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AB108AE - Apply Radio Frequency (RF) Fundamentals to Optimize Wi-Fi Designs

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Jerrod Howard
Outdoor PLM

aruba
a Hewlett Packard Enterprise company

Session Agenda

- RF Basics Review
- Some Aruba Specifics
- Basic Indoor Office Environments
- Warehouse and Industrial
- Outdoor and Mesh

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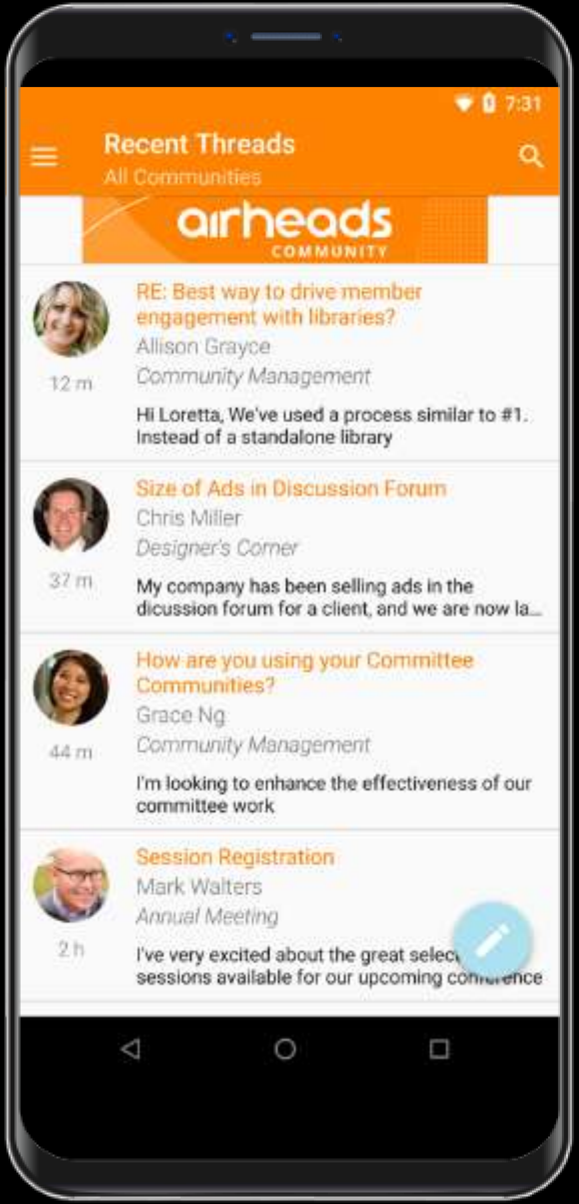

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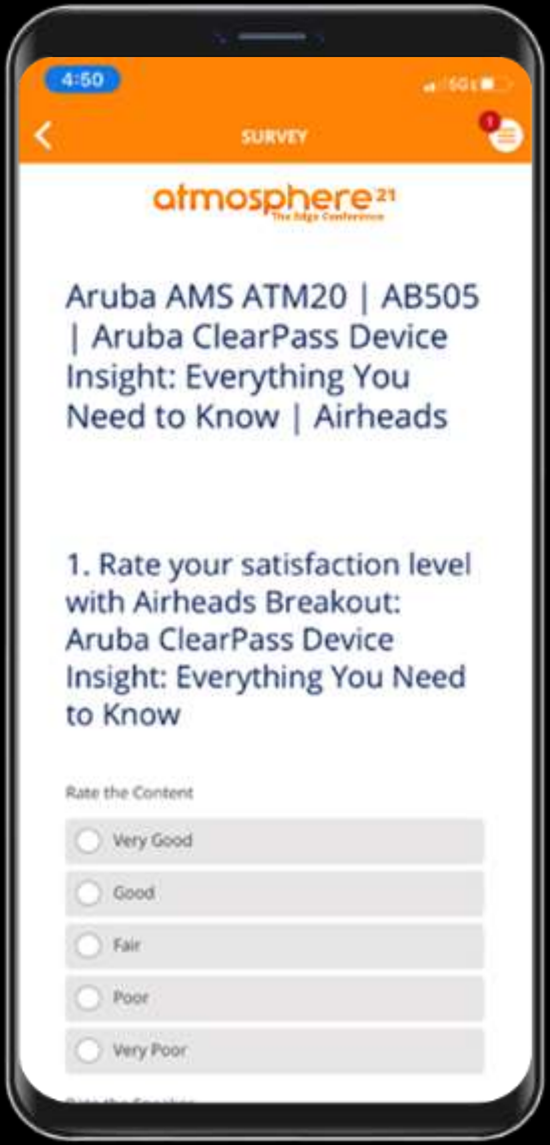

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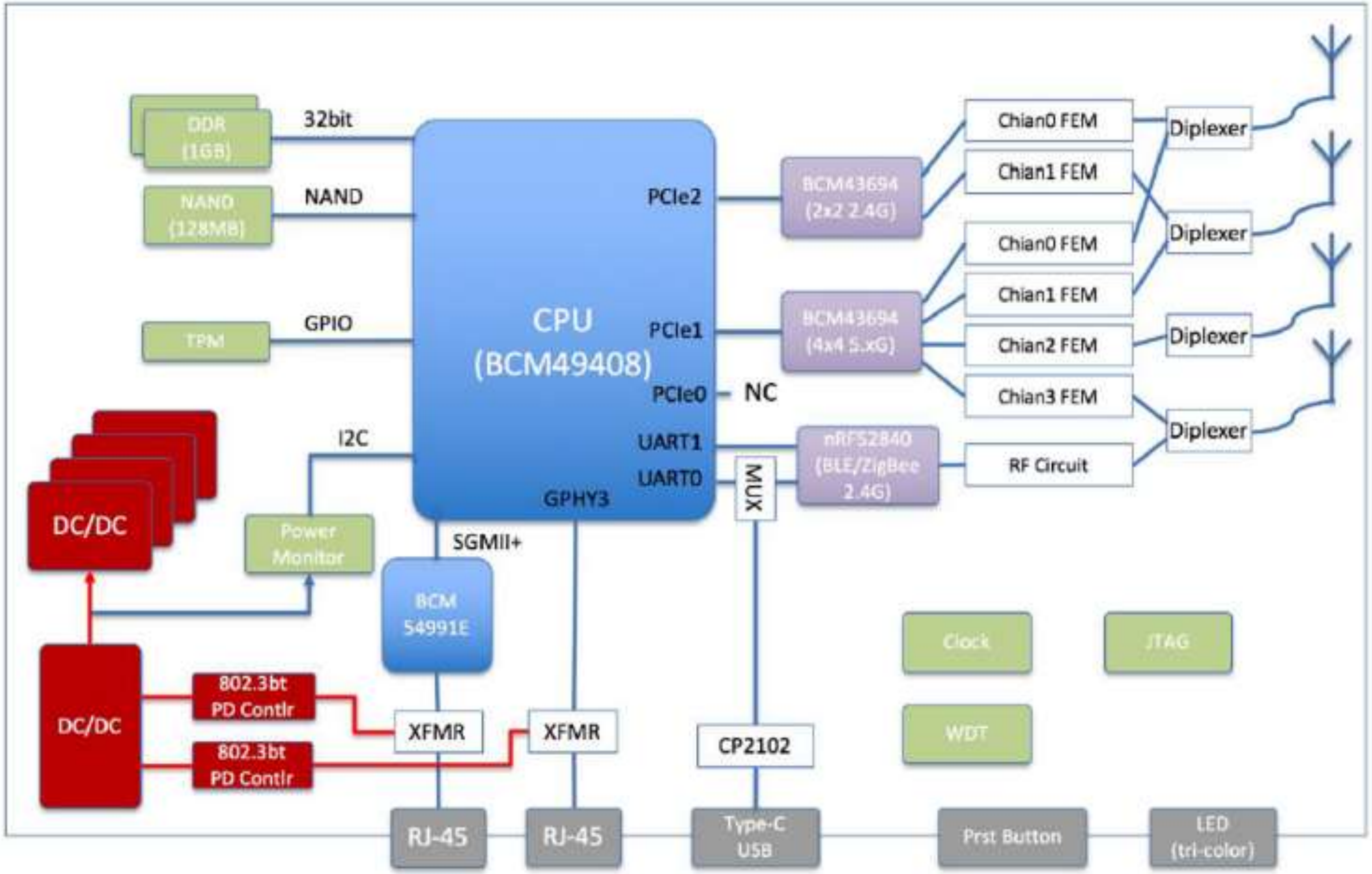
1 – RF Basics

Core components of a Wi-Fi Access Point

– Major Components of an AP
  – CPU and Chipset – Is the 'engine' of the AP (generally speaking)
  – Memory/Flash – is the storage of the AP (flash stores the OS, memory is where it runs)
  – TPM – Trusted Platform Modules contain and store security credentials
  – Physical Network Interfaces – is the 'how' in connecting the AP to the network
  – **Radios – are the wireless transmitters and receivers of the AP**
  – **Antennas – is what 'shapes' the RF energy from the radios to the clients, as well as allowing the AP to 'hear' the clients**



*** In some cases, APs may be a 'System on a Chip' (SOC) where the CPUs, Chipsets, and Radios are all on the same silicon**

What are the components of the AP’s EIRP?

Total AP power (EIRP - Effective Isotropically Radiated Power) is derived from three main components:

1. **Conducted Power** – generally represented in power per chain of each MIMO radio
   - Indoor generally is a maximum of 18dBm per chain
   - Outdoor/Industrial generally is a maximum of 22-23dBm per chain
   - Power is adjustable in 0.1dBm increments
2. **MIMO Gain**
   - MIMO gain is calculated with 10log(#chain)
     - 2x2 radio = 10log(2) = 3dB MIMO gain adder
     - 4x4 radio = 10log(4) = 6dB MIMO gain adder
     - 8x8 radio = 10log(8) = 9dB MIMO gain adder
3. **Antenna Gain**
   - Antenna gain is rated by both peak gain (highest peak in pattern) as well as the uncorrelated gain of all the antennas (where each radio chain has an antenna).
   - Think of the uncorrelated gain as being the ‘average’ or ‘smoothing’ of the total pattern

How does Aruba calculate EIRP?

– Aruba uses this method to ensure as much as possible consistency in AP power output between APs and antennas used, where the system adjusts conducted power based around MIMO gain and antenna gain to run at the correct power assigned by Airmatch or per the configuration.

  – *Note: Other vendors do not always use this type of calculation, as such, the 'conducted power settings' on some vendors APs may only show the true conducted power but not the antenna or MIMO gain. It's important to understand this concept when doing vendor comparisons in either bakeoffs or when a new system is going in.*

EIRP = Per-Chain Conducted Power + MIMO GAIN + Antenna Gain

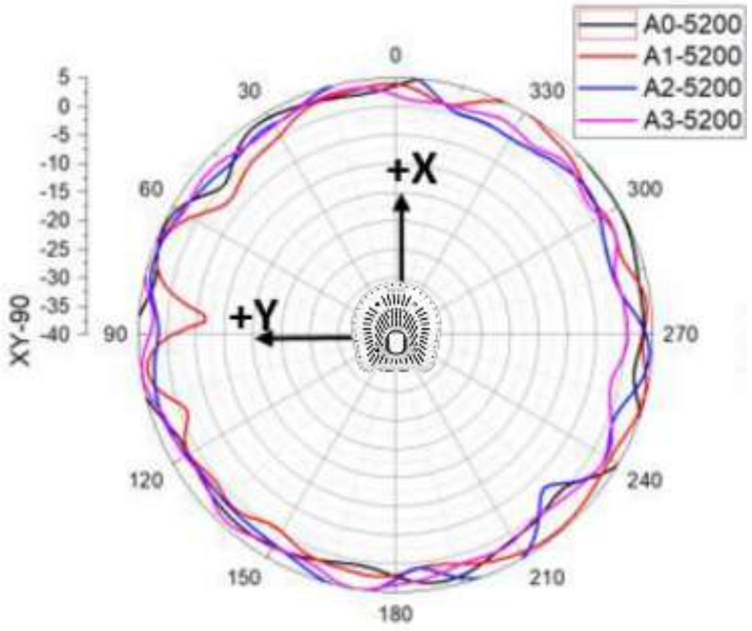
Multiple AP models to compare how the individual values works out as follows when EIRP set to 18dBm:

AP Model	5Ghz Radio	Max Per Chain (dBm)	Per-Chain Conducted	MIMO Gain (10log(X))	Antenna Gain (dBi)	EIRP Value (dBm)
AP-505	2x2	18dBm	9.4dBm	3dBm	5.6dBi	18dBm
AP-535	4x4	18dBm	8.5dBm	6dBm	3.5dBi	18dBm
AP-555	8x8	18dBm	7.0dBm	9dBm	2.0dBi	18dBm
AP-575	4x4	22dBm	7.0dBm	6dBm	5.0dBi	18dBm

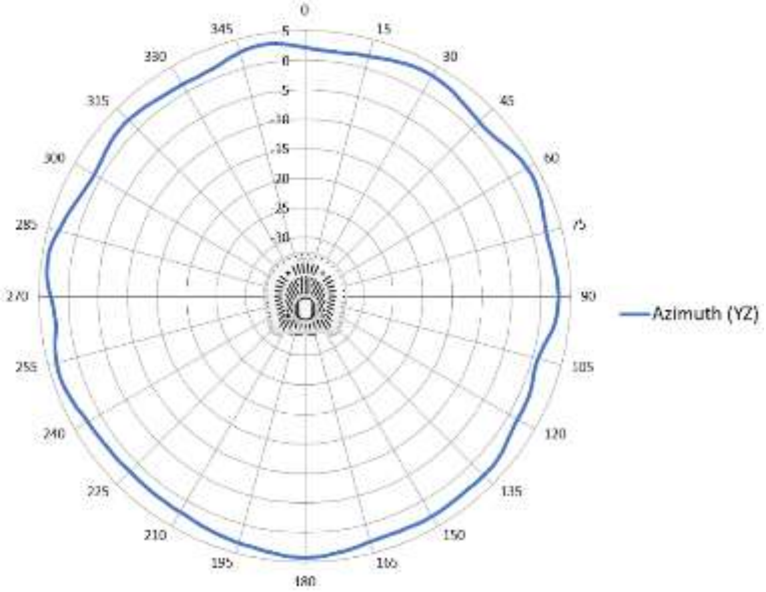
What Are Uncorrelated Antenna Patterns?

– Because MIMO radios have multiple chains, and thus multiple antennas, each antennas has its own ‘pattern’.

– To allow for a more easily digestible patterns and regulatory compliance, the individual antenna patterns are ‘averaged’

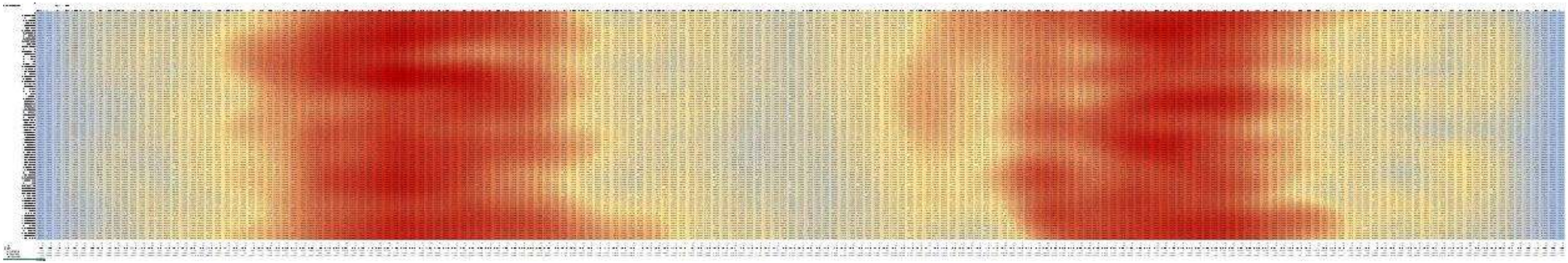


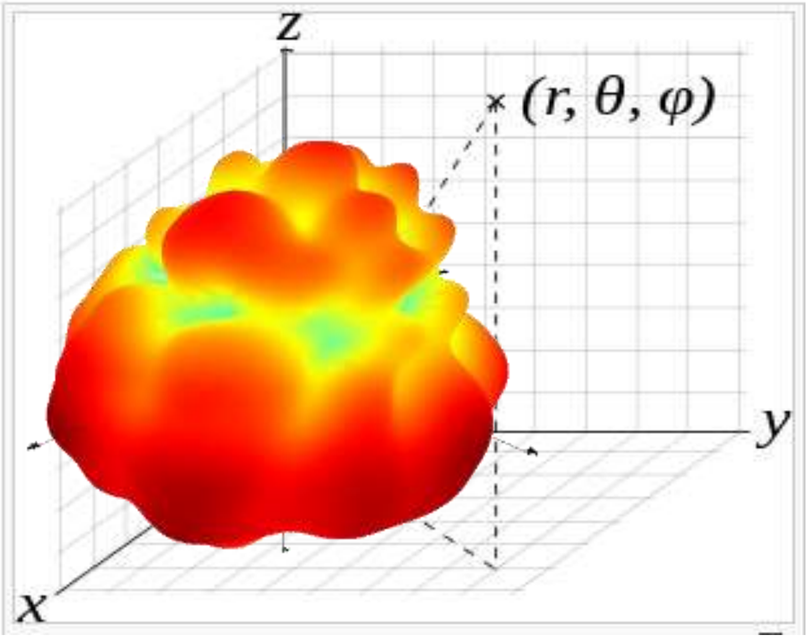
AP-575 4x4 5Ghz
@90deg H-plane

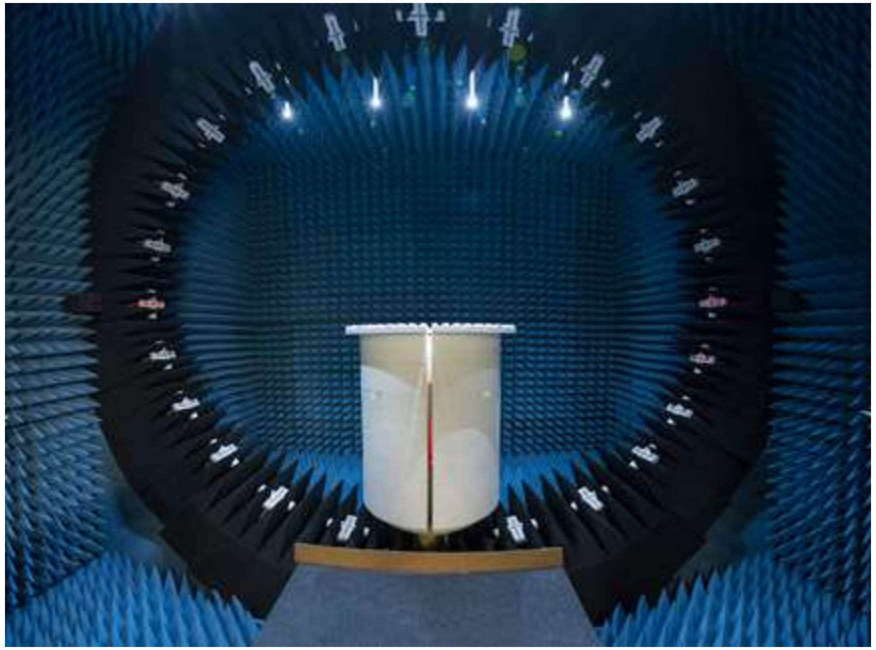


AP-575 4x4 5Ghz
@90deg H-plane

What does a raw antenna plot look like?



