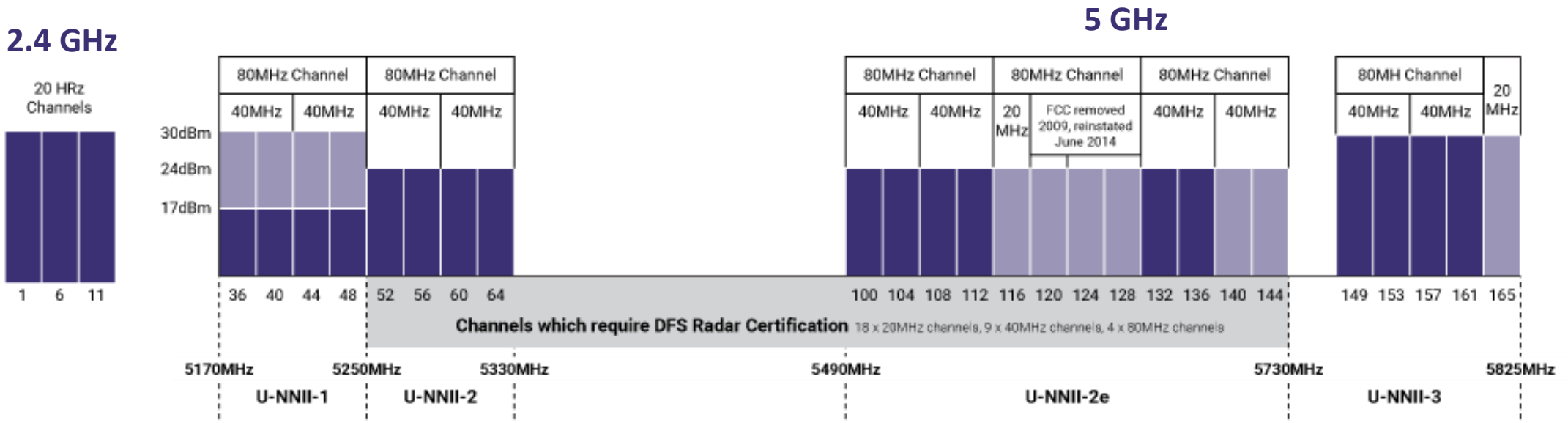
2018 CALIX CONNEXIONS | INNOVATION AND USER CONFERENCE

