Outdoor Network Engineering

Chuck Lukaszewski, CWNE #112, ACMP, AWMP

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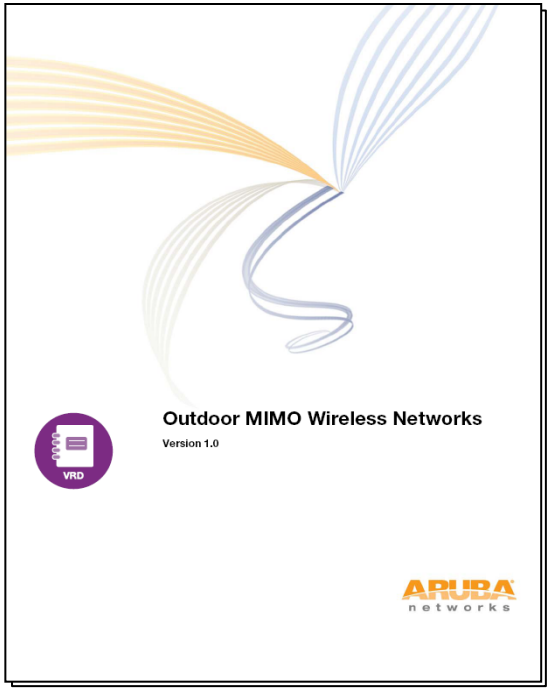
Agenda

- **Access Network Examples**
  - University Campus Pervasive Coverage
  - High Density Outdoor Plaza
- **Mesh Network Examples**
  - K-12 Temporary Classroom PtMP Mesh with MST200
  - High-availability MST200 Configuration
  - US Marine Corps FOB High-Capacity Mesh with ArubaOS
- **Installation Best Practices**

Welcome!



This seminar presents the Outdoor MIMO Wireless Networks VRD

Please download this document from the Aruba Design Guides web page

http://www.arubanetworks.com/technology/design_guides.php

Please ask questions as we go

Thank you for attending

Aruba Outdoors - Bridging or Routing?

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Campus Extension

- WLAN outdoor extension
- Controller-based solution
- Single-hop links

Outdoor AP175

Municipal & Industrial

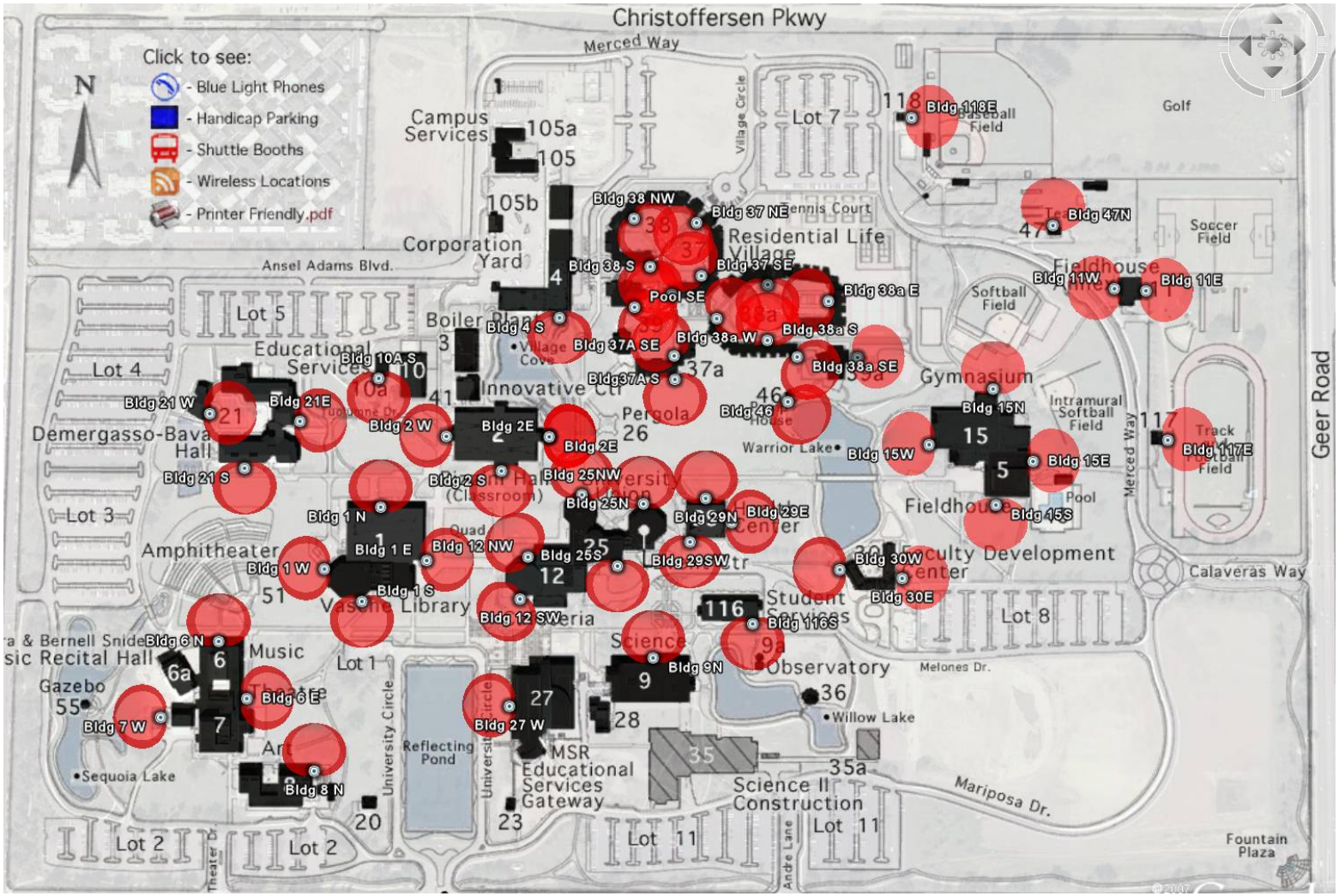
- Wide Area Networks
- Decentralized approach
- Multiple mesh hops required

MSR Mesh Routers

Customer Example - Access

University Campus Extension

Typical College Campus = 0-1 Hops



Campus Extension Planning

- **Requirements broad - often historical buildings**
  - Often starts with school perimeter for security
  - Common areas for student access – quads, hotspots, arenas
  - Parking lots and garages for safety
- **AP count is driven by AP's / User for dense areas**
  - Design Goal is typically 3-4 AP's per user in dense areas
  - Design Goal is typically 2 AP's per user in sparse areas
- **For planning include 10 db for design margins**
  - Due to foliage on most U.S. campuses in common areas

Extending the Campus Network Outside

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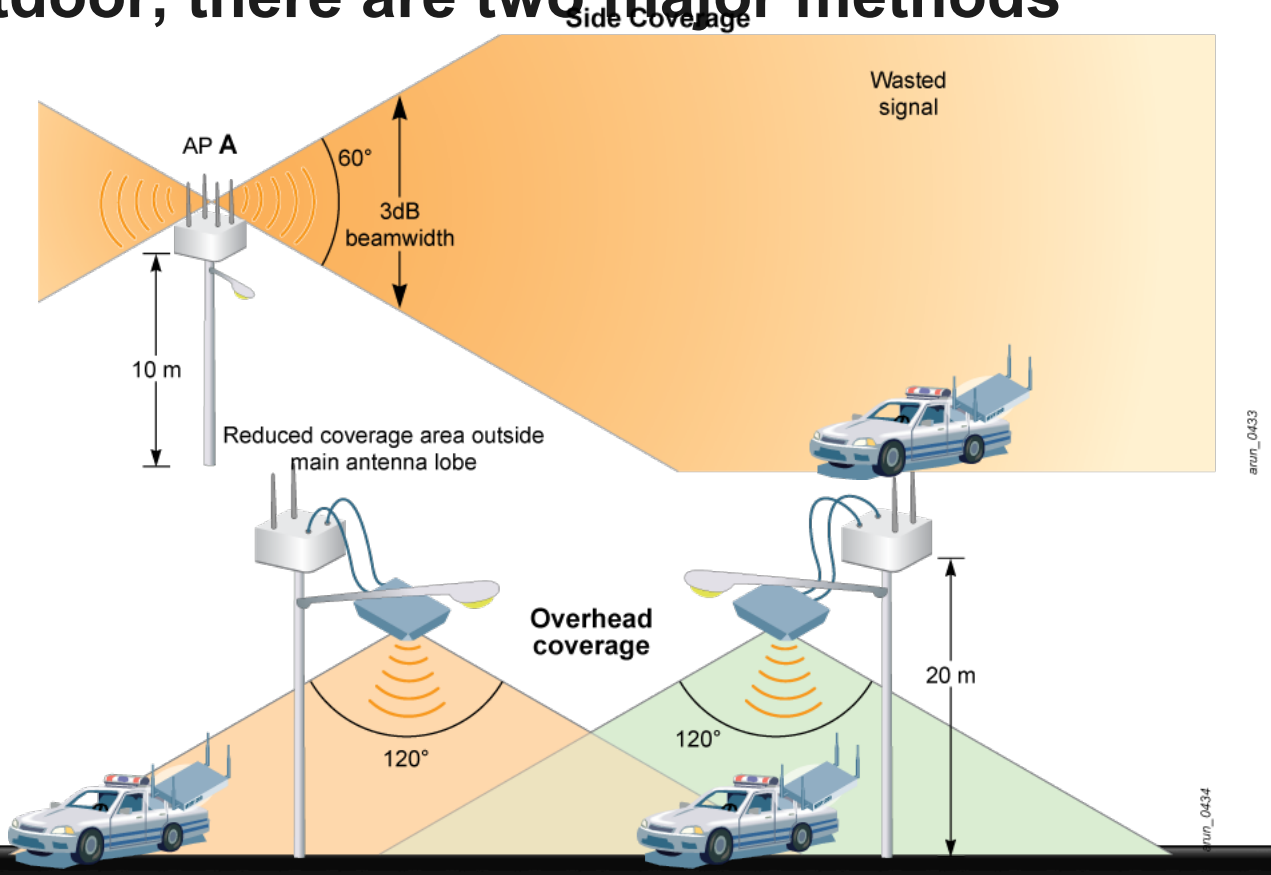
Outdoor Wi-Fi
- Ruggedized Enclosures
- 802.11n Wireless Backhaul & Access
- Centralized Multi-Purpose Mgmt

Coverage Strategies

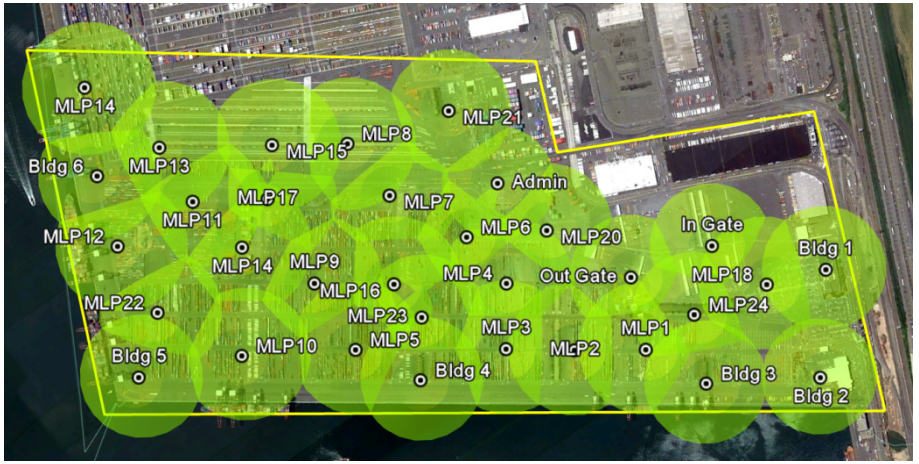
A coverage strategy is a method of delivering access-layer signal into a wireless service area

