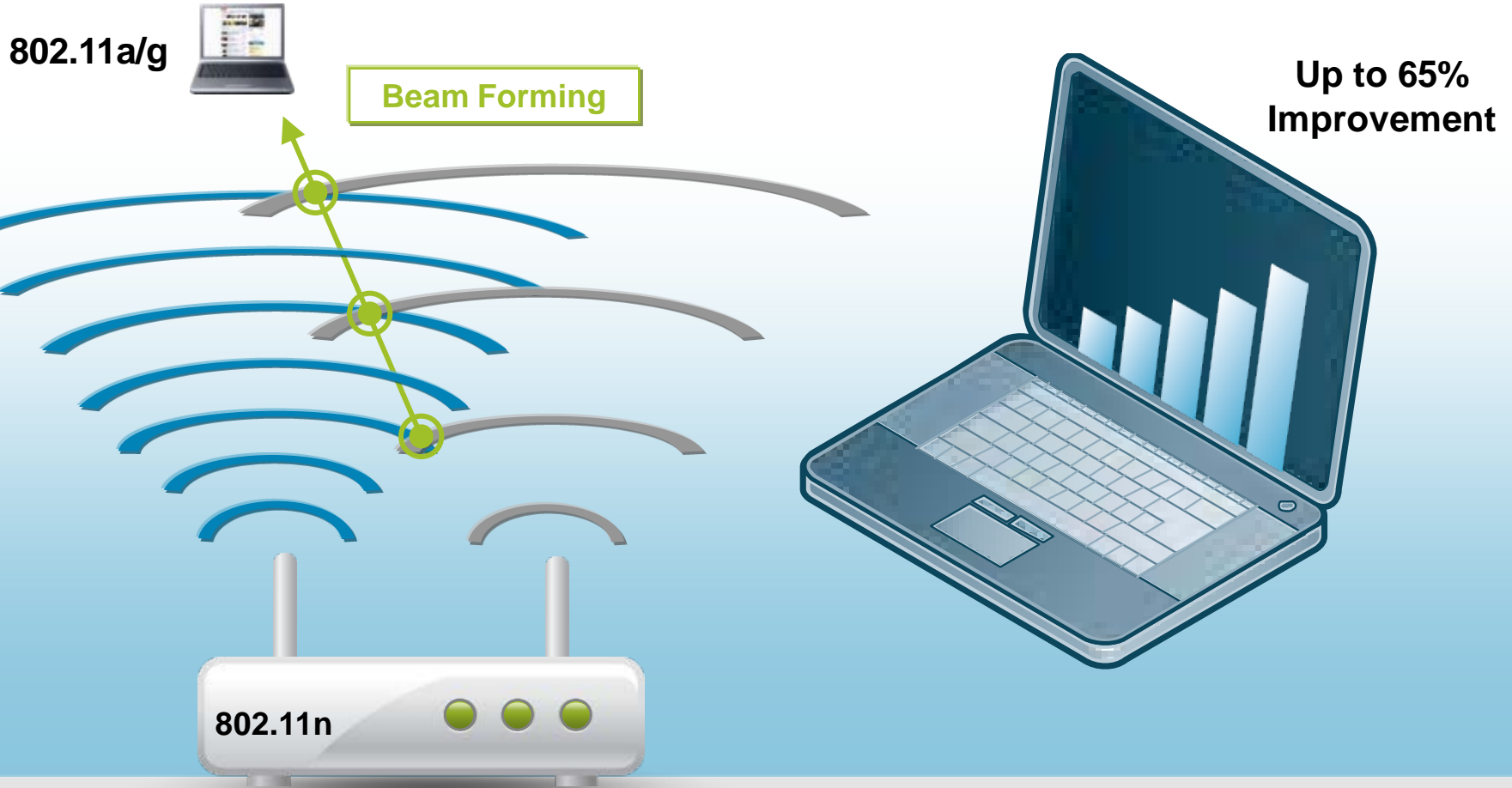


802.11n

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

The Solution

Cisco Innovation: ClientLink

