Presented by
Aruba Networks

WiFi Capacity Planning

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People move. Networks must follow.™

ARUBA networks

Aggregate Throughput for Mixed Clients

Table 16 *TCP Bidirectional Mixed PHY Scaling Test (Aggregate Channel)*

Clients	1	6	10	20	30	40	50
100% HT20	84.6 Mbps	68.5 Mbps	59.9 Mbps	59.8 Mbps	54.2 Mbps	52.0 Mbps	46.8 Mbps
75% HT20 / 25% 802.11a	N/A	53.2 Mbps	46.9 Mbps	43.9 Mbps	43.8 Mbps	41.1 Mbps	38.4 Mbps
50% HT20 / 50% 802.11a		44.1 Mbps	41.6 Mbps	34.5 Mbps	32.9 Mbps	29.8 Mbps	26.9 Mbps
25% HT20 / 75% 802.11a		43.1 Mbps	39.6 Mbps	34.3 Mbps	32.0 Mbps	27.3 Mbps	28.0 Mbps
100% 802.11a	22.4 Mbps	17.3 Mbps	16.9 Mbps	14.9 Mbps	14.9 Mbps	14.3 Mbps	14.0 Mbps

Throughput per Client

Choosing a Concurrent User Target

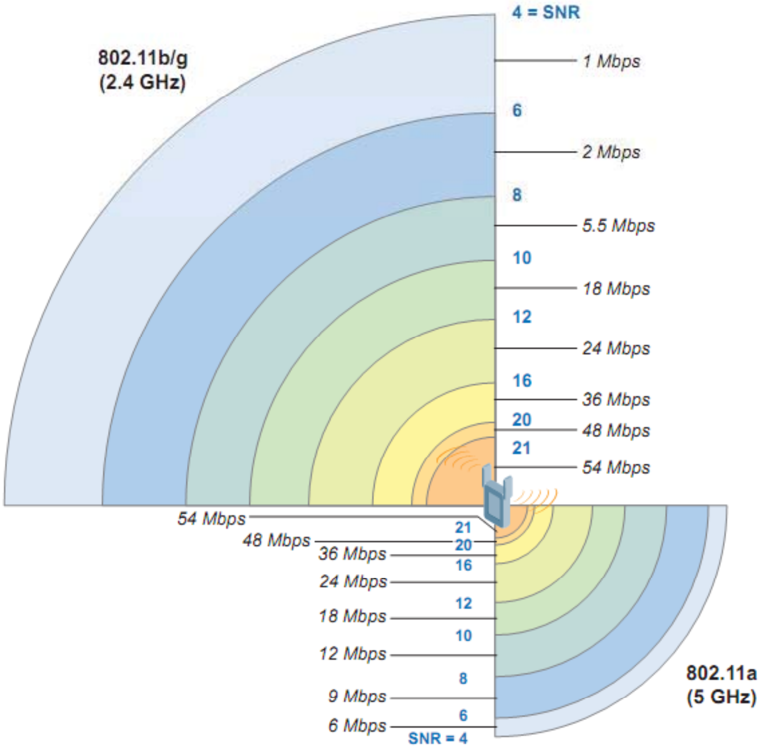
Use Table 3 to choose the concurrent user limit for each 5-GHz HT20 AP. First, choose the row that corresponds to your expected mix of legacy and 802.11n clients. Then find the column whose throughput is closest to the capacity goal you chose in Step #1. Note the client count at the top of the column and proceed to Step #4: Predict Total Capacity on page 27.

Table 3 *TCP Bidirectional Mixed PHY Scaling Test (Per Client)*

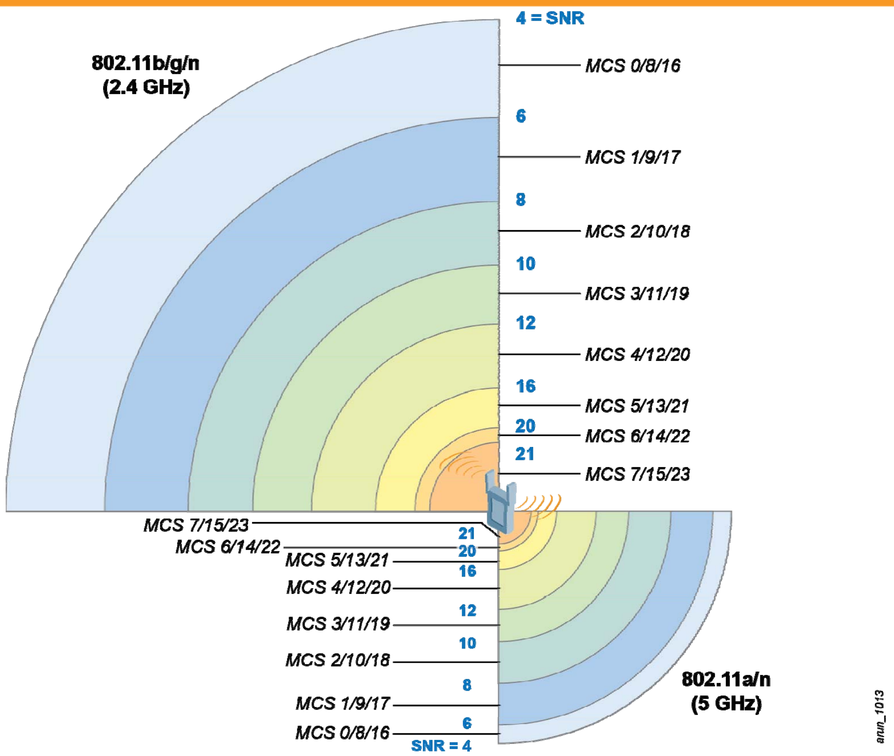
	Clients				
	10	20	30	40	50
100% HT20	5.99 Mbps	2.99 Mbps	1.81 Mbps	1.30 Mbps	0.94 Mbps
75% HT20 / 25% 11a	4.69 Mbps	2.20 Mbps	1.46 Mbps	1.03 Mbps	0.77 Mbps
50% HT20 / 50% 11a	4.17 Mbps	1.73 Mbps	1.10 Mbps	0.75 Mbps	0.54 Mbps
25% HT20 / 75% 11a	3.96 Mbps	1.72 Mbps	1.07 Mbps	0.68 Mbps	0.56 Mbps
100% 11a	1.50 Mbps	0.75 Mbps	0.50 Mbps	0.36 Mbps	0.28 Mbps

Data Rate and SNR

Cell Radius Varies with Data Rate



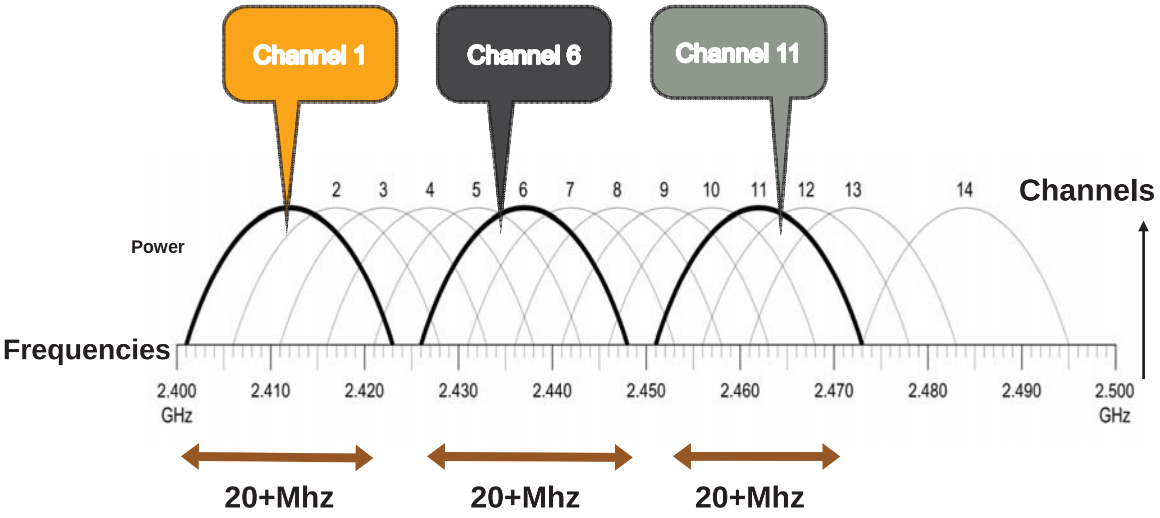
AP Coverage



IEEE 802.11 - WiFi

- **The basic 802.11 MAC layer uses the Distributed Coordination Function (DCF) to share the medium between multiple stations. DCF relies on CSMA/CA and optional 802.11 RTS/CTS to share the medium between stations. This has several limitations:**
  - if many stations communicate at the same time, many collisions will occur, which will lower the available bandwidth (just like in Ethernet, which uses CSMA/CD)
  - there are no Quality of Service (QoS) guarantees. In particular, there is no notion of high or low priority traffic.
  - once a station "wins" access to the medium, it may keep the medium for as long as it chooses. If a station has a low bit rate (1 Mbit/s, for example), then it will take a long time to send its packet, and all other stations will suffer from that

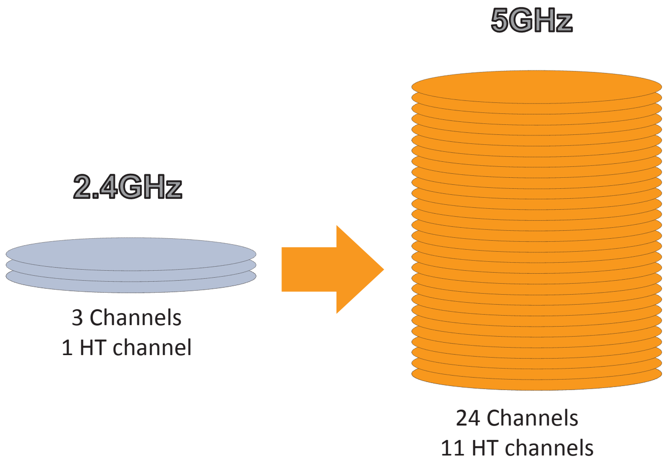
2.4GHZ WLAN channels



WLAN signal is spread over 20+Mhz so adjacent channels are not usable in the same physical area.

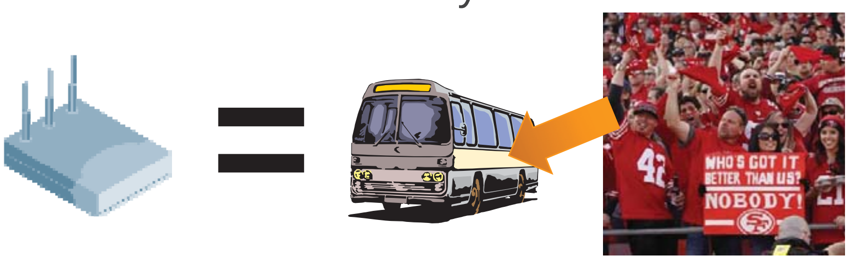
Capacity is limited in 2.4GHz

And many interferers in 2.4GHz, like microwave, bluetooth, cordless phone, …etc.

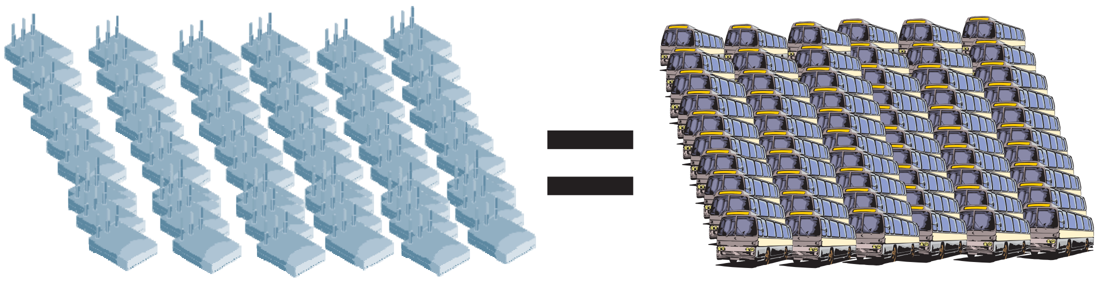


Understanding Association Capacity

- Association capacity means the number of devices that the HD WiFi network can "carry".