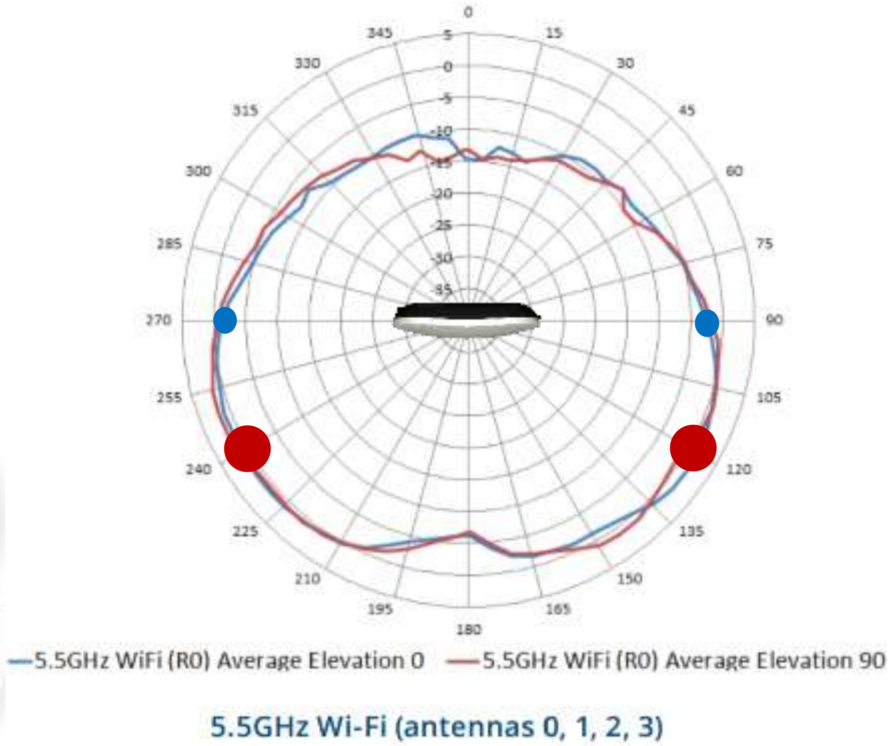




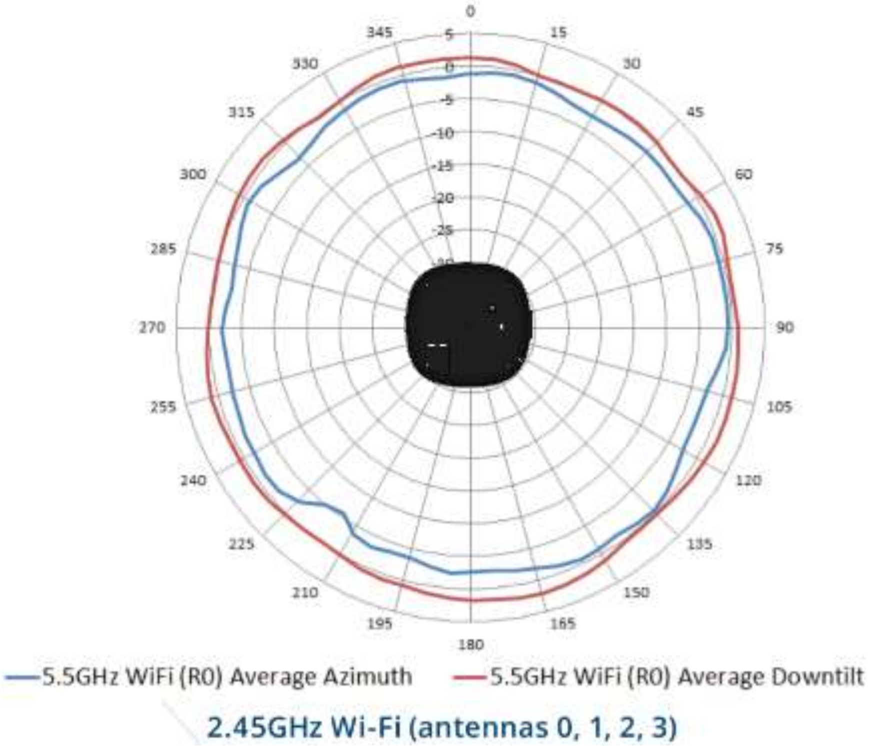
What do the Azimuth versus Downtilt Patterns show?

– When looking at the AP's E-plane, @90 and 270 (small blue dots) show the 'Average Azimuth' with zero downtilt'

– Looking at the E-plane 30deg downtilt (@120 and 240deg), the gain value is slightly higher (large red dots)



AP-535 E-Plane



AP-535 H-Plane

What about AP to Client RF Power Imbalance?

– There is a persistent belief that AP and client power should be balanced for proper link budget

– However, with MIMO, different radio characteristics, and positional interference, the reality is that AP power and client power don’t necessarily need to be balanced, allowing for more AP power compared to a client’s power.

Downlink 4 dBi AP Antenna

AP tx Power per Branch	18.0	dBm	
4 branch power sum	6.0	dB	= 10 log(# of chains)
antenna gain AP	4	dBi	
Cable losses	0	dB	Enter as positive number
Net AP EIRP	**28**	**dBm**	<-- **This is what is entered in the controller**
Client Rx antenna gain	0	dBi	
Client 1 Chain MRC	0	dBi	
Client Rx noise floor	-94	dBm	
total downlink path loss	**122**	**dB**	

Downlink 4 dBi AP Antenna

AP tx Power per Branch	18.0	dBm
2 branch power sum	3.0	dB
antenna gain AP	4	dBi
Cable losses	0	dB
Net AP EIRP	**25.0**	**dBm**
Client Rx antenna gain	0	dBi
Client 1 Chain MRC	0	dBi
Client Rx noise floor	-94	dBm
total downlink path loss	**119.0**	**dB**

Uplink 4 dBi AP Antenna

Client tx Power per Branch	**14**	**dBm**	
1 branch power sum	0	dB	= 10 log(# of chains)
antenna gain client	0	dBi	
Net Client EIRP	**14**	**dBm**	
AP Rx antenna gain	4	dBi	
AP 4 Chain MRC	6.0	dBi	
AP Cable losses	0.0	dB	
AP Rx noise floor	-99	dBm	
total uplink path loss	**123**	**dB**	

Uplink 4 dBi AP Antenna

Client tx Power per Branch	**14**	**dBm**
1 branch power sum	0	dB
antenna gain client	0	dBi
Net Client EIRP	**14**	**dBm**
AP Rx antenna gain	4	dBi
AP 2 Chain MRC	3.0	dBi
AP Cable losses	0.0	dB
AP Rx noise floor	-99	dBm
total uplink path loss	**120.0**	**dB**

2 – RF Specifics to Aruba

Aruba's AP Model 'Map'

– Aruba AP naming conventions are based on the following criteria (generally speaking):
  – APs with built in antennas – end in 'odd' number
  – APs with connectors for external antennas – end of 'even' number
  – Lower numbers in the range are entry-level/low cost, larger numbers are highest performing models

Notes the Wi-Fi Technology
1 = 11n // 2 = 11ac // 3 = 11ac Wave 2 // 5 = 11ax // 6 = Wi-Fi 6E

Notes the performance level and environment
0-5 = Indoor/Hardened, 6-8 = Outdoor
High number = higher performance

Notes the antenna or connector
Odd = Integrated Antennas // Even = Connectorized Antennas
3 or 5 = Omni Antennas // 7 = Directional Antenna
8 = Industrial AP (318/518) RP-SMA

AP-XXX(Z)

Notes any special use case
Indoor = H = Hospitality // R = RAP // RP = Remote AP with PSE
Outdoor = EX = Hazardous Locations

Aruba's AP Model Chart

1. Class of Product
Indoor
Remote and Hospitality
Outdoor and Industrial
Special Use Case

2. Level of Performance
Flagship
Very High Performance
Mainstream
Entry-Level
Low Cost

Indoor	Wi-Fi 6E	Wi-Fi 6	Wi-Fi 5
Flagship	*AP-655*	AP-555	AP-340
Very High Performance	*AP-635*	AP-530	AP-330
Mainstream	---	AP-510	AP-320 AP-310
Entry Level	---	AP-500	AP-300
Low Cost	---	---	AP-303

Remote and Hospitality	Wi-Fi 6	Wi-Fi 5
Main Stream	AP-505H	AP-303H
Entry Level	AP-503H	---
Low Cost	---	AP-203R AP-203H

Outdoor	Wi-Fi 6	Wi-Fi 5
Flagship	*AP-580*	---
Mainstream	AP-570	AP-370
Entry Level	AP-560	AP-360

Industrial	Wi-Fi 6	Wi-Fi 5
Mainstream	AP-518	AP-318

Special Use Case	Wi-Fi 6
Governments	FIPS/TAA Version
Hazardous Location	AP-580EX AP-570EX AP-560EX AP-370EX/ATEX

Special use cases follow the same performance guidelines, there are just special SKUs to support those use cases

5 GHz Constant EIRP vs. 6 GHz Constant PSD

Low Power Indoor APs† in 6 GHz are limited to 5 dBm/MHz constant power spectral density (PSD). This compensates for noise floor rise, thus incentivizing use of wide channels.

Channel Width		20 MHz	40 MHz	80 MHz	160 MHz	320 MHz
Noise Floor Rise vs. 20MHz			+3 dB	+6 dB	+9 dB	+12 dB
5 GHz UNII-2b	**EIRP**	**30 dBm**	**30 dBm**	**30 dBm**	**30 dBm**	**30 dBm**
	PSD (dBm/MHz)	17	14	11	8	5
	EIRP - Noise	30 dBm	27 dBm	24 dBm	21 dBm	18 dBm
6 GHz LPI	**EIRP**	18 dBm	21 dBm	24 dBm	27 dBm	30 dBm
	PSD (dBm/MHz)	***5***	***5***	***5***	***5***	***5***
	EIRP - Noise	18 dBm	18 dBm	18 dBm	18 dBm	18 dBm

"Effective EIRP" drops in wide channels due to noise floor rise

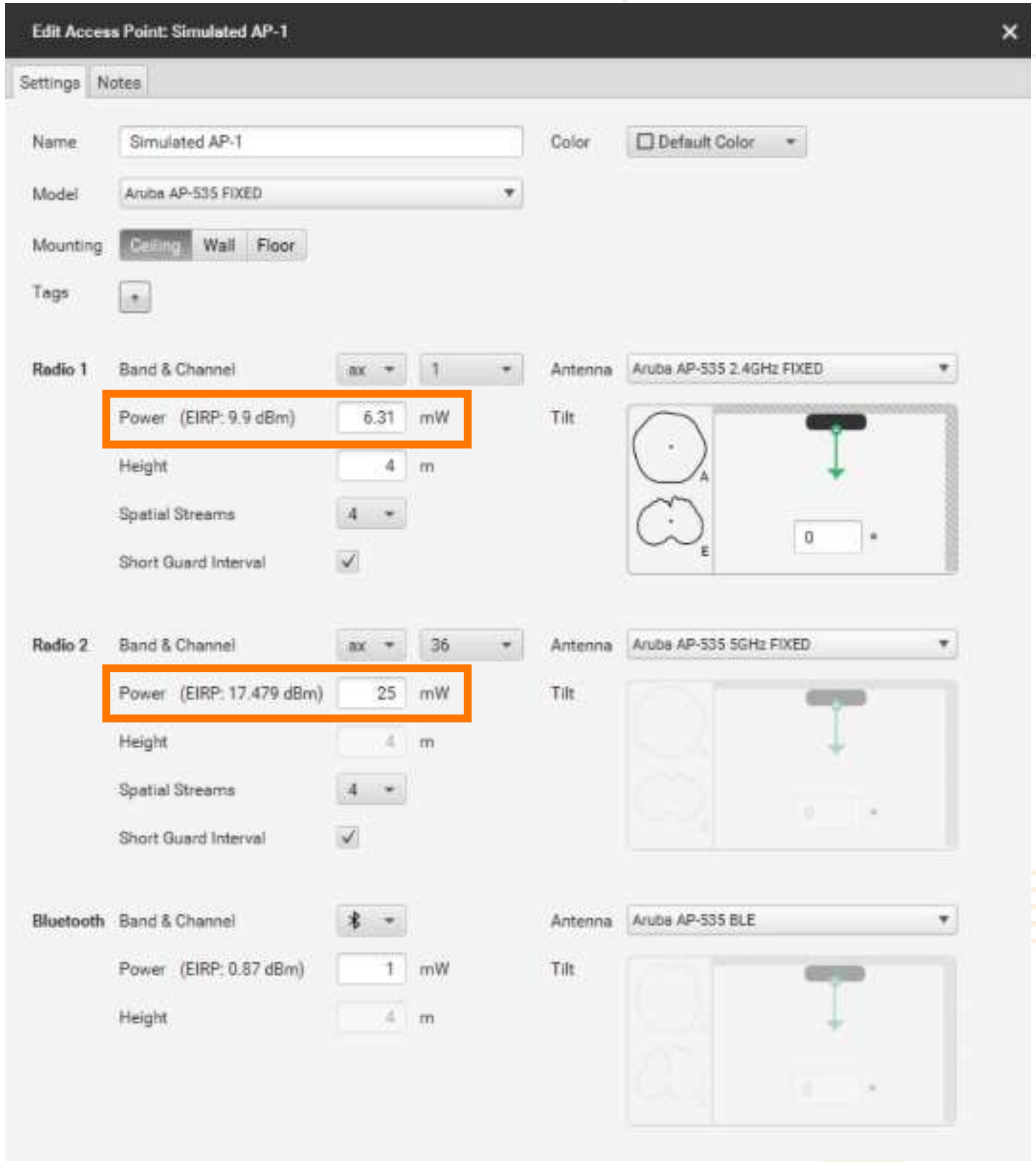
With constant PSD, the AP increases power to compensate in wide channels

- This means our RF design and EIRP expectations are contingent on channel width in terms of max PSD, against an overall 'design target' of minimum coverage SNR.
- Now, depending on your focal point, are you designing for a min SNR which should (in theory) be similar through channel widths, or you design to a 'throughput' target, which allows for narrower channels with more separation between the active channels

† *Note: AFC APs in 6 GHz still use constant EIRP.*

A note about Ekahau and other planning tools

- Note if using Ekahau, Ekahau does NOT calculate AP EIRP like Aruba, Ekahau only takes conducted power + antenna gain for EIRP.
- By default, Ekahau (on an example AP-535) will use 6.3mW conducted on 2.4Ghz and 25mW conducted on 5Ghz, regardless of AP model or MIMO streams supported.
- In essence, Ekahau's EIRP value is off in dBm in the amount of the MIMO gain provided by the outdoor AP, and is (to some degree) 'under-representing' the coverage the AP will provide on it's configured settings.
- Indoor AP antenna gain, expecting full reflections, includes the MIMO gain in the antenna pattern values.
- To accommodate for this discrepancy, in translating the plan to deployment, you can either
  - Include the MIMO differences as part of the client offset for outdoor APs
  - Define the 'Aruba EIRP' levels ahead of time and then configure the planned APs in Ekahau with the correct conducted power to properly reflect the actual Aruba EIRP