For outdoor, there are two major methods

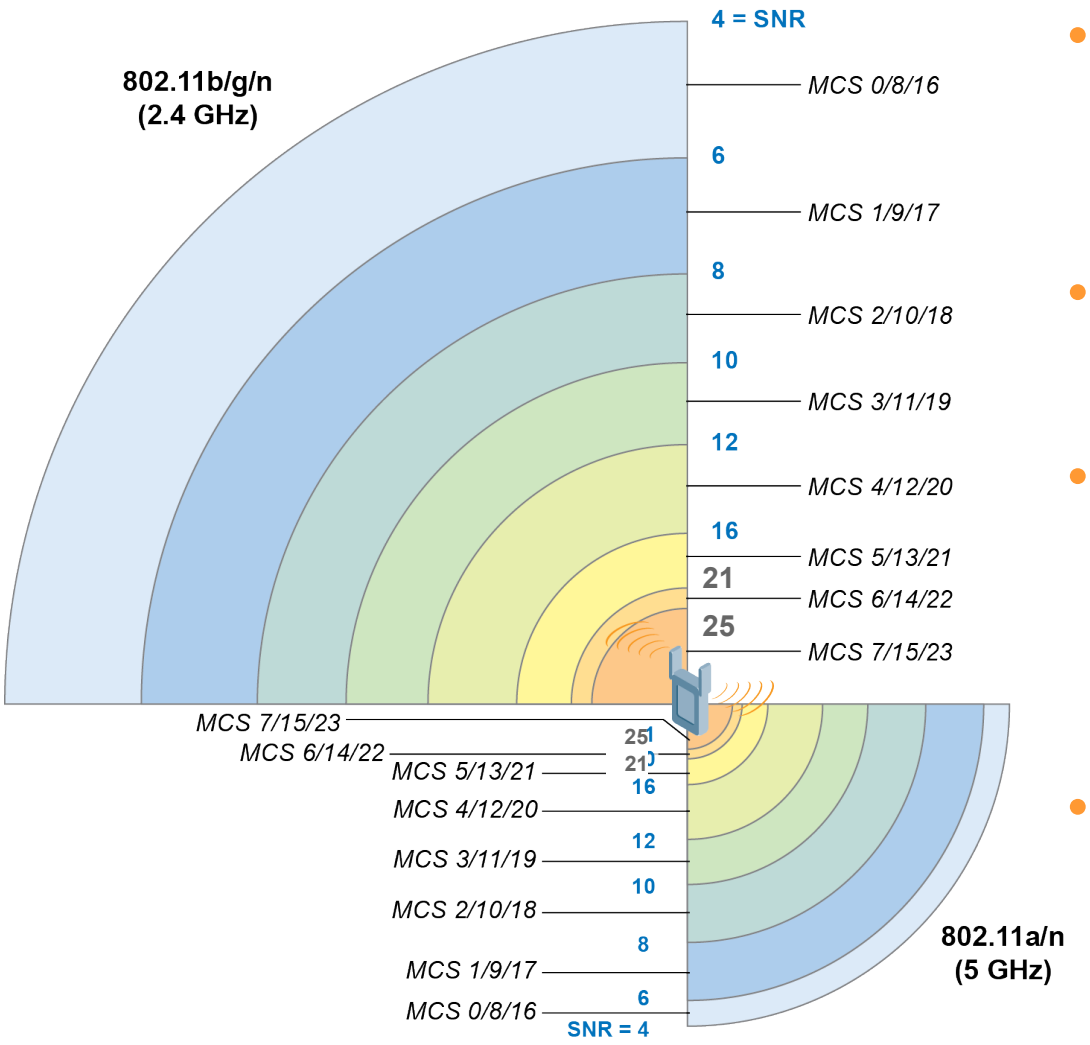


Dense vs. Sparse Coverage

Just like Indoors – Capacity is determined by AP Density

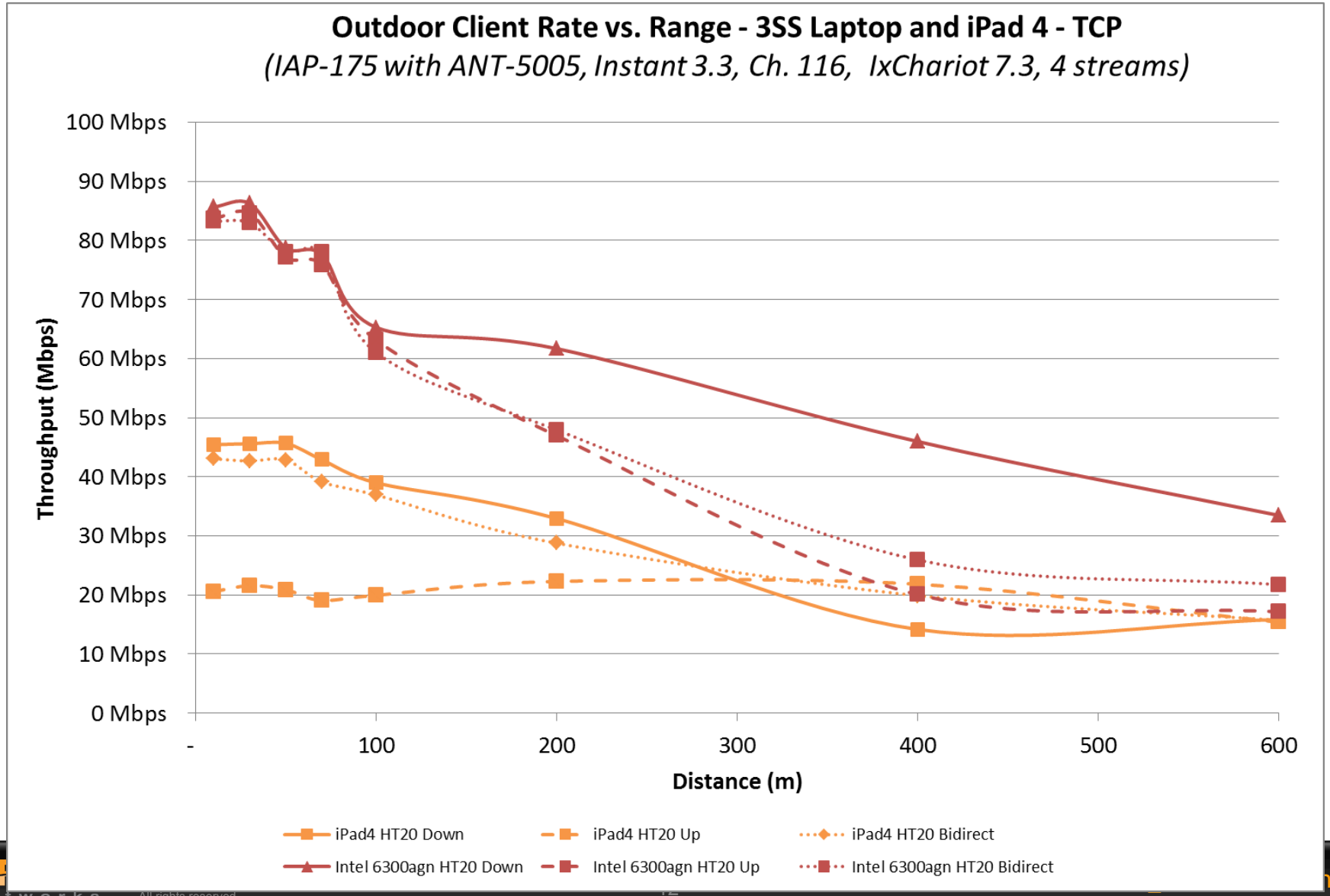


Selecting a Target Cell Edge Data Rate



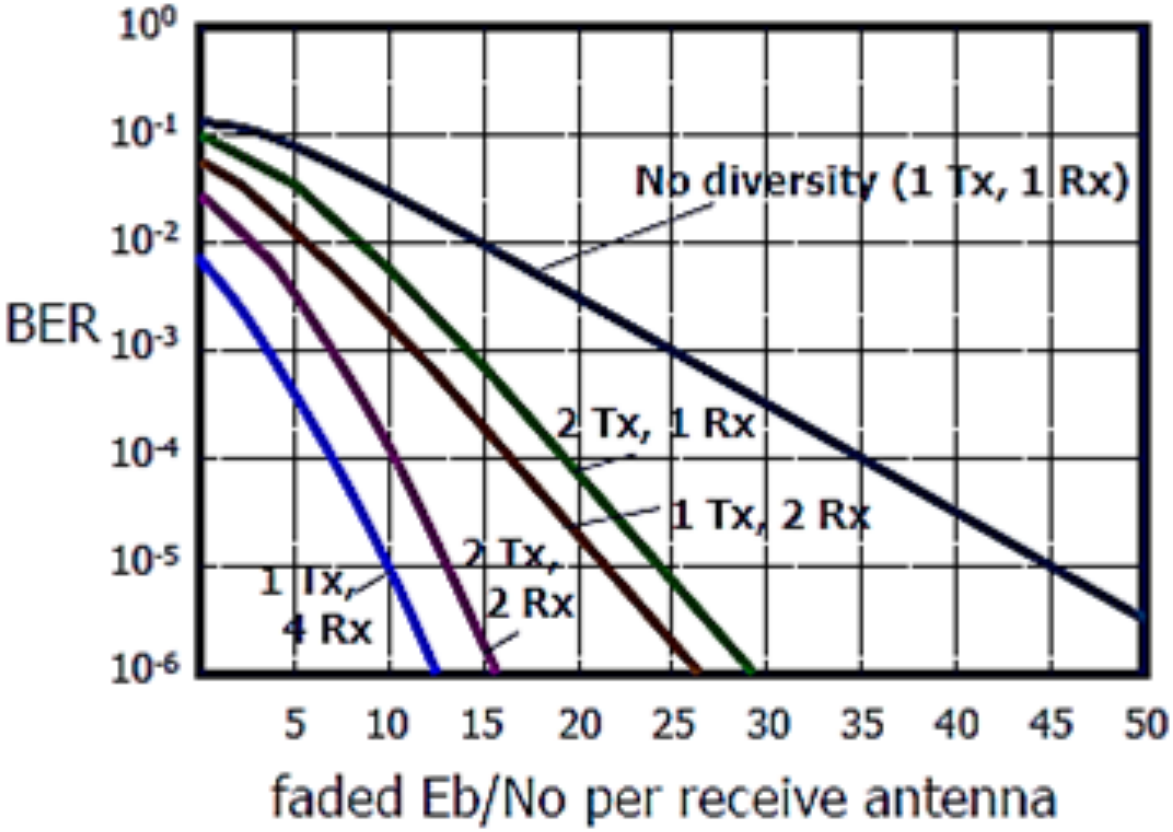
- Each 802.11 data rate requires minimum SNR to demodulate
- Applications typically determine data rate
- Manufacturers of some voice & data devices recommend "minimum SNR"
- Aruba recommends MCS2/10/18 minimum for coverage reliability

Client Rate vs. Range to 600m

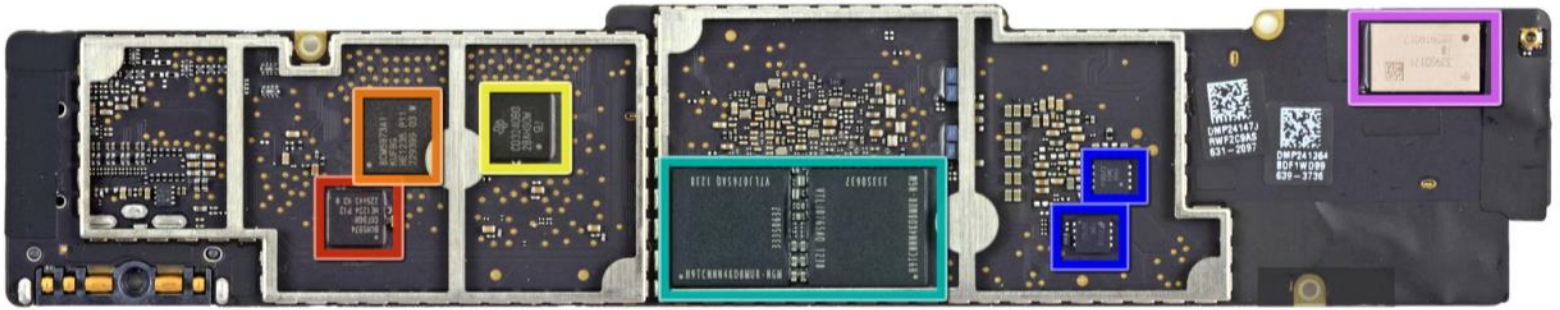


Bit Error Rates by Radio Chain Count

- Additional radio chains provide RX diversity in 802.11n
- 1x1:1 SISO devices do not have any diversity
- 1x1:1 SISO devices are vulnerable to multipath fading



