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#CiscoLive

The bridge to possible

Designing Enterprise Wireless Networks

for Large Complex Environments

Alan Dumdei TSA Wireless COE

BRKEWN-2036

Goals for this session

- Understanding of some of the challenges of complex environments.
- Be able to relate these challenges and solutions to your network.
- Arm you with:
  - Things to watch out for
  - Solutions and work arounds
  - Tools to help you in your wireless deployment

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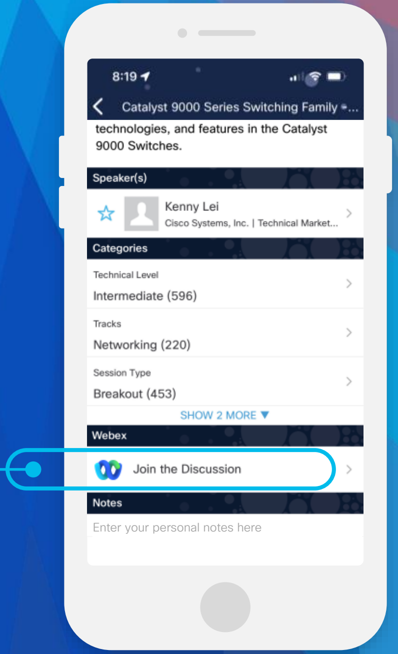

8:19

Catalyst 9000 Series Switching Family •...

technologies, and features in the Catalyst 9000 Switches.

Speaker(s)

☆ Kenny Lei
Cisco Systems, Inc. | Technical Market...

Categories

Technical Level
Intermediate (596)

Tracks
Networking (220)

Session Type
Breakout (453)

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Who is Al?

The important stuff!

Just fun

Build

Play

Running/Biking/Exploring

It’s Texas…we smoke everything!

Agenda

- Introduction
- Analysis of 3 Verticals
- High Level Architectures
- High Availability
- Multicast
- RF Design
- 6GHz
- AI RRM
- Security Concerns

Analysis of 3 verticals

General requirements and use cases

Higher Ed

Scale

- 10-20K AP
- 200K+ Clients

Reliability

- Key

Cost/Performance

- Cost

Hospitality

Scale

- 20-50K AP
- 200K+ Clients

Reliability

- Key

Cost/Performance

- Balanced

Health Care

Scale

- 6-8K AP
- 40K+ Clients

Reliability

- Key++

Cost/Performance

- Performance

Architectural and use case requirements

Higher Ed

Architecture
- L3 to the buildings
- Bonjour
- Fragmented

Typical Use Cases
- Eduroam
- Dormitory & Personal Use
- BYOD

Unique Challenges
- R&D Facilities
- Multiple Campuses

Hospitality

Architecture
- L3 to MDF
- Hybrid Data Center
- Operations and guest experience

Typical Use Cases
- Guest
- RLANs
- High-Capacity Venues

Unique Challenges
- Aesthetics
- Constantly changing environment
- International operations

Health Care

Architecture
- L3 to floor w/segmentation
- Multicast
- Location Services (BLE/Wi-Fi)

Typical Use Cases
- Still have 2.4GHz only devices
- Always on
- BYOD

Unique Challenges
- Radiology
- Operating Rooms
- VoWiFi

Deployment and operational use cases

Higher Ed

Operational
- Seasonal Change Windows
- Often have coding skills on staff
- Visibility Critical

Security Challenges
- Research and Development
- Students

RF Design
- Large outdoor areas
- Areas of high capacity
- Leakage between buildings

Hospitality

Operational
- Off hours
- Relatively small staff
- Visibility Critical

Security Challenges
- Gaming
- Office/BOH

RF Design
- Arenas/Conference Space
- Metal ceiling
- High rise structures

Health Care

Operational
- Zero down time
- Consistent performance
- Visibility Critical

Security Challenges
- HIPPA
- Patient monitoring devices
- Wired devices

RF Design
- Lots of cinderblock construction
- Must balance 2.4GHz with 5 and 6GHz

High Level Architectures

Considerations in wired/wireless architectures

Wired considerations for wireless architectures

Switching

- L3/L2 challenges
  - Switching/Routing
  - Roaming
- PoE

Segmentation

- VLAN
- VRF
- SGT

Gateway Requirements

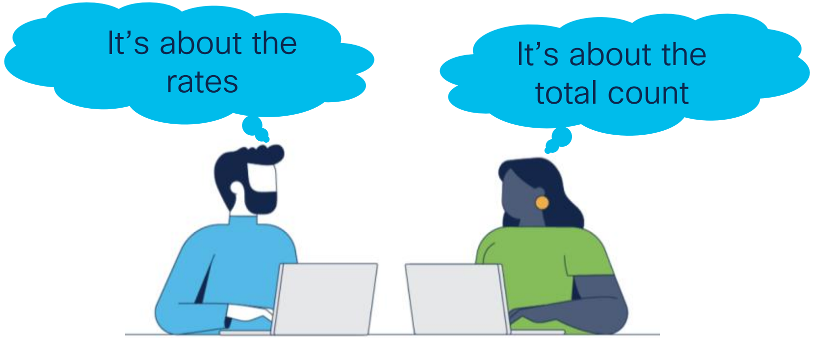
- CAM Table
- Throughput
- IP helper

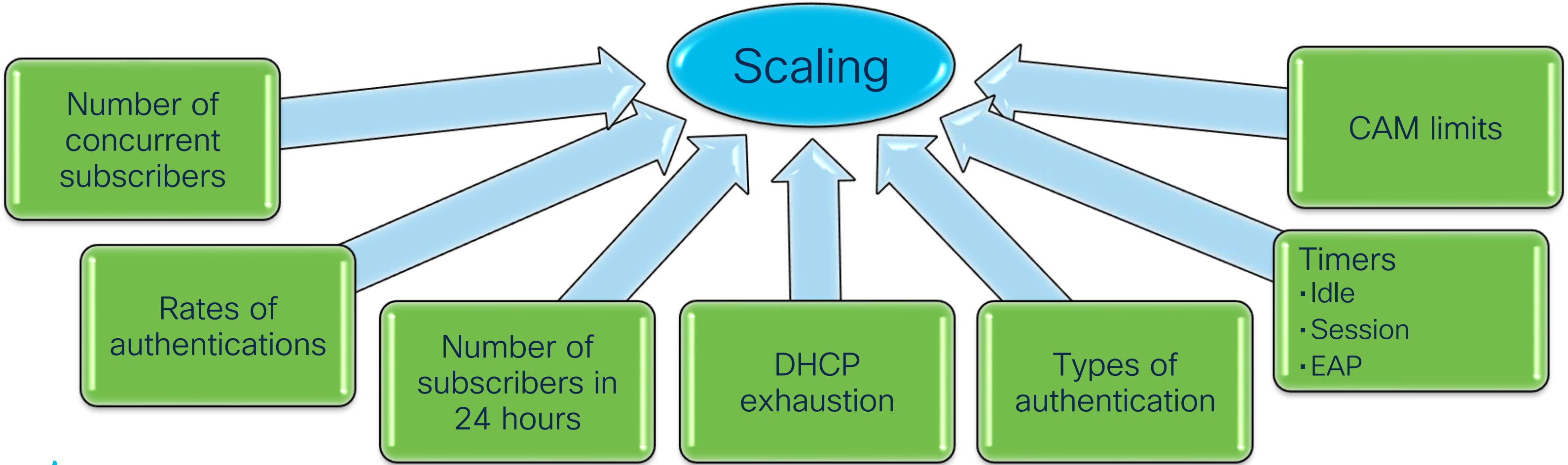
Cloud Considerations

- Private vs Public
- Must be FlexConnect LS
- Manageability

Think scale!

Wait not that kind of scale!





Scaling

Number of concurrent subscribers

Rates of authentications

Number of subscribers in 24 hours

DHCP exhaustion

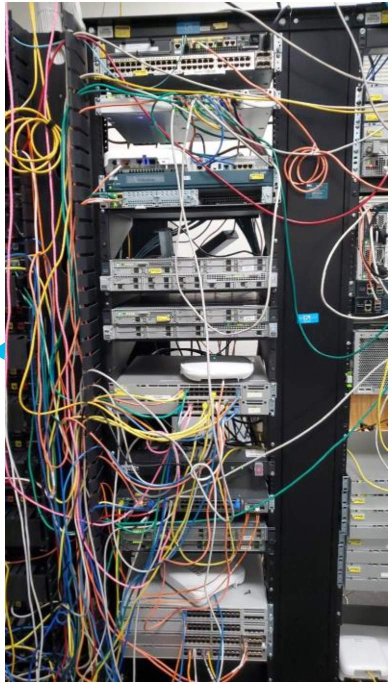
Types of authentication

Timers
- Idle
- Session
- EAP

CAM limits

Architecture/scale example for events center

- Conference lets out and 15K subscribers will roam from conference center to the hotel.
  - Using open SSID with Web Auth (as an example)
  - Watch out for “Pull out your phones and…”
  - RF discussion not covered here (in RF Design Section).
  - Central Switching used to minimize large L2 domains (L3 to the AP) but similar design considerations are made for local switching.



Know your requirements first!!

Architecture/scale example for events center

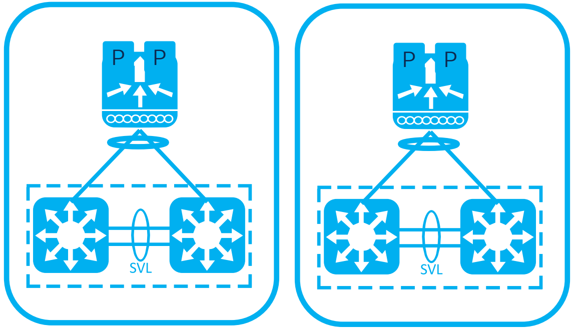
Design considerations (PLAN!)

- Where are the L3 roaming boundaries?
- Dot1x authentication rates (75-150 Auth/sec per node depending on types)
- MAB (400+ Auth/sec per node depending on type)
- 15K concurrent subscribers (AAA/WLC/DHCP/Switch)
  - CAM table on core switch…are there multiple controllers? Multiple hops to GW?
  - Subnet sizes/VLAN Groups
- Enable Proxy ARP to minimize broadcast/unicast traffic
- Pure capacity phones (1-8Mbps streaming) target < 100 clients per AP/Radio
- Idle timer
  - Reducing this will help with WLC capacity
  - Increasing this will reduce re-authentication as clients sleep, move, etc.