What is Advanced Cellular Coexistence (ACC)

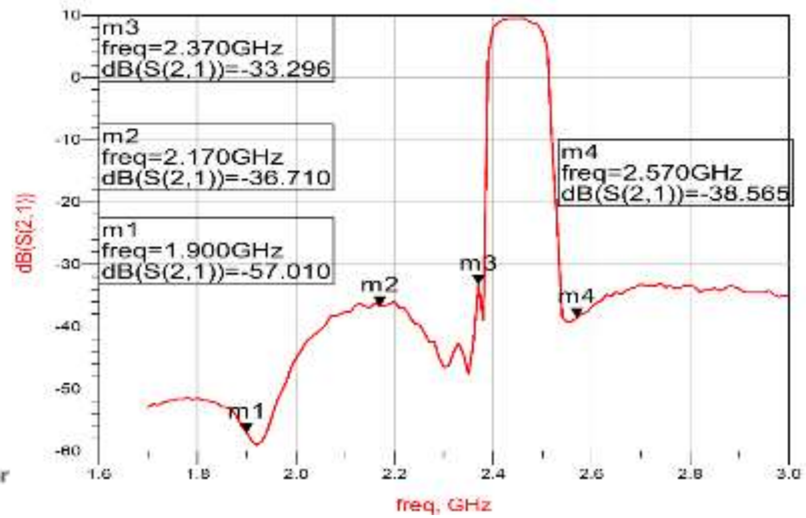
– Proliferation of DAS and new LTE bands at 2.6 GHz are creating issue for Wi-Fi solution

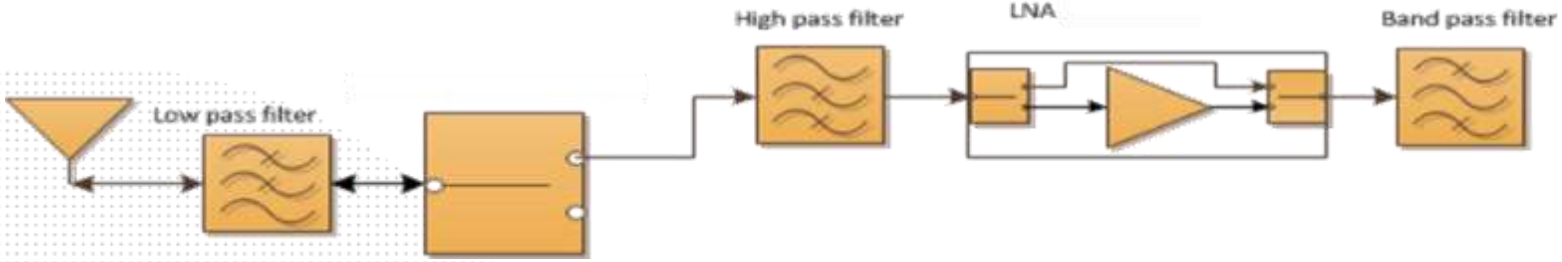
– All HPE Aruba APs have implemented significant filtering into the 2.4 GHz radio portion to combat this

– Design solution

  – Use high-linear LNA followed with a high-rejection filter to achieve rejection target and little sensitivity degradation;

  – Design target: Minimal Sensitivity degradation with -10dBm interference from 3G/4G networks (theoretical analysis).



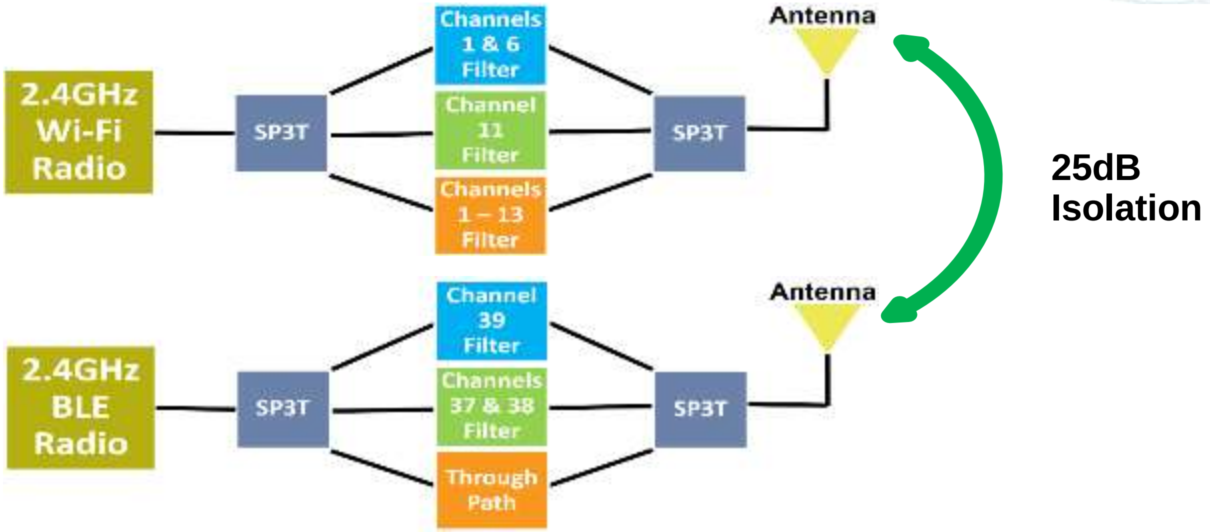


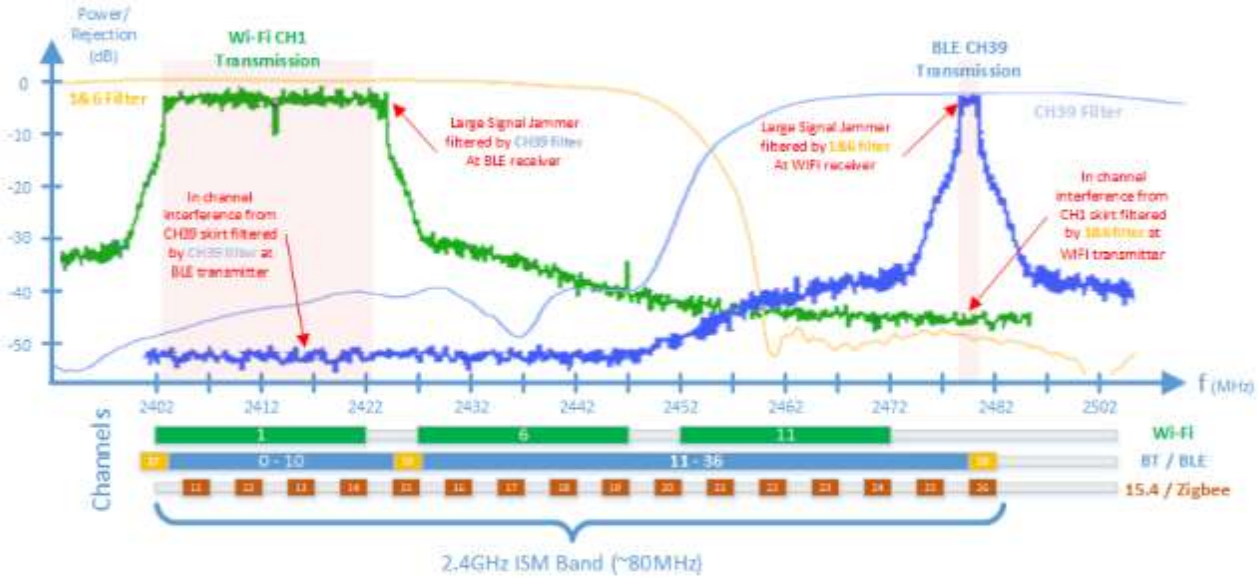
What is Advanced IoT Coexistence (AIC)

– A combination of smart filtering and software scheduling

– Allowing for simultaneous operation in the 2.4GHz band of the Wi-Fi WLAN and BLE/Zigbee IOT radios without performance degradation of either one

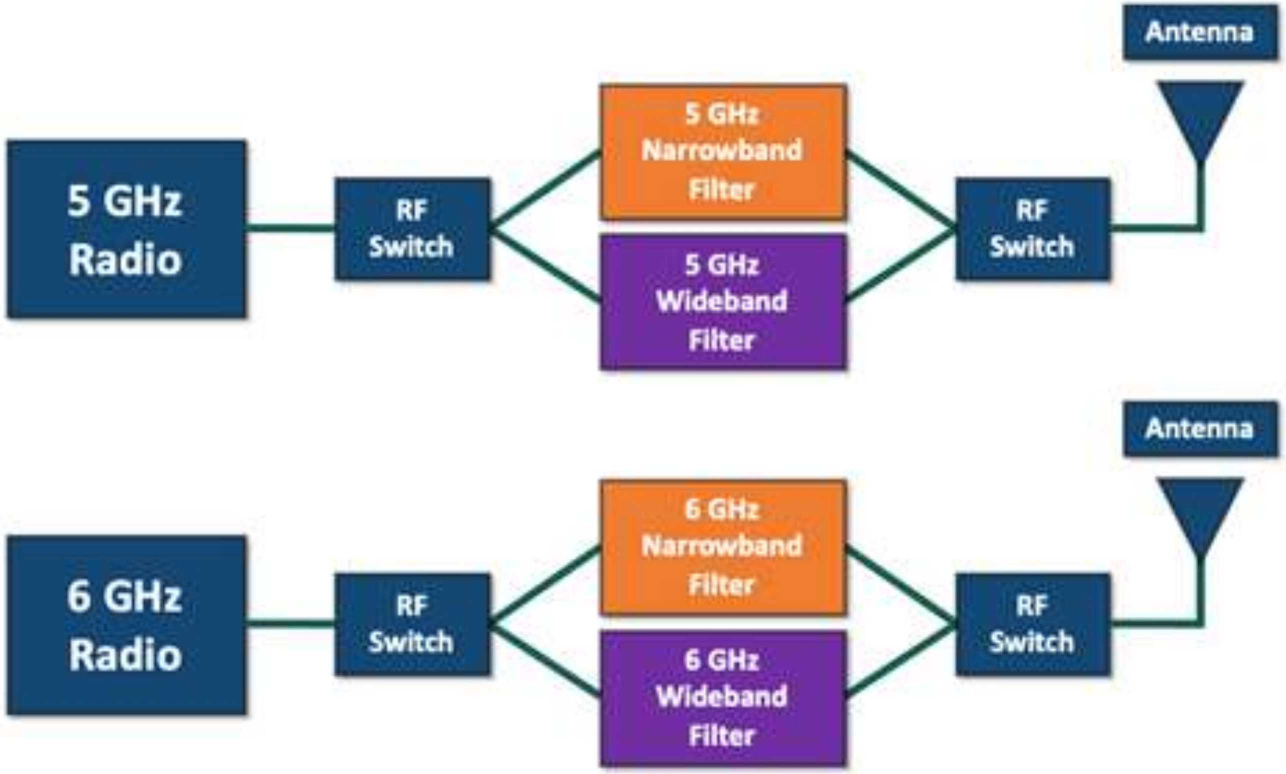
– Traditional radios need to time-share the band (if coordinated) or will cause mutual interference





Ultra Tri-Band Filtering

- A combination of smart filtering and software scheduling
- Allowing for simultaneous operation in the 2.4GHz band of the Wi-Fi WLAN and BLE/Zigbee IOT radios without performance degradation of either one
- Traditional radios need to time-share the band (if coordinated) or will cause mutual interference



3 – Basics of Indoor Office Spaces

Office Space – It's not just a movie…

- With enterprise Wi-Fi, the indoor office space is the most commonly deployed environment and is the environment most Wi-Fi engineers have the most experience with.
- Can be broken up into multiple design models:
  - **Coverage Plan** – Where the AP coverage minimally overlaps to provide contiguous coverage over the given area
  - **Capacity Plan** – Where an indoor area has large numbers of users where the user density is driving the AP density
  - **Hybrid Coverage/Capacity Plan** – This planning is more involved and requires more information, defining which areas derive their AP placement based on how the areas are used, which areas need more AP density due to larger user counts, or require more redundancy
- In many cases, indoor office environments are generally easier to design and deploy
  - Usually a contiguous ceiling-scape to use
  - Usually easily within an IDF/wiring closet
  - Most offices have open ceiling plans or plenum spaces which make the cabling runs fairly easy
  - Generally do not require lift equipment to install APs, ladders work well here
- ***…but not all office spaces are the same…***
- **Note: So far, our guidance is anything designed for 5GHz, where the equivalent power requirements are within the PSD limits, they should perform equivalent.**

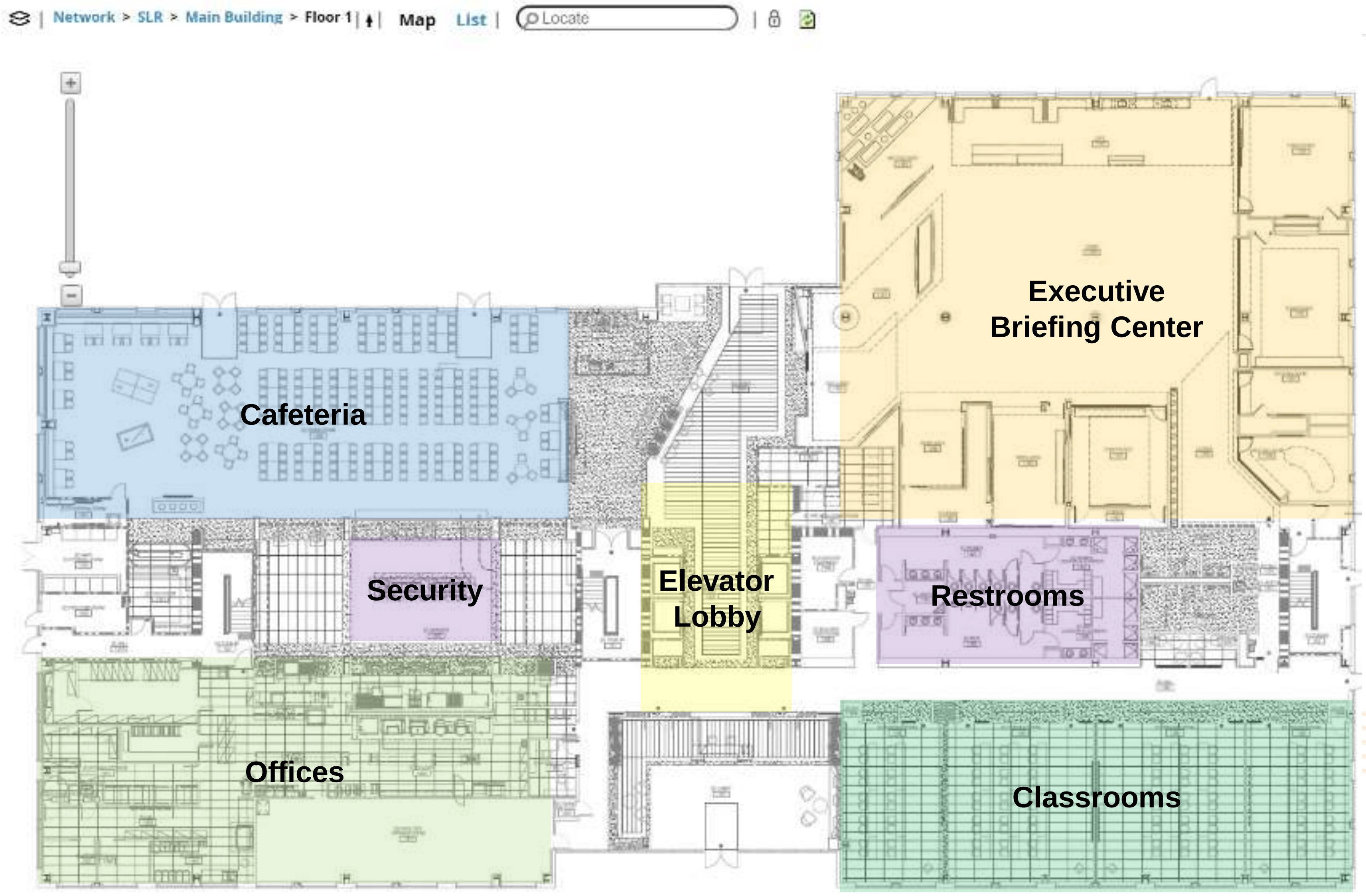
What does a typical office environment look like?

– Below is the Aruba HQ building’s first floor

– Cafeteria and Classrooms should be considered high density

– The Executive Briefing Center has multiple enclosed conferences rooms that could be full of people, or if an event is held in the EBC

– Office area is normal density



What does a typical office environment look like?