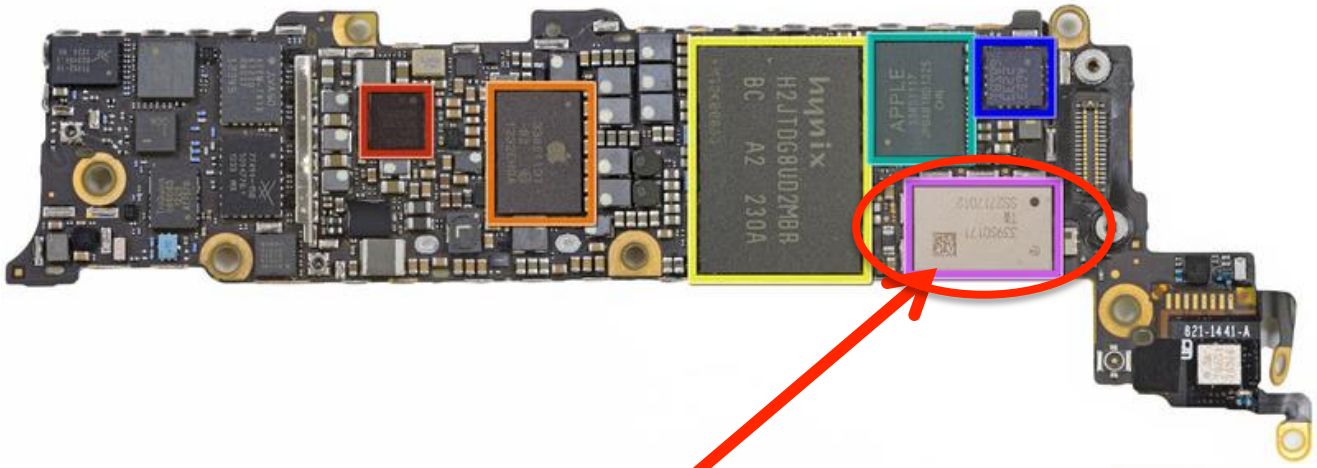
iPad4 Teardown



Murata 339S0171 Broadcom BCM4334 WiFi Module

iPhone 5 Teardown

All iPhones and all iPads are 1x1:1 devices with 1 antenna chain



ONLY 1 Antenna!!!

iPhone 5
WiFi Radio

http://www.ifixit.com/Teardown/iPhone+5+Teardown/10525/3

Galaxy S4 Teardown

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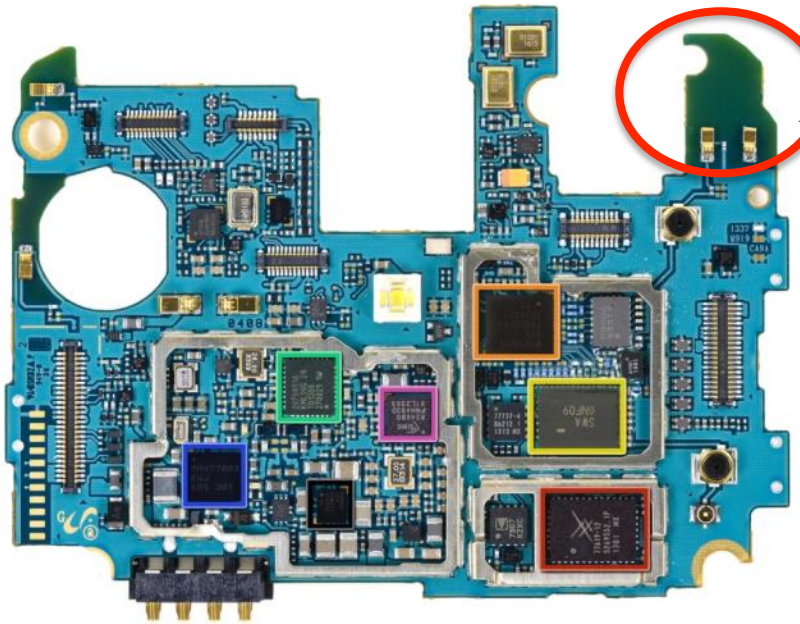
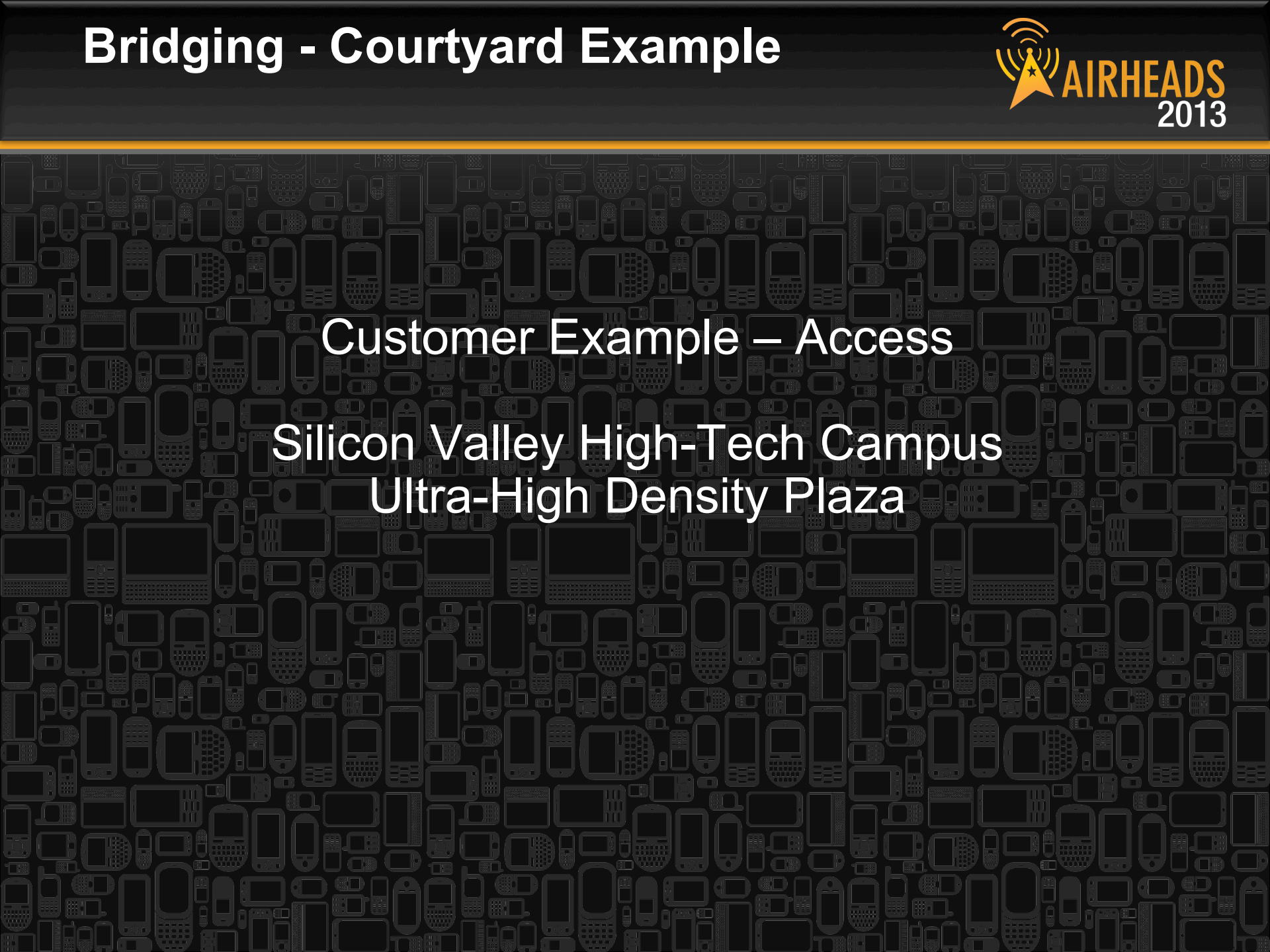
BCM4335 5G WiFi MAC/baseband/radio

Skyworks SKY85303-11 2.4G Bluetooth 256QAM??



Bridging - Courtyard Example



Customer Example – Access

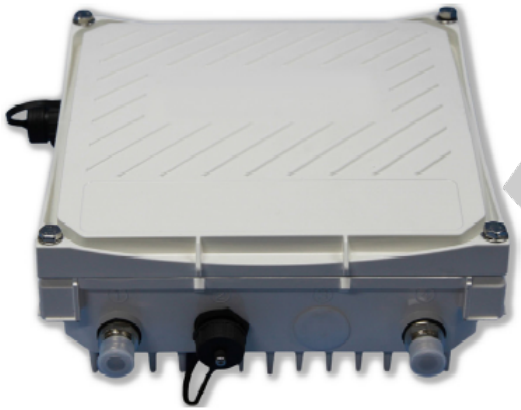
Silicon Valley High-Tech Campus
Ultra-High Density Plaza

Customer Requirements

- **Association capacity = 3,000 devices**
  - Dual band (2.4 GHz and 5 GHz) client access
  - Heterogeneous mix of make / model / WNIC devices
- **Active Users = 33% of associated devices**
- **Leverage existing controllers & AirWave**
- **Minimize interference with the indoor network**

Coverage Zone - Overhead

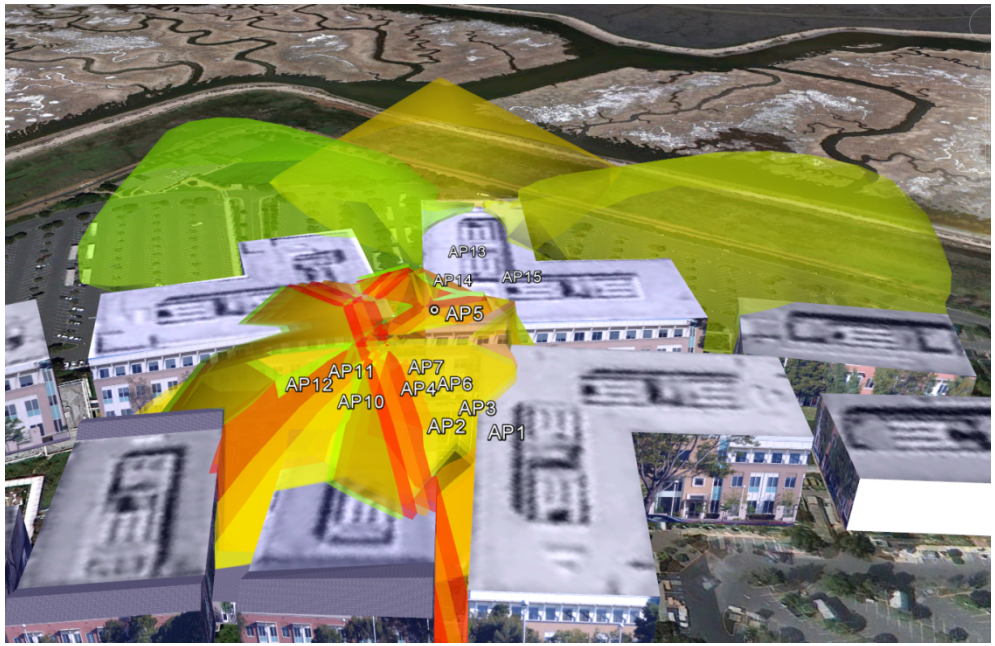
Aruba (I)AP-175

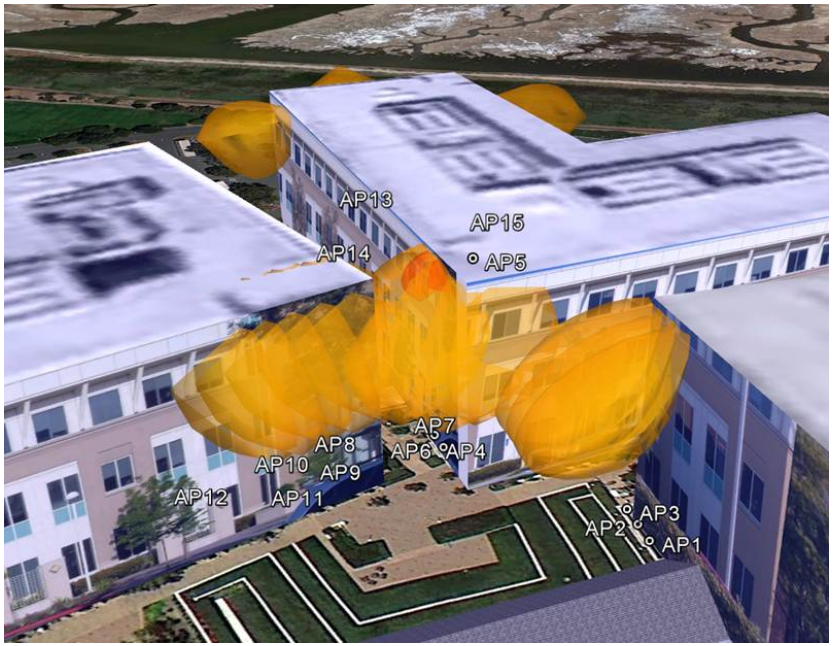


802.11n Outdoor AP

- **Performance**
  - Dual radios, 2.4-GHz and 5-GHz
  - 300Mbps data rate per radio
- **Purpose built**
  - IP66 and NEMA 4X protection
    - Changes to allow IP66/67 rating coming soon
  - POE, AC and DC versions
- **Unprecedented Visibility**
  - Always-on visibility to noise sources
  - Integrated wireless security on all radios
- **Flexible Deployment**
  - Point-to-Point and Point-to-Multipoint
  - Mesh for wireless backhaul

3D Model of RF Coverage Solution





- 12 APs mounted to parapets of 3 buildings
- Highly directional D607 sector antennas 60°H x 60°E
- Combined mechanical & electrical tilt = 30°
- 3D model on right shows -55dBm cell edge

