Cisco live!

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IMAGINE

INTUITIVE

BRKEWN-2017

Understanding RF Fundamentals and the Radio Design of Wireless 802.11ax (Wi-Fi 6) Networks

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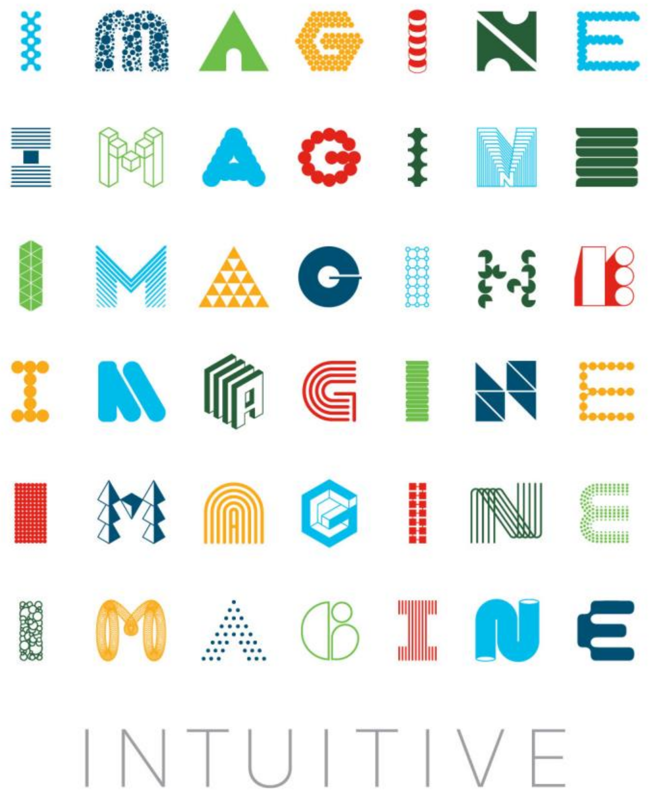


Session Abstract

This session focuses on understanding Radio Frequency part of designing and deploying a Wireless LAN Network.

This session will start with a quick review of radio and then dive into High Efficiency 802.11ax networks.

It will cover topics such as 802.11 radio, MU-MIMO, AP & antenna placements, how to read antenna pattern…

…Generally HOW THINGS WORK ☺

Agenda

- What is radio and how did we get here? Fast review of the past
- Deep dive into 802.11ax why it matters and what it addresses
- Understanding QAM modulation, OFDM, OFDMA, Fundamentals of Beam-forming both standards based and Cisco ClientLink – as well as BSS Coloring, Target Wake Time etc.
- Basic understanding of 802.11n and 802.11ac fundamentals including MIMO, MU-MIMO, Channel bonding, Multi-path, Spatial Streams, etc.
- Installation challenges, when to use different APs – avoiding potential problem

What we won't be covering

- Wireless Security (dedicated sessions for that)
- Clean Air (separate sessions for that)
- wIDS/wIPS (Wireless Intrusion Prevention Systems)
- High density deployments (separate session for that)
- LBS (Location Based Services) or Context Aware / CMX
- Walled garden, captive portals
- SP Wi-Fi, 3G/4G offload and Passpoint
- WLAN management (Cisco Prime)
- 802.11n/ac going beyond RF characteristics

Tomorrow is the most important thing in life.
Comes into us at midnight very clean.

It's perfect when it arrives and puts itself in our hands.
It hopes we've learned something from yesterday

Source: John Wayne's Grave Marker
Newport Beach, California USA

Thank you for choosing this Cisco Live presentation today and wishing everyone a great tomorrow & 2019 year ☺

Now lets get started…

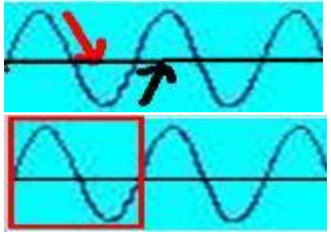
What is RF?

Wi-Fi name & timeline
Radio Frequency Principles &
How we got on these channels?

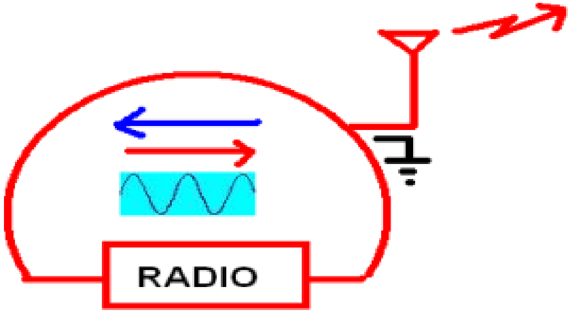
Basic Understanding of Radio...

Battery is DC
Direct Current

Typical home is AC
Alternating Current



AC Frequency 60 Hz or 60 CPS – Cycles Per Second



Waves travel back and forth so fast they actually leave the wire

Frequency is how fast the AC current goes back and forth
AC is very low frequency 50-60 Hz (Cycles Per Second)
Radio waves are measured in kHz, MHz and GHz

The lower the frequency, the physically longer the radio wave – Higher frequencies have much shorter waves, and as such, it takes more power to move them greater distances*.

*NOTE: This is why 2.4 GHz goes further vs. 5 GHz (given same amount of RF power, antenna gain etc).

Popular Radio Frequencies:

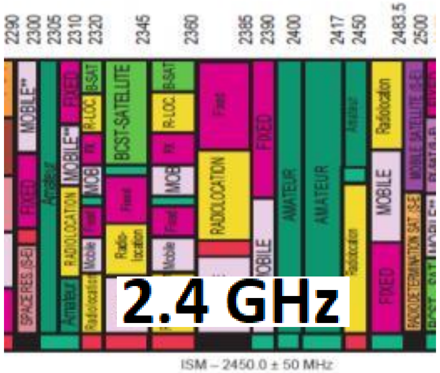
AM Radio 520-1610 KHz
Shortwave 3-30 MHz
FM Radio 88 to 108 MHz
Aviation 108-121 MHz
Weather Radio 162.40 MHz
GSM Phones 900 & 1800 MHz
DECT Phones 1900 MHz
Wi-Fi 802.11b/g/n 2.4 GHz
Wi-Fi 802.11a/n/ac 5 GHz
Wi-Fi .11ax enhancements to 2.4G and 5GHz

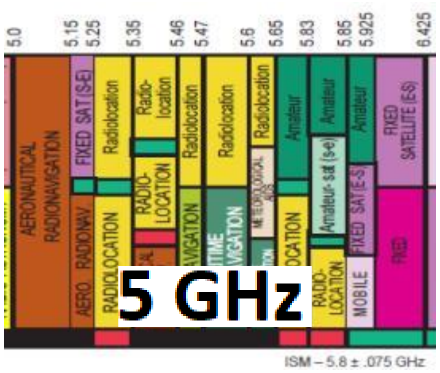
Spark transmitter

Where did we get this spectrum?

Who was on it first? Why is it "unlicensed" 2.4 GHz travels further but limited channels

For Your Reference





There are licensed users of 2.4 and 5GHz

Wi-Fi is an "unlicensed" service

It has beginnings in the ISM Industrial Scientific Medical band where it was not desirable or profitable to license such short range devices.

When the US military declassified Spread Spectrum in mid-80's Aironet and others were motivated to develop it for unlicensed use.

The first frequencies available for Wi-Fi use were in the 2.4 GHz range but was limited – 5 GHz open up more channels but certain channels are Dynamic Frequency Selection "DFS" we must leave if we detect a licensed user

IEEE Designators / Frequencies

802.11af – 54-790 MHz
802.11ah – 900 MHz
802.11b/g/n – 2.4 GHz
802.11a/ac – 5 GHz
802.11ax – (2.4 & 5 GHz)
802.11ad – 60 GHz

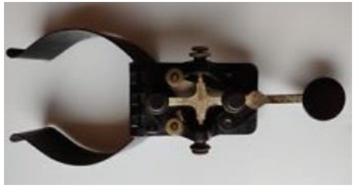
Note: A new 3.5 GHz band "CBRS" Citizens Broadband Radio Service is (evolving)… Service Provider / LTE

Radio Mobility & Portability Drive Innovation…

Evolution – Device side of things ⇔ Radio Side of things

1978 Ham Radio
w/Touch Tone Pad

Early Cell Phones
Looked like radios
then became smaller

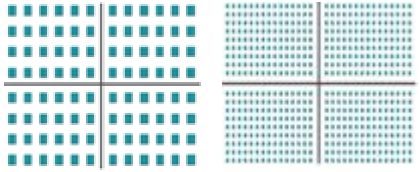


Morse code **1 RF Stream**
●●●● ●● **“bits of data”**
and portable (leg clamp)

Voice then Video

Make it a
computer then
SHRINK IT AGAIN!

X25 Packet Radio
Then “Wi-Fi” with
MORE STREAMS…



Pack in lots more
“bits of data” &
SHRINK IT AGAIN!

Understanding Wi-Fi… Radio Improvements…

802.11
1 Ant. 1SS

802.11b
2 Ant. 1-SS

1997-2003

Early PTC DOS/Win
1 Antenna 1 Stream

802.11a/g
Go FASTER

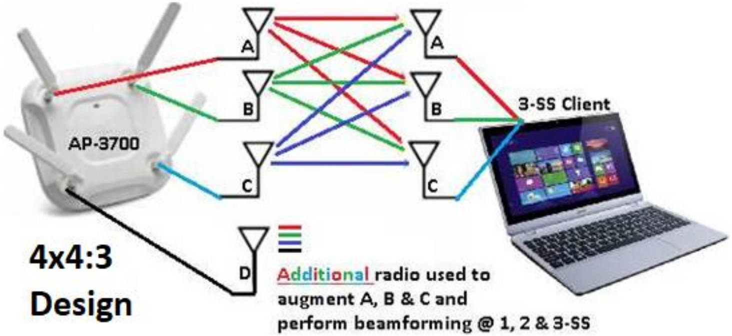
2003

Cisco AP-1240
1-Spatial Stream
w/2 Antennas for
Diversity Per Band

802.11n
More Radios

802.11ac
More Streams

2007-2016



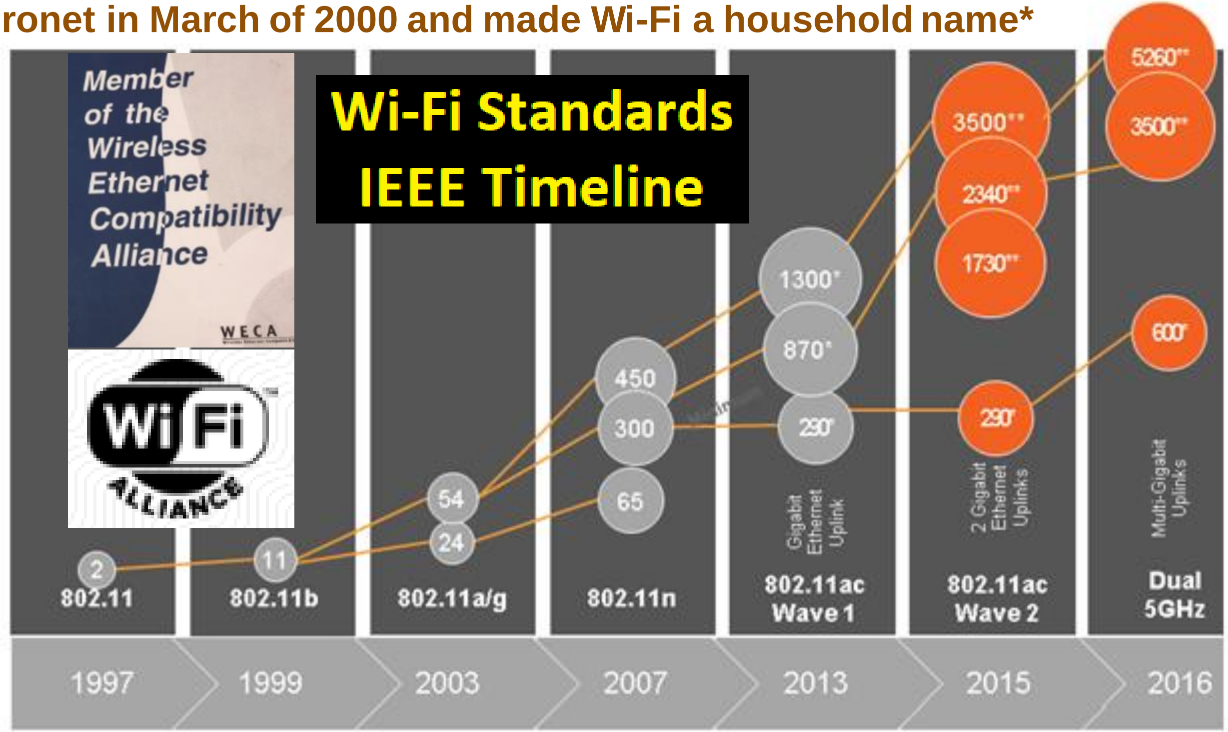
More Antennas 4 per band
Multiple Spatial Streams
Multiple Radios – MRC Diversity
Wider Channels – Bonding
About performance & SPEED…

Wi-Fi Standards and Timeline

Cisco acquired Aironet in March of 2000 and made Wi-Fi a household name*

Aironet

In 1999 Aironet a founding member of WECA along with Interbrand came up with the name "Wi-Fi"



Same fast speeds has Dual 5GHz + Hyperlocation, Cisco DNA Analytics + Intelligent Capture

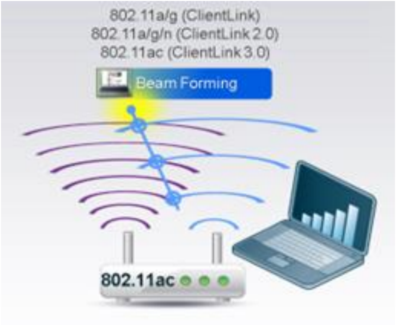
1998 Aironet AP-4800E*

***The AP-4800e was one of the very 1st Access Points to reach wired speeds @ 11 Mbps now 20 years later the new AP-4800 is the best in class 802.11ac Wave-2 Access Point**

****NEW 2018** Cisco-Aironet AP-4800**

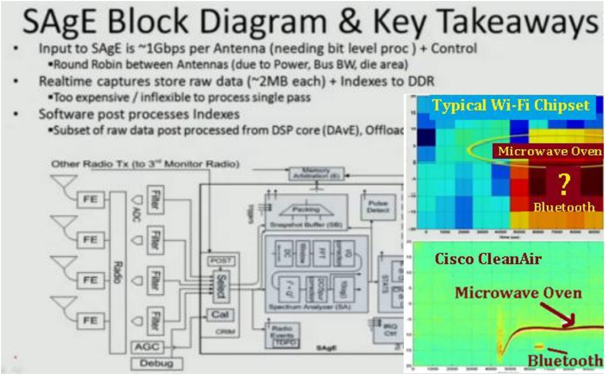
20 years later, Cisco-Aironet is still known for "best in class APs"

Best in Class Enterprise APs are all about Cisco Innovation



ClientLink TxBF

Cisco Beamforming - improved coverage for 802.11a/g/n clients



CleanAir Spectrum Analysis

Identify interference – RF Spectrum Analyzer
Self Healing – Self Optimizing Wireless Network

XoR Radio Dual 5 GHz Flexible Radio + mGig

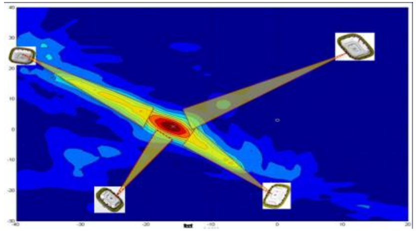
Faster throughput – lower channel utilization – enhances HDX experience

AP Sensor Functionality

+ Dedicated Hardware Sensors

Wireless Performance Analytics, Real-time Client Troubleshooting and Proactive WLAN Health Assessment

Cisco DNA Ready



True Client Location Accuracy

Hyperlocation (Precise Location)

Wayfinding, client tracking, Bluetooth low energy beaconing

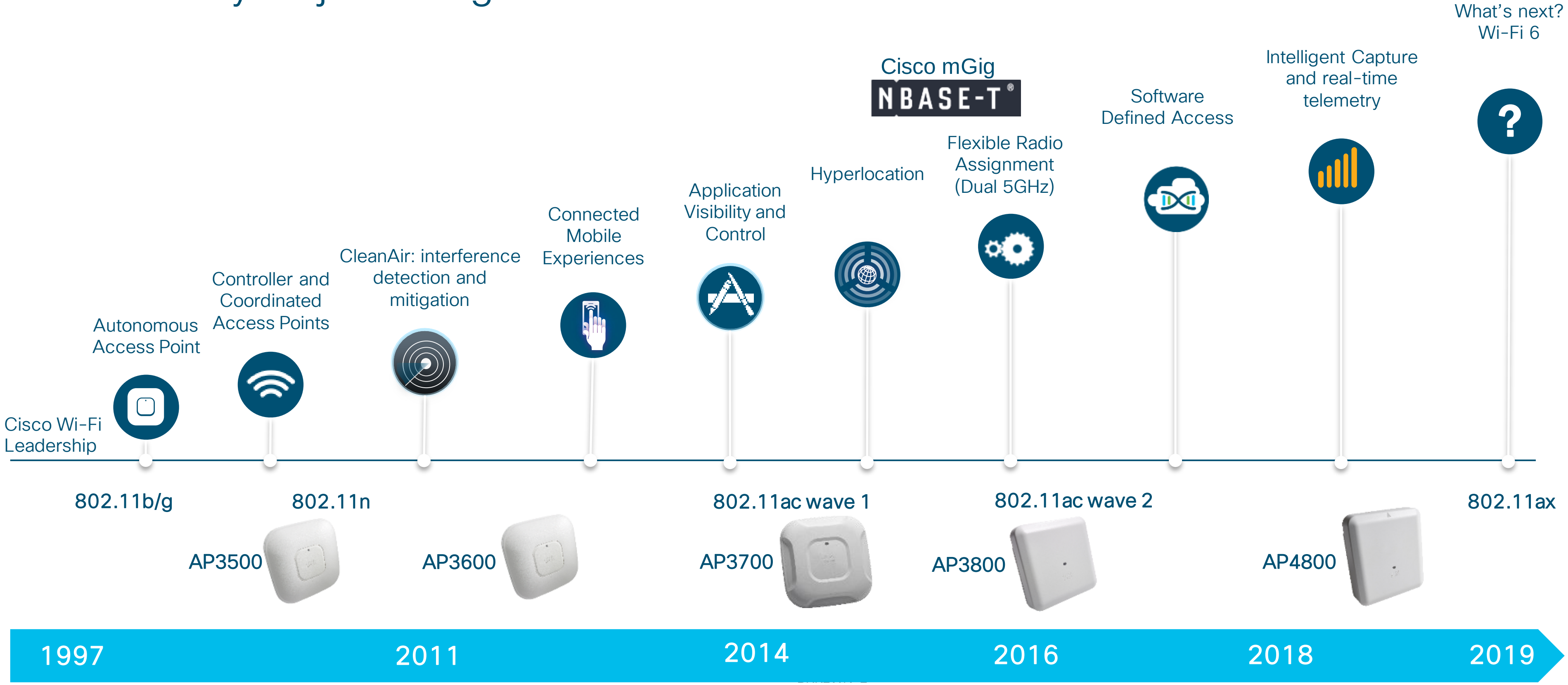
AP-1800s

Understanding Wi-Fi 6

.11ax Building upon the Foundations of .11n and 802.11ac Wave-1 & 2

History of Industry-Leading Wi-Fi Innovations

For Every Major Change In WLAN Over The Last 20+ Years



Next Generation 802.11ax is also called “Wi-Fi 6”

Wi-Fi 6 is a “Generations” Approach similar to the Cellular Industry naming.

Telecommunications Industry “generations” 3G,4G,4GLTE, 5G…

802.11ax	**Wi-Fi 6**
802.11ac	**Wi-Fi 5**
802.11n	**Wi-Fi 4**

Note: 802.11ax and Wi-Fi 6 are interchangeable Engineering and Marketing Terms for same thing.

You may sometimes hear the term “HEW” High Efficiency Wireless also used.

Why does Wi-Fi 6 Matter? What is the big deal?

Performance and capacity

3-4x Performance and Capacity over 802.11ac wave 2: support high bandwidth applications like next generation video with 4K/8K and AR/VR

Determinism and reliability

Cellular-like reliability and QoS, IoT optimized: APs service hundreds of connected devices with the right QoS and increased amount of data uplink/downlink

Battery savings

Massive battery savings for mobile device with improved reliability & coverage

Cisco only – value differentiations	Software differentiation from the Access Point, from Catalyst Wireless Controllers and from Cisco DNA
Cisco – Hardware innovations	Cisco purpose-built RF ASIC – Best in Class AP designs

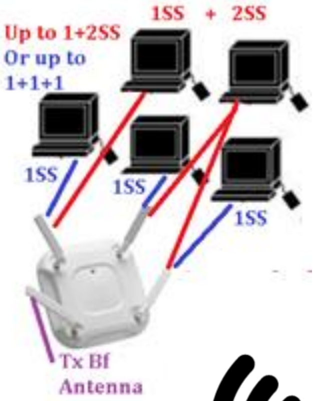
Let's look at what Wi-Fi 6 is trying to address…

Problem – 802.11ac doesn't help everyone equally…

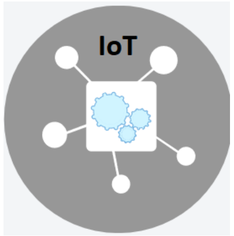
Speed & performance YES but it needs to be better for all users and also spectrum efficient.

.11ac was about speed but real need is parallel processing for spectrum efficiency

MU-MIMO only in DL
Not widely adopted



Pkt. Agg – Does *NOT* address Small packet latency of IP phones
Nor does it help IoT devices with battery life or 2.4 GHz spectrum inefficiencies



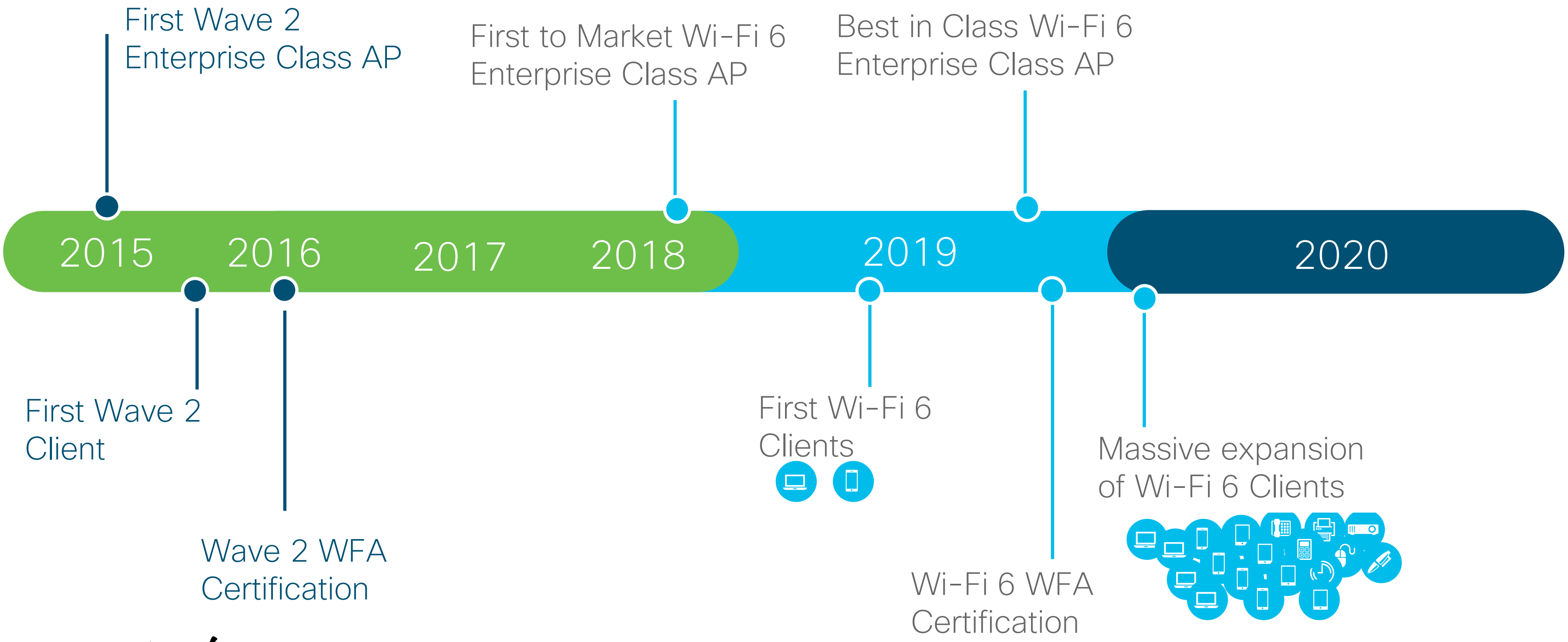
Everyone needs to get on NOW equally
More IoT, VoIP & more 2.4 GHz personal devices coming online

Need for more Parallel UL/DL Transmissions & OFDMA performance
Need for spatial frequency reuse and Spectral Efficiency (1024 QAM)

Need to drive standards into the Actual clients - AP scheduling and client participation becomes table stakes so the entire WLAN has RF efficiency improvements.

Next Generation Technology a Multi-Year Journey

Wi-Fi 6 benefits realized after clients reach critical mass, CY2020 and beyond



Sunday snapshot of clients @ CLEUR – Most are .11ac

“tweeted out” to show no .11g clients were online and 1.95TB of data flowed ☺

Early morning snapshot of the network

.11ac came out in 2014 However there are still.11n clients on the network

It will be at least 3-4 years before .11ax becomes the majority

BUT it will happen..

Differences Wi-Fi 5 and Wi-Fi 6

A look at the Physical Layer Enhancements in .11ax

Take-aways…

Wi-Fi 5	Wi-Fi 6	Take-aways
5.0 GHz band only	2.4 GHz and 5 GHz enhancements	2.4 GHz enhancements for small packets and sleep (IoT)
4X4 MIMO	Up to 8X8 MIMO – Note: Possible first releases of 8X8 may be PRE-STANDARD – What is Optional ?	Double Streams Faster T-PUT (8x8 Certification still a bit fluid)
Multi-User MIMO (one to many) <downstream>	Multi-User MIMO (one to many) <upstream and downstream> up to 8x8	Multi-User MIMO UP/DN and small packet (phone & IoT)
Modulation type OFDM	Modulation type OFDM, OFDMA OFDMA – Aggregates multiple users into single larger packets 4x longer Symbol Time 12.8 (us)	OFDMA & Longer Symbol time helps with Outdoor Links and cellular offloading
Bandwidth 20,40,80, 80+80, 160	Bandwidth 20,40,80, 80+80, 160	No change in Channel Plan
Data Subcarrier Modulation BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM	Data Subcarrier Modulation BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM 1024-QAM	Faster Modulation @ 1024-QAM
Channel reuse – CSMA	Channel reuse – CSMA also Optimistic CSMA – supports parallel transmissions in nearby BSS's "coloring"	Allows for additional channel utilization

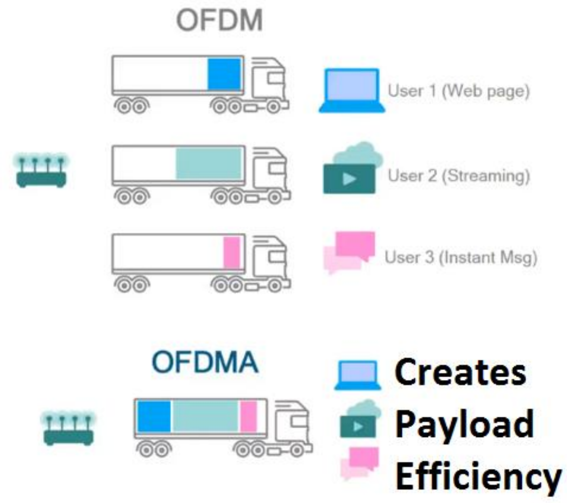
Low-Density Parity-Check **(LDPC)** - method of ECC used over noisy channels was optional **now required in .11ax**

802.11ax Next-Generation Improvements

For Your Reference

Introduction of OFDMA

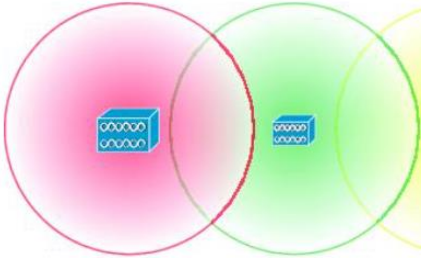
Orthogonal Frequency-Division Multiple Access



Introduction of Optimistic CSMA (Parallel Transmissions)

BSS Color - Looks at Signal strength and identity of BSS essentially does CSMA on it's own BSS but does not need to for other nearby cells if detected preamble is below a threshold

New Field called BSS Color in the preamble frame – allows additional channel utilization



Modulation Coding
.11ac MCS 0-9
.11ax MCS 0-11 **(new 1024-QAM)** 25% higher throughput

More Radios (8x8) – Note: First releases of 8x8 may be pre-standard
MU-MIMO on UPLINK as well as DOWNLINK

"Target Wait Time" - Scheduled sleep and wake times (Power Saving)
Longer guard interval / preamble for outdoor applications (cellular offloading)

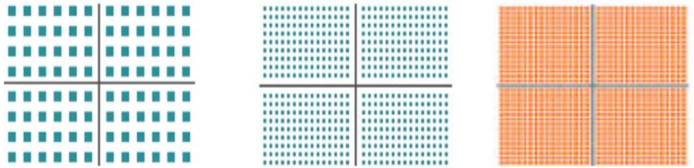
802.11ax is all about High Efficiency Wireless

These improvements are RF enhancements to make EVERY microsecond "ON THE AIR" matter.