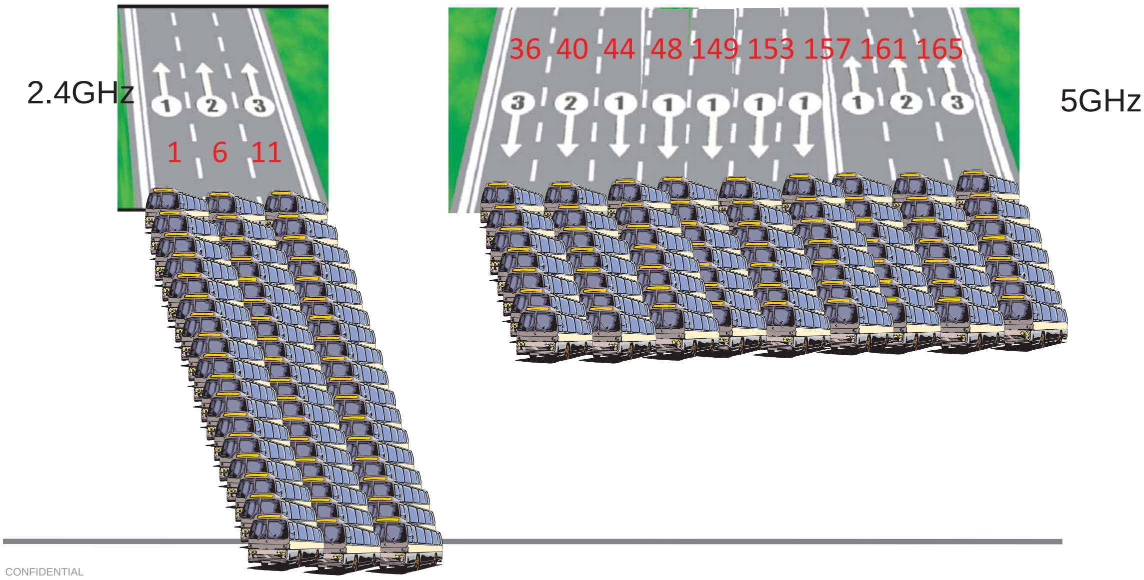


- To add association capacity, all we have to do is add APs



Understanding Transmit Capacity

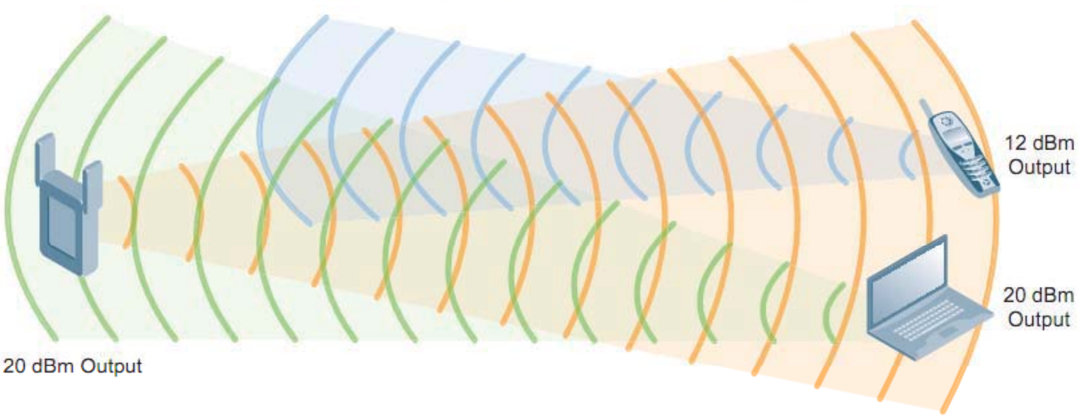
- Transmit capacity is the number of lanes on the road
- "Stacking" APs on the same channel will block on uplink pipe before channel capacity.



Mismatched Client and AP Power Output

- The worst combination is high power APs with low power clients. A symptom of this problem is having "5 bars" on the client device, but still having a a poor connection. The client can hear the AP but the AP cannot hear the client. This condition is illustrated in Figure 35.

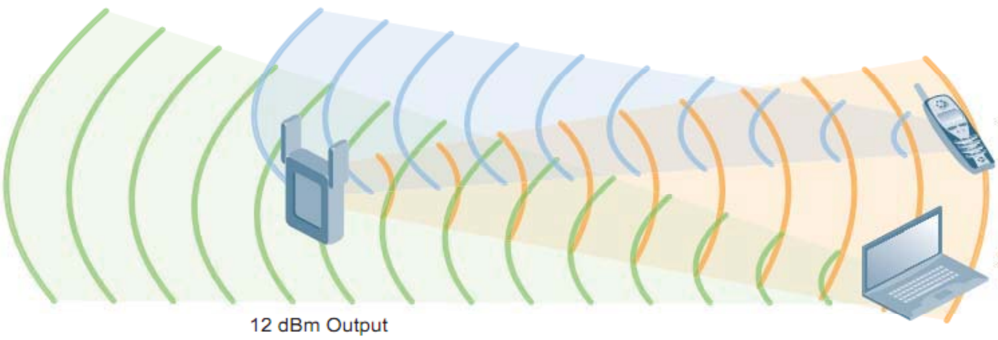
Figure 35 *Mismatched Client and AP Power Output*



When low-power devices are present

- When reduced-power client devices are present in a coverage zone, higher AP density is required. Lowering AP output power to match the least capable client is to shrink the effective cell size for all data rates on each AP.
- To minimize unnecessary rate adaptation due to higher collision activity, it is a requirement to reduce the number of supported rates. This may be accomplished by just enabling 24-54-Mbps legacy OFDM rates.

Figure 36 *AP Power Output Matched to Least Capable Client Device*



CCI and ACI

How the 802.11 Carrier Sense Works

802.11 networks use Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), in which each station with data to transmit utilizes a carrier sense mechanism to determine whether the channel is busy or idle. Unlike Ethernet, where collisions can be physically detected, two or more frames colliding on the air leave no evidence. For this reason, both a virtual carrier sense and a physical carrier sense must report an idle channel before a station may transmit:

- **Physical Carrier Sense:** For the channel to be idle, the Clear Channel Assessment (CCA) must report that no energy is detected above a defined threshold. CCA is a complex subject beyond the scope of this guide. For purposes of HD WLANs, the key point is that strong ACI will cause the CCA to report a channel as busy.
- **Virtual Carrier Sense:** For the channel to be idle, the Network Allocation Vector (NAV) must be zero. All 802.11 frames contain a preamble that includes a length field that tells receiving stations how much time that frame will take on the air. When a Wi-Fi station receives a frame with a valid preamble from any other station—whether part of the same Basic Service Set (BSS) or not— it must use the duration field to set a counter called the NAV. This is essentially a timer that is always counting down. As long as the NAV is greater than zero, the virtual carrier knows that the medium is busy. This is the primary mechanism of detecting so-called co-channel interference. It is not interference per se, like Bluetooth, but a way of ensuring that only one station can transmit at a time.

ACI Effects

Consider the HD WLAN in Figure 32, which has three pairs of APs and clients, each one on an adjacent 20-MHz channel. Pairs 1 and 3 are transmitting heavy-duty cycle traffic such as a video stream. All six stations are configured to use 20 dBm EIRP.

AP2 and station 2 on channel 40 now want to transmit and perform a CCA. Because pair 1 is only 3.2 ft (1 m) away, their transmissions are received at -44 dBm, while signals from pair 2 travel 6.5 ft (2 m) and are received at -50 dBm. Neither AP2 nor station 2 are allowed to transmit because the detected energy exceeds the CCA threshold, even though no one else is using the channel.

Figure 32 *ACI Example with APs and Clients at Short Range*

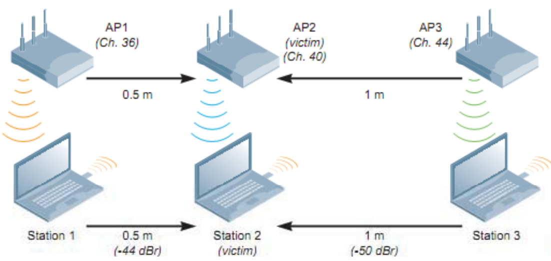
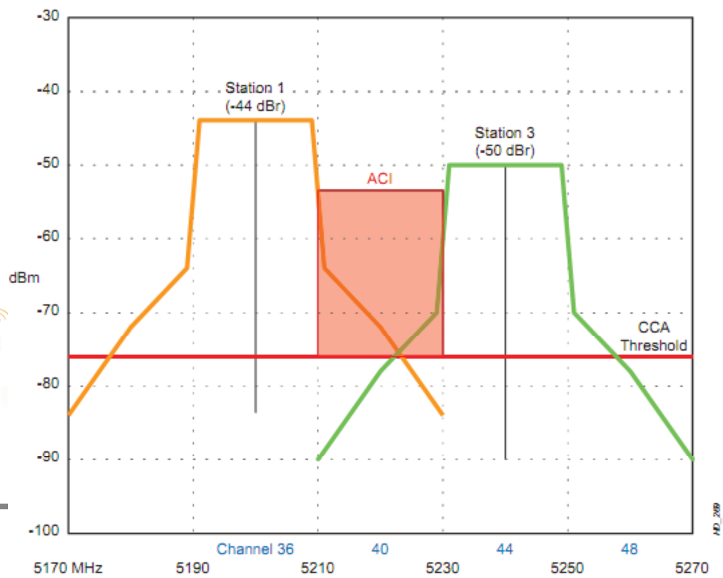
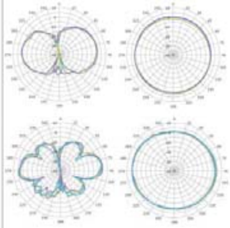


Figure 33 *Frequency Domain Illustration of ACI at Short Range*



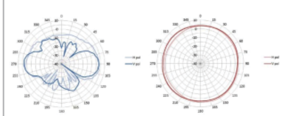
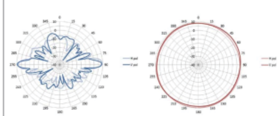
Antenna Selection

Antenna Pattern

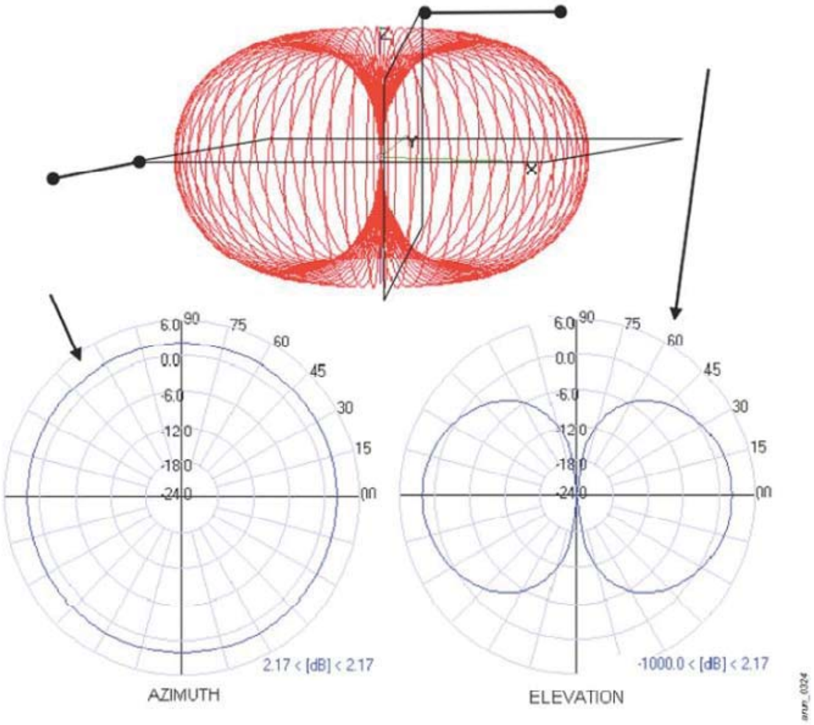
Model	Type	Band(s)	Typical Gain	Polarization & Element Type	Bandwidth (Degrees)		VSWR	Max Input Power	Connector(s)	Dimensions (mm)	Operating Temperature	Antenna Patterns
					H-plane	E-plane						
AP-ANT-1F 	Omnidirectional	2.400GHz - 2.500GHz	2.0dBi	Vertical, linear	360	50	< 2.0 : 1	2W	1x RP-SMA/m, direct-mount	127 x 39 x 19	-10C to +55C	
		4.900GHz - 5.875GHz	5.0dBi		360	25						