Capacity Planning Analysis

- **Required Association user capacity = 3,000 devices**
- **Required Active user capacity = 800 devices**

Band	Associated User Capacity	Active User Capacity
2.4GHz	4 APs * 3 channels * 150 devices = 1,800 devices	33% of Associated Capacity / 4 channel reuses = 150 devices
5GHz	12 APs * 1 channel * 150 devices = 1,800 devices	33% of Associated Capacity / 1 channel reuse = 600 devices
Total	**3,600 devices**	**800 devices**

Installation View from Ground

Building 1 Close-up

Building 1 Installation

Building 2 Closeup

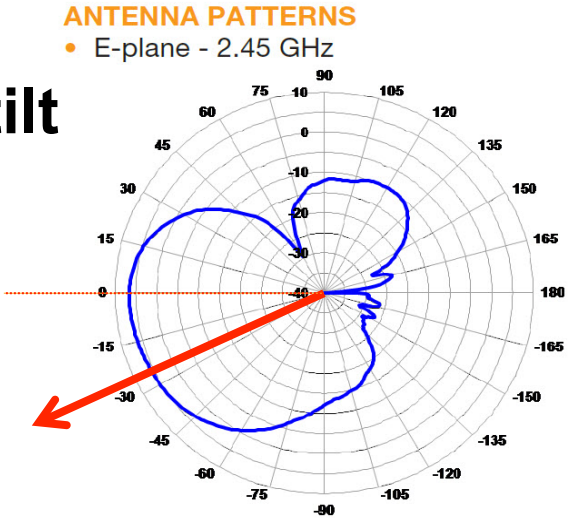
Aggregate Coverage SNR

2.4 GHz

5 GHz

Installation Gotchas

- **Four Aruba antenna models have <u>significant</u> natural / electrical downtilt**
  - ANT-2x2-D607, AP-ANT-18
  - ANT-2x2-D805, AP-ANT-17



Bridging Case Study

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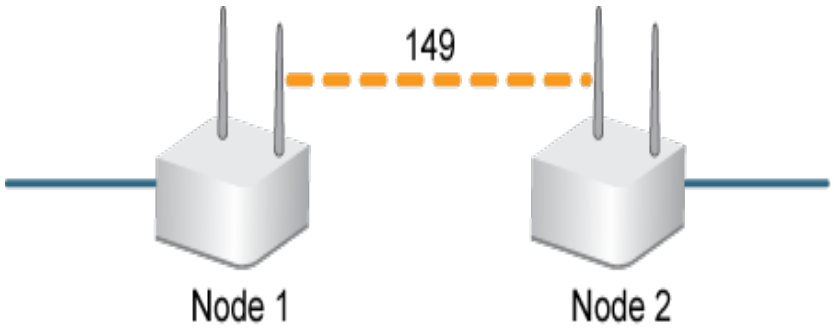
Customer Example – Simple Bridging

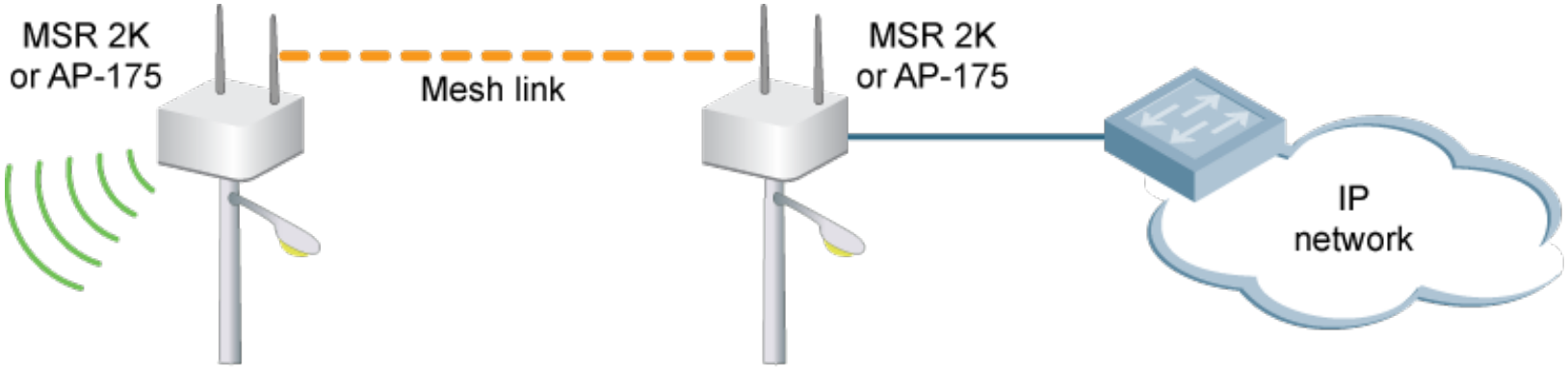
K – 12 School Campus
Temporary Remote Classroom Backhaul

Bridging for Campus LAN's

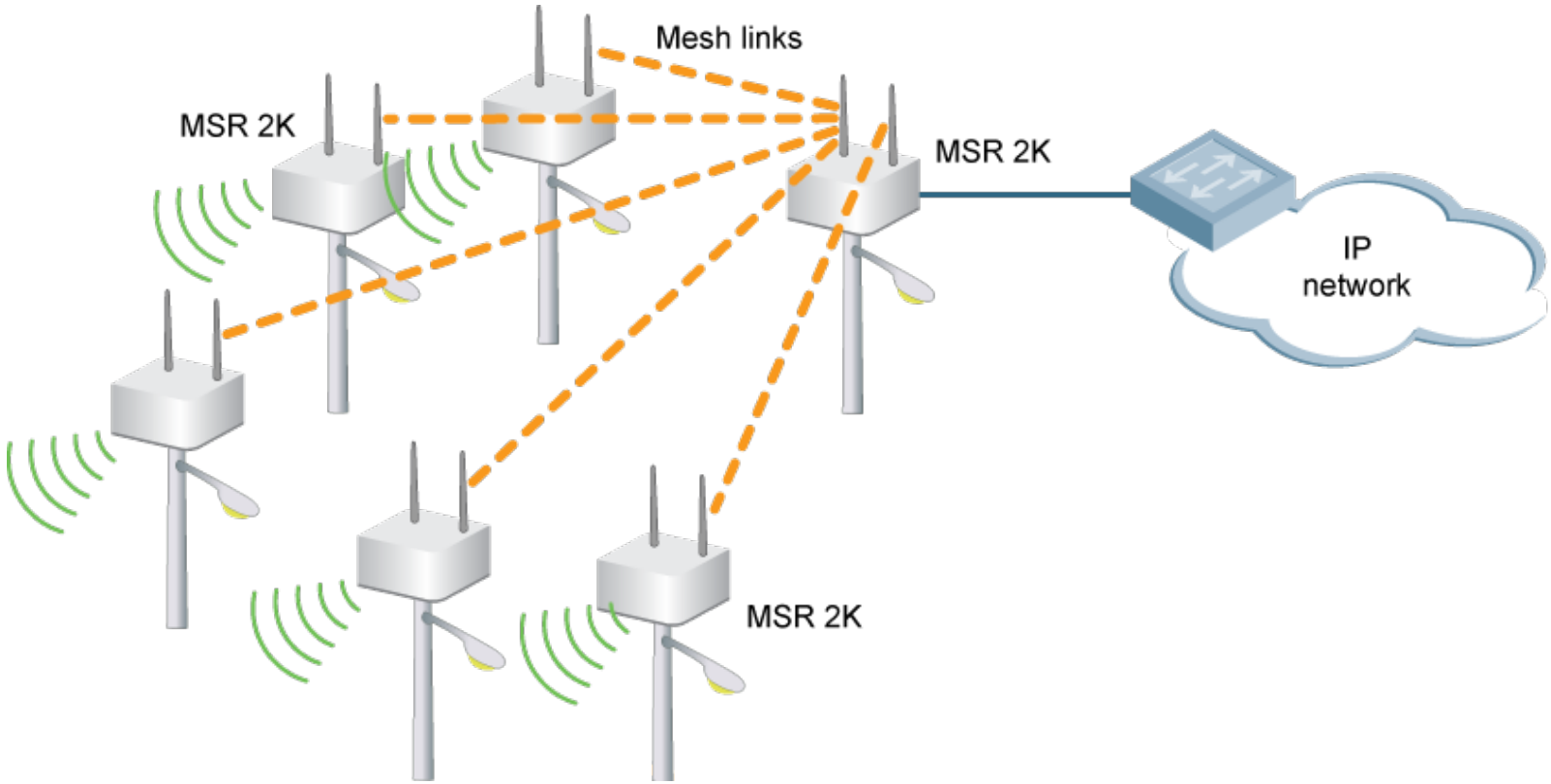
- **Simple products and simple installations**
  - MST-200 (AirMesh) installed by today's integrators
  - Typically - mounting rights require no extra permissions
- **Bridging transparently extends ArubaOS**
  - Outdoor network is transparent to Aruba controllers and AP's
  - Role based users and existing policies simply extended
  - Spanning Tree Algorithm used to prevent broadcast loops
- **Installation locations tend to be reachable**
  - No towers or climbing installations required
  - Building roof-tops generally have some access method

Terminology - Point to Point Bridging

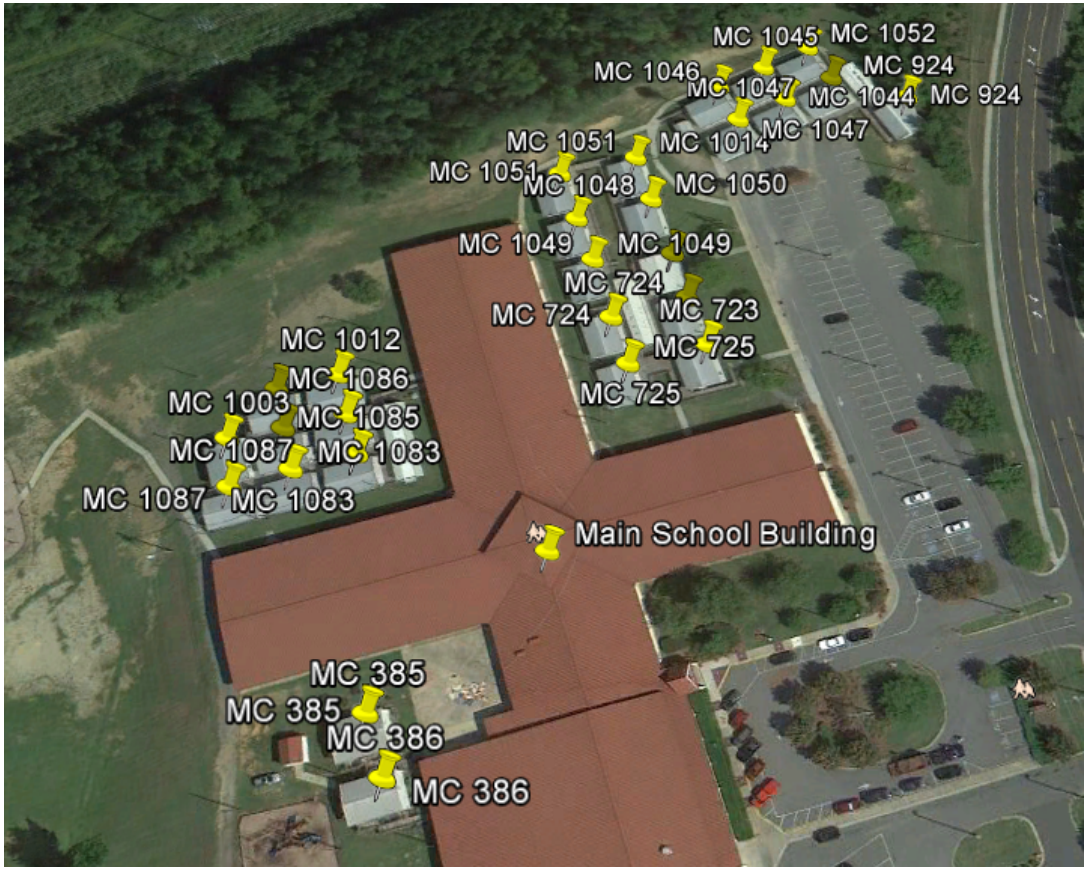




Terminology - Point to Multi-point

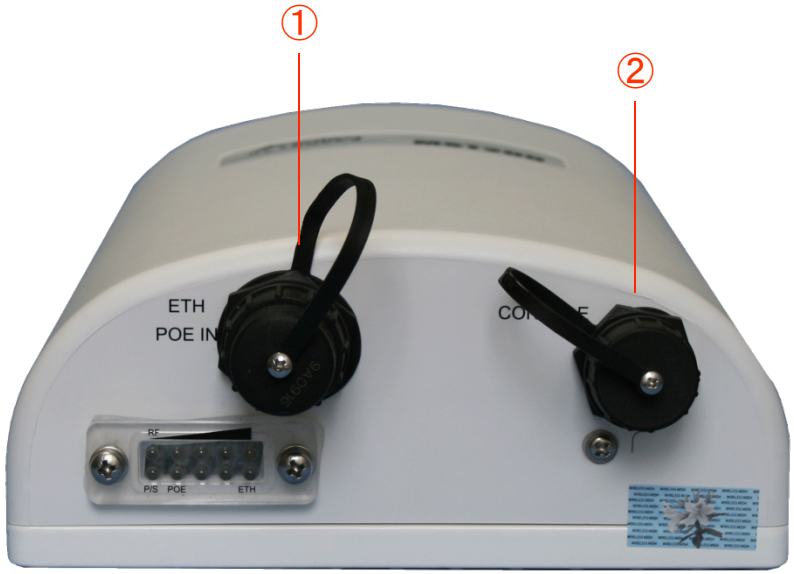


Simple Outdoor Point to Multi-Point



- **Portable Classrooms require network access**
  - Trailers change location and number yearly - wireless is a fit!