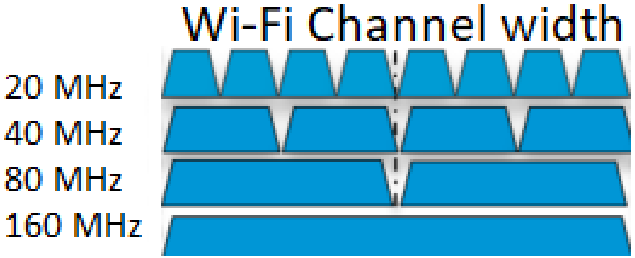
- .11ax High Efficiency Wireless (HEW) is all about optimizing the time spend "ON THE AIR" and how much information is on the air during any given Micro Second "uS"
- Four things determine Air Time efficiency
  1. Data Rate (Modulation Density) or QAM – (how many Bit's per Radio Symbol) 64 QAM is more robust but 1024 QAM is a lot faster
  2. Number of Spatial Streams & Spatial reuse (introduction of OFDMA and Resource Units)
  3. Channel Bandwidth – How Many Frequencies can we modulate at one time
  4. Protocol Overhead – Preamble/Ack/BA, Guard Interval "GI" etc.

Modulation Density Gains

64 QAM	256 QAM	1024 QAM



802.11agn	802.11ac	802.11ax
6b/symbol	8b/symbol	10b/symbol



Note: Channel Bonding reduces range as the power is spread out with each additional 20 MHz adding a 3 dB penalty in SNR and the greater the QAM the harder it is for the receiver to decode therefore it is more sensitive to noise.

.11ax Data-rate Chart for 1 Spatial Stream

Complex Modulation, Guard Interval and channel bonding is key to single radio performance.

For Your Reference

Modulation and coding schemes for single spatial stream

MCS index[a]	Modulation type	Coding rate	Data rate (in Mb/s)[b]							
			20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
			1600 ns GI[c]	800 ns GI	1600 ns GI	800 ns GI	1600 ns GI	800 ns GI	1600 ns GI	800 ns GI
0	BPSK	1/2	4(?)	8.6	8(?)	17.2	17(?)	36	34(?)	36(?)
1	QPSK	1/2	16	17	33	34	68	72	136	144
2	QPSK	3/4	24	26	49	52	102	108	204	216
3	16-QAM	1/2	33	34	65	69	136	144	272	282
4	16-QAM	3/4	49	52	98	103	204	216	408	432
5	64-QAM	2/3	65	69	130	138	272	288	544	576
6	64-QAM	3/4	73	77	146	155	306	324	613	649
7	64-QAM	5/6	81	86	163	172	340	360	681	721
8	256-QAM	3/4	98	103	195	207	408	432	817	865
9	256-QAM	5/6	108	115	217	229	453	480	907	961
10	1024-QAM	3/4	122	129	244	258	510	540	1021	1081
11	1024-QAM	5/6	135	143	271	287	567	600	1134	1201

Up to 1.2Gb with 1 radio, up to 11 Gb* with 8 radios @ 160 MHz

*Devices were presented at CES 2018 with a top speed of 11Gbit/s

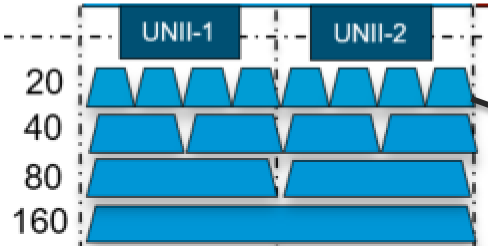
Source https://en.wikipedia.org/wiki/IEEE_802.11ax

1024-QAM 40 MHz Channel (314 Sq. meters)

- Single-antenna devices (smart-phone) should see MCS10-11 (Gigabit speeds) → <u>**35% faster than 11ac**</u>

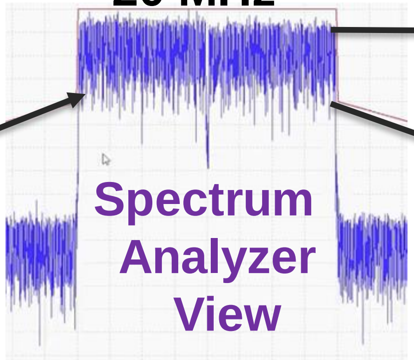
Understanding OFDM – RF Modulation Carrier

.11ax uses OFDM but also implements OFDMA for High Efficiency Wireless

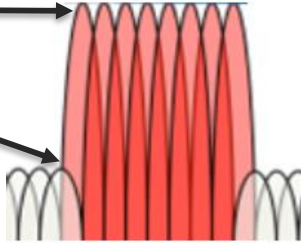


20 MHz Channel

20 MHz



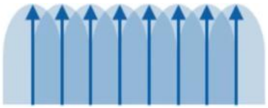
20 MHz



OFDM divides the available spectrum into sub-channels that can be independently modulated and de-modulated

The technology works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver.

Note: The wider the channel, the more sub-channels available however, range is reduced because the **same amount of power** is now **spread across wider spectrum** – so receiver has to work harder to hear the weaker signal.

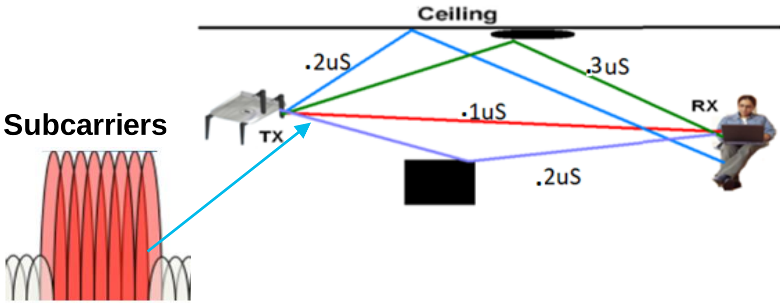


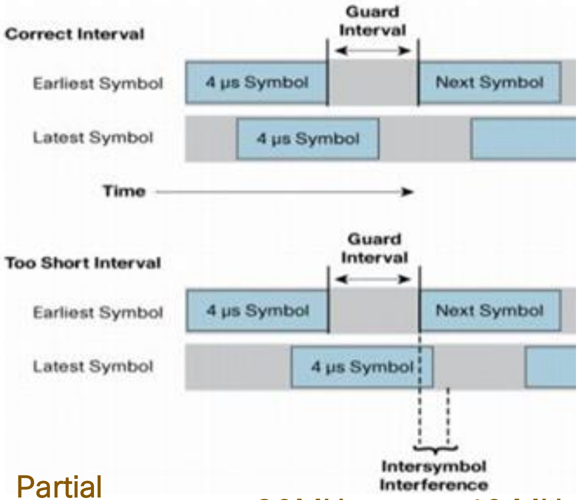
Subcarrier spacing Is 312.5 kHz apart and Protected by a Guard Interval (short or long)*

***Note: .11ax subcarriers are much closer @ 78.125 kHz**

Understanding Guard Interval "GI"

For Your Reference





Guard Interval (GI) – Period of time between each a OFDM symbol (subcarrier) that is used to minimize inter-symbol interference.

This type of interference is caused in multipath environments when the beginning of a new symbol arrives at the receiver before the end of the last symbol is done.

Partial "N" rate chart

20MHz 40 MHz

Modulation	Streams	Signal BW = 20 MHz GI = 800 nS	GI = 400 nS	40 MHz GI = 800 nS	GI = 400 nS
16-QAM	3	117	130	243	270
64-QAM	3	195	216.7	405	450

195 216.7 405 450Mb

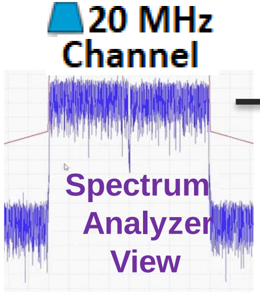
802.11n/ac supports GI of 400nS & 800nS – (Shorter = faster rates)

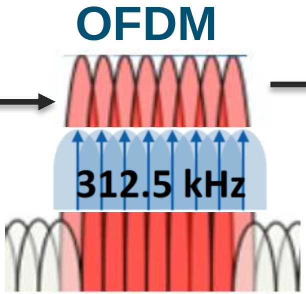
802.11ax the guard interval is 0.8, 1.6 & 3.2 uS (longer = outdoor use)

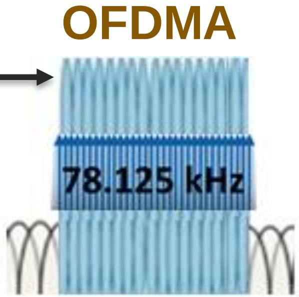
(.11ax subcarriers are more dense so the shorter GI of 400nS (0.4uS) is not used for .11ax rates)

Understanding an OFDM and OFDMA

Both divide into sub-channels (carriers) but OFDMA has more and the concept of Resource Units.



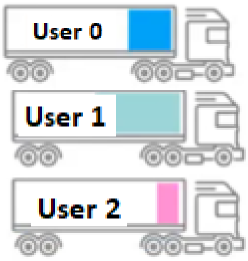


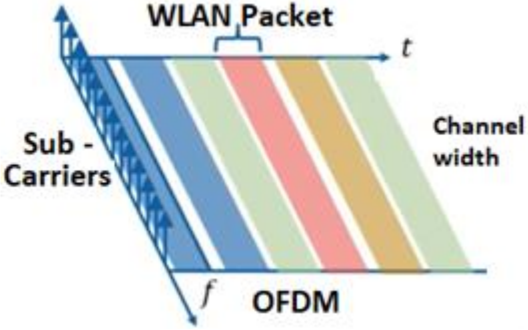


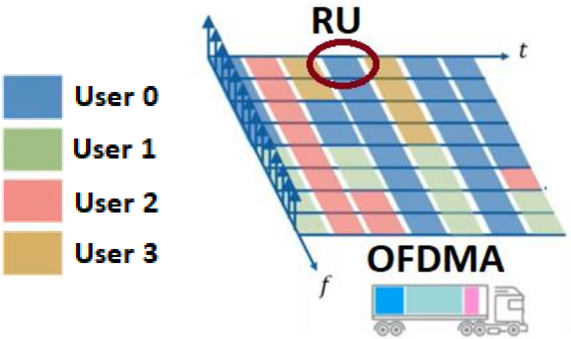
OFDMA divides the same 20 MHz spectrum into many more smaller subcarriers that can carry small packets faster.. Using Resource Units (RU) it allows each subcarrier to handle multiple users

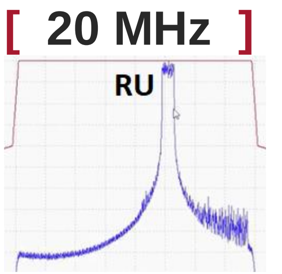
OFDM divides the available spectrum into sub-channels that can be independently modulated and demodulated but each subcarrier has data for only one user at a time - OFDMA = more users at a time.

Take-away – all packets big and small get processed MUCH FASTER









Spectrum efficiency

Understanding OFDMA Resource Units

For Your Reference

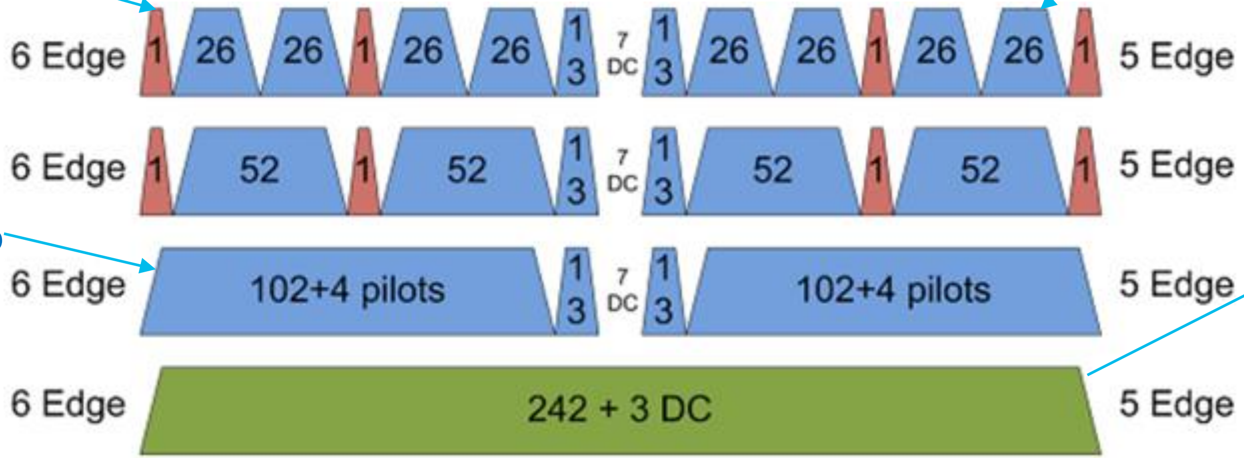
Each RU can be a different modulation scheme or coding rate determined by control information, scheduling etc.

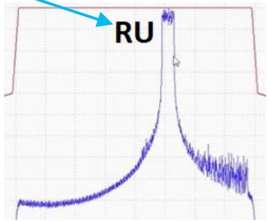
Up to 9 users per 20 MHz
Tiny RUs ideal for IoT

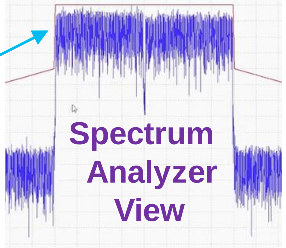
RU's are indexed

Min. RU size For MU-MIMO

20 MHz Channel RUs







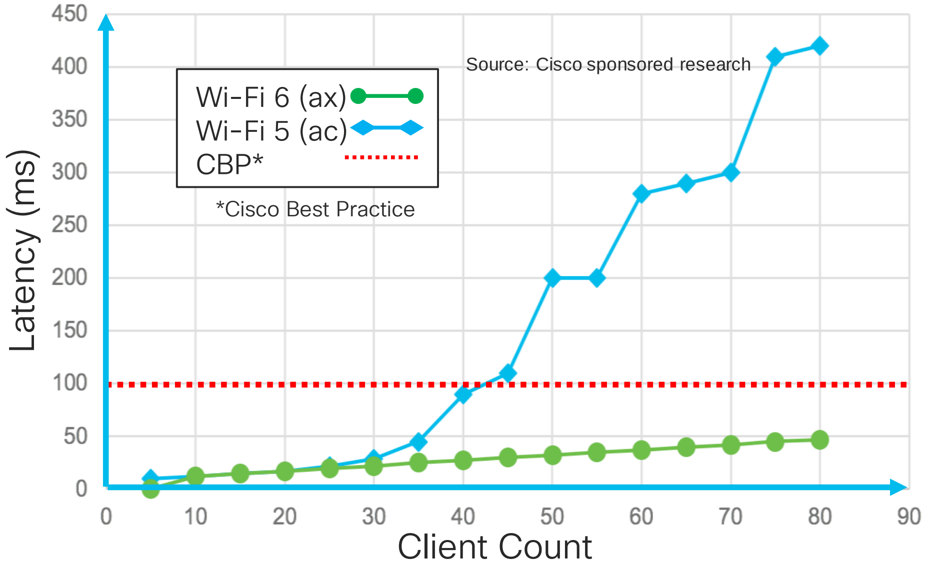
20 MHz

http://www.ni.com/white-paper/53150/en/

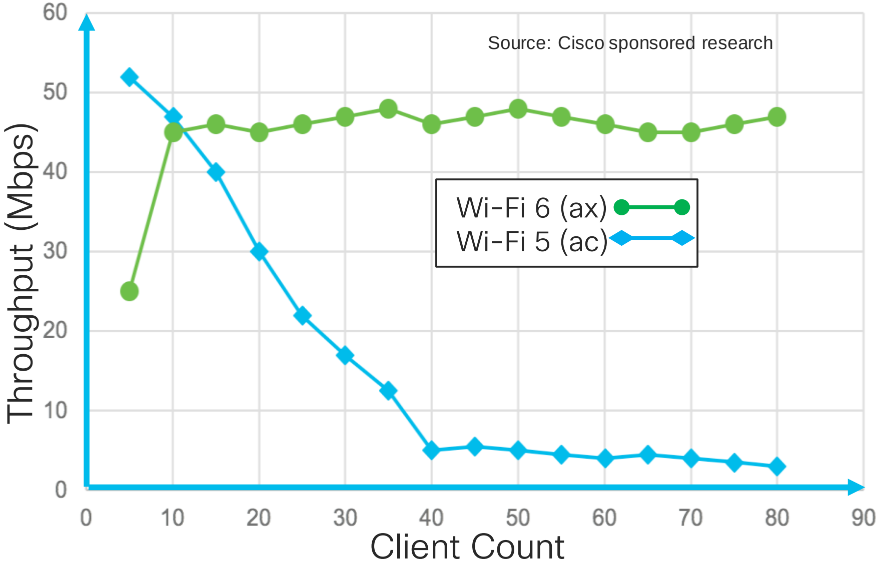
802.11ax (OFDMA) provides determinism at scale:

Enabling high-quality voice/video/data services cost effectively

Linear VOICE delay



Consistent DATA throughput

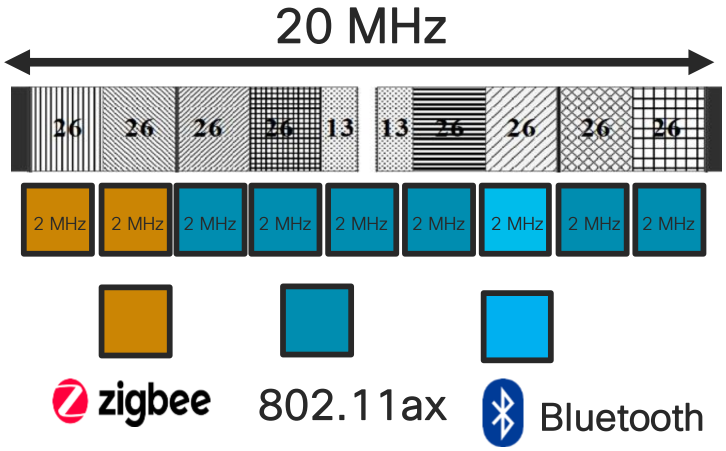


Wi-Fi 6 is not only cost-effective & ubiquitous but is now capable of delivering SLAs

802.11ax RU & Target Wake Time Benefits for IoT

Better Battery Life and co-existence via RF efficiency improvements

- 802.11ax RUs and TWT available in 2.4/5G GHz for IoT
- Thanks to 2 MHz channels, Coexistence with other 2.4 GHz IOT technologies is much more effective
- Any Channel can be left blank (no 802.11ax) to allow other technologies to operate



Target Wake Time

Target Wake Time (TWT) provides an effective mechanism to schedule transmissions in time.

Phones and IoT devices can sleep conserving battery life and then wake to take advantage of multi-user transmissions, and coexist in high-density RF environments with ease.

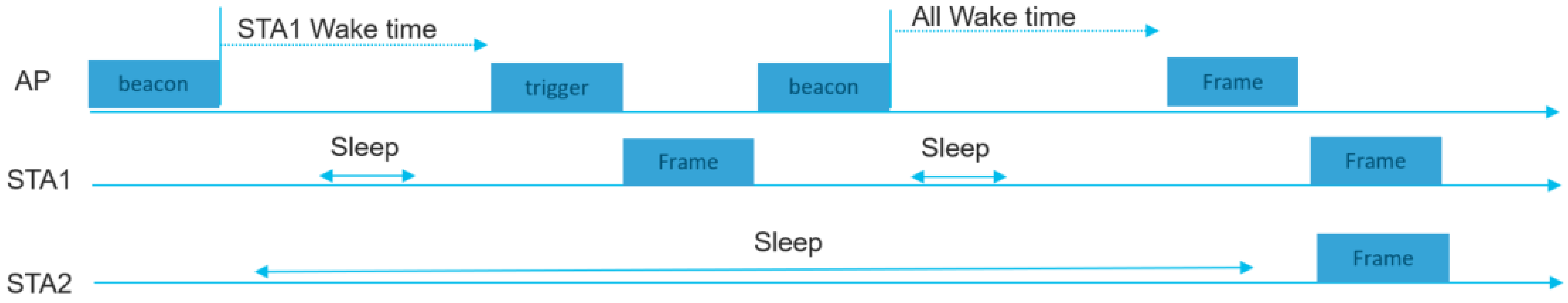
For Your Reference

Target Wake Time – Putting Devices to Sleep

- With Target Wake Time (TWT), the AP can schedule phones and IoT devices sleep for long durations **(up to 5 years)** and then wake the individual device up.

- Devices can be configured to wake up as a group to communicate at the same time sharing the channel for increased network capacity and reduced battery drain.

- Use of BSS Color field and UL/DL flag in preamble to enable intra PPDU power Saving



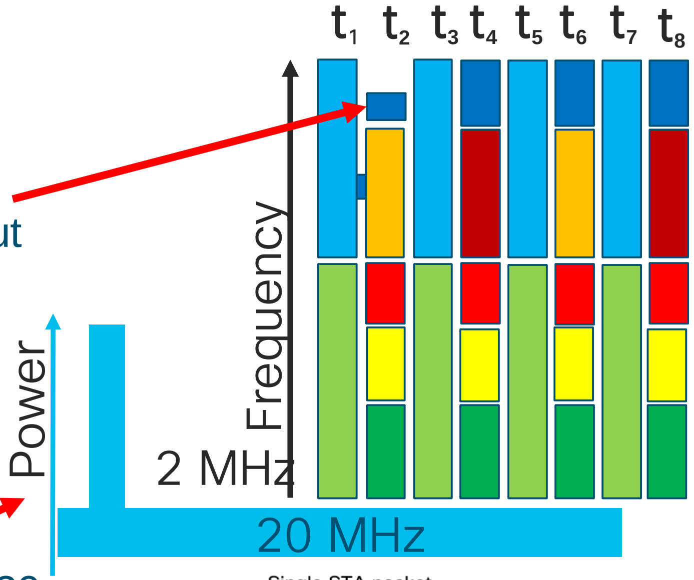
OFDMA Benefits for IOT

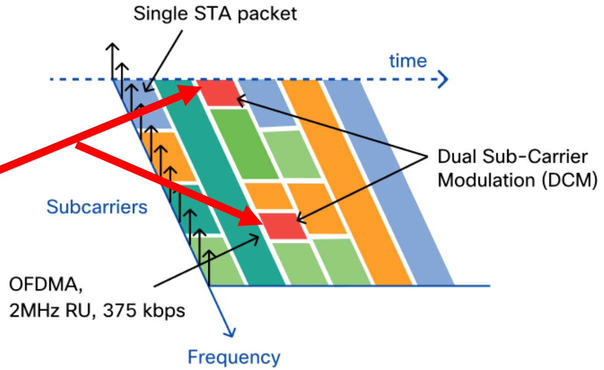
OFDMA, 375 kbps Low Power, Low Throughput

- Using a single 2 MHz Resource Unit the AP and client can exchange **at 375 kHz** for low throughput and low power consumption ideal for IoT

- 802.11a/g/n/ac allowed only ~6-6.5 Mbps minimum, creating wasted bandwidth and higher RF power consumed.

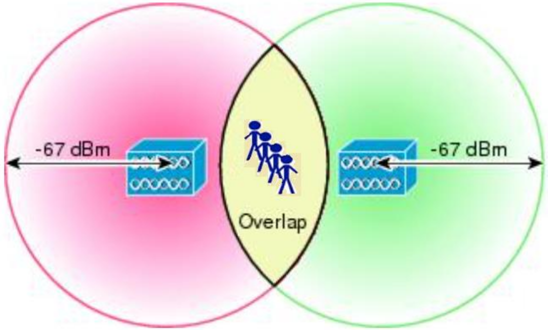
- Longer Distance benefit as the power used for a 20 MHz channel could be concentrated into a single 2 MHz RU
    - Better Link Budget
    - No more cost to battery
    - DCM (Dual Subcarrier Modulation) RU can be repeated in another subcarrier for resiliency





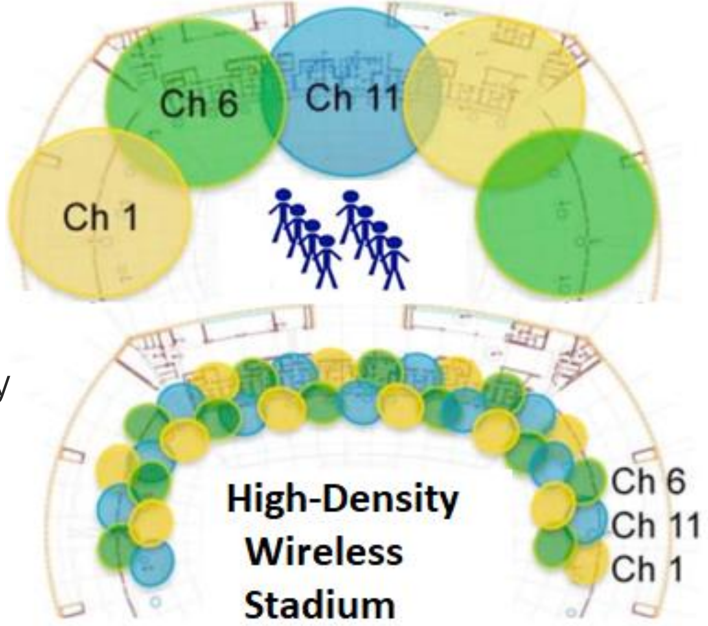
2.4 & 5G High Density issues given – limited channels

2.4 GHz only has 3 non-overlapping channels 5 GHz channels reduced with channel bonding



The limiting factor in a high density design is typically co-channel interference “CCI”. With only three non-overlapping Wi-Fi channels at 2.4 GHz, frequency reuse is high. Cells using the same channel can be too close (and this is sometimes unavoidable)

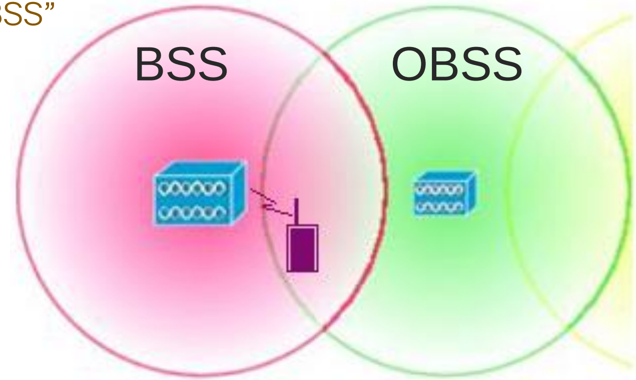
Wi-Fi CCA is very sensitive, so clients have to back-off and wait – **Biggest contributor OBSS CCI is high density clients running too much Tx power.** ☹



Directional antennas and Cisco’s RX-SOP (adjustable squelch) is used today But not dynamic and requires RF experience

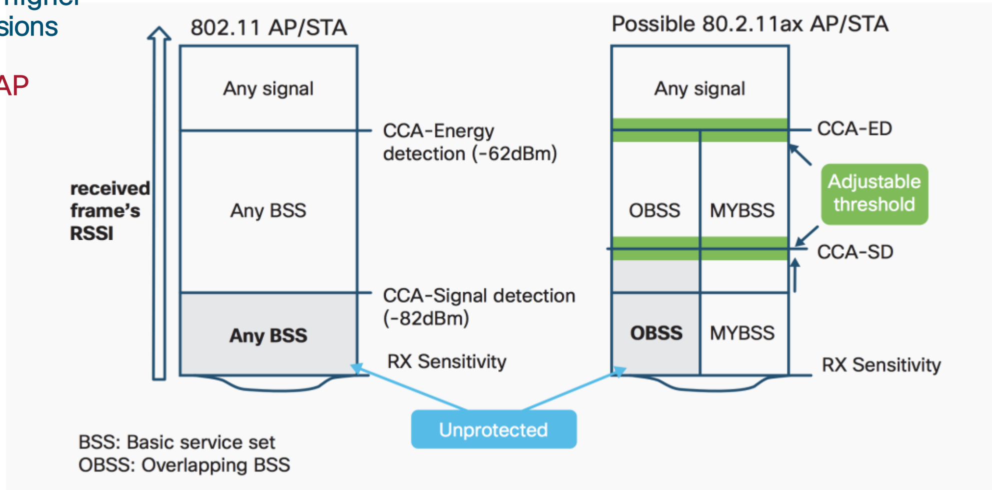
BSS Coloring – Spatial Reuse & addressing interference

Basic service Set "BSS" and Overlapping Basic Service Set "OBSS"



- **BSS Color** – All devices within a BSS send the same value (color), which will be different than other nearby BSSs (or OBSSs)
  - Each BSS (AP) uses a different "color" (6 bits in the preamble)
  - Each user (station) learns its BSS color upon association, allowing it to identify other BSS's as OBSS
  - Stations detecting the same BSS color (intra-BSS) use a lower RSSI threshold for deferral which reduces Intra BSS collisions
  - Stations detecting a different BSS color (Inter-BSS) use a higher RSSI threshold, which allows more simultaneous transmissions
- OBSS Packet Detection is dynamic and managed by the AP
- If a station reduces its TX power, the device *can* raise its inter-BSS CCA thresholds and transmit ☺
  - TX Power reduction is based on Sounding Packets
  - Effectively RF locating the Client within the cell
  - The closer the client is to the AP, THE LOWER it's transmitted power can be

Benefit - Overcomes the problem of Clear Channel Assessment limitations

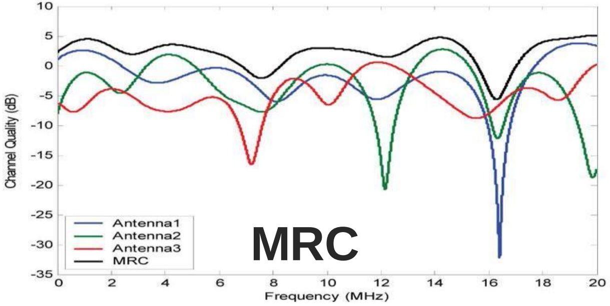


Benefits of OFDMA & BSS Coloring

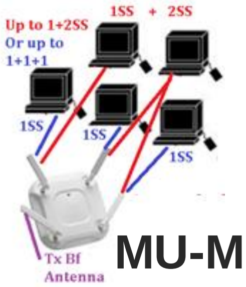
- IOT and VoIP – OFDMA allows parallel processing of multiple clients greatly reducing jitter and latency of packets both large and small.
- OFDMA and BSS Coloring are enhancements that also benefit 2.4 GHz where many IOT clients operate and/or High-density networks are desired
- Outdoor distances increase as additional Guard Interval time, longer preamble and narrower subcarriers are easier to decode better in interference prone areas
- Algorithms for BSS coloring reward the client by letting it transmit if it can reduce power (making airwaves more efficient) allowing more clients on the air at the same time. *Channel reuse now possible for higher performance.*

