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Enterprise company

# 講題 - 行動優先校園網路 – Why Aruba WiFi6 AP

## THE ARUBA ARCHITECTURE

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Solution Manager, Taiwan
Aruba, a Hewlett Packard Enterprise company

# Agenda (大綱)

1. 無線網路於頻段上之發展 (802.11ax, WiFi 6)
2. 行動優先校園網路 - The Aruba Architecture and Why Aruba

# 無線網路於頻段上之發展
# (802.11ax, WiFi 6)

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# SMART INNOVATIONS FOR AN EXTRAORDINARY EDGE EXPERIENCE.

NEW

**802.11ax Access Points**

WPA3 &
Wi-Fi Enhanced Open

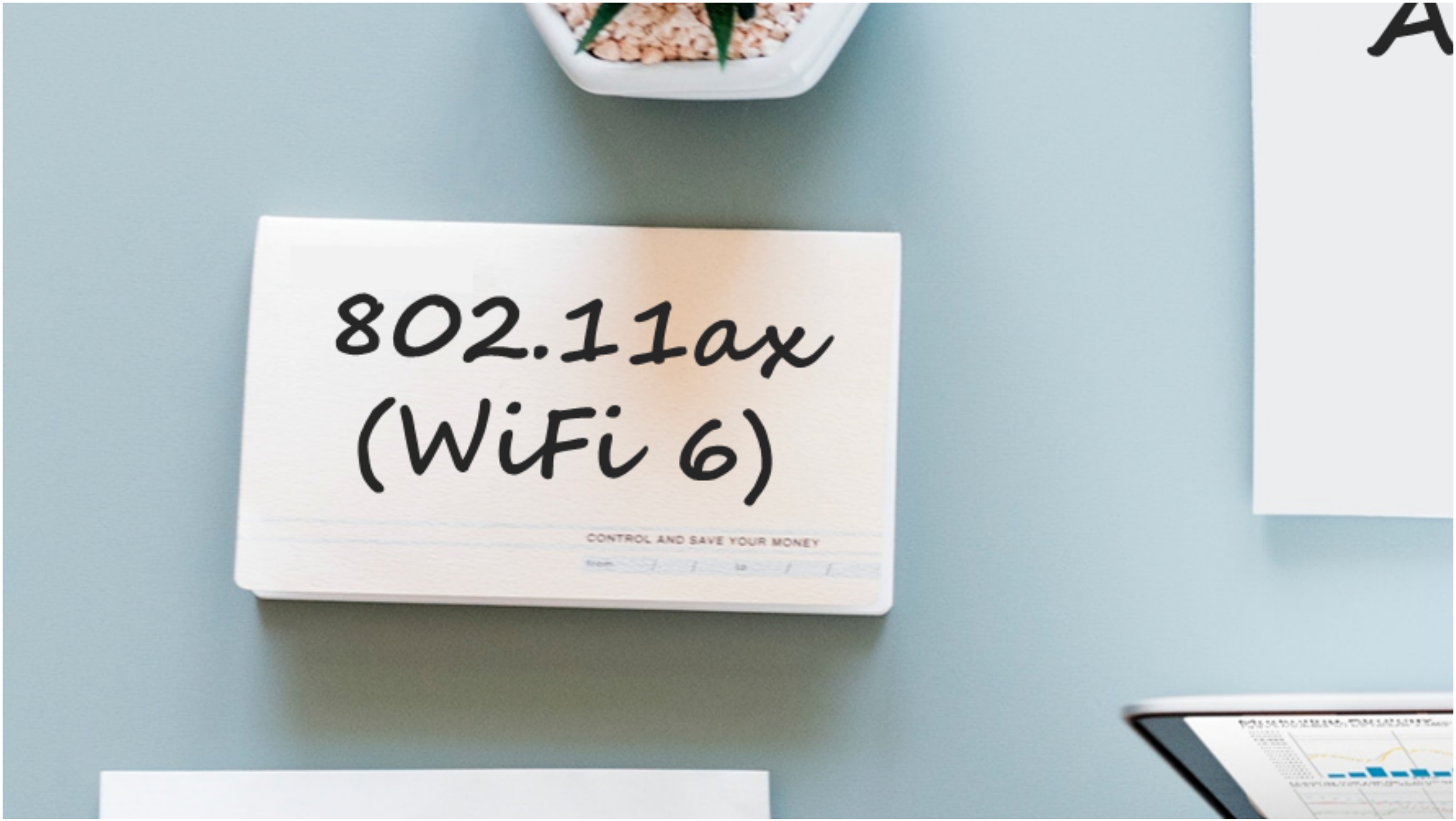
ENHANCED

**AIOps**
**AI-powered Automation & Assurance**

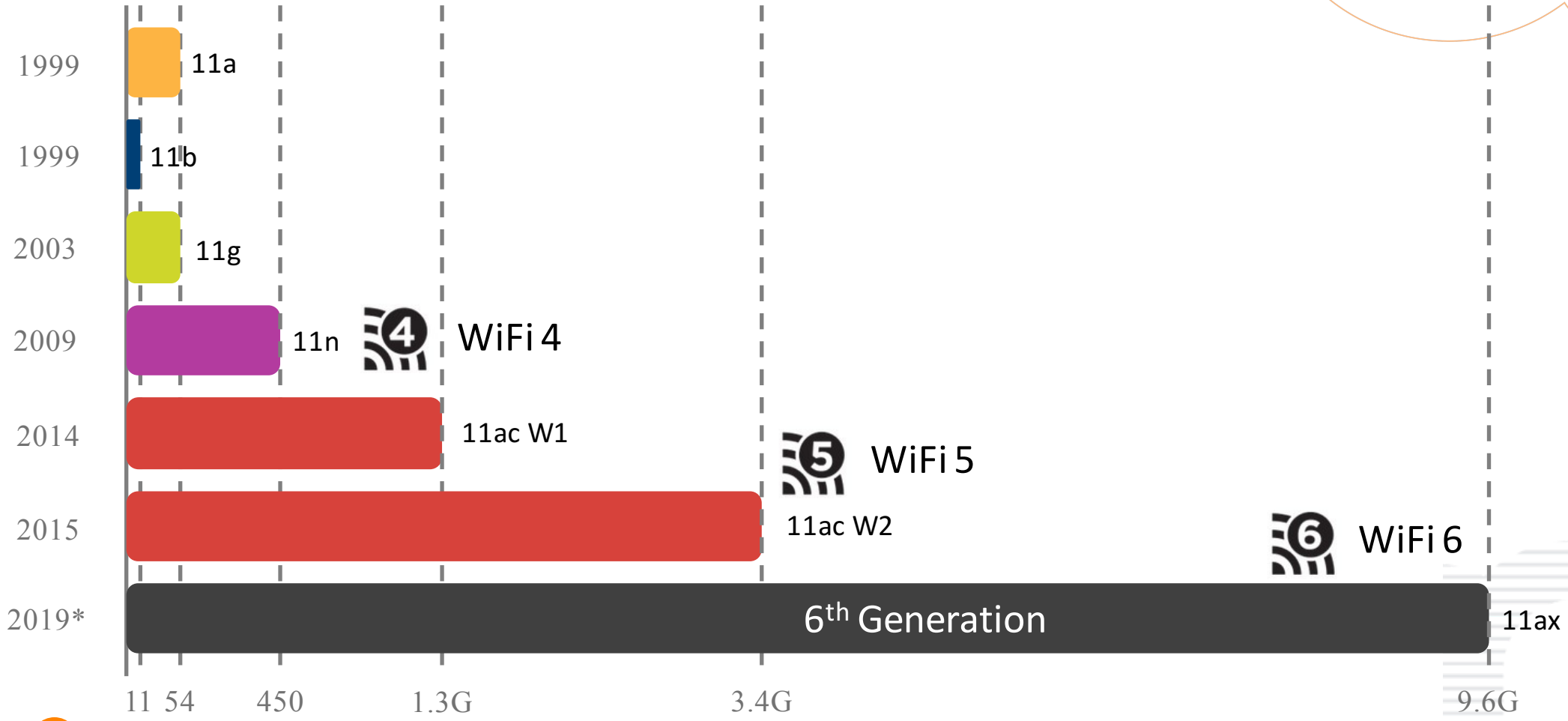
Green AP

# Agenda

1. 802.11ax Technology
2. Aruba 5xx series campus AP
3. Use cases


802.11ax
(WiFi 6)
CONTROL AND SAVE YOUR MONEY

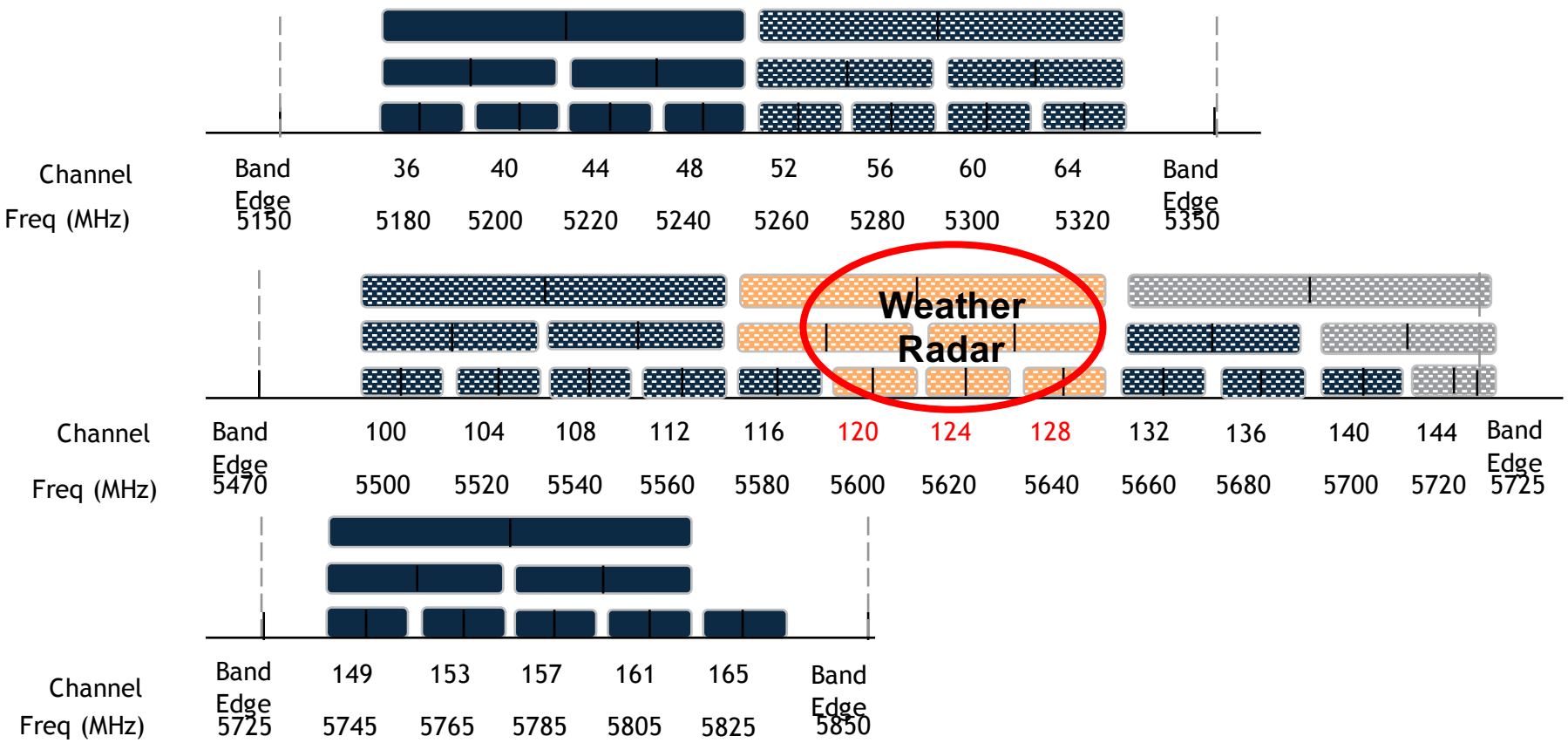
# Evolution Of WiFi



# 802.11ac v.s. 802.11ax

| 802.11ac (2012): | 802.11ax (2018): |
| --- | --- |
| • 5 GHz only<br>• Even wider channels (80, 160 MHz)<br>• Better modulation (256-QAM)<br>• Additional streams (up to 8)<br>• Beam forming (explicit)<br>• MU-MIMO<br>• Backwards compatibility with 11a/b/g/n | • 2.4 GHz and 5 GHz supported<br>• OFDMA uplink and downlink<br>• Extends and generalizes OFDM<br>• Introduces the concept of Resource Units (RU's)<br>• Massive parallelism<br>• Better modulation (1024-QAM)<br>• Uplink MU MIMO<br>• Spatial re-use (BSS color)<br>• Backwards compatibility with 11a/b/g/n/ac |

# 802.11ac, 802.11ax Channels (FCC)




UNII I and UNII II
2x 80 MHz
4x 40 MHz
8x 20 MHz

UNII II extended
3x 80 MHz
6x 40 MHz
12x 20 MHz

US UNII III
1x 80 MHz
2x 40 MHz
5x 20 MHz

# 11ax Overview

- **2.4 GHz band** so oversubscribed in heavily populated areas as to be unusable, the Wi-Fi community feels there are still many opportunities for this band particularly for **IoT** where its **superior propagation** characteristics can be exploited.
- Radio technologies proposed for **802.11ax** use many characteristics: multi-user MIMO, beamforming, OFDMA, and others
- WPA2 certification will be replaced during 2018 with **WPA3**, and it is anticipated that all 802.11ax equipment should also be WPA3-compliant

## Why 802.11ax?

WiFi 6 (802.11ax)

# Maximizing Efficiency

Increase **4x average throughput per device** in dense deployment

Enhanced operation in **2.4 & 5 GHz bands**

**Improve power efficiency** of client devices

What Is In 802.11ax?

# OFDMA

Downlink & Uplink

# What Is In 802.11ax?

## 802.11ax

**O**RTHOGONAL
**F**REQUENCY
**D**IVISION
**M**ULTIPLE
**A**CCESS

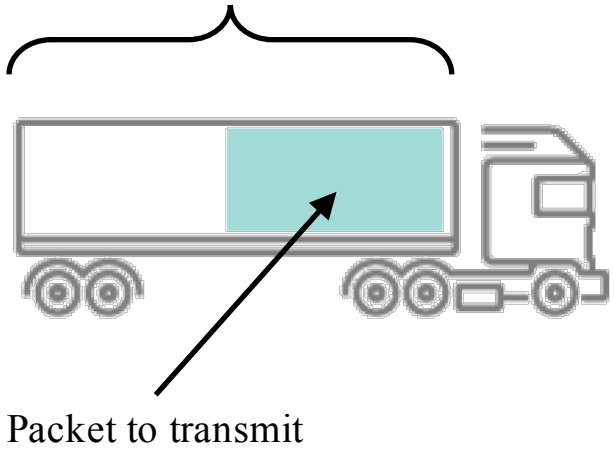
## Pre-802.11ax

**O**RTHOGONAL
**F**REQUENCY
**D**IVISION
**M**ULTIPLEXING

# What Is In 802.11ax?

## Pre-802.11ax

**OFDM**

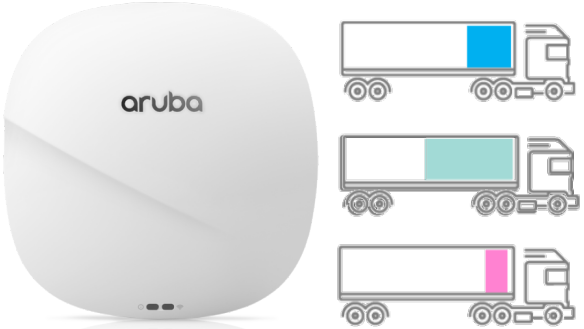


# What Is In 802.11ax?

## Pre-802.11ax

**OFDM**

Inefficient with small packets

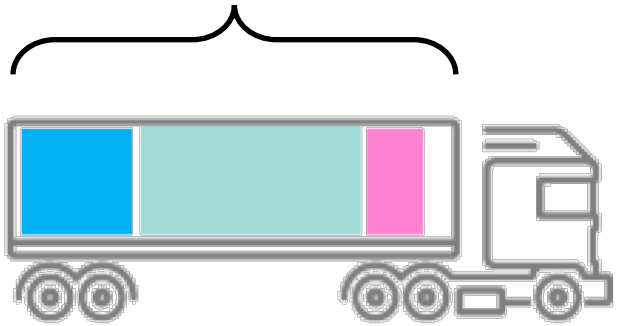


# OFDMA

What Is In 802.11ax?

802.11ax

Channel width is divided
into sub-channels



Resource Units (RUs)

Smallest is RU-26

9 x RU-26 in 20MHz

Up to 9 recipients!

# 802.11ax selected rates (Mbps, short GI)

| MCS | Modulation | RU-26 | RU-52 | RU-106 | RU-242 | RU-484 | RU-996 |
|---|---|---|---|---|---|---|---|
| | | 2.0 MHz | 4.1 MHz | 8.3 MHz | 18.9 MHz | 37.8 MHz | 77.8 MHz |
| 0.0 | BPSK 1/2 | 0.9 | 1.8 | 3.8 | 8.6 | 17.2 | 36.0 |
| 1.0 | QPSK 1/2 | 1.8 | 3.5 | 7.5 | 17.2 | 34.4 | 72.1 |
| 2.0 | QPSK 3/4 | 2.6 | 5.3 | 11.3 | 25.8 | 51.6 | 108.1 |
| 3.0 | 16-QAM 1/2 | 3.5 | 7.1 | 15.0 | 34.4 | 68.8 | 144.1 |
| 4.0 | 16-QAM 3/4 | 5.3 | 13.2 | 28.1 | 51.6 | 103.2 | 216.2 |
| 5.0 | 64-QAM 2/3 | 7.1 | 14.1 | 30.0 | 68.8 | 137.6 | 288.2 |
| 6.0 | 64-QAM 3/4 | 7.9 | 15.9 | 33.8 | 77.4 | 154.9 | 324.3 |
| 7.0 | 64-QAM 5/6 | 8.8 | 17.6 | 37.5 | 86.0 | 172.1 | 360.3 |
| 8.0 | 256-QAM 3/4 | 10.6 | 21.2 | 45.0 | 103.2 | 206.5 | 432.4 |
| 9.0 | 256-QAM 5/6 | 11.8 | 23.5 | 50.0 | 114.7 | 229.4 | 480.4 |
| 10.0 | 1024-QAM 3/4 | | | | 129.0 | 258.1 | 540.4 |
| 11.0 | 1024-QAM 5/6 | | | | 143.4 | 286.8 | 600.5 |

# OFDMA

What Is In 802.11ax?

802.11ax

Uplink OFDMA

3x more system capacity

- Serve more clients
- Lower latency
- Good for low data rates
- Good for small packets

# MU-MIMO

Downlink

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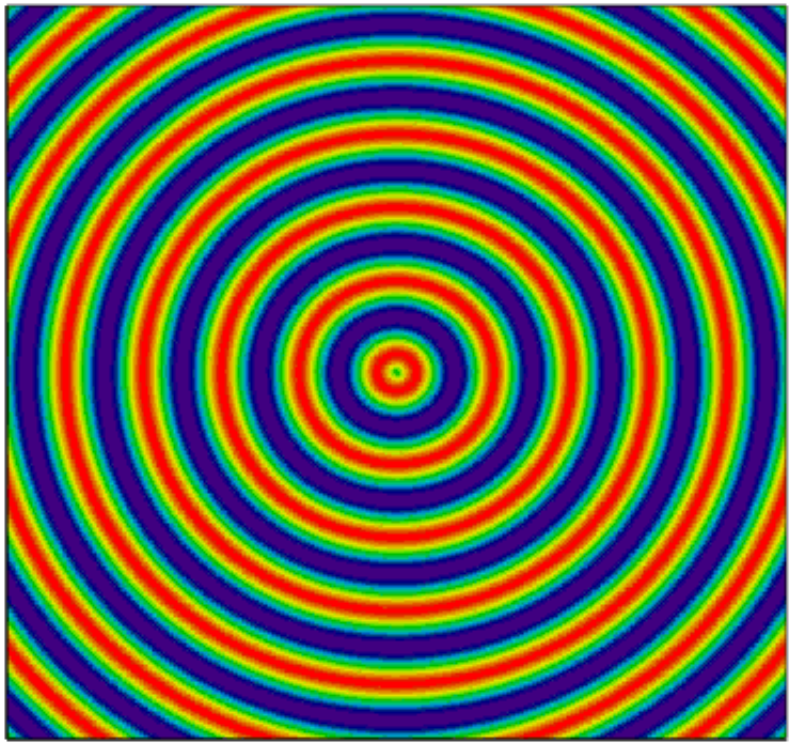
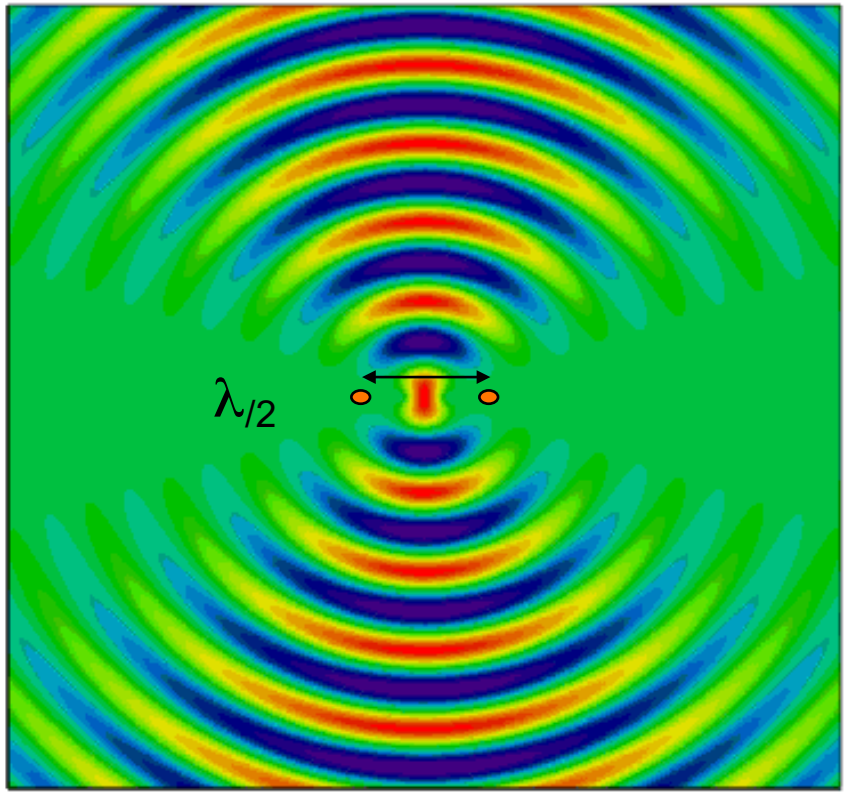
# BASIC BEAMFORMING