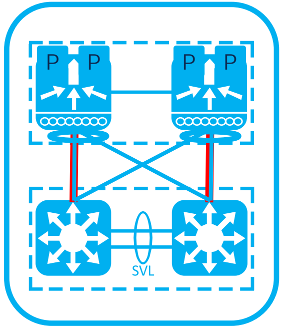
High Availability

How do I include this in my design

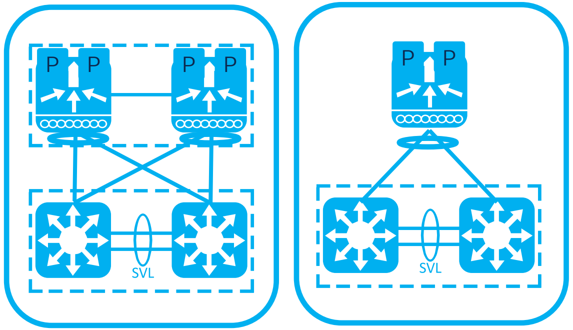
High Availability Architectures for WLCs



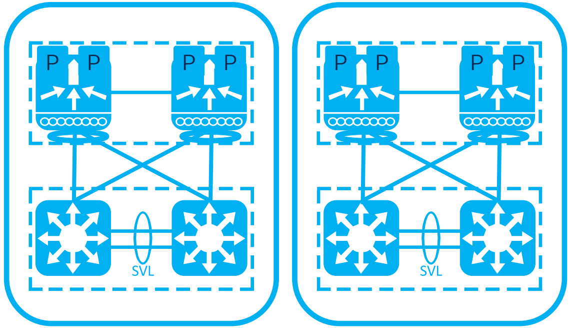
AP Fail-Over (N+1)



SSO

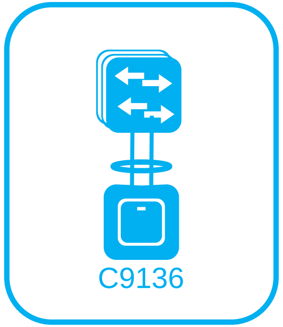


SSO + One

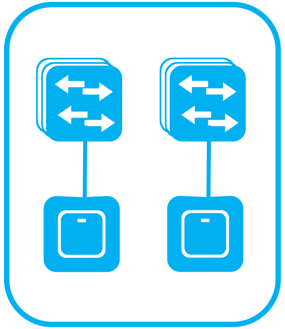


SSO + SSO

High Availability Architectures for APs



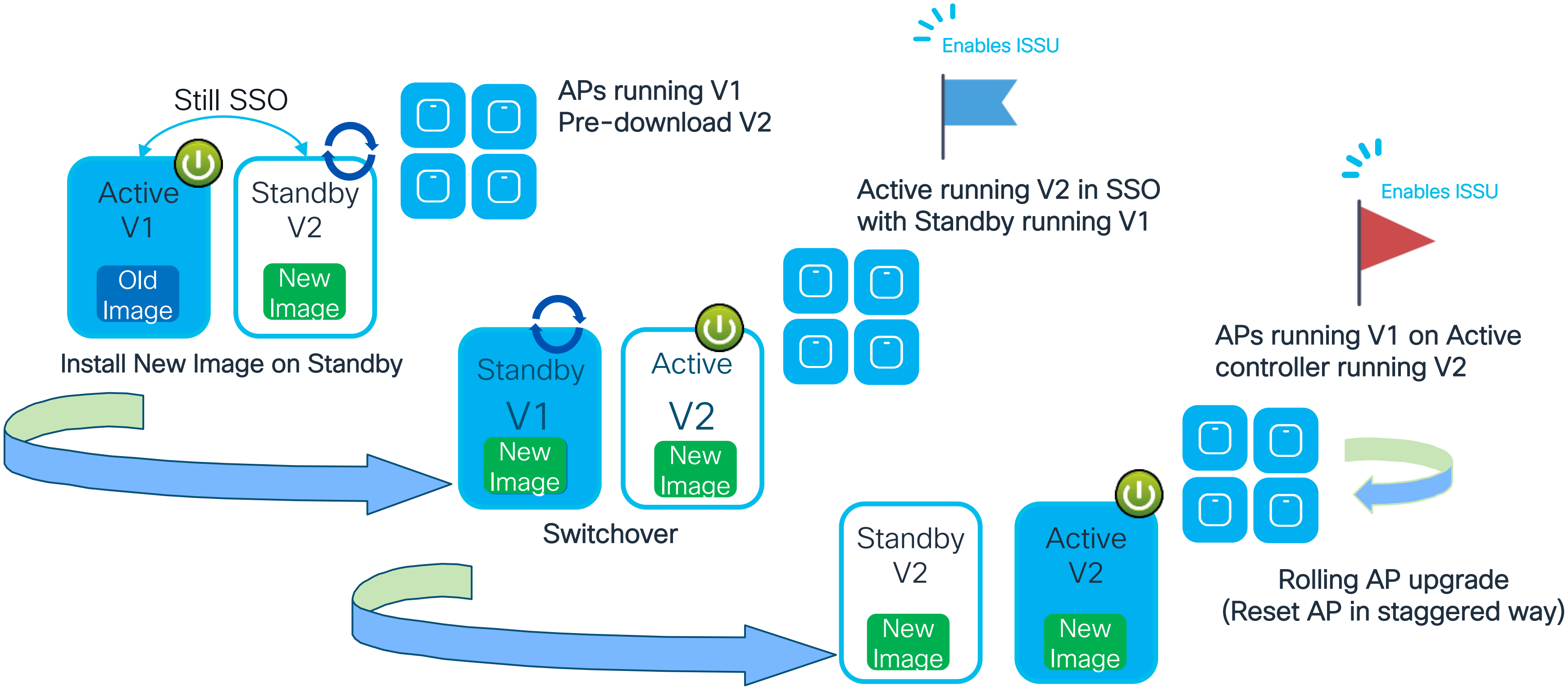
AP Dual Connection



Overlapping Coverage

Switching for AP HA
- Perpetual PoE
- Fast PoE
- Stack Power
- Stackwise
- Stagger Switches

ISSU Process



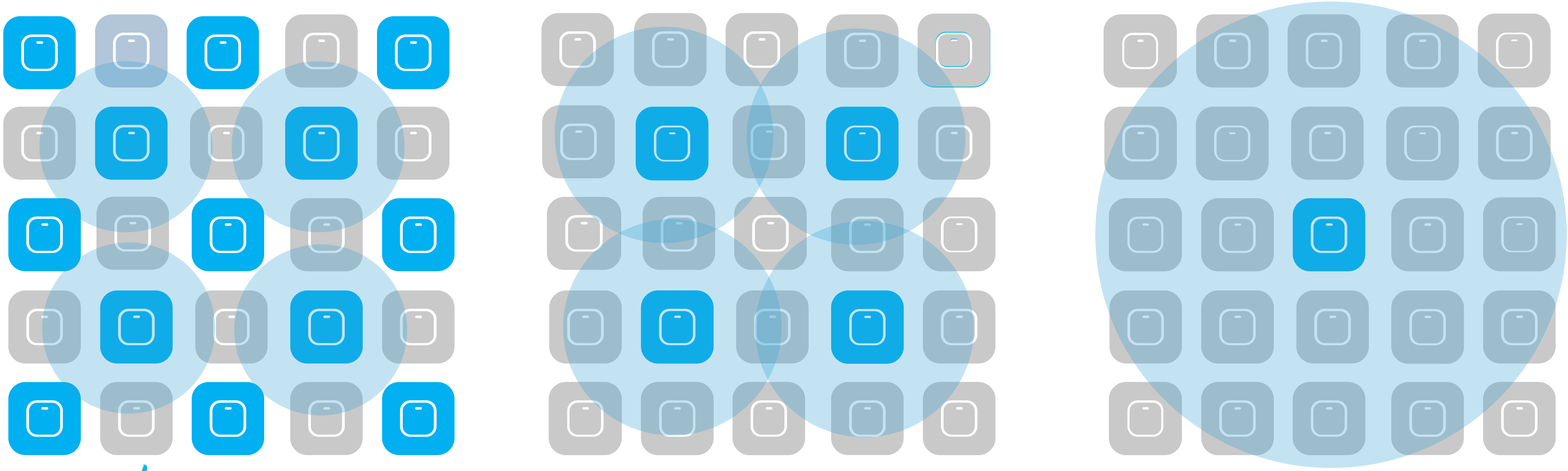
Note: “Hitless” and “ISSU” are not the same thing

Install New Image on New Standby

Neighbor Marking for Rolling AP Upgrade

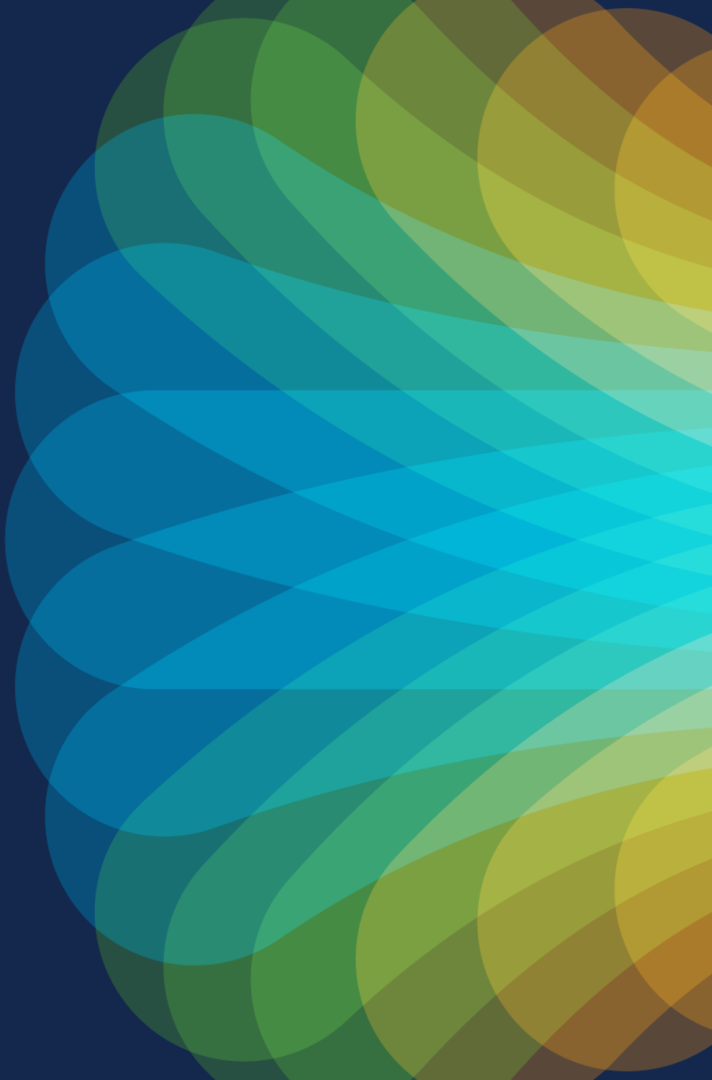
User selects % of APs to upgrade in one go [5, 15, 25]

- For 25%, Neighbors marked = 6 [Expected number of iterations ~ 5]
- For 15%, Neighbors marked = 12 [Expected number of iterations ~ 12]
- For 5%, Neighbors marked = 24 [Expected number of iterations ~ 22]