Understanding MU-MIMO & Spatial Streams

There is a lot to this… so a short review of RF fundamentals is necessary…

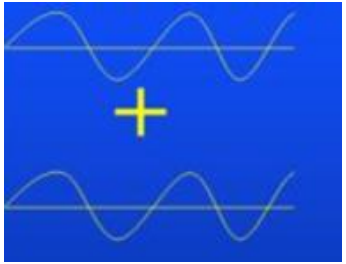


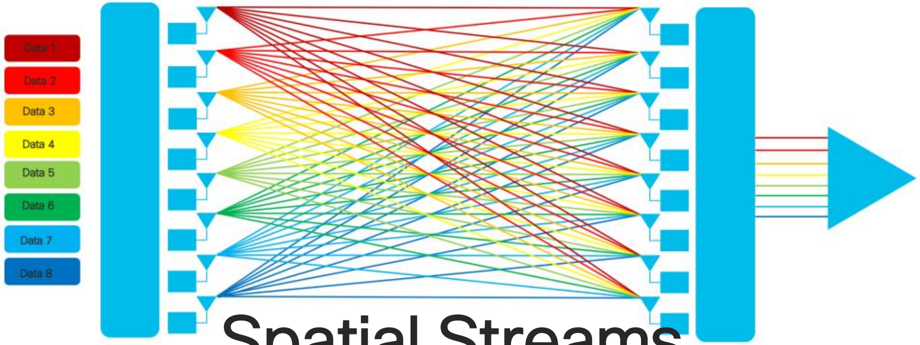
MRC



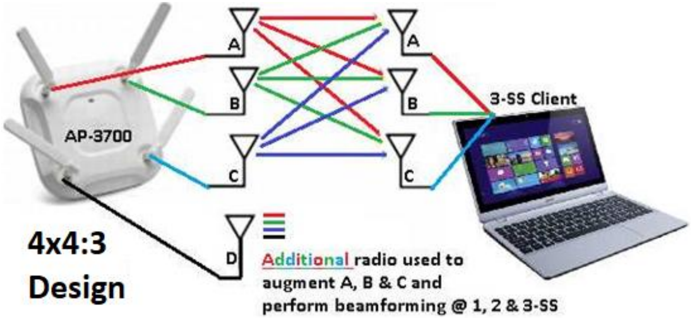
MU-MIMO

Multi-Path





Spatial Streams



Beamforming

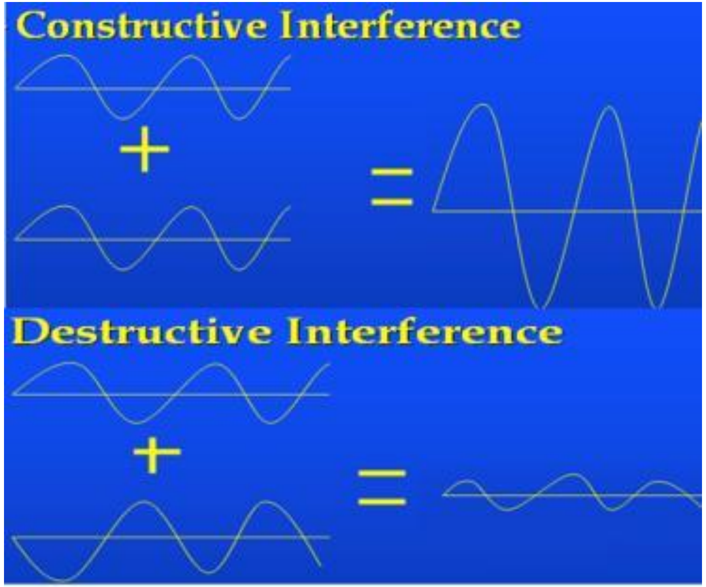
Understanding Multipath Diversity and Beamforming

Understanding Multipath

Multi-path can change Signal Strength

As radio signals bounce off metal objects they often combine at the receiver

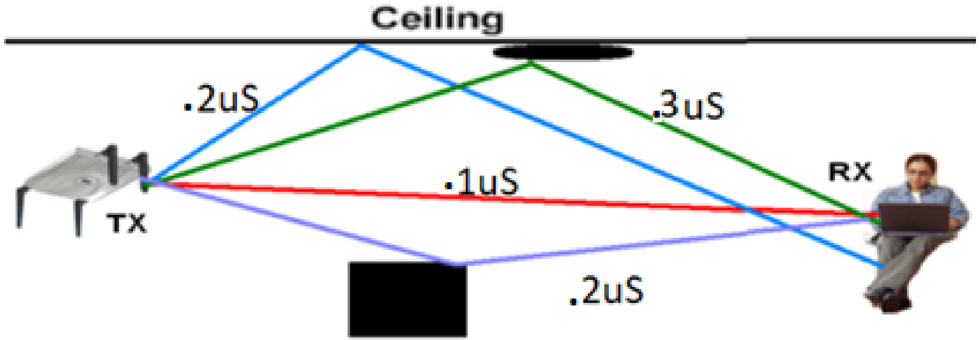
This often results in either an improvement “constructive” or a “destructive” type of interference

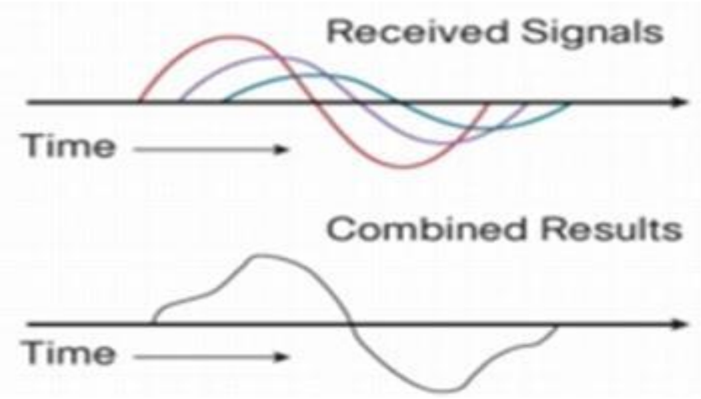


Note: Bluetooth type radios that “hop” across the entire band can reduce multipath interference by constantly changing the angles of multipath as the radio wave increases and decreases in size (as the frequency constantly changes). The downside is that throughput using these “hopping” methods are very limited but multipath is less of a problem

Understanding Multipath

Multipath Reflections Can Cause Distortion





As the radio waves bounce, they can arrive at slightly different times and angles causing signal distortion and potential signal strength fading

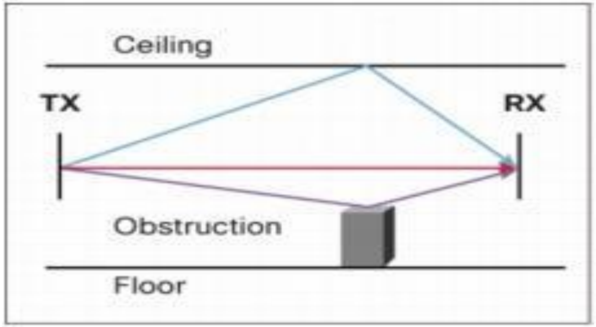
Different modulation schemes fair better – 802.11a/g introduced OFDM modulation based on symbols and is an improvement over the older modulation types used with 802.11b clients – .11ax added OFDMA increasing Guard Interval to help with Multipath

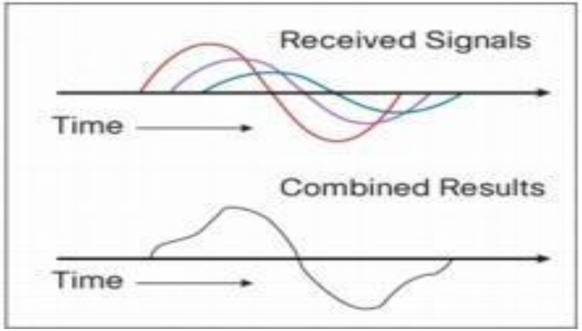
Access Points with more receivers can use destructive interference (multipath) as a benefit but it is best to try and reduce multipath conditions

Understanding Antenna Diversity (SISO)

802.11a/b/g had just one radio per band diversity was limited

Non-802.11n diversity Access Points use two antennas sampling each antenna choosing the one with the least multi-path distortion



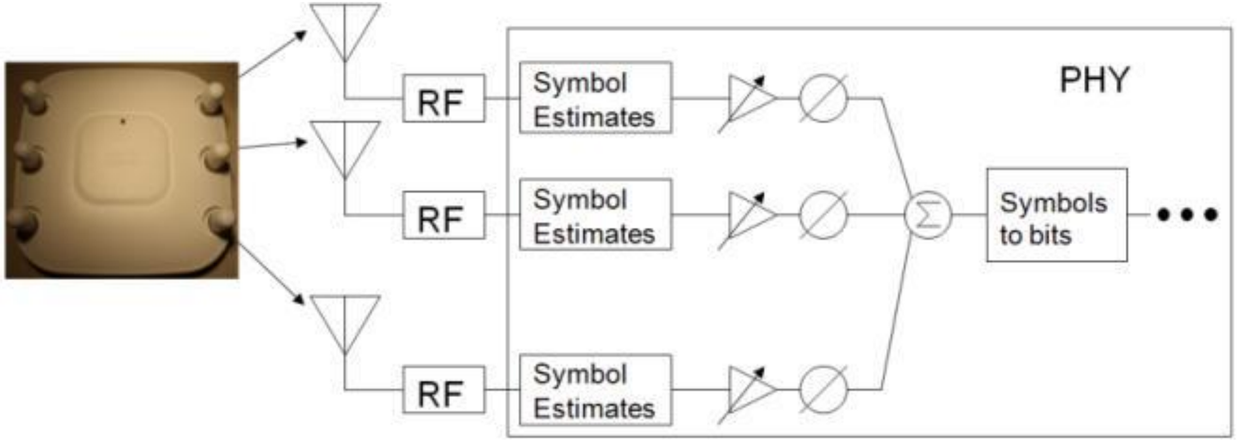


Cisco 802.11a/b/g Access Points start off favoring the right (primary antenna port) then if multi-path or packet retries occur it will sample the left port and switch to that antenna port if the signal is better.

Note: Diversity Antennas should always cover the same cell area

Understanding Diversity (MIMO)

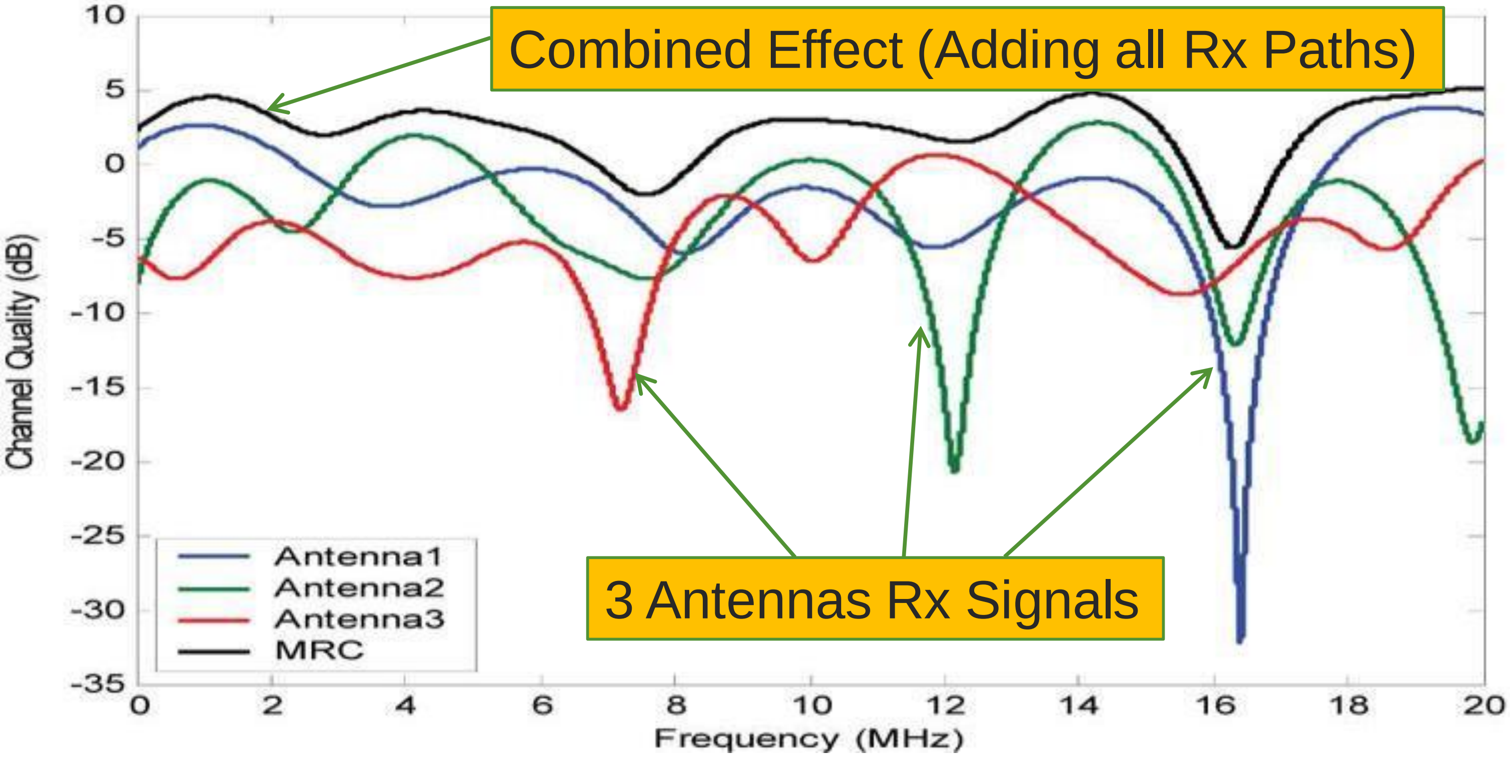
MRC Maximal Ratio Combining (Three Radios for simplicity) with .11ax supports 8 radios



- Receiver benefit as each antenna has a radio section
- MRC is done at Baseband using DSP techniques
- Multiple antennas and multiple RF sections are used in parallel
- The multiple copies of the received signal are corrected and combined at Baseband for maximum SNR (Signal to Noise) benefit
- This is a significant benefit over traditional 802.11a/b/g diversity where only one radio is used

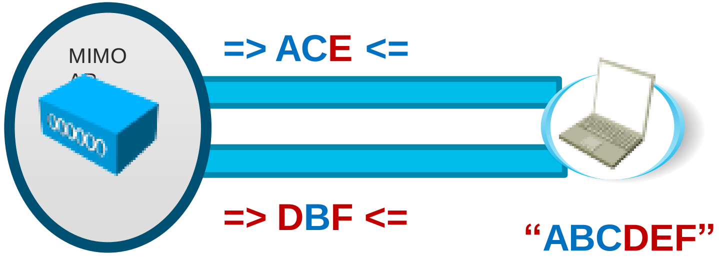
MRC Effect on Received Signal

Maximal Ratio Combining



MIMO – Multiple Input Multiple Output

Spatial Multiplexing (transmitting streams) first introduced in 802.11n



Sending side: send more symbols, in parallel (spatial multiplexing)
Each occurrence is a "stream" complementing the other

Left Channel Audio "ABC"

Right Channel Audio "DEF"

Clients such as tablets and smart phones typically support only 1 or 2 spatial streams as they typically don't have the battery or physical space for multiple radios. Larger clients (laptops and desktops) often support 3 Spatial Streams

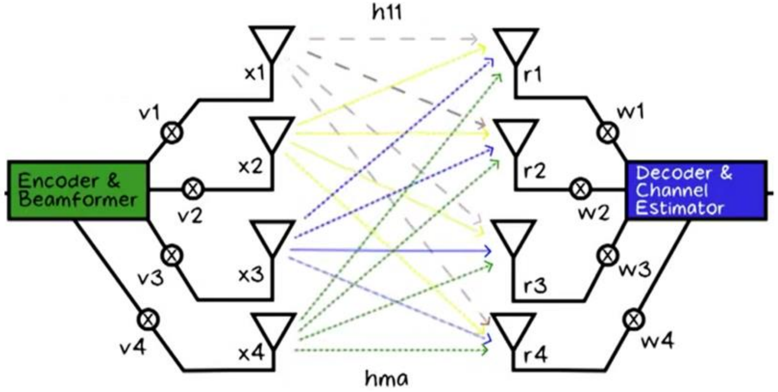
More streams means more information can be sent at the same time (faster throughput)

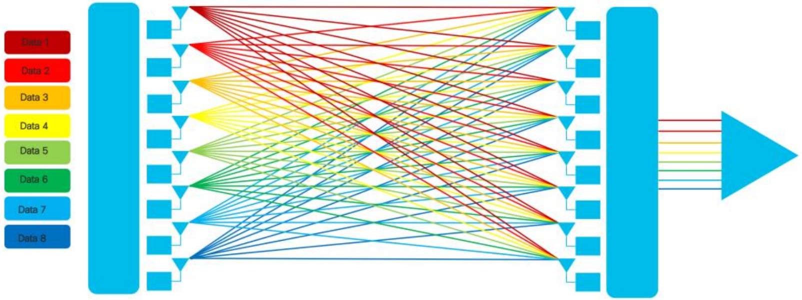
Similar to FM radio stations which use fixed channels but each channel has 2 "audio" streams

In our case we have two or more "data" streams…

802.11ax Spatial Streams – Up from 4 to 8 SS

- Some Access Points support 4-SS others 8-SS
- Spatial reuse is not new, however what we can do with it expands under 802.11ax
- Spatial multiplexing allows for a 1-1 increase in the spectrum under ideal conditions
- Higher modulation densities require higher SNR to protect against corruption
- 802.11ax provides 8 SS which can be mixed and matched to reinforce signal and increase SNR on any of the other SS's data





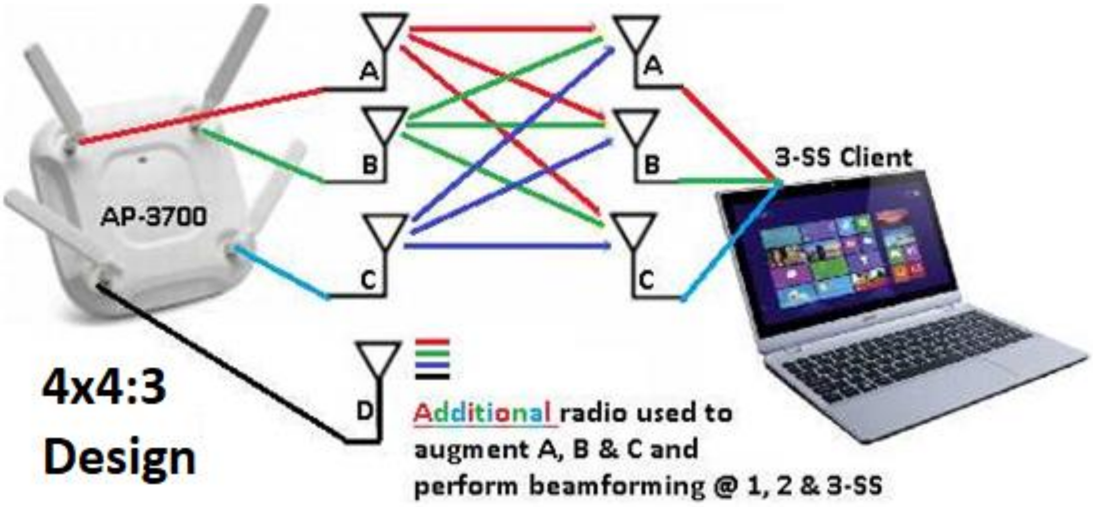
The Fundamentals of Spatial Streams – TechWise TV
https://www.youtube.com/watch?v=EeK4ISiN0Dw

Transmit Beamforming (TxBF) Spatial Streams

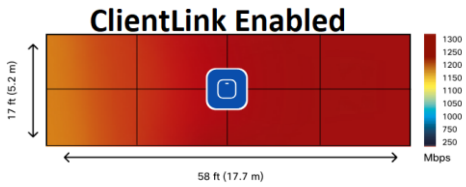
For a long time IEEE Standards based beamforming was not implemented

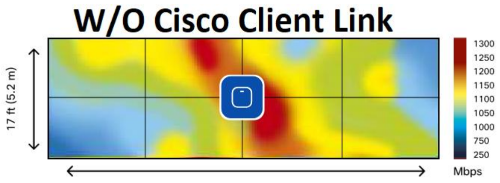
.11n & acW1 TxBF not adopted
.11acW2 TxBF implemented
.11ax MUST support

ClientLink – Cisco method of TxBF (Transmit Beamforming)
Supports .11a/g/n/acW1



4x4:3 = 4 Transmitters, 4 Receivers and support for 3 Spatial Streams





ClientLink works on downlink
Stronger signal = less retries maintaining higher datarates

Multi-User MIMO (MU-MIMO)

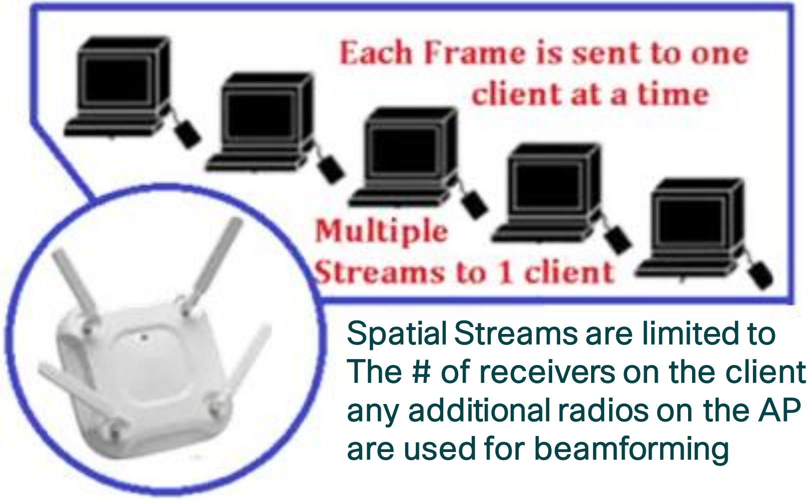
Review of 802.11ac Wave-2 and then 802.11ax

Multi-User MIMO (MU-MIMO) introduced 11ac Wave-2

How does it work? Why is it an advantage?

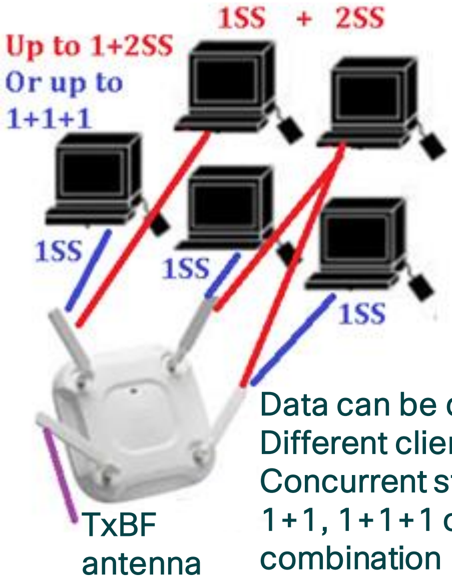
Some folks like to use the analogy of "Hub" and "Switch" SU ver. MU (not exactly accurate) but in MU-MIMO Clients are able to benefit in the downstream link for higher aggregate throughput by essentially "tuning out" (nulling) portions of the RF to better decode their traffic reducing interference.

This is Single-User MIMO



Spatial Streams are limited to The # of receivers on the client any additional radios on the AP are used for beamforming

This is Multi-User MIMO

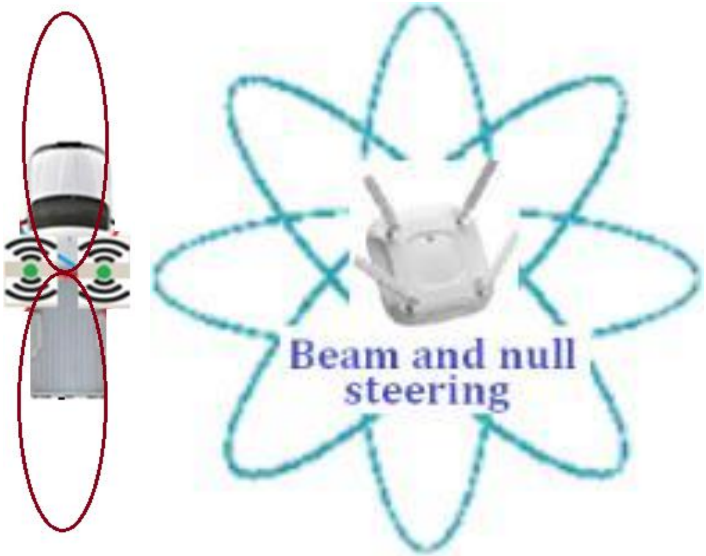


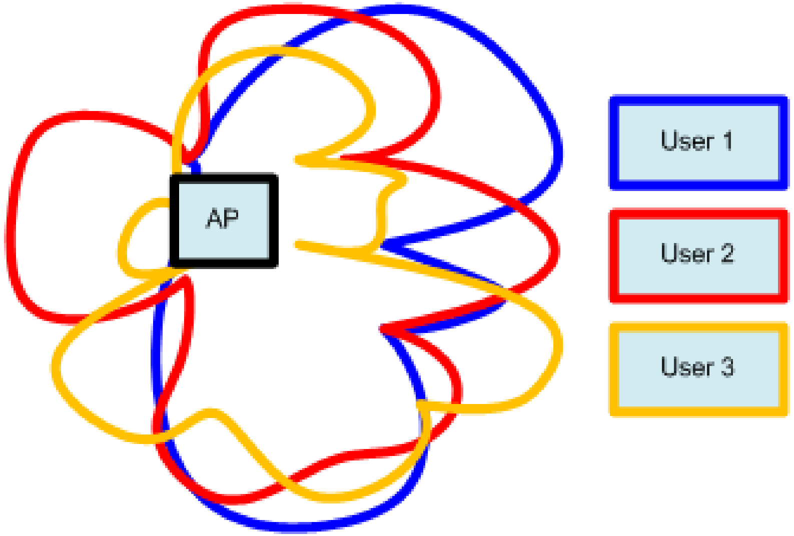
Data can be directed to Different clients in Concurrent streams in a 1+1, 1+1+1 or 1+2 stream combination

Max 3SS simultaneously

Multi-User MIMO (MU-MIMO) .11ac Wave2

Occurs when TxBF is able to focus the RF at a client while creating a null to the other clients



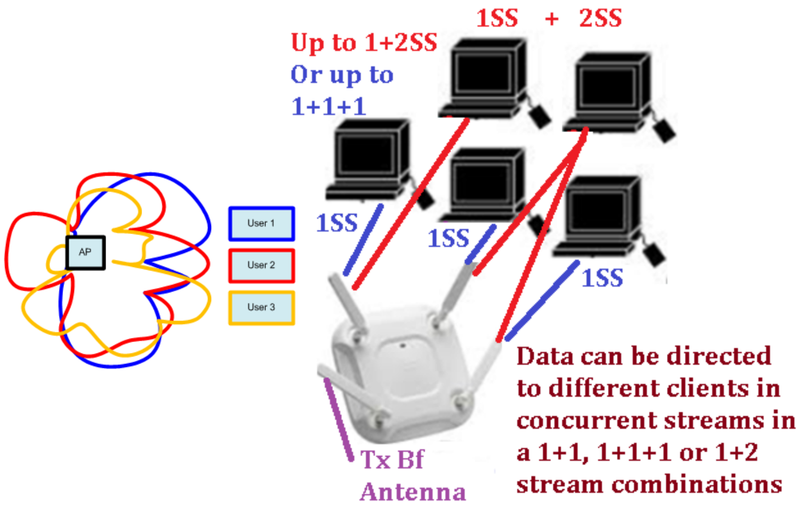


Similar to what the truck did with two antennas , using TxBF we have 4 antennas, and can place the signal <u>anywhere we want</u>

While TxBF (directing) the signal at say <u>User1</u>, you have to <u>also</u> create a NULL or lower signal for <u>Users 2 & 3 etc.</u>

Multi-User MIMO (MU-MIMO) .11ac Wave-2

Performs TxBF, while nulling and also sending similar size data packets using 4th antenna TxBF



AP is using the 4th antenna to beam-form and null. In reality the clients are ideally spaced apart around the AP and not clustered together like the diagram depicts.

Each Wave-2 client sends CSI (Channel State Information) about how to best beam-form to it.

The AP then determines how it will beam-form and null to each of the 2-3 clients and then clusters these “ideal” clients into groups.

On a per-packet-basis each member of a group receives a similar size packet at the same time (downstream).

Multi-User MIMO (challenges) .11ac Wave-2

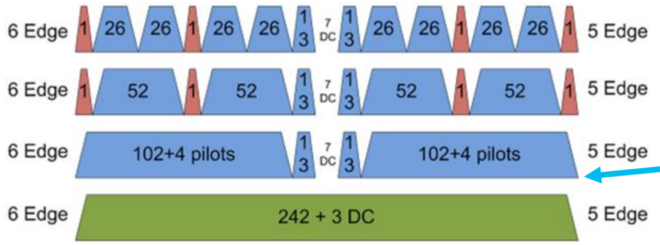
- **MU-MIMO is complex and challenging:**
  - Requires precise (CSI) channel state information to maintain deep nulls so each MU-MIMO client can properly decode its data without too much interference from the other clients
  - MU-MIMO CSI, pre-coding group data adds overhead as does their acknowledgements etc. The more MU-MIMO clients there are the more likelihood that the "law of diminishing returns" kicks in
  - Rate adaptation is SLOW – Wave-2 clients to be integrated into new laptops, tablets and phones
  - Lower quality clients – may be sensitive to MU grouping overhead, client driver version issues, they might report less helpful data in the "sounding" CSI data etc.?

Wave-2 clients supporting MU-MIMO can be found here
http://wikidevi.com/wiki/List_of_802.11ac_Hardware

Wi-Fi 6 enhancements to Multi-User MIMO

The previous slides for .11acW2 holds true for .11ax - HOWEVER… there are NEW supported features:

- MU-MIMO is now supported in Uplink and Downlink
- 8 MU-MIMO transmissions (users in a group) up from 4
- MU Station UL and DL ACKs come back in parallel *USING OFDMA*
- AP calculates a channel matrix for each user and simultaneous steer beams to different users (creating groups and managing)
- Each MU-MIMO transmission may have its own MCS rate
- Larger RU frames 106 and above are used for MU-MIMO
- MU and SU-MIMO is decided by AP w/MU- favoring larger packets



106 (102+4) is the minimum RU size for MU-MIMO

Wi-Fi 6 - 802.11ax Design and Deployment considerations

When should I refresh to Wi-Fi 6?