- Aruba HQ building's second floor
- Office desks are fairly well spread out
- Conference rooms can get very crowded
- Kitchen area can get crowded at lunch

Obstacles to look out for in Office Space planning

– Elevators – Elevators are ‘encased’ in a concrete enclosure (usually as a firewall) which will significantly attenuate the RF propagation

– Stairwells – same as elevators, the staircases are ‘encased’ in a concrete enclosure (usually as a firewall) which will also significantly attenuate the propagation

– Glass – Glass comes in to play in multiple vectors:

  – Glass-lined offices or conference rooms will likely need their own AP, since it’s not 100% that an AP will be able to transmit through the glass effectively

  – Exterior glass of the Low-E variety will significantly attenuate the RF

– Specialized environments or mounting locations

  – In cases where the APs cannot be visible, options are either under floor, inside enclosures with external antennas, or some other accommodation that will require specialized RF planning and testing

  – When putting APs in challenging locations (elevators, outdoor coverage or mesh, etc) may require some specialized and bespoke solutions to be developed

  – For corporate theaters, those can be treated as mini-Large Public Venues (LPVs) depending on the client counts

So what is needed to plan for indoor office spaces?

- Accurate scaled floor plans:
  - Drawing should either reflect the wall types, or a description of the wall types, for the areas where RF may be expected to penetrate said walls
  - Ceiling type and height, along with expected mounting
  - Capacity or user/device count per area
  - Drawings should show or note where the wiring closets (IDFs) are located
  - Identify any unique obstacles in the areas (glass offices, unique ceiling obstructions, etc) that will need coverage or that may impair RF propagation
  - Lots of pictures help as well to help relay the static floor plan to what the look/feel is of the coverage areas
- Account for multi-floor coverage in the placement of the APs (avoid as much as possible direct over/under AP placement, and instead stagger the indoor APs
  - Multi-floor plans should include the material between floors to gauge inter-floor attenuation
- Guidance from customer on performance expectations (coverage plan, capacity plan, hybrid plans, typical applications used, etc)

Best practices in regards to AP placement strategies

- Mark up the floor plans into smaller, more digestible ‘chunks’ to design around
- Be aware of AP height and it’s impacts to coverage, and leverage creative mounting solutions where needed
  - Pendant mounts with high ceilings can help bring the APs closer to the users and make them easier to service
  - Wall mounting with special wall mount brackets if the ceiling is not viable
  - Under floor AP enclosures can be used
- A good SNR target is anywhere from -55dBm to -65dBm to drive cell size per-AP, depending on the capacity needs
  - Depending on environment that puts the designed sq ft per AP to around 1500-2000sq ft per AP (generally)
  - Actuals may vary, sq ft per AP calculations should be reserved for ‘napkin math’ until a planned design is done
- AP power should be anywhere from 18-23dBm EIRP for 5Ghz, with a 9-15dBm EIRP for 2.4Ghz, but use the planning tools to compare/contrast for each environment.

Example Office Pictures (upcoming new Aruba HQ!)

4 – Warehouse and Industrial Spaces

A Space All Its Own - Warehouses

- What makes warehouses so difficult to design to?
  - Share many of the same considerations regarding large coverage areas
  - Have large, tall obstacles to accommodate
  - Coverage per AP is much larger (3-8k sq ft per AP)
  - More challenging mounting locations, cable planning, and obstacles to design around
  - The larger spaces and longer distances make regular indoor APs inadequate in most cases
  - Connectorized APs add additional hardware and labor costs, and increase risk

- Other factors to account for:

- How large is the warehouse
- How tall are the ceilings
- How tall are the racks
- What is the client density
- Is there any locationing or wayfinding
- What is stored on the shelves
- How much does the layout change
- How much do the contents change
- Is outdoor a component of the design
- ***What are the client types***

Commonalities with Warehouses

- Warehouses typically (but not always) are large indoor spaces, often not 100% environmentally controlled, with an arrangement of tall shelving storing products or materials
- Shelving arrangements can be very uniform (aka easier to plan) or may have odd/irregular shelving arrangements (aka more difficult to plan for)
- There is usually an ‘intake’ and ‘outgoing’ area where goods are brought in and shipped out, respectively, usually on or along the sides of the warehouse
- Most warehouses have a wide walkway around the perimeter of the warehouse
- The middle and interior parts of the floor plan are usually storage and shelving
- Some warehouses may have what is called a ‘PicMod’ or a multi-floor area within the warehouse where people can walk along and pick smaller parts out
- Ceilings are usually 30-40ft (but can vary widely)
- Often there will be processing equipment or unique elements within the warehouse (conveyor belts, large HVAC ducts, indoor walk-in freezers or refrigerators, etc)

Caveats Incoming! – 6Ghz Indoor for Industrial Spaces

- Most warehouses and large industrial indoor spaces run APs at higher than 18dBm (sometimes over 30dBm EIRP @ 5GHz).
  - *Workaround is you must run much wider channels to run higher power levels, and you will not have industrial chassis and the antennas will not be optimized for tall ceilings.*
- Many warehouse and industrial spaces uses connectorized solutions, but 6Ghz LPI forbids this, as well as making a ruggedized chassis.
- While we are seeing more modernization happening in warehouses, we still know historically that warehouse HHTs are usually the last upgraded in a technology cycle. But then we hope to have a more diverse selection of product options.

In short, be aware of the limitations, and know things wil be changing often!

- People will want to try and force indoor solutions into their warehouses to put more services on the network layer. Note that LPI limits the types of products we can use, and their use cases in some instances are questionable.
- We all need to be mindful of how both our customers and partners try to push the limits, and what we see our competition doing, or trying to do. We, the Wi-Fi industry, want to preserve this access, and respect the incumbents and work towards our cooperative better good. If bad actors try to go too far, it could weaken our standing now or later on.

Why Use Outdoor APs in Warehouses?

- Warehouse environments are not always fully environmentally controlled, temperatures can get extreme on the ceiling, leaks and precipitation can occur, animal and insect deposits can occur.
- Outdoor APs are weatherized, can survive the wider temperature extremes (even in refrigerators and freezers)
- Outdoor APs have more appropriate antenna solutions and radio power levels that better serve covering larger areas at taller heights typical in most warehouses
- Outdoor APs and their mounting solutions are more ruggedized and can be staged, provisioned, and installed more quickly and securely, without the need for enclosures and external antennas that lead to higher costs in ancillary hardware and installation time, all with less risk and longer term maintenance schedules
  - While the network equipment for a warehouse can seem expensive, in many cases the overall cost to install the APs themselves cost as much or more per AP than the AP itself. This includes:
    - Ancillary materials
    - Labor and lift equipment
    - Loss in revenue while sections of the warehouse production stops

Aruba Warehouse General Recommendations

– From the concepts outlined previously, Aruba recommends the following guidelines for warehouses:

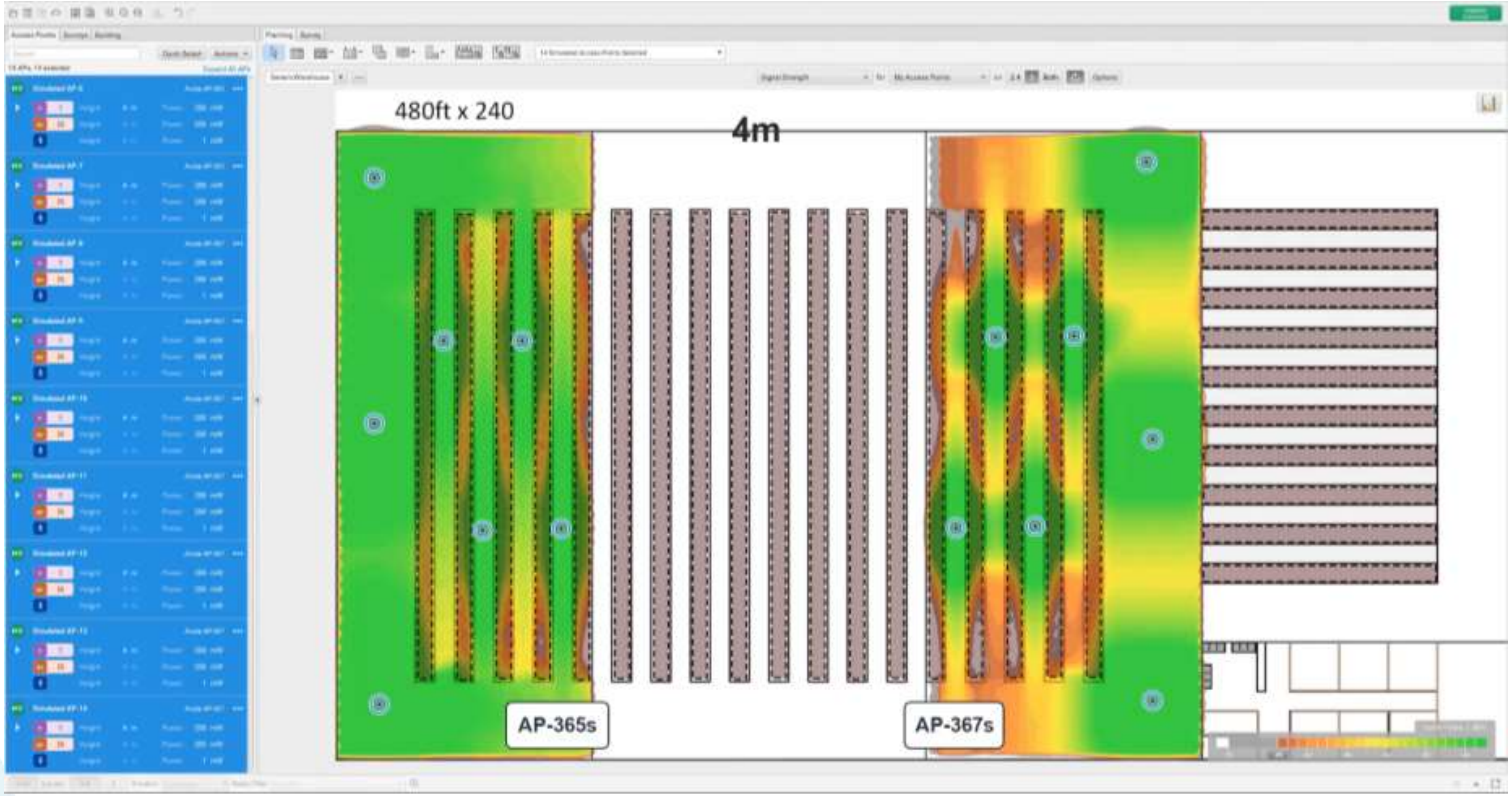
- Use AP-565 and AP-567 with the industrial AP mounts for ease of install, security, and simplicity
- Use of AP-565 for lower ceiling heights (45-50ft and under), and AP-567 for higher ceilings
- Always at least one AP per aisle (length of aisles may necessitate more than one AP per aisle, space APs accordingly based on design guidelines)
- Maximize separation between the AP and the top of the racks
- Create ‘cellularized’ coverage from the ceilings. Wall mounting should be used as little as possible, unless absolutely unavoidable. Goal is to minimize wide-scale RF propagation across the entire deployment

– Design guidelines for same-aisle AP spacing:

- AP-565 –
  - 50-65m spacing between APs on the same aisle or perimeter
- AP-567 –
  - 40-50m spacing between AP on the same aisle or perimeter when installed up to 13-14m (45-50)ft high
  - 50-65m spacing between APs on the same aisle or perimeter when installed over 14m (50ft) high

AP Type versus Height Above Ground

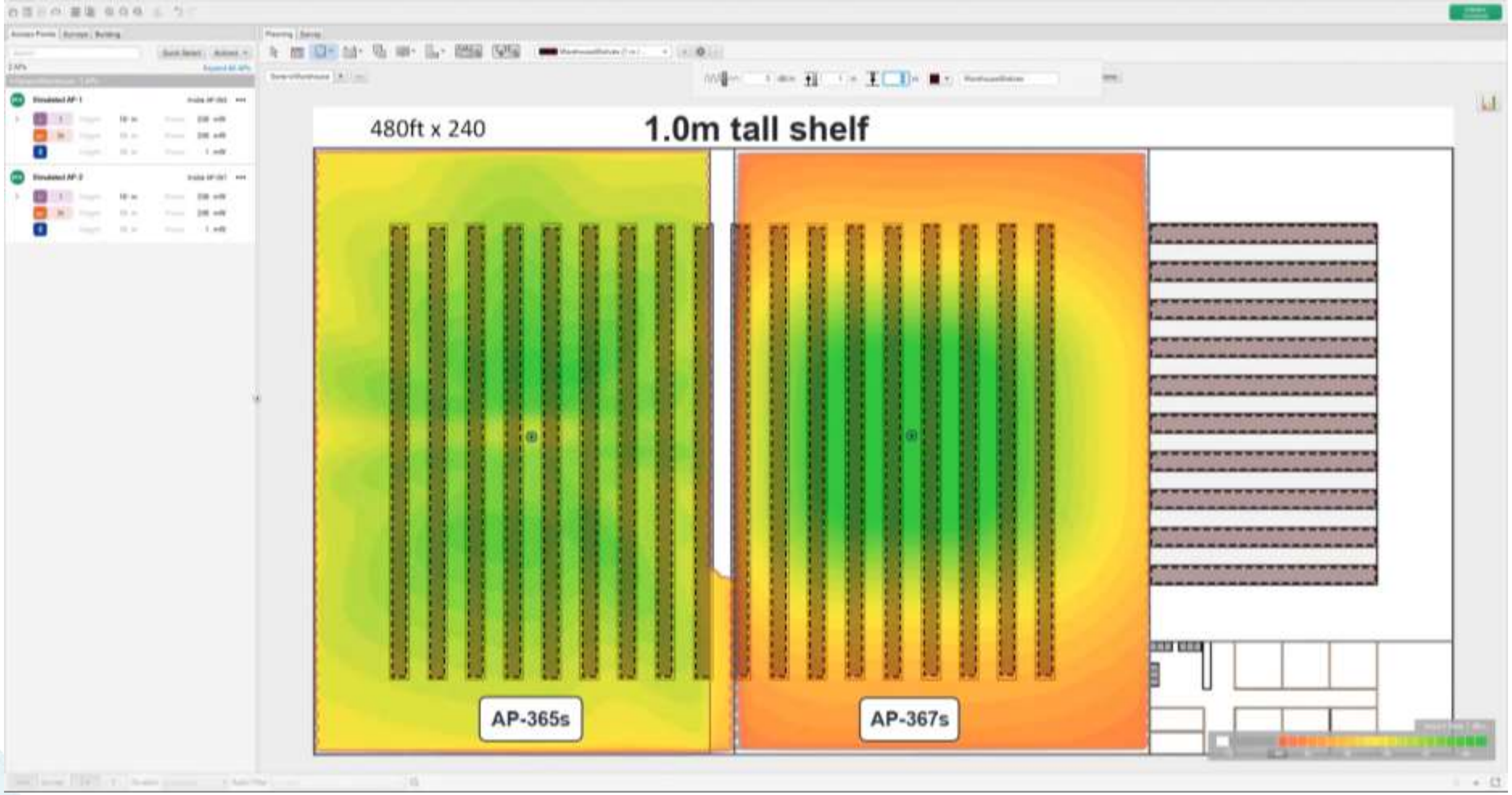
- AP-365 v AP-367 (20dB@2.4Ghz, 25dB@5Ghz EIRP)
- Shelving height @ 8m (5dB/m) and 60m (200ft) long
- **AP height from 4m to 18m above the ground (12ft to 60ft)**



Ekahau Survey Pro used as a predictive modeling tool to visually represent coverage