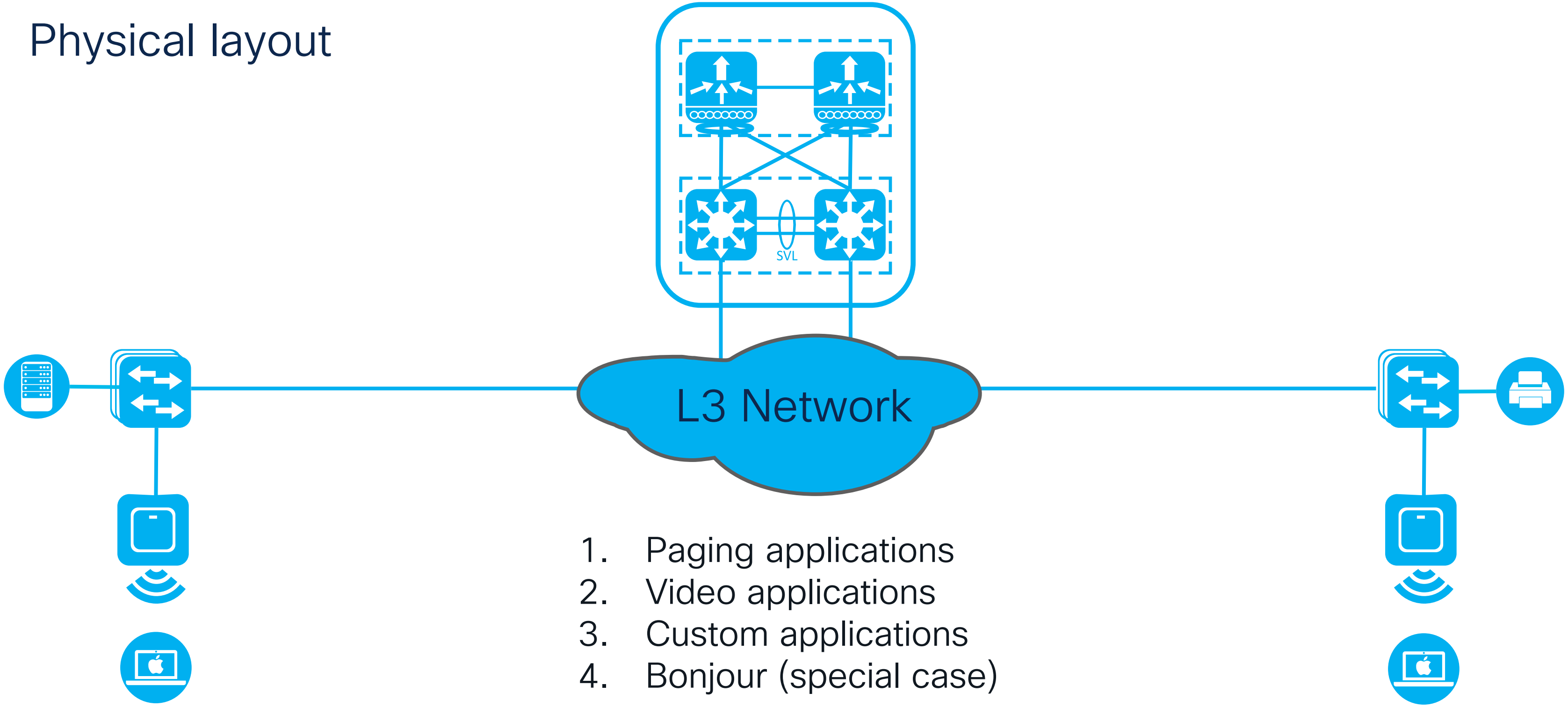
Multicast

What is it and how does it affect my design



Multicast

Physical layout

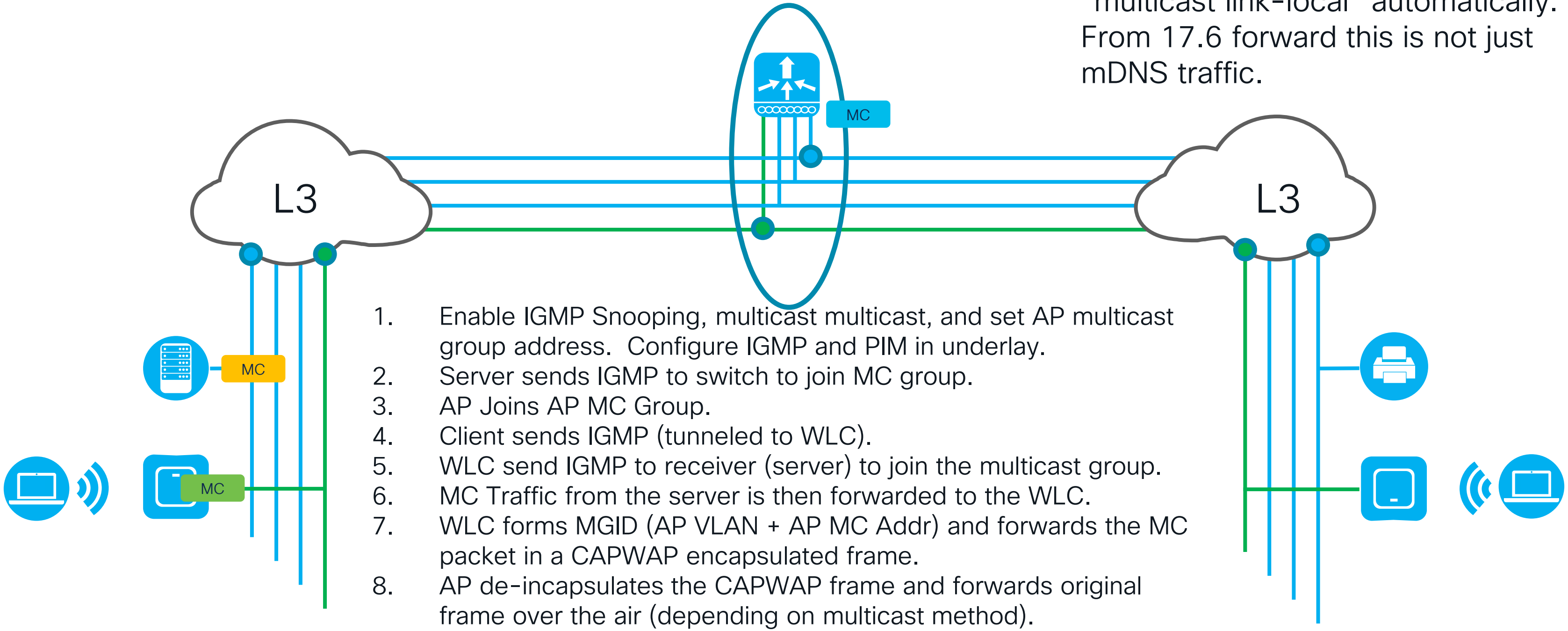


1. Paging applications
2. Video applications
3. Custom applications
4. Bonjour (special case)

Multicast-Multicast vs Multicast-Unicast

Local Mode (central switching)

Note: Enabling Multicast enables “multicast link-local” automatically. From 17.6 forward this is not just mDNS traffic.

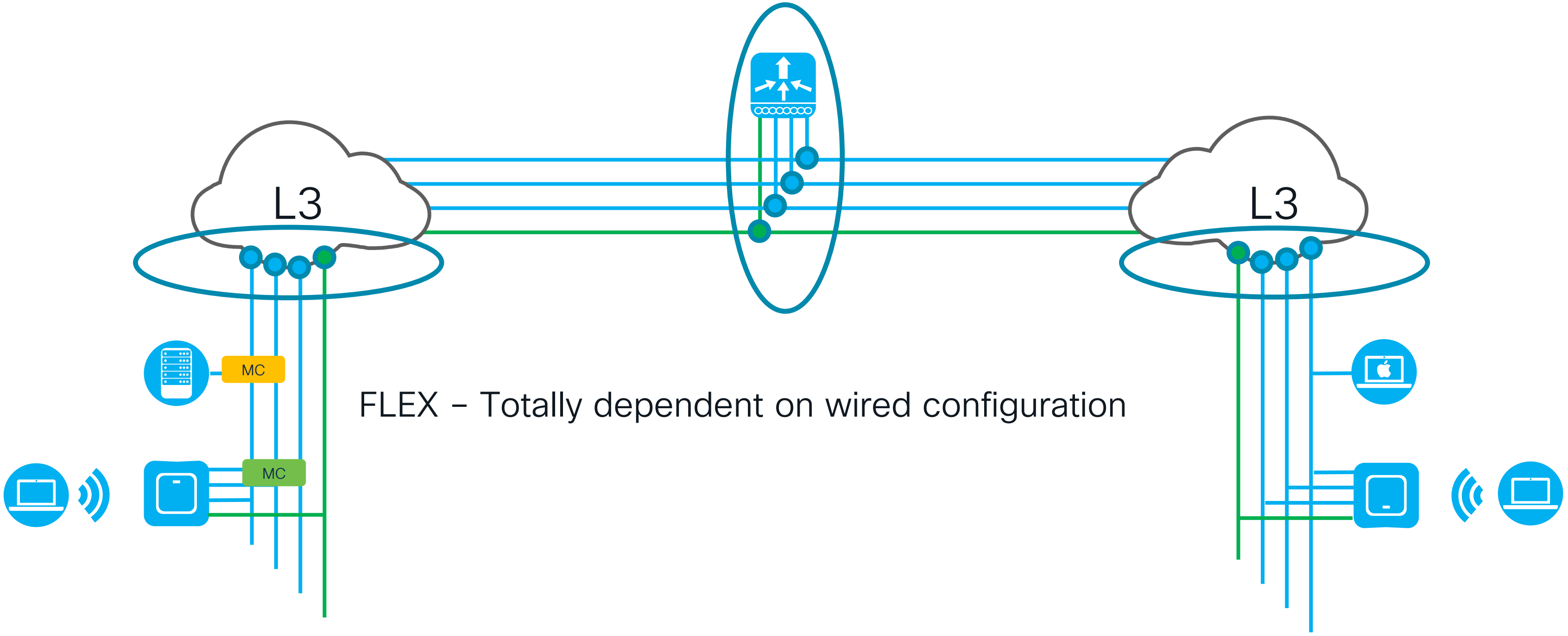


1. Enable IGMP Snooping, multicast multicast, and set AP multicast group address. Configure IGMP and PIM in underlay.
2. Server sends IGMP to switch to join MC group.
3. AP Joins AP MC Group.
4. Client sends IGMP (tunneled to WLC).
5. WLC send IGMP to receiver (server) to join the multicast group.
6. MC Traffic from the server is then forwarded to the WLC.
7. WLC forms MGID (AP VLAN + AP MC Addr) and forwards the MC packet in a CAPWAP encapsulated frame.
8. AP de-incapsulates the CAPWAP frame and forwards original frame over the air (depending on multicast method).

What is directed multicast?

Multicast-Multicast vs Multicast-Unicast

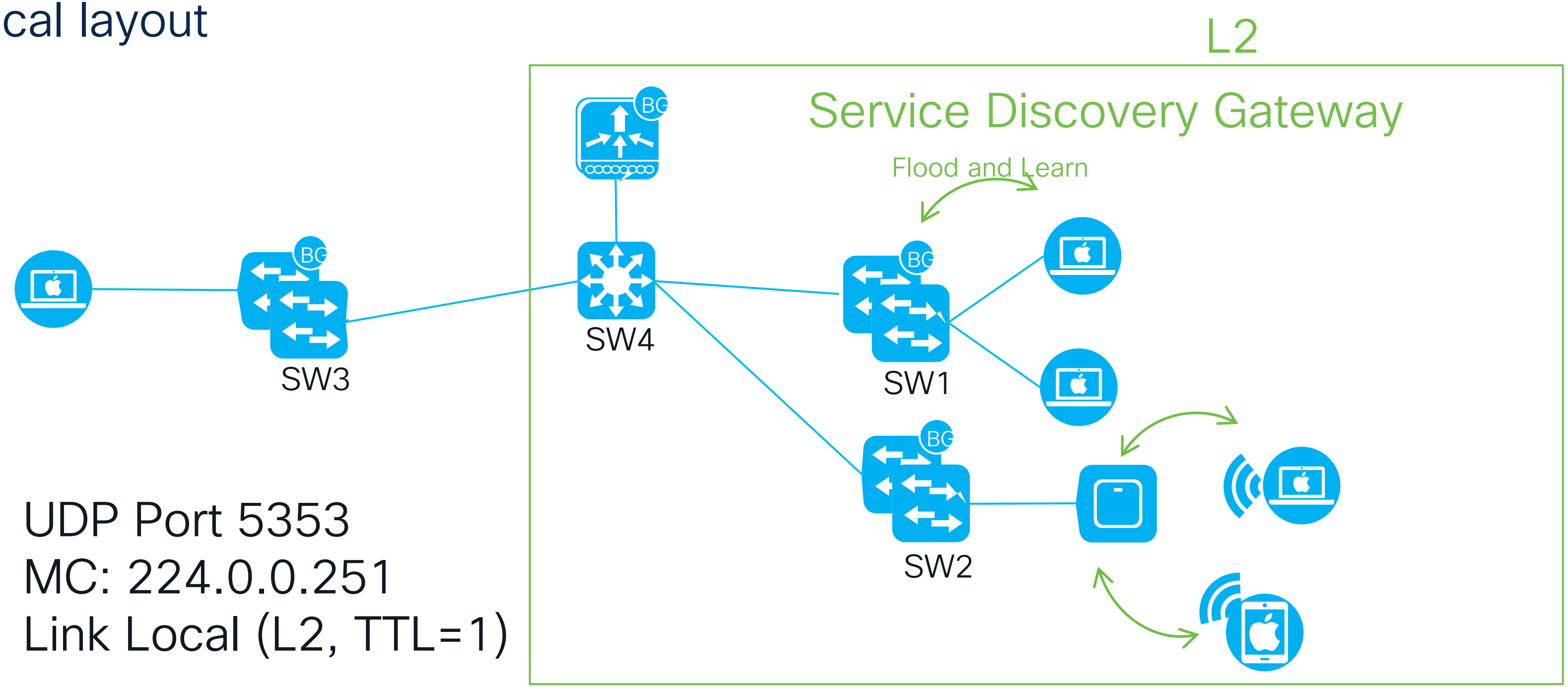
Flexconnect Mode (local switching)