# Antenna Basic Physics

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

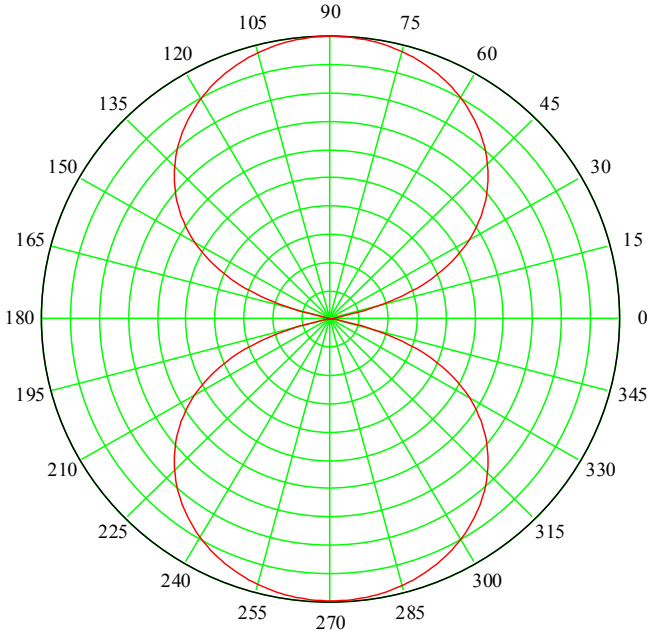


# Building Arrays: 2 Elements

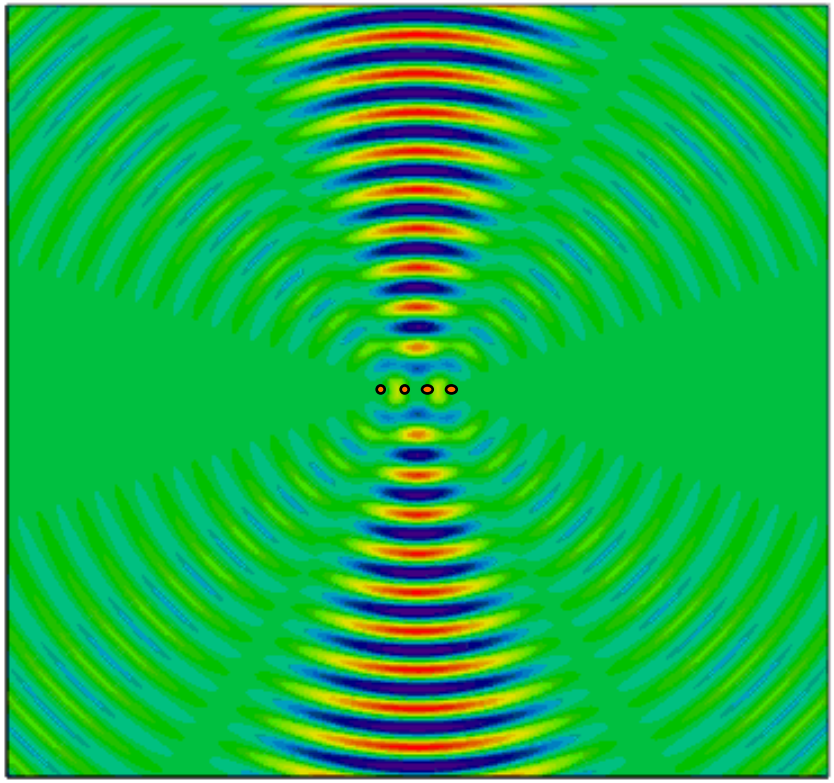



- By introducing additional antenna elements we can control the way that the energy radiates
- 2 elements excited in phase

dB Plot

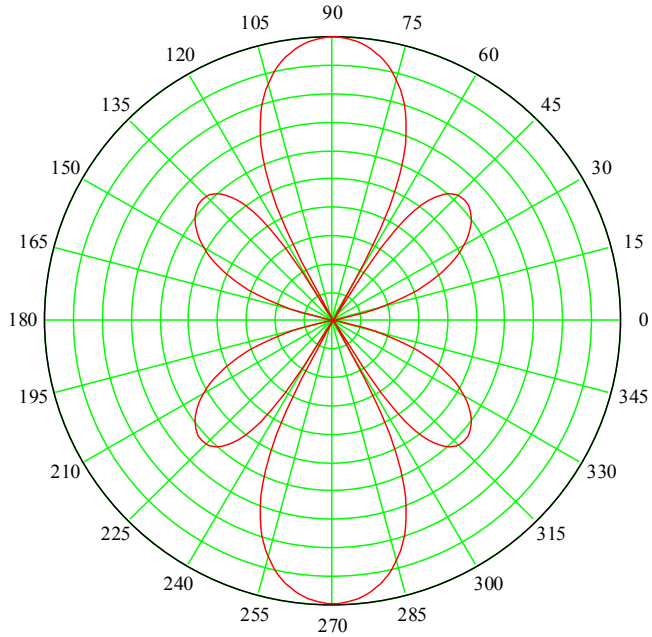


# Building Arrays: 4 Elements

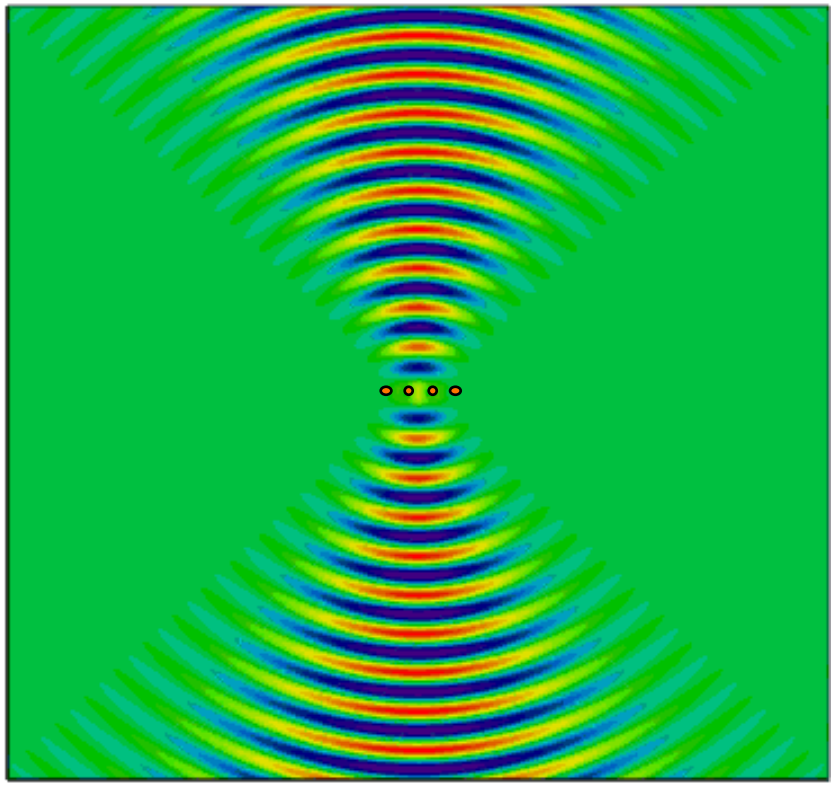


- By introducing additional antenna elements we can control the way that the energy radiates
- 4 elements excited in phase
  - Equal amplitude

dB Plot

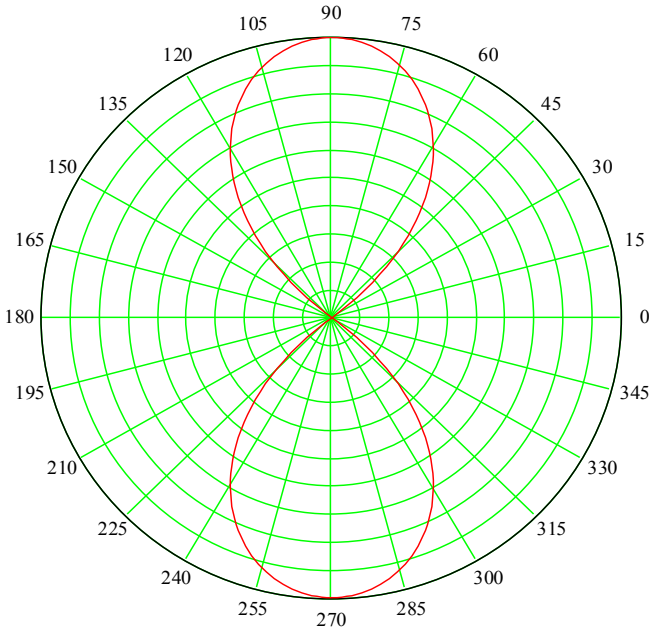


# Building Arrays: 4 Elements

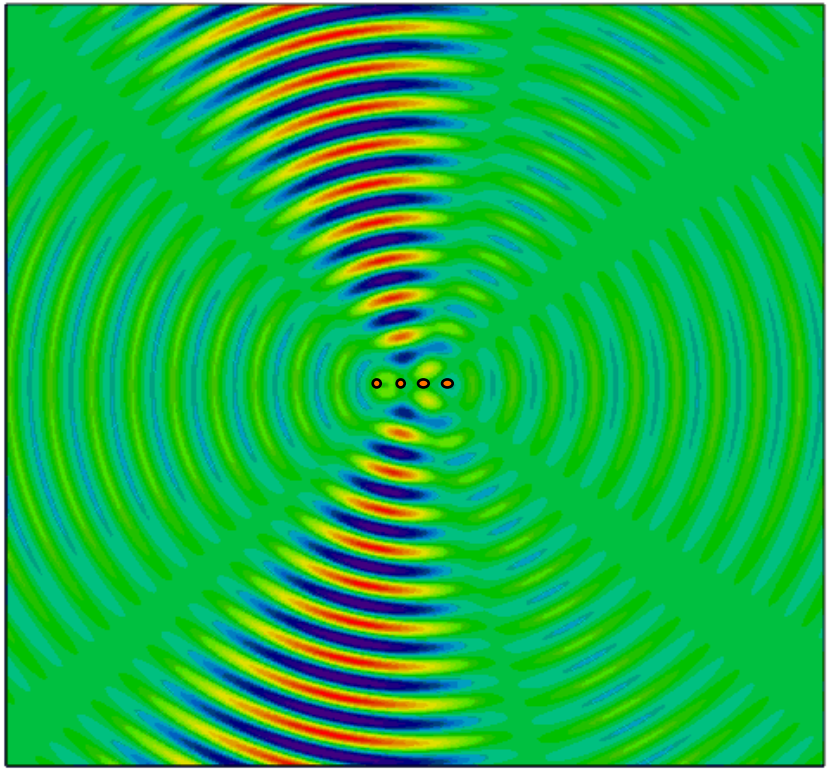


- By shaping the amplitude we can control sidelobes
- 4 elements excited in phase
  - **Amplitude 1, 3, 3, 1**

dB Plot

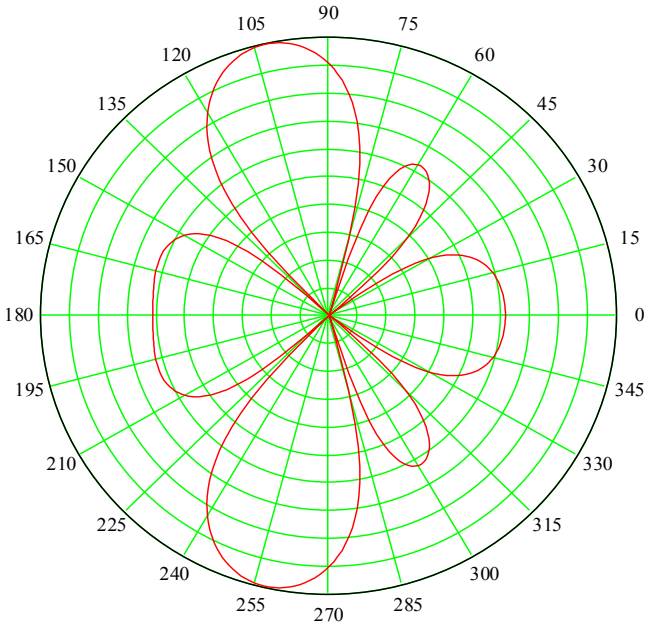


# Building Arrays: 4 Elements Phase



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

dB Plot



What Is In 802.11ax?

# MU-MIMO

Transmit Beamforming

What Is In 802.11ax?

# MU-MIMO vs OFDMA

| MU-MIMO | OFDMA |
| --- | --- |
| Capacity ⬆ | ⬆ Efficiency |
| Speeds ⬆ | ⬇ Latency |
| High bandwidth apps 👍 | 👍 Low bandwidth apps |
| Clients 📶 | 👍 Low data rates |
| | ⬆ Clients |

Complementary

# BSS COLOR

## Spatial Reuse

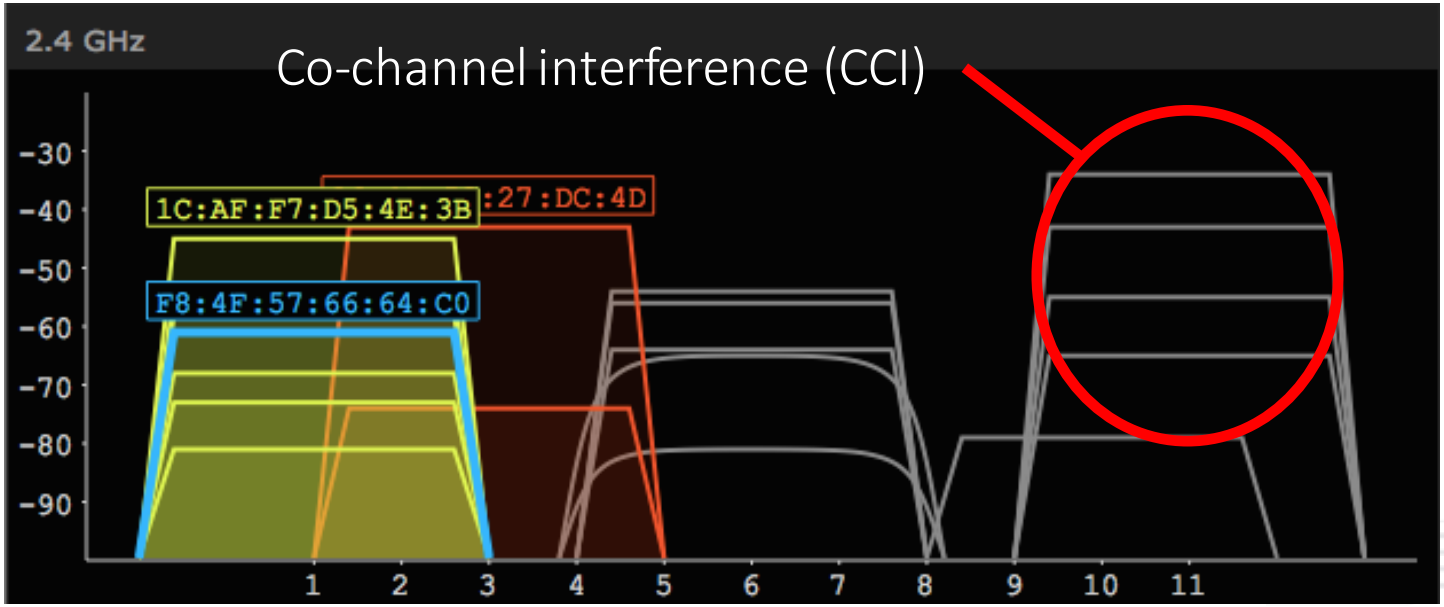
# What Is In 802.11ax?

**BSS COLOR**

Spatial Re-use

Overlap channels degrade performance due to collision avoidance protocol, CSMA/CA

Listen-before-talk protocol




CSMA/CA: Carrier Sense Multiple Access with Collision Avoidance

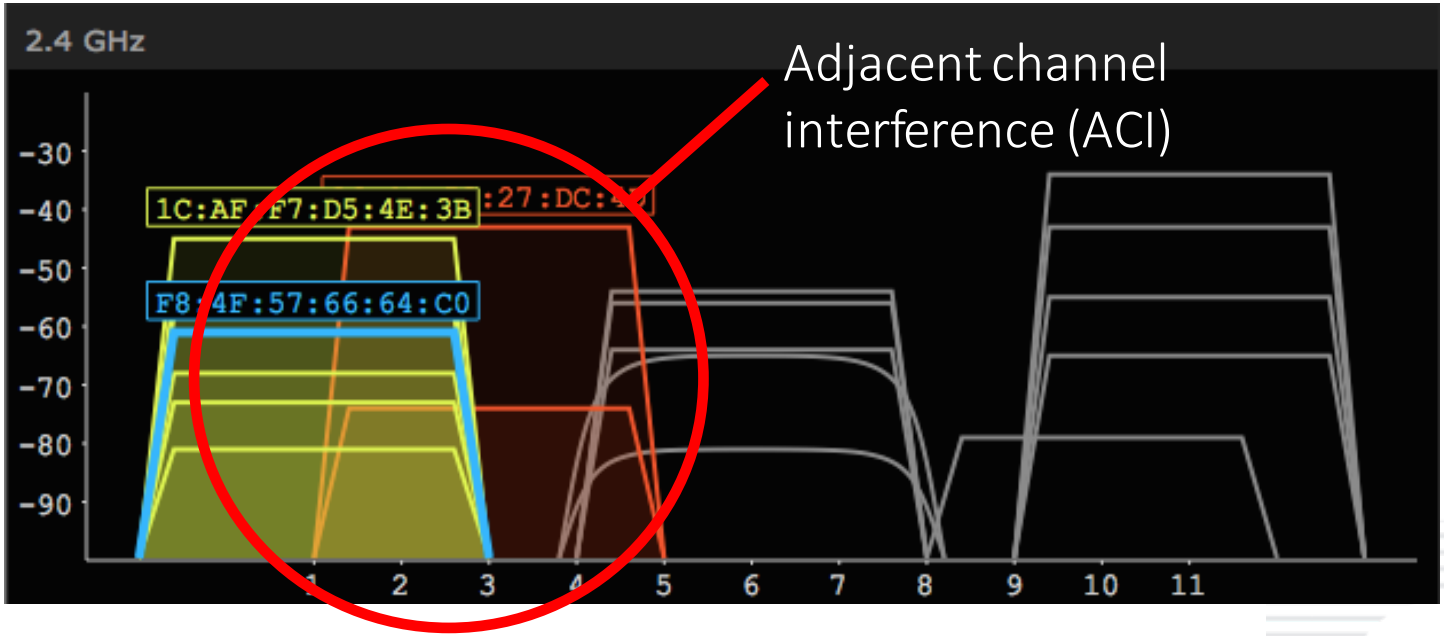
# What Is In 802.11ax?

## BSS COLOR

Spatial Re-use

Overlap channels degrade performance due to collision avoidance protocol, CSMA/CA

Listen-before-talk protocol



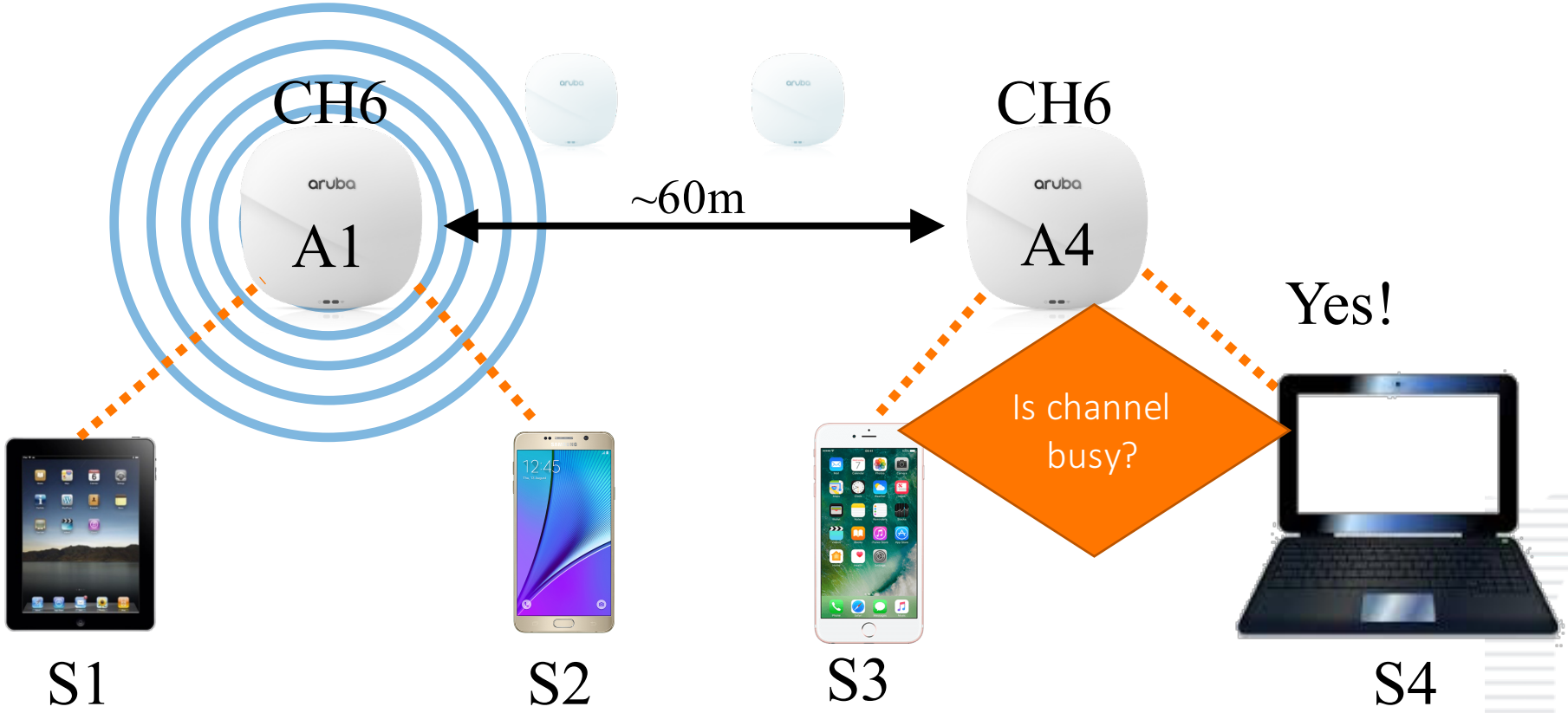

CSMA/CA: Carrier Sense Multiple Access with Collision Avoidance

What Is In 802.11ax?

# BSS COLOR

Spatial Re-use

## The problem



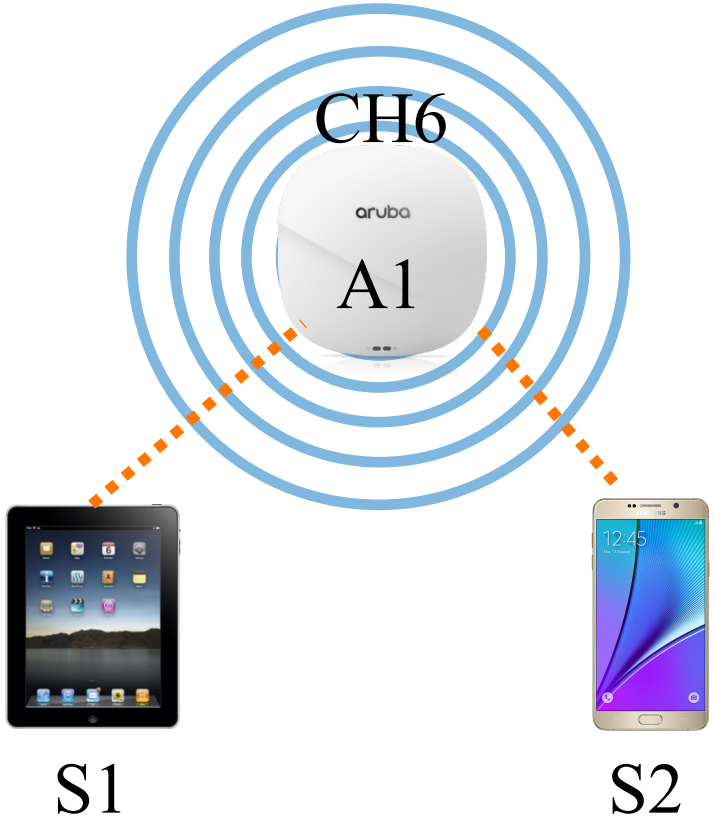
# What Is In 802.11ax?