Antenna Patterns

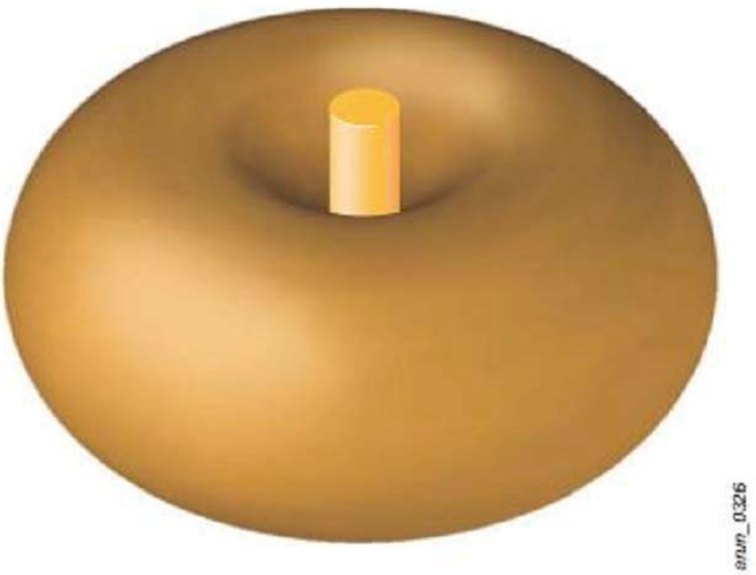
ARUBA networks ANTENNA LINE MATRIX: **OUTDOOR ONLY (N-MALE)**

Model	Band	Gain	Polarization & Element Type	Beamwidth	Dimensions	Max Input Power	Operating Temperature	Antenna Pattern (2450Mhz and/or 5500Mhz) Direction of Maximum Gain at 0° Unless Noted
AP-ANT-2x2-5005 2 Omni Antennas 2x2 MIMO Pair 	5.150 - 5.875 GHz	5.0 dBi	Vpol: Linear, Vertical Hpol: Linear, Horizontal Both: N-type Male	Vpol: E-Plane – 29° Hpol: E-Plane – 33° Both: H-Plane - 360°	200 x 25 x 25 mm 140 g	10 watts Impedence - 50 Ω VSWR <2.0:1	Operating: -30° F to +70° C Storage: -40° C to +85° C	
AP-ANT-2x2-5010 2 Omni Antennas 2x2 MIMO Pair 	5.150 - 5.875 GHz	10.0 dBi	Vpol: Linear, Vertical Hpol: Horizontal, Vertical Both: N-type Male	Vpol: E-Plane – 8° Hpol: E-Plane – 9.5° Both: H-Plane - 360°	Vpol: 490 x 25 x 25 mm Hpol: 451 x 25 x 25 mm	10 watts Impedence - 50 Ω VSWR <2.0:1	Operating: -30° F to +70° C Storage: -40° C to +85° C	

Dipole Antenna



Dipole Antenna



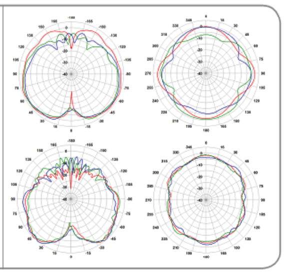
High Gain Omni Antenna (Elevation View)

mounted at a 40 ft ceiling height
High Gain Omni

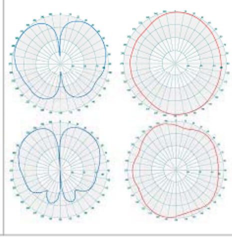
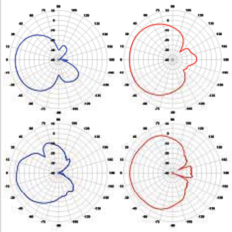
- Coverage does not reach the clients on the floor
- Interfere with other APs on the same channel

Antenna Pattern

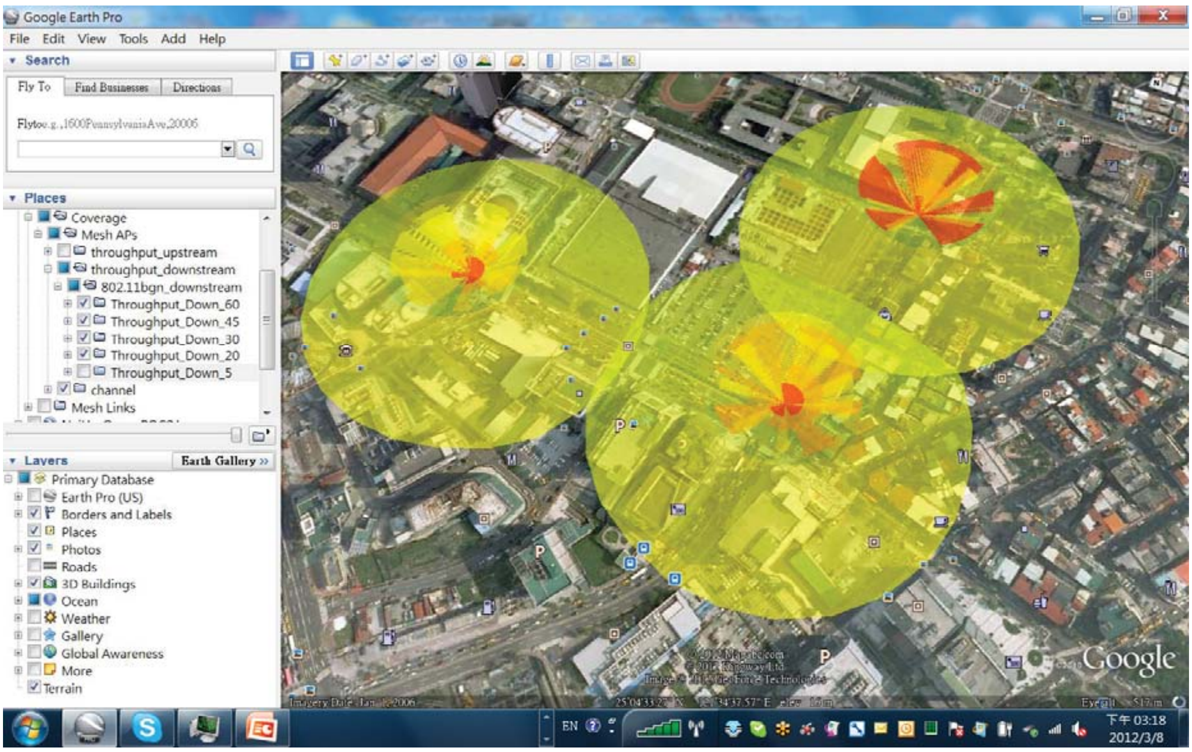
ANTENNA LINE MATRIX: **INDOOR ONLY (RP-SMA)**

Model	Band	Gain	Polarization & Element Type	Beamwidth	Dimensions	Max Input Power	Operating Temperature	Antenna Pattern (2450Mhz and/or 5500Mhz) Direction of Maximum Gain at 0° Unless Noted
AP-ANT-16 Downtilt Omni MIMO 3-Element Array 	2.4-2.5 GHz	3.9 dBi	Vertical Downtilt 3x RP-SMA 3x 36" pigtails	E-Plane – 60° H-Plane – 360°	12.13" x 3.62" x 0.86" 30.82 x 9.2 x 2.2 cm	2 watts Impedence - 50 Ω VSWR <2.0:1	-40° F to +158° F -40° C to +70° C	
	4.9-5.9 GHz	4.7 dBi						

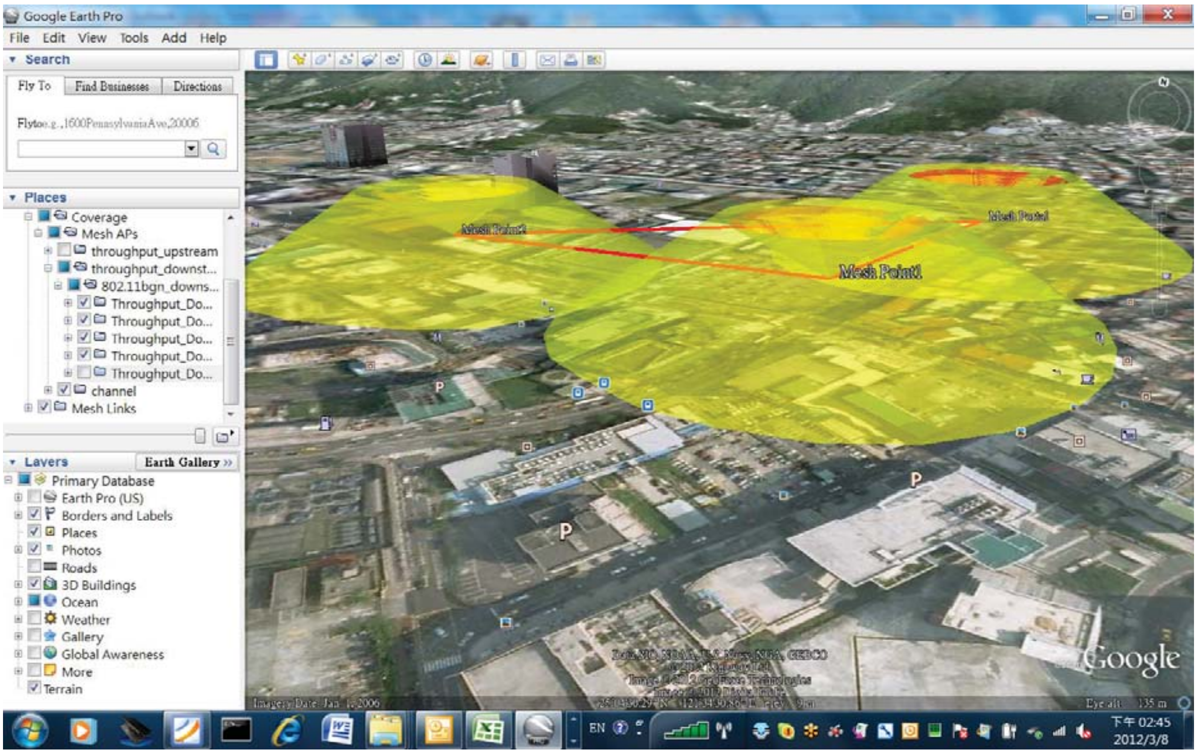
Antenna Patterns

Model	Type	Band(s)	Typical Gain	Polarization & Element Type	Bandwidth (Degrees)		VSWR	Max Input Power	Connector(s)	Dimensions (mm)	Operating Temperature	Antenna Patterns
					H-plane	E-plane						
AP-ANT-90 	Downtilt diversity omni	2.400GHz - 2.500GHz	3dBi	Vertical, linear downtilt	360	57-61	< 2.0 : 1	2W	2x N-type/m, pigtail cable	157 x 93 x 23	-40C to +70C	
		4.900GHz - 5.990GHz	3dBi		360	55-59						
ANT-2X2-D805 	120 Degree 2x2 MIMO sector	2.400GHz - 2.500GHz	5dBi	Linear dual-slant +/-45 degrees	120	70	< 1.8 : 1	20W	2x N-type/m, pigtail cable	200 x 200 x 33	-40C to +70C	
		5.150GHz - 5.875GHz	5dBi									

Downtilt Antenna



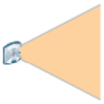
Downtilt Antenna



RF Coverage Strategies

Coverge Strategies

Overhead Coverage: This refers to placing APs on the ceiling above the seats in the auditorium, usually with a special low-gain antenna with a radiation pattern directing the signal at the floor.

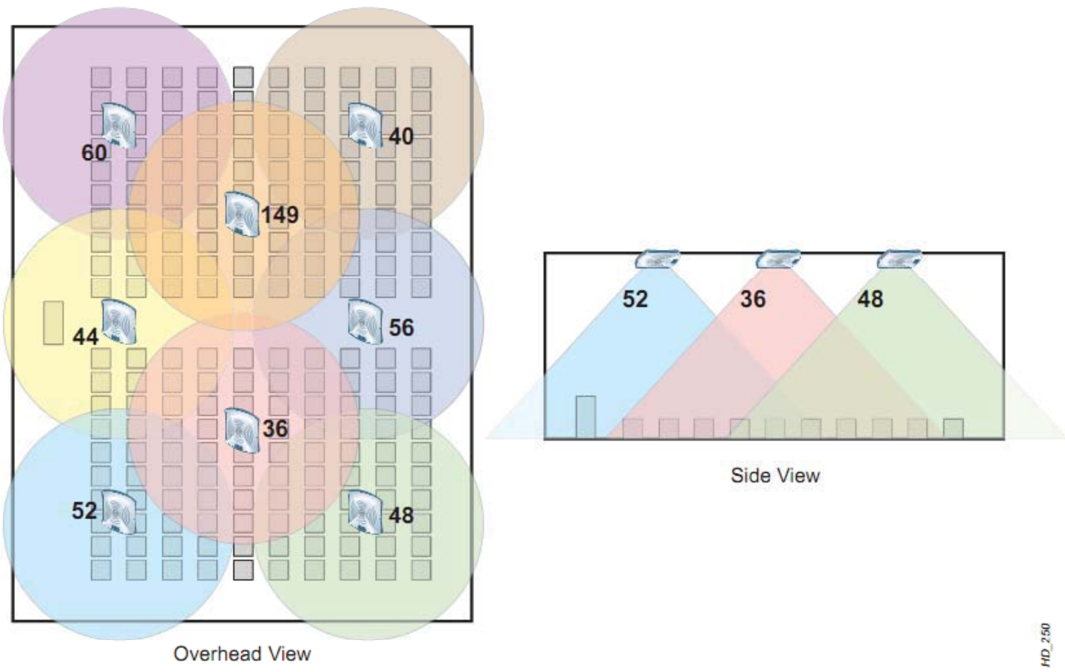


Side Coverage: The AP is mounted to walls and/or pillars that exist in the auditorium, generally no more than 12 ft (4 m) above the floor. Either directional or omnidirectional antennas can be used, with the direction of maximum gain aimed sideways across the seats.