FLEX – Totally dependent on wired configuration

Bonjour/mDNS Example

Physical layout

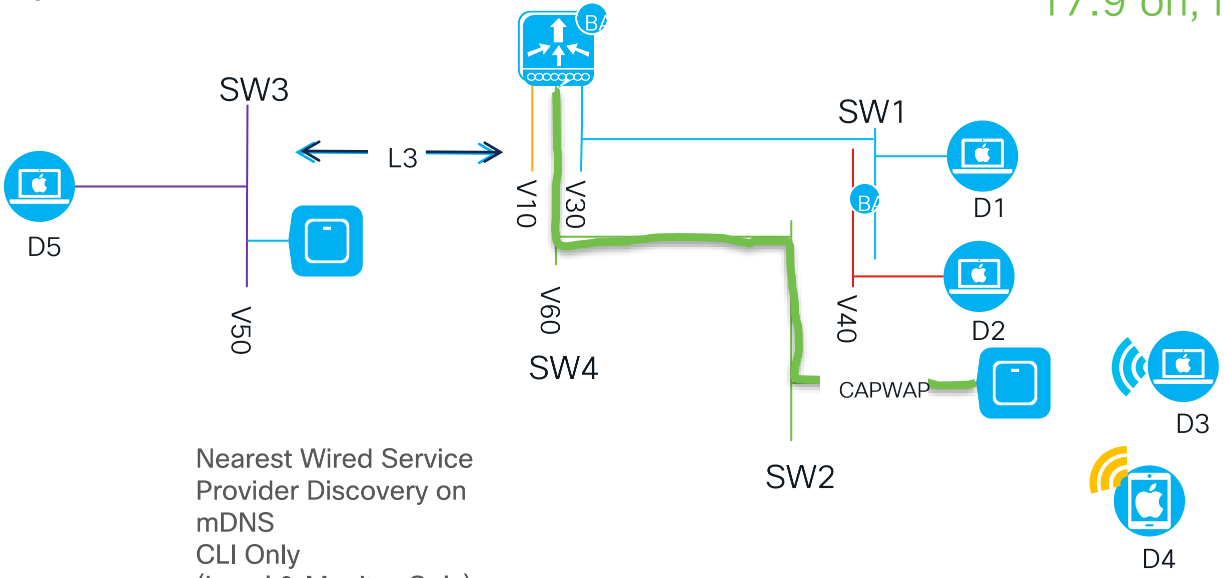


UDP Port 5353
MC: 224.0.0.251
Link Local (L2, TTL=1)

Bonjour/mDNS Example

Logical layout

Effects Control Plane/CPU
Use location
17.9 on, no SVI required



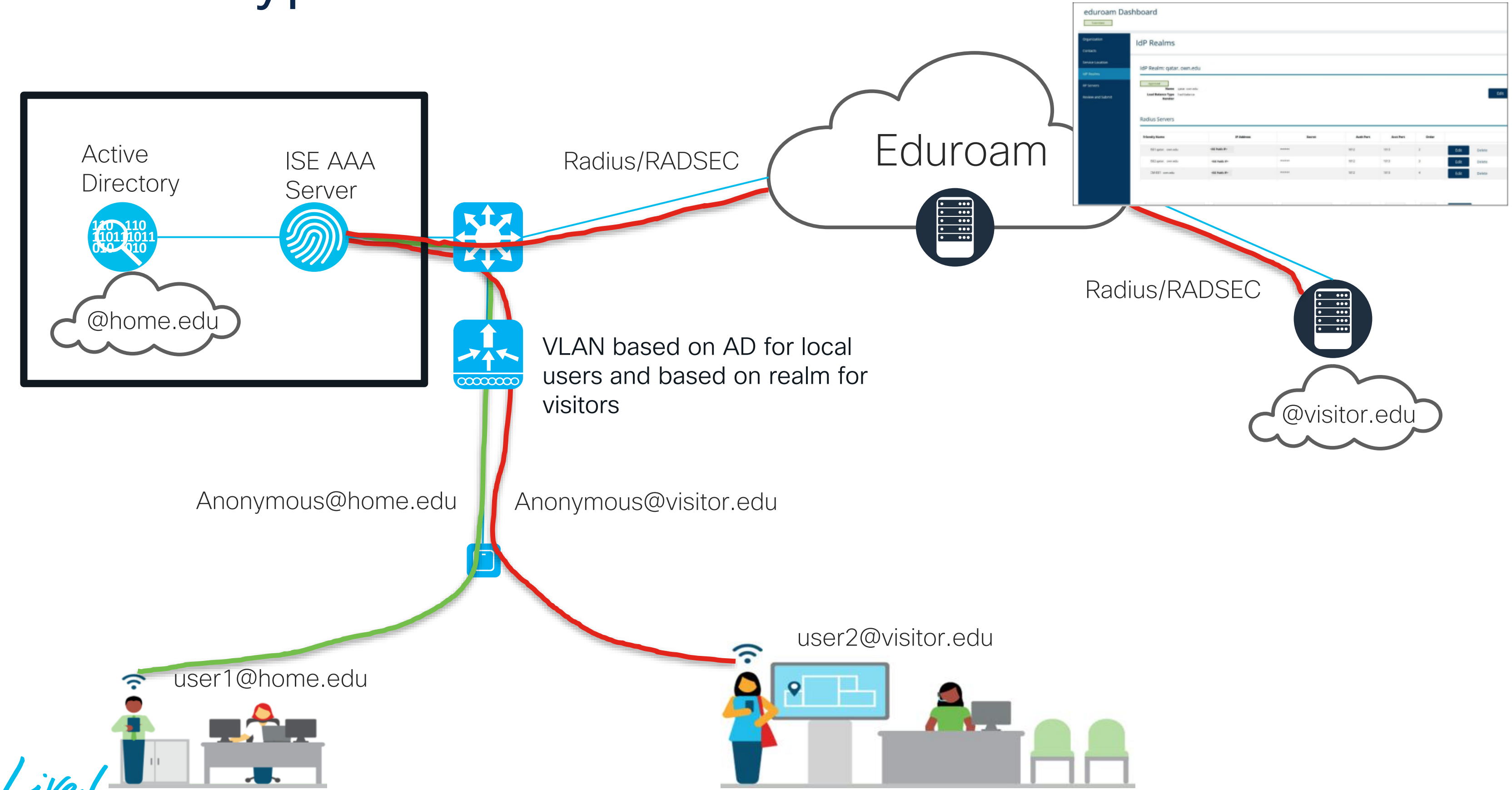
Nearest Wired Service Provider Discovery on mDNS
CLI Only
(Local & Monitor Only)

UDP Port 5353
MC: 224.0.0.251
Link Local (L2, TTL=1)
BA = Bonjour Agent

4. Eduroam

A different approach to an old requirement

Eduroam Typical Authentication



IdP Realms

IdP Realm: qatar. own.edu

Approved

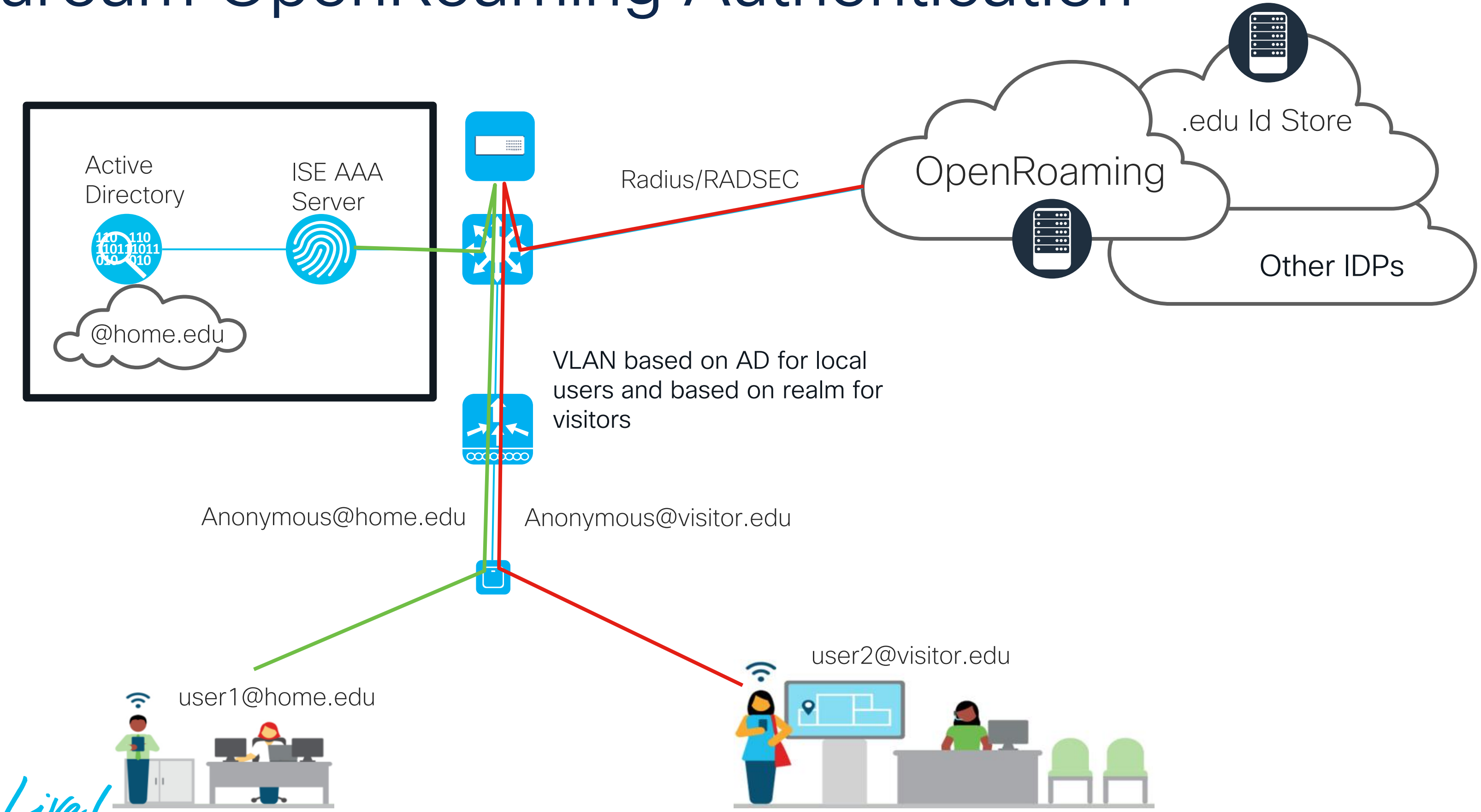
Name qatar. own.edu

Load Balance Type Random FastBalance

Radius Servers

Friendly Name	IP Address	Secret	Auth Port	Acct Port	Order	
ISE1.qatar. .own.edu	<ISE Public IP>	******	1812	1813	2	Edit Delete
ISE2.qatar. .own.edu	<ISE Public IP>	******	1812	1813	3	Edit Delete
CM-ISE1 .own.edu	<ISE Public IP>	******	1812	1813	4	Edit Delete