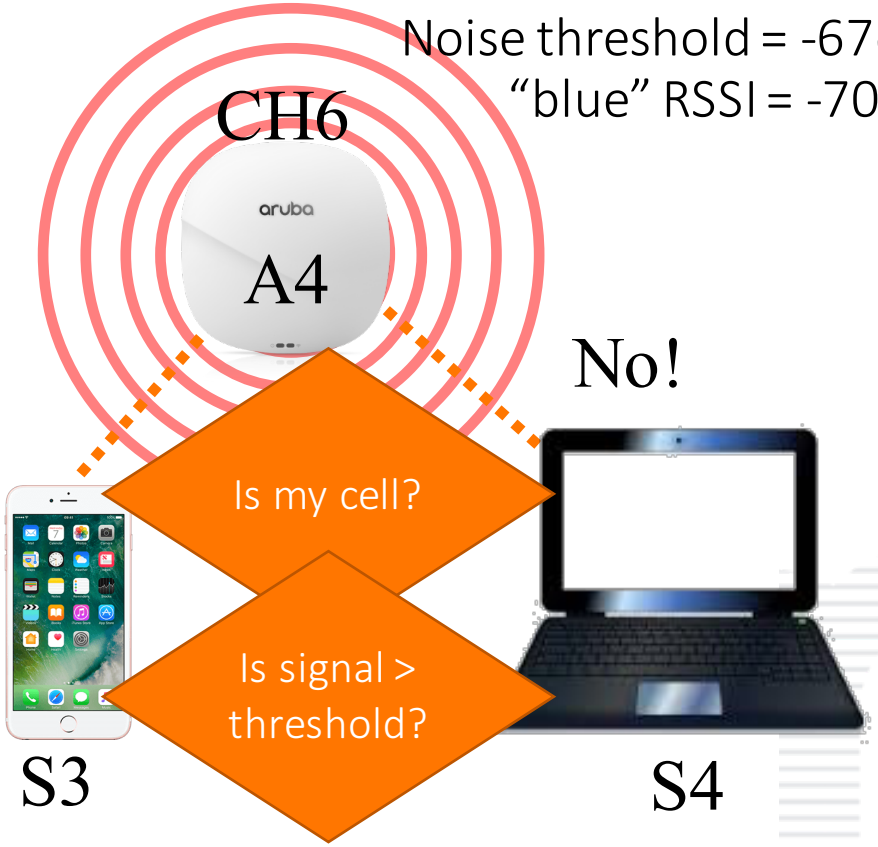
# BSS COLOR

Spatial Re-use

## The solution

Color bit in beacon



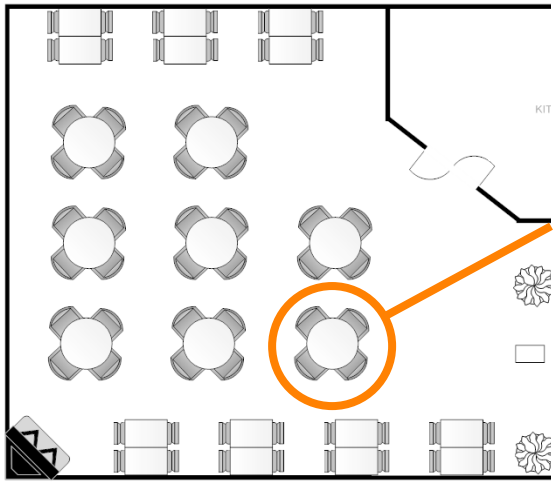



# What Is In 802.11ax?

## BSS COLOR

Spatial Re-use

### The example



Every table represents an AP with several clients connected

This environment is equivalent to all APs operating in the same channel.

- You are at a table with your friends
- You can hear others speaking (from other tables) – same channel
- If the noise level is not high, you can talk – signal* < threshold
- If it is too noisy, you can't talk – signal > threshold

Signal* - signal from other tables (that is not your "color")

# BSS COLOR

## Implications

2.4GHz is back!

Wide channels

*all 802.11ax clients associated

Aruba's ax-aware ClientMatch differentiates

# TARGET WAKE TIME

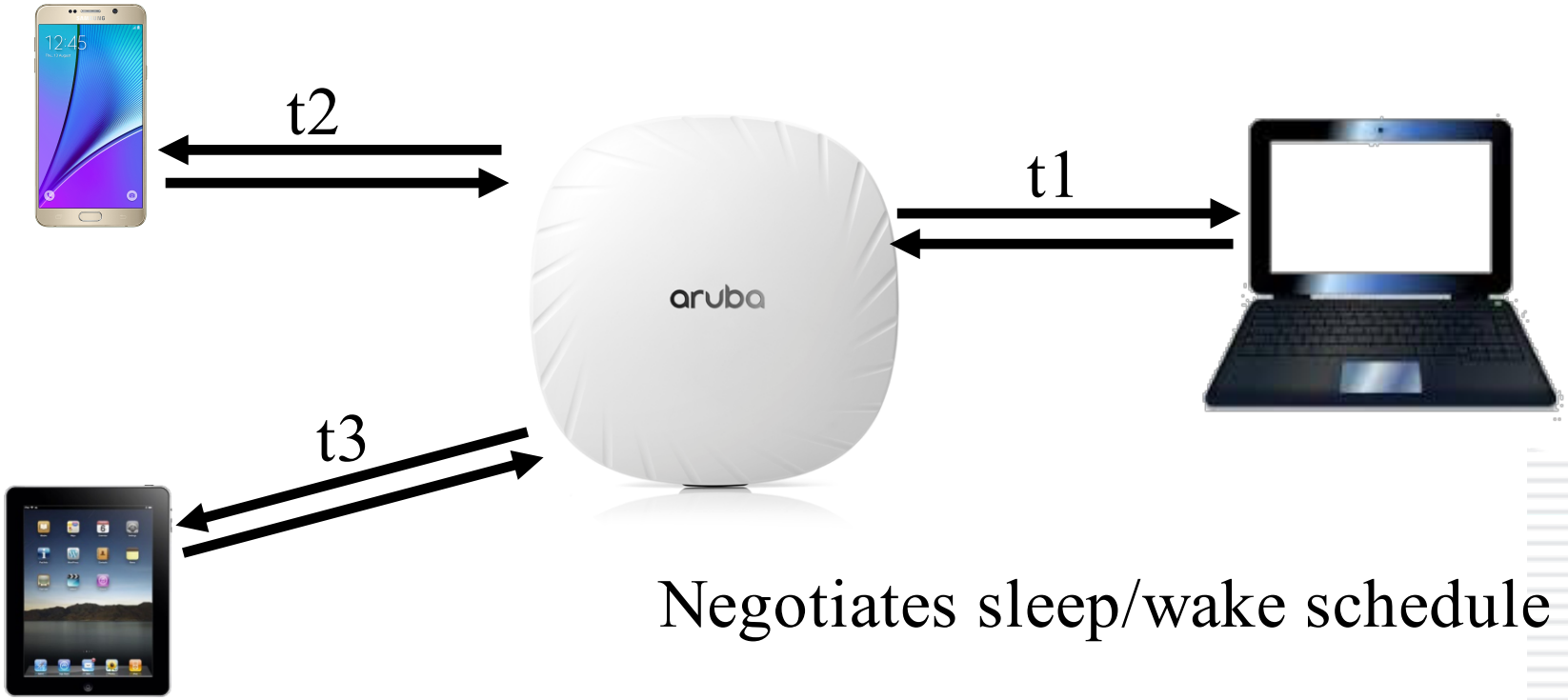
Longer Battery Life

What Is In 802.11ax?

# TARGET WAKE TIME

Longer Battery Life

Borrowed from 802.11ah



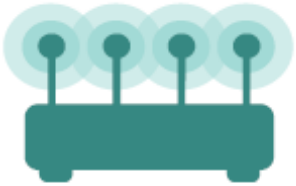

Negotiates sleep/wake schedule

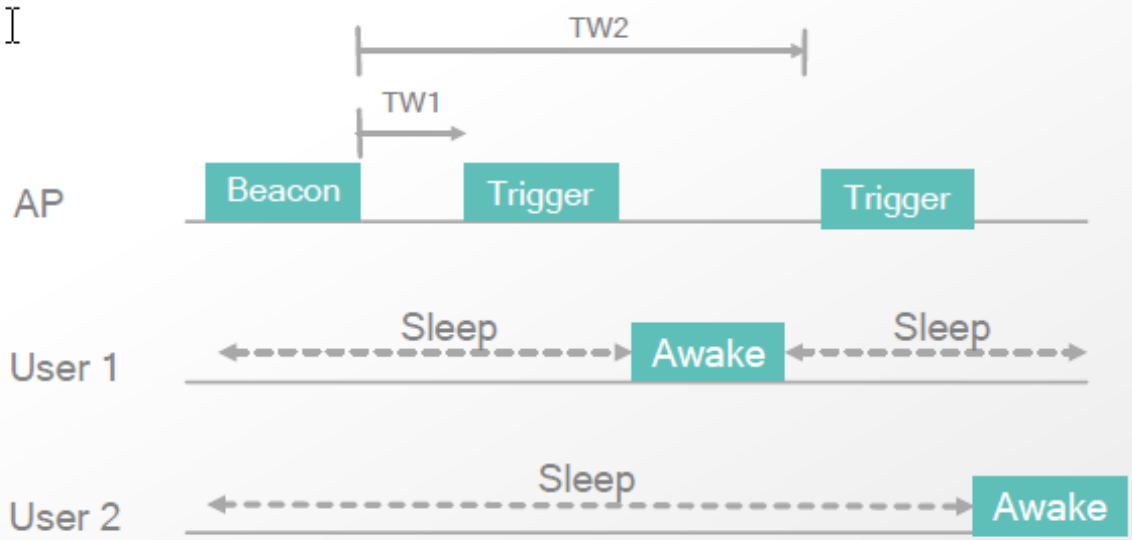
What Is In 802.11ax?

# TARGET WAKE TIME

Longer Battery Life

Up to 10x





Reduces contention and overlap between stations

Can be scheduled for multi-user transmission

# 802.11ax important features

## Increase average throughput per device by at least 4x in a dense deployment

| Feature | Benefit | Improvements over 802.11ac** |
|---|---|---|
| New OFDM symbol | Increases efficiency by reducing guard interval and pilot tone overhead | 20% higher data rates over 802.11ac |
| OFDMA downlink & uplink | More clients, lower latency. More efficient for low data rates, short packets. | ~ 3x system capacity for short packets or many clients |
| MU-MIMO downlink and uplink for up to 8 clients | More efficient in grouping clients, reducing sounding and ack overhead | ~ 2x capacity over 802.11ac |
| Spatial re-use (BSS color) | Better performance for overlapping, dense APs ( beneficial for congested venues) | ~ 2x capacity over 802.11ac |
| High-order modulation 1024 QAM | Higher data rates under good conditions | 25% over 802.11ac |
| Target Wait Time | Extended sleep mode for longer battery life | ~ 3-10x battery life |
| 20 MHz – only client option | Simpler, longer-battery-life IoT devices | Lower cost chips |

** estimates

# 802.11ax (Wi-Fi 6) technology

Increase **4x average throughput** in a dense deployment scenario

**Maximizing capacity and efficiency** and ensuring that **all devices in a crowded network get the bandwidth they require**

**Improve power efficiency** of client devices- battery saving

# Aruba WiFi6 AP and Why Aruba - AP-5xx

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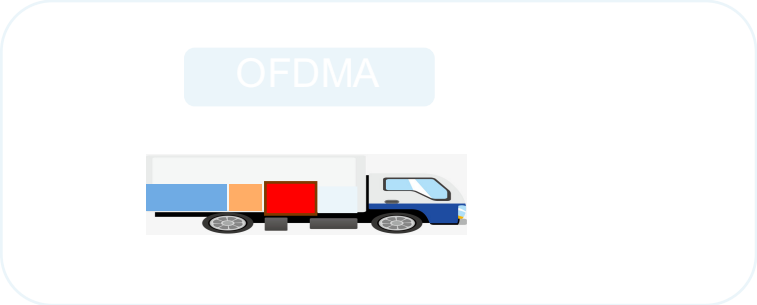
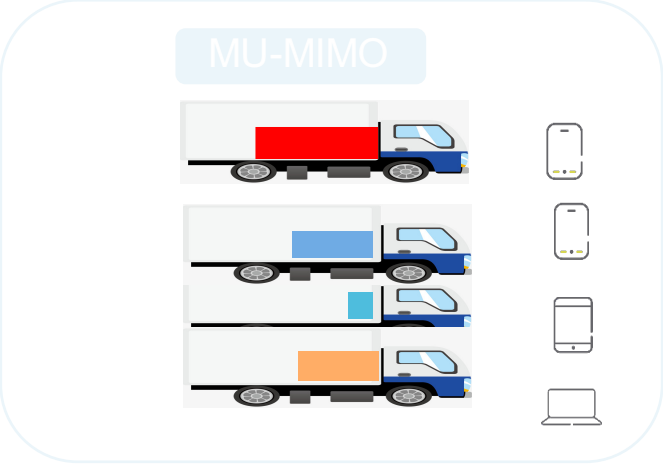
# High performance experience with multi user features

## OFDMA( uplink and downlink) and MU-MIMO ( downlink)

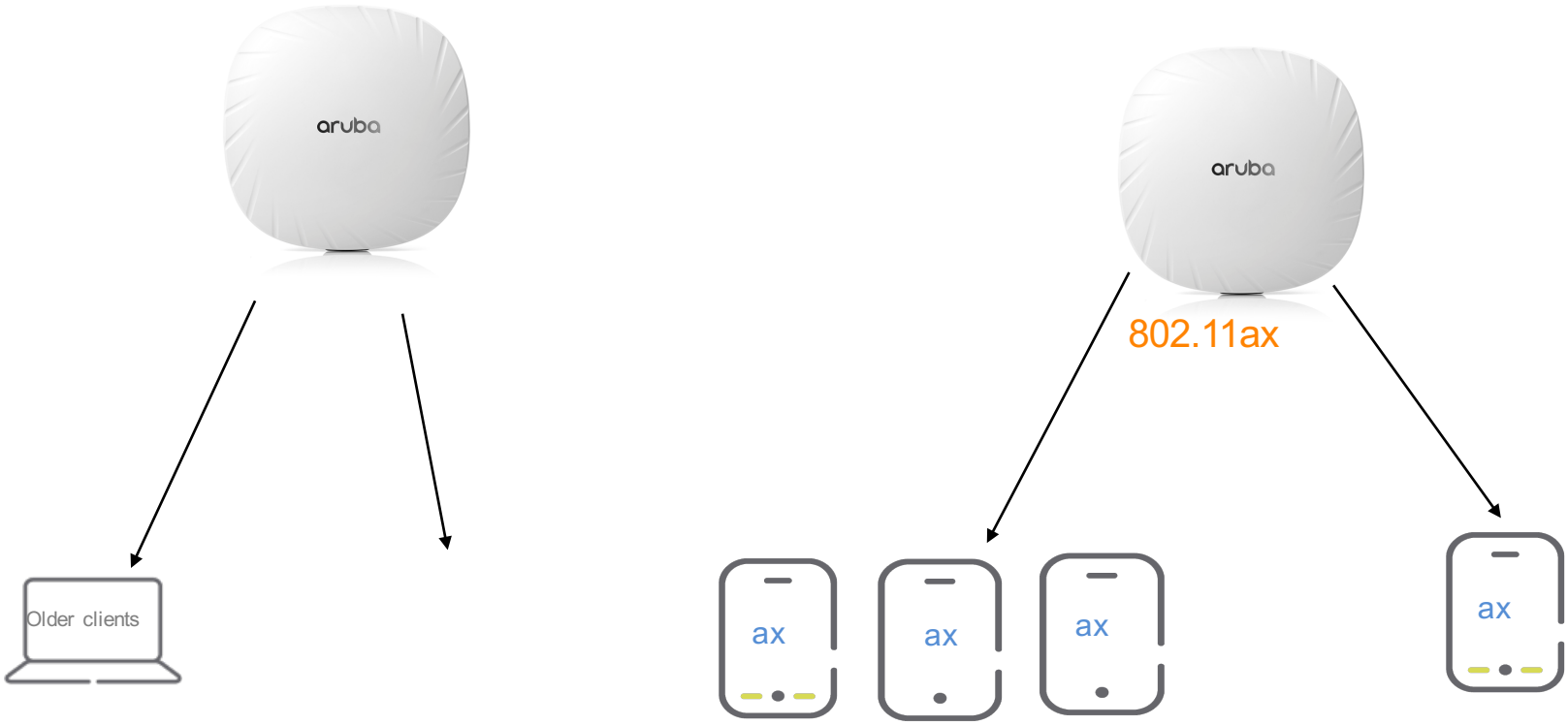
Congestion and delay




| | |
|---|---|
| OFDMA increases efficiency and capacity | MU-MIMO increases capacity |
| OFDMA reduces latency for voice and IoT | MU-MIMO results in higher speed and throughput per user – transmit to up to 4 clients |
| Ideal for low bandwidth , small packets ( voice and IoT), latency sensitive applications | Ideal for higher bandwidth applications such as HD Video or large files |

# Boost performance of multi-user with ax-aware ClientMatch




ClientMatch

By moving all ax clients to the ax APs we can utilize OFDMA or MU-MIMO efficiently to boost the performance of the network

# Intelligent adaptive RF and Intelligent traffic control

## Good user experience

### AirMatch

- Enhanced user experience while roaming in large dense environments
- **AI-powered** self-optimizing RF planning - enhancement to ARM
- Provides channel, channel bandwidth and power planning

### AppRF

- Automatically identifying traffic using DPI
- Prioritizing traffic per user ,device and application
- Use cases: prioritize Skype for Business for employees but deprioritize for contractors

# IoT ready – Universal connectivity for IoT

- **New 802.15.4 radio** supports **Zigbee** and potentially other standards
  - Zigbee use cases include digital door locks in hotels and digital signage for retail
- **First Bluetooth 5 radio** integrated into an AP
  - Traditional location and asset tracking support
- Cost effective and easy to manage universal IoT connectivity with **Zigbee and Bluetooth 5** cover 74% of IoT use cases
- IoT battery life savings with Wi-Fi 6 Target Wake Time (TWT) support
- 802.11ax provides dedicated channels in OFDMA - simultaneous transmission of IoT connections with low latency

Integrated Zigbee Radio & BLE

Bluetooth®

First Wi-Fi Vendor with integrated Wi-Fi 6, BLE 5, and 802.15.4

# Enhanced security with WPA3 and Enhanced Open

### Wi-Fi Alliance WPA3

- Passwords are harder to crack with SAE (Simultaneous Authentication of Equals)
- WPA3-Enterprise simplifies configuration and enhances encryption (Suite B /256-bit encryption)

### Wi-Fi Alliance Enhanced Open

- Secure user traffic in open networks such as coffee shops
- All wireless traffic gets encrypted with OWE (Opportunistic Wireless Encryption)

### ArubaOS Security features

- MultiZone, Dynamic Segmentation, PEF, RF Protect and WebCC

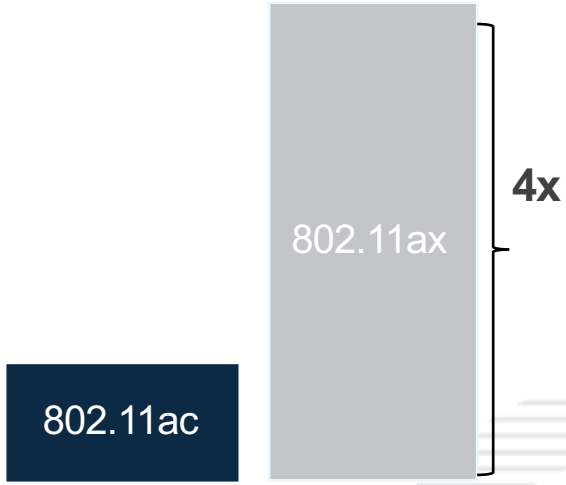
**Aruba is the FIRST to get WPA3 Certification!**

# Aruba 5xx series access point

## A differentiated experience beyond 802.11ax

- **High performance**
  - Multi user capabilities with *OFDMA and MU-MIMO*
  - Boost performance of multi-user features with *ax -aware ClientMatch*
  - RF optimization with AI-powered *AirMatch*
  - Intelligent traffic management with *AppRF*
- **IoT and location ready**
  - Universal IoT connectivity with Zigbee & Bluetooth 5
  - Mobile engagement and asset tracking support
- **Flexible PoE option**
  - Still operate even if there is not enough PoE power with *Intelligent Power Monitoring* (IPM)
- **Enhanced Security**
  - ArubaOS core security and better encryption with Wi-Fi Alliance WPA3 and Enhanced open
- **Always on connectivity**
  - 24/7 network uptime with LiveUpgrade and Seamless Failover

**Max aggregate peak data rate 5.4Gbps Controller/Instant deployment**




**4x better capacity in dense deployment**

# 802.11ax Indoor AP platform

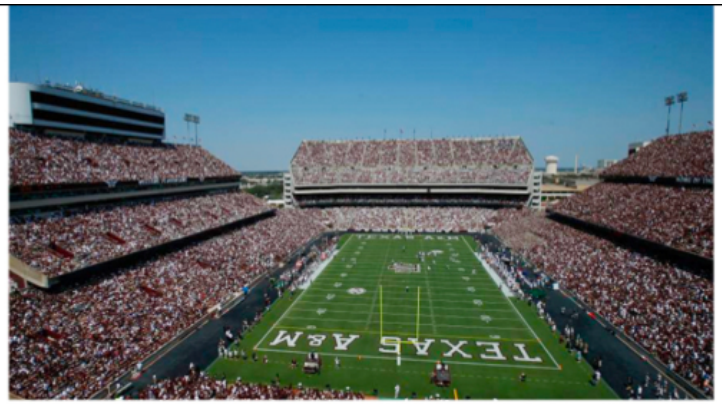
## Platform comparison matrix

| | AP-51x (BRCM) | AP-53x (QCA) | AP-555 (QCA) |
|---|---|---|---|
| 5GHz radio (HE80) | 4x4 | 4x4 | 8x8 or dual 4x4 |
| 5GHz radio (HE160) | 160 | 80 + 80 | 80 + 80 |
| 2.4GHz radio | 2x2 | 4x4 | 4x4 |
| Dual-5GHz | No | No | Yes* |
| 1024-QAM | Yes | Yes | Yes |
| Max number of clients per radio | 512 (100) | 1024 (150) | 1024 (150) |
| Peak datarates (5GHz / 2.4GHz / aggregate) | 4.8 / 0.57 / 5.37 Gbps | 2.4 / 1.15 / 3.55 Gbps | 4.8 / 1.15 / 5.95 Gbps |
| DL-OFDMA | Yes | Yes | Yes |
| UL-OFDMA | Yes | Yes | Yes |
| DL-MU-MIMO | Yes | Yes | Yes |
| Max no. of RUs (HE80) | 16 | 37 | 37 |
| Wired ports | 1x 2.5Gbps + 1x 1Gbps | 2x 5Gbps | 2x 5Gbps |
| Peak power (with/without USB) | 26.5W / 20.8W | 32.1W / 26.4W | 44.2W* / 38.2W |
| POE-PD (typical) | Class 4/3 | Class 5/4 | Class 5/4 |
| Size (internal antenna variants) | 200 x 200 x 46 (mm) | 240 x 240 x 53 (mm) | 260 x 260 x 58 (mm) |

aruba

a Hewlett Packard Enterprise company

# 行動優先校園網路
# The Aruba Architecture and Why Aruba



# Building Environments for Student Success

## Mobile-First Campus

**Uninterrupted experience**

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# ARUBA'S MOBILE FIRST ARCHITECTURE