Outdoor Bridging – MST 200



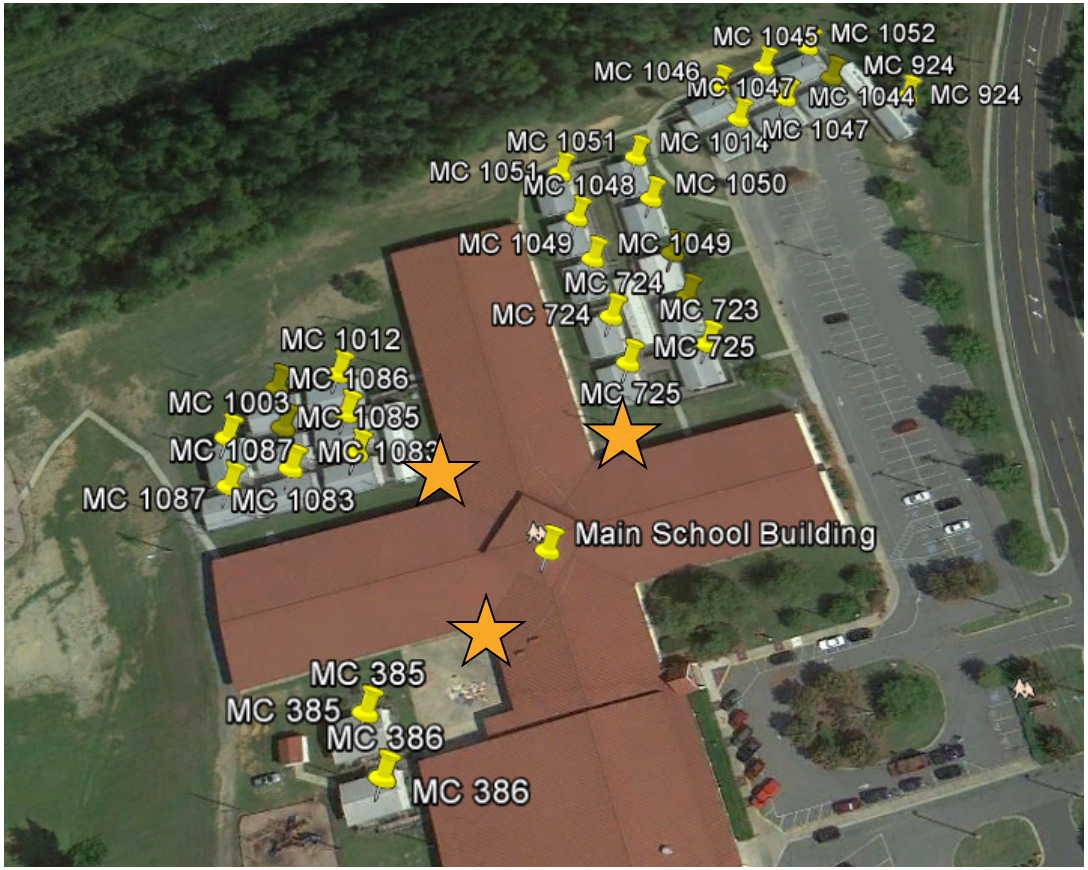
1	Console Interface	2	POE IN Ethernet Interface

Main School – Portal Installation

- **Simple products and simple installations**
  - MST-200 (AirMesh) can be installed by today's integrators
- **Key Design Considerations**
  - Channel assignment / re-use

Mobile Classroom - Installation

Simple Outdoor Point to Point

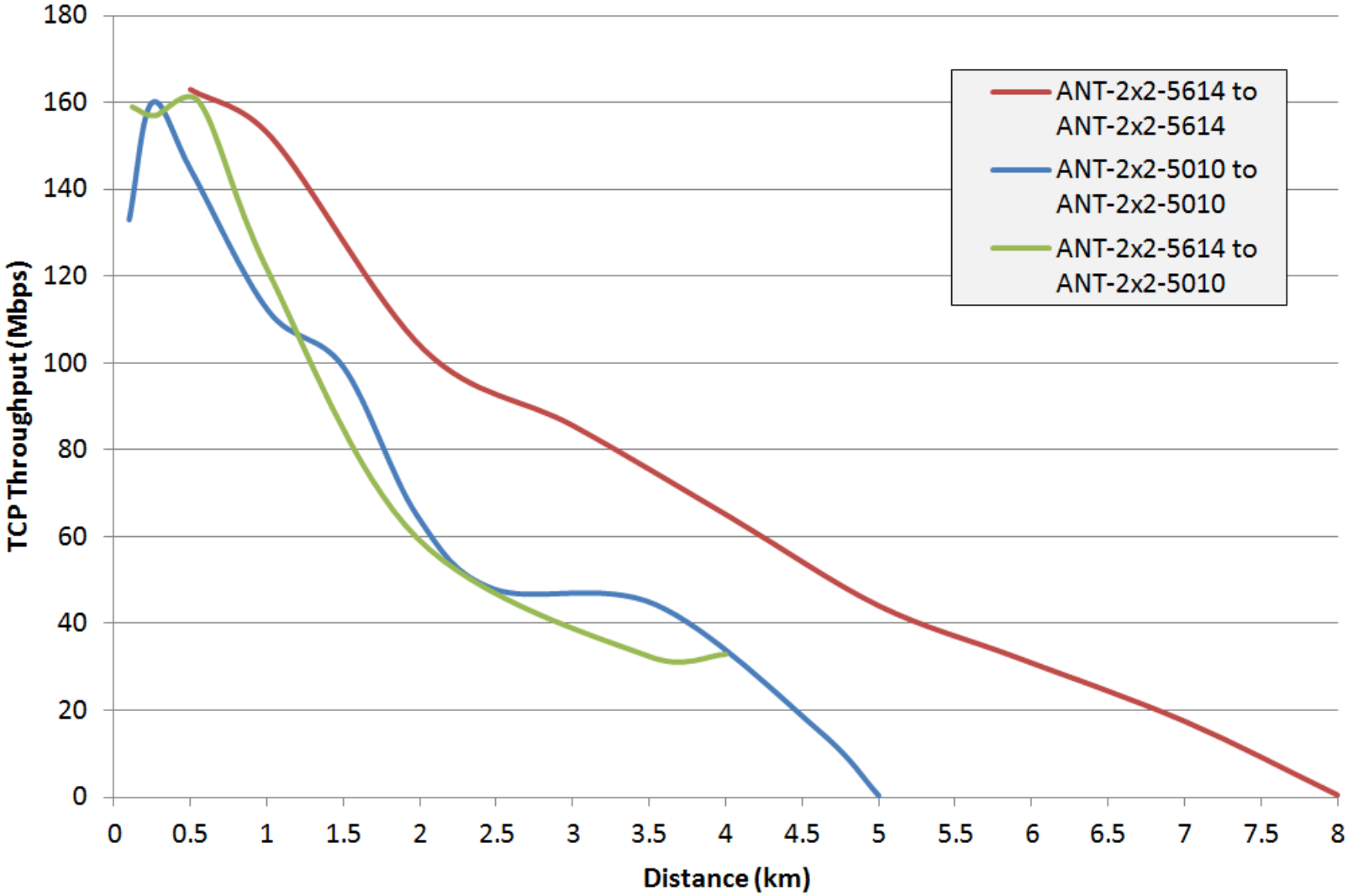


- **Use Buildings to isolate RF for channel re-use**
  - Portals face trailers but below roof-line to avoid ACI / CCI

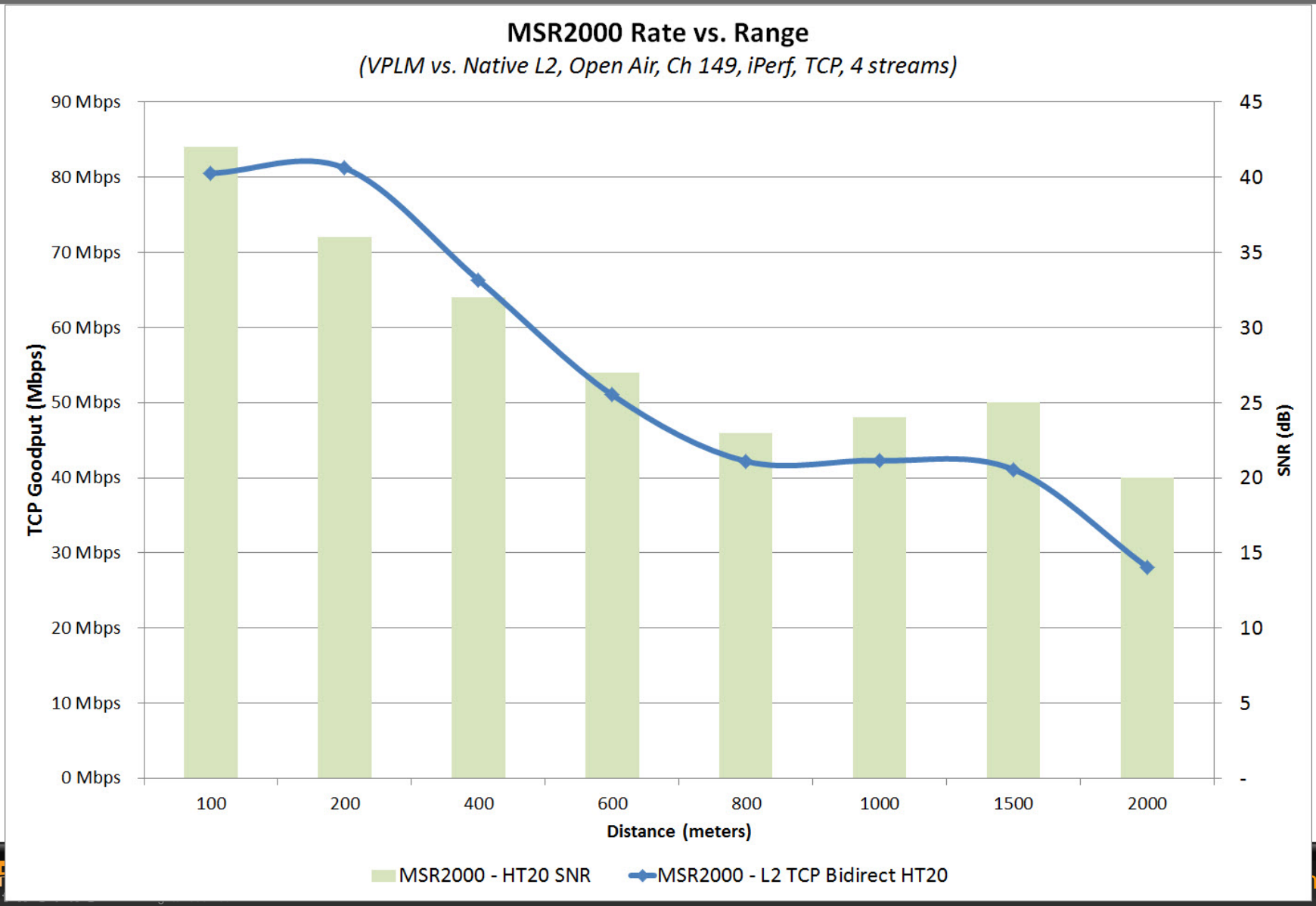
Capacity Planning

- **For maximum capacity we need channels**
  - Use 20 MHz channels not 40 MHz - more channels available
- **Example of 20 trailers in one area:**
  - Five UNI III channels are available for use outdoors in U.S.
  - ~80 Mbps of TCP good put out to a few hundred yards
  - ~80 / 20 = Four Trailers per channel = ~20 Mbps per trailer
- **Node to node contention factors**
  - Similar to classrooms – at 5 active nodes = 20% degradation
  - Consider one portal and four remote trailers = 5 nodes
  - The 20 Mbps per trailer now drops 20% = ~70 Mbps
  - At 10 nodes per channel expected throughput = ~60 Mbps