Eduroam OpenRoaming Authentication



VLAN based on AD for local users and based on realm for visitors

* 17.12 adds support for Transition Mode

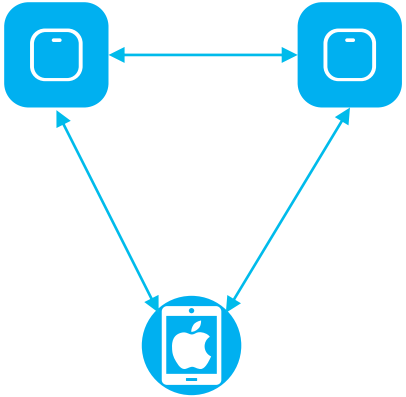
Eduroam Considerations

- Be sure network is sized to support additional Eduroam users
- Local AAA (ISE) is authenticating server for local Eduroam users.
- Visitors AAA is authenticating server for visiting Eduroam users.
- Outer identities are anonymous and routed.
- Can use standard forms of EAP:
    - PEAP
    - EAP-TLS
    - EAP-TTLS
    - EAP-FAST
- Can use configuration assistance tool (CAT) for client to simplify onboarding.
- Typical process is to create 2 WLANs with the same name for 2.4 & 5, and 6GHz. *

RF Design

Legacy bands and 6GHz

General design guidelines

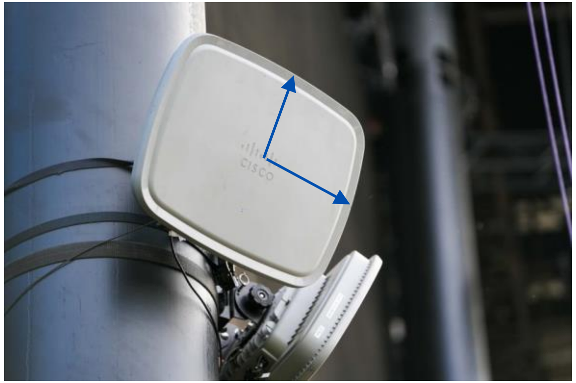


- Three things to watch
  - AP Downlink
  - Client Uplink
  - AP Neighbors
- It’s all about SNR and time
  - Directional antennas help to reduce interference in high-capacity areas.
  - Increase basic rates, decrease SSID count
  - RX SOP can be your friend
  - Use of .11v & .11k action frames are good but do take airtime
    - .11K can cause high CPU.
  - .11r very helpful for 11r compatible clients (especially .1x like Open Roaming)

Early versions of RX-SOP

High Density RF Design

- You cannot compensate for poor RF design with optimization!
- The challenge is more what do the APs not hear than what they hear.
- Find APs with highest client counts (DNA Assurance Network Health)
  - Adjust TPC for more even distribution
  - Band Select and Load balancing are secondary effects
- The 9104s make sure you understand orientation
  - Portrait or Landscape
  - DCA/TPC not useful as sidelobes are very low and hence very little AP2AP
    - Manual RF plan
    - Use a RF design tool to help with this.

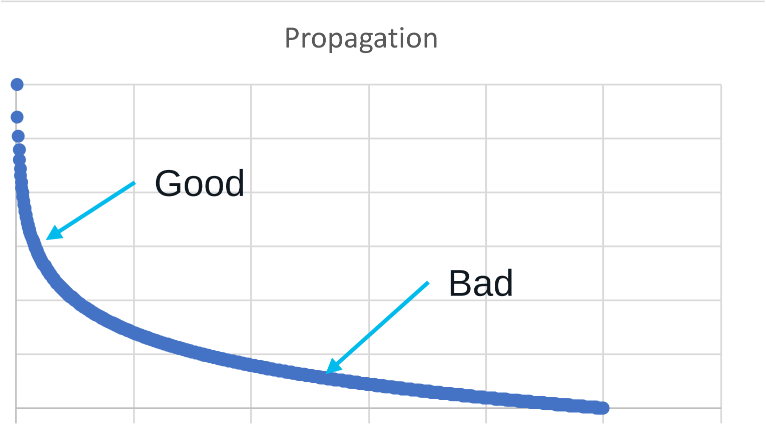


Things that make design challenging

- Fire walls and beams (especially behind walls)
- Stair wells and elevators
- Esthetics
- Clean room/OR
- Small rooms with cinder block construction
- Building/Classrooms that are very close together

Designing for location

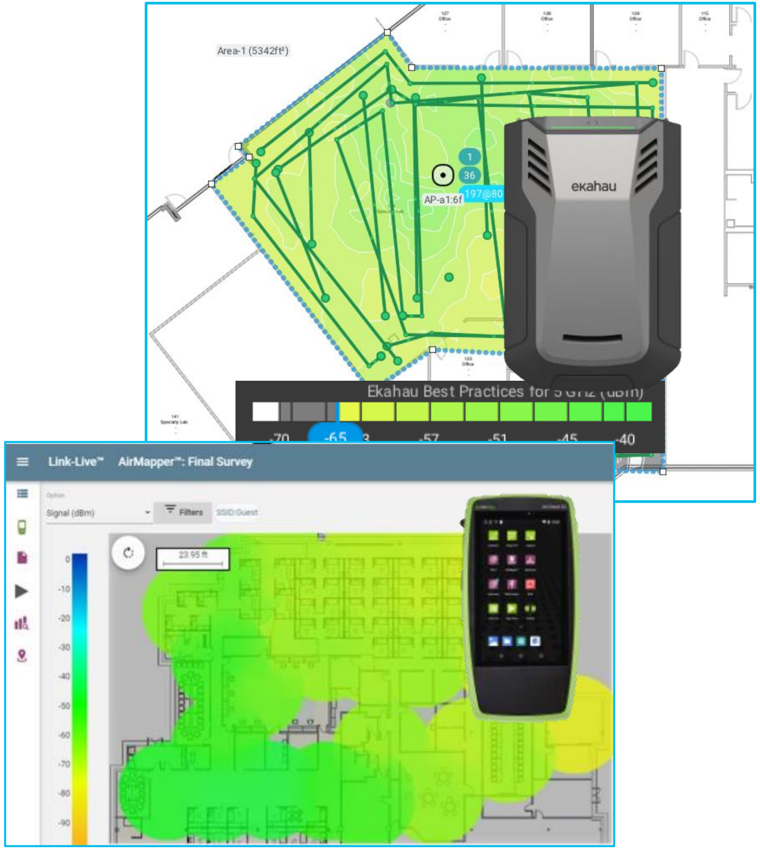
- For RSSI based location what is desirable is a small change in distance is a big change in RSSI
- Need APs dispersed angles (-75dBm)
- Location only with within AP perimeter.
- Walls and floors add distance
- Directional antennas:
  - Directional antenna help the rate of signal change between APs.
  - Important that you get the right AP MAC addresses in the right location and the right direction for the antenna.



Predictive vs Measured

When is good enough, good enough?

- A Measured Site Survey is an actual measurement of the RF Coverage in each space
- Ekahau and NetAlly both have Instruments specifically for measuring Wi-Fi
- Predictive Surveys often good enough
  - Garbage in, garbage out
  - Bound predictive with measurements



6GHz

How do I use it in my design

Things to note about 6GHz LPI

- FCC 5dBm/MHz, 30dBm Max, ETSI 10dBm/MHz, 23dBm Max.
- Typically, 1:1 overlay if existing APs at power level 3 or higher.
- 6GHz Mandates WPA 3 which include PMF mandatory.
- Only “permanently attached integrated” antennas can be used.
- No wildcard probing allowed.
- Introduces 4 new methods of discovery:
  - Reduced Neighbor Report (RNR) Out-of-Band discovery.
  - Preferred Scanning Channels (PSC) In-Band discovery.
  - Fast Initial Link Setup (FILS) In band discovery.
  - Unsolicited Probe Response (UPR) In band discovery.

9166D1 Wi-Fi 6 Access Point

NEW

Cisco® Catalyst® 9166D1-x

Directional, Tri-Radio with 12 Spatial Streams!

Orderability in FY ’24 Q1

Penta-Radio Architecture

1. 2.4 GHz Client Radio: 4x4:4SS
2. 5 GHz Client Radio: 4x4:4SS
3. 6 GHz Client Radio 4x4:4SS (XOR to 5GHz)
4. Dedicated tri-band auxiliary radio
5. 2.4 GHz IoT Radio

Directional antenna architecture

- 2.4+5 GHz: 6 dBi gain (70x70 deg), 6 GHz: 8 dBi (60x60)*
- Same X,Y as CW9166I – and only 0.1cm taller!
- Wide support for pan/tilt combinations

Internet of Things Capabilities

- Built-In Environmental Sensors
- Application Hosting Technology
- USB port with 4.5 W power output

5 Multigigabit (mGig) PoE Port

- Optional DC Power

Subject to change

*2/5/6 mode

† SW support post-FCS

Design Considerations

- No external antennas options for high ceiling designs
- Wide variety of clients behavior
  - Some clients only use RNR which means you must transmit legacy bands.
  - Roaming from WPA 2 to WPA 3 is reauthentication
  - Roaming between WLANs with different policy profiles requires reauthentication.
  - Clients are often looking for strong signals at 6GHz to join (>-65dBm)
  - Can have RNR with PSC and FILS or UBR

Use Cases

- 3 Band SSID
- All WPA3
- Control of devices

BOH/Office

- Separate 2.4+5 and 6GHz
- WPA 2 legacy
- WPA 3 6GHz
- Same SSID

General Use

- Separate 2.4+5 and 6GHz
- WPA 2 legacy
- WPA 3 6GHz
- Different 6GHz SSID

Special Case

- Separate 2.4+5 and 6GHz
- WPA 2 transition legacy
- WPA 3 6GHz
- Same 6GHz SSID

Not recommended

17.12 adds support for Transition Mode
1 profile to rule them all!