## Powering the Experience Economy

Technology Partners | GTM Partners | Alliances | Airheads and Developers

BEST-IN-CLASS ECOSYSTEM

API

OPERATIONS & SD-WAN | SECURITY | LOCATION | ANALYTICS AND ASSURANCE

AOS

Aruba OS | AirWave / Central | ClearPass | IntroSpect | Meridian | NetInsight | UXI

SOFTWARE PLATFORM

API

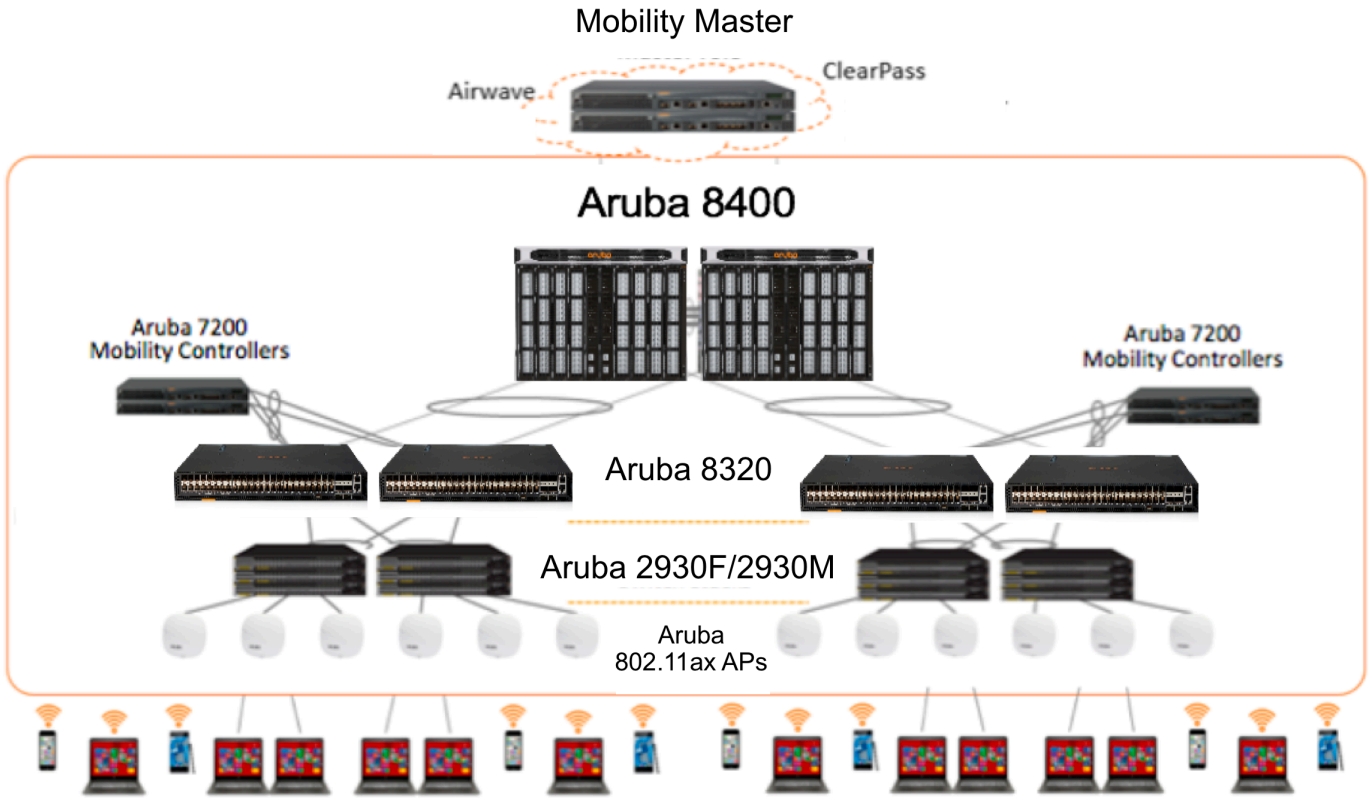
WI-FI | BLE | TAGS | REMOTE ACCESS | VIA CLIENT | WIRED ACCESS | WIRED CORE/AGG | WAN | EDGE COMPUTE

SECURE INFRASTRUCTURE

CAMPUS | BRANCHES | INDUSTRIAL

SECURE | SIMPLE | AUTONOMOUS

# Mobile First Campus




- Assured User Experience
- Optimized for Mobile Apps
- App, Device, User Aware
- Unified Policy Enforcement

# CHALLENGES
# AT THE EDGE

### TECHNOLOGY SILOS HINDER AGILITY

Fragmented management of switching, wireless, security, and WAN edge platforms cause significant challenges in provisioning, monitoring, and troubleshooting

### SECURITY THREATS INCREASE NETWORK COMPLEXITY

The security landscape is rapidly changing due to personal devices and IOT becoming commonplace attack vectors

### MANUAL OPERATION AND POOR VISIBILITY CREATE FRAGILE NETWORKS

Manual actions are slow and will likely lead to human error. Lack of data makes troubleshooting and issue resolution painful

**Networks Must Do More**

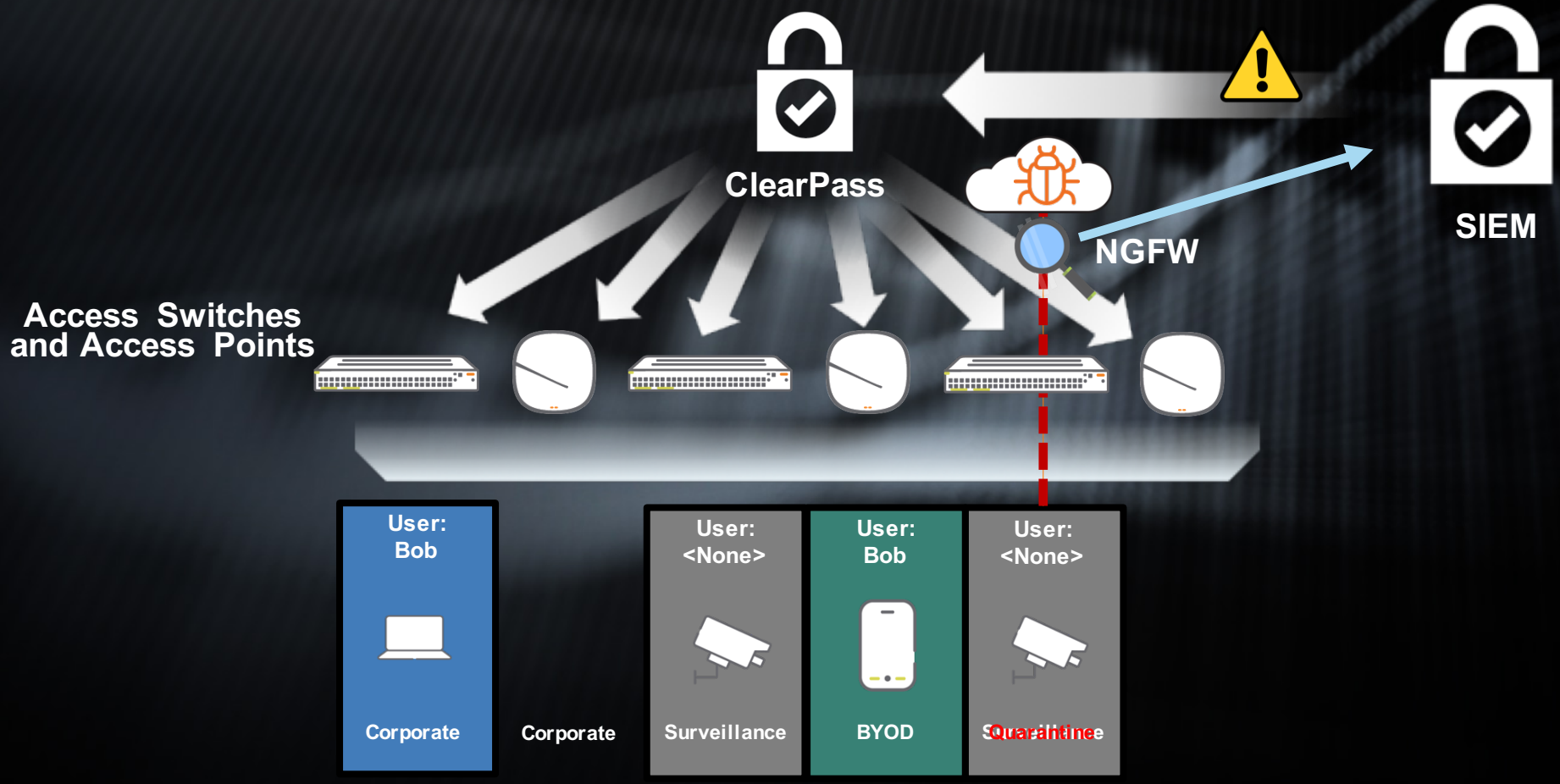
# CONTEXT-AWARE, NETWORK-DRIVEN SECURE ACCESS

# EXTENSIBLE POLICY

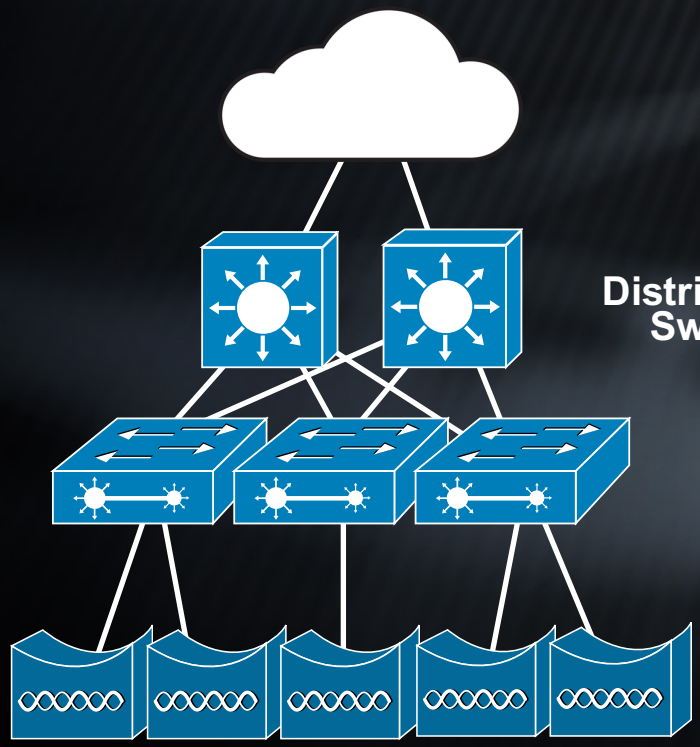
- Network Access Management
- Device Provisioning
- Device Visibility
- Visitor Management
- Compliance