Shelving Height with Fixed AP Height

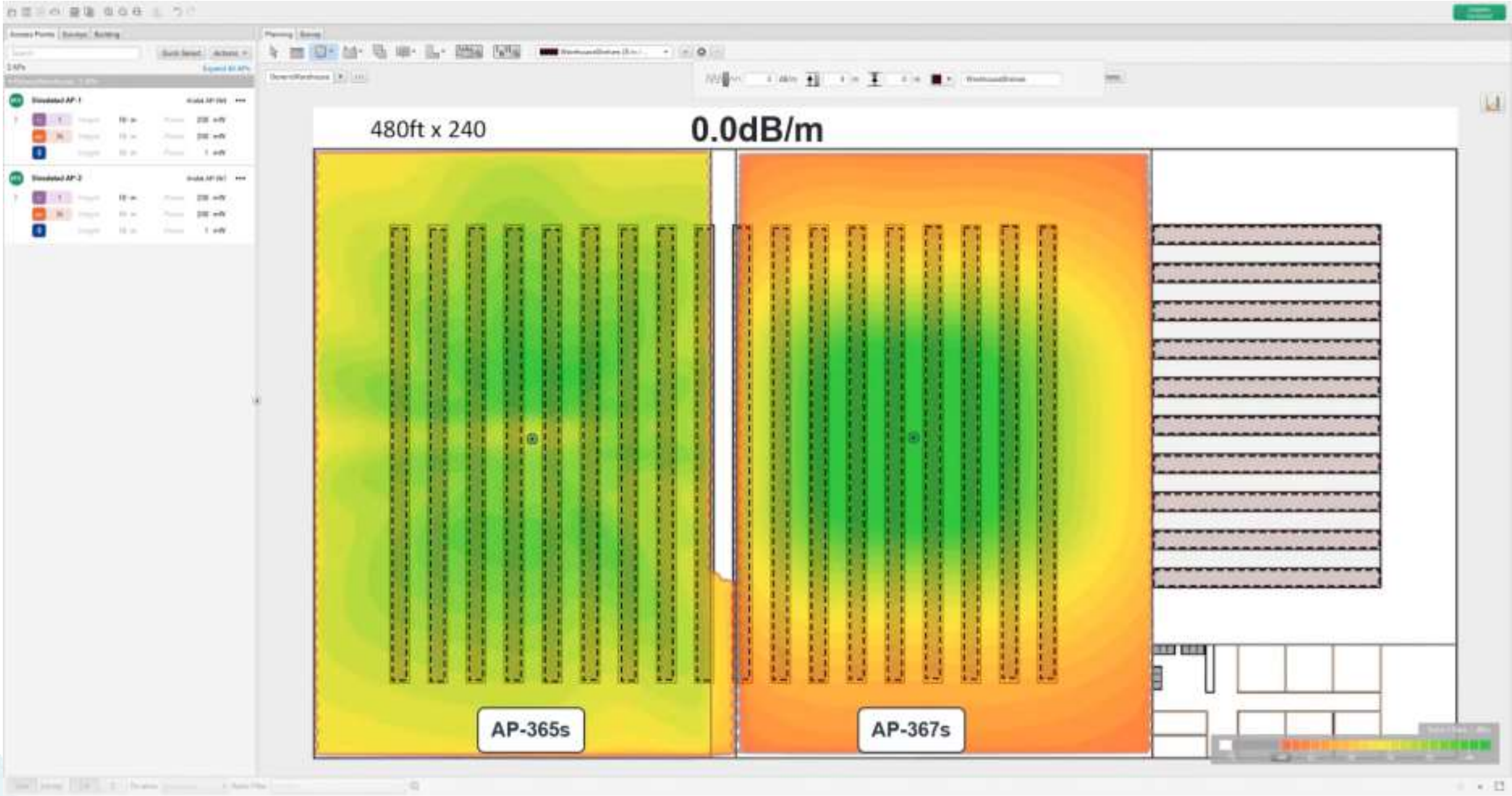
- AP-365 v AP-367 (20dB@2.4Ghz, 25dB@5Ghz EIRP)
- AP height at 10m (33ft)
- **Shelving height varies from1m to 10m tall (5dB/m) and 60m (200ft) long**



Ekahau Survey Pro used as a predictive modeling tool to visually represent coverage

Shelving Attenuation with Fixed AP and Shelving Height

- AP-365 v AP-367 (20dB@2.4Ghz, 25dB@5Ghz EIRP)
- AP height at 10m (33ft)
- **Shelving height 8m (26ft) tall (attenuation from 0dB/m to 6dB/m) and 60m (200ft) long**

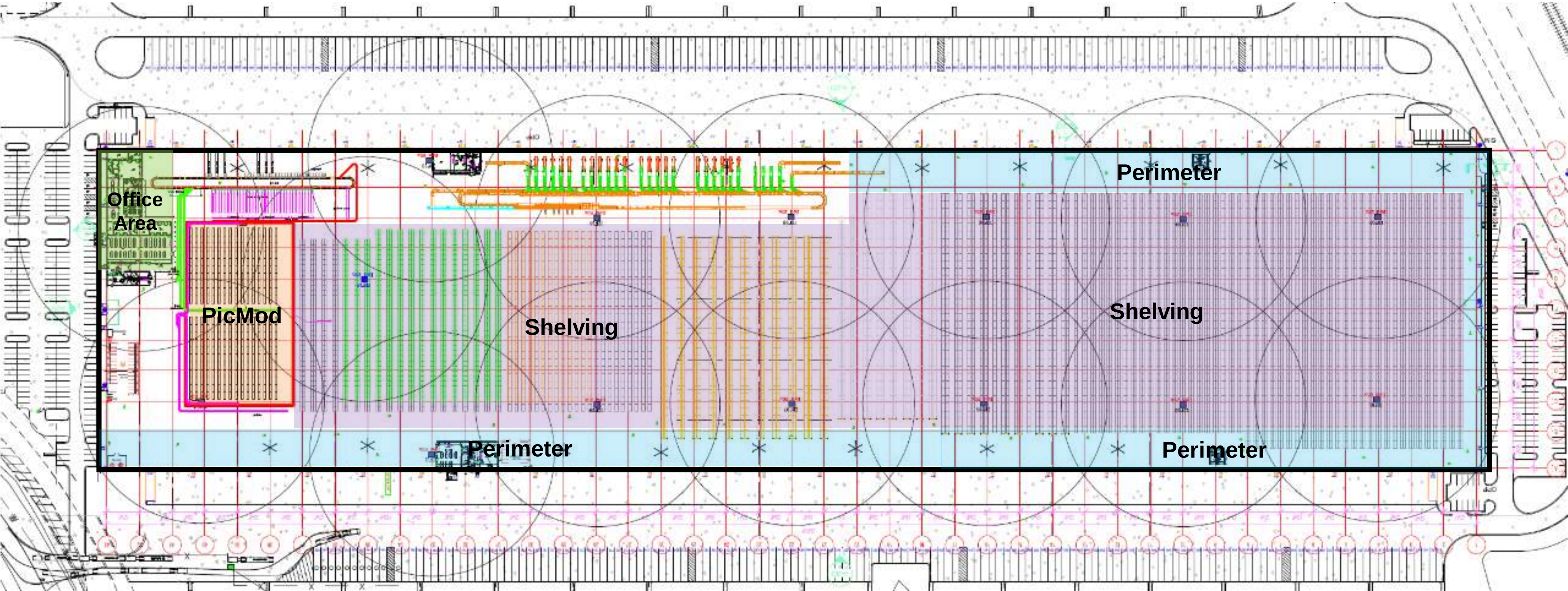


Ekahau Survey Pro used as a predictive modeling tool to visually represent coverage

So let's look at a REALLY large warehouse

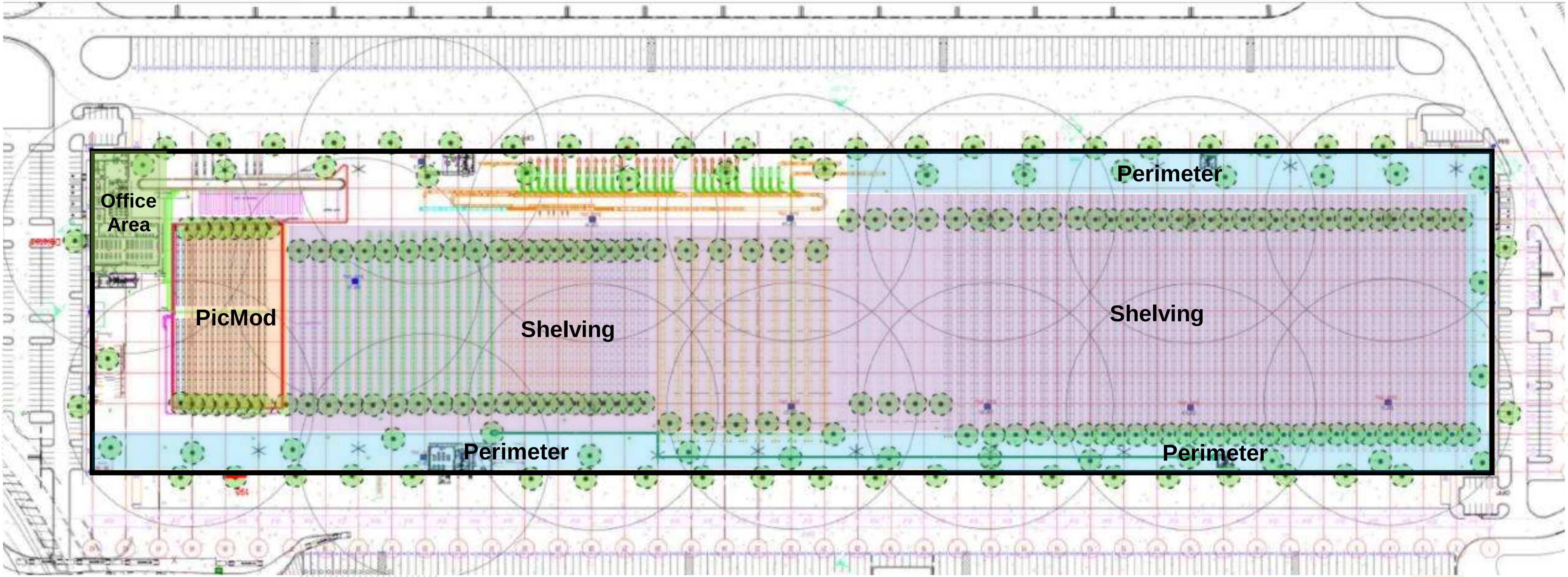
– Customer has 1.3mil sq ft warehouse, storing finished goods for online retail

– In the neighborhood of ~200 APs, so approx. 6,500sq ft per AP



Let's look at the resulting design

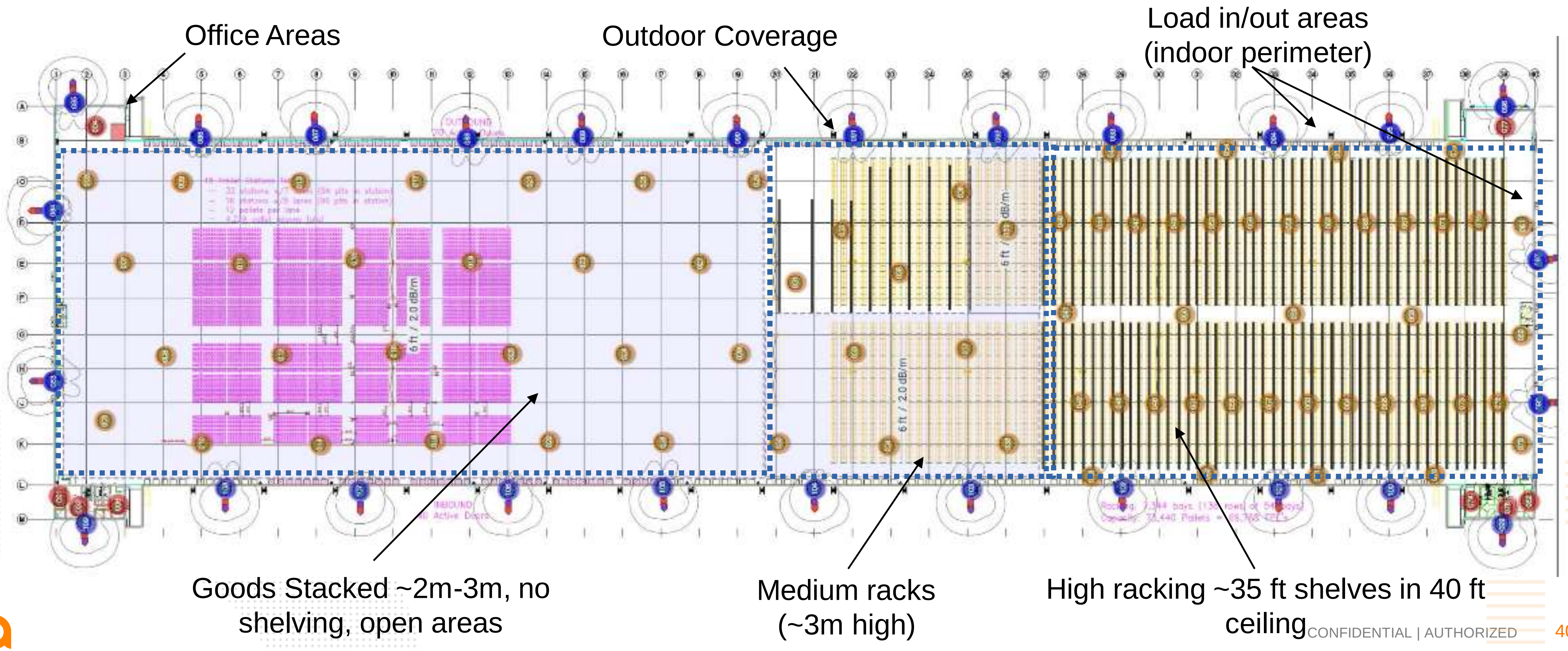
- Use all AP-36x indoors and outdoors, with AP-367s ceiling mounted with 45deg downtilt aimed down each aisle (at least one AP per aisle) – This was a customer-driven requirement
- Each functional area was planned separately



Let’s look at a different type of warehouse

– This warehouse is a mix of open palletized storage and shelving

– Each area is broken down into its functional area, and then uniformly planned in each area



The Warehouse Design / Deploy Process

When planning for a warehouse deployment, the process can be thought of as three separate phases of activities. Proper planning and process adherence will ensure consistent results and success for each and every deployment.

Phase 1: Pre-Visit and Predictive Site Survey - Collect plans, data, requirements, existing equipment and build a first-draft predictive plan and have a meeting with all stakeholders to review

Phase 2: Physical Site Survey – Verify data from Phase 1, account for any variances and inconsistencies from Phase 1 and incorporate the data, do physical survey validation of existing system and validate with new equipment

Phase 3: Prepare Design of Record – A final plan of record for what the new system will be, with agreement from all stakeholders, to be used for the actual installation.

The Warehouse Design / Deploy Process

Phase 1: Pre-Visit and Predictive Site Survey

1. Obtain scaled drawings/images (PDF preferred) of all areas to be covered showing racking layout, interior and exterior walls, height of ceilings, height and depth of racking in each area
2. Obtain layout of existing wireless deployment, including AP model and antenna types, placement, installation height and methods (wall, ceiling, post, etc), IDF locations, and wireless running configuration (power and channel plan/bands in use)
3. Obtain information (type, band capability, model and firmware level as applicable) for all planned client devices and use cases, e.g. handheld scanners, voice over wifi phones, laptops, etc.
4. Hold teleconference with stakeholders to review all information provided, noting specifically any known problems with the existing deployment coverage or other functionality. Review warehouse use, including types of goods stored in each area (liquids, dry goods, etc) and seasonal variations

Phase 1: Pre-Visit and Predictive Site Survey (continued)

5. Create a model of the existing coverage in a modeling tool (Ekahau preferred) using current AP model and antenna, if possible.
6. General Criteria Summary:
    - Primary AP Coverage: -65 dBm (-60 dBm if voice is required)
    - Secondary AP Coverage: -72 dBm (failover criteria)
    - Assume closed doors: (use solid walls in model appropriate for construction type)
    - Use Attenuation areas for Racking based on:
        - dry goods/unknown (3 dB/m)
        - liquids (10 dB/m)
7. Create a model of proposed coverage using existing AP locations first, then moving or adding APs to fit recommended best practices
8. Hold a teleconference with stakeholders to review existing and proposed predictive models, noting any areas of significant concerns or questions to evaluate during Phase 2 (Physical Site Survey - optional)

Phase 2: Physical Site Survey

Walk entire site to verify that information provided for existing deployment is accurate, using laser tools to measure all dimensions

- Verify racking layout including aisles lengths and widths, racking heights and depths
- Verify ceiling height and AP installation heights
- Verify any new proposed AP locations are compatible with proposal
- Verify IDF locations
- Verify all existing APs are active
- Photograph representative of each proposed AP installation type and location

Optional: Use Ekahau sidekick to obtain a survey of all existing coverage by walking all aisles (Passive Survey of existing coverage)

Optional: For each area with specific questions or significant proposed changes in coverage strategy, perform a limited survey using an Aruba AP mounted in a manner representative of the future proposed installation. This is a passive survey using a test SSID (a.k.a. AP on a stick survey). The purpose of this step is to provide data specific to the new proposal to assist with answering any questions or demonstrate improvement with the proposed design over the existing deployment.

Phase 3: Prepare the Design of Record

Document

- Title
- Site Information (Name, Address, Contacts)

Review of existing deployment

- Existing layout, each floor, showing APs and IDFs (no heatmap)
- Predictive coverage of existing layout at -65 dBm (1st AP coverage)
- Predictive coverage of existing layout at -72 dBm (2st AP coverage)
- If applicable, measured survey of existing coverage from site walk
- Review of site walk / physical survey additional information

Review of proposed deployment

- Proposed layout, each floor, showing APs and IDFs (no heatmap)
- Predictive coverage of proposed layout at -65 dBm (1st AP coverage)
- Predictive coverage of proposed layout at -72 dBm (2st AP coverage)
- If applicable, review of any measurements with proposed AP from physical survey

Summary

New Design: How to actually place APs? (example process)

Look at the unique areas as zones that will have different requirements, AP types, or coverage objectives:

1. Start with high racking zones (AP565 up to 13-14m or 45-50 ft , AP567 >14m or 50ft)
   a) Place APs in the staggered pattern – every aisle or every other aisle as appropriate for types of good stored
2. Fill in around the perimeter load in/ load out areas with an AP every 150 ft, place these APs strategically on aisles that are empty or have the AP at the far end
3. Next fill in Open Areas (AP565 up to 13-14m or 45-50ft, AP567 > 14m or 50 ft)
   a) APs on a grid, every ~ 50-65m (150-200 ft)
4. Add outdoor APs (AP567) – wall mounted oriented out away from the building
   a) APs every ~50m or 150ft linear along outer walls
5. Add office area APs (typically whatever indoor AP fits the applications)
6. Celebrate! ENJOY your new rock solid WiFi warehouse design!