Ensuring Successful Home Wi-Fi Deployments

Bret McElwee

Wi-Fi Standards

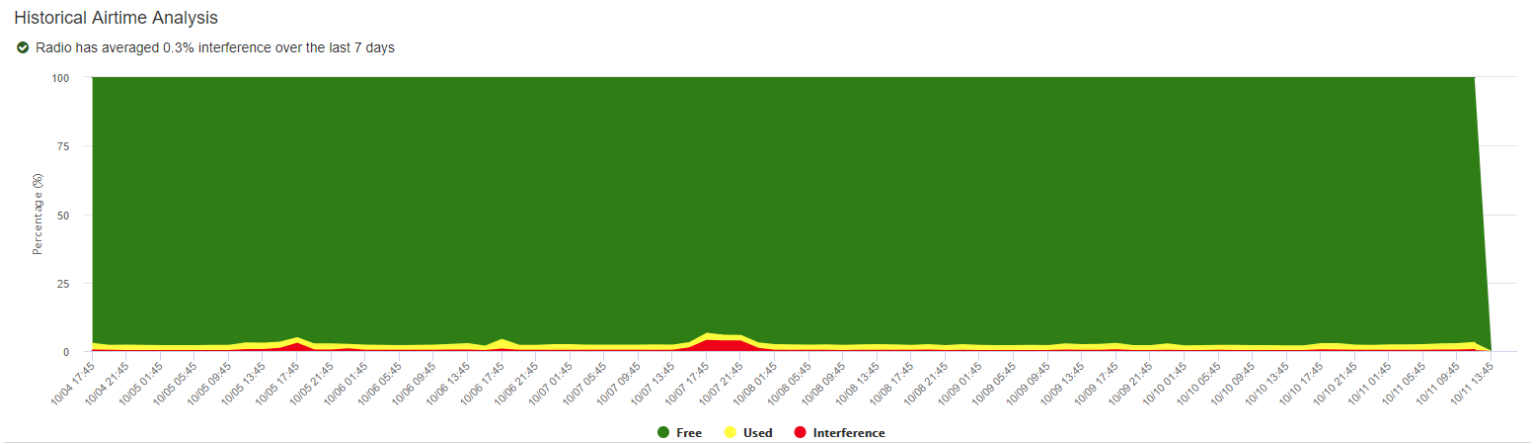
Getting to Know the Wi-Fi Spectrum

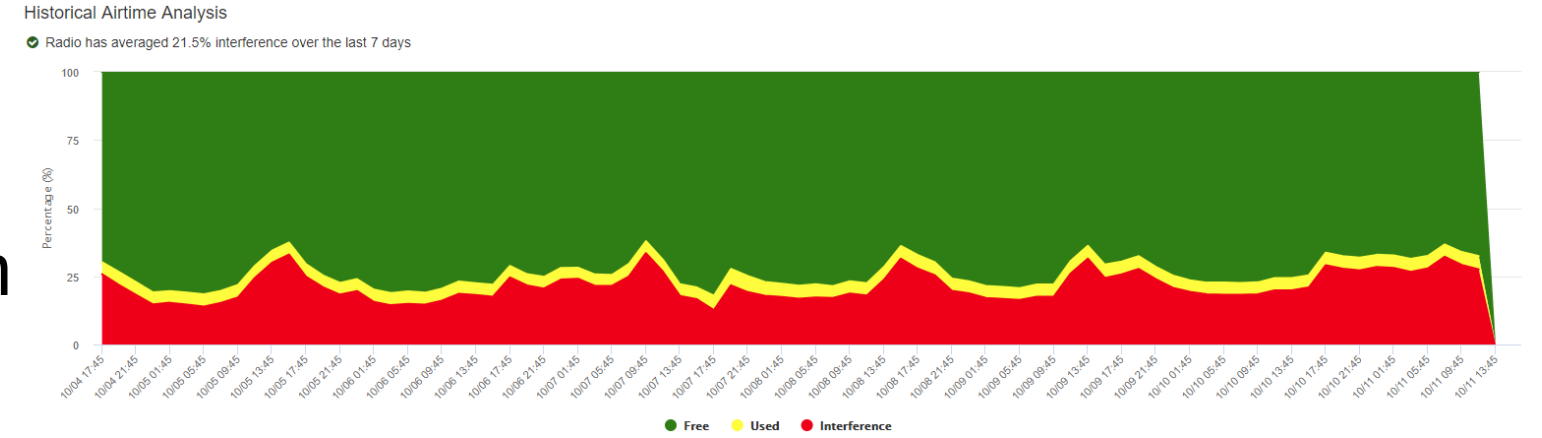


	2.4 GHz	5 GHz
Number of non-overlapping 20 MHz channels	3	18 (including DFS channels)
Number of non-overlapping 40 MHz channels	1	9
Number of non-overlapping 80 MHz channels	0	4
Range	Better	Good

2.4 GHz vs 5 GHz – A Typical Home

- 2.4 GHz averaged 21.5% interference
- 5 GHz averaged 0.3% interference
- These are results in a condominium and are fairly typical
- 5 GHz is still less congested than 2.4GHz in most locations





Comparison of IEEE 802.11 Standards

Standard	Release Date	Band (GHz)	Bandwidth (MHz)	Modulation	Advanced Technologies	Maximum Data Rate (PHY Rate)
802.11	1997	2.4	20	DSSS, FHSS	N/A	2 Mbps
802.11a	1999	5	20	OFDM	N/A	54 Mbps
802.11b	1999	2.4	20	DSSS	N/A	11 Mbps
802.11g	2003	2.4	20	DSSS, OFDM	N/A	54 Mbps
802.11n	2009	2.4, 5	20, 40	OFDM	MIMO (up to 4 spatial streams)	600 Mbps
802.11ac	2013	5	20, 40, 80, 160	OFDM	MIMO, MU-MIMO (up to 8 spatial streams)	6.93 Gbps
802.11ax	2019	2.4, 5	20, 40, 80, 160	OFDM, 1024 QAM	MIMO, UL & DL MU-MIMO*, Scheduled OFDMA**, Sub-Bands*** 1024-QAM****	4x 802.11ac speeds

Bottom Line: 11ax allows you to go further and faster than 11ac

802.11ax Features
*Multi-User MIMO on both Downlink and Uplink
**Scheduled OFDMA allows media access in time and frequency space for higher efficiency
***Sub-Bands allow greater range at the expense of lower bandwidth
****1024-QAM – 25% Higher Capacity than 256-QAM in 11ac