ClearPass

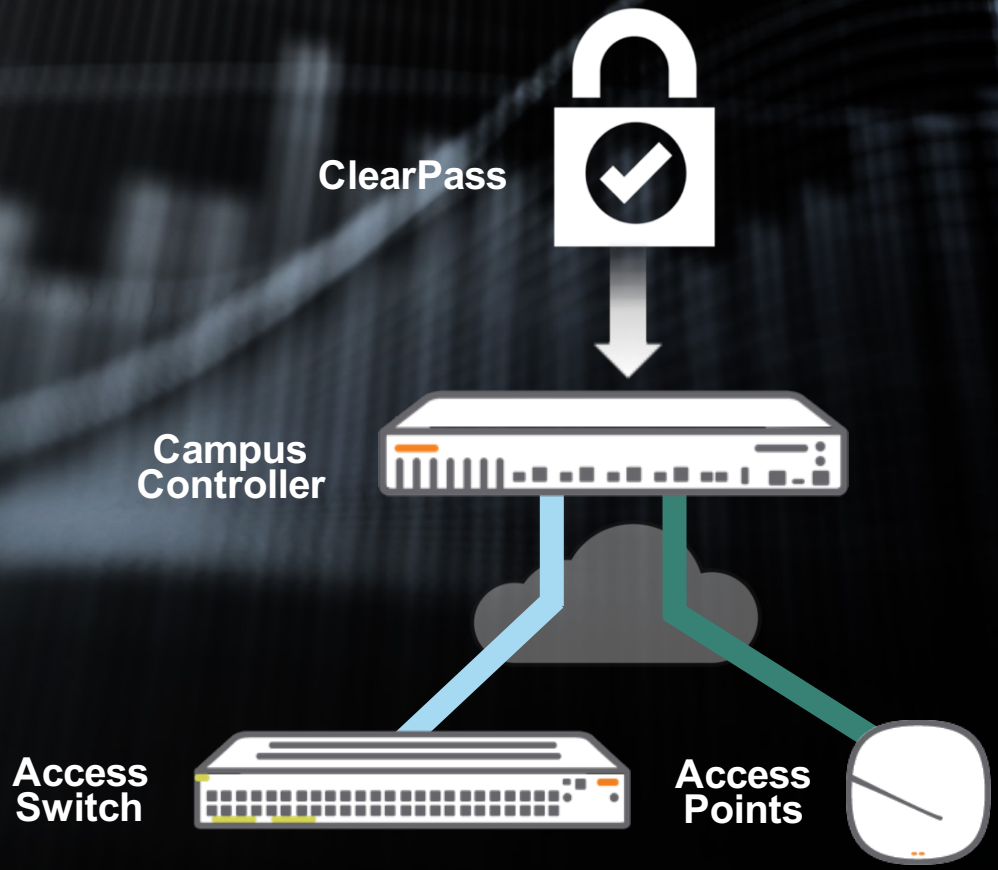
# UNIFIED POLICY DEFINITION



# POLICY OVERLAY

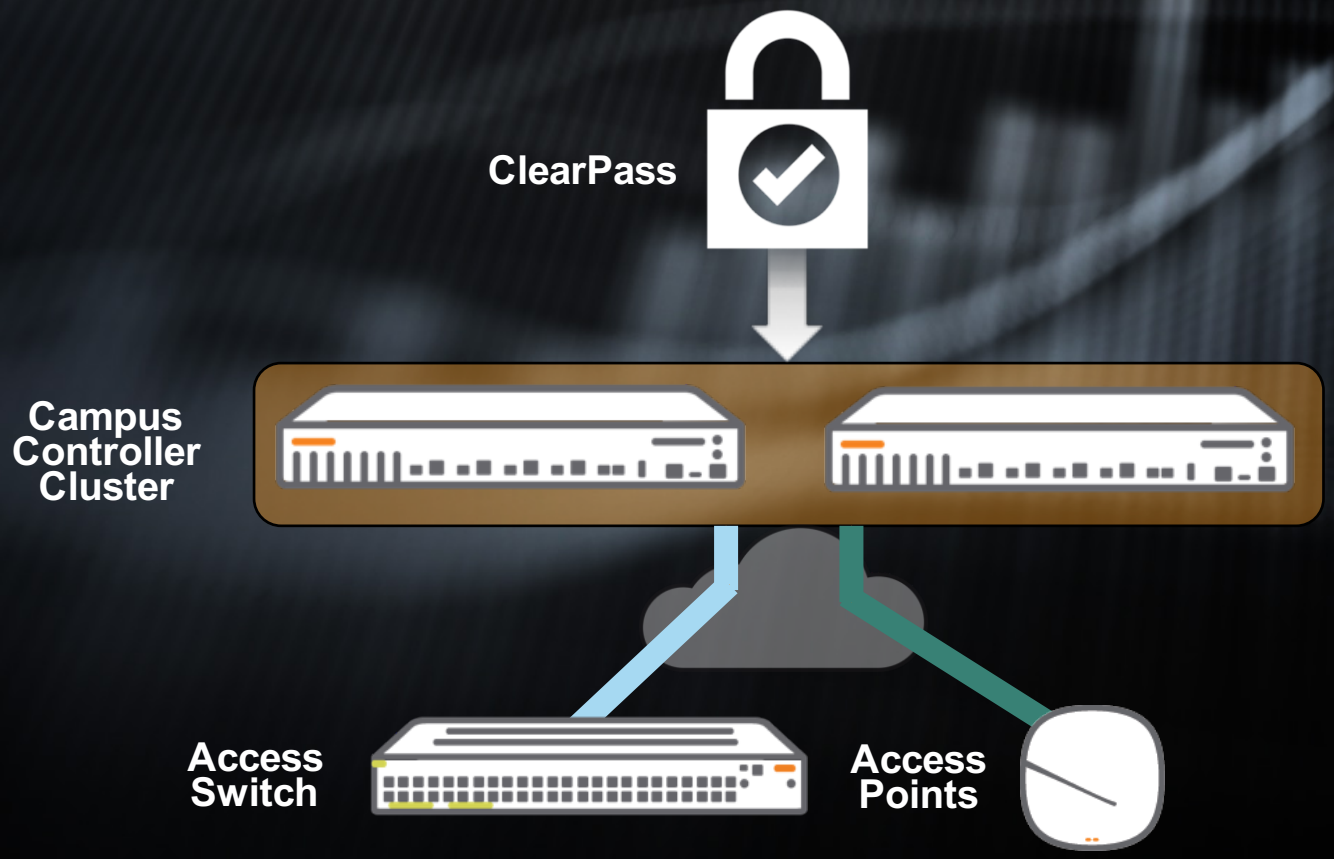



Previous Model

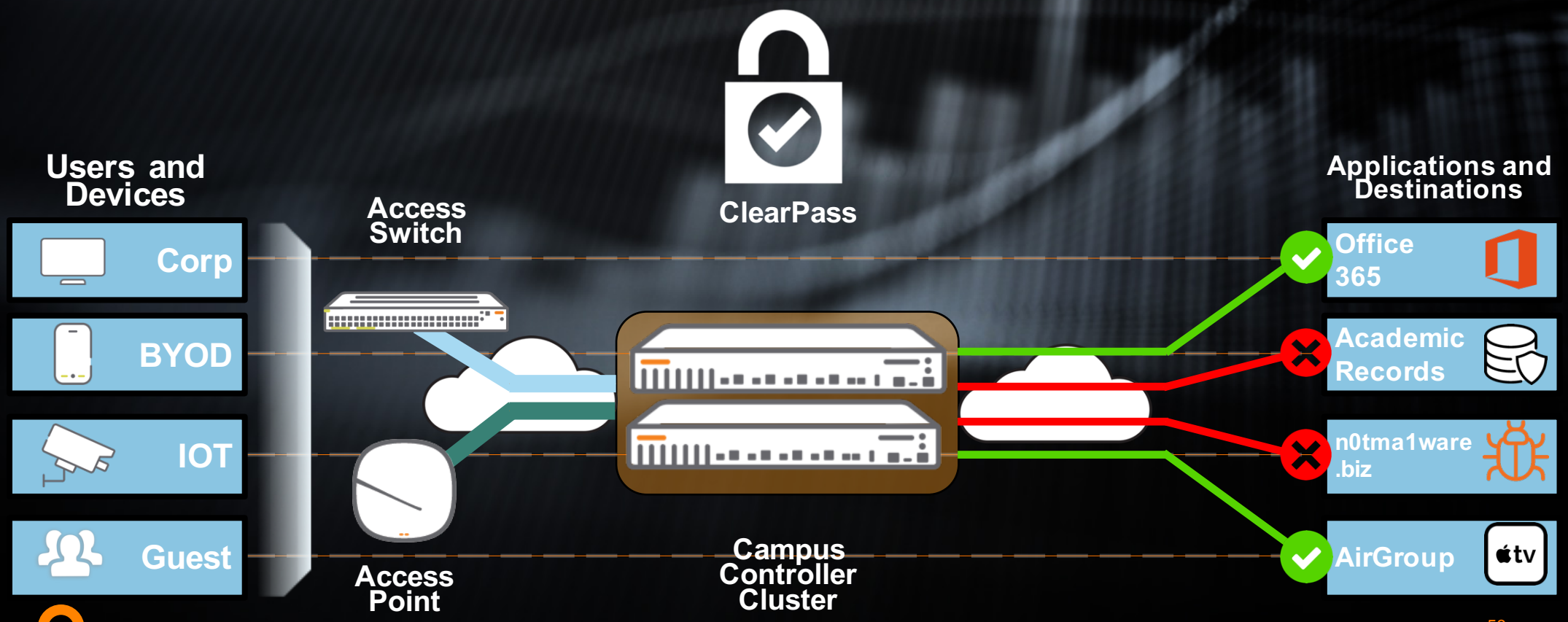



New Model

# HIGH AVAILIBILITY



# DYNAMIC SEGMENTATION

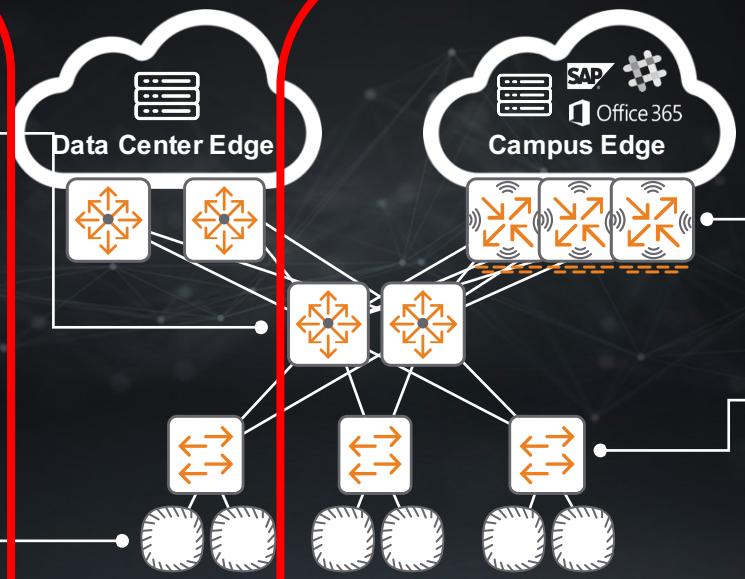


**UNDERLAY** CONNECTIVITY | **OVERLAY** POLICY | **SERVICES** CLOUD NATIVE

# THE ARUBA ARCHITECTURE CAMPUS

### CX CORE SWITCHING
Virtual Switching Extension (VSX)
Live Upgrade
Network Analytics Engine (NAE)

### ACCESS POINTS
AP as an IOT Platform
Live Upgrade
AirSlice




### GATEWAY
Physical and Virtual
Controller Clustering
AppRF DPI Engine

### CX ACCESS SWITCHING
60W PoE and Smart Rate
Virtual Switching Framework (VSF)
Network Analytics Engine (NAE)

**FLEXIBILITY** | **HIGH AVAILIBILITY** | **RICH TELEMETRY**

UNDERLAY
CONNECTIVITY

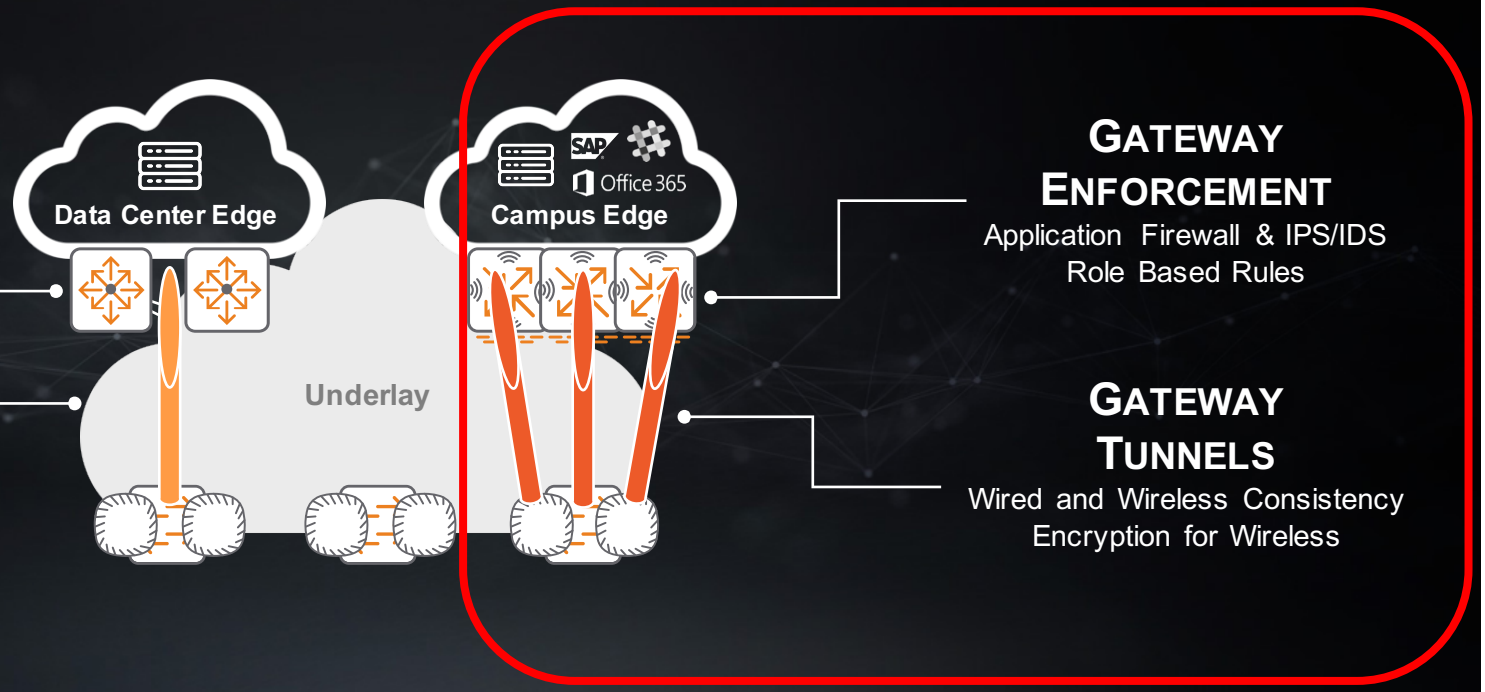
OVERLAY
POLICY

SERVICES
CLOUD NATIVE

# THE ARUBA ARCHITECTURE CAMPUS

**SWITCH TO SWITCH ENFORCEMENT**
Line Rate Enforcement (L4 ACLs)
Extension Directly to DC

**SWITCH TO SWITCH TUNNELS**
Multi-Vendor Support
Color-less Port Assignment




**GATEWAY ENFORCEMENT**
Application Firewall & IPS/IDS
Role Based Rules

**GATEWAY TUNNELS**
Wired and Wireless Consistency
Encryption for Wireless

SEGMENTATION

TRANSPORT INDEPENDENCE

SERVICE INSERTION

**UNDERLAY**
CONNECTIVITY

**OVERLAY**
POLICY

**SERVICES**
CLOUD NATIVE

# THE ARUBA ARCHITECTURE CAMPUS

## Central

- Management
- Control Services
- Analytics
- Orchestration

### MANAGEMENT
Unified Client App Visibility
Hierarchical Configuration

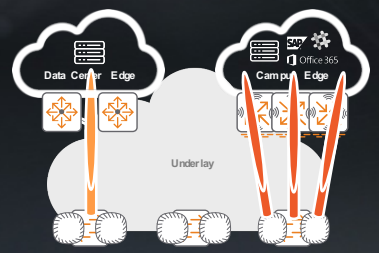
### CONTROL SERVICES
AirMatch and ClientMatch
UCC

### ANALYTICS
Infrastructure-wide Data
AI Insights

### ORCHESTRATION
Workflow Driven
Cross Infrastructure

## ClearPass

Policy Management




**FLEXIBLE DEPLOYMENT** **ELASTICITY** **EXTENSIBILITY**

# Architecting for Tomorrow

## AIOps

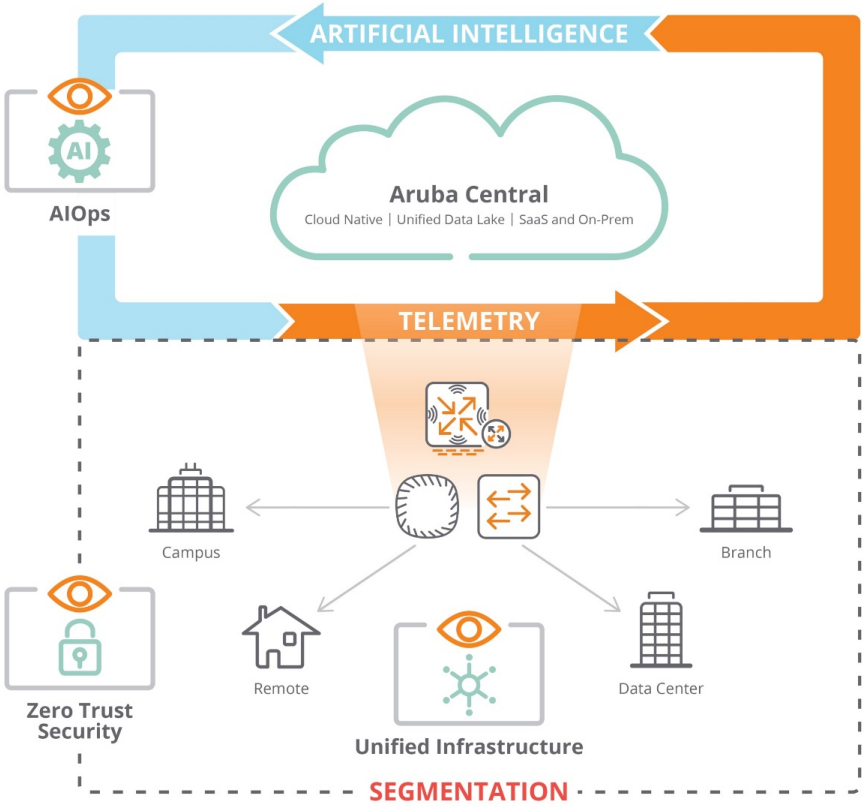
# WHAT IS AIOPS?

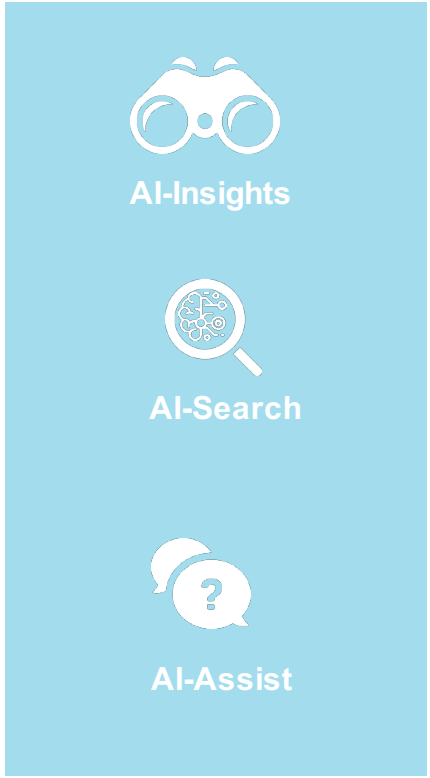
"AIOps (Artificial Intelligence for IT operations) combines big data and machine learning to automate IT operations processes, including event correlation, anomaly detection and causality determination."

Gartner 2019[1]

# Aruba Edge Services Platform - AIOps

## Automating and Protecting the Intelligent Edge




- Network Tuning & Optimisation
- Find & Fix
- Automatic Anomaly detection

- Natural Language Search
- Reduced Click Count

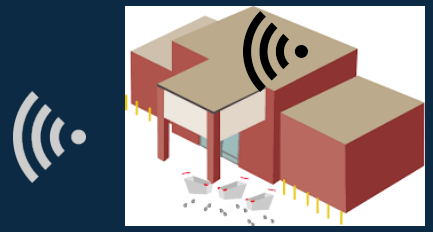
- Automate Troubleshooting
- Deliver efficiency to the IT Ops teams

# CONTINOUSLY MONITOR AND OPTIMZE

## AI INSIGHTS

### Problem

Passerby traffic dragging down network performance



### Solution

Aruba AI Insights recommended setting changes to reduce passerby traffic by 95% while maintaining inside traffic

### Result

**25% improvement in network performance with no additional hardware**

Aruba Confidential. For Internal Use Only.

Aruba Central

app-mario.arubathena.com/frontend/#/GLOBAL_INSIGHTS

aruba Central

Search or ask Aruba

Global

Network Health | WAN Health | Summary | AI Insights

3 hours

Manage

- Overview
- Devices
- Clients
- Guests
- Applications
- Security
- Network Services

Analyze

- Alerts & Events
- Audit Trail
- Tools
- Reports

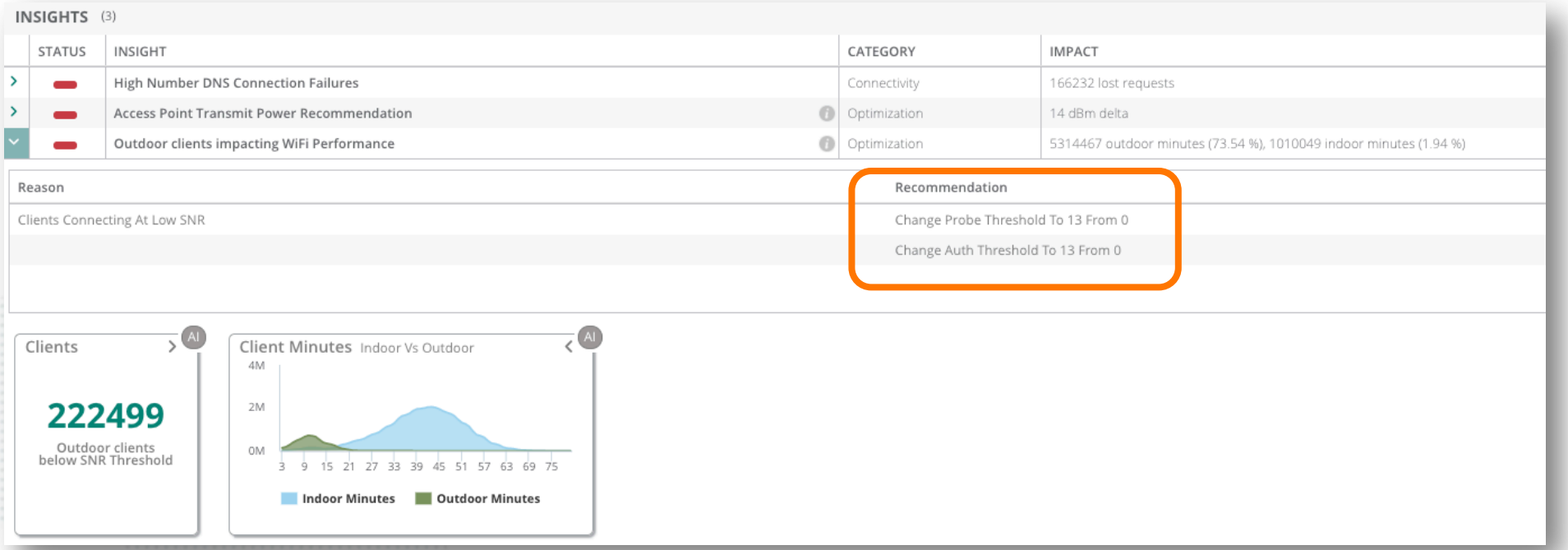
Maintain

- Firmware
- Organization

## INSIGHTS 29

| | STATUS | INSIGHT | CATEGORY | IMPACT |
|---|---|---|---|---|
| > | | Clients with Excessive 2.4 GHz Dwell Time | Optimization | 75 % Client Devices |
| > | | 802.1x Authentication Failures | Connectivity | 3551 Failures |
| > | | Access Points with High 2.4 GHz Utilization | RF Info | 153 Radios |
| > | | Access Points with High 5 GHz Utilization | RF Info | 174 Radios |
| > | | Excessive Access Point Reboots | Health | 5 Reboots |
| > | | Excessive DNS Request Failures | Connectivity | 606 Failures |
| > | | Excessive DNS Delays | Connectivity | 14956 Average Delay (msec) |
| > | | High Number DNS Connection Failures | Connectivity | 5245 Lost Requests |
| > | | Switch with High CPU Utilization | Switch Health | 4 Switches |
| > | | Switch with High Memory Utilization | Switch Health | 4 Switches |
| > | | Clients with High Roaming Latency | Roaming | 91.49 % Roams |
| > | | Gateway with High CPU Utilization | Gateway Health | 13 Gateways |
| > | | Gateway with High Memory Utilization | Gateway Health | 19 Gateways |
| > | | Gateway Tunnels Down | Gateway Health | 5 Tunnels Down |
| > | | Access Point Transmit Power Recommendation | Optimization | 14 dBm Delta |
| > | | Outdoor Clients Impacting Wi-Fi Performance | Optimization | 5314467 Outdoor Minutes (73.54 %), 1010049 Indoor Minutes (1.94 %) |
| > | | Coverage Hole Detected | Optimization | 8986 Client Devices |
| > | | DHCP Timeout | Connectivity | 32 failures |

# Outdoor clients impacting Wi-Fi performance




- Passerby (outdoor) clients connect at low rates to APs and degrade indoor performance
- AI Insights models the difference between indoor and outdoor clients using multiple factors
- AI Insights provides visibility and develops configuration recommendations to prevent passerby clients from connecting to the network.

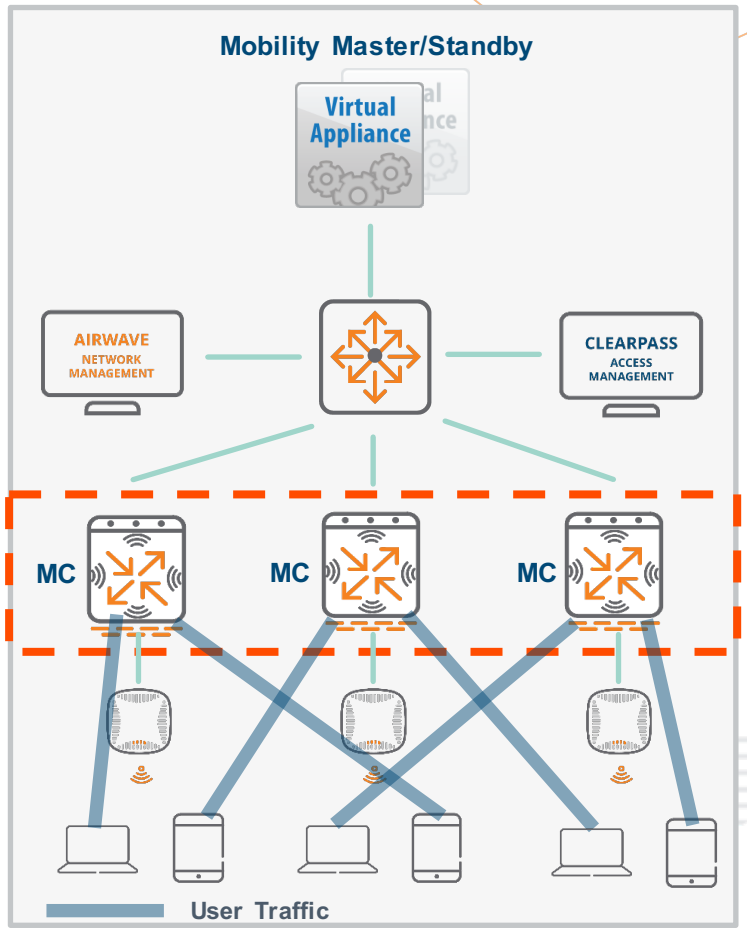
# Solution (at this moment):
## Mobile First Architecture
## Controller Clustering

1. **Stateful Client Failover**
   User traffic uninterrupted upon controller failure

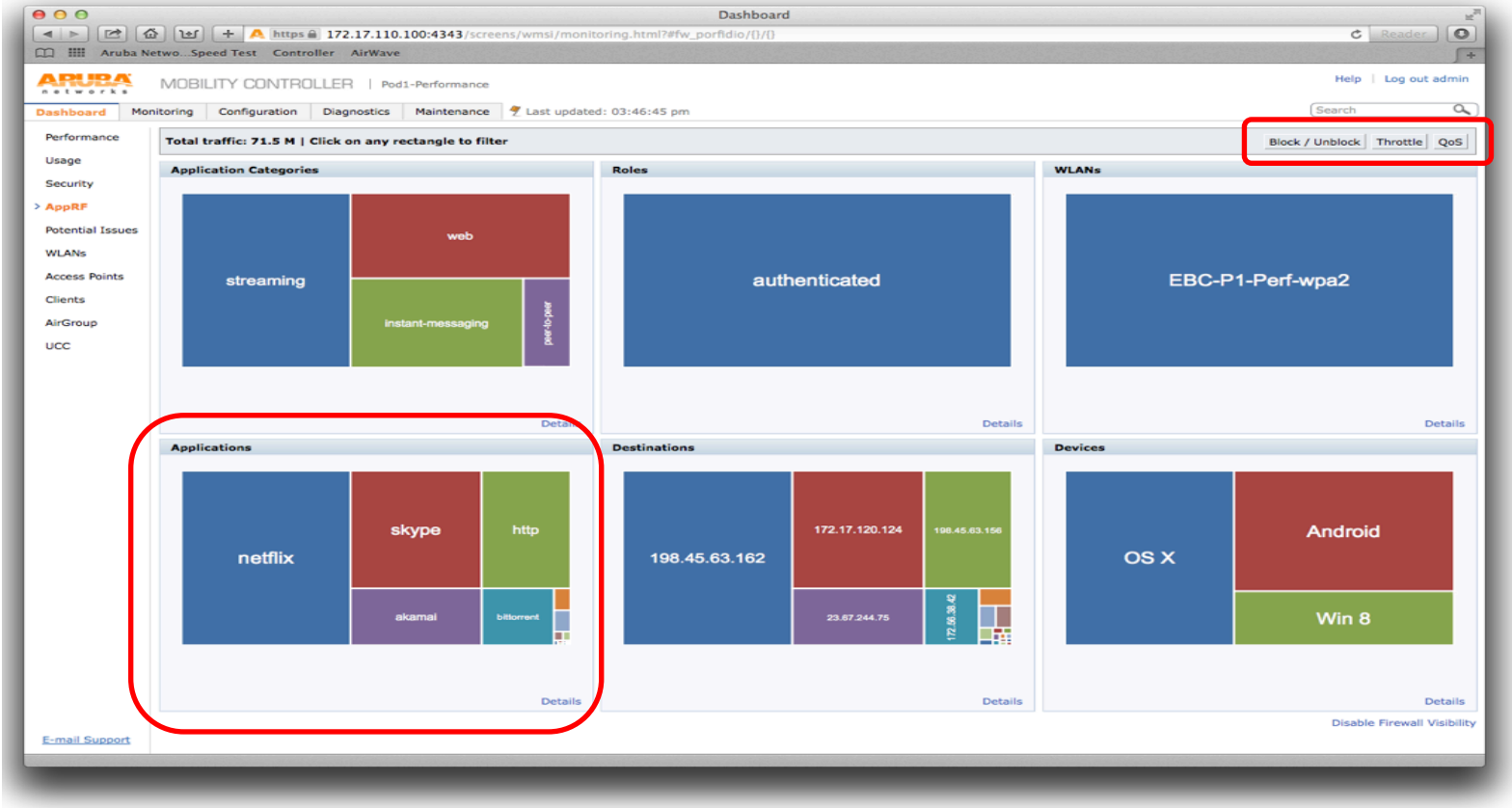
2. **Seamless Campus Roaming**
   Clients stay anchored to a single Mobility Controller when roaming across controllers

3. **Client Load Balancing**
   Users automatically load balanced across cluster members

4. **AP Load Balancing**
   APs are automatically load balanced across cluster members



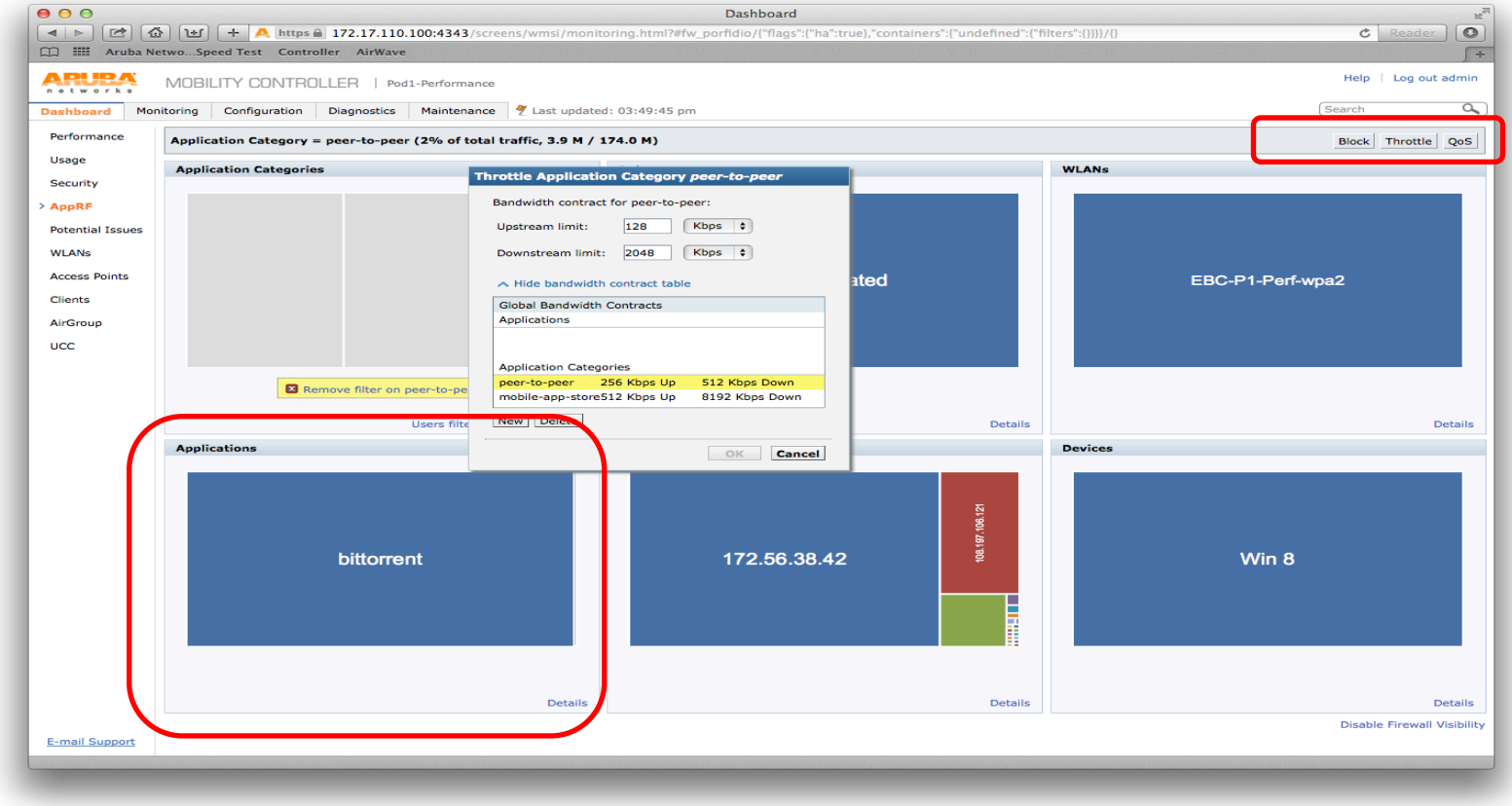
# Application Monitoring and Control (AppRF)