Floor Coverage: This design creates picocells using APs mounted in, under, or just above the floor of the auditorium, with a low-gain downtilt antenna reversed to face straight up at the ceiling. This strategy is the only one that can allow for multiple channel reuse inside a room of 10,000 ft^2 (930 m^2) or less.

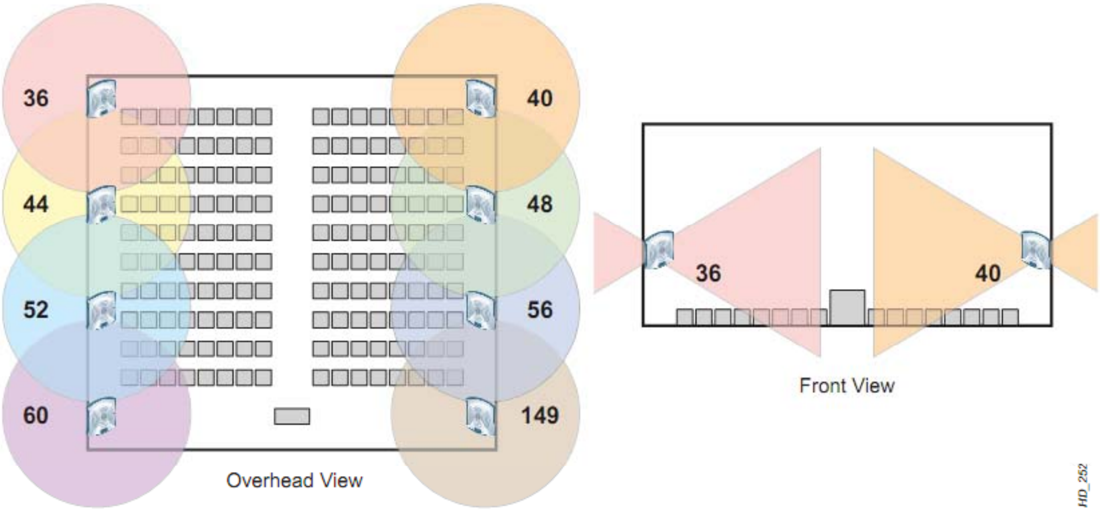
Overhead Coverage

Figure 11 *Simplified Overhead Coverage Example*

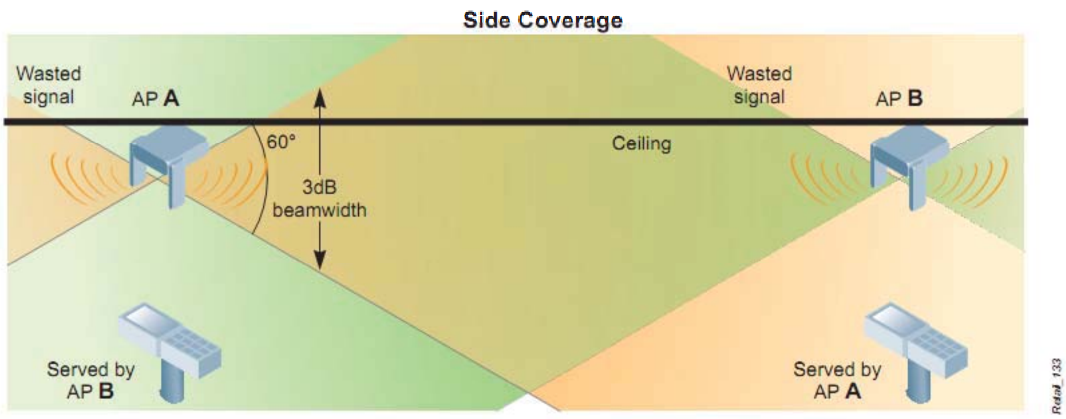


Side Coverage

Figure 15 *Simplified Side Coverage Example with Integrated Antenna*

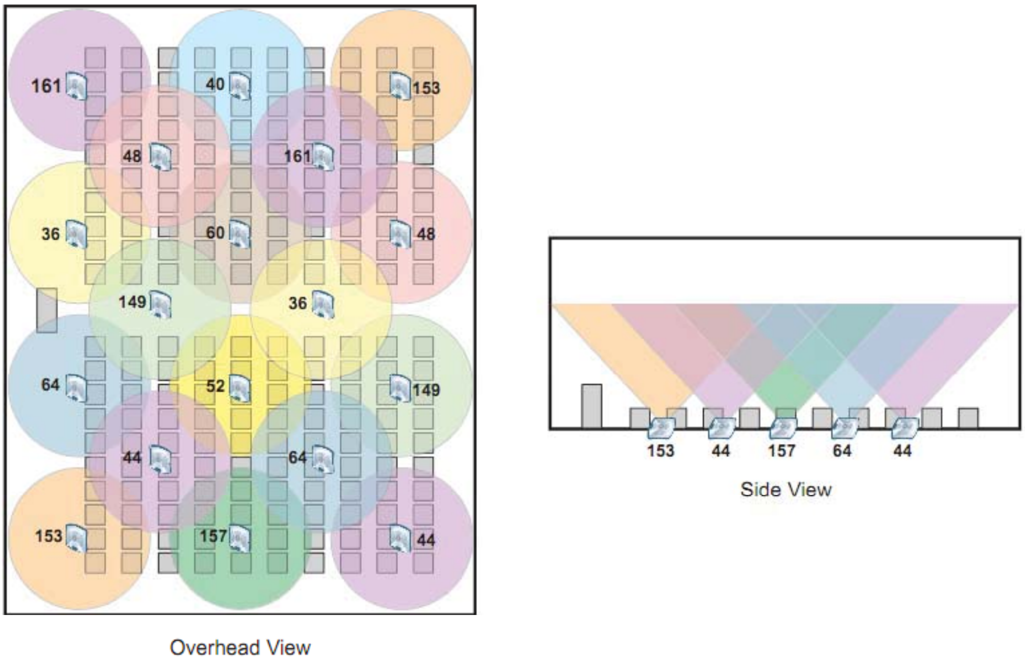


Side Coverage

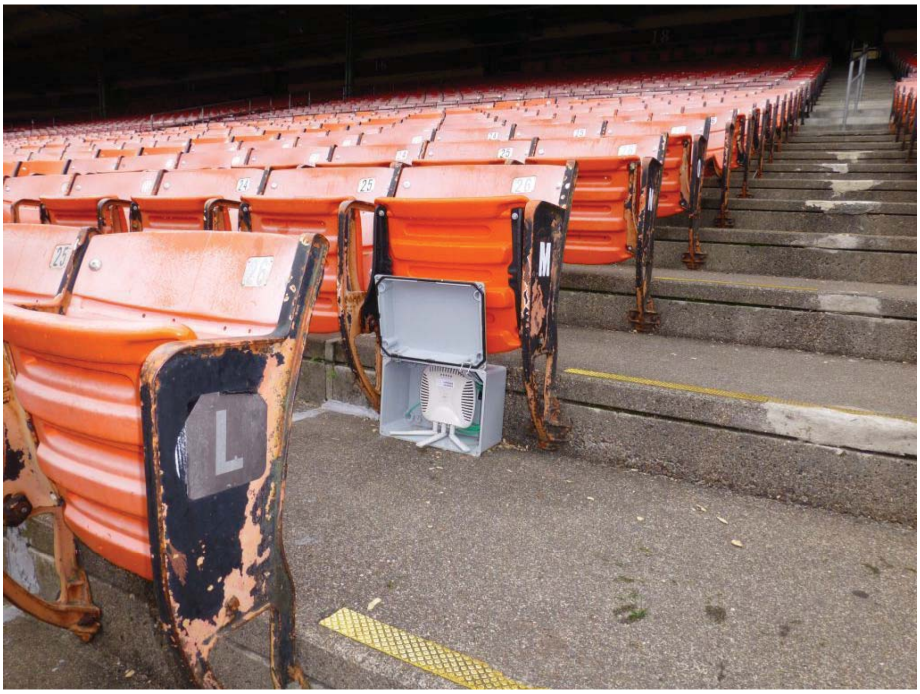


Floor Coverage (Picocell Coverage)

Figure 18 *Simplified Picocell Coverage Example*



Floor Coverage



WiFi Features

AP 內建Wi-Fi晶片支援Spectrum Analysis -協助您看出無線上Non-WiFi 之干擾源

辨識 並自動避開 Non Wi-Fi 干擾源

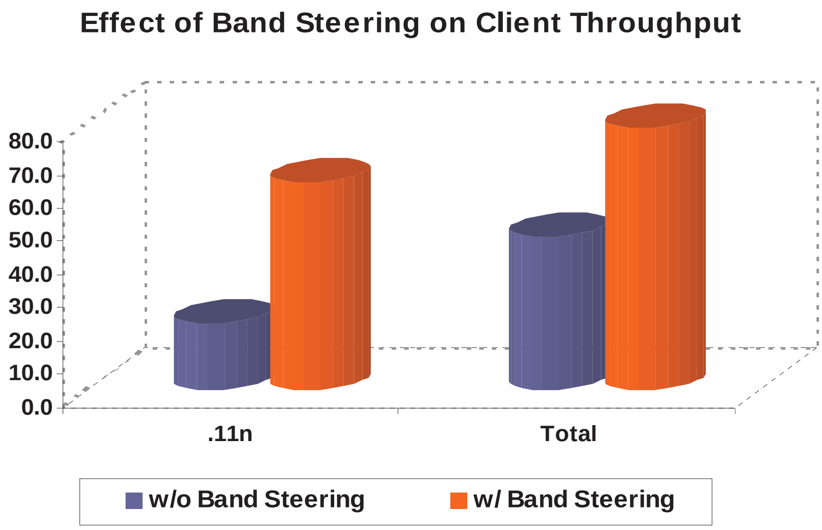
Cost Effective
- Integrated to Wi-Fi chipset in all Aruba 802.11n APs
- Does not require specialized AP or external laptop for monitoring

Always On
- No specialized chip in AP
- No need to spare scanning time
- Record and Playback on Demand

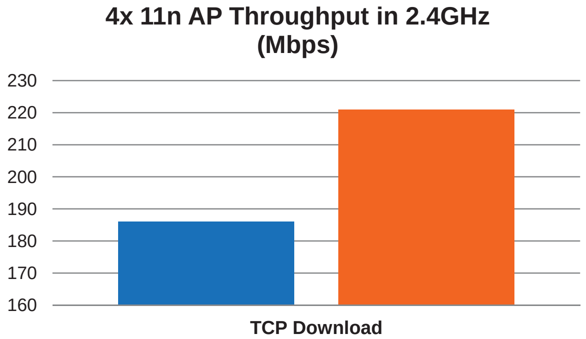
Detailed Charts
- 14 simultaneous views within the Aruba Mobility Controller
- No need for external laptop

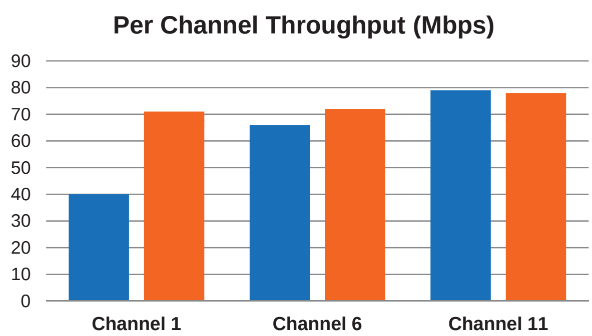
Band Steering Improves the Network Performance