- BOH/Office
  - If you can control the devices.
  - Cisco has this deployed in certain offices
  - Fast roaming works across bands
- General use
  - Accommodates legacy clients
  - Not fast roaming between bands
  - Some clients may “bounce” causing disruption to client and network loading.
  - Typically recommended for Eduroam
- Special Case
  - Like General Use
  - Can help reduce the bounce in general use
  - RNR is still effective
  - Clients will often stay at 5GHz
- Not recommended
  - It works
  - Client may think they are on WPA3 when on WPA2

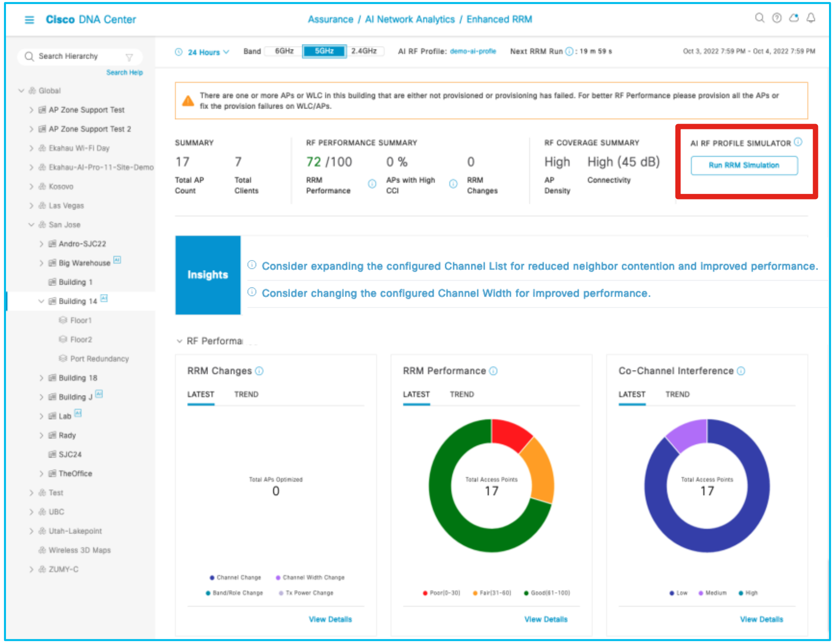
AI RRM

The next generation of RF management

AI Enhanced RRM

NEW! In Cisco DNAC 2.3.4

- What is RRM?
- The goal for AI Enhanced RRM since the beginning has been to provide clear, and actionable information
- Insights give Actionable suggestions on how to improve the configurations
- AI RF Profile Simulator – allows the Admin to model the suggestions in a safe environment using their own data from the Analytics Cloud



Cisco DNA Center — Assurance / AI Network Analytics / Enhanced RRM

24 Hours | Band: 6GHz, 5GHz, 2.4GHz | AI RF Profile: demo-ai-profile | Next RRM Run: 19 m 59 s | Oct 3, 2022 7:59 PM - Oct 4, 2022 7:59 PM

There are one or more APs or WLC in this building that are either not provisioned or provisioning has failed. For better RF Performance please provision all the APs or fix the provision failures on WLC/APs.

SUMMARY: 17 Total AP Count; 7 Total Clients

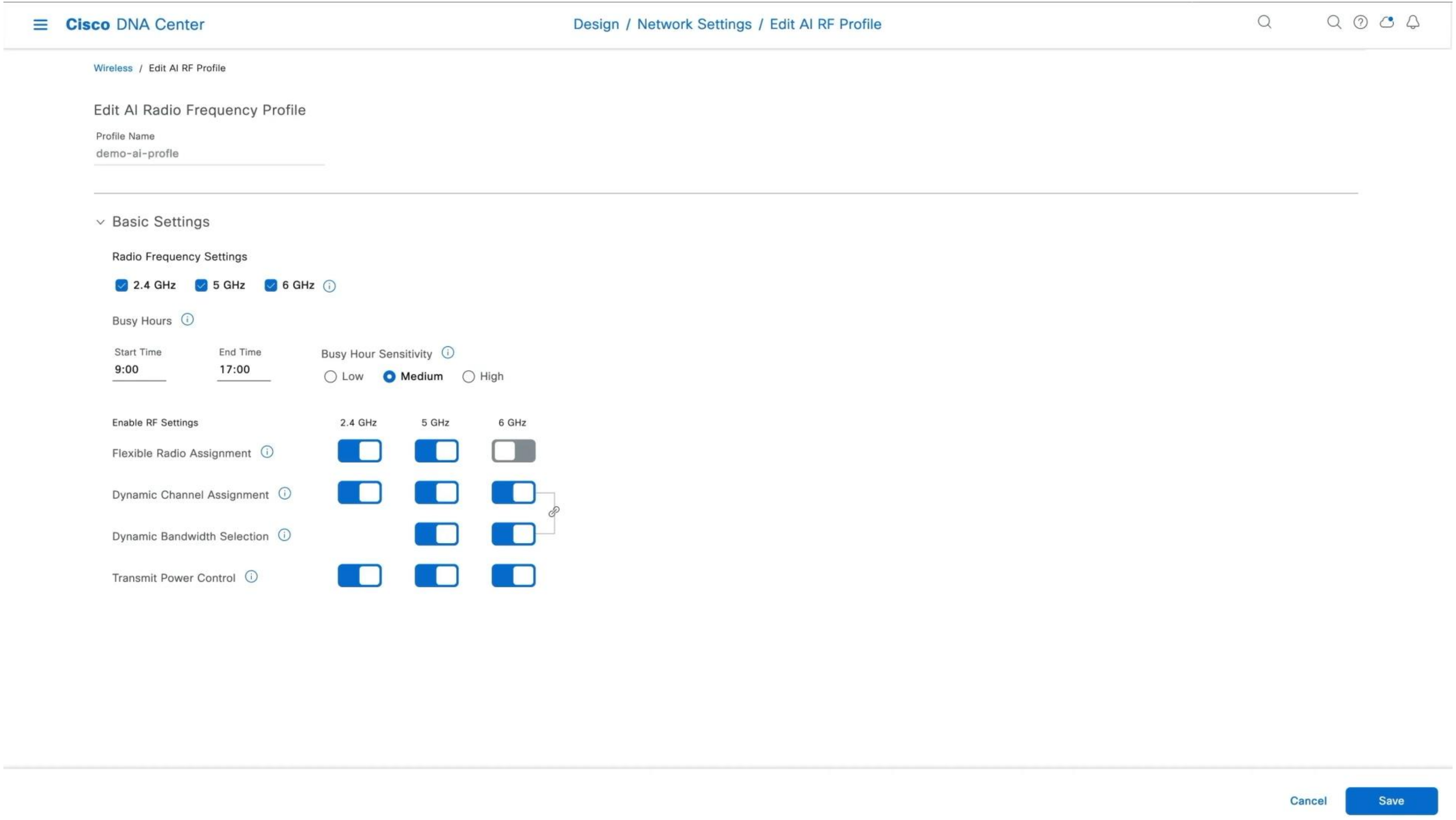
RF PERFORMANCE SUMMARY: 72 /100 RRM Performance; 0 % APs with High CCI; 0 RRM Changes

RF COVERAGE SUMMARY: High AP Density; High (45 dB) Connectivity

AI RF PROFILE SIMULATOR: Run RRM Simulation

Insights

- Consider expanding the configured Channel List for reduced neighbor contention and improved performance.
- Consider changing the configured Channel Width for improved performance.



≡ **Cisco** DNA Center

Design / Network Settings / Edit AI RF Profile

Wireless / Edit AI RF Profile

Edit AI Radio Frequency Profile

Profile Name
demo-ai-profle

⌄ Basic Settings

Radio Frequency Settings

☑ 2.4 GHz ☑ 5 GHz ☑ 6 GHz ⓘ

Busy Hours ⓘ

Start Time: 9:00

End Time: 17:00

Busy Hour Sensitivity ⓘ

○ Low ● Medium ○ High

Enable RF Settings	2.4 GHz	5 GHz	6 GHz
Flexible Radio Assignment ⓘ	●	●	○
Dynamic Channel Assignment ⓘ	●	●	●
Dynamic Bandwidth Selection ⓘ		●	●
Transmit Power Control ⓘ	●	●	●

Cancel Save

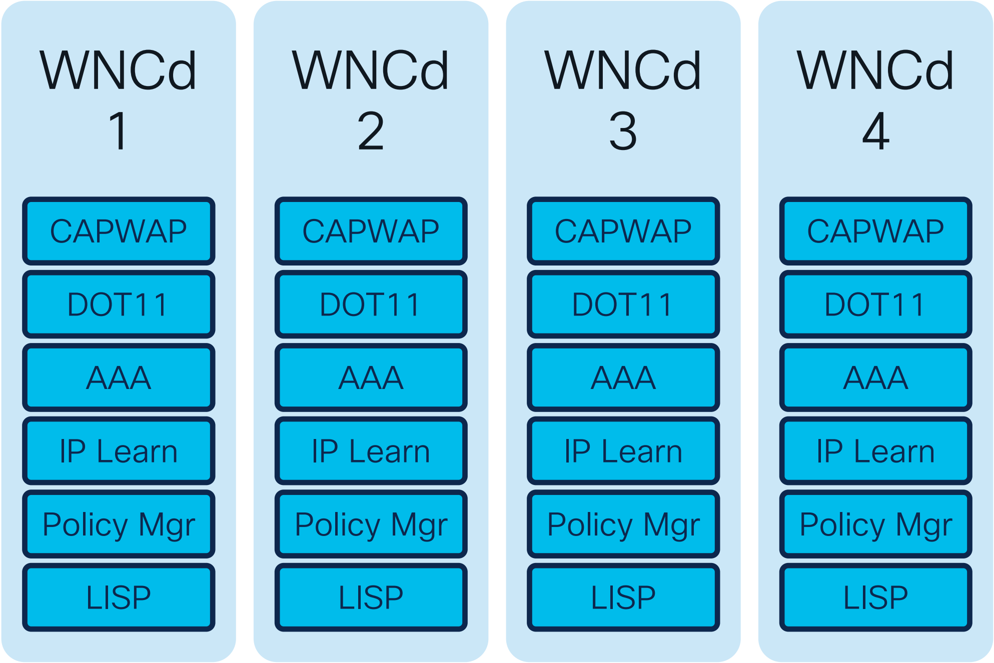
8. WNCd

What is it and how does it affect my design

WNCd, what is it

- AireOS was single threaded, a task was received, scheduled and processed.
  - This worked ok but when it became busy it affected everything.
  - Sort of all or nothing approach
- IOS-XE (C9800) added multithreaded support
  - The Wireless Network Control daemon (WNCd) was created
  - The number of WNCd processes varied from 1 to 8 based on the size of the Wireless Lan Controller.
  - Each process runs independent of the other processes.
  - The processes are responsible for managing AP and Client sessions

More about WNCd



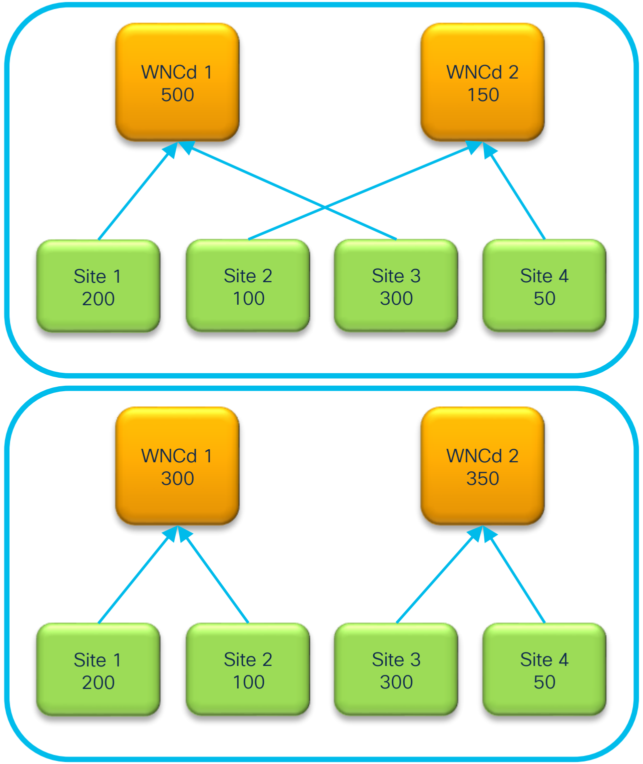
WNCd 1	WNCd 2	WNCd 3	WNCd 4
CAPWAP	CAPWAP	CAPWAP	CAPWAP
DOT11	DOT11	DOT11	DOT11
AAA	AAA	AAA	AAA
IP Learn	IP Learn	IP Learn	IP Learn
Policy Mgr	Policy Mgr	Policy Mgr	Policy Mgr
LISP	LISP	LISP	LISP