Depends – 802.11ac product are good for several years – 11ax clients are a year away

- Where are you in your major purchasing cycle? Do you have to spend money soon or risk losing it? Most enterprise life cycles (based on funding) refresh laptops/phones every 2-3 years and WLAN infrastructure every 3-5 years.
- Where are you today? .11n? .11ac Wave 1 or Wave 2? – If you have .11acW2 you can easily afford to wait.
- If you tend to keep infrastructure a really long time stretching it out 5-7 years you may want to wait for .11ax to mature a bit.
- Regardless of .11ax or .11ac you are still using the same applications so little has changed. How is your network today? .11ax is about spectrum efficiency and you <u>wont see improvement over 11ac until you have .11ax clients at ~30%</u>

Wi-Fi 6 Timeline

By 2020 only about 40-50% of clients will be shipping - .11ax adoption may be slow because people have recently adopted to .11ac as Wave-2 <u>is still pretty fresh.</u>

Thoughts on using .11ac & .11ax

Early .11ax APs only standards based – Wave-2 can be a better fit.

Application / Thoughts	802.11ac Wave 2	Early 802.11ax
Large Enterprise WLAN, public venue, Hospital, where connectivity and stability most important	AP28/38/4800 are best in class – Proven and mature technology – advanced features	High potential but lots of features and complexity that can introduce new challenges
Upgrading a smaller WLAN, or a new area or building – Desire to have cutting edge technology	Good Choice	Opportunity to get next generation at price parity with backward compatibilty with /802.11ac
Need for Hyperlocation, advanced analytics, CleanAir, Best in class WLAN	Excellent choice with AP-4800	First AP releases will not have "best in class" features but will concentrate on the standards
College or University where students are bringing in the very latest technology – Desire to showcase latest and greatest technology	AP-4800 good choice for great performance and high density areas – suggest Hybrid approach best in class W2 with some areas 802.11ax	Great choice as some students actually make their college decisions based on Wi-Fi having the latest standards and fastest speeds.
Small to medium size business, running older 802.11g/n – It's time to upgrade as I have budget	Good – Significant improvements over .11n Many options from 18x/28/38/4800 series	Might be a better choice if it appears you hold on to technology for a long time
I recently upgraded my network .11ac with AP-4800s – Now I see 802.11ax is available –	The AP-4800 is the BEST ACCESS POINT TODAY .11ax products with best in class features not due until 2020 also to realize true .11ax performance the network needs 20-30% .11ax clients	Consider small deployment in areas where you think you may have 2.4 GHz issues as newer IoT clients and BSS coloring feature may help
I have a requirement for outdoor wireless, I understand 802.11ax had outdoor enhancements	Cisco has a line of outdoor Access Points that are very good and available today	Outdoor .11ax and clients at least a year away but could deploy indoor AP in NEMA enclosure

Cisco-Aironet Indoor AP Product Portfolio

The industry's most comprehensive and innovative access point portfolio

Good - Enterprise class	Better	Best in class
Ideal for small to medium-sized deployments	Mission critical	High density

1815 Series

Indoor/high-powered Indoor Wall plate/teleworker

- 2x2:2 SS 80 MHz
- 867 Mbps performance
- Tx beamforming
- Integrated BLE[1]
- Max transmit power (dBm) per local regulations[2]
- 3 GE local ports, including 1 PoE out[3]
- Local ports 802.1X ready[3]
- USB 2.0[4]

1830/1850 Series

- 3x3:2 SS 80 MHz/4x4:3 SS 80 MHz
- 867 Mbps or 1.7 Gbps performance
- 1 or 2 GE ports uplink
- Internal or external antenna (1850)
- Tx beamforming
- USB 2.0

2800 Series

- 4x4:3 SS 160 MHz
- 5 Gbps performance
- 2.4 and 5 GHz or dual 5 GHz
- 2 GE ports uplink
- Cisco CleanAir® and ClientLink
- Internal or external antenna
- Smart antenna connector
- USB 2.0

3800 Series

- 4x4:3 SS 160 MHz
- 5 Gbps performance
- 2.4 and 5 GHz or dual 5 GHz
- 2 GE ports uplink or 1 GE + 1 Multigigabit (5G)
- Cisco CleanAir and ClientLink
- StadiumVision™
- Internal or external antenna
- Smart antenna connector
- USB 2.0
- Modularity for investment protection

4800

- 4 embedded radios (3 Wi-Fi and 1 BLE)
- 4x4:3 SS 160 MHz
- 5 Gbps performance
- 2.4 and 5 GHz or dual 5 GHz
- 2 GE ports uplink or 1 GE + 1 Multigigabit (5G)
- Embedded Hyperlocation
- Real-time analytics and packet capture
- Cisco CleanAir and ClientLink
- Internal antenna
- USB 2.0
- Integrated BLE

Understanding Power via PoE

802.3af (15.4W) PoE

802.3at (30W) PoE

[1] Future availability [2] Available for high-powere only [4] Available for teleworker only

Cisco AP-4800 - Our Very Best Flagship AP

OUR BEST ACCESS POINT – Most advanced .11ac Wave-2 AP with NO EQUAL

- Intelligent Capture
- Built-in Hyperlocation
- Unique Cisco DNA Analytics Radio w/ (Digitally switched antenna array)

- Innovations beyond the Wi-Fi specification – permits security monitoring, packet capture, instant network analysis

- Increasing network capacity without impacting client serving radios.

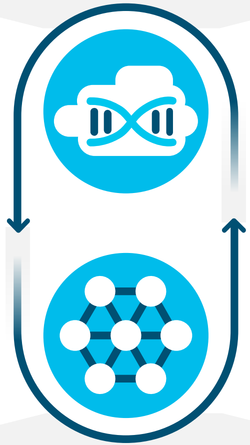
Early .11ax (first iterations) won't be "best in class" – so for large public venues today they lack core features found in products like the AP-4800

Right Now = Catalyst 9800, 4800 AP and Cisco DNA

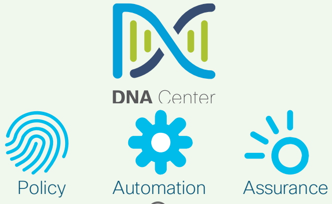
new

Digitize people, spaces and things with Cisco DNA Spaces

Automate provisioning and policy on an infrastructure designed for IBN



Streaming telemetry and insights to take the right action at the right time



Cisco DNA Center

- Design, Provision,
- Automate
- 360◦ Context Graph
- Apple iOS WiFi Analytics

new

Catalyst 9800 Wireless Controller

- Always-on
- Secure
- Deploy Anywhere

Aironet 4800 Access Point

- Intelligent Capture
- 24x7 dedicated monitoring radio
- <3m median Hyperlocation accuracy

Cisco-Aironet Access Points for Outdoor Applications

DNA Ready | RF Excellence | CMX

New

1540

- 802.11ac Wave 2, MU-MIMO
- 2x2:2, 80MHz, 867 Mbps
- Ultra low profile
- Internal antenna model (I)
- Internal directional antenna model (D)
- PoE (802.3af) power
- Centralized, FlexConnect, Mesh* and Mobility Express

New

1560

- 802.11ac Wave 2, MU-MIMO
- 3x3:3, 80MHz, 1.3Gbps (I)
- 2x2:2, 80MHz, 867Mbps (E/D)
- Internal or External antenna model (I/E)
- Internal directional antenna model (D)
- SFP
- Flexible Antenna Ports
- CleanAir and ClientLink
- Centralized, FlexConnect, Mesh and Mobility Express

802.11ac Wave 2

1570

- 802.11ac Wave 1
- 4x4:3 80 MHz; 1.3 Gbps
- External antenna model (EAC)
- Cable Modem model (IC/EC)
- SFP
- GPS
- PoE Out 802.3at (Ext Ant. only)
- Flexible Antenna Ports
- CleanAir and ClientLink
- Modularity (Ext Ant. only)
- Centralized, FlexConnect and Mesh

Cable Modem Version Only (IC/EC)

- DOCSIS 3.0, 24x8
- Internal or External antenna

.11ax Installations – What do you have installed today?

- Before refreshing to Wi-Fi 6 its time to do a review of your existing WLAN issues as well as identifying any new location, BLE or IoT requirements

- 1:1 replacement <u>assumes</u> the AP was installed in the best place to begin with?

- While new Wi-Fi 6 features might be able to help mitigate a bad or poor design <u>*NOTHING BEATS*</u> reviewing what is in place now and <u>*INSTALL IT RIGHT the 1st time*</u> ☺

Newer .11ax APs will have more radios up to 8x8

1st APs will be standards based “GOOD” with later APs being BEST IN CLASS (3rd half 2019)

There will be .11ax models that only support 4x4 while others will support 8x8

Wi-Fi 6 (.11ax)
4x4:4

Wi-Fi 6 (.11ax)
8x8:8

When using mGig (NBASE-T)
4x4 port up to 2.5G
8x8 will have support for 5G

External antenna models will likely require more RF connectors or the use of a Cisco DART connector.

DART connectors allow multiple and/or smart antennas to be installed **with one insertion. Faster install time & smaller connector footprint.**

Think about upgrading to N-Base-T

If I have it and I'm having trouble then what? – Look at the cable system

For Your Reference

Troubleshooting mGig (N-Base-T)

Cable Type	Port Speed	Total Cable Length	6-a-1 Bundled Cable Length	Patch Panel Cable and 3 Connecters	Mitigation Plan to improve performance
Cat 5e	10GE	N/A	N/A	N/A	Upgrade cable to Cat 6a
	5GE	100m	>30m	10m (2x5)	1) Use "Downshift" 2) Reduce number of connectors 3) Change patch cable to solid core cable 4) Reduce bundled cable length to be <30m 5) Use Cable Diagnostic or Cable Tester to determine end-to-end Cable quality
	5GE	100m	<30m		5GE
	5GE	55m	Fully bundled	10m	5GE
	2.5G	100m	Fully bundled	10m	2.5GE

Downshift Option that permits system to detect and lower speeds when noise occurs rather than maintaining a fixed value

Table 2: ALSNR support risk for 2.5G and 5G applications

0m <= Bundled cabling length <= 50m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured

50m <= Bundled cabling length <= 75m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured

75m <= Bundled cabling length <= 100m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured

ALSNR Risk	High	Medium	Low

http://www.panduit.com/ccurl/901/950/nbase-t-white-paper,0.pdf

Cisco Multigigabit Products

For Your Reference

4500E

- Best In Class Modular Access
- New 48 Ports Line Card
- 12 Ports of Multigigabit per slot
- Up to 96 multigigabit ports per system

3850

- Industry leading Fixed Access
- 24 & 48 Port Stackable Switches
- 24 & 12 Multigigabit Ports
- New Uplinks

3560CX

- NG Workspace switch
- Multigigabit in smallest form factor
- POE/POE+
- Instant Access support

48-port Catalyst 3850 Multigigabit Switch

Downlinks:
36 x 1G LineRate 10/100/1000BASE-T, PoE/PoE+/UPoE, EEE, MACSec

12 x GE/mGig/10GT – LineRate, 100M/1GE/mGiG/10GBASE-T, PoE/PoE+, PoE/PoE+/UPoE, EEE, MACSec

Uplinks:
4x10GE SFP+, 2 x 40G (NEW), 8x10G (NEW)

24-port Catalyst 3850 Mulitgigabit Switch

Downlinks:
- 24 x GE/mGig/10GT
- EEE, MACSec
- PoE/PoE+/UPOE

Uplinks:
4x10GE SFP+, 2 x 40G (NEW), 8x10G (NEW)

Site Survey? What tool do I use for Wi-Fi 6?

ekahau WIRELESS DESIGN

https://www.ekahau.com/

In a recent webinar Ekahau stated their tool will be ready for .11ax in the 1st half of 2019

iBwave

http://www.ibwave.com/

A good URL to find .11ax clients when they become available

https://wikidevi.com/wiki/List_of_802.11ax_Hardware

NETSCOUT

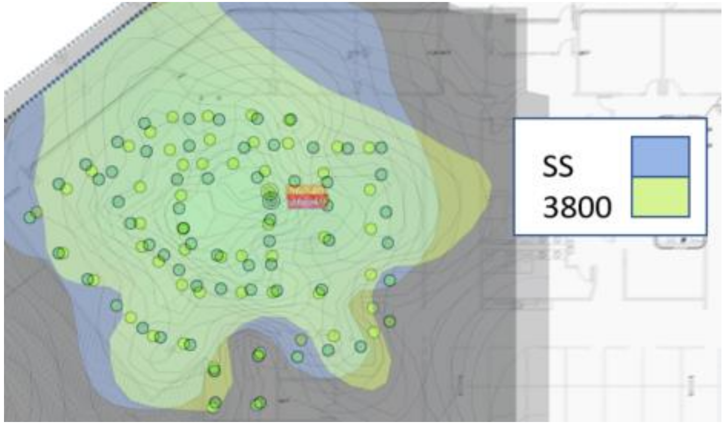
AirMagnet Survey PRO

https://enterprise.netscout.com/

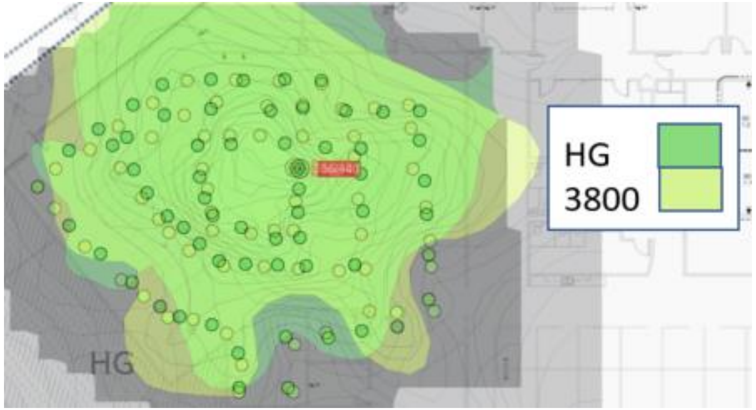
For more on Wi-Fi 6 Spectrum analysis, and best practices see Cisco Live session BRKEWN-3010

Upgrading Access Points 1:1 or another survey?

Access Points have always had similar heat maps – The design goal is to maintain a uniform coverage cell between products but improve the connection experience (faster speeds less retries)



AP-3800 & .11ax 4x4

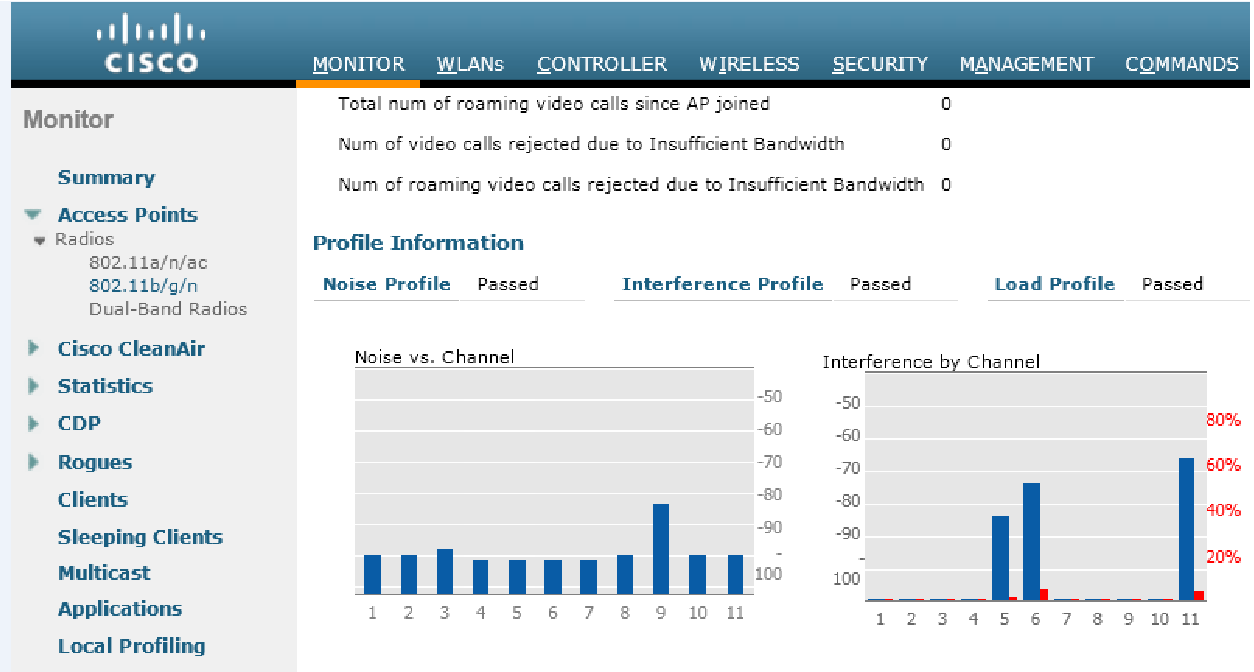


AP-3800 and .11ax 8x8

- Keep Access Points mounted at least 2 meters away from each other
- Rule of thumb - **Europe 1 AP per 250 Sq. Meters** - **US 1 per 2500 Sq Ft.**

Is there a way to see co-channel interference or noise?

Answer: For each AP, you can go to **Monitor > AP > choose a radio**, and see the interference levels reported at this AP position, for all channels,



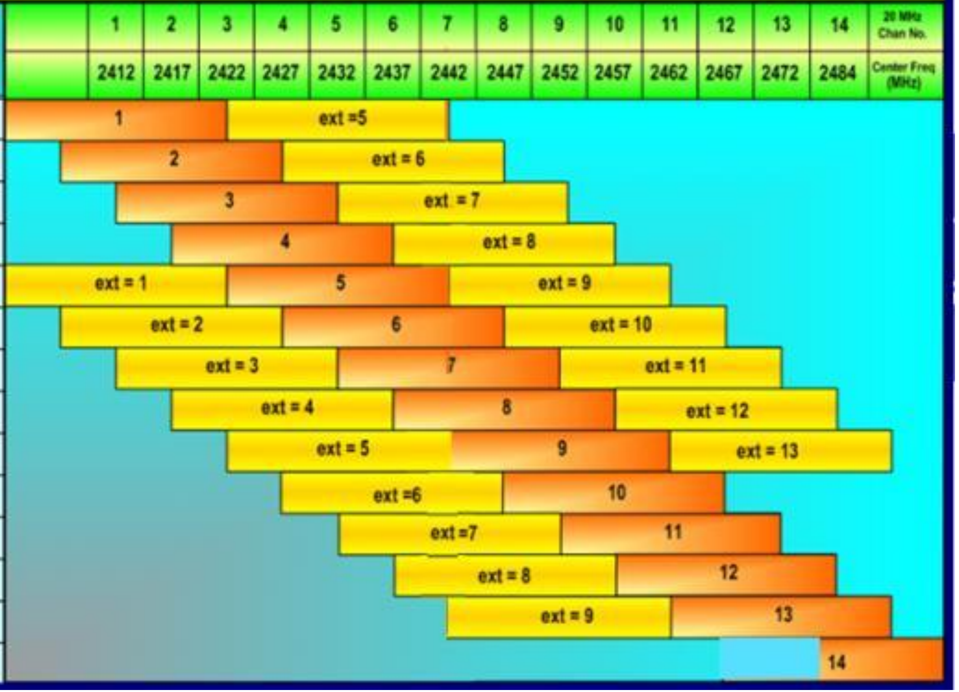
2.4 GHz Channels and Bandwidths

For Your Reference

40 MHz Not Permitted or Supported (Enterprise WLAN) as not enough spectrum

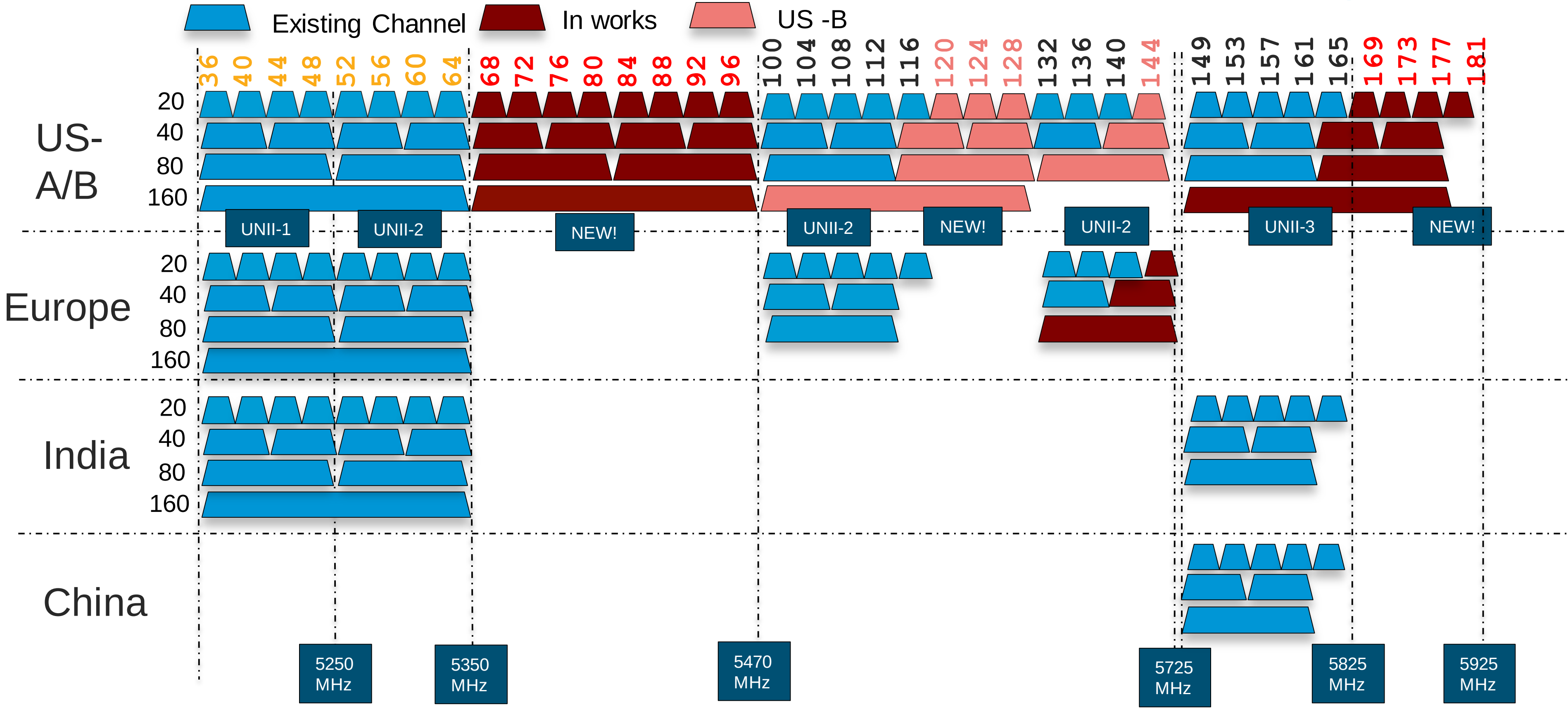
2.4 GHz Bandwidths

Domain	Ch ID	Freq (MHz)	Center Ch 20 MHz	Center Ch 40 MHz	Cntrl Ch	Ext Ch	Exten Upper or Lower
US & ROW	1	2412	1	3	1	5	Upper
	2	2417	2	4	2	6	Upper
	3	2422	3	5	3	7	Upper
	4	2427	4	6	4	8	Upper
	5	2432	5	3, 7	5	1, 9	Low, Up
	6	2437	6	4, 8	6	2, 10	Low, Up
	7	2442	7	5, 9	7	3, 11	Low, Up
	8	2447	8	6, 10	8	4, 12	Low, Up
	9	2452	9	7, 11	9	5, 13	Low, Up
	10	2457	10	8	10	6	Lower
	11	2462	11	9	11	7	Lower
ROW	12	2467	12	10	12	8	Lower
	13	2472	13	11	13	9	Lower
	14	2484	14	NA	14	NA	NA



5 GHz Channels and Bandwidths - 20/40/80/160

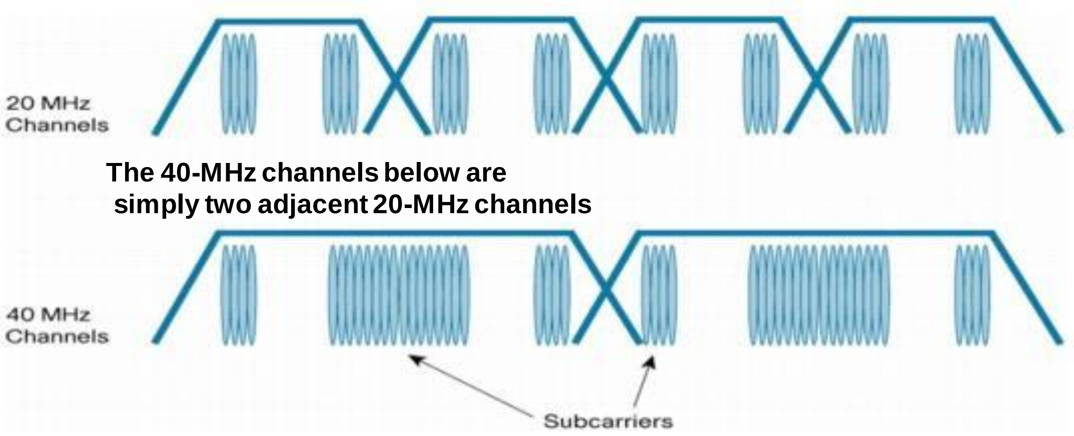
For Your Reference



Channel Bonding – Subcarriers – Example 20 & 40MHz

802.11n,ac&ax can use both 20 & 40 MHz channels.

Trading distance for throughput as bonded channels decreases RF by 3-dB power spread across band

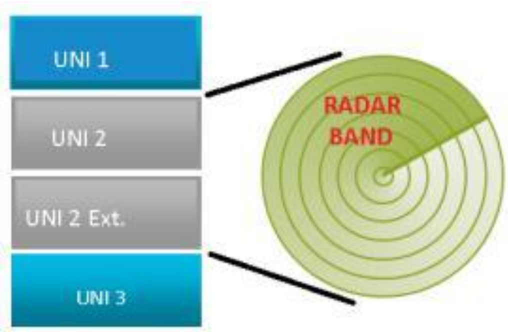


When using the 40-MHz bonded channel it takes advantage of the fact that each 20-MHz channel had a small amount of the channel that is reserved at the top and bottom, to reduce interference in those adjacent channels so it gains extra subcarriers.

When using 40-MHz channels, the top of the lower channel and the bottom of the upper channel don't have to be reserved to avoid interference. These small parts of the channel can now be used to carry information.
By using the two 20-MHz channels more efficiently in this way… 802.11n/ac/ax achieves slightly more than doubling the data rate when moving from 20-MHz to 40-MHz channels – this also happens going from 40 to 80 MHz and 80 to 160 MHz

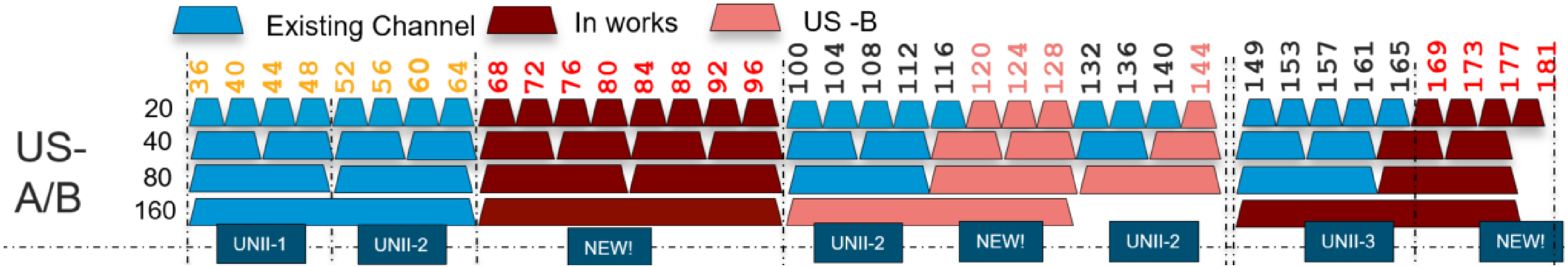
.11ac and .11ax can bond all the way up to 160 MHz Channels

Wi-Fi 5 GHz Channels & Dynamic Frequency Selection



Note: 5 GHz channels do not have the overlap that 2.4 GHz channels have but they often use "DFS" Dynamic Frequency Selection to enable sharing of the band

When Radar is present – (near Airports or Military areas) This can result in lower available channels and loss of some UNI-2 and UNI-2 extended bands (negotiated with licensed users of the band)



Access Points detect radar activity and change channels so as not to cause interference with licensed services who have priority

Integrated Antenna? – External Antenna?

Integrated Antenna

USE CASE

- Aesthetics (carpeted areas)
- No additional antenna costs
- Less “things” to install
- Hyperlocation more elegant
- Sometimes better for high ceilings

External Antenna

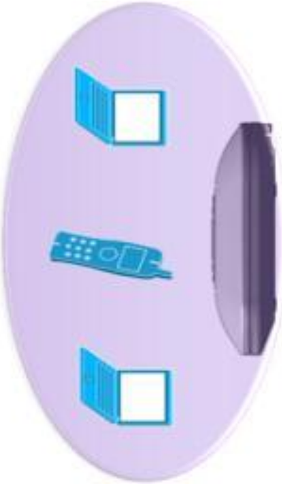
USE CASE

- Industrial applications high temp.
- External or directional antennas are desired (inside/outside) use
- Dual 5 GHz (Macro/Maco)
- Longer Range

Wall Mounting Access Point with Internal Antennas

Wall mounting is acceptable for small deployments such as hotspots, kiosks, transportation or small coverage areas.
But NOT for Enterprise deployments.