- 1x11b + 1x11g + 1x11a + 1x11n client mix
- 108% increase in 802.11b throughput, 162% increase in 802.11g throughput
- 217% increase in 802.11n throughput, 70% increase in total throughput



Load Balancing across Channels





Better Client Distribution

- Cisco load balances 6 clients on ch1, 3 on ch6, 3 on ch11
- Aruba load balances 4 clients on each of ch1, ch6, ch11

Higher Total Throughput

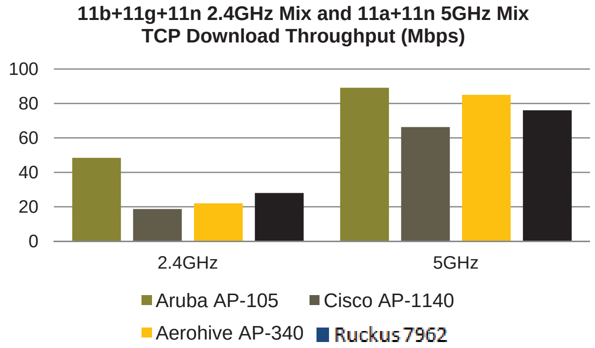
- Cisco delivers 186Mbps total
- Aruba delivers 221Mbps total *(20% higher)*

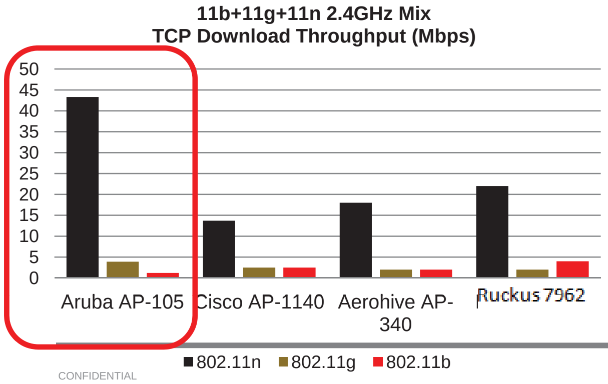
Similar Channel Throughput

- Cisco delivers 40+66+79 Mbps
- Aruba delivers 71+72+78 Mbps

	AP 1/Channel 1	AP 2/Channel 6	AP 3/Channel 11	AP 4/Channel 1
Cisco	3	3	3	3
Aruba	2	4	4	2

Airtime Fairness
-Mix Type Client Performance Protection





Higher 11n Throughput
- 2x to 3x better 11n performance compared to competition

802.11b Awareness
- Only Aruba offers 11b awareness – hence greater peak mix type throughput

Higher Total Throughput
- 10-30Mbps higher throughput compared to competition

ArubOS Features

- ✓ **Receive Sensitivity Tuning**: Receive sensitivity tuning can be used to fine tune the APs to "ignore" clients that attempt to associate at a signal level below what is determined to be the minimum acceptable for a client in the intended coverage zone. This tuning helps to reduce network degradation to outside interference and/or client associations that may be attempted below the minimum acceptable signal level based on the desired performance criteria.
- ✓ **Disabling Low Rates**: By definition, any high-density coverage area has APs and clients in a single room or space. To minimize unnecessary rate adaptation due to higher collision activity, it is a requirement to reduce the number of supported rates. This may be accomplished by just enabling 24-54-Mbps legacy OFDM rates. However, all 802.11n MCS rates must be enabled for compatibility with client device drivers.
- ✓ **"Chatty" Protocols:** A "chatty" protocol is one that sends small frames at frequent intervals, usually as part of its control plane. Small frames are the least efficient use of scarce airtime, and they should be reduced whenever possible unless part of actual data transmissions. Wherever chatty protocols are not needed, they should be blocked or firewalled. These protocols include IPv6 if it is not in production use, netbios-ns, netbios-dgm, Bonjour, mDNS, UPnP, and SSDP.

802.11ac Wave 2 Technology Deep Dive and Deployment Recommendations

Video for 802.11ac Wave 2 Technology Deep Dive

More Detail Please See

http://community.arubanetworks.com/t5/Airheads-Conference-Vegas-2015/Breakout-802-11ac-Wave-2-technology-deep-dive-and-deployment/td-p/218559

2

802.11ac Technology Overview

Think of 11ac as an extension of 11n

- 11n specification introduced/leveraged:
  - 2.4 and 5 GHz supported
  - Wider channels (40 MHz)
  - Better modulation (64-QAM)
  - Additional streams (up to 4 streams)
  - Beam forming (explicit and implicit)
  - Backwards compatibility with 11a/b/g

11ac Wave 1 introduced:

- Even wider channels (80 MHz)
- Better modulation (256-QAM)
- Additional streams (up to 8)
- Beam forming (explicit)
- Backwards compatibility with 11a/b/g/n
  - Refer to http://www.802-11.ac.net for in-depth information

4

Wave 2 of 11ac

- **What will wave 2 802.11ac offer?**
  - MU-MIMO
    - Use AP MIMO resources more effectively
    - Transmit data to multiple devices simultaneously: for example 4SS AP streaming data to four 1SS clients simultaneously
  - 4x4:4SS
    - Benefit of additional stream mostly for MU-MIMO
    - Not anticipating any 4x4:4SS client devices
    - Adds 33% to max data rate in SU-MIMO
  - VHT160
    - Doubles max datarate
    - Practical problem: only 2 VHT160 channels available in entire 5GHz band
- **Max 5GHz radio data rates increases again!**
  - 450 (11n 3x3 HT40), 1,300 (11ac 3x3 VHT80), 3,467 (11ac 4x4 VHT160)

Implementation Evolutions

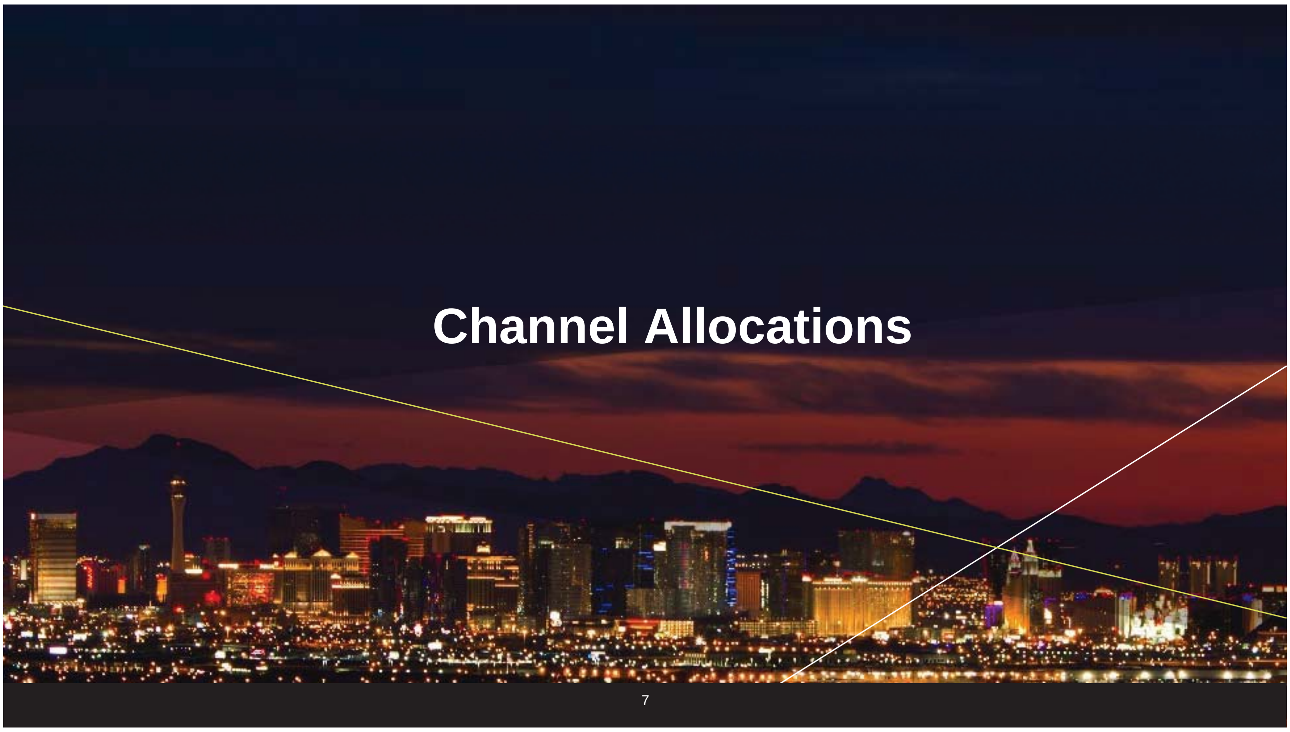
11n Initial APs
- 2 SS
- 40 MHz
- 64 QAM

11ac Wave 1 (Initial)
- 3 SS
- 80 MHz
- 256 QAM

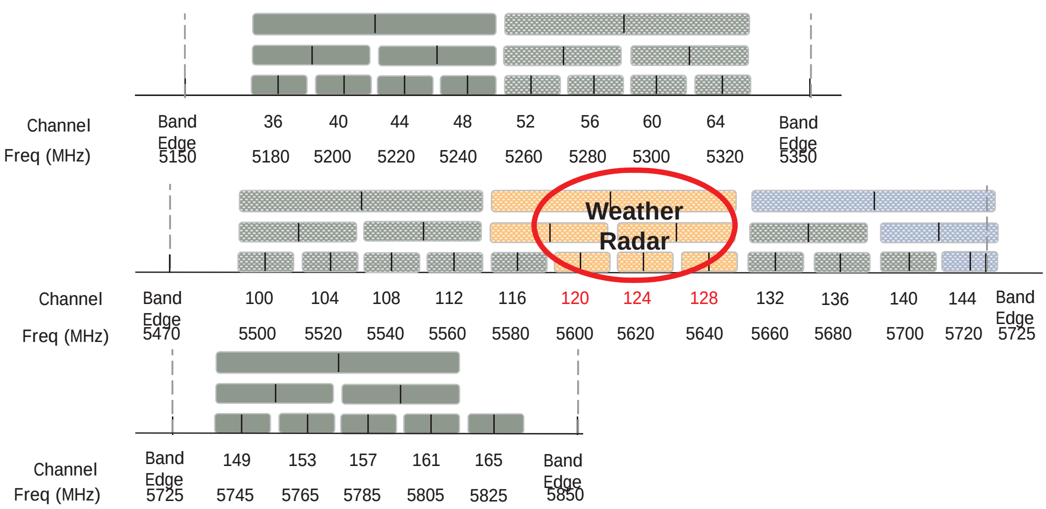
→

11n Mature
- **Up to 3 SS**
- 40 MHz
- 64 QAM

11ac Wave 2
- **Up to 4 SS**
- **Up to 160 MHz**
- 256 QAM
- **MU-MIMO**



802.11ac Channels (FCC)



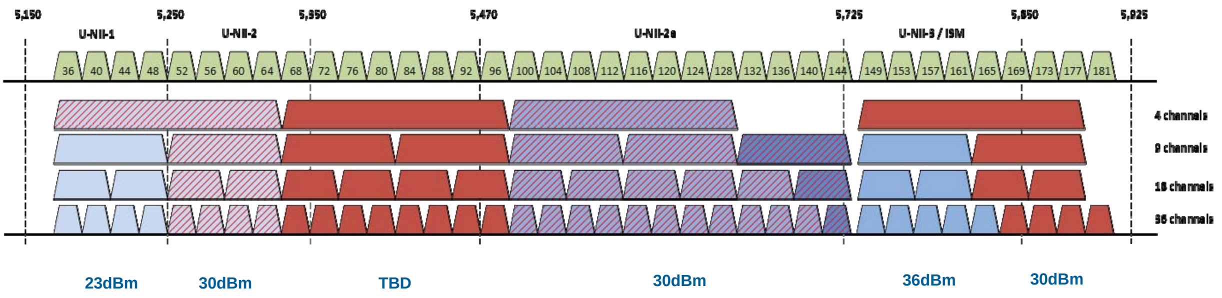
<u>UNII I and UNII II</u>
2x 80 MHz
4x 40 MHz
8x 20 MHz