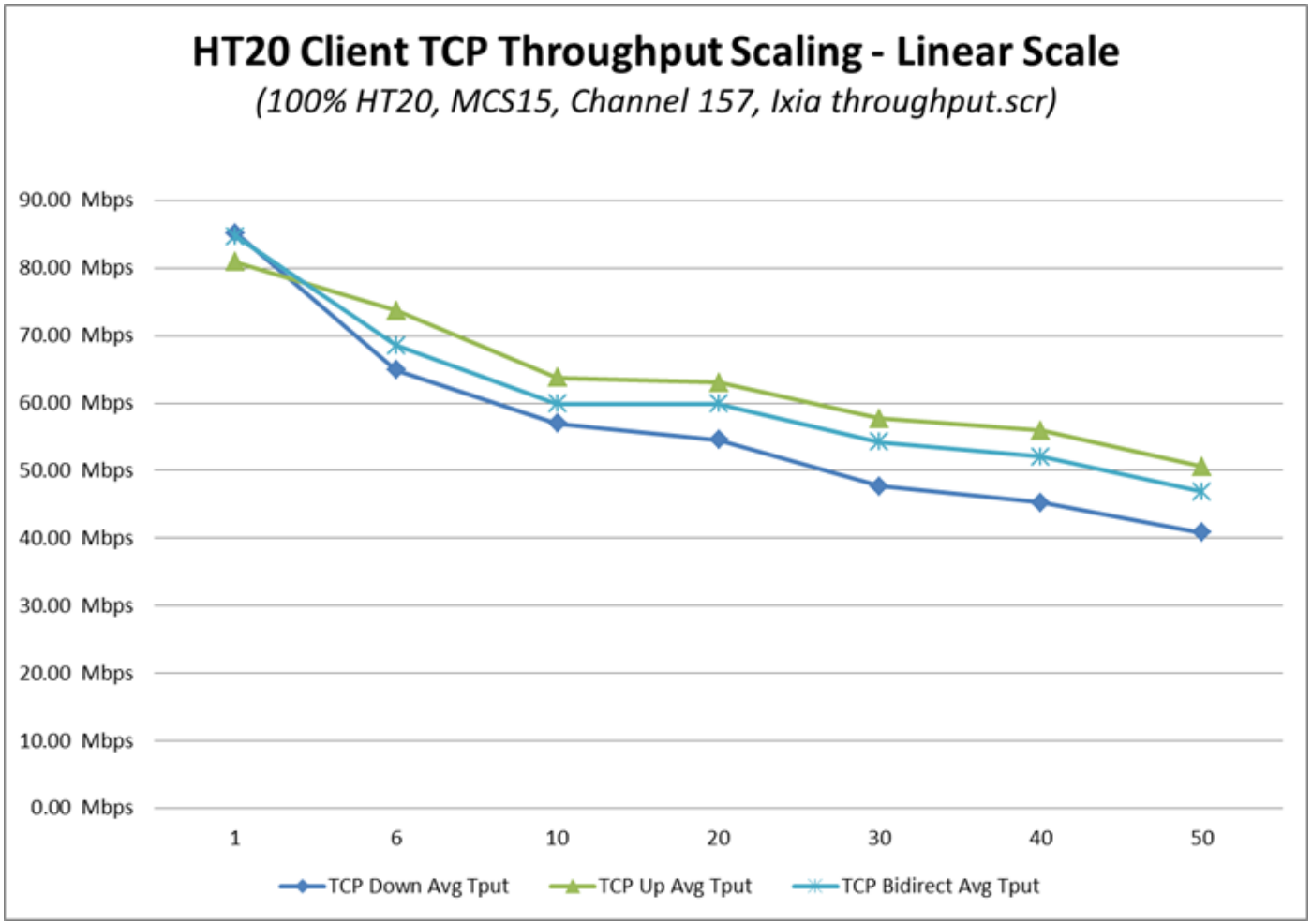
Aruba MIMO Antennas – Range Test



Mesh Rate vs. Range to 2KM



Adjusting for Multiple Mesh Points



Bridging – High Availability

Lab Example – Bridging

Redundant High Availability
Layer 2 Bridging Setup

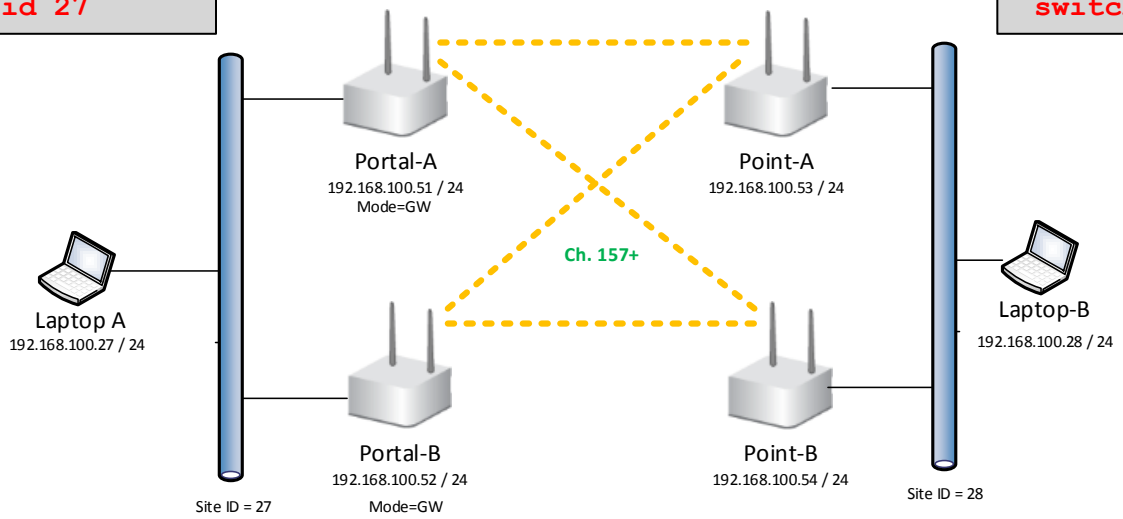
Customer Requirements

- **Fully redundant Point to Point link**
- **Capable of withstanding loss of 1 radio on either side of the link – simultaneously**
- **Full HT40 or HT20 throughput**
- **Layer-2 transparent bridging supports ArubaOS**

Network Topology & GigE/0 Config

```
interface gigabit-ethernet 0
 mode gateway
 switchport access vlan 1
 switchport site-id 27
```

```
interface gigabit-ethernet 0
 mode access
 switchport access vlan 1
 switchport site-id 28
```



- Quantity (4) MST-200 single-radio bridges
- Configured with default L2 operation
- Different site IDs configured for each L2 segment
- Common mesh channel, PSK and mesh ID

Testbed Setup

- MST200s should be separated by 2 meters horizontally or 1 meter vertically
- Two Cat6/5E STP runs can share a single building penetration for power & data
- MST200 includes mount kit will direct-attach to building or standard mast hardware.

Mesh Status Before Simulated Failures

Mesh View from Portal-A

```
Radio 0 Wireless mode:na-ht40plus, Wireless channel:157
InterfaceName       PeerMAC           PeerHostName     PeerRadio State Time      LinkQuality DataRate RSSI SNR InputRate  OutputRate
dot11radio 0/wds 1  00:17:7b:27:70:09 Point-B          0         up    0:9:40    70%         270M     52   52  33.96 Kbps 11.65 Kbps
dot11radio 0/wds 2  00:17:7b:27:84:f7 Point-A          0         up    0:9:9     70%         270M     79   79  30.50 Kbps 5.53 Kbps
```

Mesh View from Portal-B

```
Radio 0 Wireless mode:na-ht40plus, Wireless channel:157
InterfaceName       PeerMAC           PeerHostName     PeerRadio State Time      LinkQuality DataRate RSSI SNR InputRate  OutputRate
dot11radio 0/wds 0  00:17:7b:27:70:09 Point-B          0         up    0:8:45    70%         270M     51   51  44.79 Kbps 25.11 Kbps
dot11radio 0/wds 1  00:17:7b:27:84:f7 Point-A          0         up    0:8:1     70%         270M     55   55  30.47 Kbps 6.92 Kbps
```

Mesh View from Point-A

```
Radio 0 Wireless mode:na-ht40plus, Wireless channel:157
InterfaceName       PeerMAC           PeerHostName     PeerRadio State Time      LinkQuality DataRate RSSI SNR InputRate  OutputRate
dot11radio 0/wds 7  00:17:7b:27:73:e9 Portal-A         0         up    0:9:31    66%         270M     58   58  37.59 Kbps 16.53 Kbps
dot11radio 0/wds 8  00:17:7b:27:8b:73 Portal-B         0         up    0:8:13    52%         270M     58   58  31.09 Kbps 1.35 Kbps
```

Mesh View from Point-B

```
Radio 0 Wireless mode:na-ht40plus, Wireless channel:157
InterfaceName       PeerMAC           PeerHostName     PeerRadio State Time      LinkQuality DataRate RSSI SNR InputRate  OutputRate
dot11radio 0/wds 7  00:17:7b:27:73:e9 Portal-A         0         up    0:10:15   67%         243M     52   52  44.63 Kbps 21.91 Kbps
dot11radio 0/wds 8  00:17:7b:27:8b:73 Portal-B         0         up    0:9:10    65%         270M     53   53  40.42 Kbps 22.13 Kbps
```

Demonstration Video

- We will demonstrate a high availability MST200 link surviving the disconnection of a random mesh point and mesh portal.

- Failover/convergence time for a lost node on the active traffic path is less than one second.

ArubaOS Mesh - Large Scale

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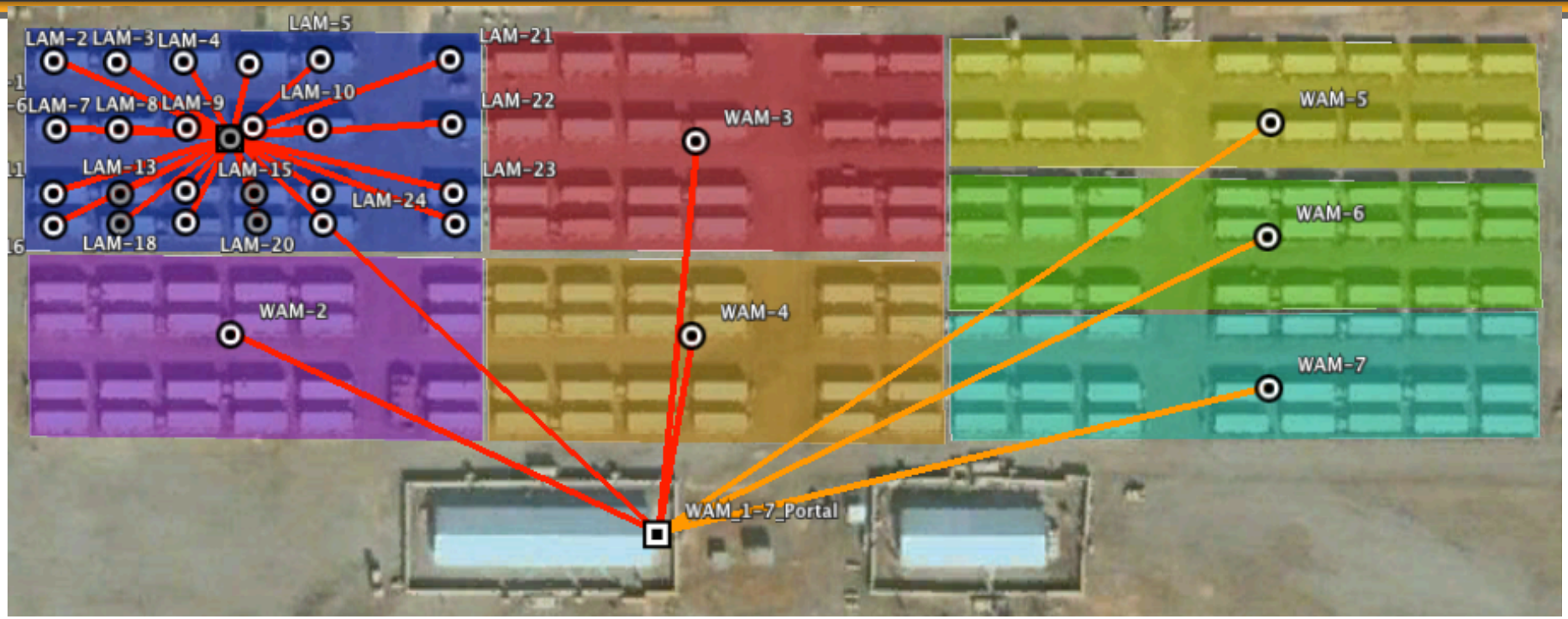
Customer Case Study – Access + Mesh