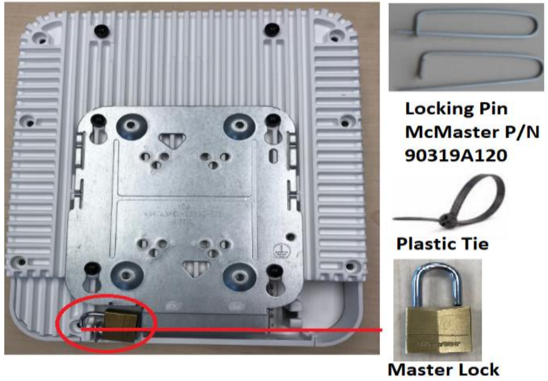
Coverage is always more uniform when installed on the ceiling tile or grid area



Note: Wall mounting may create unwanted coverage areas on the floor above or below

This is not desirable for voice as it may cause excessive roams as the pattern is directional (up/down)

Mounting APs and Third Party Solutions



3rd Party in-tile mounts, Plastic skins to change AP color etc. can improve some installs - see AP-4800 deployment guide for more

http://cs.co/9000Dcum8

Thoughts on Cisco Partner Solutions…

Installations/aesthetics can often be enhanced by the use of Third Party Solutions

- Creative ceiling solutions (above/below) tile
- Outdoor NEMA enclosures
- Changing the color of an AP
- Bracketry / Tripods for antenna and AP co-location
- Solar / Battery Options
- Site Survey hardware/software
- Rugged mounting for mining/Earth moving vehicles
- Custom Application antennas*

*Cisco does not certify or test Third Party antenna solutions

Popular Cisco Partner URLs

- Oberon Wireless
- http://www.oberonwireless.com/
- AccelTex Solutions
- http://acceltex.com/
- Ventev
- http://www.ventev.com/

Never Paint an Access Point use a "skin" instead

Skins for blending (hiding) AP

Courtesy of AccelTex Solutions

Understanding Cisco Access Point Colors

What is the RAL or Pantone color used for Cisco WLAN Products?

RAL is a color matching system used in Europe https://en.wikipedia.org/wiki/RAL_colour_standard

Pantone LLC is a U.S. Corporation best known for its Panton Matching System (PMS) a proprietary color space used in a variety of industries. https://en.wikipedia.org/wiki/Pantone

Cisco does not use these methods of color so there is no official recommendation or match to such system. Cisco Systems, Inc. has two popular colors used for its Aironet Brand of WLAN products.

- **Cisco Light Gray** used on most indoor Access Points and most antennas
- **Cisco Medium Gray** used on most outdoor Access points and some outdoor antennas

Indoor AP's (Cisco Light Gray)

- Semi-Gloss Texture Powder Coating:
  - Cardinal Industries C031-WH120 (Indoor/Outdoor)
  - Sherwin Williams HWT2-J2453 (Indoor)
  - Akzo Nobel JA343C (Indoor/Outdoor)
- High-Gloss Smooth Powder Coating:
  - Cardinal Industries T009-WH12 (Indoor/Outdoor)
  - Sherwin Williams UWS8-J2653 (Indoor/Outdoor)

Painting voids Warranty

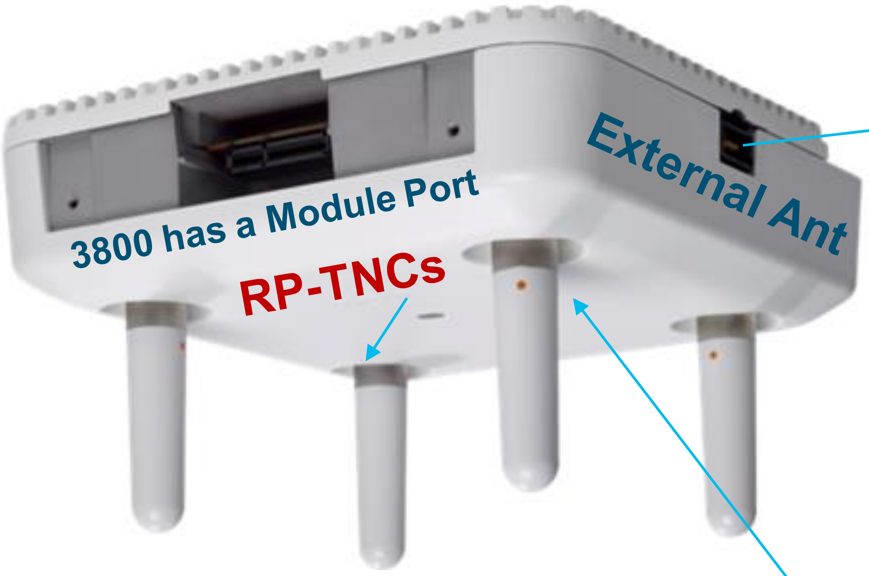
Outdoor AP's (Cisco Medium Gray)

- Low Bake Wet Paint for Plastic:
  - Akzo Nobel Paint code: 820-EJS-10227
- High Bake Wet Paint for Sheet metal (can be used for touch-up):
  - Akzo Nobel Paint code: 821-EJS-10318
- Indoor Powder Coating:
  - Texture Finishing. Akzo Nobel Paint Code: EL57GC
  - Texture Finishing. Sherwin Williams Paint code: SW-HAT2-J2622
  - Smooth Finishing. Akzo Nobel Paint Code: EL58GC
- Outdoor Powder Coat:
  - Texture Finishing. Sherwin Williams Paint code:SW-DAT1-J3487
  - Smooth Finishing. Sherwin Williams Paint code: SW-PAS2-J3547

Mixing AP types and use of External Antennas

- It is recommended that you do not mix Access Points of different models types in a “salt and pepper” fashion.
- Keep like Access Points together especially the AP-4800 as it has special Cisco DNA features like Intelligent Capture that diminishes in performance when clients roam across non-AP4800 Access Points.
- If you have need to External antennas, use the AP2800/3800e with the smart antenna connector if will give you the most flexibility
- Don’t mount the AP in the IDF closet and then remote the antennas
- Keep all antenna cable runs as short as possible
- Mount the AP as close to the USERS as you reasonable can

External Antenna Devices - AP-2800/3800e



Adapter can take you from DART to same RP-TNC as on the AP.

DART insertion (antenna or adapter) causes the XOR radio 2.4 or additional 5 GHz radio to go out this secondary antenna port.

Integrated antenna versions are designed for mounting on a ceiling (carpeted areas) where aesthetics is a primary concern

Without the DART installed both 2.4 and 5GHz are on the Primary TNCs

Identifying RF Connectors

For Your Reference

RP-TNC Connector

Used on most Cisco Access Points

"RP-SMA" Connector

Used on "cost reduced" products (Linksys...)

"N" Connector

15xx Mesh and outdoor APs

"DART" Connector

.11ax multiple antennas & location services

Keep all antenna cables as short as possible

Cables introduce loss and more potential points of failure

For Your Reference

This is a chart depicting different types of Microwave LMR Series coaxial cable.

Cisco uses Times Microwave cable and has standardized on two types:
Cisco Low Loss (LMR-400)
Ultra Low Loss (LMR-600)

LMR-600 is recommended when longer cable distances are required

Larger cables can be used but connectors are difficult to find and larger cable is harder to install

Trivia: LMR Stands for “Land Mobile Radio”
Some cables are Plenum (low smoke rated)

Some Antenna Cables Characteristics

For Your Reference

LMR®-400 TIMES MICROWAVE SYSTEMS

Flexible Low Loss Communications Coax

Frequency (MHz)	30	50	150	220	450	900	1500	1800	2000	2500	5800
Attenuation dB/100 ft	0.7	0.9	1.5	1.9	2.7	3.9	5.1	5.7	6.0	6.8	10.8
Attenuation dB/100 m	2.2	2.9	5.0	6.1	8.9	12.8	16.8	18.6	19.6	22.2	35.5
Avg. Power kW	3.33	2.57	1.47	1.20	0.83	0.58	0.44	0.40	0.37	0.33	0.21

LMR®-600

Flexible Low Loss Communications Coax

Frequency (MHz)	30	50	150	220	450	900	1500	1800	2000	2500	5800
Attenuation dB/100 ft	0.4	0.5	1.0	1.2	1.7	2.5	3.3	3.7	3.9	4.4	7.3
Attenuation dB/100 m	1.4	1.8	3.2	3.9	5.6	8.2	10.9	12.1	12.8	14.5	23.8
Avg. Power kW	5.51	4.24	2.41	1.97	1.35	0.93	0.70	0.63	0.59	0.52	0.32

Foil shield and braid

LMR-400 3/8 inch

LMR-600 ½ inch

Cisco P/N for cable (breakdown)

AIR-CAB-050-LL-R

AIR - Aironet

CAB – Cable

050 - Length

LL - Low Loss

(LL=LMR-400, ULL=LMR-600)

R - RP-TNC

(connector type "R" and "N")

Antenna Basics
Different types of antennas

A Radio Needs a Proper Antenna

As the frequency goes up, the radiating element gets smaller

Antennas are identified by color
Blue indicates 5 GHz
Black indicates 2.4 GHz
Orange indicates Both

Omni-Directional antennas like the one on the left, radiate much like a raw light bulb would everywhere in all directions

Directional antennas like this "Patch" antenna radiate forward like placing tin foil behind the light bulb or tilting and directing the lamp shade

Antennas are custom made for the frequency to be used. Some antennas have two radiating elements to allow for both frequency bands (2.4 and 5 GHz) in one antenna enclosure.

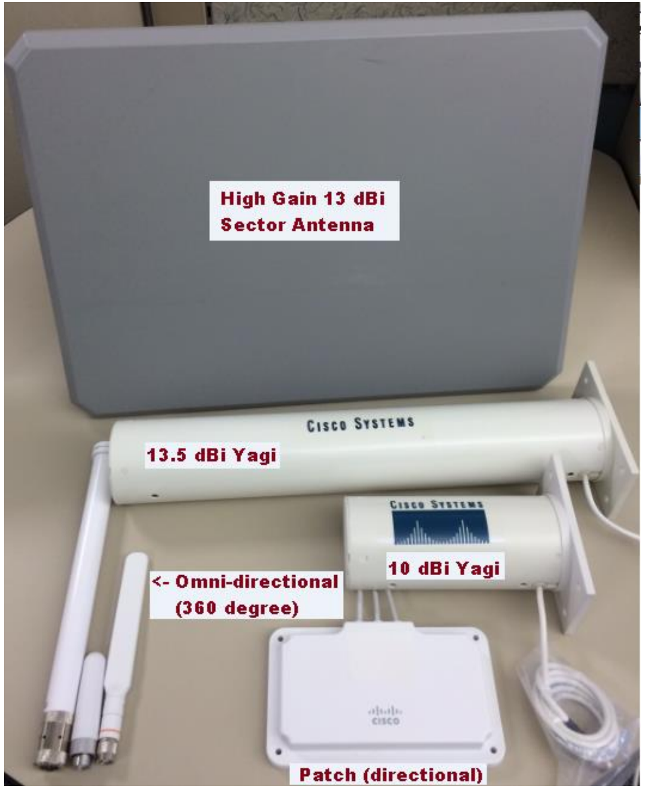
Note: Same RF energy is used but results in greater range as it is focused towards one direction, at the cost of other coverage areas

For Your Reference

Antenna Basics

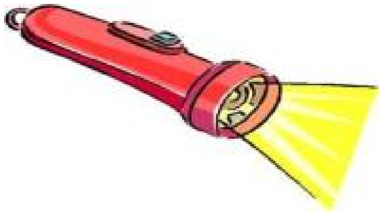
- Antenna - a device which radiates and/or receives radio signals
- Antennas are usually designed to operate at a specific frequency
- Some antennas have more than one radiating element (example Dual Band)
- Antenna Gain is characterized using dBd or dBi
  - Antenna gain can be measured in decibels against a reference antenna called a dipole and the unit of measure is dBd (d for dipole)
  - Antenna gain can be measured in decibels against a computer modeled antenna called an "isotropic" dipole <ideal antenna> and the unit of measure is dBi the "i" is for isotropic dipole which is a computer modeled "perfect" antenna
- Wi-Fi antennas are typically rated in dBi.
  - dBi is a HIGHER value (marketing folks like higher numbers)
  - Conventional radio (Public safety) tend to use a dBd rating.
  - To convert dBd to dBi simply add 2.14 so a 3 dBd = 5.14 dBi

Identifying different types of Wi-Fi antennas



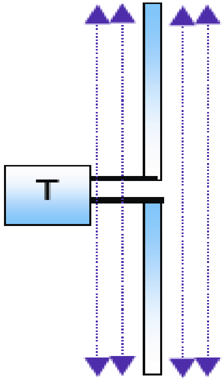
Higher gain antennas are physically bigger as they contain more radiating elements to help focus the energy in a given direction. <u>You don’t get more RF power, you are just focusing the same amount of energy to go further</u>

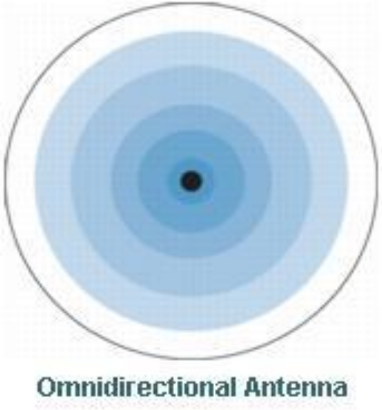
Think Omni versus Directional (focused)



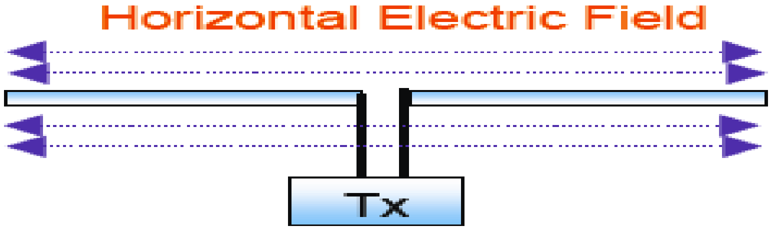
How Does a Omni-Directional Dipole Radiate?

The radio signal leaves the center wire using the ground wire (shield) as a counterpoise to radiate in a 360 degree pattern





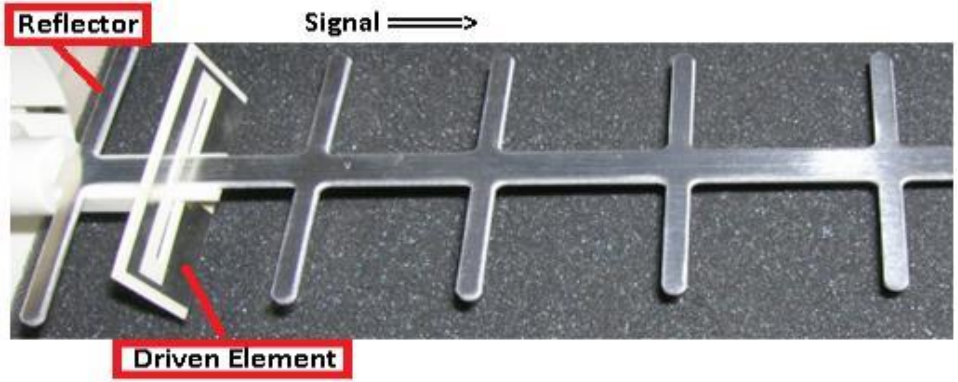
Low gain
Omni radiates much like a light bulb “360” degrees

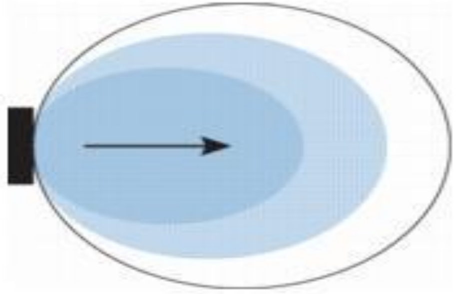


How Does a Directional Antenna Radiate?

Although you don't get additional RF power with a directional antenna, it does concentrate the available energy into a given direction resulting in greater range.

Also a receive benefit - by listening in a given direction, this can limit the reception of unwanted signals (interference) from other directions for better performance





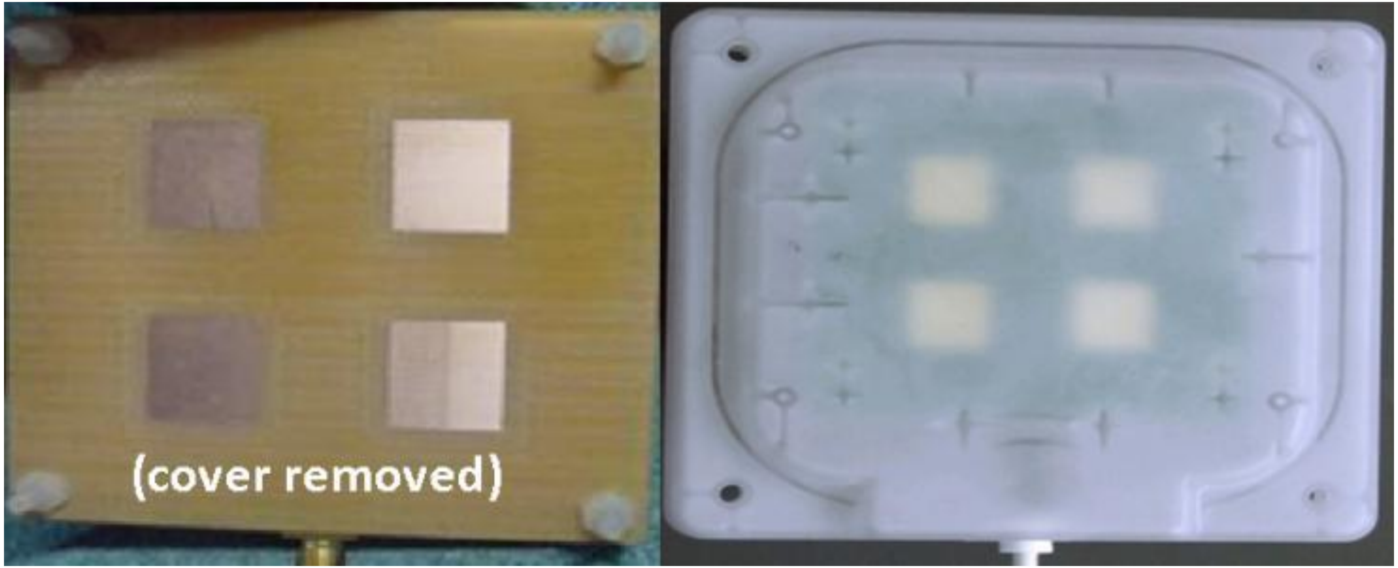
YAGI Antenna

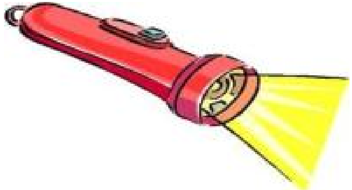
A dipole called the "driven element" is placed in front of other elements. This motivates the signal to go forward in a given direction for gain.

(Inside view of the Cisco AIR-ANT1949 - 13.5 dBi Yagi)

Patch Antenna: a look inside

Patch antennas can have multiple radiating elements that combine for gain.
Sometimes, a metal plate is used behind the antenna as a reflector for more gain.





Patch and Yagi designs favor the direction the antenna is pointed – like a flashlight

Cisco 9.5 dBi Patch - AIR-ANT5195-R

Antennas Identified by Color

For Your Reference

Cisco Antenna
Color Coding Scheme

Black indicates: 2.4 GHz
Blue indicates: 5 GHz
(Single Radiating Elements)

Orange indicates both:
2.4 & 5 GHz (Dual Radiating Elements)

Used on 1600,1700,1850, 2600, 2700, 2800, 3600, 3700 & 3800 Series Access Points

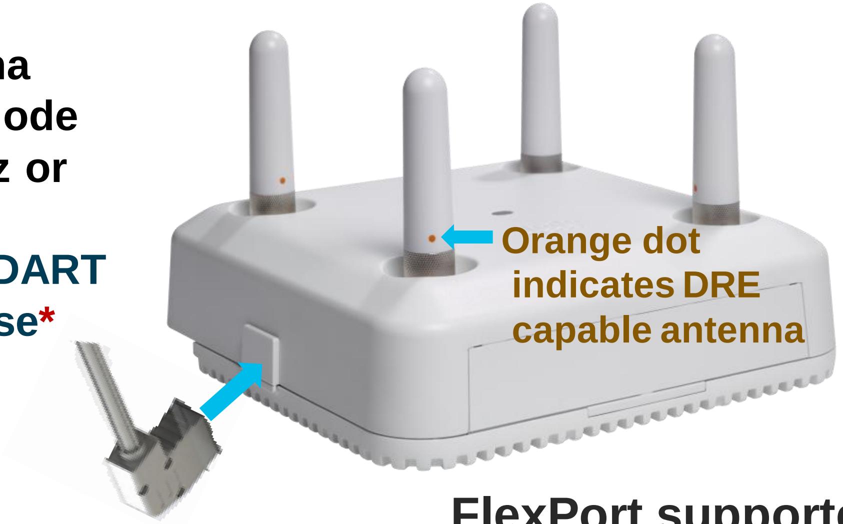
A Single Band antenna it has a Single Radiating Element (SRE)
If antenna is Dual Band (orange in color) it has a Dual Radiating Elements (DRE)
Note: Dual Band antennas *not orange* in color may contain SRE's in each band

FlexPort - Some products the antenna port is configurable

You choose if it is a Single or Dual Radiating Element (creating different cells indoors/outdoors)

Default DRE mode with 2.4 and 5 GHz on antennas

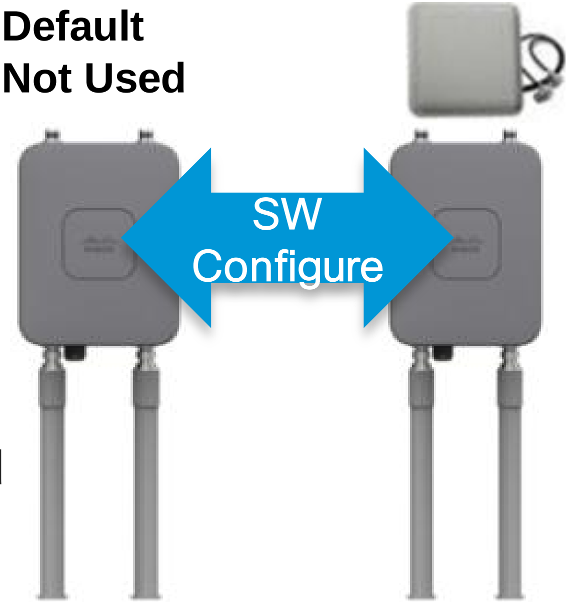
Single band antenna SRE Mode 2.4GHz or 5 GHz when DART is in use*



Orange dot indicates DRE capable antenna

5 GHz only SRE

Default Not Used



2.4 & 5GHz DRE

2.4 GHz SRE

FlexPort supported On some models Indoor & outdoor

* AP-3800e If used in receive only for monitoring it will serially cycle both bands for analytics

Understanding and Interpreting Antenna Patterns

The Richfield Ohio (Aironet) Facility

Creating the patterns you see in the spec sheets

Satimo software compatible with Stargate-64 System. Basic measurement tool is Agilent 8753ES Analyzer.

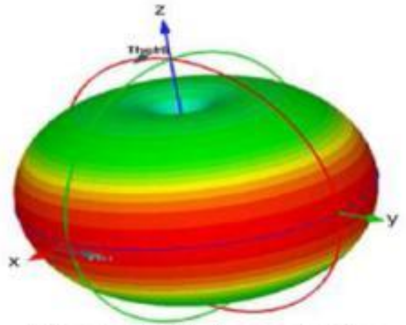
Cisco Anechoic chamber using an 45 cm absorber all the way, around 1-6 GHz

Anechoic means "without echo"

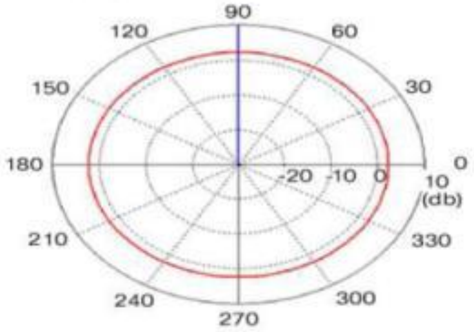
Understanding Antenna Patterns

Dipole (Omni-Directional)

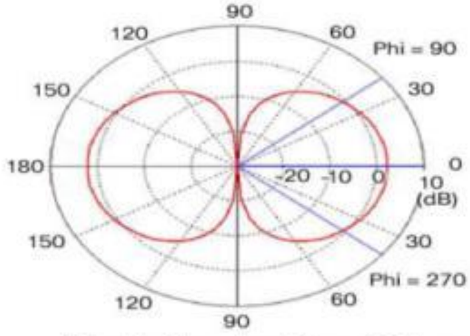
Dipole Antenna Model



Dipole 3D Radiation Pattern



Dipole Azimuth Plane Pattern

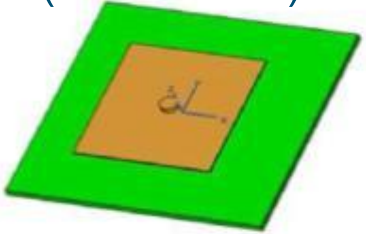


Dipole Elevation Plane Pattern

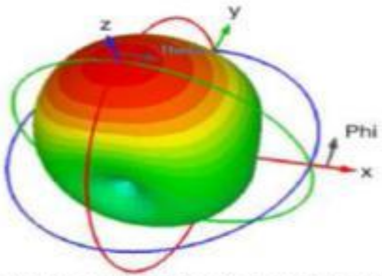
Low gain dipoles radiate everywhere think “light bulb”

Understanding Antenna Patterns

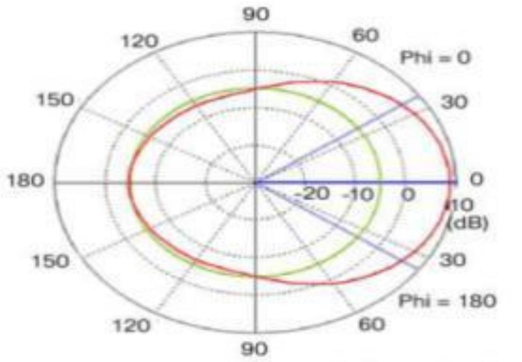
Patch (Directional)



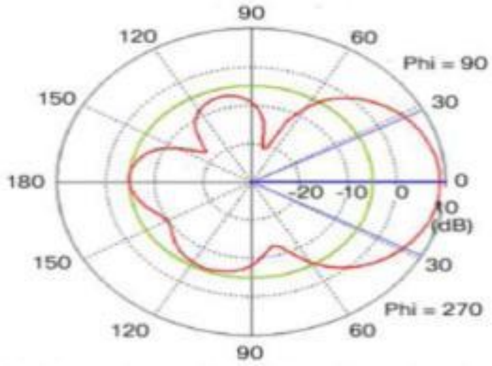
Patch Antenna Model



Patch Antenna 3D Radiation Pattern



Patch Antenna Azimuth Plane Patter

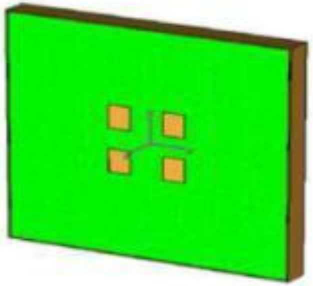


Patch Antenna Elevation Plane Pattern

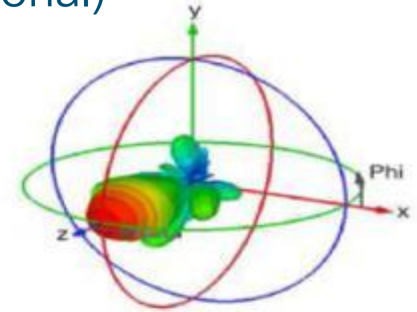
A low gain Patch Antenna

Understanding Antenna Patterns

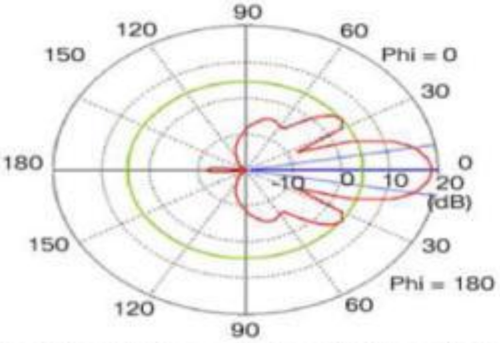
Patch (Higher Gain Directional)



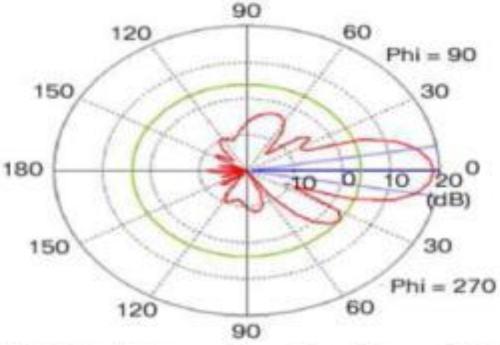
4x4 Patch Array Antenna



4x4 Patch Array 3D Radiation Pattern



4x4 Patch Array Azimuth Plane Pattern

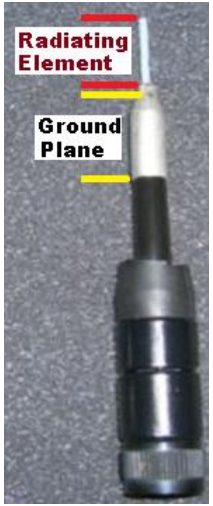


4x4 Patch Array Elevation Plane Pattern

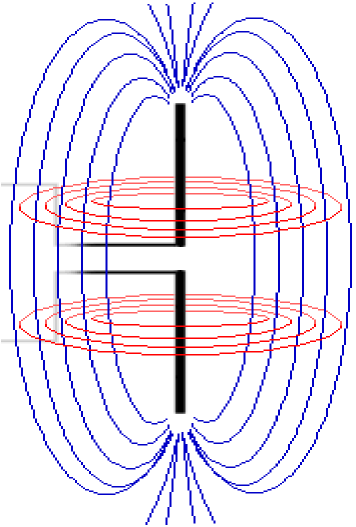
A High Gain Four Element Patch Array

Specialty antennas

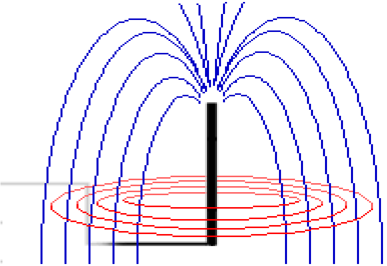
Antenna Theory (Dipole & Monopole)