<u>UNII II extended</u>
3x 80 MHz
6x 40 MHz
12x 20 MHz

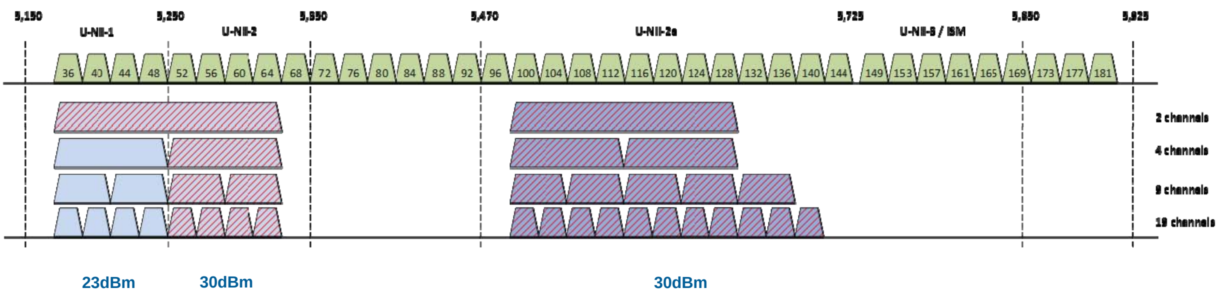
<u>US UNII III</u>
1x 80 MHz
2x 40 MHz
5x 20 MHz

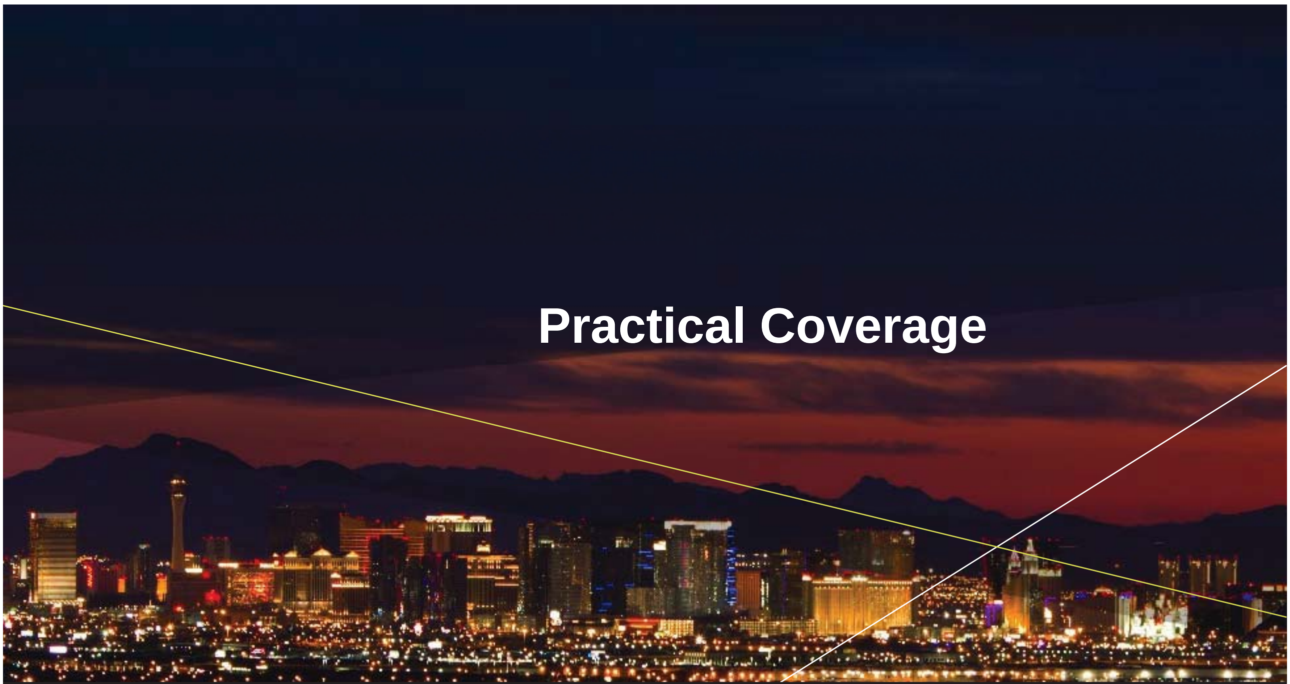
8

Potential Future 5GHz FCC Channel plan



Current 5GHz ETSI Channel plan



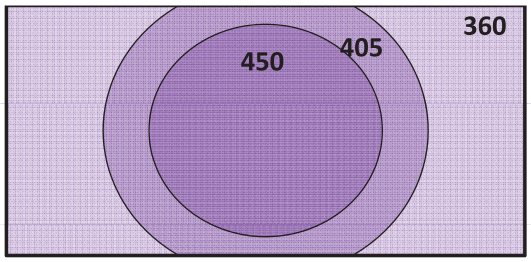


Practical Coverage

11

Coverage Example

1. **Sample coverage for 3x3:3 11n AP (or 3x3:3 11ac AP with 11n clients) in HT40 mode**

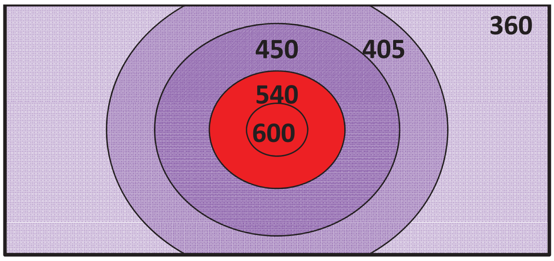


Coverage area sustains MCS5 and up

12

Coverage Example

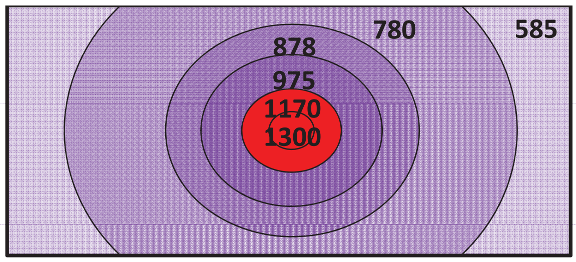
2. **Upgrade to 3x3:3 11ac AP with 11ac clients, still using 40Mhz channels (VHT40)**



Radius for 600Mbps (MCS9) area is 1/4 of that for 450Mbps (MCS7)

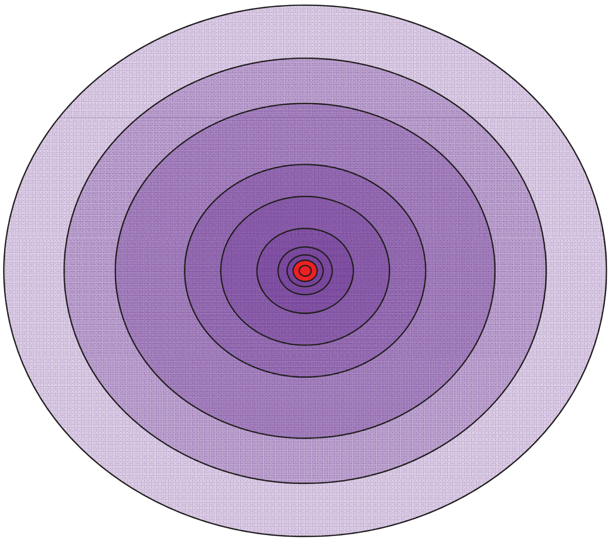
Coverage Example

3. **Equivalent range for clients using 80MHz channels (VHT80)**



– Rates roughly double, relative range for each of the MCS rates does not change, but 80MHz range is ~70% of equivalent (same MCS) 40MHz range

Relative Range 802.11ac Rates



Signal level and relative range

	-dB	r %
MCS0	**87**	**63**
MCS1	**85**	**50**
MCS2	**83**	**40**
MCS3	**79**	**25**
MCS4	**76**	**18**
MCS5	**71**	**10**
MCS6	**66**	**5.6**
MCS7	**63**	**4.0**
MCS8	**58**	**2.2**
MCS9	**51**	**1.0**

Datarate

	40MHz	80MHz
MCS0	**45**	**97.5**
MCS1	**90**	**195**
MCS2	**135**	**292.5**
MCS3	**180**	**390**
MCS4	**270**	**585**
MCS5	**360**	**780**
MCS6	**405**	**877.5**
MCS7	**450**	**975**
MCS8	**540**	**1,170**
MCS9	**600**	**1,300**

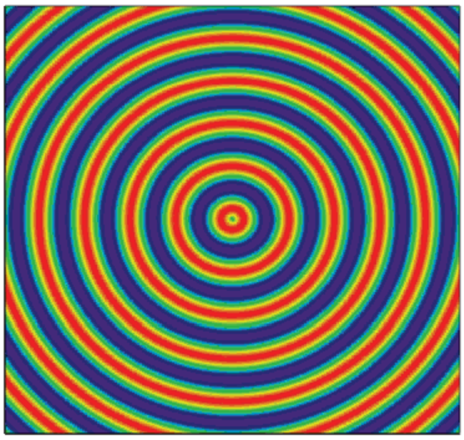
What about Wave 2 coverage?

About the same-

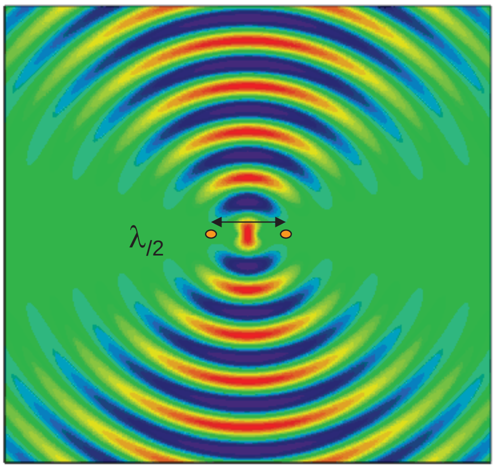
- 160 MHz is just two 80 MHz sandwiched together
  - No increase in noise floor
- No new modulations are introduced
  - No new circles in the bulls eye
- Additional streams do not change coverage area

Antenna Basic Physics

- **When the charges oscillate the waves go up and down with the charges and radiate away**
- **With a single element the energy leaves uniformly.**
- **Also known as omni-directionally**

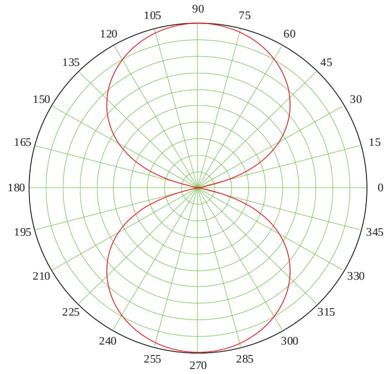


Building Arrays: 2 Elements

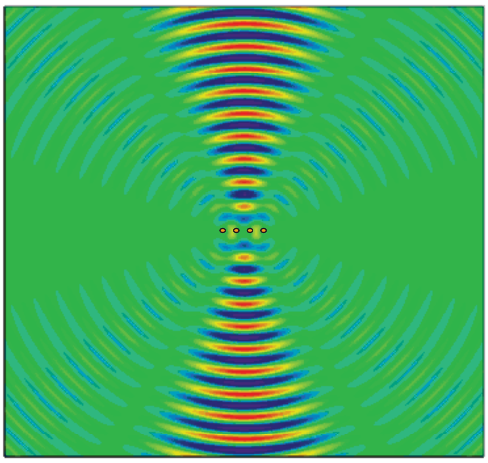


- **By introducing additional antenna elements we can control the way that the energy radiates**
- **2 elements excited in phase**

dB Plot

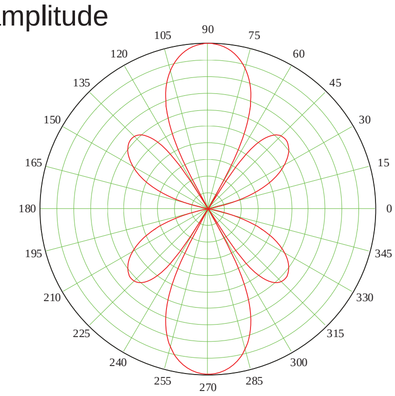


Building Arrays: 4 Elements

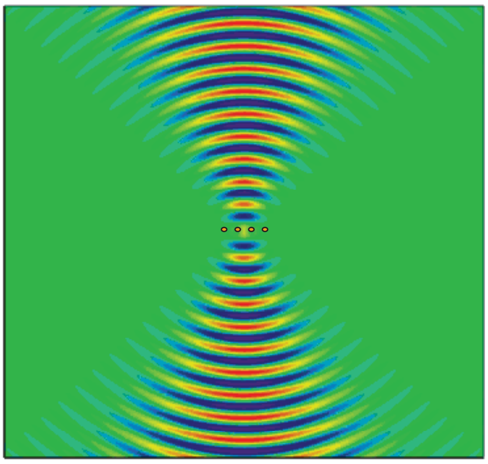


- **By introducing additional antenna elements we can control the way that the energy radiates**
- **4 elements excited in phase**
  - Equal amplitude