5 – Outdoor

“How Far”?

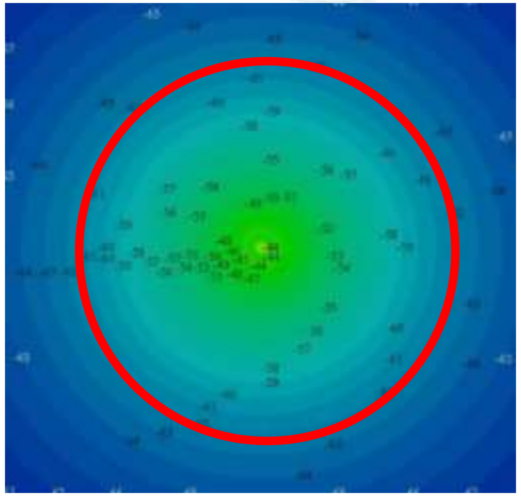
- A number of factors come in to play when determining ‘how far’ an outdoor AP will cover
  - AP power, antenna, directionality, regulatory, wall or pole mount, etc
  - Line of sight to the client, are there people, vehicles, trees, buildings or obstacles in the way
    - https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.833-9-201609-I!!PDF-E.pdf
    - https://lra.le.ac.uk/bitstream/2381/31383/1/2014ADEGOKEASPhD.pdf
  - What type and number of clients, bandwidth requirements, applications, etc
- Overlapping coverage and interference
  - Channel re-use, adjacent/co-channel interference, etc all apply and must be considered, as well as neighbouring interference from nearby locations. Free space can make it more challenging
- The Human Factor
  - As outdoor has fewer APs per given area, and are covering much larger areas, the orientation of the human holding the client device matters for attenuation, higher up is generally better
  - For large client density areas, overhead AP installation is required or the pathloss through a crowd will be too great and range will be greatly decreased
  - In less client dense area where the client devices are more spread out and crowd densities are less, it’s not as much of an issue

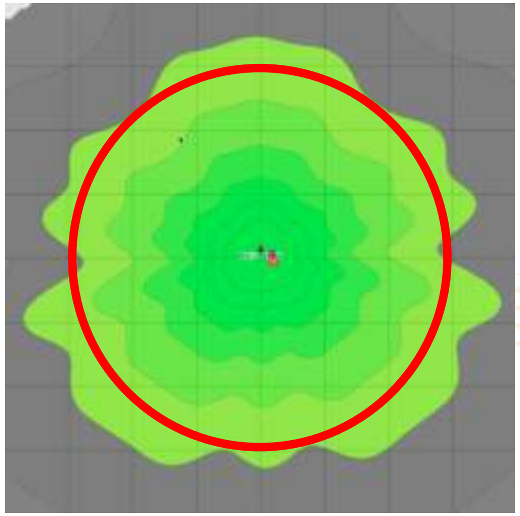
AP-575/375 - General Design Guidance

– AP-575/375
  – Can be thought to reliably produce a 150-200m radius of outdoor coverage (line of sight, barring any trees, buildings, etc).
  – If no overlap is required, can be planned with spacing of ~300-400m
  – Mounting height ideally should be at approx 4-6m above ground. Viable anywhere from 1m up to 30m, understanding the RF impacts
  – Flat, long wall mounting locations can cause issue with outside RF penetrating indoors, causing client issues. If long wall mounting, look at AP-377/577 firing out

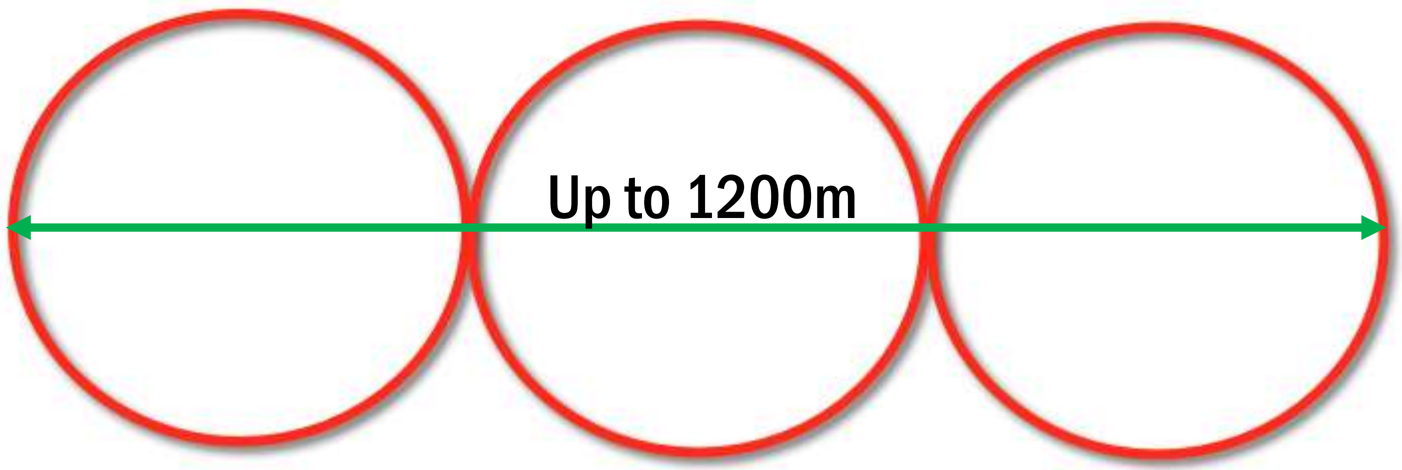
– Pole Mount versus Wall Mount
  – Pole mounts should use the AP-270-MNT-V1
  – Wall mounts should use the AP-270-MNT-V2

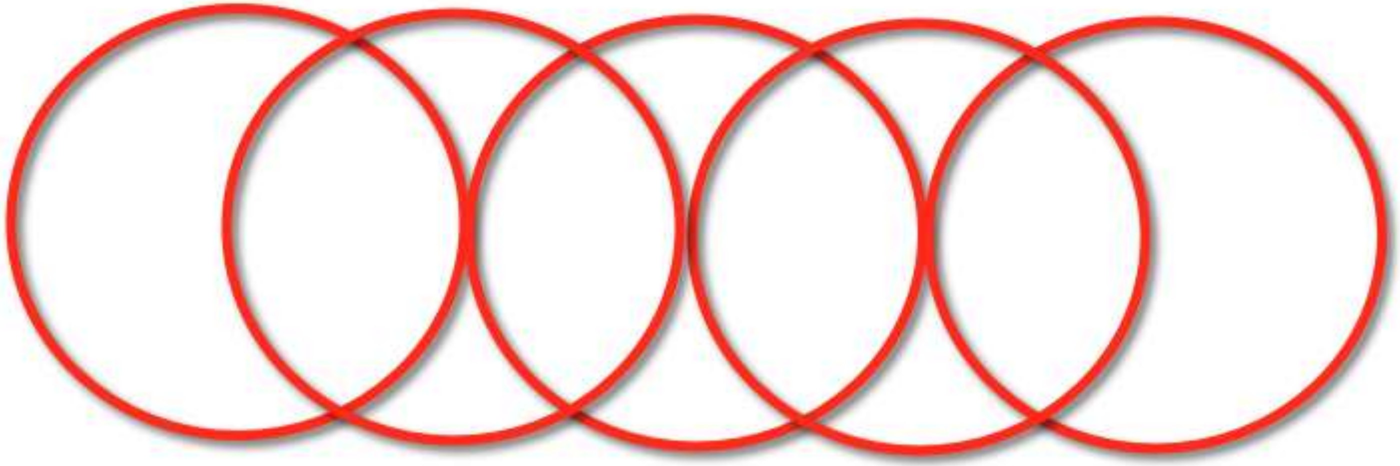
– Ceiling Mounts
  – If the ceiling is parallel to the ground, the AP-270-MNT-H2 can be used
  – If the ceiling is parallel or sloped relative to ground, the AP-270-MNT-H1 or AP-270-MNT-H3 can be used





AP-575/375 - General Design Guidance





Top-Down views of AP coverage

No Overlap

- Three APs would cover up to ~1200m distance
- Larger separation for better channel separation and lower ACI/CCI
- If one AP fails, there will be a gap

100% Overlap

- Would take five APs to cover the same distance
- One AP can fail and still have 100% coverage
- Higher AP density results in higher ACI/CCI to account for

AP-577/377 - General Design Guidance

– General Guidance

  – Is a directional AP (80deg x 80deg)

  – Relative to heading, the perpendicular coverage (sides) are approx 50-75m wide on each side, whereas the parallel coverage can cover out to 250-300m to a client

  – If no side to side overlap is required, they can be planned along a wall with spacing of ~100-150m

  – Mounting height ideally should be at or below 10m above ground aimed straight out parallel to the ground. For every 5m above 10m, downtilt the AP 5 degrees should be applied

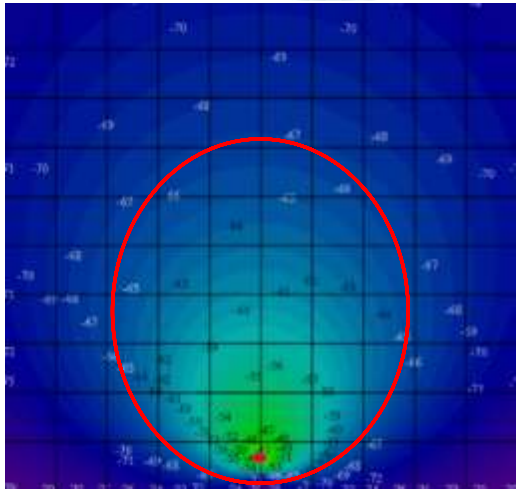
  – Best for wall mounting to minimize interior RF penetration

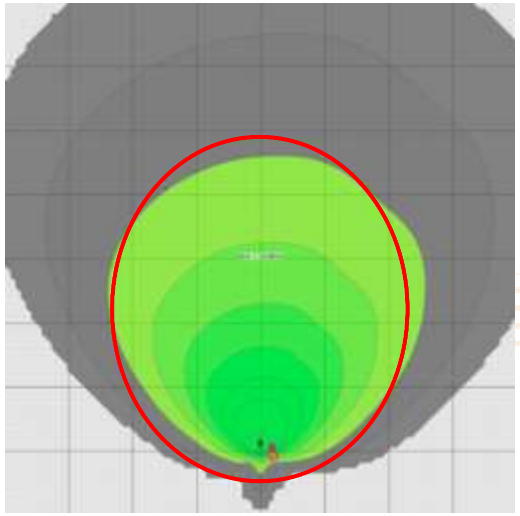
– Mounts

  – Wall mounts below 10m should use the AP-270-MNT-H2

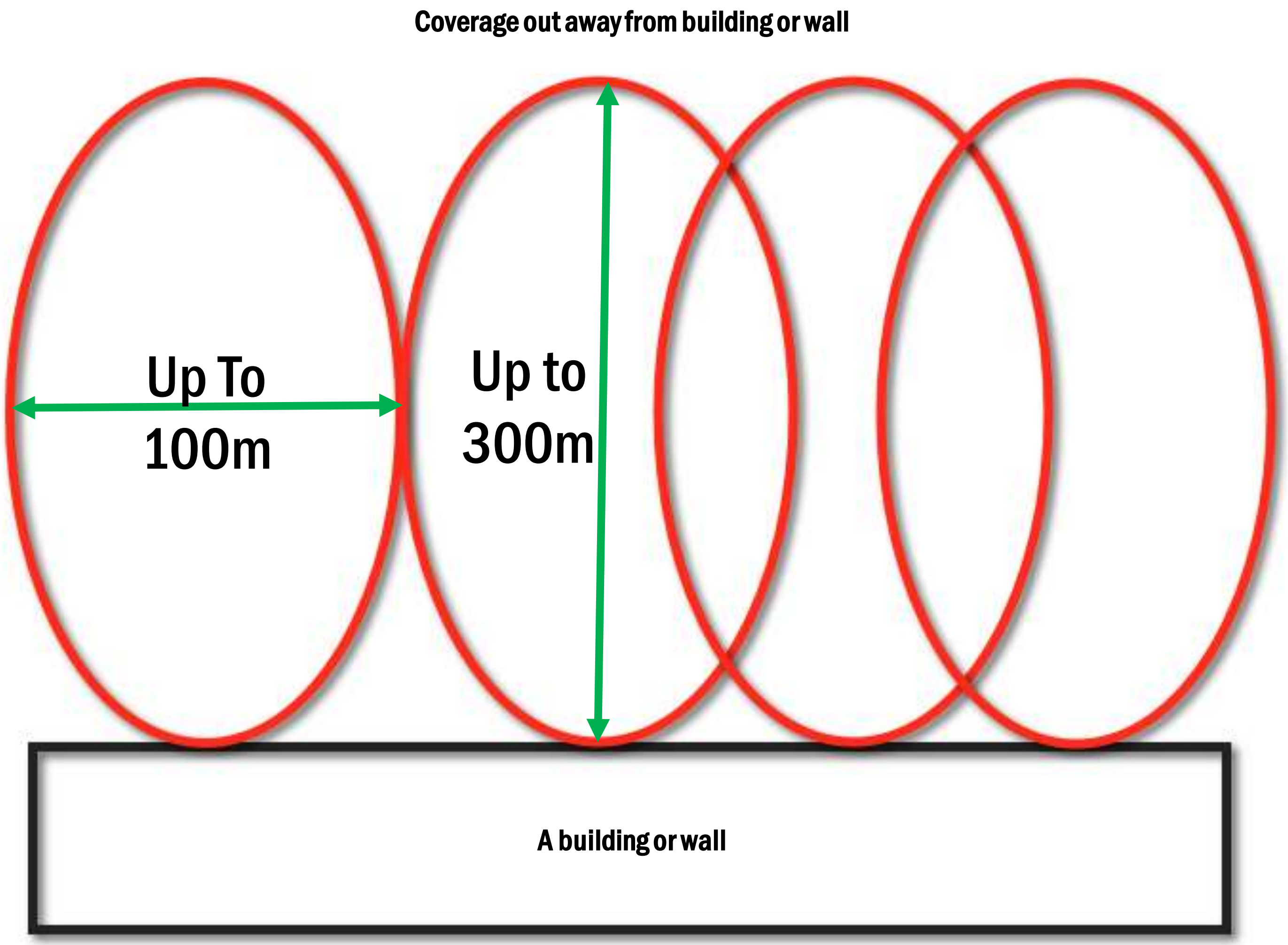
  – Any pole or wall mounts above 10m should use the AP-270-MNT-H1 or AP-270-MNT-H3

  – AP-577/377ss can be used in Very High Density (VHD) deployments as a dual-band client access AP (read the High Density VRD for more)





AP-577/377 - General Design Guidance



Top-Down views of AP coverage

No Overlap

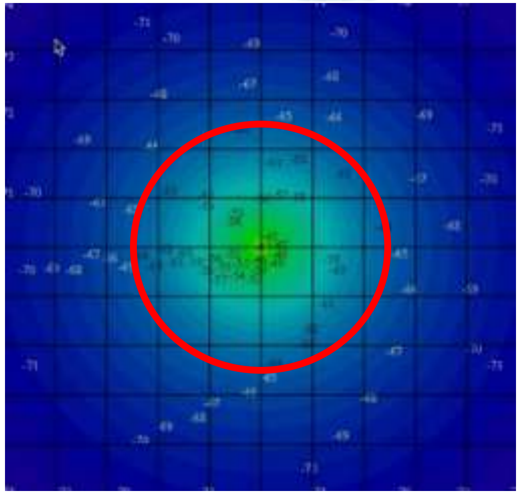
- Three APs would cover up to ~100-wide, and out to ~300m away
- Better separation for better channel separation and lower ACI/CCI
- If one AP fails, there will be a gap

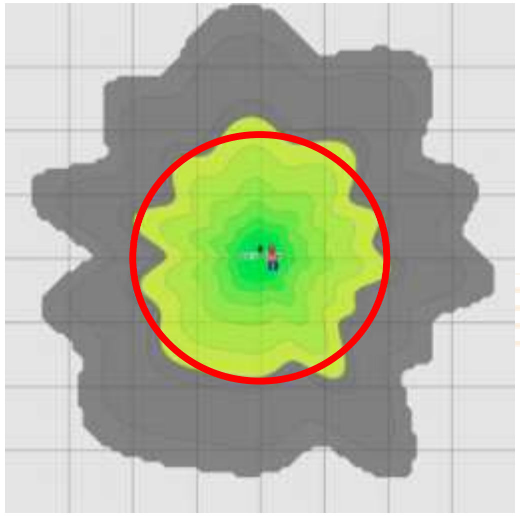
100% Overlap

- Overall distance out doesn’t change based on AP density
- One AP can fail and still have 100% coverage
- Higher AP density results in higher ACI/CCI to account for