## Simple Control

- Select by:
  - application
  - **app category**
  - role
  - address
- Apply policy (block, throttle, prioritize)
- Eliminates complexity of configuration

# Application Monitoring and Control (AppRF)

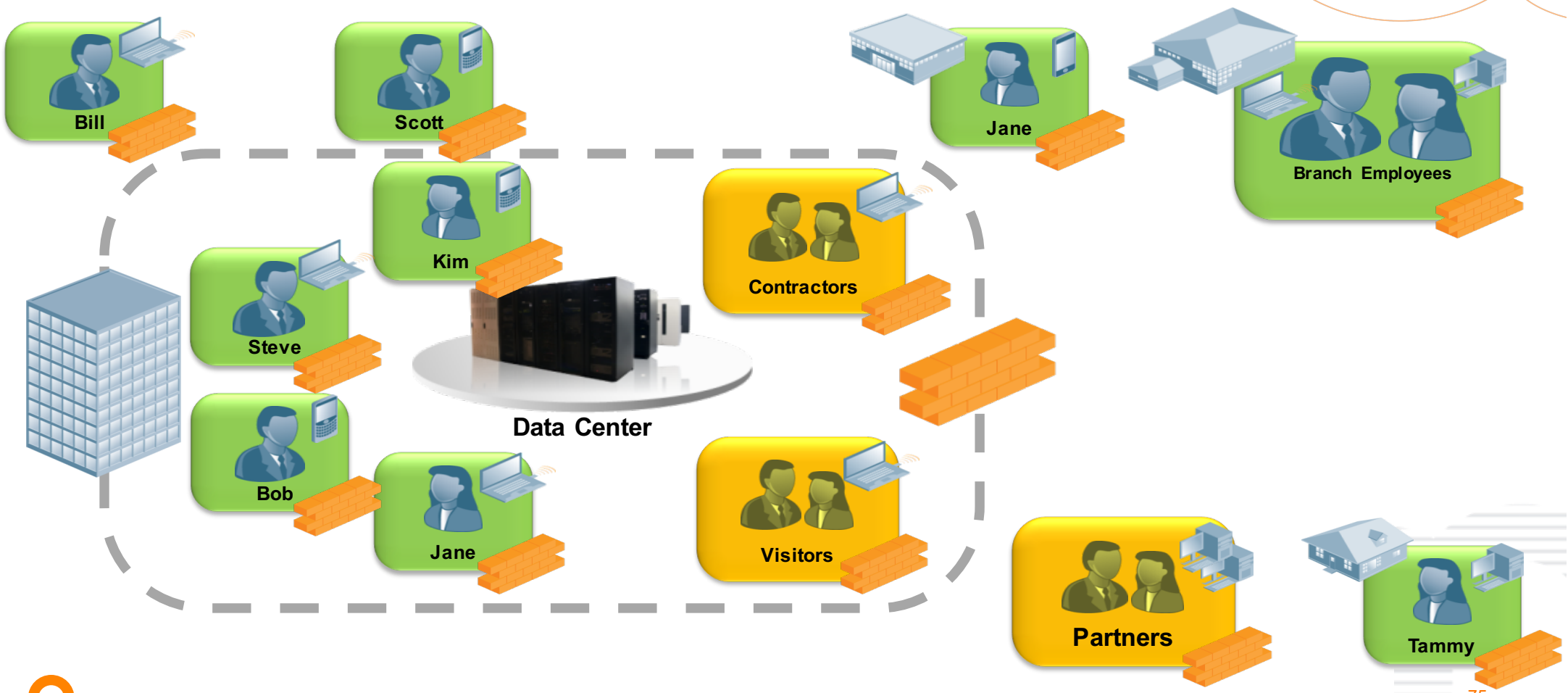



## Simple Control

- Select by:
  - application
  - **app category**
  - role
  - address
- Apply policy (block, throttle, prioritize)
- Eliminates complexity of configuration

# Context-Aware Policies & Enforcement

## -Stateful Firewall



# Smart Air

## -User Logging details (Airwave)

aruba | AirWave

NEW DEVICES 1 | UP 6 | DOWN 6 | MISMATCHED 1 | ROGUE 542 | CLIENTS 4 | VPN SESSIONS 0 | VPN USERS 2 | ALERTS 7 | Log out admin

**Device Info**

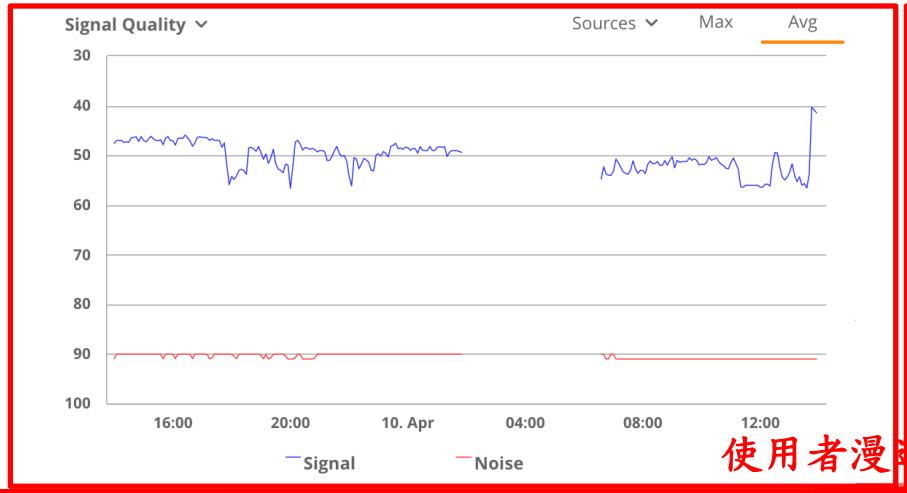
| | |
|---|---|
| Username: | kent |
| Device Name: | |
| Device Type: | iPad |
| MAC Address: | E8:B2:AC:1A:A4:44 |

使用者的訊號品質

**Current Association**

| | |
|---|---|
| Connection Mode: | 11ac 5GHz |
| Duration: | 6 hours 56 minutes |
| IP Address: | 172.16.14.248 |
| Hostname: | |

使用者的工作量(頻寬使用)



使用者漫遊歷史紀錄

| USERNAME | AP/DEVICE | AOS DEVICE TYPE | CONNECTION MODE | ASSOCIATION TIME | DURATION | AVG. SPEED | AVG. SIGNAL QUALITY | TOTAL DATA USED |
|---|---|---|---|---|---|---|---|---|
| kent | AP335-1 | iPad | 11ac 5GHz | 4/1/18, 6:18 AM | 3 minutes | 866 Mbps | 40 | 0 B |
| kent | AP335-1 | iPad | 11ac 5GHz | 4/1/18, 6:31 AM | 16 hours ... | 863 Mbps | 43 | 4.07 GB |
| kent | AP335-1 | iPad | 11n 2.4 GHz | 4/1/18, 10:53 PM | 5 seconds | 865 Mbps | - | 960 KB |
| kent | AP335-1 | iPad | 11ac 5GHz | 4/1/18, 10:53 PM | 3 hours 5 ... | 865 Mbps | 47 | 15.5 MB |

# Smart Air

## -Client Details - Device Classification (Airwave)

aruba | AirWave

NEW DEVICES 1 | UP 6 | DOWN 6 | MISMATCHED 1 | ROGUE 542 | CLIENTS 4 | VPN SESSIONS 0

Log out admin

- Groups
- APs/Devices
- Clients
  - Overview
  - Connected
  - All
  - Rogue Clients
  - Guest Users
  - Client Detail
  - Diagnostics
  - VPN Sessions
  - VPN Users
  - Tags
- Reports
- System
- Device Setup
- AMP Setup
- RAPIDS

**Detail for E8:B2:AC:1A:A4:44**

**Device Info**

| | |
|---|---|
| Username: | kent |
| First Seen: | 10/5/2017 11:35 PM CST on AP335-1 for 3 hrs 7 mins |
| Last Seen: | 4/10/2018 1:04 PM CST on AP335-1 for 6 hrs 38 mins |
| Device Type: | iPad |
| Network Interface Vendor: | Apple, Inc. |
| Connection Mode: | 802.11ac |
| Channel Width Capability: | VHT 40MHz |
| Spatial Streams Capability: | 2 |
| AOS Device Type: | iPad |
| Aruba HTTP Fingerprint: | - |
| Classification: | Unclassified |
| Watched Client: | Yes No |
| Notes: | |

Show additional properties

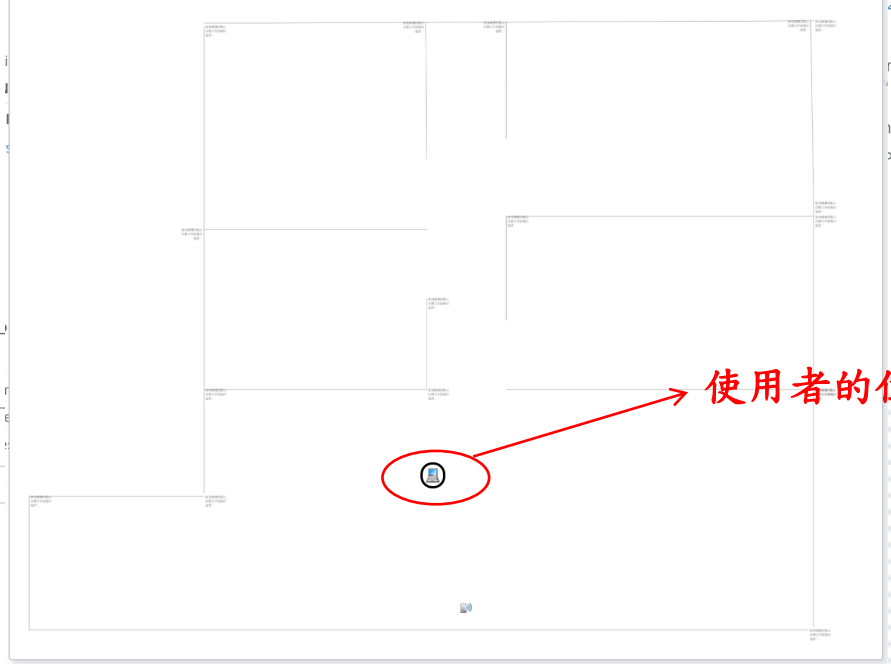
Save | Open controller web UI... | Run command...

**Current Association**

| | | | |
|---|---|---|---|
| Username: | kent | | |
| Role: | employee | AP/Device: | AP335-1 |
| Signal Quality: | 37 | Controller: | 7010-Local-1 |
| Association: | 4/10/2018 6:25 AM CST | Group: | 7010-Local-1 |

kent on Home_LAB -> Home Building -> Floor 1

Placement | Heatmap | Data-rate | Health



# Airwave AppRF Report (Application Monitoring)

10/15/2018 12:00 AM CST to 10/16/2018 12:00 AM CST
Generated on 10/16/2018 2:56 AM CST

## Top Applications

| | |
|---|---|
| dailymotion | 75.8% |
| facebook | 8.2% |
| http2 | 6.1% |
| Other | 5.6% |
| https | 4.3% |

| Application | Total Bytes |
|---|---|
| dailymotion | 8.42 GB |
| facebook | 908.75 MB |
| http2 | 679.87 MB |
| https | 477.04 MB |
| udp | 87.60 MB |
| yahoo | 86.74 MB |
| line | 86.44 MB |
| baidu | 79.06 MB |
| google | 73.25 MB |
| youtube | 32.98 MB |
| google-ads | 23.11 MB |
| flashplugin-update | 22.38 MB |
| vrrp | 19.69 MB |
| amazon-aws | 19.15 MB |
| itunes | 15.81 MB |
| ssl | 14 MB |
| icloud | 6.29 MB |
| taboola | 5.49 MB |
| fastly | 5.27 MB |
| apple | 5.06 MB |
| ymail2 | 5.05 MB |
| scorecardresearch | 4.84 MB |
| adsafeprotected | 4.78 MB |
| instagram | 4.32 MB |
| tubemogul | 3.77 MB |
| gstatic | 3.58 MB |
| appnexus | 2.97 MB |
| dns | 2.73 MB |
| appstore | 2.72 MB |
| facebook-video | 2.65 MB |

## Top Destinations

| | |
|---|---|
| Other | 42.8% |
| proxy-075.dc3.dailym… | 18.5% |
| proxy-073.dc3.dailym… | 17.5% |
| proxy-44.sv6.dailymo… | 12.4% |
| facebook | 8.9% |

| Destination | Total Bytes |
|---|---|
| proxy-075.dc3.dailymotion.com | 1.88 GB |
| proxy-073.dc3.dailymotion.com | 1.79 GB |
| proxy-44.sv6.dailymotion.com | 1.26 GB |
| facebook | 903.75 MB |
| proxy-024.ix7.dailymotion.com | 801.05 MB |
| vod-dm.cdn.hinet.net | 592.85 MB |
| proxy-015.ix7.dailymotion.com | 487.99 MB |
| dnsdel | 453.46 MB |
| proxy-25.sv6.dailymotion.com | 372.75 MB |
| proxy-010.ix7.dailymotion.com | 276.30 MB |
| proxy-063.dc3.dailymotion.com | 225.54 MB |
| d.line-scdn.net | 133.05 MB |
| proxy-042.ix7.dailymotion.com | 116.21 MB |
| proxy-37.sv6.dailymotion.com | 96.02 MB |
| 6.mms.vlog.xuite.net | 84.66 MB |
| obs-tw.line-apps.com | 70.09 MB |
| tb-video.bdstatic.com | 69.39 MB |
| proxy-020.ix7.dailymotion.com | 65.47 MB |
| gcs-asia-00002.content-storage-upload.googleapis.com | 62.05 MB |
| proxy-14.sv6.dailymotion.com | 61.34 MB |
| proxy-30.sv6.dailymotion.com | 49.70 MB |
| 188.65.126.180 | 45.92 MB |
| proxy-064.dc3.dailymotion.com | 43.64 MB |
| proxy-23.sv6.dailymotion.com | 40.32 MB |
| proxy-40.sv6.dailymotion.com | 39.49 MB |
| proxy-17.sv6.dailymotion.com | 38.32 MB |
| 188.65.126.191 | 38.03 MB |
| cac-vdn-obs.line-scdn.net.line-zero.akadns.net | 33.85 MB |
| r1---sn-ipoxu-un5s.googlevideo.com | 32.54 MB |
| proxy-041.ix7.dailymotion.com | 32.28 MB |

# AppRF, including specific User's Top Applications

Details for User 'kent' with Device 'iPad'

| Application | Total Bytes | Destinations |
|---|---|---|
| baidu | 78.34 MB | tb-video.bdstatic.com, tb2.bdstatic.com, (more >) |
| google | 65.45 MB | gcs-asia-00002.content-storage-upload.googleapis.com, ssl.gstatic.com, |
| http2 | 19.44 MB | cdn2.ettoday.net, www.ettoday.net, (more >) |
| google-ads | 14.76 MB | tpc.googlesyndication.com, pagead2.googlesyndication.com, (more >) |
| facebook | 11.37 MB | facebook, dnsdel, (more >) |
| https | 10.11 MB | e11967.d.akamaiedge.net, rec.scupio.com, (more >) |
| icloud | 4.52 MB | gateway.fe.apple-dns.net, p52-keyvalueservice.icloud.com, (more >) |
| gstatic | 2.24 MB | clients1.google.com, encrypted-tbn1.gstatic.com, (more >) |
| youtube | 1.81 MB | youtube, clients1.google.com, (more >) |
| king | 1.64 MB | bling2.midasplayer.com, candycrushsodamobile.king.com, (more >) |
| appnexus | 1.11 MB | ad networks, dnsdel |
| appstore | 800.28 KB | init.itunes.apple.com, client-api.itunes.apple.com, (more >) |
| apple | 798.86 KB | dnsdel, api-glb-hkg.smoot.apple.com, (more >) |
| itunes | 767.55 KB | client-api.itunes.apple.com, dnsdel, (more >) |
| criteo | 634.77 KB | gum.criteo.com, bidder.criteo.com |
| helpshift | 485.83 KB | playrix.helpshift.com |
| akamai | 423.34 KB | supersonicads-a.akamaihd.net |
| dns | 417.58 KB | ARUBA.arubademo.aruba.com.tw, aruba.arubademo.aruba.com.tw, (more |
| everest-tech | 403.54 KB | dnsdel, cm.everesttech.net, (more >) |
| http | 366.82 KB | fc-feed.cdn.bcebos.com, www.cwb.gov.tw |

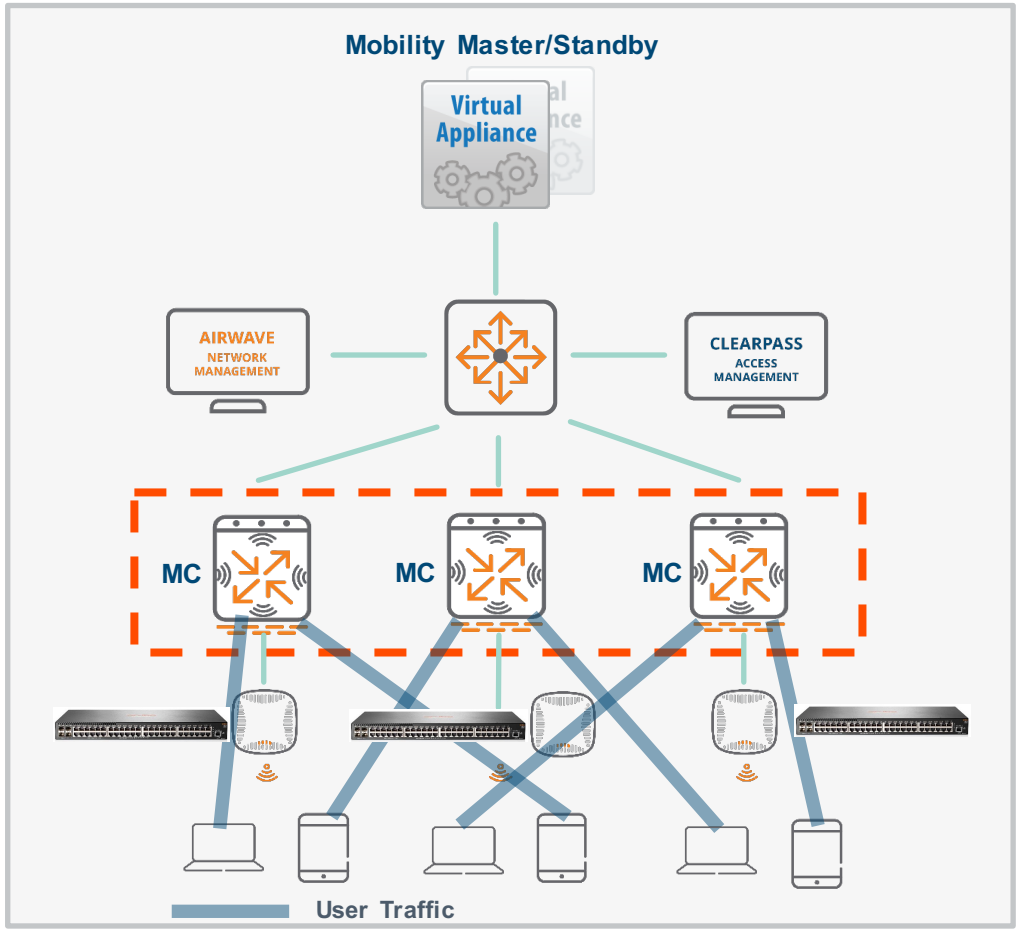
Details for User 'kent' with Device 'OS X'

| Application | Total Bytes | Destinations |
|---|---|---|
| dailymotion | 152.15 MB | proxy-042.ix7.dailymotion.com, 188.65.126.191, (more >) |
| https | 83.50 MB | 188.65.126.180, 172.16.0.174, (more >) |
| ssl | 6.75 MB | 172.16.0.193, 1-courier.push.apple.com, (more >) |
| udp | 1.42 MB | www.google.com.tw, ad networks, (more >) |
| office365 | 1.04 MB | outlook.ha.office365.com, nexus.officeapps.live.com |
| apple-update | 449.48 KB | swscan.apple.com |
| http2 | 178.81 KB | sso.arubanetworks.com |
| gstatic | 174.28 KB | ssl.gstatic.com |
| apns | 157.68 KB | init-s01st.push.apple.com, 35-courier.push.apple.com, (more >) |
| apple | 130.21 KB | world-gen.g.aaplimg.com, xp.apple.com, (more >) |
| apple-location | 108.09 KB | gspe1-ssl.ls.apple.com, gspe35-ssl.ls.apple.com, (more >) |
| dns | 104.79 KB | ARUBA.arubademo.aruba.com.tw, aruba.arubademo.aruba.com.tw, (mo |
| appstore | 95.30 KB | play.itunes.apple.com, init.itunes.apple.com, (more >) |
| mdns | 75.14 KB | 224.0.0.251 |
| scorecardresearch | 72.68 KB | scorecardresearch |
| google | 69.98 KB | safebrowsing.googleapis.com, update.googleapis.com, (more >) |
| itunes | 55.55 KB | sandbox.itunes.apple.com, play.itunes.apple.com |
| google-cache | 53.73 KB | google drive |
| linkedin | 45.41 KB | linkedin |
| ssh | 35.66 KB | 172.16.15.212, 172.16.0.186, (more >) |

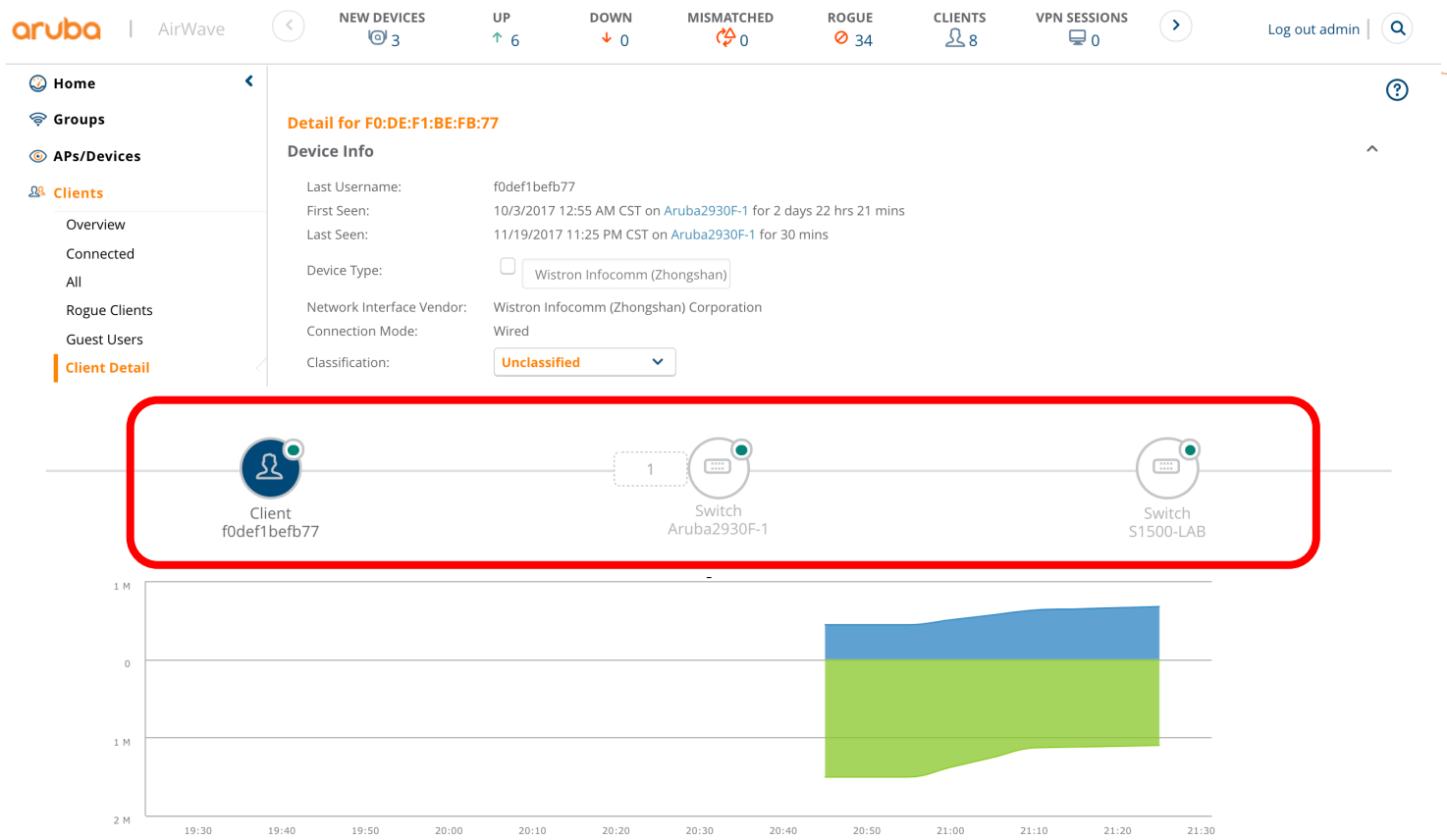
# Extending policies to wired and wireless including IoT devices