dB Plot

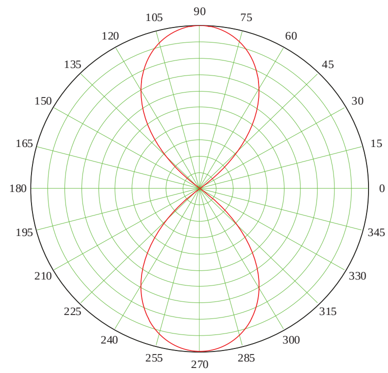


Building Arrays: 4 Elements

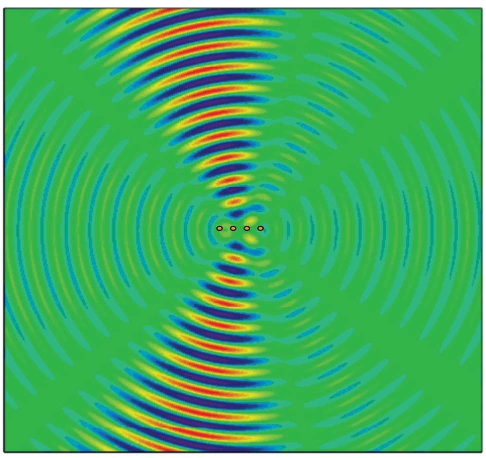


- **By shaping the amplitude we can control sidelobes**
- **4 elements excited in phase**
  - **Amplitude 1, 3, 3, 1**

dB Plot

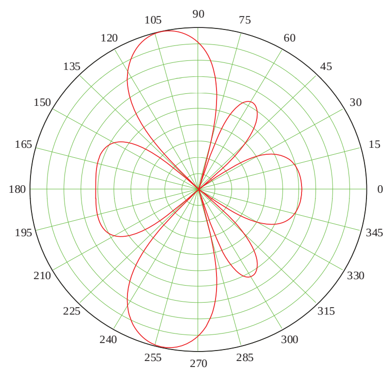


Building Arrays: 4 Elements Phase



- **By altering phase we can alter the direction that the energy travels**
- **4 elements excited with phase slope**
  - **Equal amplitude**

dB Plot



11ac Beamforming: Notes

Works with clients that support 11ac beamforming function

- This is at a minimum all 11ac client devices using Broadcom chipsets
- Support will have to come to all devices to compete with Broadcom offering

11ac beamforming is standards based

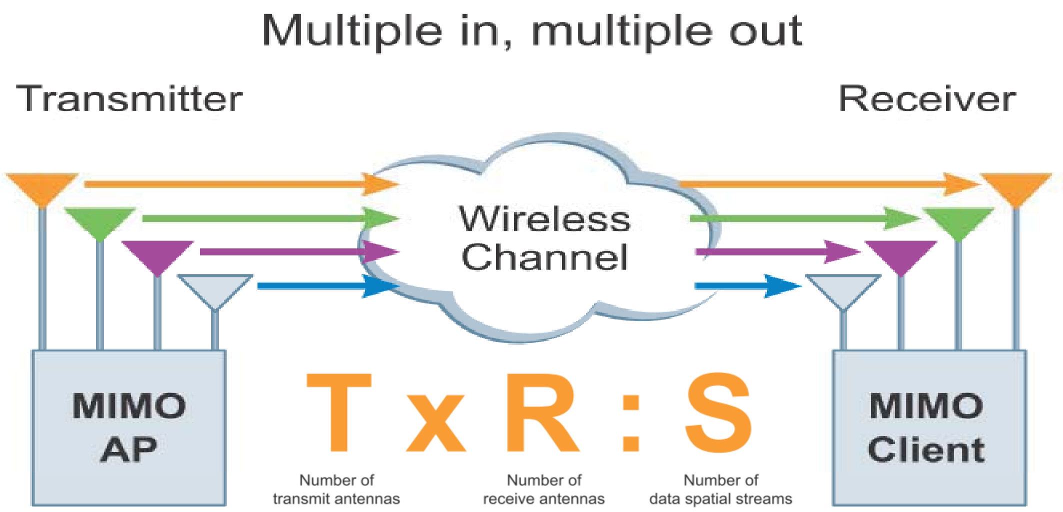
- first standard that is doing this the "right" way
- 11ac beamforming represents the consensus view of the 1000's of contributors to the standards process

11ac beamforming is implemented in baseband.

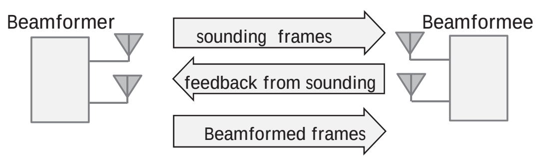
- It works with all antenna subsystems
- The total number of beamforming combinations is effectively infinite

11ac actively tracks users so has a recent channel estimate between the AP and client that is updated frequently

Background



Sounding process



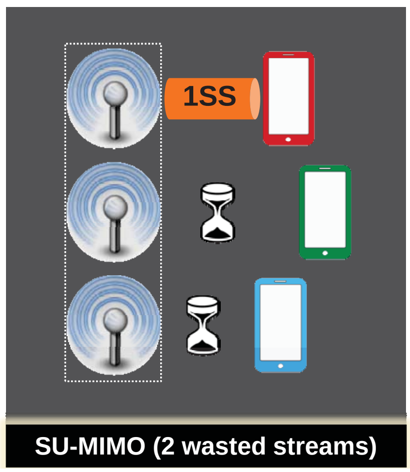
Explicit feedback for beamforming (802.11ac)
1 (Beamformer) Here’s a sounding frame
2 (Beamformee) Here’s how I heard the sounding frame
3 Now I will pre-code to match how you heard me

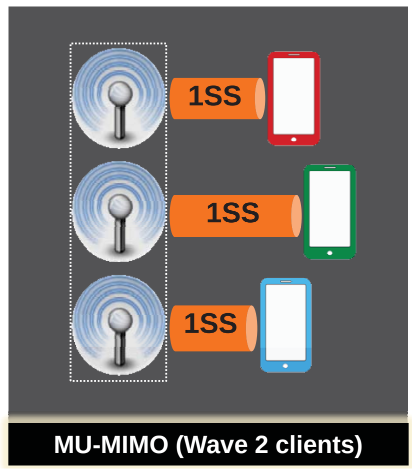
Explicit feedback for beamforming

MU-MIMO

MU-MIMO is the defining feature for "Wave 2"

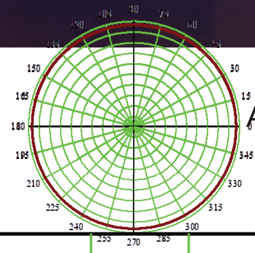
- Enables simultaneous transmissions of data from AP to multiple clients (downstream only), optimizing the use of AP resources



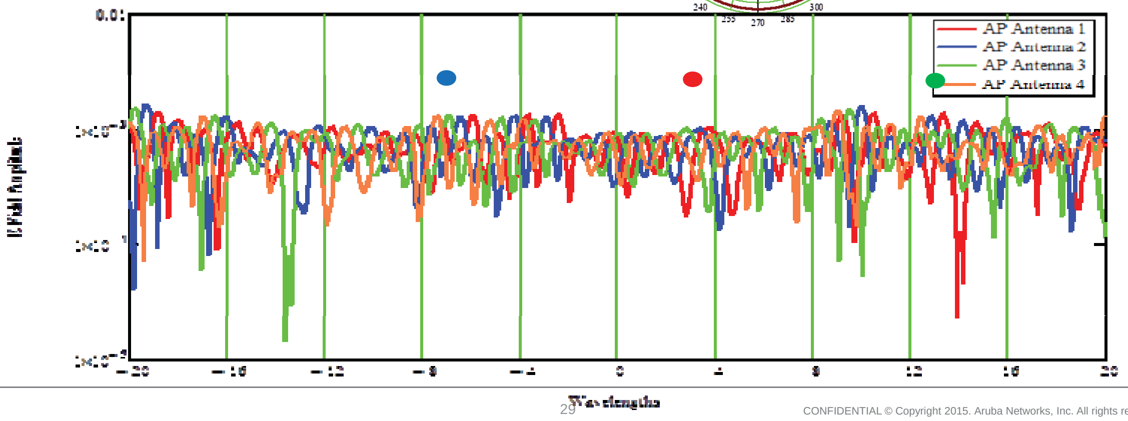


3 Clients: 4x4 AP

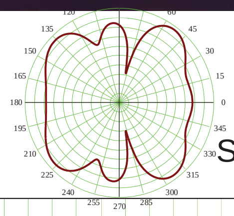
Room Width: 10m
Room Length: 10m
Room Height: 7m