Wi-Fi Data Elements

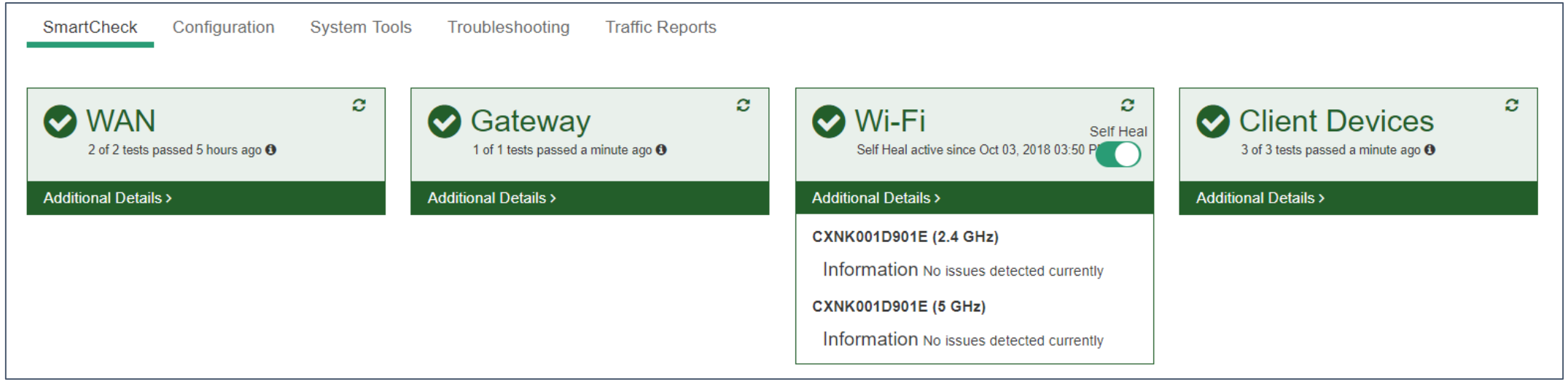
You can’t manage a Wi-Fi network unless you can see inside of it.

Why are Wi-Fi Data Elements needed?

- All support calls cost money and 10% percentage of Wi-Fi related calls require expensive truck rolls.
- To trouble shoot and manage Wi-Fi networks, it is critical to be able to see what is going on in the network.
- Self Organizing Wi-Fi autonomously reconfigures the network for optimal performance. Without Data Elements, there is no way to measure performance or see if reconfiguration has improved the performance

*To see inside the Wi-Fi network, a foundation of Wi-Fi network **Data Elements** is needed to **measure performance** of the network.*

Why are Wi-Fi Data Elements needed?



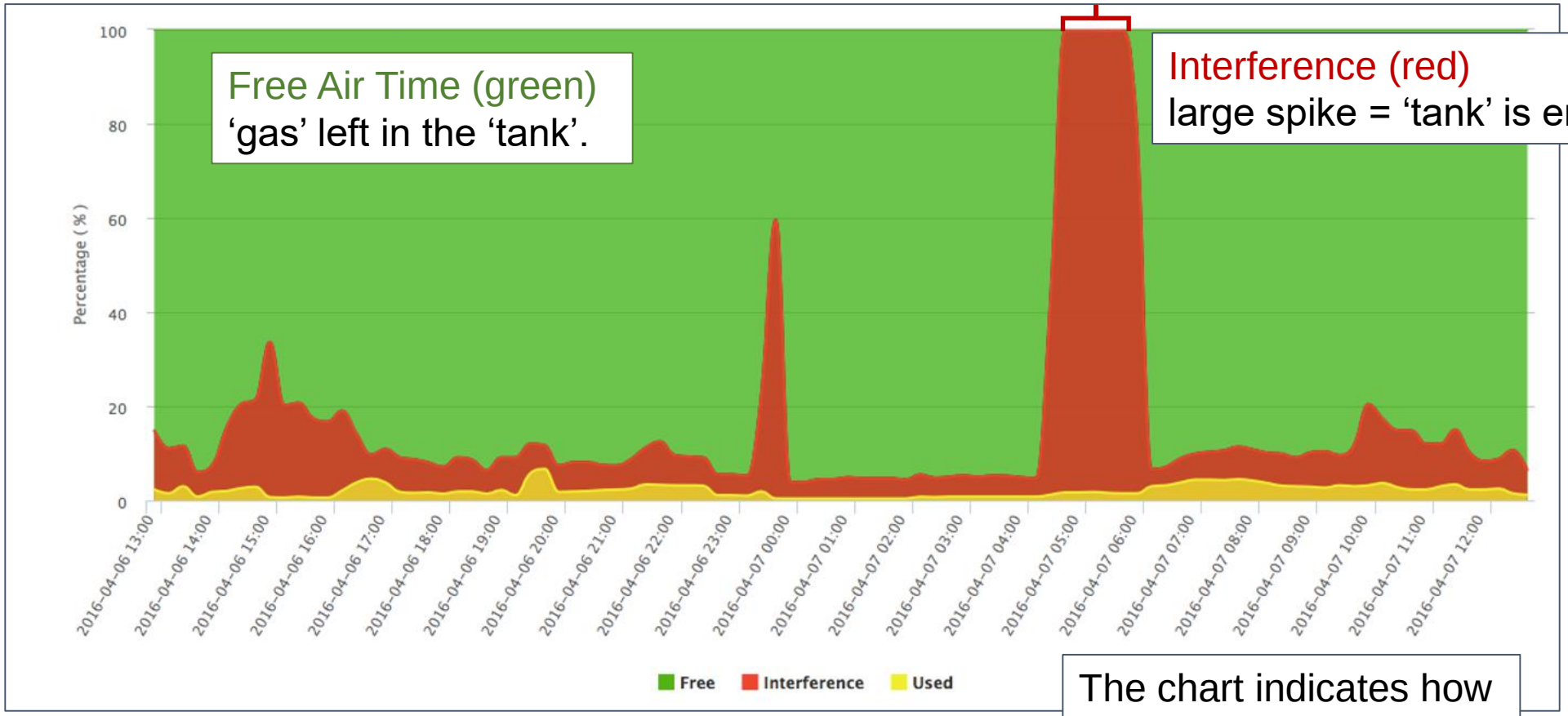
Wi-Fi Key Data Elements are used by tools such as Calix Support Cloud Smart Check to provide a simplified view of what is going on with client devices in the home.