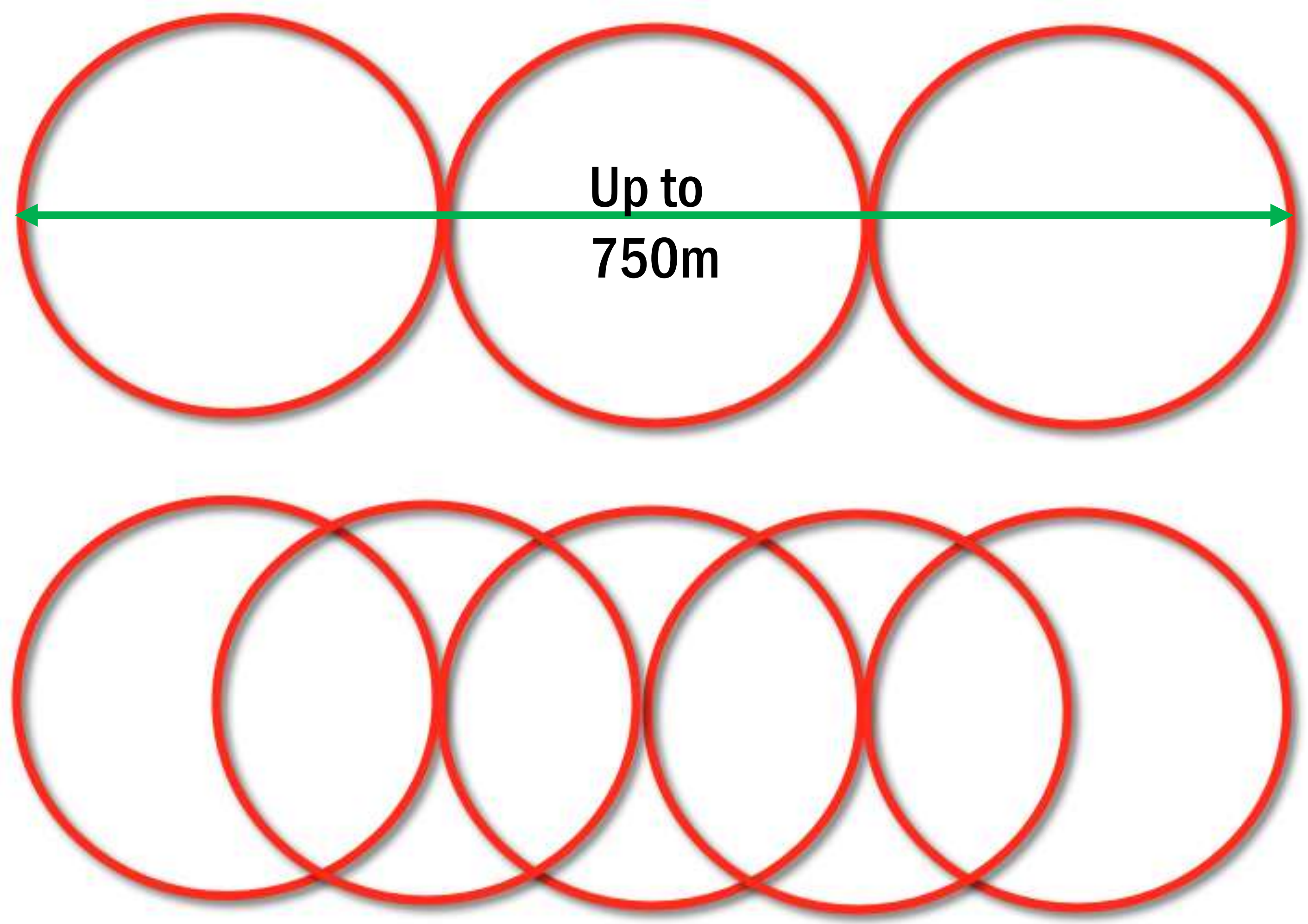
AP-565/365 - General Design Guidance

- AP-365
  - In general, the AP-365 can be though of to reliably produce a 100-125m radius of outdoor coverage (line of sight, barring any trees, buildings, etc).
  - If no overlap is required, AP-365s can be planned with spacing of ~200-250m
  - If the plan is to deploy in a courtyard or campus with trees, this distance should be halved (depending on the tree density)
  - Mounting height ideally should be at approx 4-6m above ground. The AP-365 is viable anywhere up from 1m and below 20m.
- Pole Mount versus Wall Mount
  - Pole mounts should use the AP-270-MNT-V1
  - Wall mounted AP-365s should use the AP-270-MNT-V2
- Ceiling Mounts
  - If the ceiling is parallel to the ground, the AP-270-MNT-H2 can be used
  - If the ceiling is not parallel or sloped relative to ground, the AP-270-MNT-H1 or AP-270-MNT-H3 can be used





AP-565/365 - General Design Guidance



Top-Down views of AP coverage

No Overlap

- Three APs would cover up to 600m distance
- Better separation for better channel separation and lower ACI/CCI
- If one AP fails, there will be a gap

100% Overlap

- Would take five APs to cover the same distance
- One AP can fail and still have 100% coverage
- Higher AP density results in higher ACI/CCI to account for

AP-567/367 - General Design Guidance

– General Guidance

  – Is a directional AP (90deg x 90deg)

  – Relative to heading, the perpendicular coverage (sides) of the AP-367 are approx 30-40m wide on each side, whereas the parallel coverage can cover out to 200m to a client

  – If no side to side overlap is required, they can be planned along a wall with spacing of ~60-75m

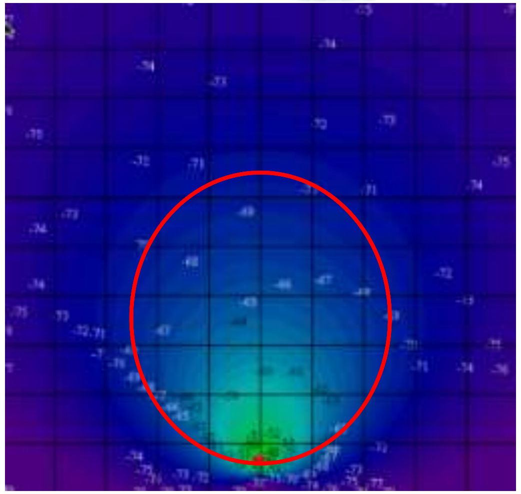
  – Mounting height ideally should be at or below 7.5m above ground aimed straight out parallel to the ground. For every 5m above 7.5m, downtilt the AP ~5 degrees

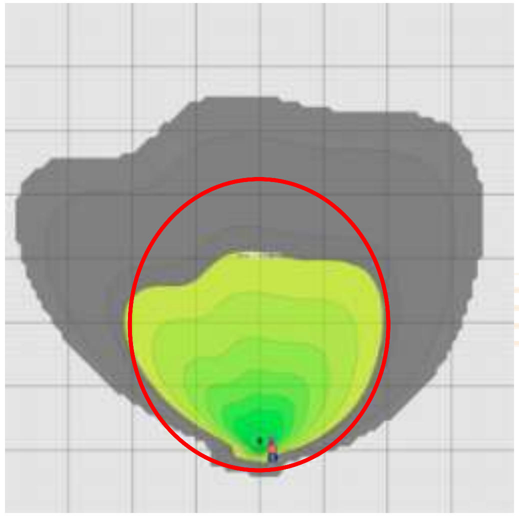
  – AP-367 can also be used with ceiling mounts (AP-270-MNT-H1/H2) for a tighter downtilt omni application

– Mounts

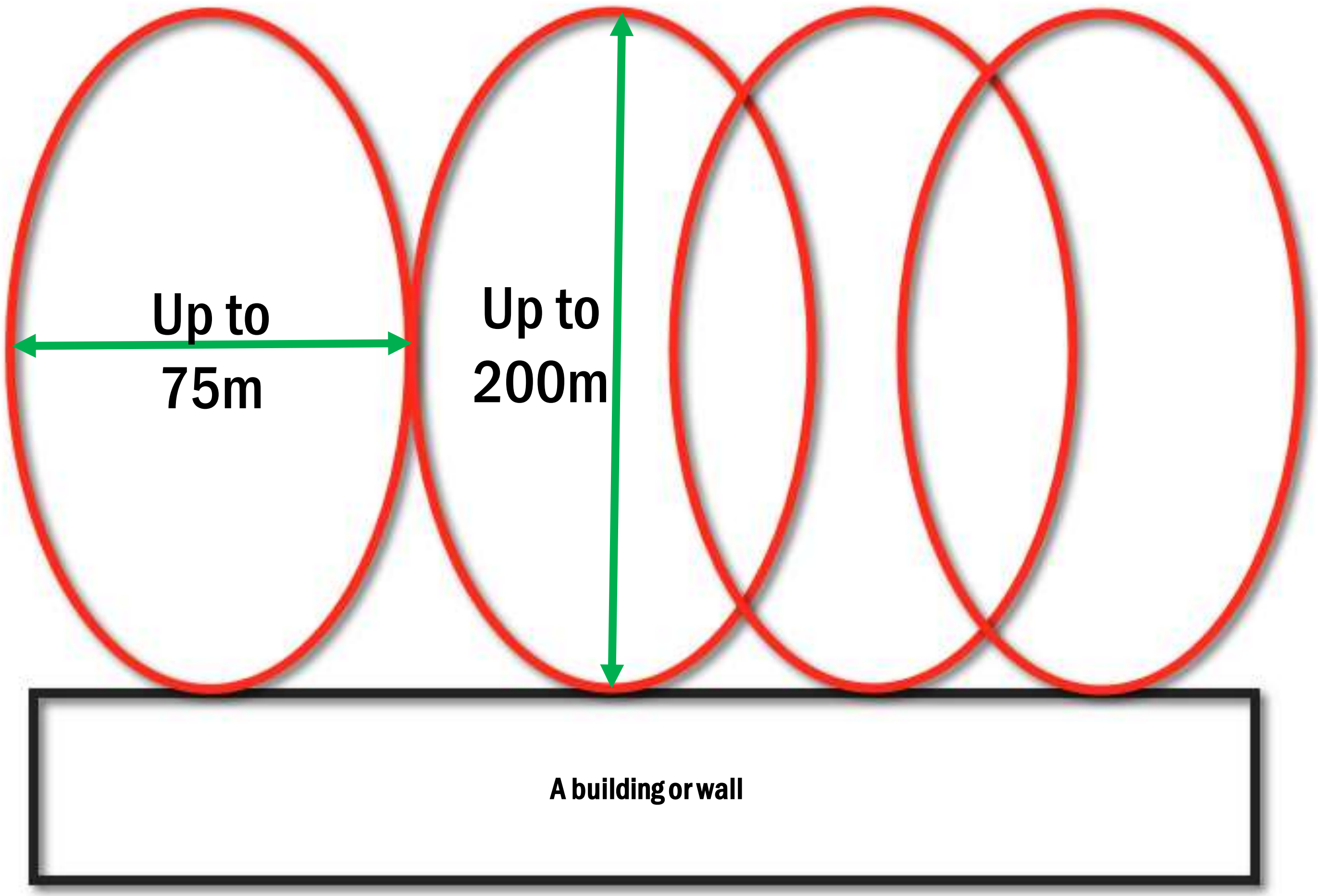
  – Wall mounts below 7.5m should use the AP-270-MNT-H2

  – Any pole or wall mounts above 7.5m should use the AP-270-MNT-H1 or AP-270-MNT-H3





AP-567/367 - General Design Guidance



Top-Down views of AP coverage

No Overlap

- Three APs would cover up to ~75m wide, and out to ~200m away
- Better separation for better channel separation and lower ACI/CCI
- If one AP fails, there will be a gap

100% Overlap

- Overall distance out doesn't change based on AP density
- One AP can fail and still have 100% coverage
- Higher AP density results in higher ACI/CCI to account for

6 - Mesh

What, exactly, is 'Mesh'?

– In Aruba-speak, it's whenever an AP talks to another AP (aka wireless AP bridge)
  - L2 Topologies (non-routing mesh)
  - VLAN Aware
  - Bridge (IAP and AOS) or Tunnel (AOS only)
  - Supports Open and WPA2-PSK encryption (please don't use open!)
  - Mesh radios can also broadcast client ESSIDs (though generally not recommended)
  - All Aruba APs support mesh, some hardware is more capable than others (more on that later)

– Most Enterprise WLAN vendors support mesh, and are built around similar L2 topologies
  - Plumbing is generally the same (L2) but have different metrics and algorithms to build topologies
  - Larger opportunities with larger mesh requirements need detailed assessments and evaluations to determine viability

Terminology Eyechart (different names but similar themes)

– Aruba Terminology

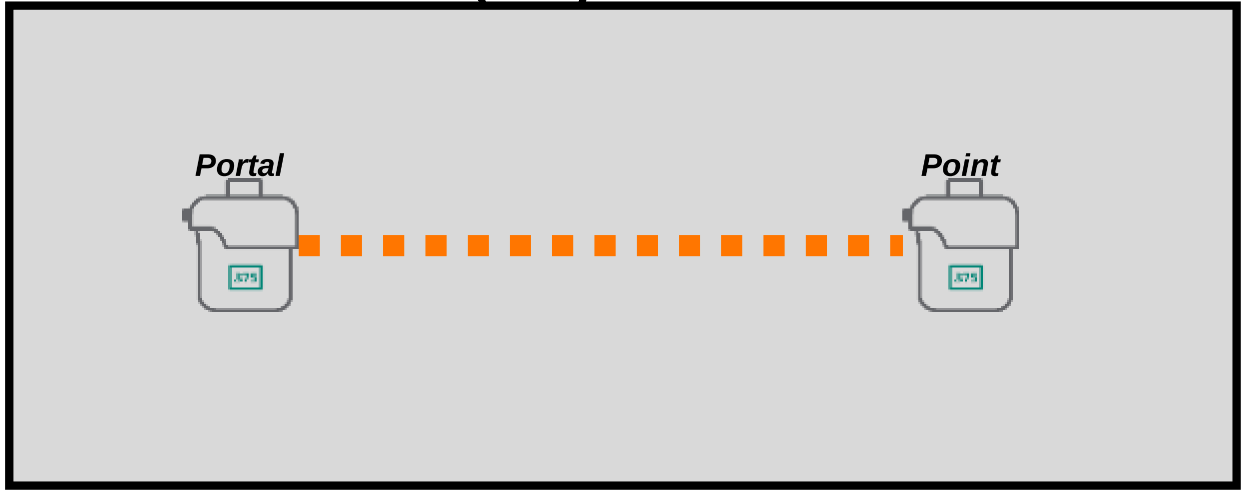
- Portal – AP supporting mesh wired to the network (MPP or Mesh Portal Point in older docs, yes that's dumb)
- Point – AP supporting mesh that is not wired to the network, where 'uplink' is over mesh (MP or Mesh Point)
- Mesh SSID (MSSID) – Is in essence, the 'ESSID' used by the Mesh APs within the same cluster
- Mesh Cluster – Is an AP Group construct that defines which MSSID is assigned to the Mesh APs.
- Bridge Mode – All wired frames are bridged out the ethernet interface (means matching L2 VLANs)
- Tunnel Mode – All wired frames are tunneled inside GRE to the controller (NA for Instant Mesh)
- Mesh Tree Notational Terms - 'Parent' is the upstream mesh neighbor, 'Child' is the downstream neighbor
  - As such, a mesh AP may have multiple 'Children', but can only have one 'Parent'

– Other Vendor's Terminology

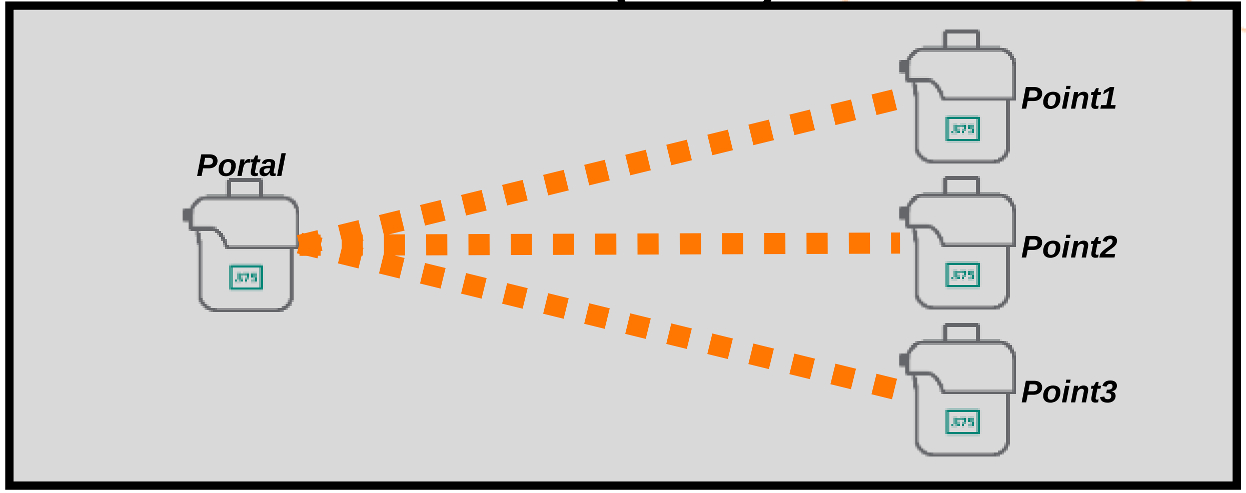
- Cisco – Root AP (aka Portal), Mesh AP (aka Point)
- Ruckus – Root AP (aka Portal), Mesh AP (aka Point), eMesh AP (Mesh AP wired through mesh)
- Meraki – Gateway AP (aka Portal), Repeater AP (aka Point)
- Other WLAN vendors have the same general templates in terms of terminology in their L2 bridging solutions