Platform	WNCd Instances
EWC (AP or C9k switch)	1
C9800-L	1
C9800-CL (S)	1
C9800-CL (M)	3
C9800-40	5
C9800-CL (L)	7
C9800-80	8

How does this affect my design

17.12 Automatic WNCd Load Balancing

- High CPU can cause APs to drop.
- Target less than 500 APs per WNCd.
- Roaming between APs on different WNCd process will add latency to the roam.
- Site Tags are used to map APs to WNCd process.
- Two methods of assigning Site Tags to WNCd processes.
  - Old – round robin
  - New – weighted grouping



WNCd Example #1

- High probe count can cause high WNCd CPU.
  - Poor coverage can drive up client probe rates
    - Coverage between buildings in campus
    - Areas where clients are entering and exiting
    - Outdoor areas
  - High roaming can increase client probe rates
    - Class lets out
    - Event starting or ending
  - If an AP goes offline this cascades

Solution

- Fix the coverage issues
- Reduce probe queue depth

WNCd Example #2

- High volumes of mDNS traffic cause WNCd CPU
  - mDNS gateway should be enable to limit mDNS
  - Enabling Apple Continuity cause high volumes of mDNS
    - Typically meant for home use.
    - Dormitory student use
    - Guest rooms guest use
  - Monterey update allows MacBook to advertise as TV
    - Classrooms
    - Meeting/conference rooms

Solution

- With mDNS gateway enabled, removed any service not required for the venue.
- For services that are enabled assign them to specific locations.

Security Concerns

Basic Concepts in Wireless Security

Wireless Security

What’s your policy!!

Manage the Environment

- ✓ Rogue Management
  Basic Wireless Security
- ✓ WIPS
  Advanced Wireless Security
- ✓ Cisco CleanAir
  Visibility of non-WiFi interferers
- ✓ Switch-port Tracing
- ✓ RLDP

Protection

- ✓ PMF or MFP (RMF)
  Secure the control
- ✓ Authentication
  Access
- ✓ Authorization
  To what?
- ✓ RBAC
  Least required, TACACs
- ✓ Encryption
  AES, CCMP, GCMP
- ✓ PSIRTS
  Vulnerabilities
- ✓ Key Management
  802.1x, PSK,SAE,OWE
- ✓ DHCP Spoofing
  Hide GiAddr, DNCP Snooping

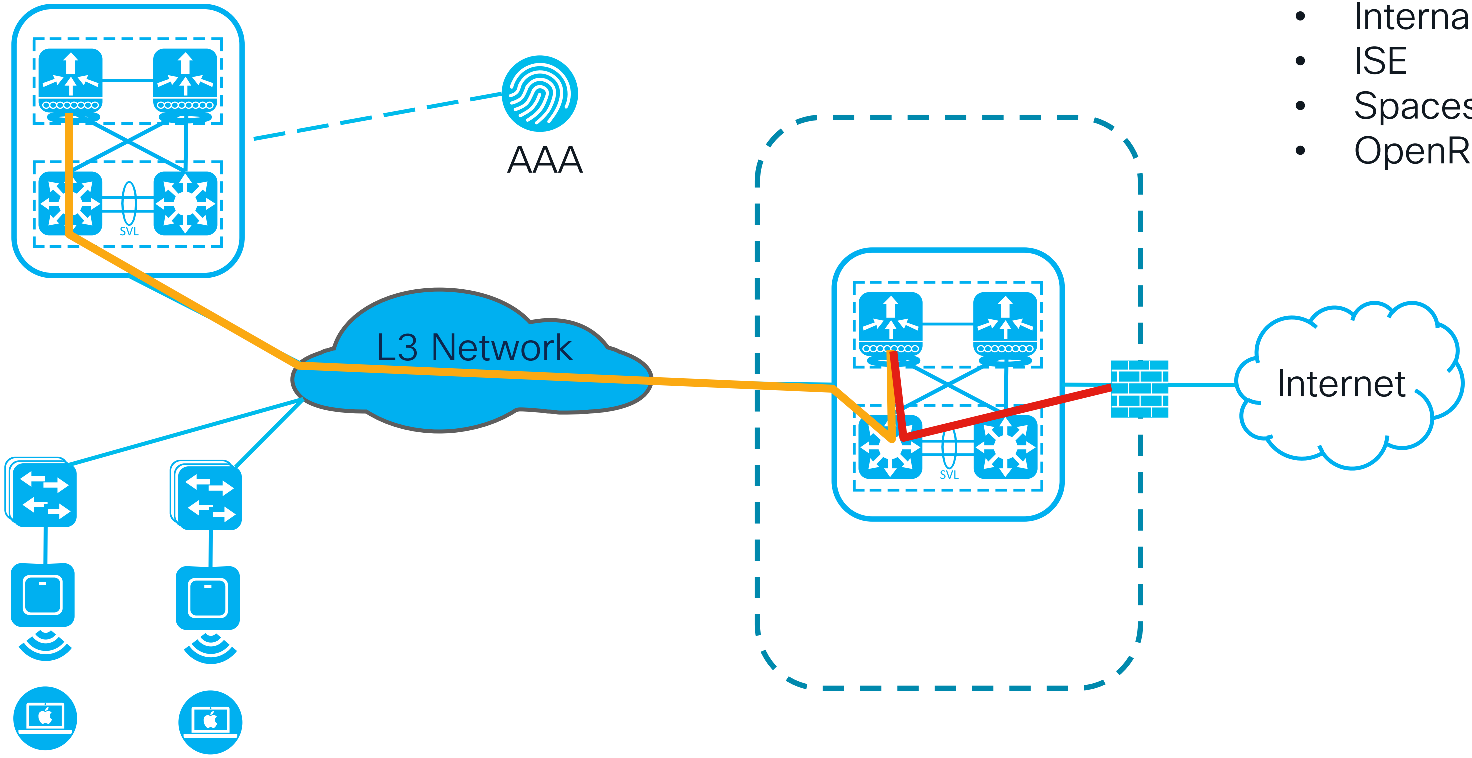
Segmentation

- ✓ Tagging
  VLAN, SGT
- ✓ ACL
  IP ACL, SG ACL, dACL, URL ACL
- ✓ Routing
  PBR, VRF, P2P
- ✓ Fabric
  Macro/Micro

8. Other Design Considerations

Considerations often overlooked

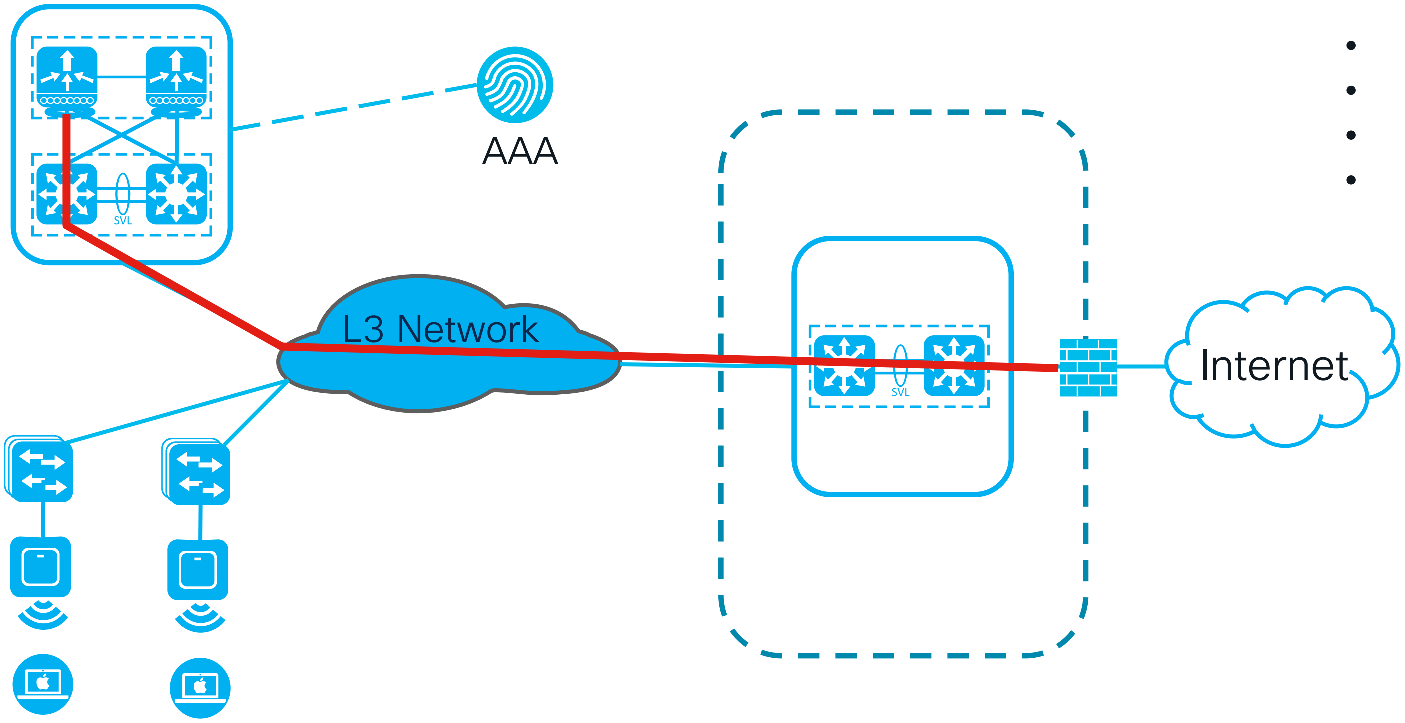
Guest Architectures (Anchor)