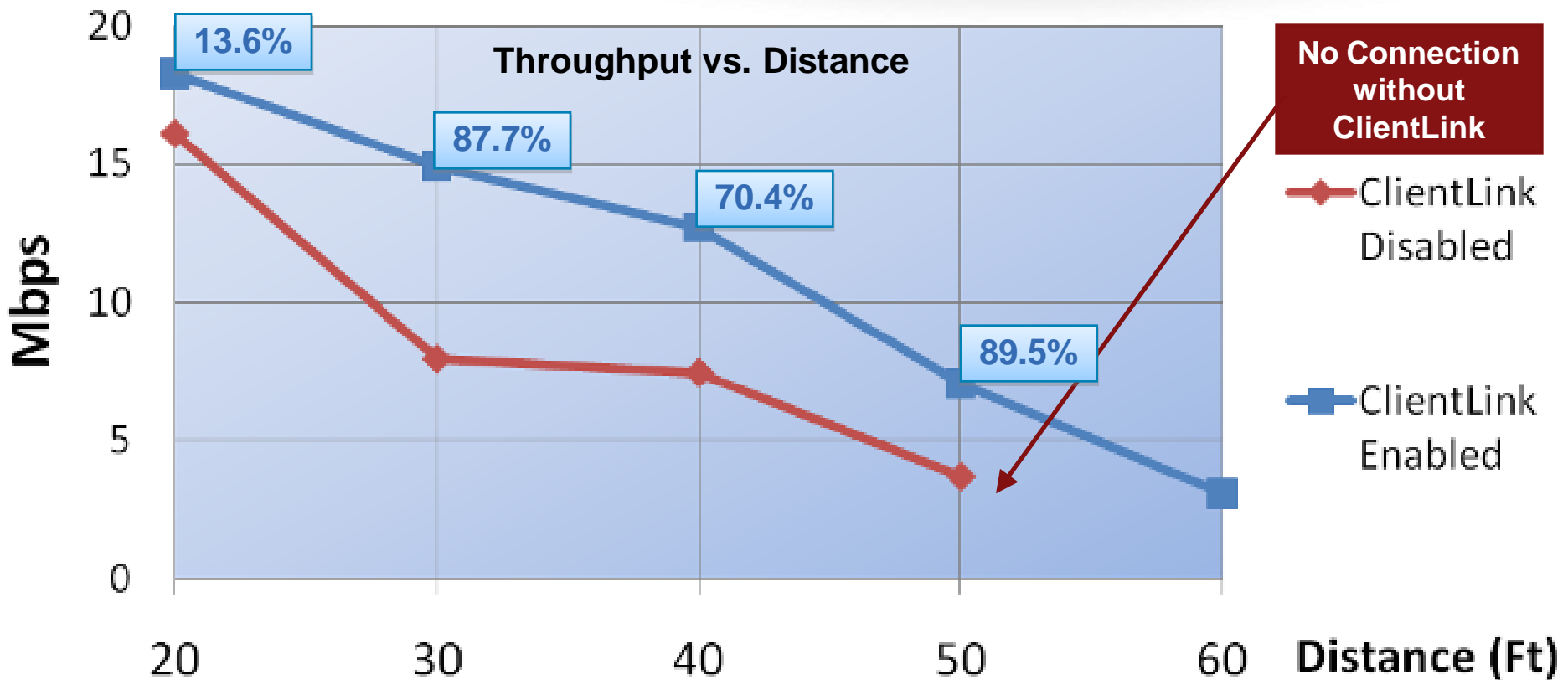


Intelligent Beam Forming Directs Signal to Improve Performance and Coverage for 802.11a/g Devices