Dipole



Monopole



A Monopole requires a (conductive surface) end fed / ground plane

A dipole does not require a ground plane as the bottom half <u>is the ground</u>

Produces a more uniform antenna pattern

808 Ft Broadcast Monopole
WSM 650 AM (erected in 1932)
Nashville Tennessee – Grand Ole Opry

Antenna Theory (Dipole & Monopole)

Monopoles were added to our antenna line primarily for aesthetics

Monopoles are smaller and require a metal surface to properly radiate

Specialty antennas for Auditoriums & Large venues

AIR-ANT2566P4W-R=

110x70
General-use patch antenna

AIR-ANT2566D4M-R=

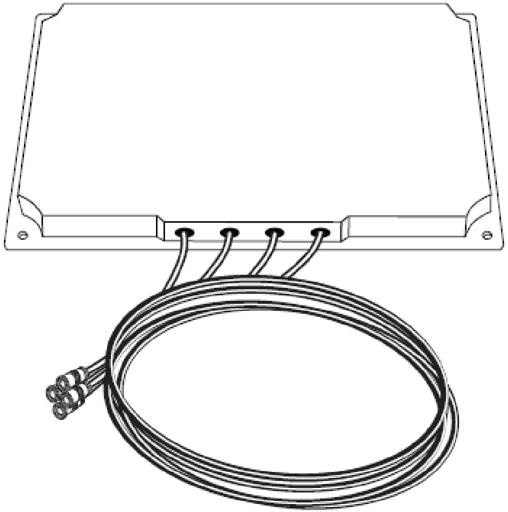
65x65
Medium ceilings/ auditoriums

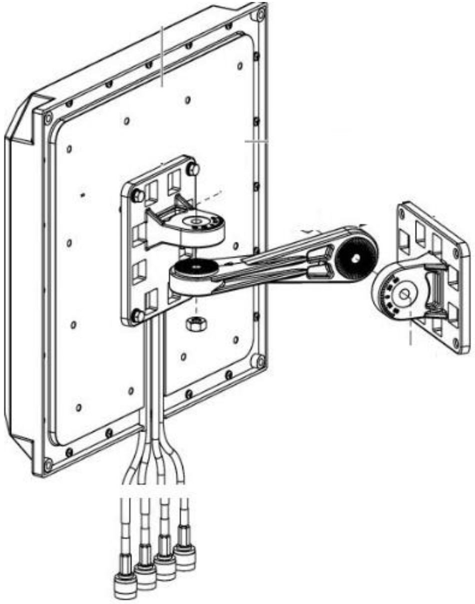
AIR-ANT2513P4M-N=

30x30
High ceiling's/ Stadiums

Specialty antennas for Auditoriums & Large venues

General-use 6dBi
Hallways – aisles
110 X 55 Azimuth/Elev
AIR-ANT2566P4W-R=



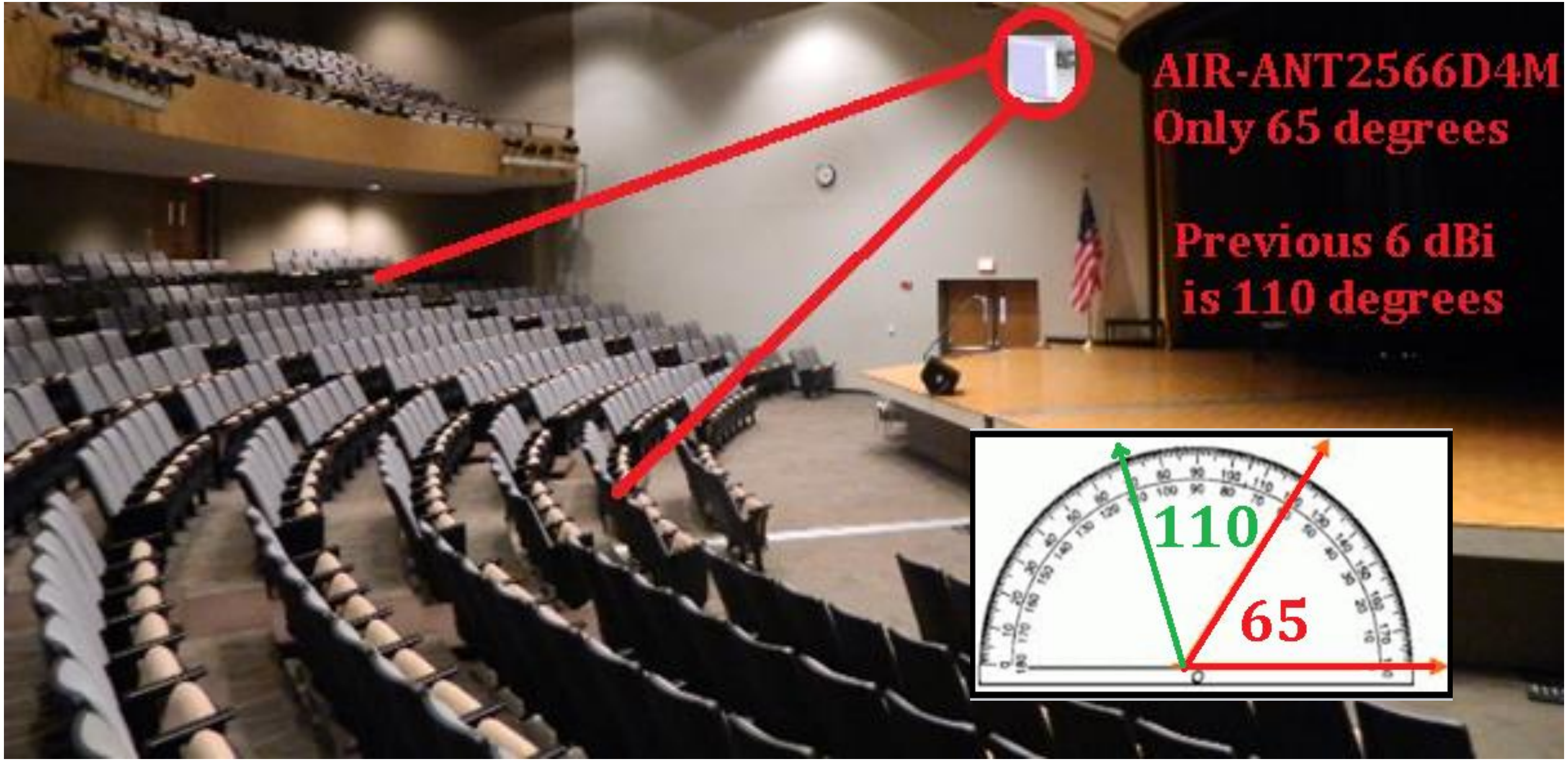


Medium ceilings 6dBi
Factories / auditoriums
65 x 65 Azimuth/Elev
AIR-ANT2566D4M-R=

High ceilings 13dBi
Stadium usage
30 x 30 Azimuth/Elev
AIR-ANT2513P4M-N=

Use case – Solving the requirement for smaller footprint

Previous AIR-ANT2566P4W was too wide for some applications @ 110 degrees



Access Point Placements

Isolation things you should know

Access Point Ceiling Placements

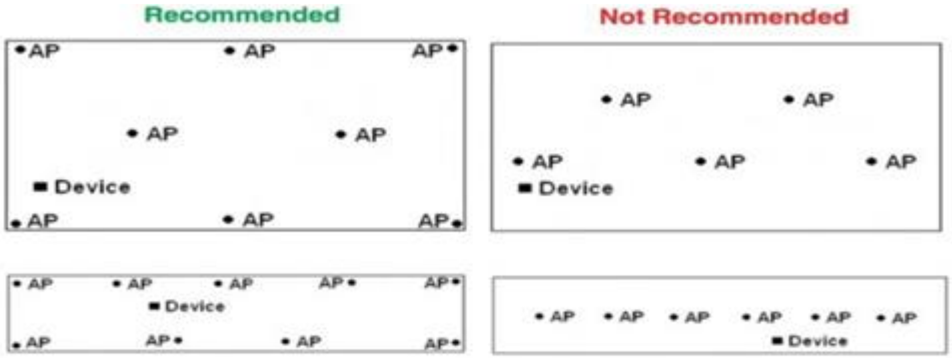
Deployment guides available for Hyperlocation, High Density, BLE etc.

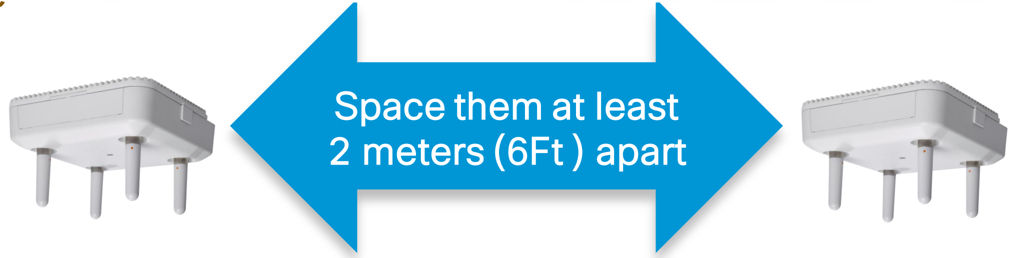
There is no ONE WAY – Access Point Placement DEPENDS…

- High Density differs from conventional 1 per sq X
- Hyperlocation & Wayfinding requires placement on a MAP
- Indoor Mesh is different requires less APs
- IoT and voice may have different requirements

Assess for the PRIMARY Purpose of the WLAN

Example of a Hyperlocation AP layout

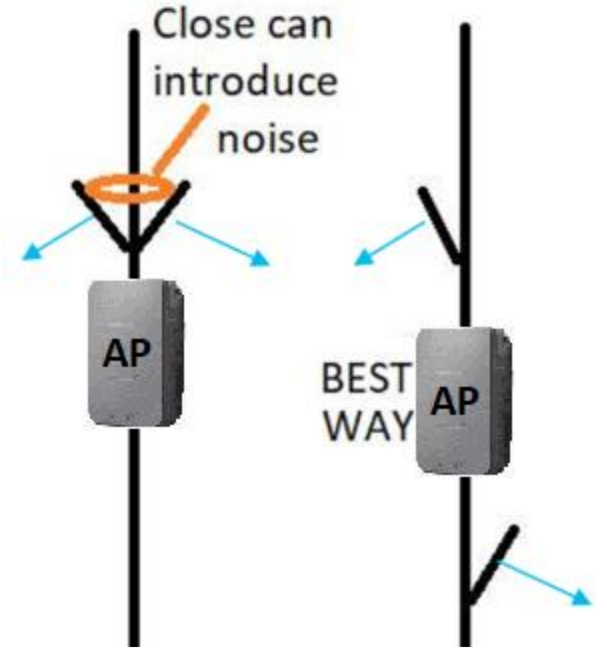


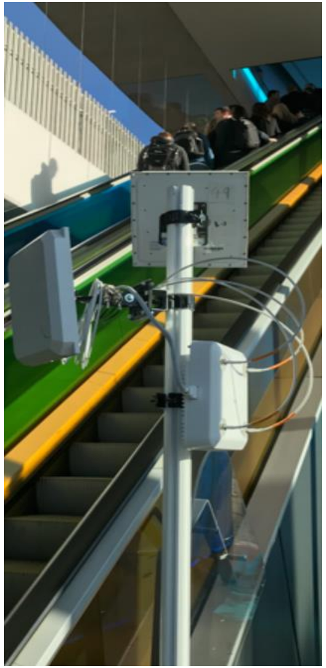


Co-Locating antennas and creating RF Isolation

You get isolation via several methods…

- Physical separation of the antennas
- Height separation of the antennas
- Antenna polarity separation
- Use of directional antennas so energy is focused away from each other
- Use of LOWER transmit power
- Use of frequencies that are further apart





The best way isn't always possible
That doesn't mean it won't work ☺

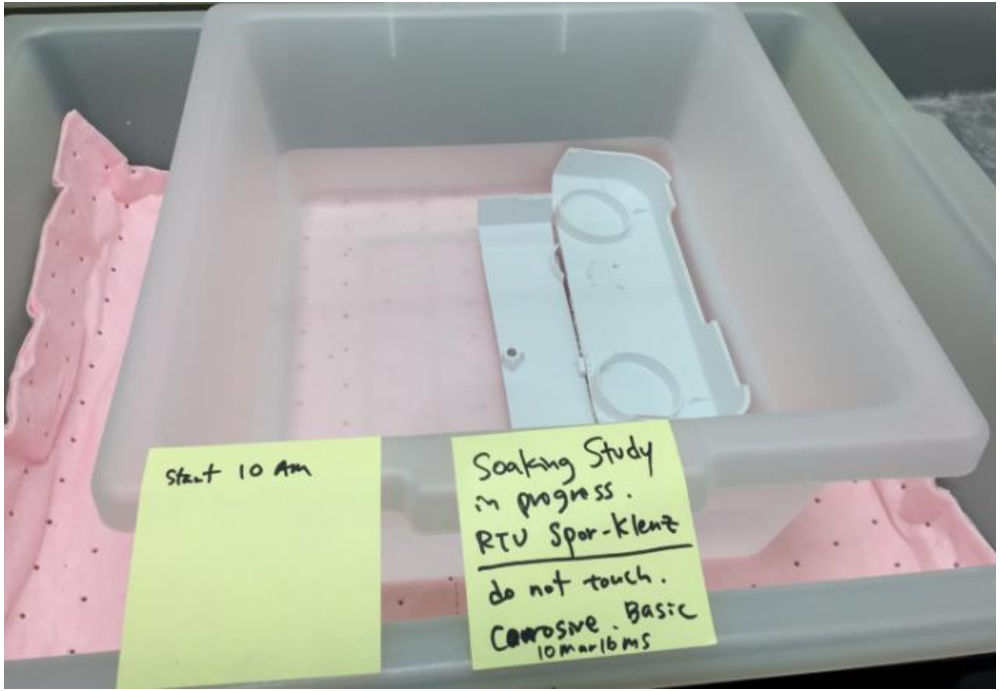
Antenna Placement Considerations

- AP antennas need placements that are away from reflective surfaces for best performance
- Avoid metal support beams, lighting and other obstructions.
- When possible or practical to do so, always mount the Access Point (or remote antennas) as close to the actual users as you reasonably can
- Avoid the temptation to hide the Access Point in crawl spaces or areas that compromise the ability to radiate well
- Think of the Access Point as you would a light or sound source, would you really put a light there or a speaker there?

Never mount antennas near metal objects as it causes increased multipath and directionality

Placements Healthcare Deployments

Access Points in infection control areas can be wiped down with SPOR-



AP2800/3800/4800 has a new plastic Lexan 945 – for better use in high temperatures and hospital clean room areas

Note: 2700/3700 use Cycloy C2800

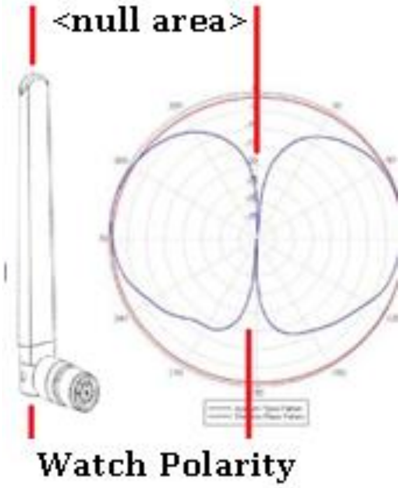
A look at some installations that went wrong

Installations that Went Wrong

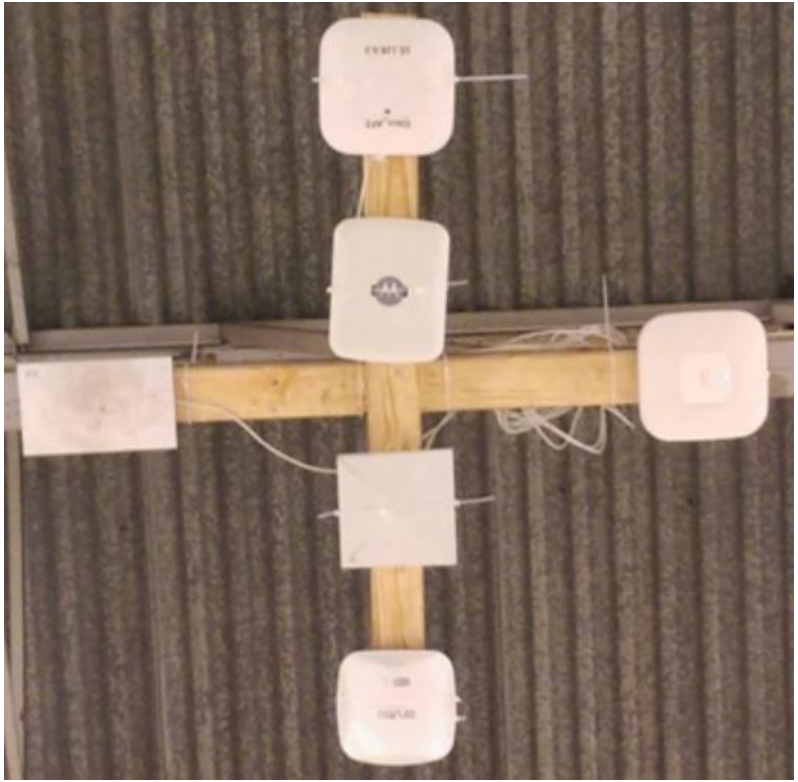
NEVER EVER MIX ANTENNA TYPES

Antennas should always cover the same RF cell

Watch dipole orientation

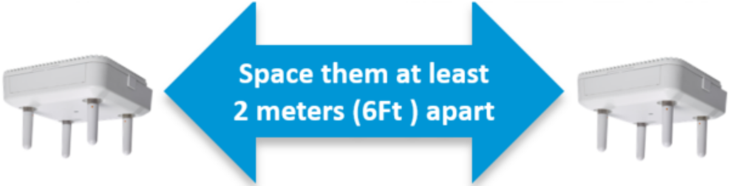


How close can you put them...



Sometimes its just for testing

Sometimes its actually deployed this way – you never know



Installations that Went Wrong

Patch antenna shooting across a metal fence
Multipath distortion causing severe retries

Mount the box horizontal and extend the antennas down and not right up against the metal enclosure

Above ceiling installs that went wrong

Yes it happens - When it does it is expensive to fix and no one is happy

Dipole antennas up against a metal box and large metal pipes. This creates unwanted directionality and multipath distortion – This also creates nulls (dead areas) and creates packet retries

When a dipole is mounted against a metal object you lose all Omni-directional properties.

It is now essentially a directional patch suffering from acute multipath distortion problems.

Add to that the metal pipes and it is a wonder it works at all

Tip: Access Points like the bldg. lights should be in the clear and as near to the users as possible

Above Ceiling Installs that Went Wrong

You Mean it Gets Worse?

Other Installations that Went Wrong

Ceiling mount AP mounted on the wall up against metal pipe (poor coverage)

Outdoor NEMA box not weatherized (just keeping the packets on ice)

Installations that Went Wrong – Really???

RF works poorly through metal or plastic coated metal cages

Installations that Went Wrong - Mesh

GOOD INSTALL

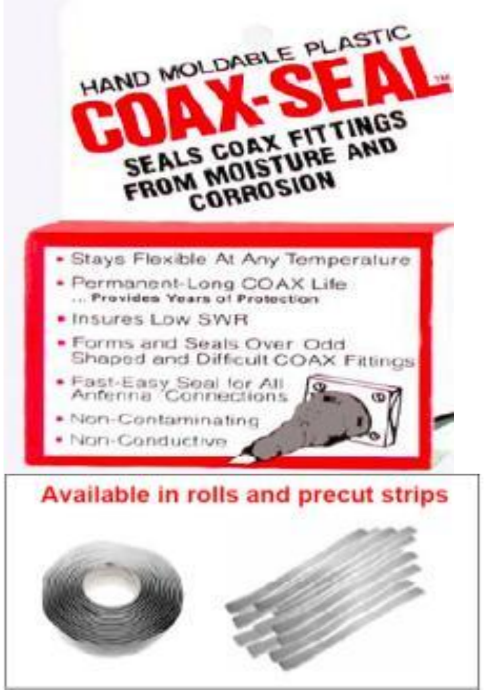
BAD INSTALLS

Installations that Went Wrong - Mesh

Installations that Went Wrong - Mesh

Building aesthetics matters – Antennas obstructed

Outdoor Weatherproofing



www.coaxseal.com

Coax-Seal can be used with or without electrical tape.

Taping first with a quality electrical tape like Scotch 33+ vinyl allows the connection to be taken apart easier.

Many people tape then use Coax-Seal then tape again this allows easy removal with a razor blade.

Note: Always tape from the bottom up so water runs over the folds in the tape. Avoid using RTV silicone or other caustic material.

Summary

- Cisco provides well engineered Access Points, Antennas, and Radio Resource Management features in the controllers
- However, you need to understand the general concepts of Radio, otherwise, it is very easy to end up implementing a network in a sub-optimal way – Whenever possible; verify coverage and mount the APs as close to the users as practical / possible

"RF Matters"

Important "Best Practices" for 802.11ac Wave 1 or 2

- ✓ 5.0 GHz Gigabit WLAN to leverage more and cleaner channels / spectrum
- ✓ -65 to -67 RSSI to solve for Data, Voice, Video, Location, & High Density
- ✓ 10 - 20% cell overlap to optimize roaming and location calculations / transactions
- ✓ Separate SSIDs for Corporate and Guest Access with Guest being Rate Limited

Wi-Fi Signal Strength - RSSI

- -65 to - 67 = Data, Voice, Video, Location, High Density
  - 1 Access Point per 2,500 square feet / every 50 feet
- -68 to - 69 = Data, Voice, Multicast & Unicast Video, Location
- -70 to - 71 = Data, Unicast Video
- -72 or greater = Data Only

802.11ac Wave 1

- 40 MHz channel width – 1 cable for GE

802.11ac Wave 2

- 80 MHz channel width – 2 cables for GE
- 80 MHz channel width – 1 cable for mGig

Cable Category

- Category 5E or better for GE or mGig

Best Practices Summary

Make it Easy **Make it work**

For Your Reference

BEST PRACTICES (AireOS)

INFRASTRUCTURE

- Enable High Availability (AP and Client SSO)
- Enable AP Failover Priority
- Enable AP Multicast Mode
- Enable Multicast VLAN
- Enable Pre-image download
- Enable AVC
- Enable NetFlow
- Enable Local Profiling (DHCP and HTTP)
- Enable NTP
- Modify the AP Re-transmit Parameters
- Enable FastSSID change
- Enable Per-user BW contracts
- Enable Multicast Mobility
- Enable Client Load balancing
- Disable Aironet IE
- FlexConnect Groups and Smart AP Upgrade

MESH

- Set Bridge Group Name
- Set Preferred Parent
- Multiple Root APs in each BGN
- Set Backhaul rate to "Auto"
- Set Backhaul Channel Width to 40/80 MHz
- Backhaul Link SNR > 25 dBm
- Avoid DFS channels for Backhaul
- External RADIUS server for Mesh MAC Authentication
- Enable IDS
- Enable EAP Mesh Security Mode

SECURITY

- Enable 802.1x and WPA/WPA2 on WLAN
- Enable 802.1x authentication for AP
- Change advance EAP timers
- Enable SSH and disable telnet
- Disable Management Over Wireless
- Disable WiFi Direct
- Peer-to-peer blocking
- Secure Web Access (HTTPS)
- Enable User Policies
- Enable Client exclusion policies
- Enable rogue policies and Rogue Detection RSSI
- Strong password Policies
- Enable IDS
- BYOD Timers

WIRELESS / RF

- Disable 802.11b data rates
- Restrict number of WLAN below 4
- Enable channel bonding – 40 or 80 MHz
- Enable BandSelect
- Use RF Profiles and AP Groups
- Enable RRM (DCA & TPC) to be auto
- Enable Auto-RF group leader selection
- Enable Cisco CleanAir and EDRRM
- Enable Noise &Rogue Monitoring on all channels
- Enable DFS channels
- Avoid Cisco AP Load

http://www.cisco.com/c/en/us/td/docs/wireless/technology/wlc/82463-wlc-config-best-practice.html

Recommended Reading

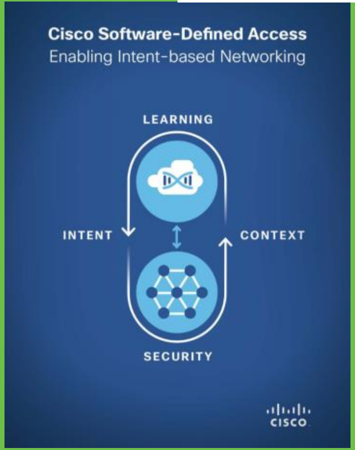
Cisco Enterprise Wireless Book & 4800 Deployment Guide

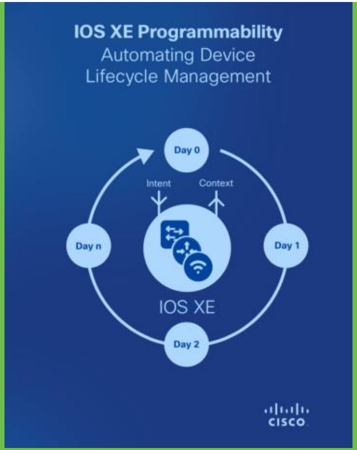
http://cs.co/wirelessbook

http://cs.co/9000Dcum8

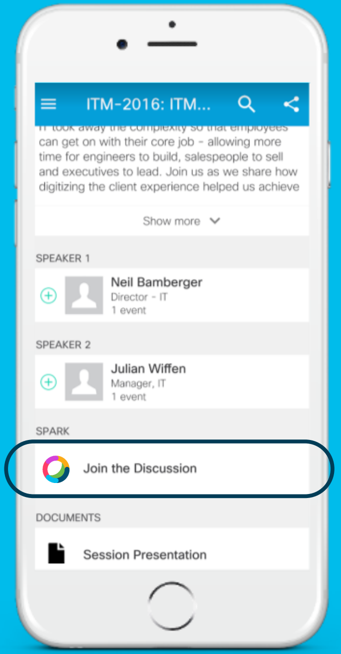
EN Booksprints

http://cs.co/cat9000book
http://cs.co/sdabook
http://cs.co/programmabilitybook
http://cs.co/wirelessbook
http://cs.co/assurancebook





Cisco Webex Teams



cs.co/ciscolivebot#BRKEWN-2017

Questions?

Use Cisco Webex Teams (formerly Cisco Spark) to chat with the speaker after the session

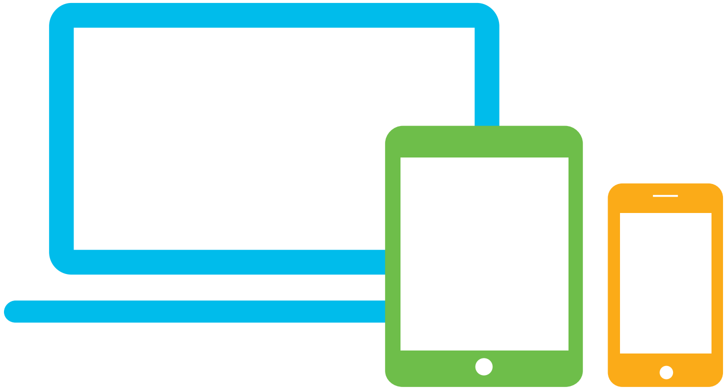
How

1. Find this session in the Cisco Events Mobile App
2. Click “Join the Discussion”
3. Install Webex Teams or go directly to the team space
4. Enter messages/questions in the team space

Complete your online session survey

- Please complete your Online Session Survey after each session
- Complete 4 Session Surveys & the Overall Conference Survey (available from Thursday) to receive your Cisco Live T-shirt
- All surveys can be completed via the Cisco Events Mobile App or the Communication Stations

Don't forget: Cisco Live sessions will be available for viewing on demand after the event at ciscolive.cisco.com



Continue Your Education

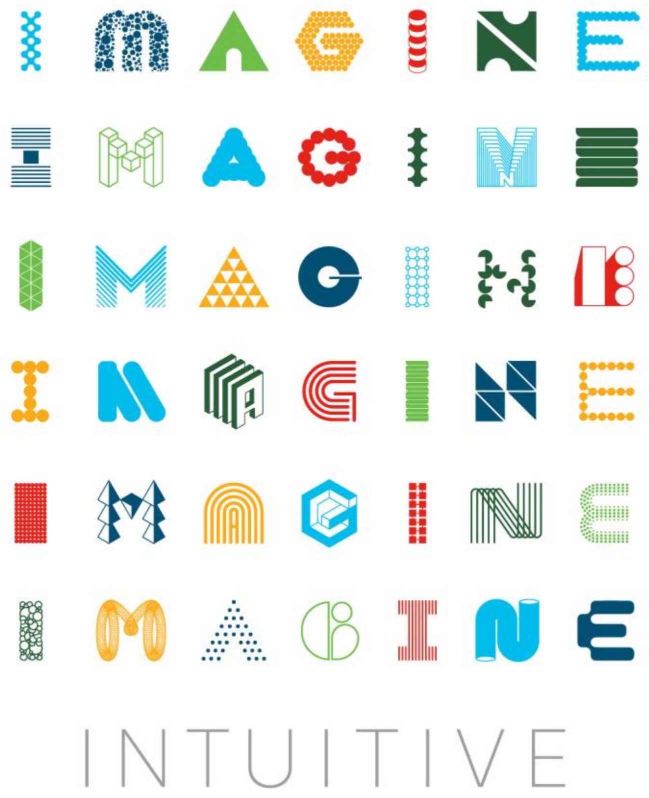
Demos in the Cisco Showcase

Walk-in self-paced labs

Meet the engineer 1:1 meetings

Related sessions

Thank you



IMAGINE

INTUITIVE

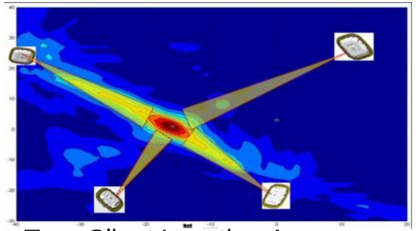
Reference Material & Things worth knowing

Deeper Dive into 4800 Understanding Micro/Macro Cells

Best in Class Wave-2 AP "or" Best in Class Location Based Services AP?