6 Key Data Elements

1. Air Time Usage – used by Access Points and Clients
2. Client PHY Rates: Maximum Capability and Actual
3. Received Signal Strength (RSSI)
4. Retransmitted Packet Rates
5. Dropped Packet Rates
6. Site Scans (Measurements of all detected neighboring Access Points and Channels)

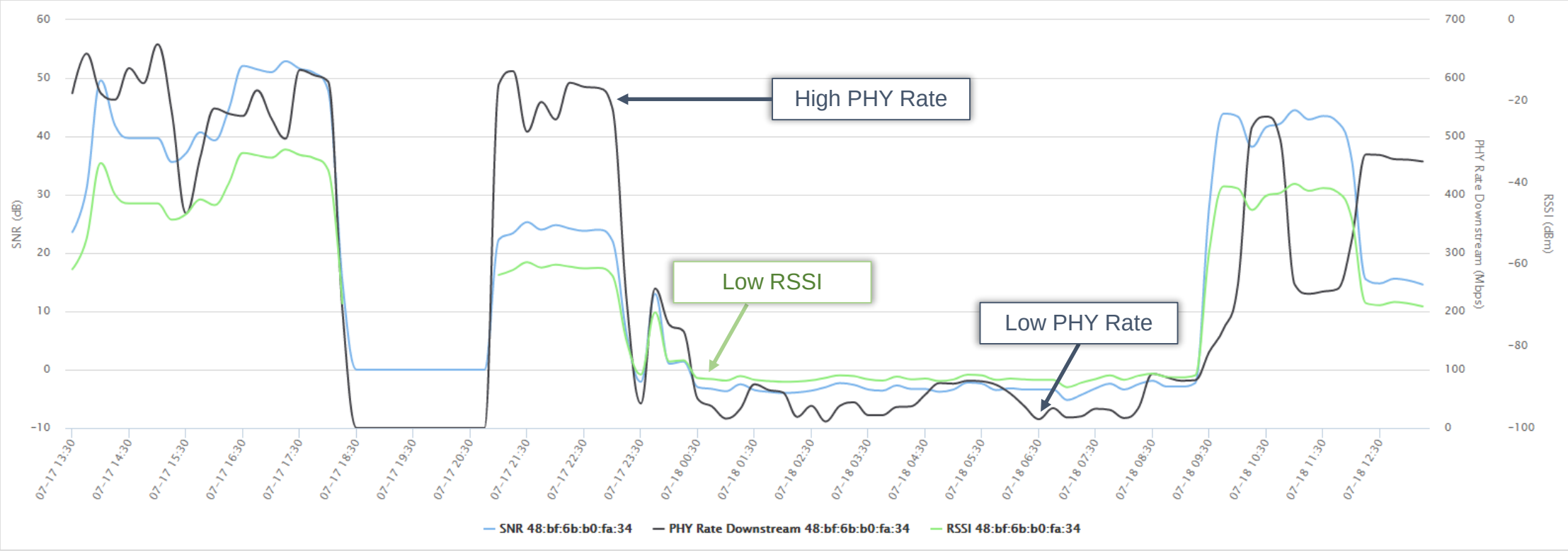
Data Element 1: Air Time Usage

No Free Air Time



The chart indicates how air time is being used.