Benefit #1: Higher Throughput per 11a/g Device



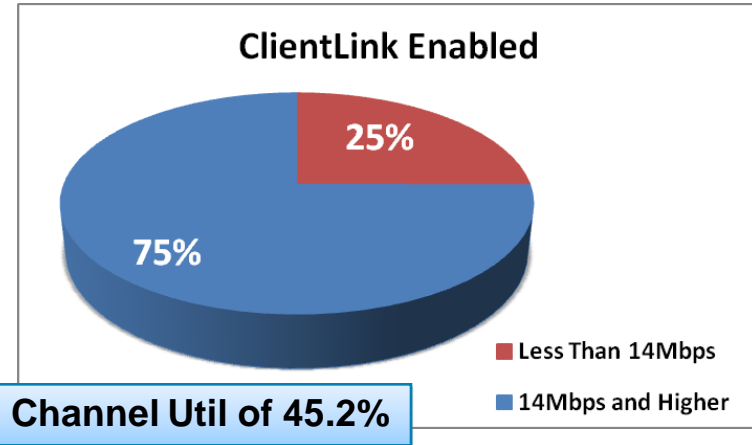
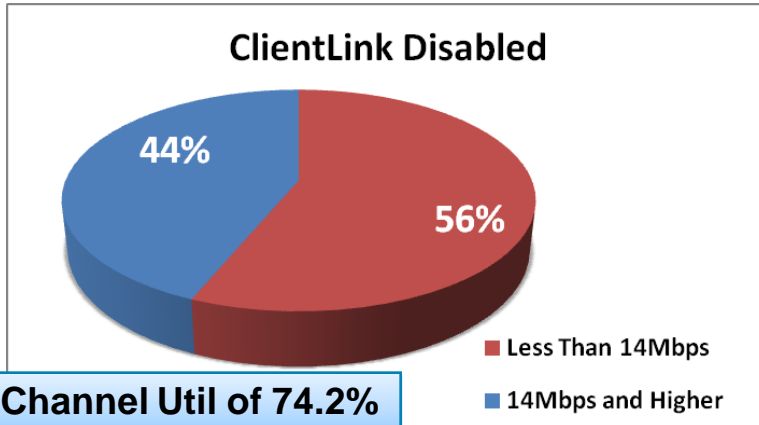
Up to **65%** Increase in Throughput



Test: 802.11a/g device with 802.11n network
Source: Miercom

Benefit #2: Higher System Capacity

Up to **27%** Improvement in Channel Capacity



- Faster data transmission, less retries = more efficient use of RF channel.
- Faster 11a/g transactions opens airtime for 11n devices, providing them improved experience