FOB Camp Leatherneck
Helmand Province, Afghanistan

US Marine Corps – High Density Access



Major applications:

- Morale, Welfare & Recreation (MWR) dept. funded the network, connect soldiers to their families at home

Ultra high capacity, high density access

- **Deployment**
  - AP-175 for WAM, and AP-85 for LAM
  - 20 – 25 AP-85s for typical LAM
  - 5 – 6 LAM clusters per WAM
  - 5 – 6 AP-175s for WAM links

The Users

Originally planned as Internet access for Marines at FOB
Major application today is voice (Skype, Lync, etc.)
WiFi access is inside barracks for practical reasons

Total ~900+ Aruba AP's serving ~20,000 users

WiFi Access Layer

- **802.11g WiFi is for users (2.4 Ghz)**
- **Antennas are placed inside some "cans" barracks**
- **Many users are far from the antenna – end of POD**
  - Lower signal quality than other "cans" that are closer
  - They use lower data rates – consume more air time
- **There are three channels available, 1-6-11**
  - "cans" contain signal well – so channel reuse viable
  - During busy hours congestion should be expected
  - We enabled a method for fair sharing of the air RTS/CTS
    - Side effect on a few older devices – but great benefits
  - Any transmitter in the 2.4 Ghz band should use 1-6-11
    - To avoid unnecessary interference – policies instituted

Heart of the Mesh Network

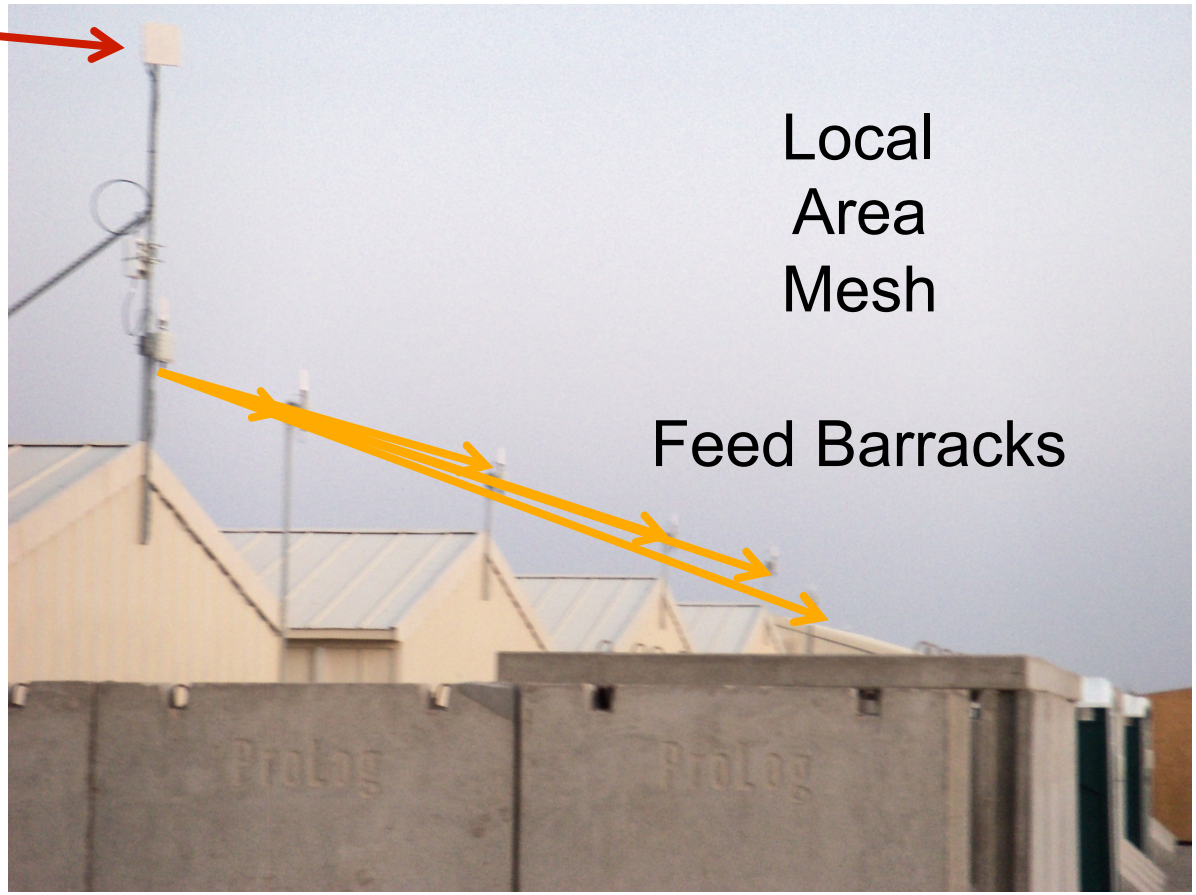
Satellite uplink / downlink + towers with AP-85 / AP-175

Wide Area Mesh - Original

1:5 Ratio (WAM link to LAM)

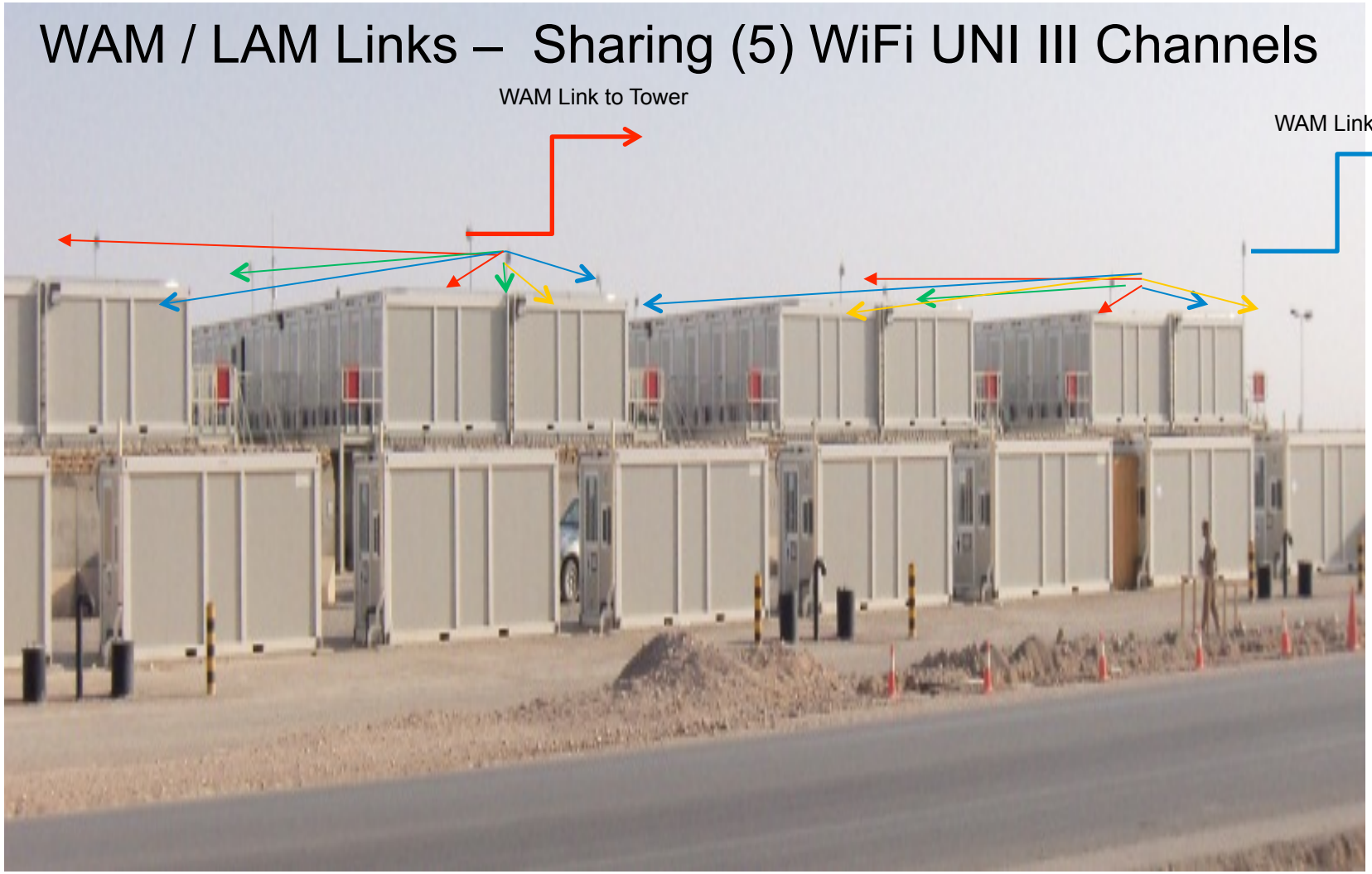
1:5 Ratio

Local Area Mesh – Single Stack



LAM AP's feed 2.4 GHz inside each barrack with Indoor antenna - serves 1 to 20 Users

Local Area Mesh – Double Stack



Optimization Summary

Phase 1 WAM and LAM links saw high self interference

- Heavy packet loss and very poor throughput
- Used a 5 channel plan on WAM Links and LAM (UNI III) (shared)

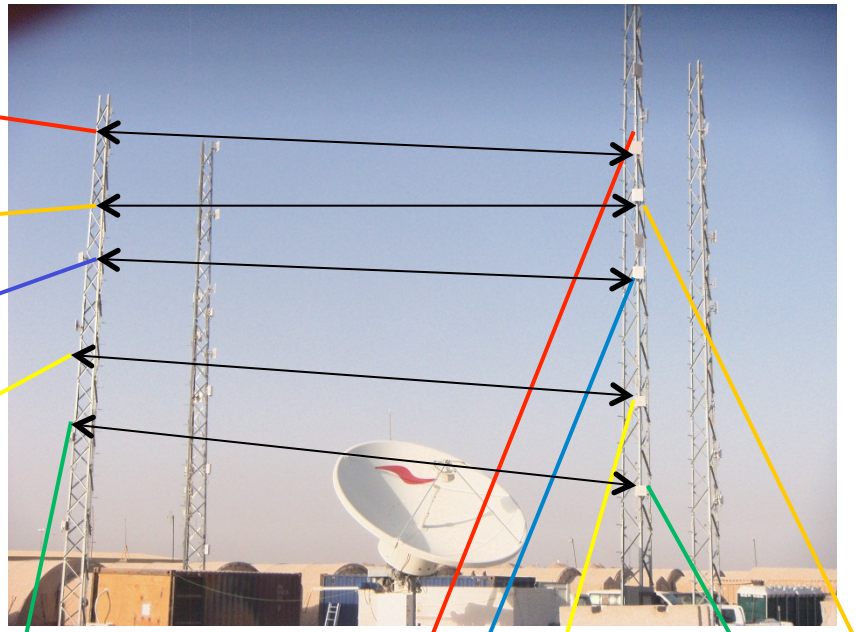
Phase 2 Optimizations

- Re-provisioned AP's higher or lower on tower to reduce interference
- Re-provisioned AP's so they are physically offset – best effort
- WAM to LAM ration increased to 1:1 by adding AP's to tower
- Reassigned LAM (4) UNI I channels (typically indoor)
- LAM uses (4) UNI I and WAM uses (5) UNI III channels for total of 9

Phase 3 - WAM is non WiFi Point to Multi-Point

LAM now has access to all 9 WiFi channels for aggregation to WAM

Wide Area Mesh – Post Optimization

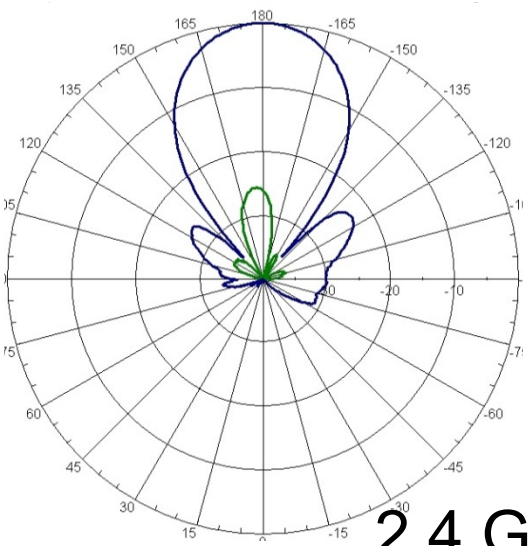


1:1 Ratio

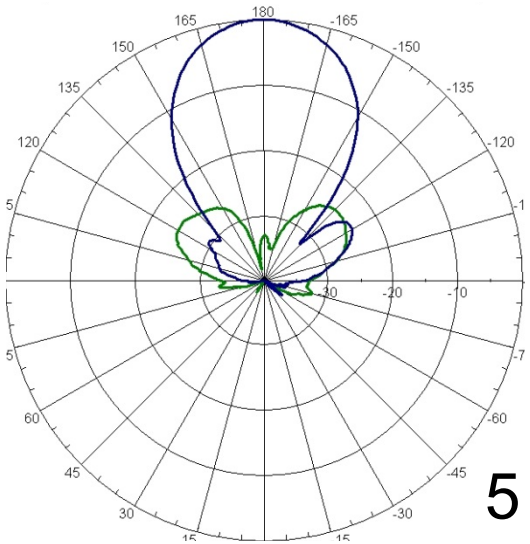
1:1 Ratio

Future Optimization – 5314 Antennas

- Use directional antennas for point to point links
- Narrow beam eliminates noise & increases SNR
- Matched 2.4 and 5 GHz patterns