Different Basic Mesh Topologies

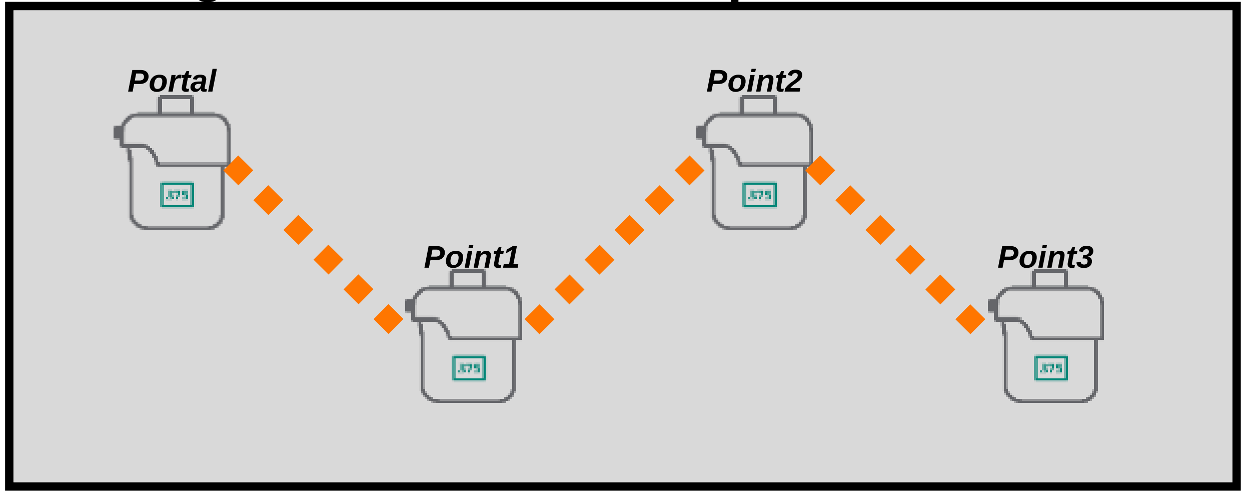
- Point to Point (PtP)



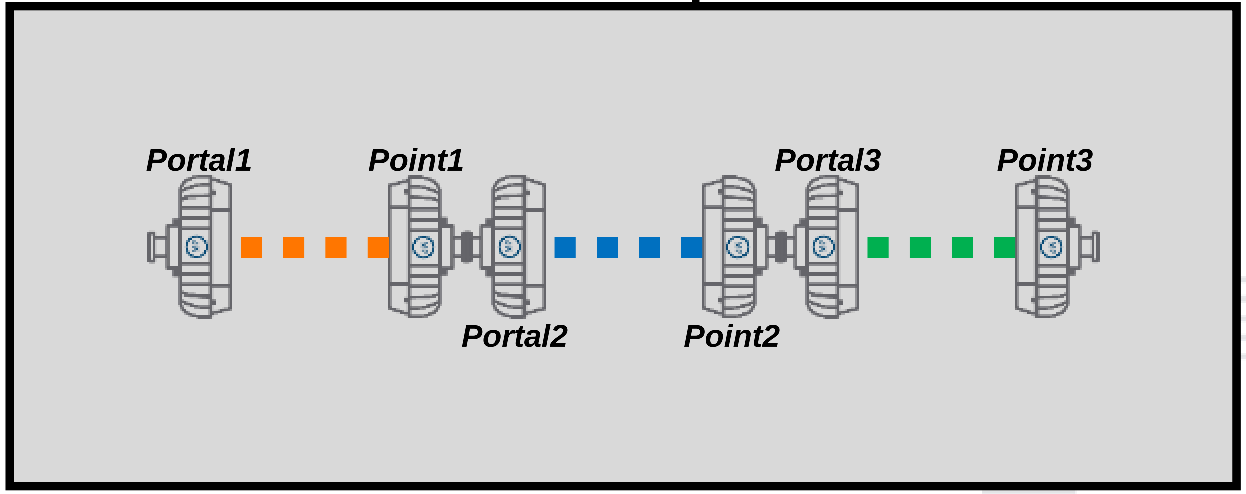
- Point to Multi-Point (PtMP)



- Single-Channel Multi-Hop Mesh

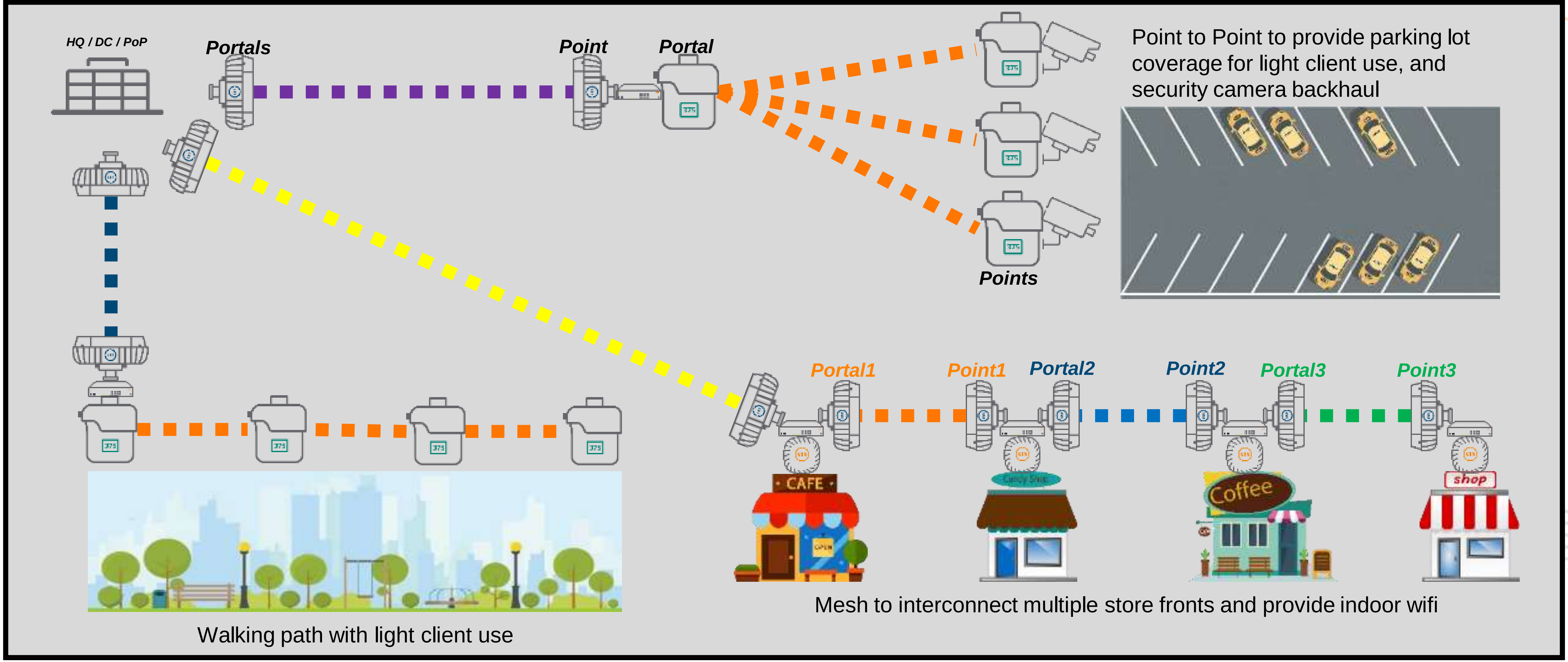


- Multi-Channel Multi-Hop Mesh



Mesh Topologies – Mix and Match For Fun

- **More complex mesh deployments can be different combinations, based on the requirements**



Factors in Picking a Solution and Topology

- Environmental
  - Obstructions / Clearance – Fresnel Zone, fencing, tree (AND species!), ugly giant bags of mostly water
  - Noise / Interference – interference dictates SNR, nearby interferers (ACI, CCI, out of band interferers)
  - Range – frequency and FSPL, antennas, regulatory rules, MIMO
- Performance
  - Range – customer requirements usually dictate maximum range or application
  - Applications (high or low bandwidth, latency sensitivity, unicast or multicast)
  - Packets Per Second (PPS) - for applications like Voice
  - Users – number of users needed to carry, how does that impact radio utilization
- Accessibility
  - Data (network, fiber, cellular) – physical connectivity requirements or how the data gets back and out
  - Power (AC, PoE, Solar) – most deployments are PoE or AC, solar is an option (requires more info)
  - Location (rooftop, poles, lighting) – installation partners are critical here

How to Calculate Mesh Throughput (Very Basic)

– Point to Point is fairly easy: calculate the pathloss, build the link budget, map SNR to MCS rate

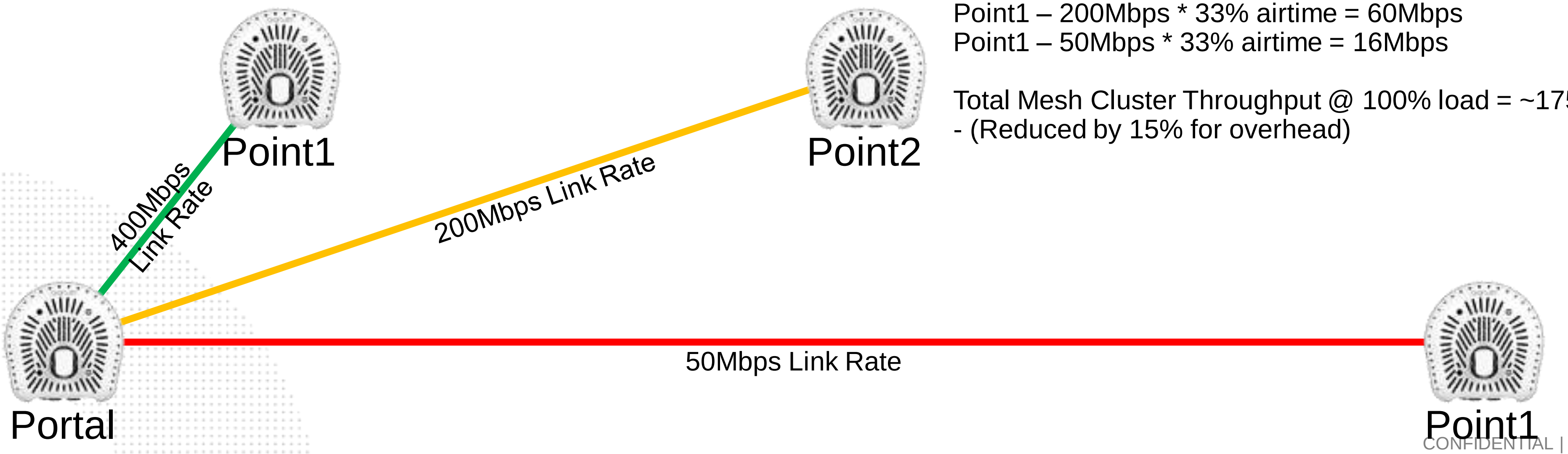
– Point to Multipoint is more challenging

  – To a large degree, the mesh cluster total bandwidth is somewhat constrained by the lowest link SNR

  – Mesh points should be able to hear each other to avoid hidden node issues (Aruba can help address this with adjusting the CTS/RTS thresholds, configurable on the AP)

  – Load for a mesh cluster should assume full load for worst case (reality is load will be highly variable)

  – Each additional mesh point can reduce overall throughput by approx. 5% in overhead



Point1 – 400Mbps * 33% airtime = 130Mbps
Point1 – 200Mbps * 33% airtime = 60Mbps
Point1 – 50Mbps * 33% airtime = 16Mbps

Total Mesh Cluster Throughput @ 100% load = ~175Mbps
- (Reduced by 15% for overhead)

BOLO - Complications Using Mesh

- **Remember that when you use mesh, you are STILL consuming 5Ghz spectrum, so the more mesh you use, the less of the 5Ghz spectrum is left over for clients. Mesh is never free in Physics!**
- All mesh APs must first be provisioned and/or configured on the wire first (there is no way to provision the mesh on the AP itself before connecting to the network)
- Mesh should be carried over the 5Ghz radios, the 2.4Ghz spectrum is not reliable and consistent enough to get stable and predictable performance
- Mesh can carry native and VLAN tagged traffic, but the native VLANs on each side of the link MUST match on the AP's uplink ports, and the native VLAN used be configured in the AP System Profile
- If the network and mesh links are expected to carry multicast traffic, be aware that the mesh points will carry that traffic at the basic rates!
  - Avoid using mesh with multicast video traffic!
  - If the wired network carries multicast traffic, look to prune that traffic or block it from going over the mesh if possible
- Backhaul of raw video feeds can lead to high duty cycle channel utilization, even if the camera's bandwidth is well below the available bandwidth over the link

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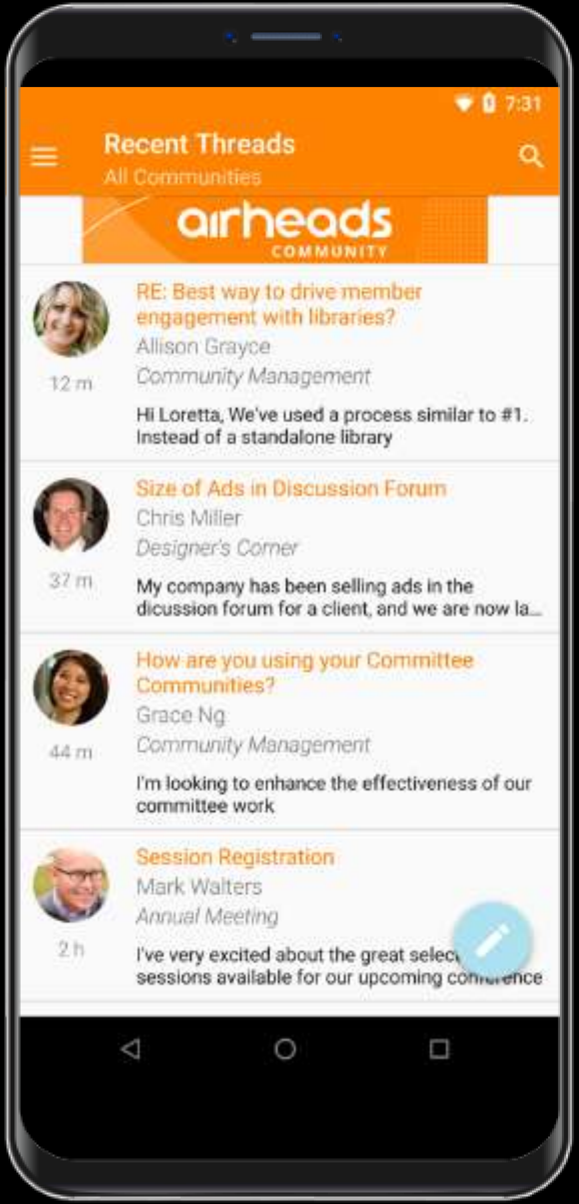

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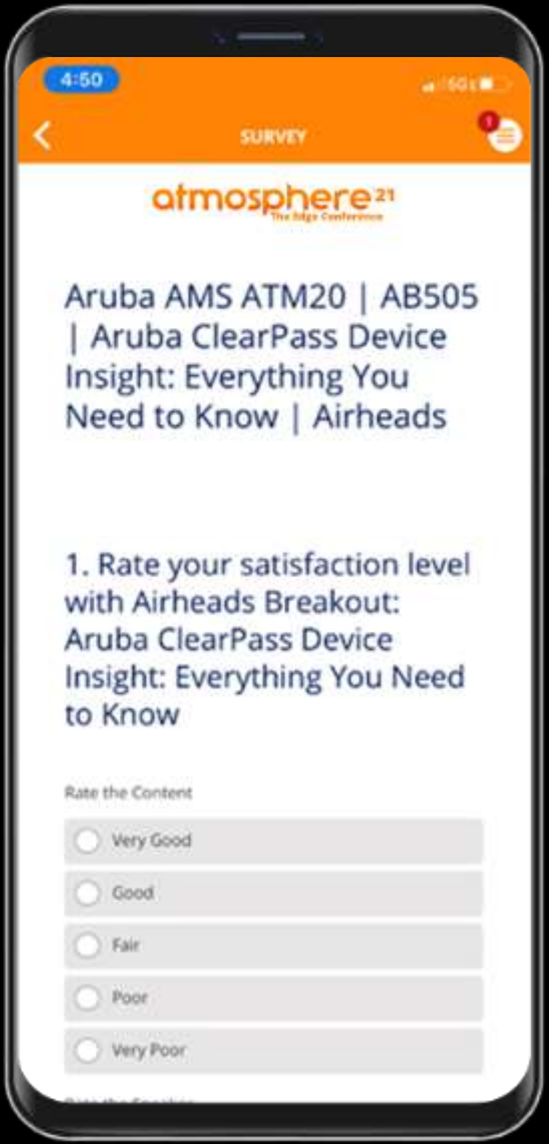

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atmosphere'22

MAKING CONNECTIONS, ANYWHERE

Thank you

jerrod.howard@hpe.com
@jerrodhoward

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