Test: 802.11a/g device measured at 16 antenna orientations w/ 802.11n network

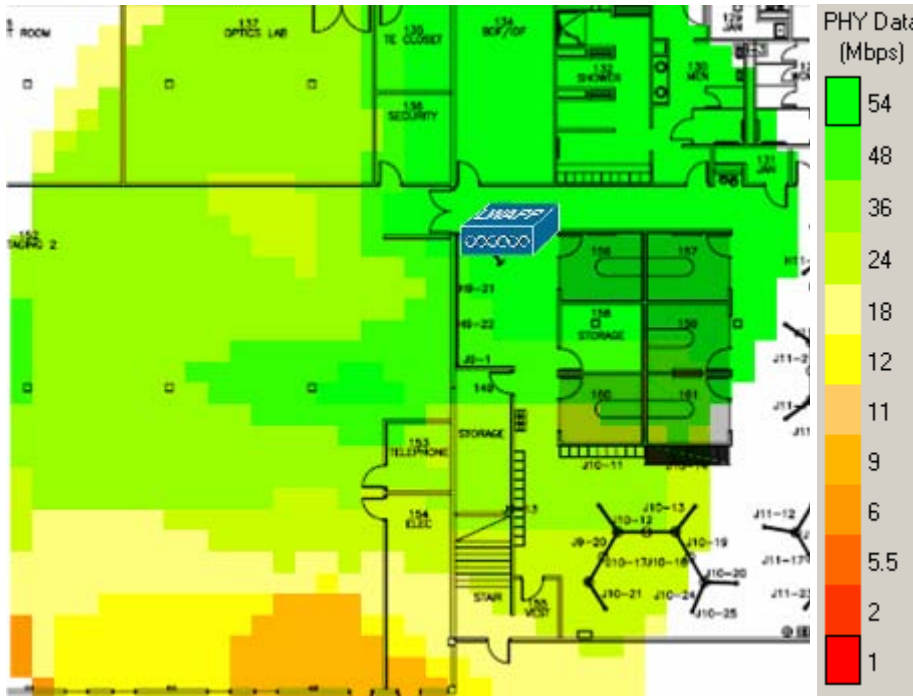
Source: Miercom

Benefit #3: Reduced Coverage Holes

Higher PHY Data Rates

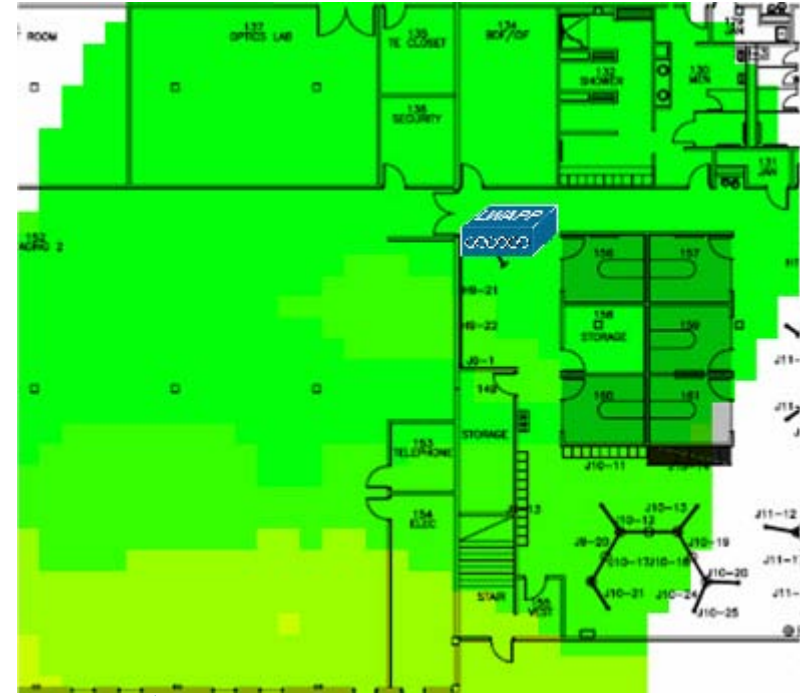


ClientLink Disabled



Lower Data Rates

ClientLink Enabled



Higher Data Rates

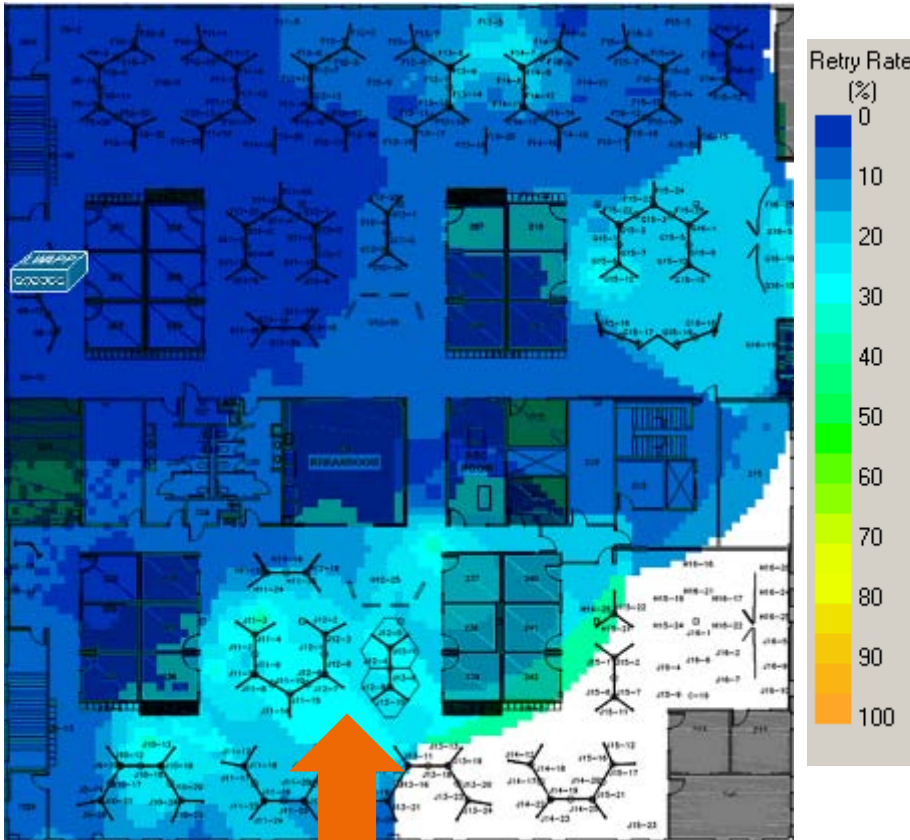
Source: Miercom; AirMagnet 6.0 Iperf Survey

Benefit #3: Reduce Coverage Holes (Cont.)