## Policy Management

# Always-On Architecture, Secure End to End Wired and Wireless



# Wired Client Detail (Airwave)




| USERNAME | AP/DEVICE | CONNECTION MODE | ASSOCIATION TIME | DURATION | LAN IP ADDRESSES | VLAN | TOTAL DATA USED |
|---|---|---|---|---|---|---|---|
| f0def1befb77 | Aruba2930F-1 | Wired | 10/15/18, 1:17 AM | 30 minutes | 172.16.14.241 | 14 | 167 MB |
| f0def1befb77 | Aruba2930F-1 | Wired | 10/15/18, 7:48 AM | 10 hours 3... | 172.16.14.241 | 14 | 6.99 GB |
| f0def1befb77 | Aruba2930F-1 | Wired | 10/15/18, 6:48 PM | 7 hours 27 ... | 172.16.14.241 | 14 | 1.11 GB |

# AppRF Report, including specific User's Top Applications

10/15/2018 12:00 AM CST to 10/16/2018 12:00 AM CST
Generated on 10/16/2018 2:56 AM CST

**Top Applications**

| | |
|---|---|
| dailymotion | 75.8% |
| facebook | 8.2% |
| http2 | 6.1% |
| Other | 5.6% |
| https | 4.3% |

| Application | Total Bytes |
|---|---|
| dailymotion | 8.42 GB |
| facebook | 908.75 MB |
| http2 | 679.87 MB |
| https | 477.04 MB |
| udp | 87.60 MB |
| yahoo | 86.74 MB |
| line | 86.44 MB |
| baidu | 79.06 MB |
| google | 73.25 MB |
| youtube | 32.98 MB |
| google-ads | 23.11 MB |
| flashplugin-update | 22.38 MB |
| vrrp | 19.69 MB |
| amazon-aws | 19.15 MB |
| itunes | 15.81 MB |

**Top Destinations**

| | |
|---|---|
| Other | 42.8% |
| proxy-075.dc3.dailym… | 18.5% |
| proxy-073.dc3.dailym… | 17.5% |
| proxy-44.sv6.dailymo… | 12.4% |
| facebook | 8.9% |

| Destination | Total Bytes |
|---|---|
| proxy-075.dc3.dailymotion.com | 1.88 GB |
| proxy-073.dc3.dailymotion.com | 1.79 GB |
| proxy-44.sv6.dailymotion.com | 1.26 GB |
| facebook | 903.75 MB |
| proxy-024.ix7.dailymotion.com | 801.05 MB |
| vod-dm.cdn.hinet.net | 592.85 MB |
| proxy-015.ix7.dailymotion.com | 487.99 MB |
| dnsdel | 453.46 MB |
| proxy-25.sv6.dailymotion.com | 372.75 MB |
| proxy-010.ix7.dailymotion.com | 276.30 MB |
| proxy-063.dc3.dailymotion.com | 225.54 MB |
| d.line-scdn.net | 133.05 MB |
| proxy-042.ix7.dailymotion.com | 116.21 MB |
| proxy-37.sv6.dailymotion.com | 96.02 MB |
| 6.mms.vlog.xuite.net | 84.66 MB |

## Wired User

Details for User '172.16.14.241' with Device '--'

| Application | Total Bytes | Destinations |
|---|---|---|
| dailymotion | 8.30 GB | proxy-075.dc3.dailymotion.com, proxy-073.dc3.dailymotion.com, (more >) |
| http2 | 649.42 MB | vod-dm.cdn.hinet.net, 210.71.222.161, (more >) |
| https | 169.32 MB | 6.mms.vlog.xuite.net, cdn.doublemax.net, (more >) |
| facebook | 73.42 MB | facebook, s.update.fbsbx.com, (more >) |
| yahoo | 32.93 MB | udc.yahoo.com, pr.ybp.yahoo.com, (more >) |
| udp | 26.18 MB | ad networks, tpc.googlesyndication.com, (more >) |
| amazon-aws | 17.75 MB | d1lnephkr7mkjn.cloudfront.net, amazon cloud drive, (more >) |
| taboola | 5.53 MB | images.taboola.com, cdn.taboola.com, (more >) |
| google-ads | 4.51 MB | r2---sn-un57sn7s.c.2mdn.net, pagead2.googlesyndication.com, (more >) |
| scorecardresearch | 4.39 MB | scorecardresearch |
| adsafeprotected | 4.30 MB | pixel.adsafeprotected.com, dt.adsafeprotected.com, (more >) |
| google | 4.11 MB | storage.googleapis.com, cdn.ampproject.org, (more >) |
| tubemogul | 3.77 MB | ud.tubemogul.com, playtime.tubemogul.com |
| ltn | 1.77 MB | img.ltn.com.tw, ent.ltn.com.tw, (more >) |
| appnexus | 1.77 MB | ad networks, dnsdel |
| dns | 1.60 MB | ARUBA.arubademo.aruba.com.tw, aruba.arubademo.aruba.com.tw, (more >) |

# Only Solution that Delivers Wired Specific IoT Connectivity

## Connect, Enforce, Protect

**Connect**

- Any IoT device
  - Up to 48 devices
  - Includes PoE+
  - Works with cameras, sensors, healthcare equipment, PoS

**Enforce**

- Policy enforcement
  - Utilize ClearPass Policy Manager and third-party security tools for real-time threat prevention

**Protect**

- Automated tunnels
  - Define what resources IoT devices can reach
  - Limit access by administrators

**IoT-Ready Switch**

# Role Mapping - ClearPass

**Policy:**

| | |
|---|---|
| Policy Name: | OnConnect Roles_v2 |
| Description: | |
| Default Role: | [Other] |

**Mapping Rules:**

| | |
|---|---|
| Rules Evaluation Algorithm: | Evaluate all |

| | Conditions | Role Name |
|---|---|---|
| 1. | (Connection:Src-IP-Address *NOT_EXISTS* ) | get IP |
| 2. | (Authorization:Kent-AD04:UserDN *EXISTS* ) | [Employee] |
| 3. | (Authorization:[Endpoints Repository]:Category *EQUALS* Computer) | Computer |
| 4. | (Authorization:[Endpoints Repository]:Category *EQUALS* Printer) | Printer |
| 5. | (Authorization:[Endpoints Repository]:Category *EQUALS* VoIP Phone) | VoIP_Phone |
| 6. | (Authorization:[Endpoints Repository]:Category *EQUALS* Access Points) | AP |
| 7. | (Authorization:[Endpoints Repository]:Hostname *CONTAINS* ipcam) | IP_CAM |
| 8. | (Authorization:[Endpoints Repository]:Status *NOT_EQUALS* Known) | New IoT device |

# Use case – Enforcement of existing device

- Device is know and has been profiled
- Assign Role
- Enforce Access controls

Endpoint | Attributes | Fingerprints

| | |
|---|---|
| MAC Address | f0def1befb77 |
| Description | |
| Status | Known client<br>Unknown client<br>Disabled client |
| MAC Vendor | Wistron Infocomm (Zhongshan) Corporation |
| Added by | Policy Manager |
| Online Status | Offline |
| Connection Type | Wired |
| Switch IP | 172.16.0.193 |
| Switch Port | gigabitethernet0/0/0 |

| | |
|---|---|
| IP Address | 172.16.14.233 |
| Static IP | FALSE |
| Hostname | kent-oa |
| Device Category | Computer |
| Device OS Family | Windows |
| Device Name | Windows Vista/7/2008 |
| Added At | Jun 29, 2017 21:47:54 CST |
| Updated At | Oct 03, 2017 18:42:14 CST |

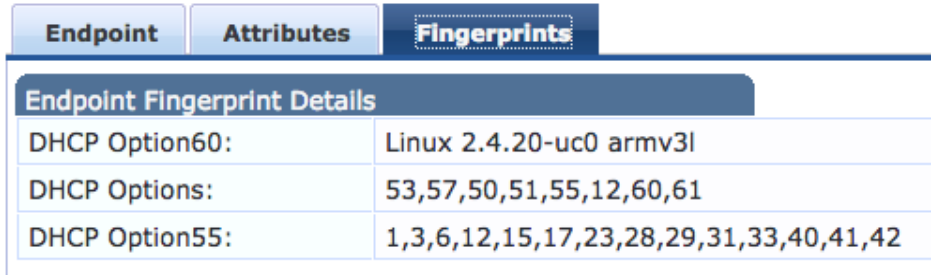
Endpoint | Attributes | Fingerprints

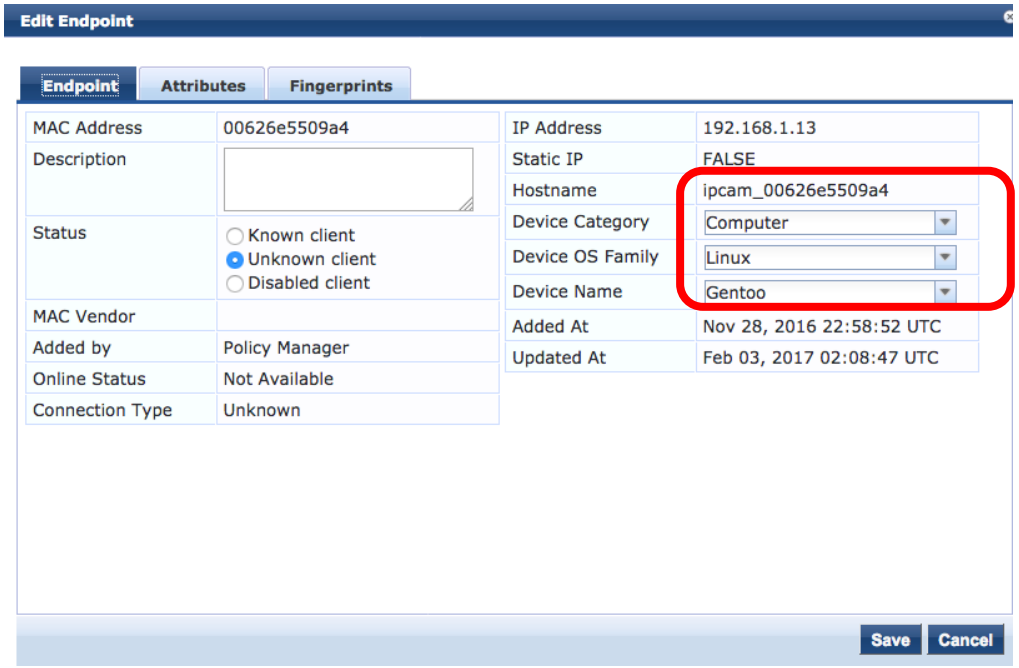
Endpoint Fingerprint Details

| | |
|---|---|
| DHCP Option60: | MSFT 5.0 |
| DHCP Options: | 53,61,12,60,55 |
| DHCP Option55: | 1,15,3,6,44,46,47,31,33,121,249,43 |

# Use case – New device with known profile

- New device detected
- Profiled
  - Profile matches defined role based access
- Inform Admin / Security
  - Text
  - Phone
  - Email
  - Pager
- Assign Role (IP_CAM)





87

# Use case – New device with unknown profile

- New device detected
- Profiled
  - Profile does not match defined role based access
- Inform Net Management / Security
  - Text
  - Phone
  - Email
  - Pager
- Assign quarantine role (New IoT device)

Endpoint | Attributes | Fingerprints

| Endpoint Fingerprint Details | |
|---|---|
| DHCP Options: | 53,55,50,54,61 |
| DHCP Option55: | 1,3,6 |

Endpoint | Attributes | Fingerprints

| | | | |
|---|---|---|---|
| MAC Address | 00a0966a7874 | IP Address | 192.168.1.3 |
| Description | | Static IP | FALSE |
| Status | Known client<br>Unknown client<br>Disabled client | Hostname | - |
| | | Device Category | Unknown |
| | | Device OS Family | Unknown |
| | | Device Name | Unknown |
| MAC Vendor | MITSUMI ELECTRIC CO., LTD. | Added At | Nov 28, 2016 18:13:19 UTC |
| Added by | Policy Manager | Updated At | Feb 03, 2017 06:26:32 UTC |
| Online Status | Not Available | | |
| Connection Type | Unknown | | |

# Role Mapping

**Policy:**

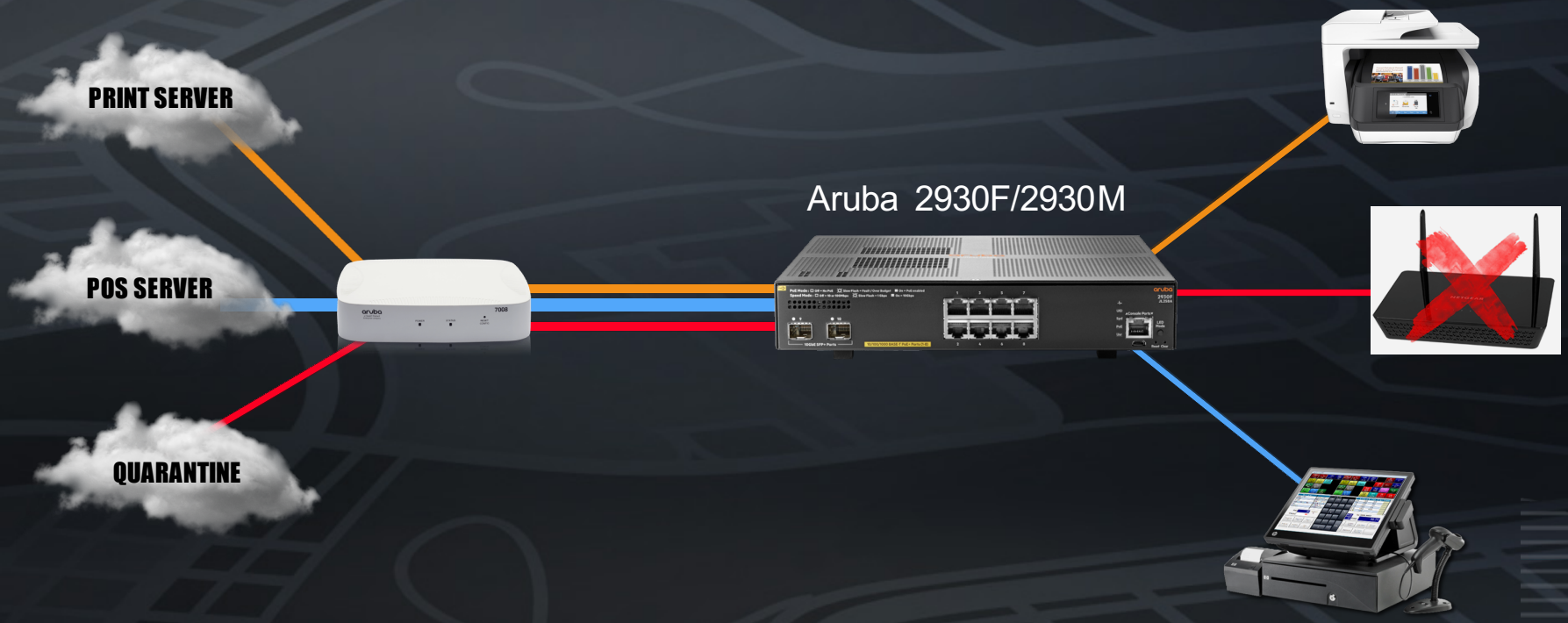
| | |
|---|---|
| Policy Name: | OnConnect Roles_v2 |
| Description: | |
| Default Role: | [Other] |

**Mapping Rules:**

| | |
|---|---|
| Rules Evaluation Algorithm: | Evaluate all |

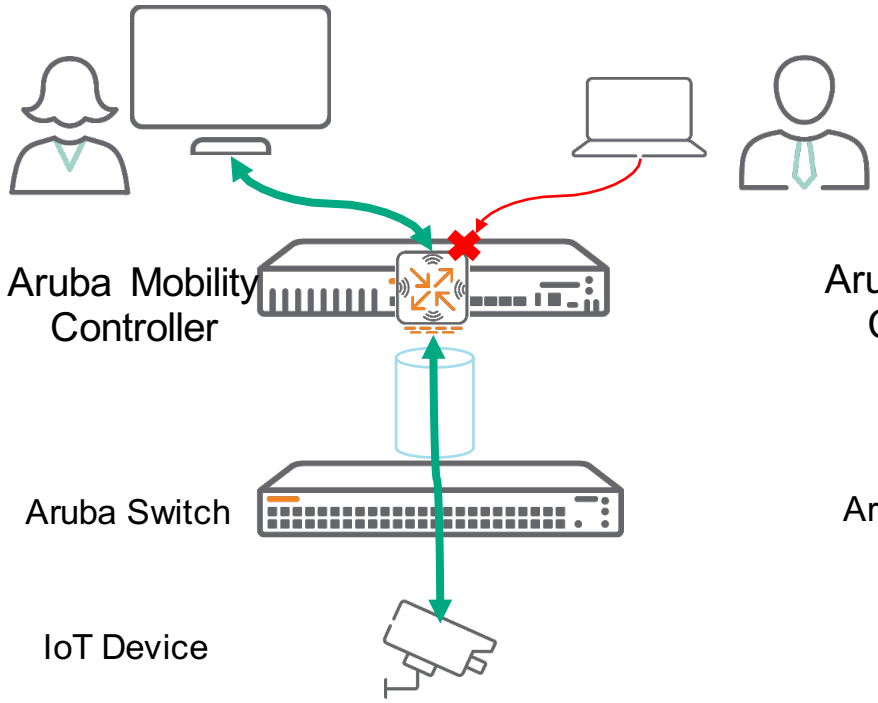
| | Conditions | Role Name |
|---|---|---|
| 1. | (Connection:Src-IP-Address *NOT_EXISTS* ) | get IP |
| 2. | (Authorization:Kent-AD04:UserDN *EXISTS* ) | [Employee] |
| 3. | (Authorization:[Endpoints Repository]:Category *EQUALS* Computer) | Computer |
| 4. | (Authorization:[Endpoints Repository]:Category *EQUALS* Printer) | Printer |
| 5. | (Authorization:[Endpoints Repository]:Category *EQUALS* VoIP Phone) | VoIP_Phone |
| 6. | (Authorization:[Endpoints Repository]:Category *EQUALS* Access Points) | AP |
| 7. | (Authorization:[Endpoints Repository]:Hostname *CONTAINS* ipcam) | IP_CAM |
| 8. | (Authorization:[Endpoints Repository]:Status *NOT_EQUALS* Known) | New IoT device |