- Internal
- ISE
- Spaces
- OpenRoaming

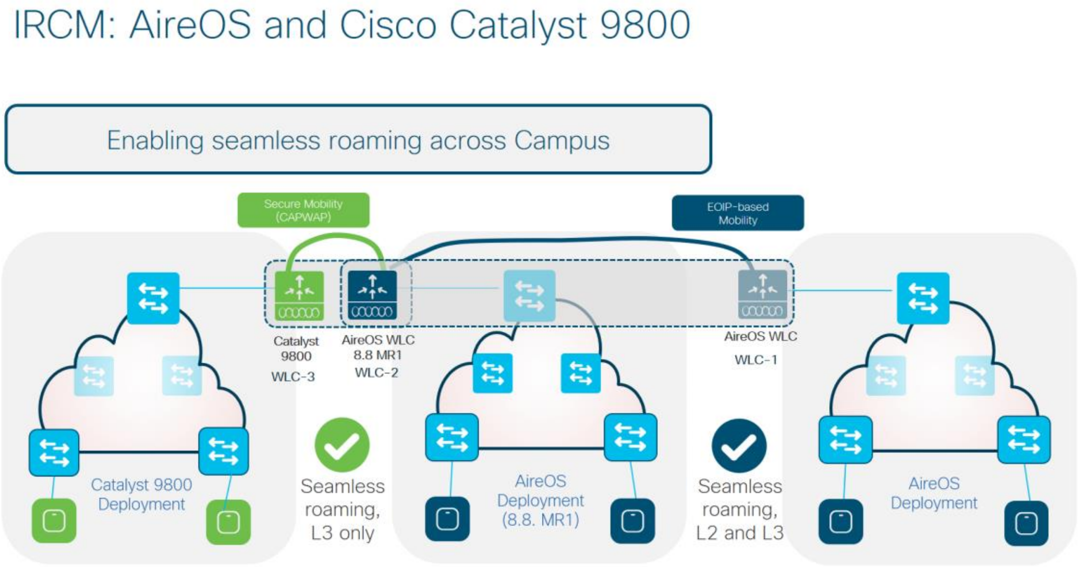
Guest Architectures

17.12 VRF from the WLC



- Internal
- ISE
- Spaces
- OpenRoaming

Inter-Release Controller Mobility



IRCM: AireOS and Cisco Catalyst 9800

Enabling seamless roaming across Campus

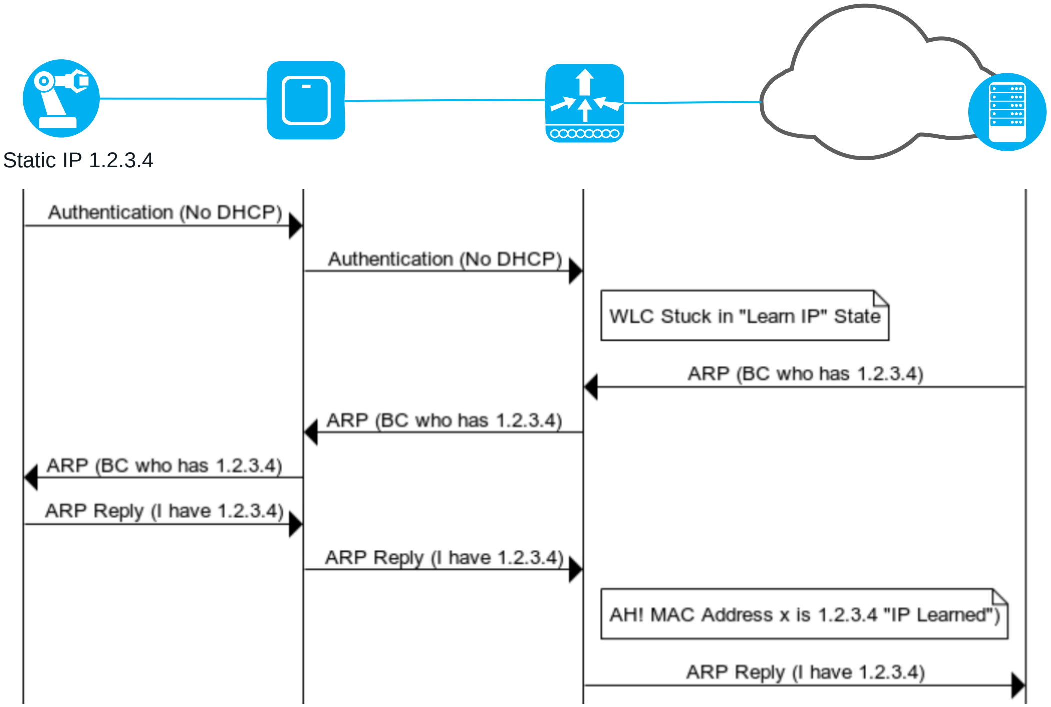
This will work for areas where you have both AireOS and IOS-XE controllers but:

- 9800 to/from AireOS is L3 Only!
- This uses a session on both controllers.
- Hits WNCd process.

Other Solutions:

- Minimize areas for roaming, no salt & pepper.
- 17.9.3 now allows for X700 series APs to coexist with X800 and all Catalyst APs.

Sleeping Clients



Static IP 1.2.3.4
Authentication (No DHCP)
Authentication (No DHCP)
WLC Stuck in "Learn IP" State
ARP (BC who has 1.2.3.4)
ARP (BC who has 1.2.3.4)
ARP (BC who has 1.2.3.4)
ARP Reply (I have 1.2.3.4)
ARP Reply (I have 1.2.3.4)
AH! MAC Address x is 1.2.3.4 "IP Learned")
ARP Reply (I have 1.2.3.4)

- Certain static IP devices such as:
  - Printers
  - IOT
  - Medical devices
- Without this enabled, devices time out with DHCP policy timeout
- Enabled per WLAN
- But: when enabled unknown ARP requests are broadcast!

11. Typical Use Cases

Example design requirements and solutions

University Campus (requirements)

- Periodic High Roaming times (Class Break)
  - High authentication/AAA
  - High dot11 activity
  - High probing
  - mDNS

University Campus

- Design strategies
  - Group dorm and classrooms in the same WNCd
  - Reduce probe queue depth
  - Enable fast roaming/key caching
  - If local AAA (ISE) use distributed architecture with load balancing
  - Ensure good coverage where roaming will occur
  - See WNCd Example 2 for mDNS solutions
  - Clean Air shows hundreds of thousands of interferers…disable that band on Clean Air

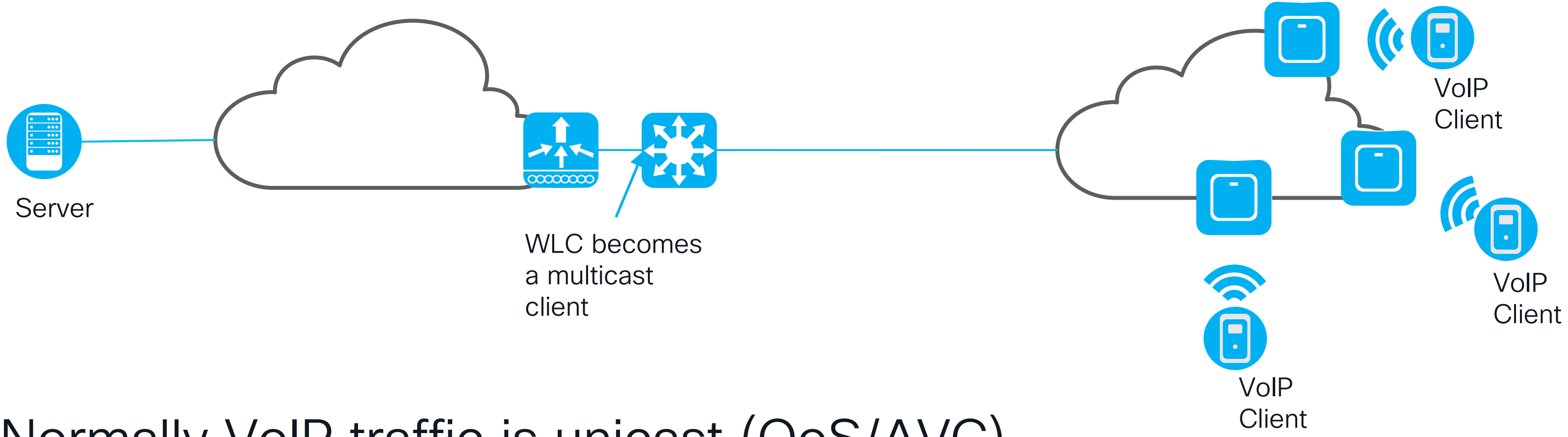
Event Center (Requirements)

- Coverage is good but:
  - High client counts (>200)
  - High roaming loads at certain times
  - Wide range of clients and client behavior

Event Center

- Design Solutions
  - Disable .11K as this is only useful at peak times and hit WNCd CPU
  - Watch out for high numbers of clients in authenticating state
    - May need to decrease EAP timeout to flush sessions not established (default is good)
  - Look for APs set to abnormally high-power levels.
  - Consider more directional antennas and APs
  - Do not enable passive client
  - Check for high ARP rates and police (>2000 Packets/sec)
  - In the case of multiple controllers on one core switch mac address capacity (CAM) is a concern.

Hospital VoIP/Badge Paging



- Normally VoIP traffic is unicast (QoS/AVC)
- Paging is multicast
  - Server send message to clients which Multicast Group to join
  - All members join the group and get page from one of the clients

Hospital VoIP/Badge Paging

- Design solutions
  - Enable snooping
  - Enabled Multicast-Multicast mode on the WLC
  - PIM Sparse Mode is used
    - L3 interfaces for AP management need PIM
    - L3 interfaces on the switch connecting to the WLC need PIM.

Useful References

Things to use later for your designs

Really good tools

- https://developer.cisco.com/docs/wireless-troubleshooting-tools/#!wireless-troubleshooting-tools/wireless-troubleshooting-tools
  - Wireless Config Analyzer Express – WCAE
  - WLAN Poller
  - WiFi Hawk
  - Wireless Debug Analyzer
  - WLC Config Converter BETA

Useful References

- WiFi 6E 6GHz WW allocations: https://www.wi-fi.org/countries-enabling-wi-fi-in-6-ghz-wi-fi-6e
- 9800 Best Practices: https://www.cisco.com/c/en/us/products/collateral/wireless/catalyst-9800-series-wireless-controllers/guide-c07-743627.html
- 6GHz Deployment Paper: https://www.cisco.com/c/en/us/products/collateral/wireless/catalyst-9100ax-access-points/ghz-unlicensed-spectrum-reg-wp.html
- Blog part 1: https://blogs.cisco.com/networking/wi-fi-6e-something-old-something-new-something-borrowed-something-blue-part-1
- Blog part 2: https://spaces.at.internet2.edu/display/eduroam/eduroam-US+Knowledge+Base
- ISE Scale Documents: https://www.cisco.com/c/en/us/td/docs/security/ise/performance_and_scalability/b_ise_perf_and_scale.html

Fill out your session surveys!

Attendees who fill out a minimum of four session surveys and the overall event survey will get **Cisco Live-branded socks** (while supplies last)!

Attendees will also earn 100 points in the **Cisco Live Challenge** for every survey completed.

These points help you get on the leaderboard and increase your chances of winning daily and grand prizes

Continue your education (related sessions)

- BRKEWN-2087 – High Density Wi-Fi Design, Deployment, and Optimization
- BRKEWN-2846 – High Availability Design with Cisco Catalyst 9800 Controllers
- BRKEWN-2031 - Design and deployment of Modern Wireless Networks
- BRKEWN-2000 – Design/Deployment and tuning of Outdoor Wi-Fi & Work Group Bridges
- BRKEWN-3413 - Advanced RF Tuning for Wi-Fi 6E with Catalyst Wireless: Become an Expert, while getting a little help from AI
- BRKEWN-1053 - Troubleshoot Cisco Wireless using Cisco DNA at a University
- BRKEWN-2658 - Implement and Troubleshoot New Features from Cisco DNA Spaces to Deliver Next Generation Location Base Solutions
- BRKEWN-2926 - Cisco Wi-Fi: how to tune your design and configurations for your most demanding clients and applications

Continue your education

- Visit the Cisco Showcase for related demos
- Book your one-on-one Meet the Engineer meeting
- Attend the interactive education with DevNet, Capture the Flag, and Walk-in Labs
- Visit the On-Demand Library for more sessions at www.CiscoLive.com/on-demand

The bridge to possible

Thank you

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Let’s go

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