Lower retry rates

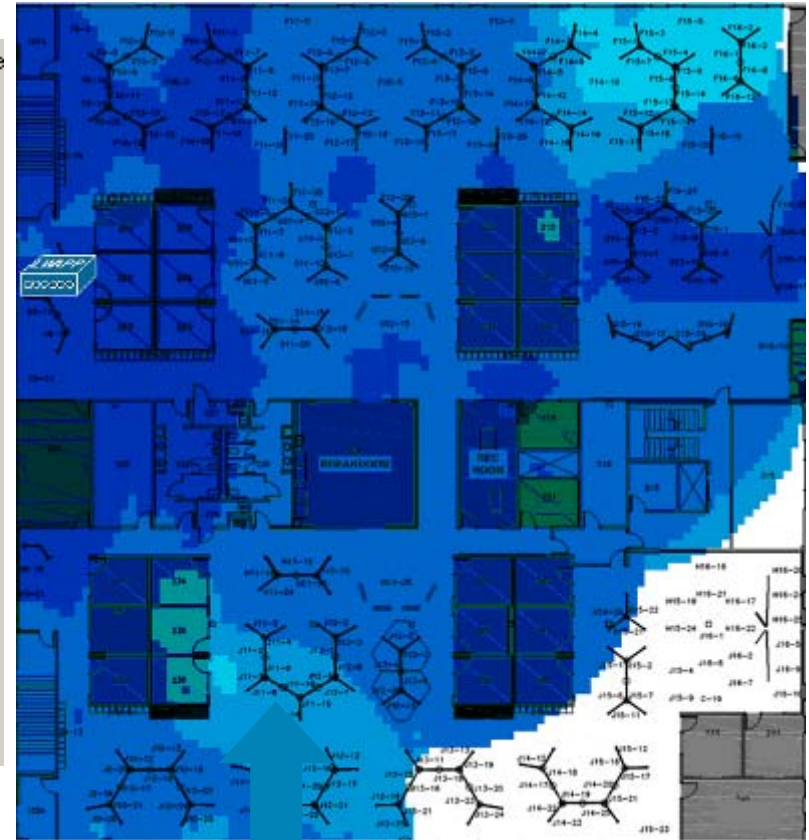


ClientLink Disabled



High Retry Rates

ClientLink Enabled



Low Retry Rates

Source: Miercom; AirMagnet 6.0 Iperf Survey

Beam Forming Enhancements

- Beam Forming will improve performance **only when data rates begin to fall**

Translation: **If the connection is already good (i.e. data rate of 54Mbps) there is no improvement**

- Measureable advantages:

Increased **SNR** at cell edges

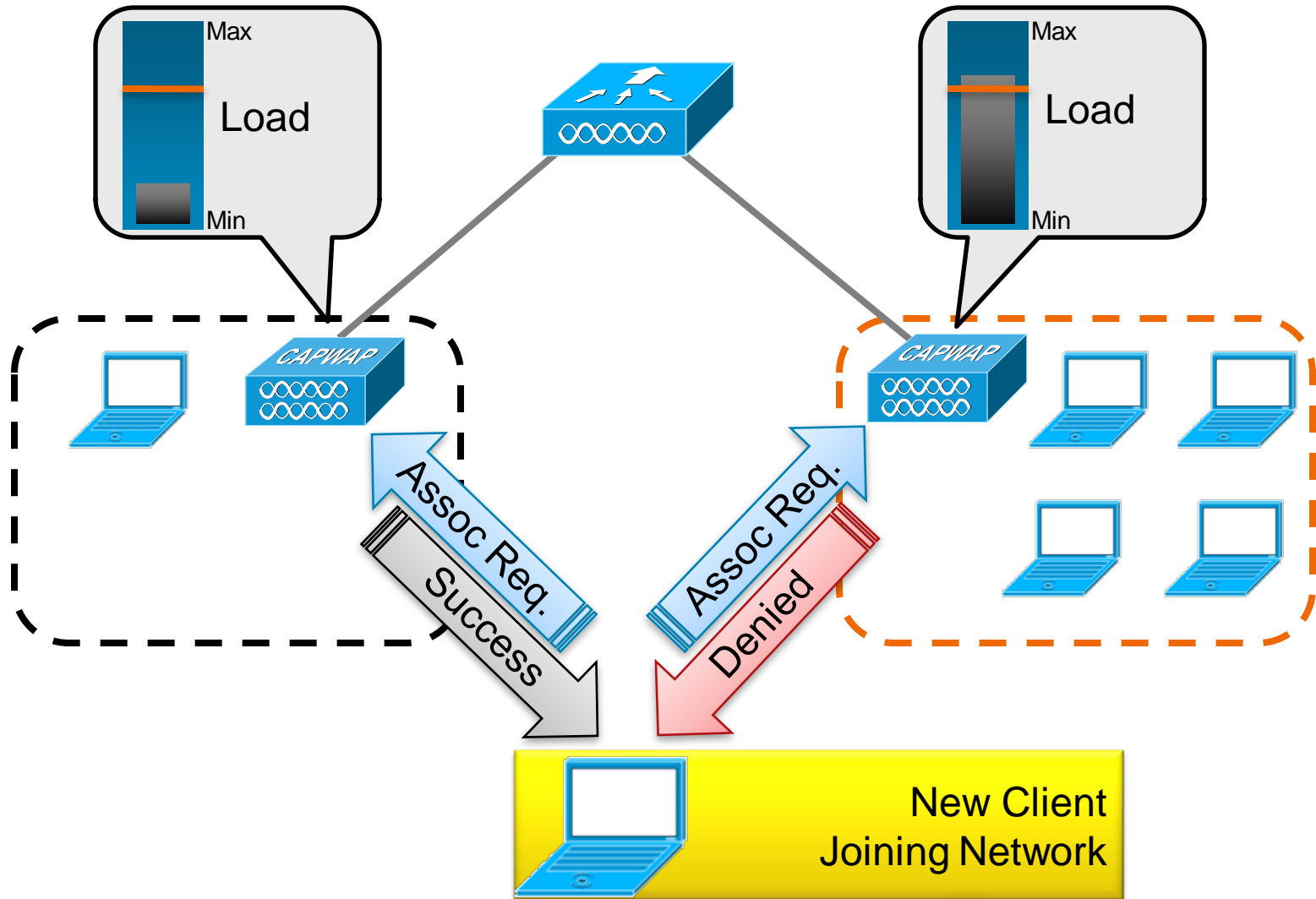
Provides

Increased downstream **data rates** at cell edges

Provides

Increased downstream **throughput** at cell edges

Load Balancing Concept



Load Balancing in Action

Packet Capture

Source	Destination	Protocol	Decode: Status Code
Intel-Client-1	Ethernet Broadcast	802.11 Probe Req	
AP-2	Intel-Client-1	802.11 Probe Rsp	
Intel-Client-1	AP-2	802.11 Ack	
Intel-Client-1	AP-2	802.11 Auth	0 Reserved Reserved
AP-2	Intel-Client-1	802.11 Ack	
AP-2	Intel-Client-1	802.11 Auth	0 Successful Successful
Intel-Client-1	AP-2	802.11 Ack	
Intel-Client-1	AP-2	802.11 Assoc Req	
AP-2	Intel-Client-1	802.11 Ack	
AP-2	Intel-Client-1	802.11 Assoc Rsp	17 Association denied because AP is unable to h...ditional...
Intel-Client-1	AP-2	802.11 Ack	
Intel-Client-1	AP-2	802.11 Deauth	
AP-2	Intel-Client-1	802.11 Ack	
Intel-Client-1	Ethernet Broadcast	802.11 Probe Req	
AP-1	Intel-Client-1	802.11 Probe Rsp	
Intel-Client-1	AP-1	802.11 Ack	
Intel-Client-1	AP-1	802.11 Auth	0 Reserved Reserved
AP-1	Intel-Client-1	802.11 Ack	
AP-1	Intel-Client-1	802.11 Auth	0 Successful Successful
Intel-Client-1	AP-1	802.11 Ack	
Intel-Client-1	AP-1	802.11 Assoc Req	
AP-1	Intel-Client-1	802.11 Ack	
AP-1	Intel-Client-1	802.11 Assoc Rsp	0 Successful

Association Allowed

AP is loaded.
Association
Denied

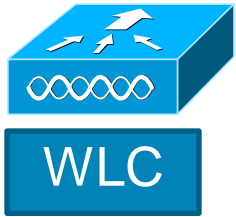


Load Balancing

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

Load Balancing Configuration



Wireless

- ▼ **Access Points**
 - All APs
 - ▼ Radios
 - 802.11a/n
 - 802.11b/g/n
 - Global Configuration
- ▼ **Advanced**
 - Load Balancing
 - Band Select
- Mesh**
- HREAP Groups**
- ▶ 802.11a/n
- ▶ 802.11b/g/n
- ▶ **Media Stream**
- Country**
- Timers**
- ▶ **QoS**