# Secure Everywhere on Wired (using ArubaOS-Switch)
# 全面阻擋 私接 IoT 設備

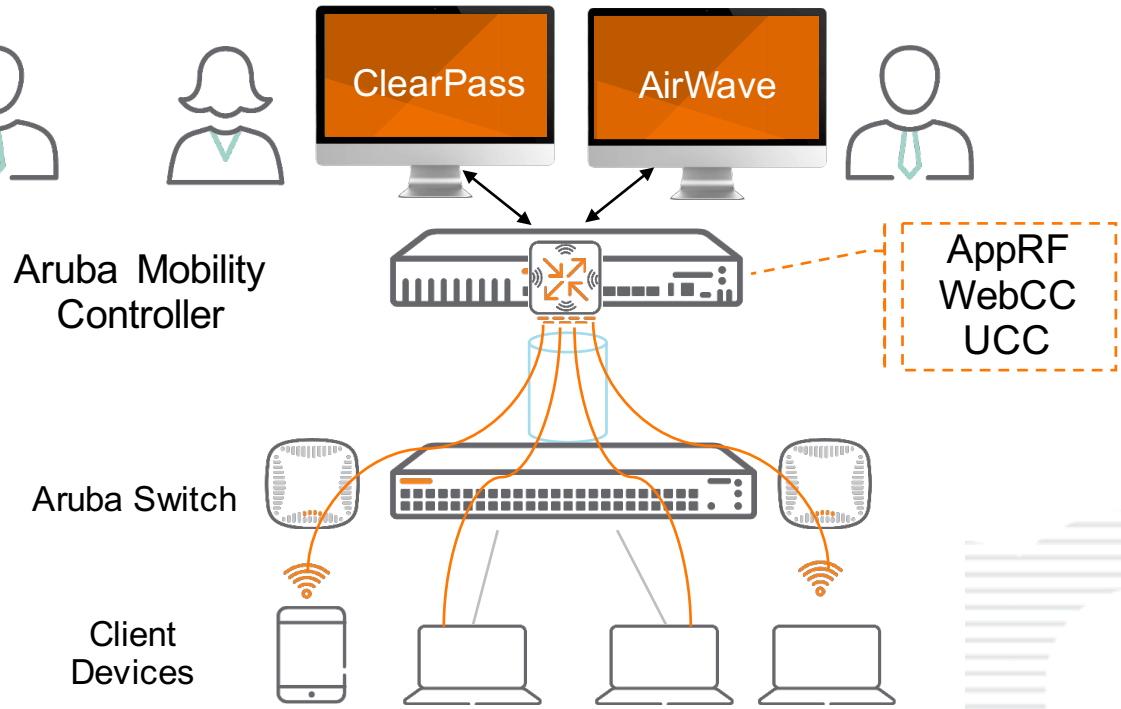


# Extending Management from Wireless to Wired and Assured User Experience on Wireless and Wired

Critical client protection



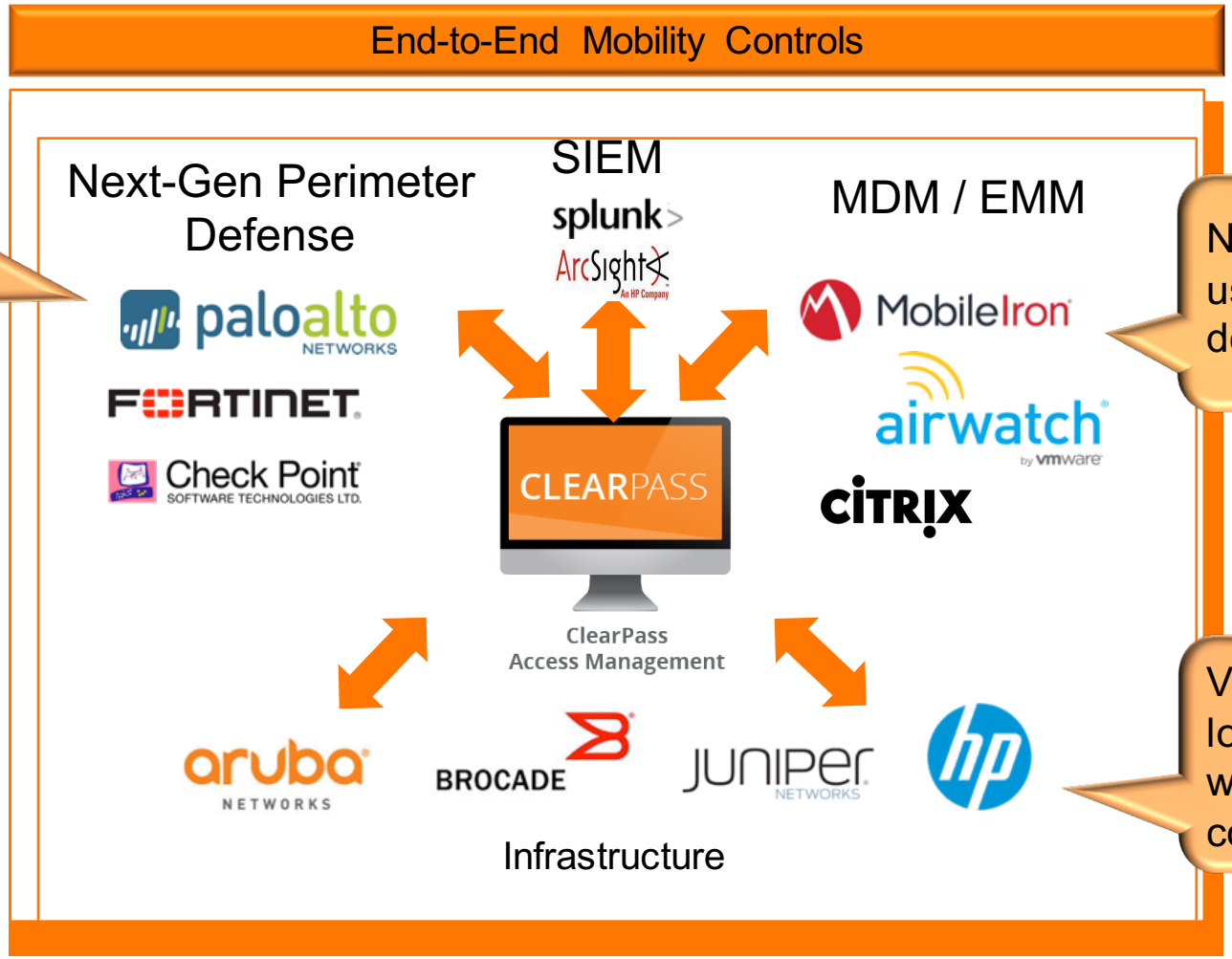

Unified policy and visibility



# Time for New Defense Model – Adaptive Trust

Granular traffic control with user and device data

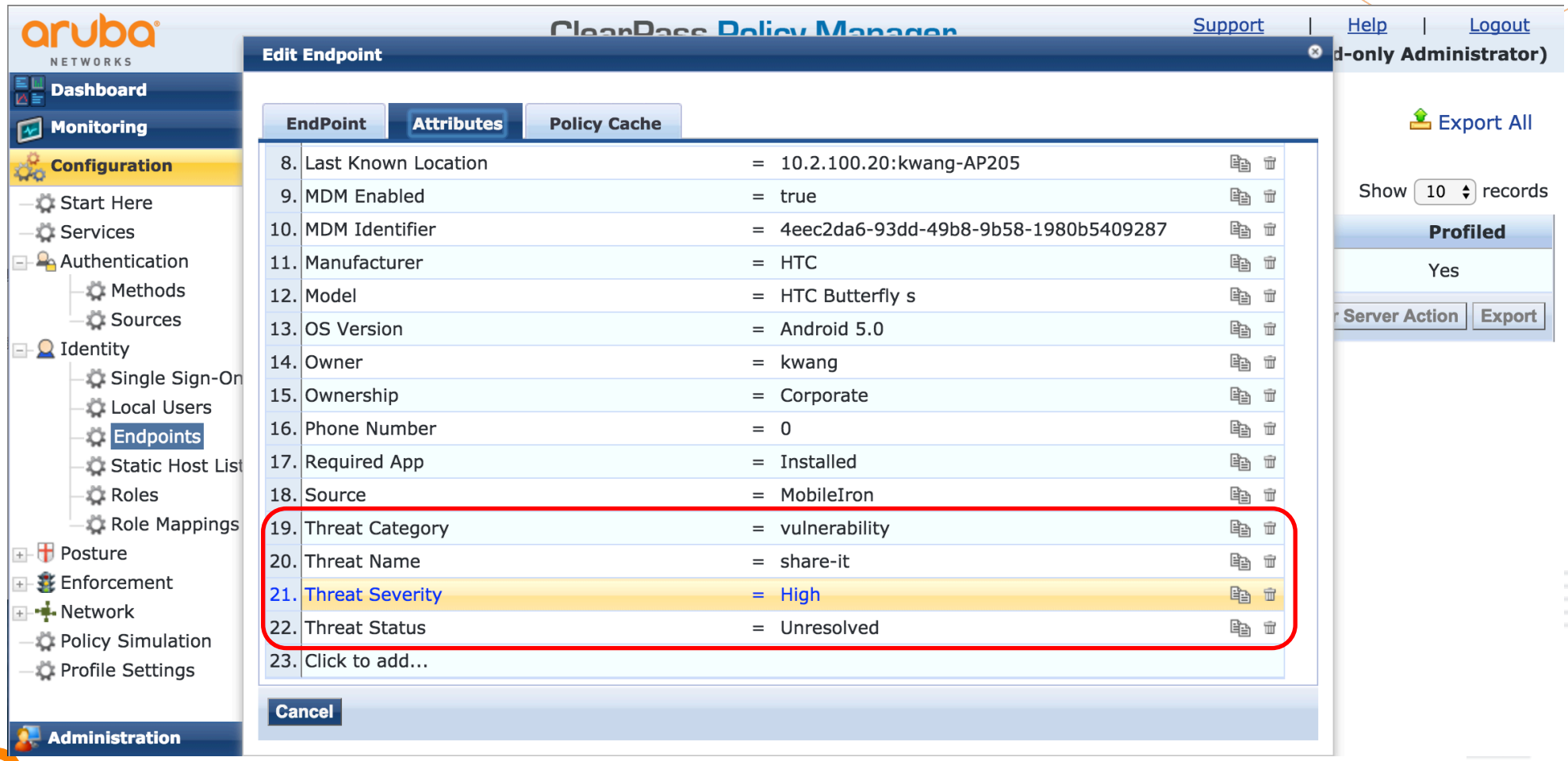
- ✔ Multivendor integration
- ✔ Context sharing
- ✔ Open API




Network controls using real-time device data

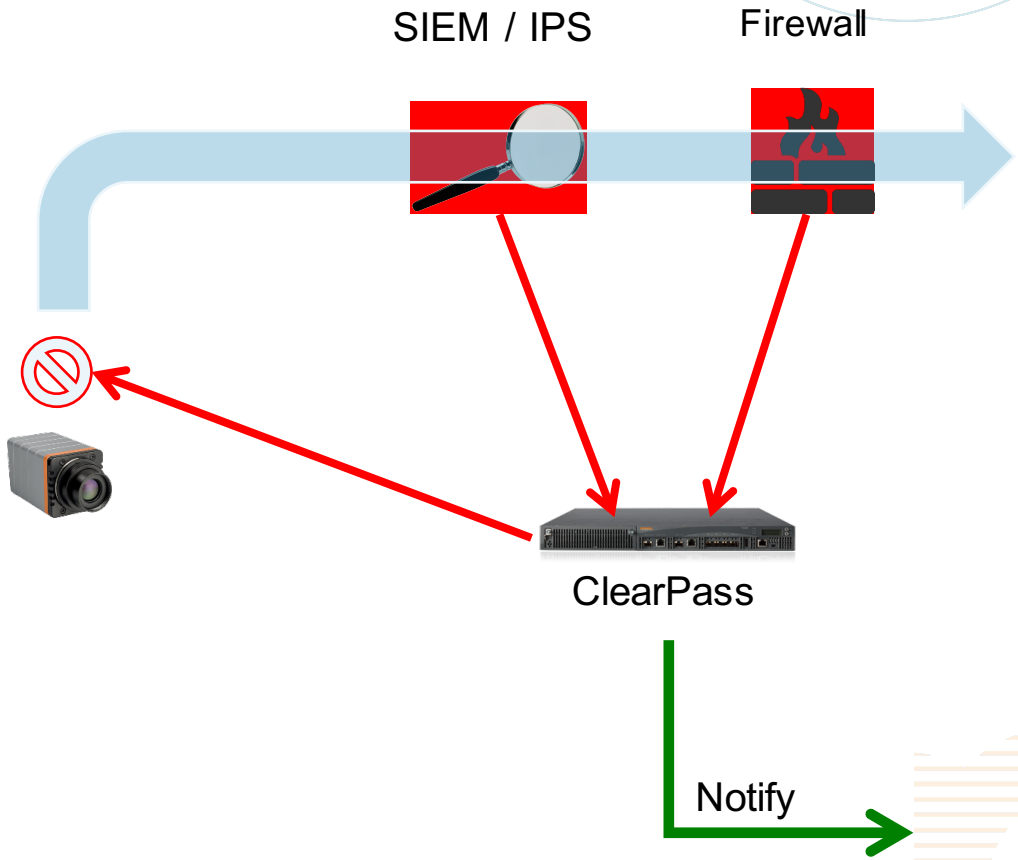
Visibility into location and time with granular controls

# Context Stores in ClearPass



# Continuing Visibility & Control

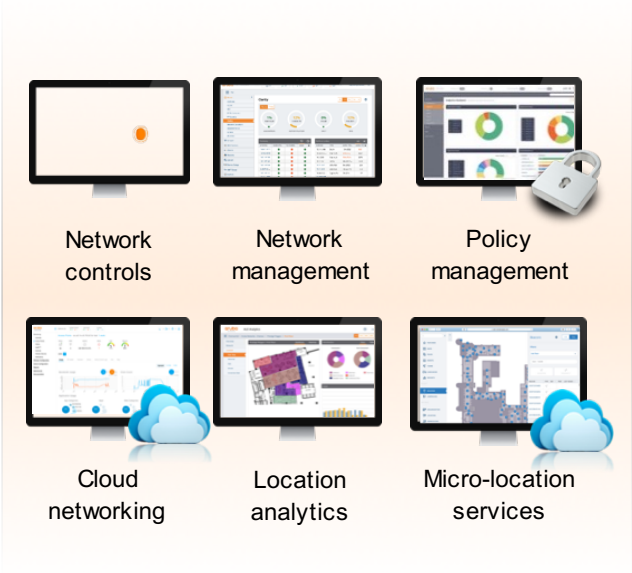
- Input from Threat monitoring / detection device triggers action
  - Quarantine device
  - Restrict access
  - Restrict bandwidth
- Alert Net Management / Security
  - Text
  - Phone
  - Email
  - Pager



# Mobile First Network

## Ready for Mobile, IoT and Future

Aruba infrastructure:
Wi-Fi, BLE, Wired, WAN



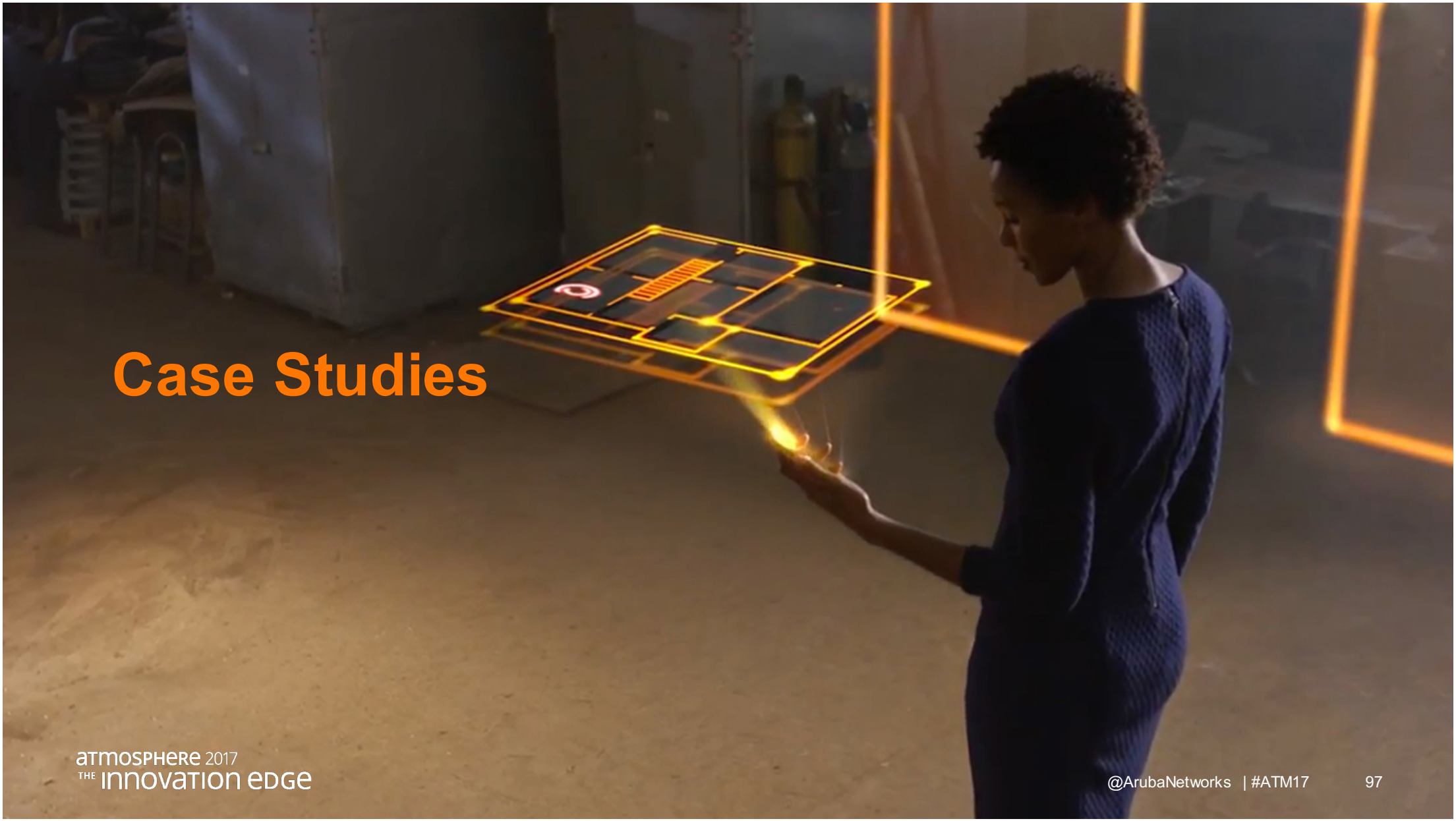

**Mobile First Platform**

**Edge Services Platform**

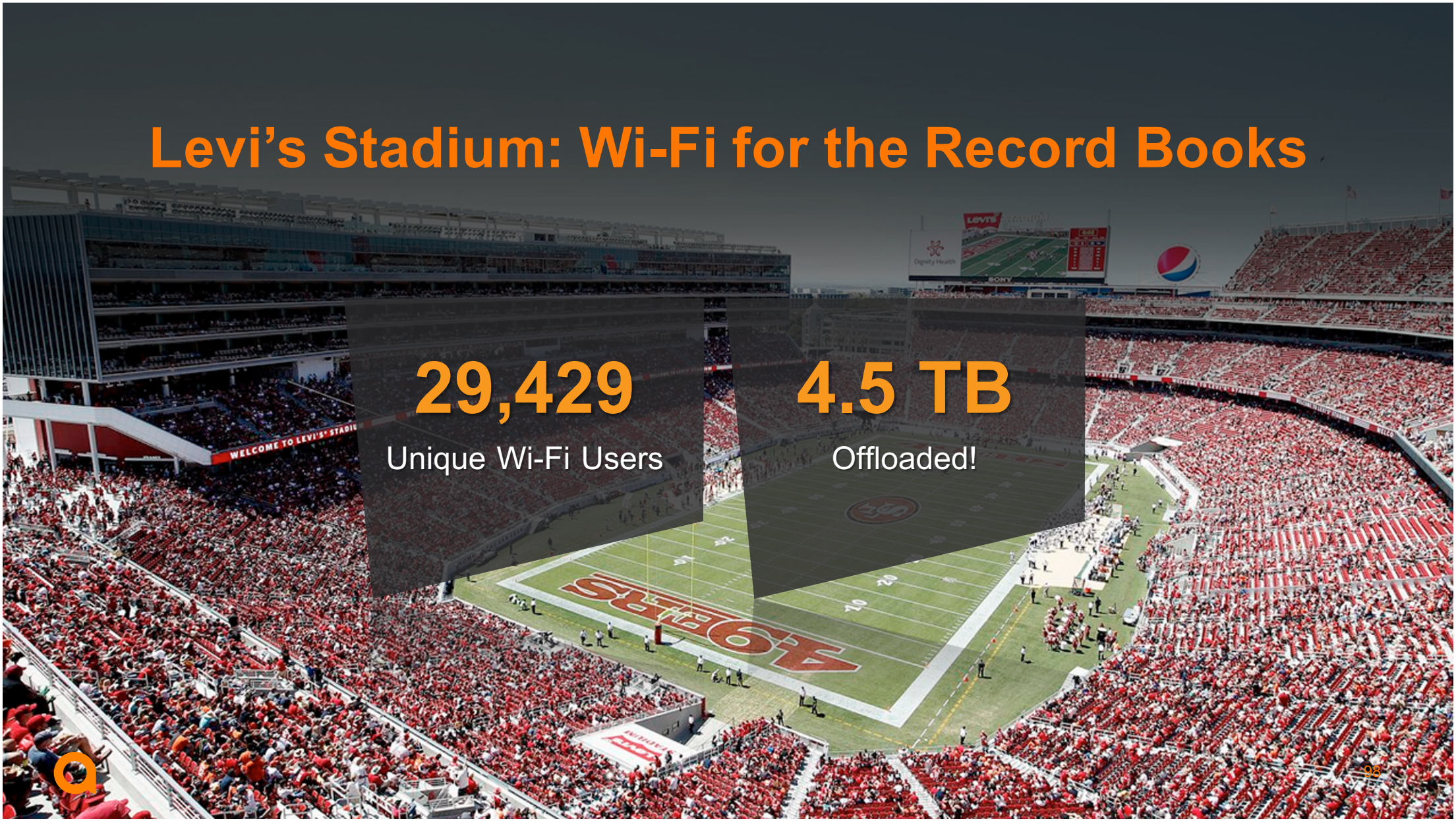
IT services

Business & user facing apps

# Case Studies



# Levi's Stadium: Wi-Fi for the Record Books




**29,429**

Unique Wi-Fi Users

**4.5 TB**

Offloaded!

# James Cook University

**ArubaOS 8 Benefits :**

- Leveraged existing **virtualized environment**
- **New UI and hierarchical** configuration
  - **Manage geographically dispersed network**
  - Design and **deploy a solution in 1hr vs 24hrs** for a new site
- Clustering **reduces downtime risk**
- AirMatch ensures student devices get **optimal Wi-Fi**

**JCU Background and challenge :**

- 25,000 students-1200 APs in dorm rooms with peak device at 8000
- Required improved network management, high availability and greater agility for responding to evolving needs

# Palo Alto Unified School District ( PAUSD)

**ArubaOS 8 Benefits :**

- Enabled unifying all of PAUSD's 18 sites w/ separate networks onto **a single network** leveraging the hierarchical Configuration
- **Visualize and manage** the entire system as a single unified Wi-Fi network - Creating a multitude of efficiencies
- **Min downtime** with Live upgrade and in-service updates
- Better control of shared devices with AirGroup
- Less complaints- better user experience

**PAUSD Background and challenge :**

- Ranked among the top U.S. public school districts, 12,500-student- 800 teachers will scale upto 50K devices
- Sought a high-performance Wi-Fi solution with streamlined management. operate with minimal overhead
- The biggest pain point was to create a single network across our 18 campuses

Palo Alto
Unified School District

# Case Study: Ohio State University (Over 85k Users)

## Reason for upgrade

- Over 400 buildings (25 million square feet) on approximately 1,700 acres.
- Replace hundreds of different departmental and dormitory networks, comprised of thick APs and other legacy equipment, with a secure, unified pervasive wireless network.

## Solution

- Consist of over 11,000 access points distributed across three core router points of presence.
- Initial deployment of 1,700 APs was deployed in 3 weeks!
- Will provide ubiquitous wireless access to over 85,000 students, faculty and staff.

## Why Aruba

- Central policy and network management
- Remote diagnostics and troubleshooting
- Mobile computing and Internet-based collaborative learning programs

*"We needed a single mobile network that worked everywhere on campus."*

Bob Corbin
Director of Telecommunications & Networking
*The Ohio State University*

# Superior Performance

**Aruba Wi-Fi, ClientMatch:** Campus-wide 11ac infrastructure maximizing devices/AP matching

**AirWave:** End-to-end management

### 集中控管式管理 降低人事成本

未建置Aruba Networks Wireless solution前，使用一般傳統無線網路服務全校師生約一萬八千人，行動設備無線網路連線約23,000人次。以0.1%的報修率來估算，每日需要排除大約23件無線網路設備連線等問題。每件報修平均花1小時處理，則電算中心需要2人專門處理與排除無線網路設備連線問題。」

而建置Aruba Networks Wireless solution後，除了以上連線等問題，更可由集中式控管交換器與無線網路管理平台，直接取得連設備設資訊、使用者資訊、連線狀態、認證狀態、數據化的連線品質與強度等，亦不需要技術人員至現場測試與排除問題，並節省約1人以上的人力成本，由一專職技術人員即可於中心端協助排除故障，大大提升整體營運效率。

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# Innovative Classroom Instruction

**Aruba Wi-Fi, AppRF:** Real-time proctored testing

**ClearPass:** Advance policy services for tablet app based learning

UNC CHARLOTTE

"A robust Wi-Fi network enables classroom innovations (app-based learning, shared communications, on-the-fly presentations, quizzing and testing ) for improving student learning."

**Bret Wood, Professor**



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# Innovative Customers

Education is Aruba's largest vertical for a reason

2500+ Universities deploy Aruba WLAN

6 of 8 Ivy League schools leverage Aruba solutions


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a Hewlett Packard Enterprise company

# Gartner recognizes HPE (Aruba) a Leader positioned furthest in completeness of vision for Wired and Wireless LAN Access Infrastructure.

Source: Gartner Magic Quadrant for the Wired and Wireless LAN Access Infrastructure
September 2019 Bill Menezes, Christian Canales, Tim Zimmerman, Mike Toussaint
ID Number: G00368944

**Figure 1. Magic Quadrant for the Wired and Wireless LAN Access Infrastructure**

This graphic was published by Gartner, Inc. as part of a larger research document and should be evaluated in the context of the entire document. The Gartner document is available upon request from Aruba, a Hewlett Packard Enterprise company. Gartner does not endorse any vendor, product or service depicted in its research publications, and does not advise technology users to select only those vendors with the highest ratings or other designation. Gartner research publications consist of the opinions of Gartner's research organization and should not be construed as statements of fact. Gartner disclaims all warranties, expressed or implied, with respect to this research, including any warranties or merchantability or fitness for a particular purpose.

# Thank You

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