2.4 GHz



5 GHz

WiFi Access Layer

802.11g/n WiFi is for user access (2.4 Ghz)

Antennas are placed inside some barracks

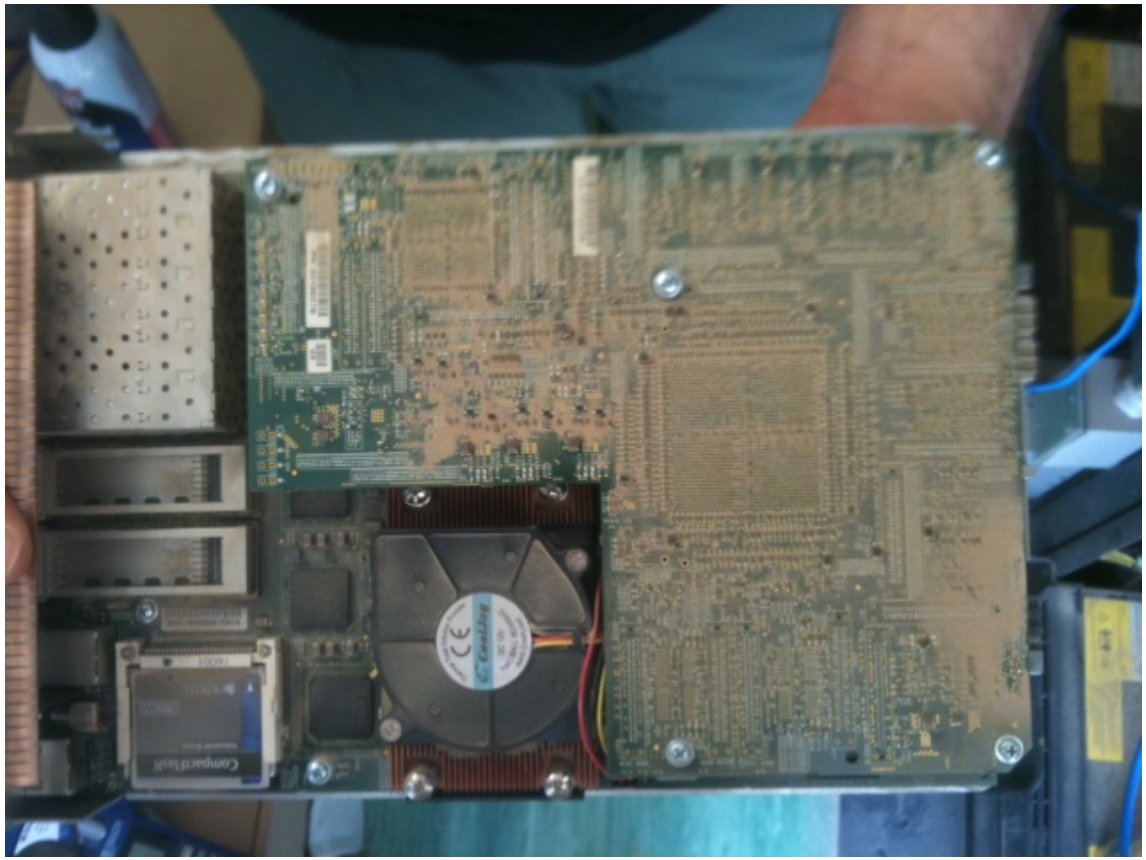
Some users are far from the antenna – end of POD

- Lower signal quality than other “cans” that are closer
- They use lower data rates – consume more air time

There are three channels available, 1-6-11

- The “cans” contain signal re;atively well – so channel reuse is viable
- During busy hours congestion should be expected
- We enabled a method for fair sharing of the air - RTS/CTS
  - Side effect on a few older devices – but great benefits
- Any transmitter in the 2.4 Ghz band should use 1-6-11
  - To avoid unnecessary interference – policies instituted across the base

Routine Maintenance



Change filters in Controller Fans ☺

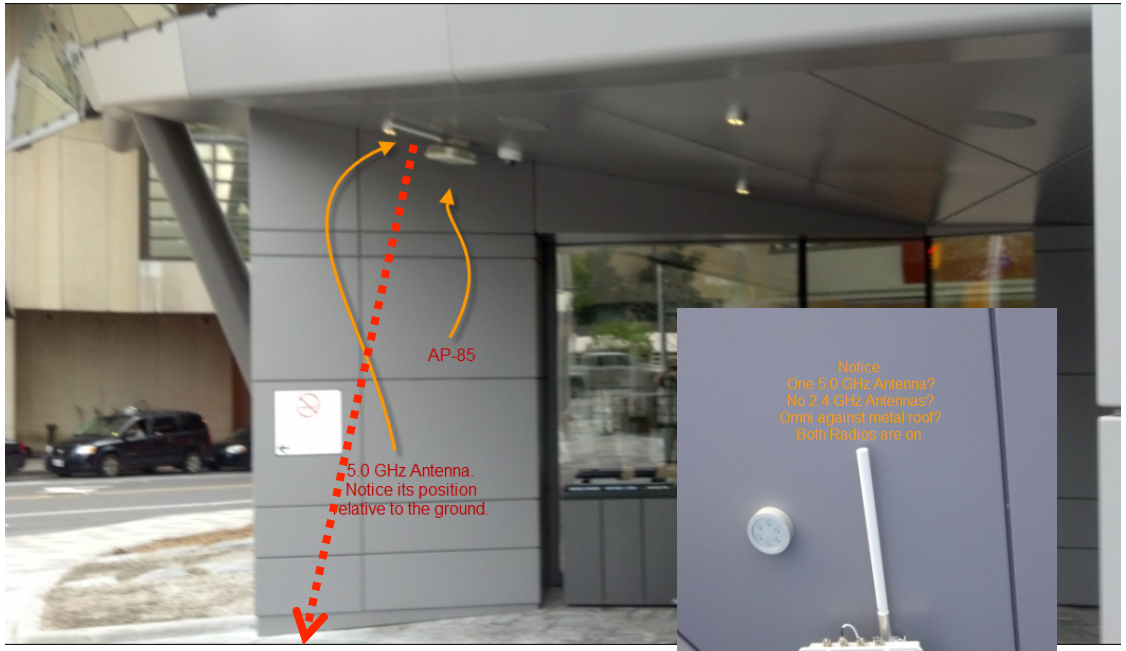
RF Installations

AIRHEADS 2013

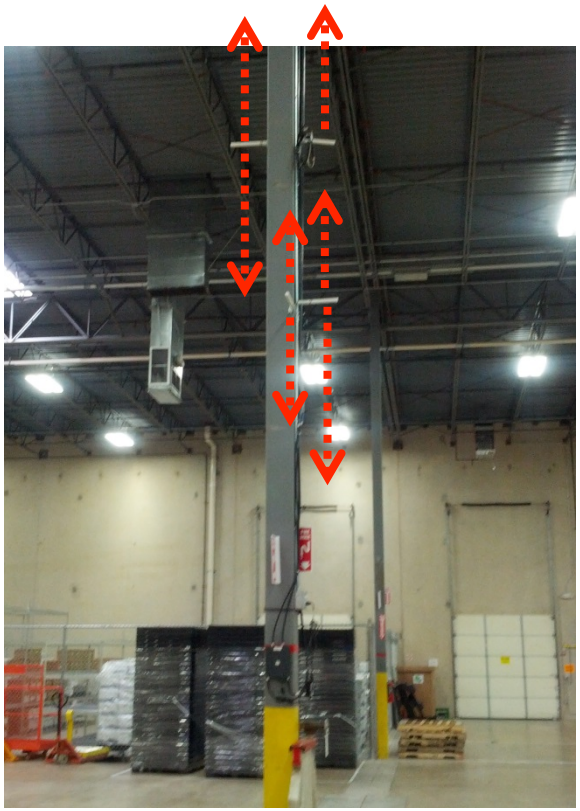
Outdoor Installation Best Practices

Real mistakes you should be sure to avoid!

Improperly Aimed Omni Antennas



Omni antennas MUST be mounted perpendicular to the ground.



Omnis are NOT yagis (or magic wands!) You do NOT point them at the target.

Connecting Only 1 Antenna

- **The previous photos also show only 1 antenna connected to the radio.**
- **Aruba regularly is asked by customers whether it is really necessary to hook up both antennas.**
  - Especially when upgrading old SISO gear to MIMO gear.
- **MIMO systems are designed to have 2 (or more) active radio chains for both TX and RX.**
- **TX power is cut in half by not connecting an antenna on the 2nd radio chain.**
- **This reduces range by 30% and coverage area by 50%.**

Correct Omni Antenna Installation

- Omnis must be installed perpendicular to the ground.
- Both antenna chains MUST have an antenna connected.
- You MUST use one H-pol and one V-pol omni antenna.
- These are sold in pairs by Aruba.

Improperly Aimed Sector Antennas

- The example on the left has the antenna aiming straight at the post, blocking the signal!
- The example on the right has the antenna aimed at the sky instead of the ground where clients are.

Bending / Damaging RF Cable

- Most cabling companies do not have experience with low-loss RF cable such as LMR or Heliax
- This installer bent the cable at 45 degrees at a building penetration.
- ANY damage to the geometry of a coaxial cable reduces its performance and increases loss.

Improper Antenna Separation

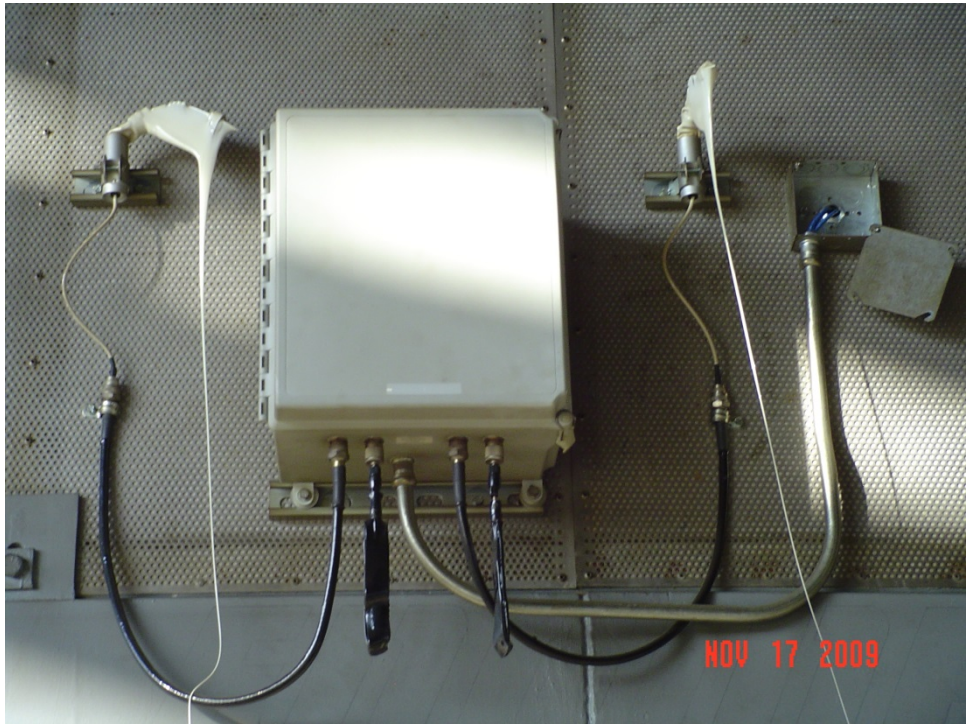
Antennas should not be placed directly against walls. This results in adverse changes to the pattern, as well as wasted signal absorbed into the structure.

When co-locating multiple antennas in an array, minimum horizontal and vertical separation distances MUST be computed to avoid having adjacent-channel interference take out all of the links

Water Ingress

- Antenna radomes are not usually sealed. They have holes at the bottom designed to vent condensation and other water accumulation.
- NEVER face the weep holes straight up – the antenna will fill with water the first time it rains!
- NEVER face a panel antenna straight down for the same reason (unless it is designed for this such as the AP-ANT-90)

Last, but not least…



Do not place antennas and enclosures immediately behind F-18 jet engines!

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Thank You