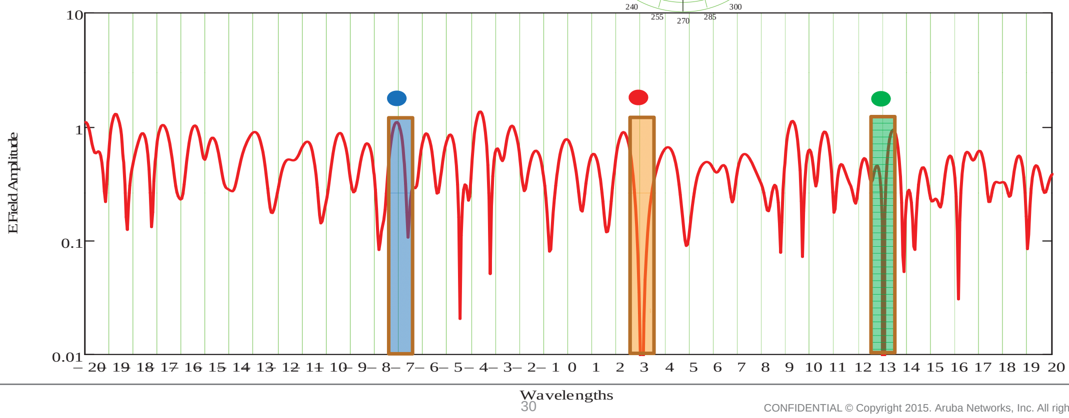
AP Antenna Pattern



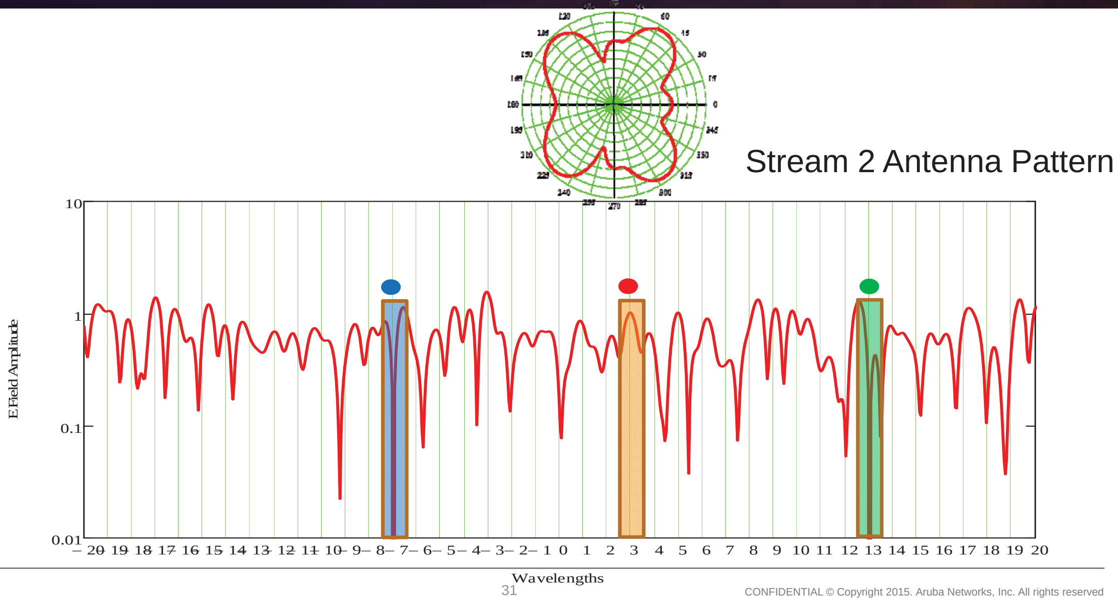
Stream 1 to Client 1



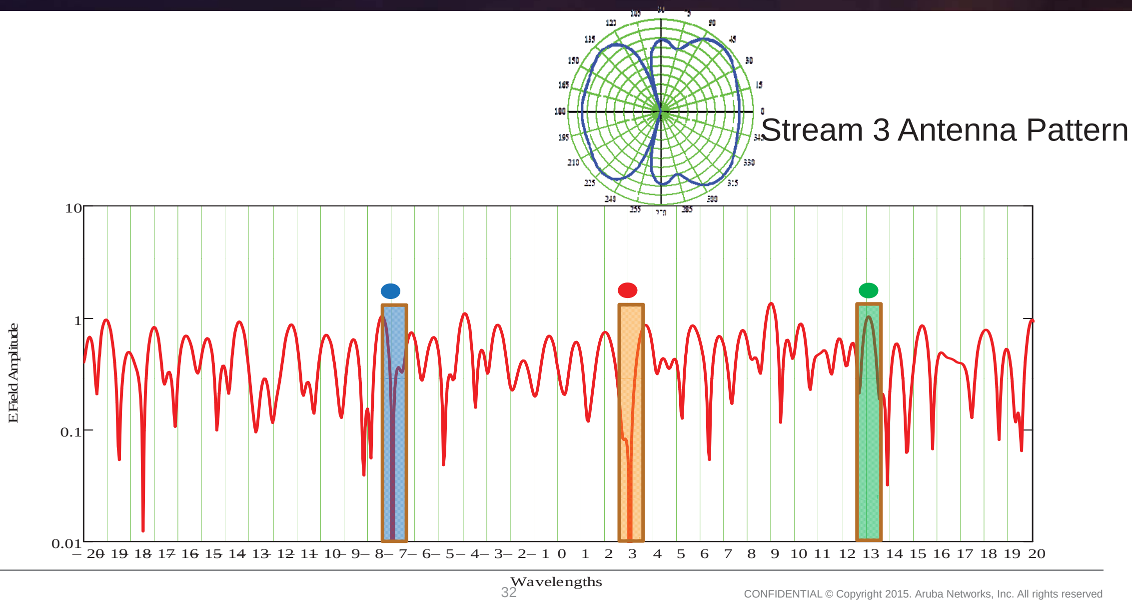
Stream 1 Antenna Pattern



Stream 2 to Client 2



Stream 3 to Client 3



MU-MIMO Challenges

- There is overhead in sounding the channel
  - If sounding is required too frequently, gains are reduced.
  - Sounding is required if previous information about the over-the-air channel is stale (the client moved, something around it moved)
  - >500us *(6 SIFS + NDPA/NDP + 2 Polls + 3 BF Reports >400us, 2x(SIFS + BAR) = ~100us)*

- Clients that would benefit most from MU-MIMO are the most likely to require frequent sounding.
  - Phones, handhelds are typically not held totally still
- Failure to sound the channel frequency enough leads to undesired inter-stream interference and lower supportable PHY rates.

33

Wave 2 Data Rates

	1 SS	2 SS	3 SS	4 SS
3 SS VHT 80 MHz	433	867	1300	N/A
4 SS VHT 80 MHz	433	867	1300	1733
3 SS VHT 160 MHz	867	1733	2600	N/A
4 SS VHT 160 MHz	867	1733	2600	3466

TCP Throughputs

	1 SS	2 SS	3 SS	4 SS
3 SS VHT 80 AP	303	607	910	N/A
4 SS VHT 80 AP	303	607	910	1213
3 SS VHT 160 AP	607	1213	1820	N/A
4 SS VHT 160 AP	607	1213	1820	2426

- 70% of data rate is best case throughput for wireless TCP traffic.
- Throughput is lost to:
  - TCP traffic
  - Management traffic
  - FEC
  - Assuming best SNR and single client

MU-MIMO Best Case 5 GHz Throughputs

- ~75% efficiency for 1 SS clients
- ~65% efficiency for 2 SS clients
- Efficiency goes down from there.
- 3 SS + 1 SS is less efficient than separately serving to 3 SS and 1 SS
- MU-MIMO has client side dependencies

MU-MIMO	1 SS clients	2 SS clients
3 SS VHT 80 AP	683	622
4 SS VHT 80 AP	910	789

MU-MIMO	max 1 SS clients	Max 2 SS clients
3 SS VHT 160 AP	910	1213
4 SS VHT 160 AP	910	1213

What does that mean for 11ac wave 2?

MU-MIMO efficiency means we see pretty much the same max real-world throughputs as wave 1

MU-MIMO allows the network to reach max throughput much more often

FCC opening up spectrum is critical to realize the potential of 160 MHz channels

Real world throughputs will be brought down from best case by:

- Client capability mix (11n and non-MU-MIMO devices)
- Client location distribution (weak SNR)
- Client count (air contention increases with number of clients)

Do I need 2.5 gbps for wireless?

Short answer: No.

Long Answer:

- > 1gbps will likely be needed at some point, but we aren’t there yet.
- No IEEE standard for 2.5 gbps
  - Limited investment protection
  - Potential wired and wireless interop issues
- Real world throughputs with 80 MHz channels will not require >1 gbps
- Wired traffic is full duplex, wireless is half
- 2.5 gbps carries a large price premium today

Deployment recommendations

VRDs are the place to start

- RF and Roaming Optimization for 11ac

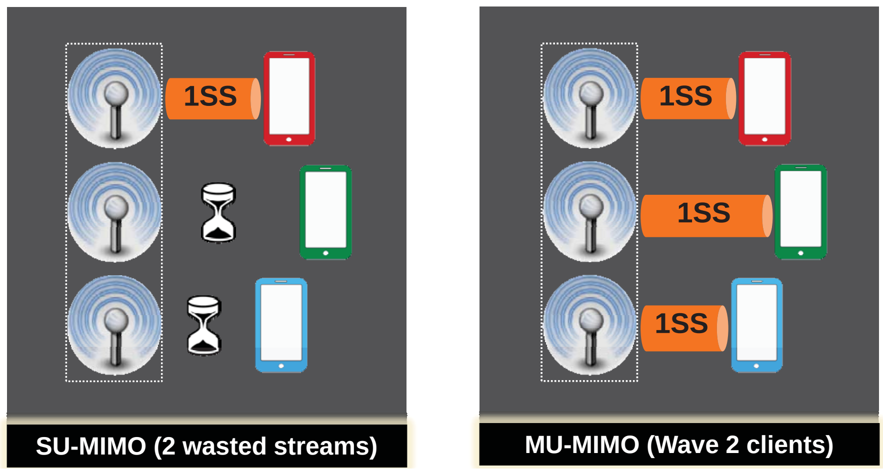
Deployment recommendations

Feature	Recommended Value	
Transmit Power (dBm)	**Open Office:** 5 GHz: Min 12/Max 15 2.4 GHz: Min 6/Max 9	**Walled office or Classroom:** 5 GHz: Min 15/Max 18 2.4 GHz: Min 6 /Max 9
Channels	80 MHz channels can be used in green field deployments. U-NII-2 and U-NII-2e (DFS) channels must be used when operating on 80 MHz channels. Remove channel 144 from list.	
AirTime Fairness	Fair Access	
Data Rates	802.11 a & g: Basic rates:12,24 802.11 a & g transmit rates: 12,24,36,48,56	
Beacon Rate (Mbps)	For both 802.11a and g radio use 12 or 24.	
Multicast rate optimization	Enable	
A-MSDU	2	

Introducing MU-MIMO on 320 Series

MU-MIMO is the defining feature for “Wave 2”

- Enables simultaneous transmissions of data from AP to multiple clients (downstream only), optimizing the use of AP resources



Introducing MU-MIMO on 320 Series

MU-MIMO is the defining feature for "Wave 2"

- Enables simultaneous transmissions of data from AP to multiple clients (downstream only), optimizing the use of AP resources

320 Series Access Points have 4x4 MIMO radios

- But there are no 4SS client devices (now or planned)
- Enabling the use of 3SS for MU-MIMO (4SS only for SU-MIMO)

Send data to three 1SS clients or one 2SS + one 1SS simultaneously

- Could theoretically triple the performance or capacity, but there's overhead and inefficiencies reducing the gain. Expect to see 2x performance.

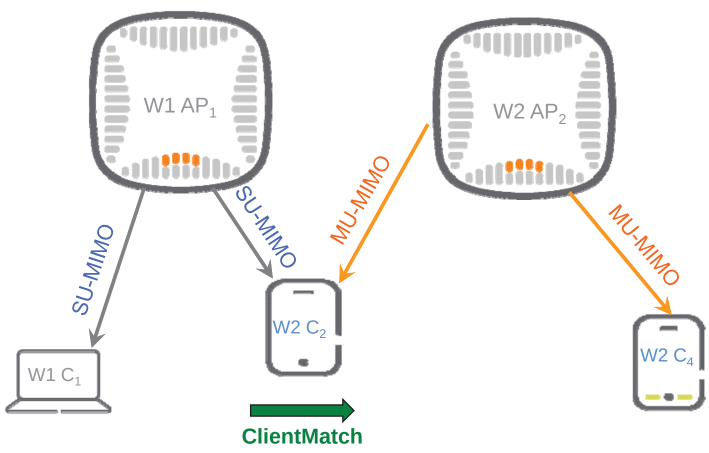
Important: MU-MIMO needs to be supported by the client as well

- Requires new client hardware (chipset)
  Not supported/enabled on any current client devices

 43

Enhanced ClientMatch™ with MU-MIMO awareness

Without Enhanced ClientMatch (3 clients)



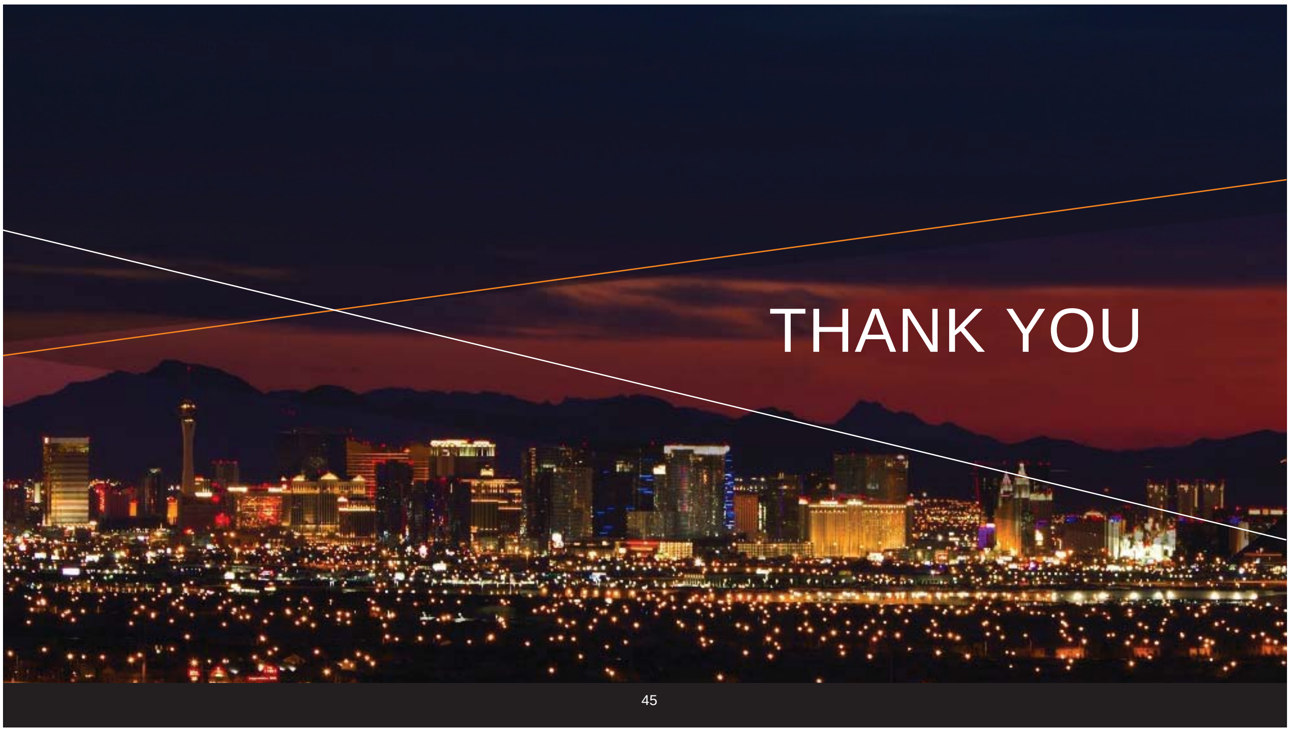
Aggregate Downstream Throughput

	Without ClientMatch	With ClientMatch
AP_1	300 Mbps	300 Mbps
AP_2	300 Mbps	450 Mbps
Network	**600 Mbps**	**750 Mbps**
ClientMatch boost →		**25%**

Efficiency of MU-MIMO

- 1SS clients deliver ~75%
- 2SS clients deliver ~65%

 44


THANK YOU
45