Customers had to choose which technology to deploy or perhaps deploy an

< OR >



True Client Location Accuracy

AP-2800 or AP-3800 Wave-2

- 802.11ac Wave 2: High-Performance 5Gbps.
- 2.4, 5GHz or Dual 5GHz.
- 4x4:3SS 160MHz.
- MU-MIMO
- 2 GE or 1 GE + 1 mGig (5G)
- Flexible Radio Architecture
- Dual 5 GHz
- Cisco DNA Sensor, Spectrum Intelligence and more...

AP-3600 or AP-3700 With Hyperlocation module

- Analytics, Asset tracking, Proximity Marketing
- Navigation and Wayfinding "true blue dot" experience
- 1 to 3 meter location accuracy (Wi-Fi Clients)
- BLE Beacon – Five centrally managed Beacons
- FastLocate – Frequent location updates (Wi-Fi Clients)
- Spectrum Intelligent Monitoring Radio and more...

Next-Generation Wave 2 802.11ac Access Point

New

Cisco Aironet® 4800

- Industry leading 4x4 MIMO:3 spatial streams (SS) Wave 2 802.11ac access points
- Tri-radio, 802.11ac Wave 2, 160 MHz
- **Built-in BLE Radio**
- Combined Data Rate of 5.2Gbps
- 2 x 5 GHz: 4x4: 3SS supporting
  - SU-MIMO / MU-MIMO
  - Flexible Radio Assignment: 2.4GHz, Dual-5GHz, Wireless Security Monitoring, and Cisco DNA-C Assurance
- 1 x 2.4GHz/5GHz for Cisco DNA Analytics, Wireless Security monitoring, and Hyperlocation
- Gigabit Ethernet and multi-Gigabit Ethernet (1G, 2.5G, 5G)
- Built-in Hyperlocation Antenna Array 16-elements <3m Accuracy (median)
- **HDX Technology**
- USB 2.0
- Analytics-enabled, Cisco DNA Ready

Redefining Analytics and Location

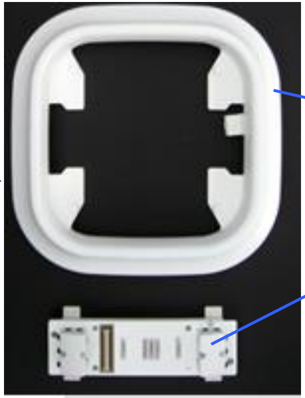
Combining Proven Technologies

Hyperlocation + AP-3800i + Additional Analytics Radio = AP-4800

Hyperlocation Components

Cisco 16 element Antenna Array
1-3m Accuracy

Hyperlocation Module



AP-4800 Integrated Solution

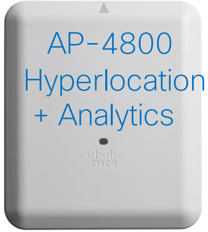
AP-3800
Dual 5GHz

Proven Hyperlocation + 3800 Technology <u>in one AP & 1 cable drop</u>

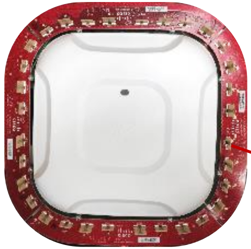
Improved Capability
- 802.11acW2
- WiFi & BLE AoA
- Time Based solutions
- + All the core features of the AP-3800

12x12"

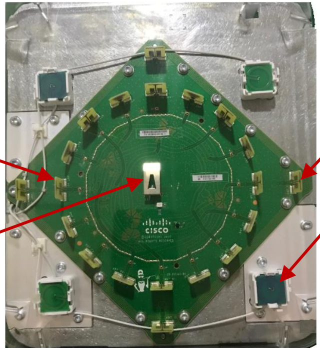
40% smaller



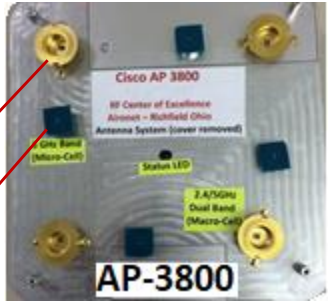
9.9x8.7"



Hyperlocation Components



Inside AP-4800
Dual 5GHz XOR + another analytics Hyperlocation XOR radio

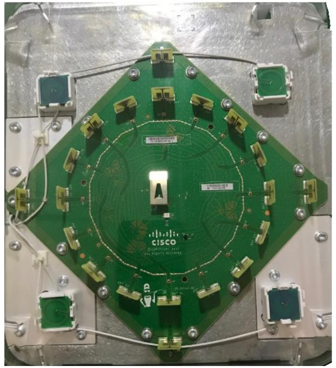


Antenna components

AP-4800 is a more advanced AP than the AP-3800

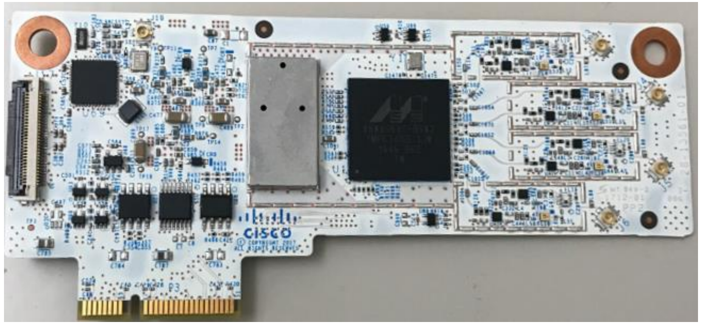
Similar to the AP-3800i but it has an additional Flexible Radio for Analytics + Advanced Hyperlocation antenna array

- Location Array antenna is now integrated
- Bluetooth Low Energy radio is now integrated
- Embedded analytics/location radio is now integrated



Hyperlocation antenna array

+



Cisco DNA Analytics, Monitoring and Location Radio

=

AP-4800
Best in Class

AP-4800 Overview

AP-4800 is the next evolution of Cisco's Wave-2 Access Point, redefining RF Excellence

- In addition to all the features supported by the AP-3800i the new AP-4800 contains the following new components:
  - Built-in Hyperlocation antenna Array, 16 Element Antenna Array for Hyperlocation, and packet monitoring
  - Analytics Capabilities providing event driven real-time data captures. This provides Real-time visibility into Cisco DNAC and potential 3rd party analytics
  - 3rd Flexible (receive only radio), specifically for Analytics, Hyperlocation, Wireless Security Monitoring, and future functionality using the programmable digital antenna array.
  - Built-in BLE Radio capable of BLE TX/RX. This is similar to the BLE radio in the WSM module for the AP3700
  - Hyperlocation AoA technology, Location accuracy on Wi-Fi similar to the AP3700 + HL module
  - Full Flexible Radio Assignment Operating modes, such as Dual-5GHz while performing Hyperlocation
  - Note: Module port on AP3800 is not available on the AP-4800 (it is used internally for the Analytics Radio)
- Code version supported below, will be introduced with a special version of 8.7

WLC	Cisco Prime	CMX	Cisco DNA	ISE	SDA Mode	ME Mode
8.7 Special	3.4	10.5	1.2	2.3 / 2.4	8.8	8.8

So why did we design the AP4800?

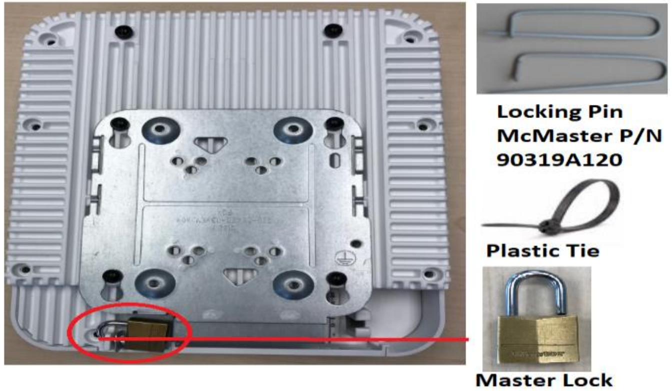
- Allows for High Density deployments solving the problem of over 2.4 GHz coverage.
- Using a Flexible Radio design gives you the choice of either 2.4/5GHz or Dual 5 GHz. Using Flexible Radio Assignment (FRA) this can happen dynamically (predefined conditions) or user assigned into a static state.
- Enhanced 160 MHz capability, MU-MIMO support etc.
- Has Hyperlocation (precise location mapping of clients) 1-3 Meters
- Has a Cisco DNA Analytics Radio for location and Cisco Intelligent Capture for troubleshooting and packet capture w/Client location and CleanAir SI

AP4800 mounted on the ceiling

AP4800	AP3800i
Length 9.9”(251.46mm)	Length 8.66” (219.96mm)
Width 8.68 (220.47mm)	Width 8.68” (220.47mm)
Thickness 2.87” (72.9mm)	Thickness 2.46” (62.48mm)
Weight 5.6 lbs (2.54 kilograms)	Weight 4.6 lbs (2.09 kilograms)

Note: Ceiling gridwork will hold 25 lbs without support wire AP = 5.6 lbs

Third party solutions & backside of AP-4800



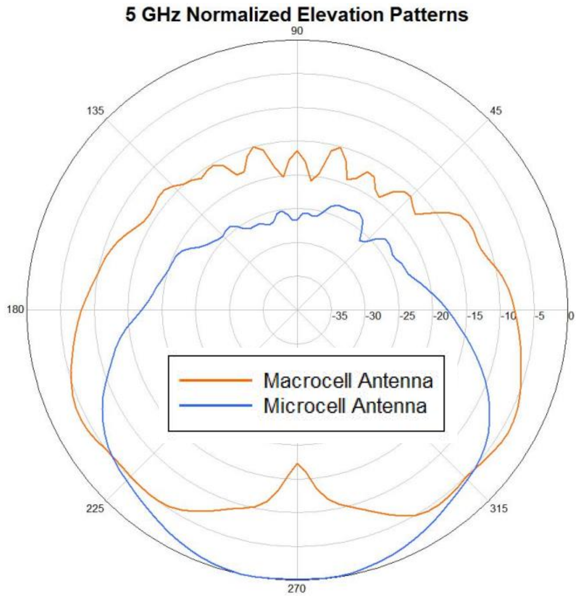
3rd Party in-tile mounts, Plastic skins to change AP color etc. can improve some installs - see AP-4800 deployment guide for more

http://cs.co/9000Dcum8

Macro/Micro Dual 5 GHz Cell

Instant Capacity

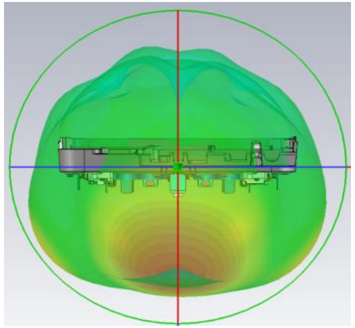
- Dual 5 GHz Macro/Micro increases efficiency
- Two 5 GHz radios address capacity – creating Macro/Micro cells increasing usable "air time"
- Conference centers and other venues can double capacity using their existing cable plan
- Using external 2800/3800 any combination of Macro/Micro or Omni & directional combinations are supported – Like 2 AP's in one housing.
- mGiG leverages throughput investment
- RF isolation happens with polarity/frequency/PWR diversity (smart antenna designs)



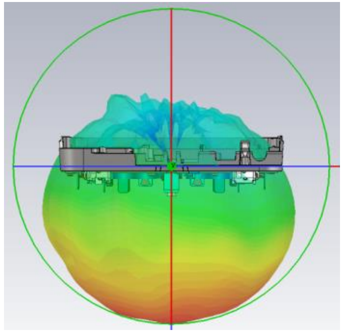
AP Internal antenna patterns 2800/3800

AP-4800 Antenna System Overview

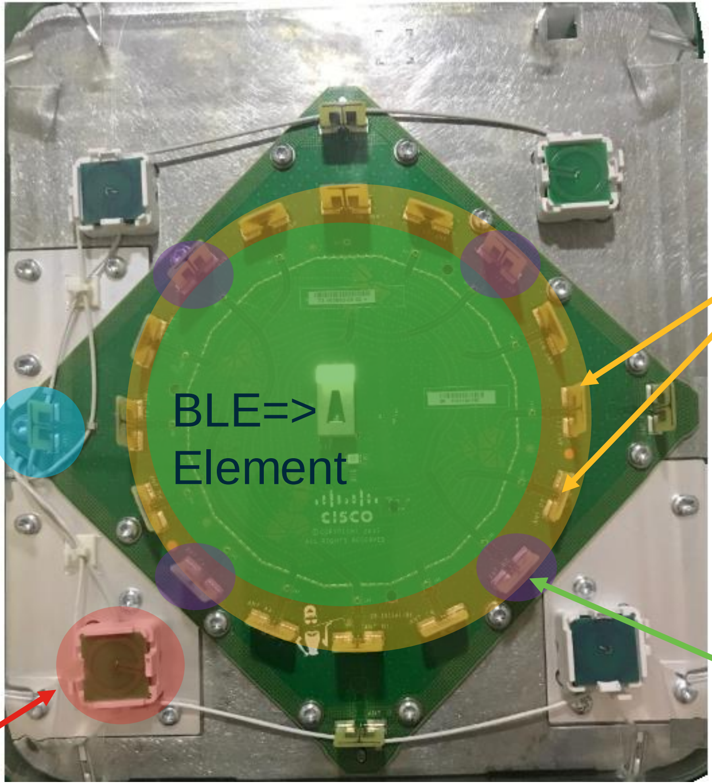
Most Advanced co-existent Antenna System (25 Elements) in a Single



(4) 2.4/5GHz Macro
Antenna Elements

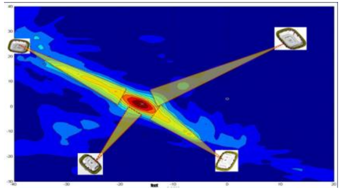


(4) 5GHz Micro Cell
Antenna Elements



Total Antenna Elements = 25

(16) Element Directional Antenna Array
(Digitally Switched)
for Location tracking

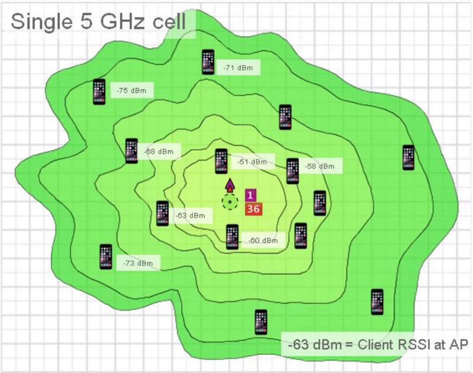


(4) Omni-Directional Elements
(Digitally Switched)
for 24x7 Monitoring &
Analytics / Cisco DNA Assurance

Why Dual 5 GHz in the AP-4800 Matters

Flexible radio (AP-3800) won Cisco's 2017 Pioneer Award for RF Innovation – and why it is in the 4800

AP2800/3800/4800 has Dual 5 GHz- A dual 5 GHz AP creating micro/macro cells with the ability to beamform (using Client-Link) will significantly enhance all 802.11a,g,n, & .11ac Wave-1 Clients.
Note: Standards Based Beamforming only works with .11w2 and .11ax



Single 5 GHz Channel

Single channel 36 utilization at 60%
(clients far away take longer airtime)

Take-away:
Using Dual 5 GHz
Means Equal Client Airtime
Faster overall data-rates &
less channel utilization

Dual 5 GHz Channels

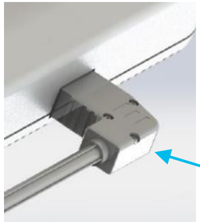
Using Micro/Macro (Dual 5 GHz)
Channel 36 @ 20% channel utilization
Channel 108 @ 24% channel utilization.

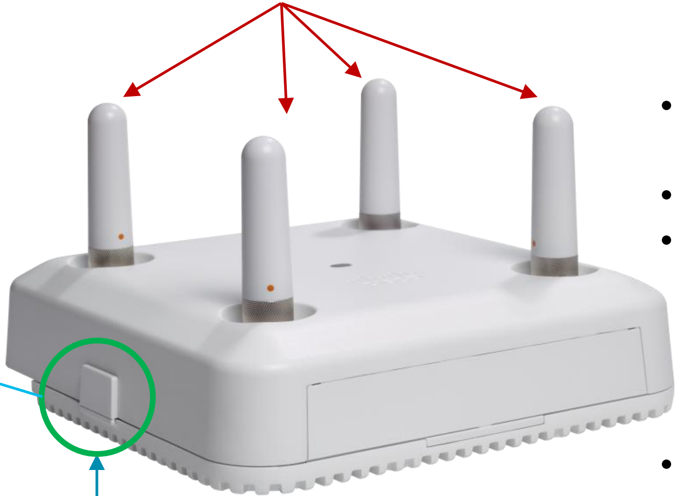
APeX Access Point Module Development

AP-3800 overview and a program to encourage 3rd party development via module for the AP-3800 “Internet of things” creating an AP ecosystem

Smart Antenna Connector – 2800e / 3800e

Primary Antenna Connectors – Dipole and Cabled Antennas



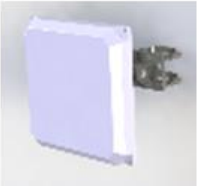


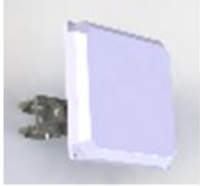
Smart Antenna Connector

Second Cabled or Location Antenna*

- Cisco designed intelligent antenna connector
- Sleek design
- Allows a second cabled antenna to be connected to the Access Point
  - Dual 5 GHz
  - Band specific antennas
  - Location antennas*
- Antenna versatility for challenging coverage deployments - High Density locations, auditorium classrooms, stadiums, arenas, convention centers…

Dual 5 GHz “E” model Macro-Macro cells or Micro-Micro cells or any combination

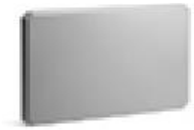




Stadium antenna deployments for different coverage areas or higher density areas

ANT-2566 in different directions or even back-to-back tilted downward for Factory and warehouse deployments

Cable allows for secondary 5 GHz radio antenna to be physically spaced away from the primary radio allowing for Macro-Macro operation



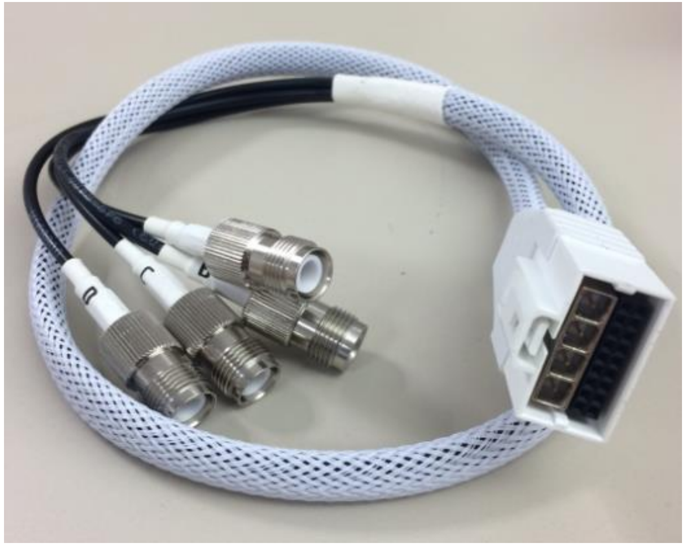
Omni + directional deployments

New Smart Antenna Connector "DART"

Allows for future "smart antennas" and single cable design for RF and digital*

*This permits all 4 antenna ports from the secondary 5 GHz radio to adapt to existing antennas and/or hyperlocation (selected models)

2800e and 3800e versions use a smart RF connector "DART" which carries digital signals as well as 4 RF connections from the secondary 5 GHz radio (smart antenna)



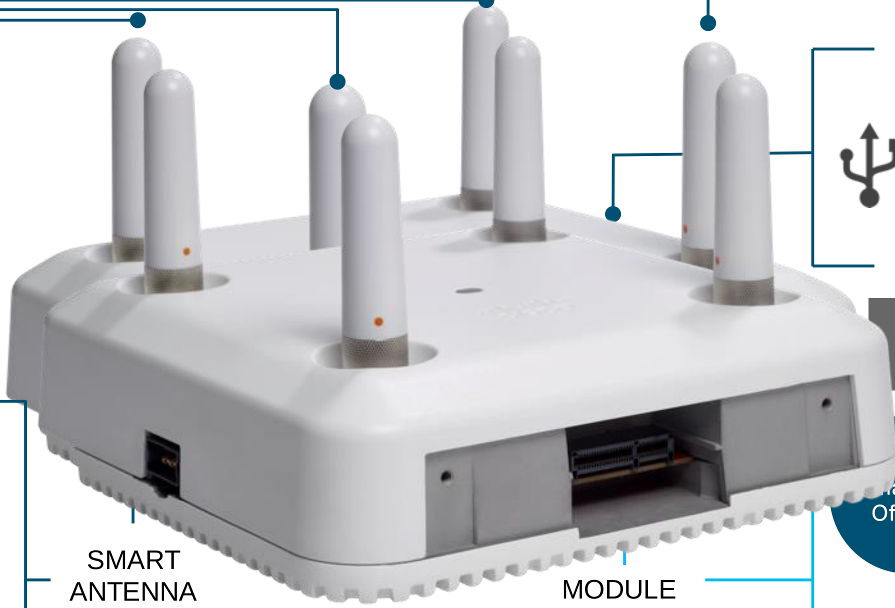
Cisco PID AIR-CAB002-DART-R

Adapter cable allows existing external antennas to be used with the secondary 5 GHz radio

Review of AP-3800i/e Port Functionality

Expandability and Investment Protection

PRIMARY ANTENNAS



Bluetooth Beacon

Other

Self-Discover / Self-Configure

Other

Panel Antenna

Directional Antennas

Antennas

SMART ANTENNA PORT

MODULE PORT

Potential Future Expandability

all Cell Offload

Bluetooth Beaconing

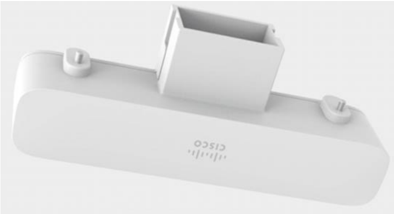
Other

Custom Application Using Linux

Future Wi-Fi Standard

Video Surveillance

AP-3800 with Developer Module



Design on the developer board then create custom modules – AP has filtering for cellular co-existence, can supply power etc.

Module SDK Supported through Devnet

http://Developer.cisco.com/site/devnet/overview

3 simple steps to becoming a DevNet member

Step 1	Step 2	Step 3
Create a Cisco ID › (if you don't already have one)	Log in to DevNet and create your account ›	Complete your profile (at any time) and earn points towards Cisco DevNet badges.

CISCO DEVNET

- ✔ Download APIs and SDKs
- ✔ Access fully-tooled sandboxes
- ✔ Set your profile to customize your notifications
- ✔ Use the Learning Labs
- ✔ Get answers on the community forums
- ✔ Receive loads of support

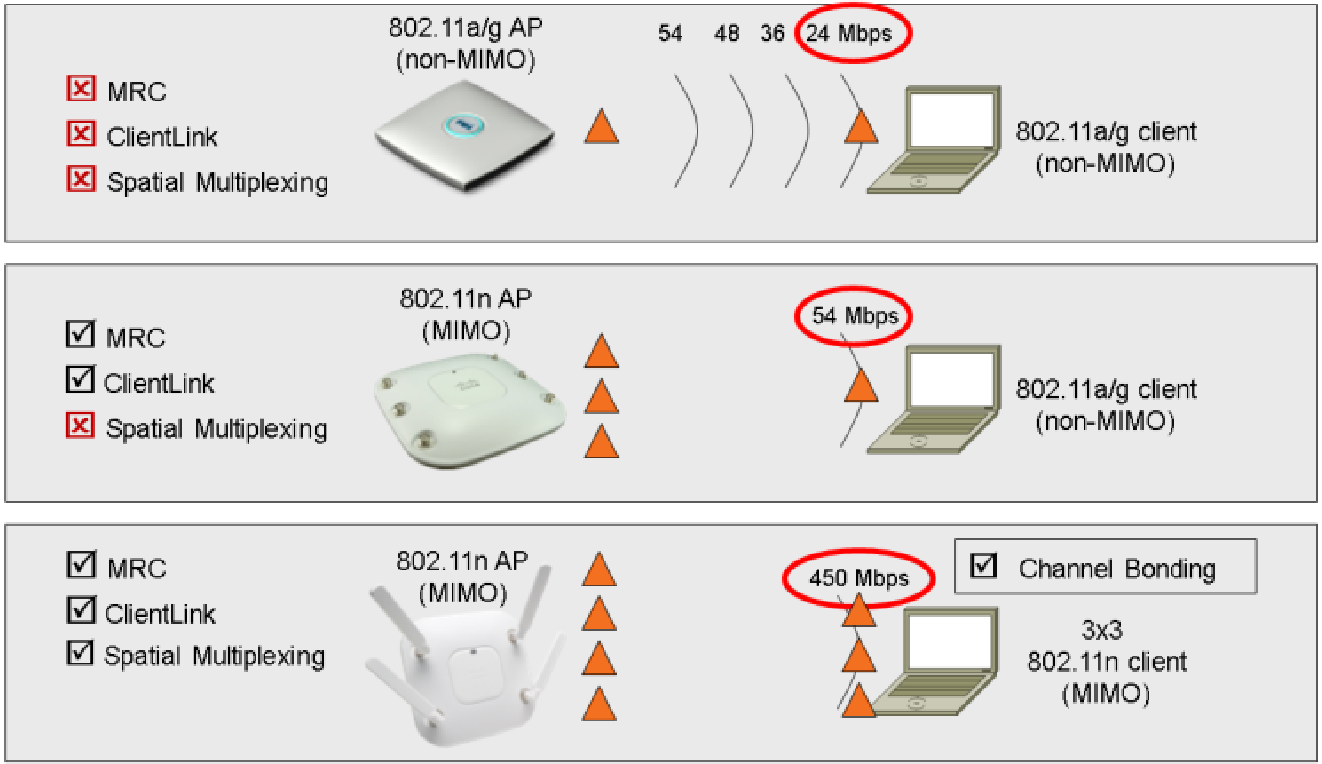
Understanding 802.11ac

Building upon the 802.11n foundation

Cisco live!

So to Recap: 802.11n Operation

Throughput Improves When All Things Come Together



Data Rates for 802.11n

(Lots of MCS rates based on modulation, streams, channel width and GI)

MCS	Coding	Modulation	Streams	Signal BW =20 MHz		40 MHz	
				GI = 800 nS	GI =400 nS	GI = 800 nS	GI =400 nS
MCS0	1/2	BPSK	1	6.5	7.2	13.5	15
MCS1	1/2	QPSK	1	13	14.4	27	30
MCS2	3/4	QPSK	1	19.5	21.7	40.5	45
MCS3	1/2	16-QAM	1	26	28.9	54	60
MCS4	3/4	16-QAM	1	39	43.3	81	90
MCS5	2/3	64-QAM	1	52	57.8	108	120
MCS6	3/4	64-QAM	1	58.5	65	131.5	135
MCS7	5/6	64-QAM	1	65	72.2	135	150
MCS8	1/2	BPSK	2	13	14.4	27	30
MCS9	1/2	QPSK	2	26	28.9	54	60
MCS10	3/4	QPSK	2	39	43.3	81	90
MCS11	1/2	16-QAM	2	52	57.8	108	120
MCS12	3/4	16-QAM	2	78	86.7	162	180
MCS13	2/3	64-QAM	2	104	115.6	216	240
MCS14	3/4	64-QAM	2	117	130	243	270
MCS15	5/6	64-QAM	2	130	144.4	270	300
MCS16	1/2	BPSK	3	19.5	21.7	40.5	45
MCS17	1/2	QPSK	3	39	43.3	81	90
MCS18	3/4	QPSK	3	58.5	65	121.5	135
MCS19	1/2	16-QAM	3	78	86.7	162	180
MCS20	3/4	16-QAM	3	117	130	243	270
MCS21	2/3	64-QAM	3	156	173.3	324	360
MCS22	3/4	64-QAM	3	175.5	195	364.5	405
MCS23	5/6	64-QAM	3	195	216.7	405	450

AP-700,1040,1140, 1250,1260,1600 & 3500 can support
Up to 2-Streams
300 Mbps using .11n rates

AP-2600,2700, 3600 & 3700 can support
Up to 3-Streams
450 Mbps using .11n rates

Upgrading Access Points 1:1 or another survey?

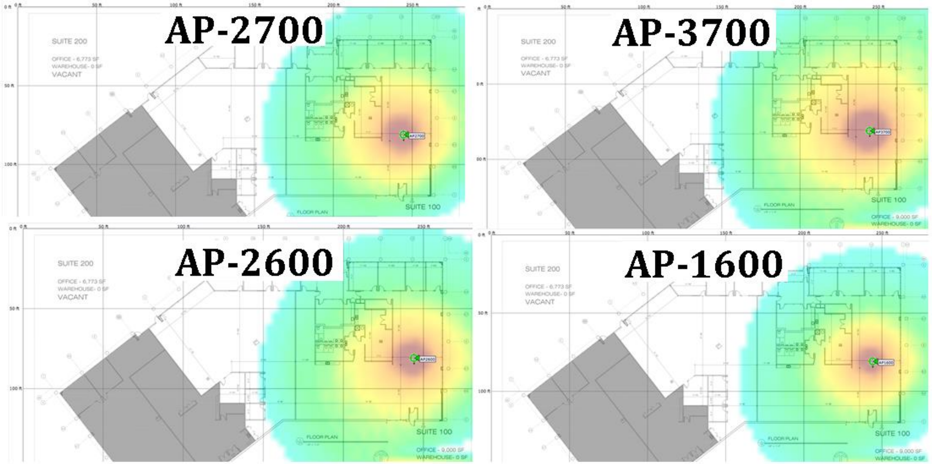
Question: If I replace my Access Points with a newer 802.11ac Access Point do I have to resurvey? Is the spacing the same between 11n and 11ac?

Answer: 11ac builds upon 11n, and cell sizes are similar. Years ago the guidelines were

1 per 5,000 Sq Feet for data only and 1 per 3,000 sq. feet for voice & location (US)

We now recommend 1 per 2,500 sq feet and no longer break it down by applications.