Load Balancing Apply

Enable Aggressive Load Balancing

Client Window Size

Maximum Denial Count

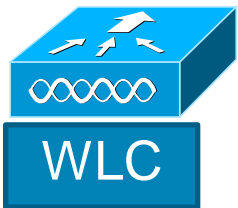
Load Balancing Statistics

Total Denied Client Count	0
Total Denial Message Sent	0
Exceeded Denial Max Limit Count	0
None 5G Candidate Count	0
None 2.4G Candidate Count	0

Load Balancing

Configuration — Per-SSID Override

- Load Balancing can introduce latency in the association and roaming process
- This latency is harmless for data applications but can negatively impact real-time applications.
- **Recommendation: Disable load balancing for WLANs that handle real-time applications such as voice and video**
- Example Below – disable load balancing for a specific WLAN



```
(Cisco Controller) >config wlan disable 2
(Cisco Controller) >config wlan load-balance allow disable 2
(Cisco Controller) >config wlan enable 2
(Cisco Controller) >show wlan 2 WLAN
Identifier..... 2
Network Name (SSID)..... NoLoadBalance
Load Balancing..... Disabled
```

Load Balancing

Caveats

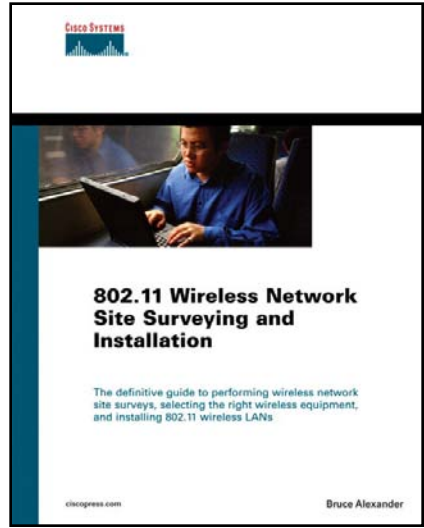
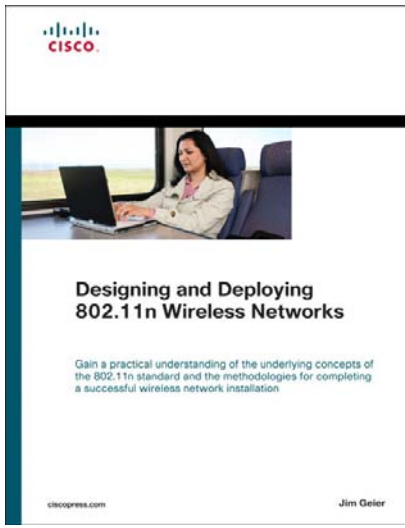
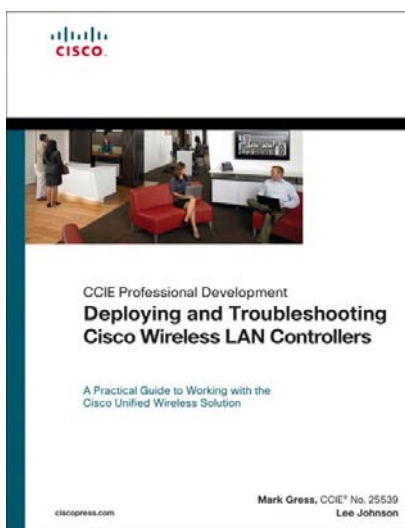
- Load balancing only occurs amongst APs on the same controller
- Load balancing requires that the client respect the “Code 17” association response and act accordingly
- Load Balancing only occurs at initial association, not on re-association.
- Some older clients simply ignore the “Code 17” response and try and associate again.
- Known clients that load balance correctly:
 - Intel 4965AGN (with 12.1 or later drivers)
 - Cisco CB-21AG (with 4.2 or later drivers)

More Information

- 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
- ClientLink Whitepaper:
http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps10092/white_paper_c11-516389.html
- ClientLink Miercom Report:
http://www.cisco.com/en/US/solutions/collateral/ns340/ns394/ns348/ns767/Miercom_Test_Report_Cisco_ClientLink.pdf

BRKEWN-2019

Recommended Reading



Housekeeping

- We value your feedback- don't forget to complete your online session evaluations after each session & complete the Overall Conference Evaluation which will be available online from Thursday
- Visit the World of Solutions
- Please remember this is a 'non-smoking' venue!
- Please switch off your mobile phones
- Please make use of the recycling bins provided
- Please remember to wear your badge at all times