In Europe we now recommend 1 AP per 250 square meters



Access Points have always had similar heat maps – There will always be slight differences but the goal is to maintain uniform coverage with less retries

It is always a good idea to check and verify coverage.

Operating Mode Comparisons –

Identifying differences between each of the different standards

802.11n	802.11ac Wave 1	802.11ac Wave 2
2.4 and 5.0 GHz band	5.0 GHz band only	5.0 GHz band only
3X3 or 4X4 MIMO	3X3 or 4X4 MIMO	4X4 MIMO
Single User MIMO (one to one)	Single User MIMO (one to one)	Multi-User MIMO (one to many)
Fast Ethernet wired equivalent	Gigabit Wi-Fi wired equivalent	Multi-Gigabit Wi-Fi capable
Usually 20 MHz Channel Width	Usually 20 or 40 MHz Channel Width	Usually 40 or 80 MHz Channel Width (160 MHz can also be supported)
Single FE or GE uplink	Single GE uplink	Dual GE uplinks or mGig uplink
PoE (802.3af) for full operation	PoE+ (802.3at) for full 4X4 operation	PoE+ (802.3at) for full 4X4 operation
Support for AES128 Encryption	Support for AES128 Encryption	Support for AES256 Encryption

Elements of 802.11ac – Wave2

802.11ac (Wave-2) improvements over (Wave-1)

- **Ability to use 1, 2, 3 (and now 4) Spatial Streams**

  An extra Spatial Stream does give you a bump in data rate @ 80MHz 1733 vs.1300 Mbps

- **Same channel bonding 20, 40, 80 (now 160 MHz)**

  1st Generation Wave-2 "1K" Series AP only support 80 MHz

  2nd Generation Wave-2 "2K" & "3K" support 160 MHz

- **Standards Based TxBF now implemented in Wave2**

  Only 11ac Wave-2 clients participate in .11ac transmit beamforming

  All other .11a,g,n,ac clients still need ClientLink for performance

- **Multi-User MIMO (MU-MIMO) support**

  Happens in Wave-2 for 11ac Wave 2 clients only

  No benefit for 11a/b/g/n clients or Wave 1 Clients

Wave-2 is based on the IEEE 802.11ac final standard ratified December 2013

For more see this URL:

Wi Fi CERTIFIED www.wi-fi.org

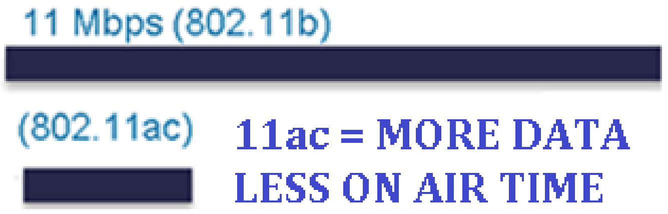
So what's driving .11ac?

The airwaves are a shared medium to improve performance, you need to be <u>spectrum efficient</u>
802.11ac is all about optimization to do that

GET OFF THE AIR
<u>STOP TALKING</u>

The goal is <u>faster throughput for everyone</u>
ability to support lots of Wi-Fi tablets, phones and laptops - <u>Moving data faster via these techniques:</u>

- **Spatial Streams – Sending data out of more than 1 antenna**
- **Channel Bonding – using more than 1 channel**
- **256 QAM - More complex modulation**
- **Guard interval – cutting down on symbol time**
- **MIMO – Multiple Input Multiple Output**
  Use of multiple radios at the same time Tx/Rx
- **MU-MIMO – Multi-User MIMO**
  Sending data to <u>MORE than one user at a time</u>



General thoughts – Why do I need 802.11ac?

Because it builds on 802.11n foundation adding faster throughput and performance

- **Need for more throughput – smart phones and tablets usually have only 1 radio**
- **Channel Bonding and more complex modulation (256-QAM) does more with only 1 radio**
- **Logical progression for significant performance from earlier technologies**
- **11b (11Mb), 11a/g (54Mb), 11n (600Mb), 11ac Wave1 (1300Mb), 11ac Wave-2 (2340Mb)**
- **Beam-forming implemented in 11ac Wave-2 but ClientLink needed for all other clients.**

802.11ac clients are emerging with laptops and tablets supporting 3 Spatial Streams and even smart phones supporting 1 & 2 spatial streams @ 80 MHz

(4-ss and/or 160 MHz is also possible)

Why is channel bonding .11n & 11ac so important?

Phones such as the HTC One & Samsung S4 have support for 802.11ac

MCS	Modulation	Ratio	20 MHz channel	40 MHz channel	80 MHz channe WAVE-1
			400 ns GI	400 ns GI	400 ns GI
0	BPSK	1/2	7.2	15	32.5
1	QPSK	1/2	14.4	30	65
2	QPSK	3/4	21.7	45	97.5
3	16-QAM	1/2	28.9	60	130
4	16-QAM	3/4	43.3	90	195
5	64-QAM	2/3	57.8	120	260
6	64-QAM	3/4	65	135	292.5
7	64-QAM	5/6	72.2	Max N rate 150	325
8	256-QAM	3/4	86.7	180	390
9	256-QAM	5/6	N/A	200	433.3

More than 1-SS requires the client have more radios which draws more power from the battery.

Most smart phones and some tablets will use 1-SS

More powerful tablets & laptops use 2 & 3-SS

The goal is to save physical size and battery life yet increase throughput

How else can you get to 433 Mbps with one radio?

Channel Bonding Wave-1 and Wave-2

For Your Reference

.11ac MCS Rates @ 1-spatial stream Wave 1 @ 80 MHz Wave-2 can support 160 MHz

MCS	Modulation	Ratio	20 MHz channel		40 MHz channel		80 MHz channel WAVE-1		160 MHz channel WAVE-2	
			800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
1	QPSK	1/2	13	14.4	27.	30	58.5	65	117	130
2	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
3	16-QAM	1/2	26	28.9	54	60	117	130	234	260
4	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
5	64-QAM	2/3	52	57.8	108	120	234	260	468	520
6	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
7	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
8	256-QAM	3/4	78	86.7	162	180	351	390	702	780
9	256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7

802.11ac Data Rates @ 1,2 & 3 Spatial Streams (Wave1)

802.11n was 450 Mbps at 40 MHz bonded @ 3-SS.

.11ac can achieve <u>nearly the same speed</u> @ 1-Spatial Stream

MCS	Modulation	Ratio	20 MHz channel	40 MHz channel	80 MHz channel WAVE-1
			400 ns GI	400 ns GI	400 ns GI
0	BPSK	1/2	7.2	15	32.5
1	QPSK	1/2	14.4	30	65
2	QPSK	3/4	21.7	45	97.5
3	16-QAM	1/2	28.9	60	130
4	16-QAM	3/4	43.3	90	195
5	64-QAM	2/3	57.8	120	260
6	64-QAM	3/4	65	135	292.5
7	64-QAM	5/6	72.2	150	325
8	256-QAM	3/4	86.7	180	390
9	256-QAM	5/6	N/A	200	433.3

802.11ac rates @ 1 Spatial Stream

802.11ac Data Rates

XX RATE NOT SUPPORTED

Spatial Streams	MCS Index	Modulation	Coding	Mb/s 20 MHz Guard Interval 800ns	20 MHz Guard Interval 400ns	40 MHz Guard Interval 800ns	40 MHz Guard Interval 400ns	80 MHz Guard Interval 800ns	80 MHz Guard Interval 400ns
2	0	BPSK	1/2	13	14.4	27	30	58.5	65
	1	QPSK	1/2	26	28.9	54	60	117	130
	2	QPSK	3/4	39	43.3	81	90	175.5	195
	3	16-QAM	1/2	52	57.8	108	120	234	260
	4	16-QAM	3/4	78	86.7	162	180	351	390
	5	64-QAM	2/3	104	115.6	216	240	468	520
	6	64-QAM	3/4	117	130	243	270	526.5	585
	7	64-QAM	5/6	130	144.4	270	300	585	650
	8	256-QAM	3/4	156	173.3	324	360	702	780
	9	256-QAM	5/6	XX	XX	360	400	780	866.7
3	0	BPSK	1/2	19.5	21.7	40.5	45	87.8	97.5
	1	QPSK	1/2	39	43.3	81	90	175.5	195
	2	QPSK	3/4	58.5	65	121.5	135	263.3	292.5
	3	16-QAM	1/2	78	86.7	162	180	351	390
	4	16-QAM	3/4	117	130	243	270	526.5	585
	5	64-QAM	2/3	156	173.3	324	360	702	780
	6	64-QAM	3/4	175.5	195	364.5	405	XX	XX
	7	64-QAM	5/6	195	216.7	405	450	877.5	975
	8	256-QAM	3/4	234	260	486	540	1053	1170
	9	256-QAM	5/6	260	288.9	540	600	1170	1300

Using Wave-2 & 4SS (Last "Eyechart")

For Your Reference

.11ac MCS rates (unlike 802.11n) don't exceed 0-9 -- but rather it is 0-9 and then you call out how many Spatial Streams

1 stream (80MHz) is 433 Mbps
2 stream (80MHz) is 866 Mbps
3 stream (80MHz) is 1300 Mbps
4 stream (80 MHz) is 1733 Mbps (Wave 2)
3 stream (160 MHz) is 2340 Mbps (Wave 2)

Note: While 4-SS appears attractive, it is very difficult to maintain a 4-SS link given you cannot beam-form a 4-SS signal given you only have 4 antennas

Beamforming requires N+1 antennas

802.11ac Data Rates

* RATE NOT SUPPORTED

				Mb/s							
				20 MHz		40 MHz		80 MHz		160 MHz	
				Guard Interval		Guard Interval		Guard Interval		Guard Interval	
Spatial Streams	MCS Index	Modulation	Coding	800ns	400ns	800ns	400ns	800ns	400ns	800ns	400ns
2	0	BPSK	1/2	13	14.4	27	30	58.5	65	117	130
	1	QPSK	1/2	26	28.9	54	60	117	130	234	260
	2	QPSK	3/4	39	43.3	81	90	175.5	195	351	390
	3	16-QAM	1/2	52	57.8	108	120	234	260	468	520
	4	16-QAM	3/4	78	86.7	162	180	351	390	702	780
	5	64-QAM	2/3	104	115.6	216	240	468	520	936	1040
	6	64-QAM	3/4	117	130	243	270	526.5	585	1053	1170
	7	64-QAM	5/6	130	144.4	270	300	585	650	1170	1300
	8	256-QAM	3/4	156	173.3	324	360	702	780	1404	1560
	9	256-QAM	5/6	*	*	360	400	780	866.7	1560	1733.3
3	0	BPSK	1/2	19.5	21.7	40.5	45	87.8	97.5	175.5	195
	1	QPSK	1/2	39	43.3	81	90	175.5	195	351	390
	2	QPSK	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
	3	16-QAM	1/2	78	86.7	162	180	351	390	702	780
	4	16-QAM	3/4	117	130	243	270	526.5	585	1053	1170
	5	64-QAM	2/3	156	173.3	324	360	702	780	1404	1560
	6	64-QAM	3/4	175.5	195	364.5	405	*	*	1579.5	1755
	7	64-QAM	5/6	195	216.7	405	450	877.5	975	1755	1950
	8	256-QAM	3/4	234	260	486	540	1053	1170	2106	2340
	9	256-QAM	5/6	260	288.9	540	600	1170	1300	*	*
4	0	BPSK	1/2	26	28.9	54	60	117	130		
	1	QPSK	1/2	52	57.8	108	120	234	260		
	2	QPSK	3/4	78	86.7	162	180	351	390		
	3	16-QAM	1/2	104	115.6	216	240	468	520		
	4	16-QAM	3/4	156	173.3	324	360	702	780		
	5	64-QAM	2/3	208	231.1	432	480	936	1040		
	6	64-QAM	3/4	234	260	486	540	1053	1170		
	7	64-QAM	5/6	260	288.9	540	600	1170	1300		
	8	256-QAM	3/4	312	346.7	648	720	1404	1560		
	9	256-QAM	5/6	*	*	720	800	1560	1733.3		

Not all Wave-2 products support 160 MHz

So how do these data rates apply in the real world?

Smartphones 210 Mbps*

1 stream (80MHz) is 433 Mbps

Tablets 460 Mbps*

2 stream (80MHz) is 866 Mbps

High End Laptops +680 Mbps*

3 stream (80MHz) is 1300 Mbps

Note: This is why GigE is fine for 802.11ac (Wave-1) Access Points – Wave-2 can exceed GigE

4SS	Desktops
3SS	Desktops / Laptops
2SS	Laptops / Tablets
1SS	Tablets / Smartphones

Wave-2 with 4 stream (80 MHz) is 1733 Mbps
No 4-ss mobility clients exist in the market today only PCIe (desktop clients))

Real throughput changes dynamically based on number of spatial streams, channel bonding MCS (radio data-rate) negotiated

The actual throughput is less than the MCS data-rate due to overhead

*Assumes 70% MAC efficiency and half duplex

Understanding Cisco Mid-Span Power Injectors

For Your Reference

AIR-PWRIN2 & 3 (pre-802.11n) APs

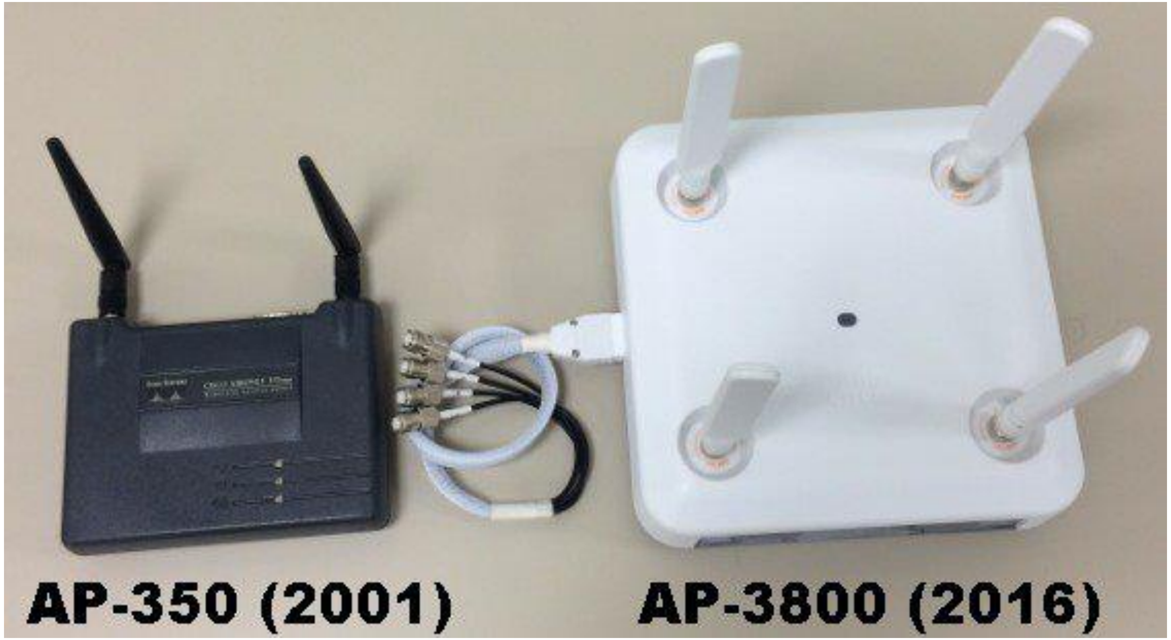
AIR-PWRIN4 802.3af (15.4W) and pre-standard (30W)
Designed for .11n and .11ac Wave1 indoor Enterprise APs

AIR-PWRIN5 802.3af (15.4W) low cost injector
Designed for Access Points that use 15W or less

AIR-PWRIN6 802.3af (15.4W) & 802.3at (30W) injector
Designed for all current Enterprise .11n, .11ac Wave1 and Wave 2

Note: AIR-PWRINJ6 is recommended for all newer Enterprise indoor Access Points (replaces earlier injectors) for most applications.

More powerful APs draw more PoE power



AP-350 had 1 radio and only utilized 6 Watts

AP-3800 has 12 Radios, mGig, powerful CPU, lots of RAM
Powers at 30W w/o module

AP-2800 Powers at 26 Watts

Local Power Supply - Cisco PID = AIR-PWR-50
AIR (Aironet) PWR (Power) 50 (50 Watt)

AP-3800 also supports local 50W power supply
For use with option modules – uPoE also supported

For Your Reference

More powerful APs draw more PoE power

AP 2800 & AP 3800 - Power Requirements

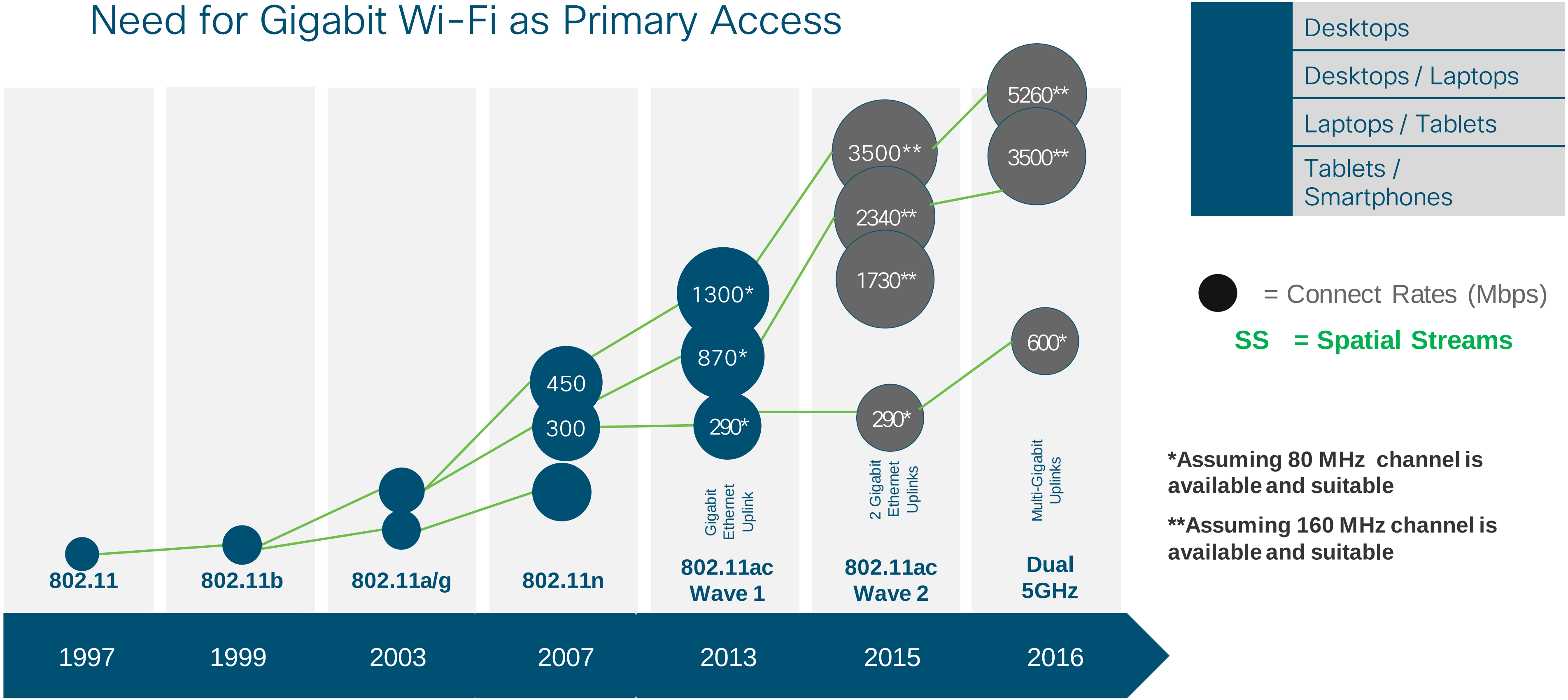
		Description	AP Functionality	PoE Budget @PSE (Watts)	802.3af Or PWRINJ5	802.3at PoE+ PWRINJ6	802.3bt uPoE
2800	PoE 802.3at	2800 – Out of the Box (8.2.x.x)	All Features Enabled*	26W	✘	✔	✔

		Description	AP Functionality	PoE Budget @PSE (Watts)	802.3af Or PWRINJ5	802.3at PoE+ PWRINJ6	802.3bt uPoE AIR-PWR50
3800	PoE 802.3at	3800 – Out of the Box (8.2.x.x)	All Features Enabled* Except Module support	30W	✘	✔	✔
3800	PoE 802.3bt (uPoE)	3800 – Out of the Box (8.2.x.x)	All Features Enabled* Including Module support	52W	✘	✘	✔

* USB support not available at FCS may increase power up to 3W

Wi-Fi Connectivity Speed Timeline

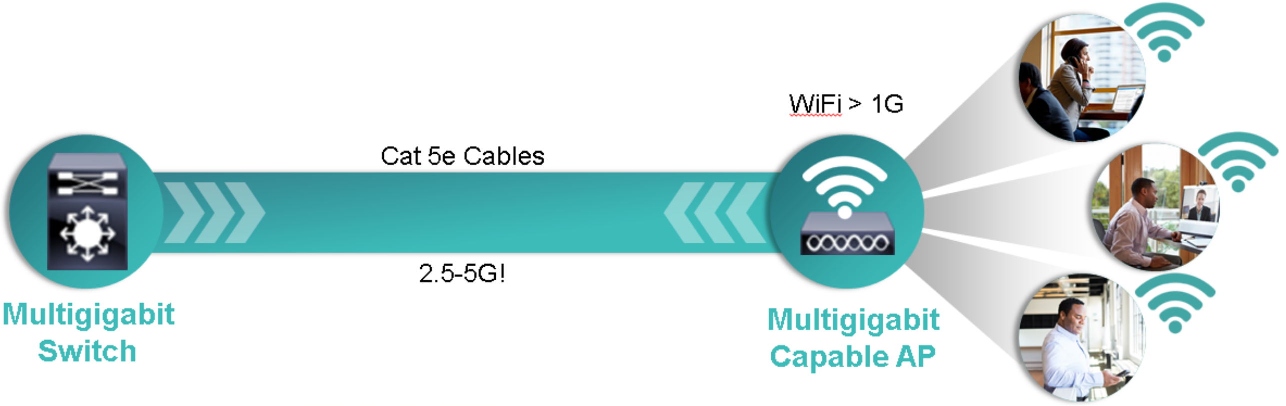
Need for Gigabit Wi-Fi as Primary Access



***Assuming 80 MHz channel is available and suitable**

****Assuming 160 MHz channel is available and suitable**

Cisco Multigigabit (mGig) using NBASE-T



Cisco Multigigabit with NBASE-T™

Is a game-changing innovation allowing enterprise networks to evolve beyond 1G	Enables 2.5 and 5 Gbps up to 100m on legacy cables	Supports all PoE standards up to 60W

Delivers up to 5X Speeds in Enterprise without replacing Cabling Infrastructure

3800 mGig Cabling Support – Maximum Flexibility

Cable Type	FE	1G	2.5G	5G
Cat5e	●	●	●	● * 55-100m
Cat6	●	●	●	●
Cat6a	●	●	●	●

- Auto-negotiation of cable type of speeds supported
- *5G speeds limited to distance of 55m impacted with 6-n-1 bundles on Cat5e

What if I’m not able to get mGig speeds?

Troubleshooting mGig (N-Base-T)

Cable Type	Port Speed	Total Cable Length	6-a-1 Bundled Cable Length	Patch Panel Cable and 3 Connecters	Mitigation Plan to improve performance
Cat 5e	10GE	N/A	N/A	N/A	Upgrade cable to Cat 6a
	5GE	100m	>30m	10m (2x5)	1) Use “Downshift” 2) Reduce number of connectors 3) Change patch cable to solid core cable 4) Reduce bundled cable length to be <30m 5) Use Cable Diagnostic or Cable Tester to determine end-to-end Cable quality
	5GE	100m	<30m		5GE
	5GE	55m	Fully bundled	10m	5GE
	2.5G	100m	Fully bundled	10m	2.5GE

Downshift

Option that permits system to detect and lower speeds when noise occurs rather than maintaining a fixed value

Cisco Multigigabit Products

For Your Reference

4500E

- Best In Class Modular Access
- New 48 Ports Line Card
- 12 Ports of Multigigabit per slot
- Up to 96 multigigabit ports per system

3850

- Industry leading Fixed Access
- 24 & 48 Port Stackable Switches
- 24 & 12 Multigigabit Ports
- New Uplinks

3560CX

- NG Workspace switch
- Multigigabit in smallest form factor
- POE/POE+
- Instant Access support

48-port Catalyst 3850 Multigigabit Switch

Downlinks:
36 x 1G LineRate 10/100/1000BASE-T, PoE/PoE+/UPoE, EEE, MACSec

12 x GE/mGig/10GT – LineRate, 100M/1GE/mGiG/10GBASE-T, PoE/PoE+, PoE/PoE+/UPoE, EEE, MACSec

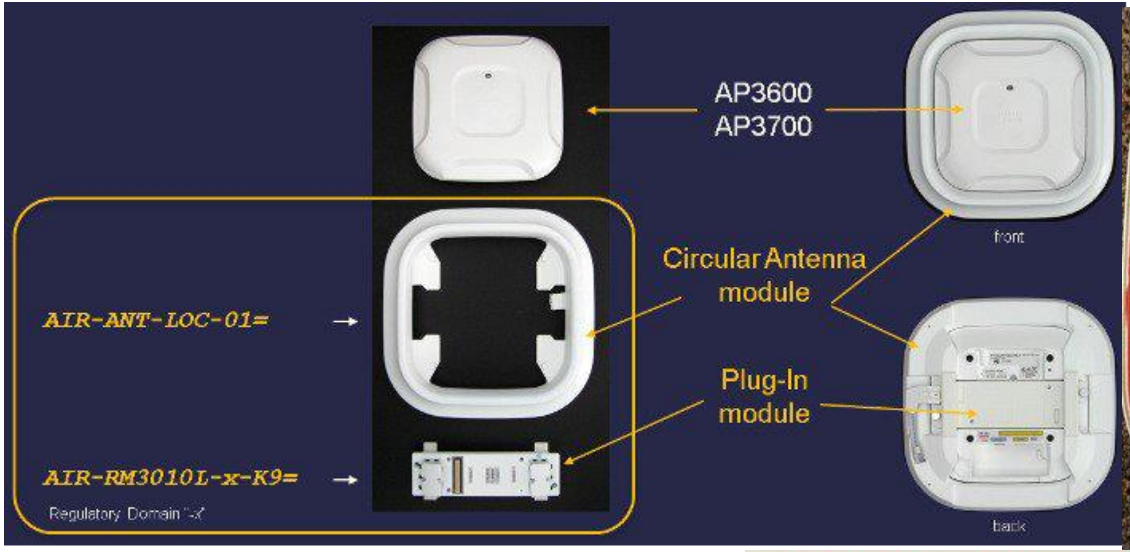
Uplinks:
4x10GE SFP+, 2 x 40G (NEW), 8x10G (NEW)

24-port Catalyst 3850 Mulitgigabit Switch

Downlinks:
- 24 x GE/mGig/10GT
- EEE, MACSec
- PoE/PoE+/UPOE

Uplinks:
4x10GE SFP+, 2 x 40G (NEW), 8x10G (NEW)

Specialty Antennas - Hyperlocation

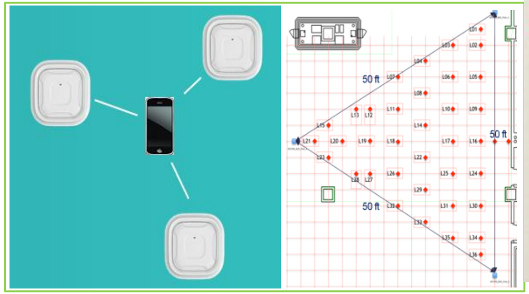


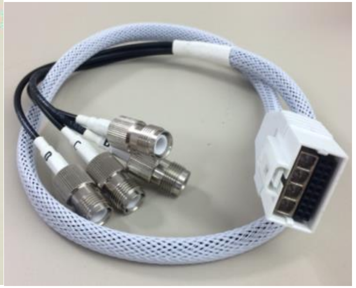
2.4/5G

2.4/5 Monitor

BLE

32 Element array

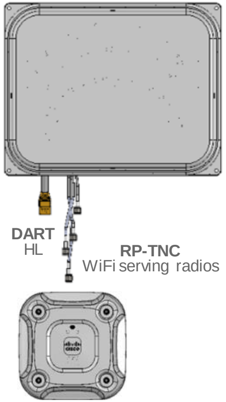


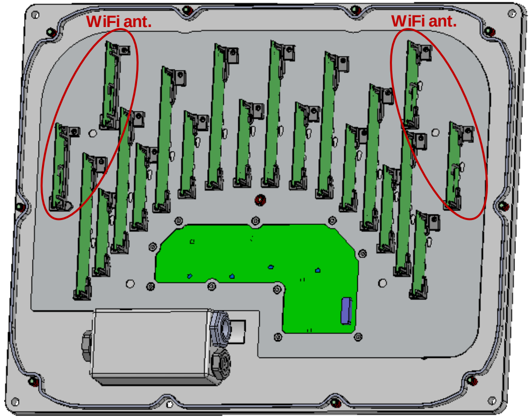


Specialty Location Antennas

AP3600/3700 add on
Enterprise office, retail,…
(horizontal install)

Large hall, warehouse, atrium,
high ceiling, Outdoors
(vertical install)





WiFi Ant.: Az/El ≈ 105°/60°, Gain ≈ 3 dBi

Omni Location + no WiFi

- •PID: AIR-ANT-LOC-01=
- •3602i/e, 3702i/e
- •Enterprise office, retail , …
- •Horizontal install, on ceiling
- •DART (HL mod) + RP-TNC (E ver., WiFi)
- •Dual-band
- •≈ 2x12x12”
- •Oct. 2015

Directional Location + Directional WiFi

- •PID: AIR-ANT25-LOC-02=
- •3602i/e, 3702i/e & 2802e, 3802e, 3802p
- •Large Halls, Warehouse, Atriums
- •Vertical install
- •DART (Location) + RP-TNC (WiFi)
- •Dual-band
- •≈ 2x14x18”
- •3602/3702 ≈ Sep 2016
- •2800/3800 tbd

cisco

IMAGINE

INTUITIVE