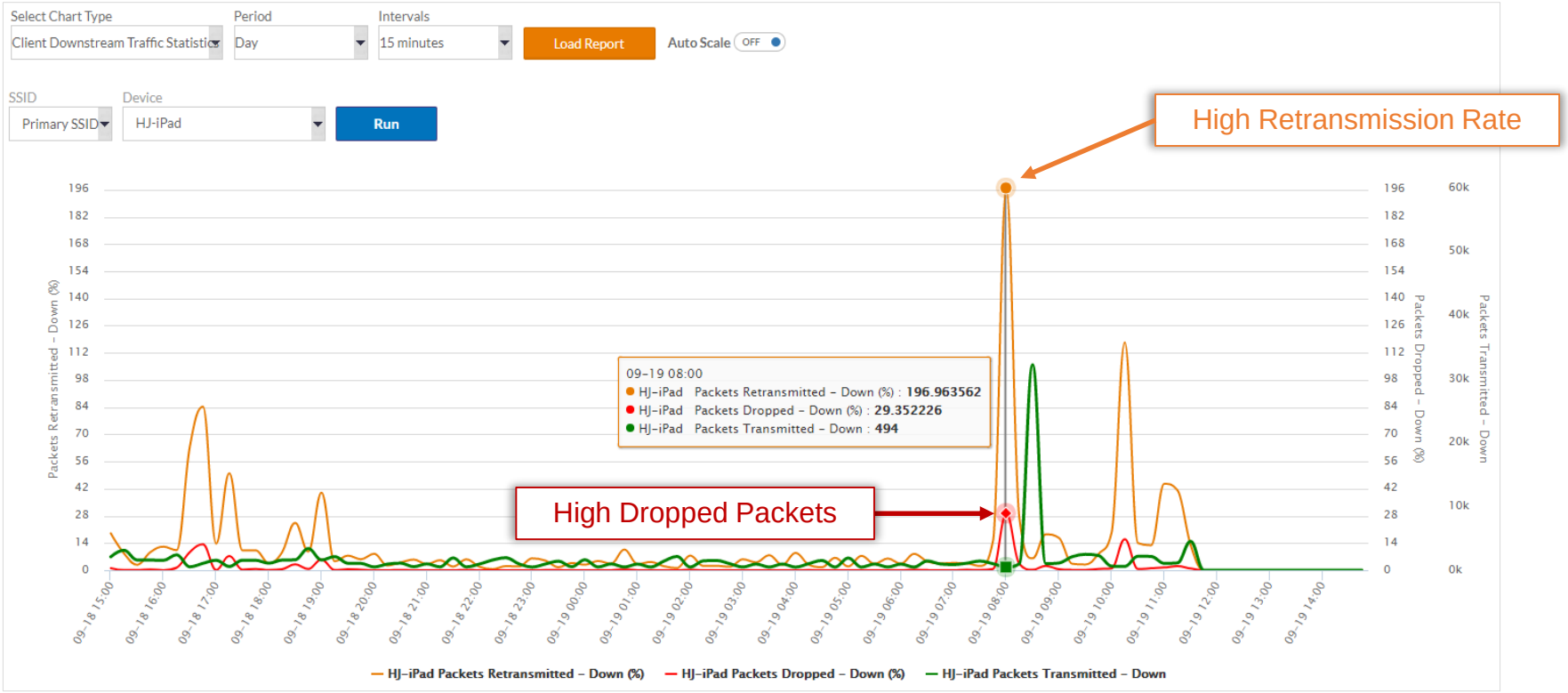
Data Element 2 - 3: Client PHY Rates / RSSI



Poor Client PHY rates or low Received Signal Strength Indicator (RSSI) can result in poor performance for the user applications.

- May be due to legacy Wi-Fi STA technology, low signal strength, distance or walls between STA and AP, or interference.
- PHY rate needed depends on applications, IoT may not need high PHY rates, however 4K Video Streaming does.

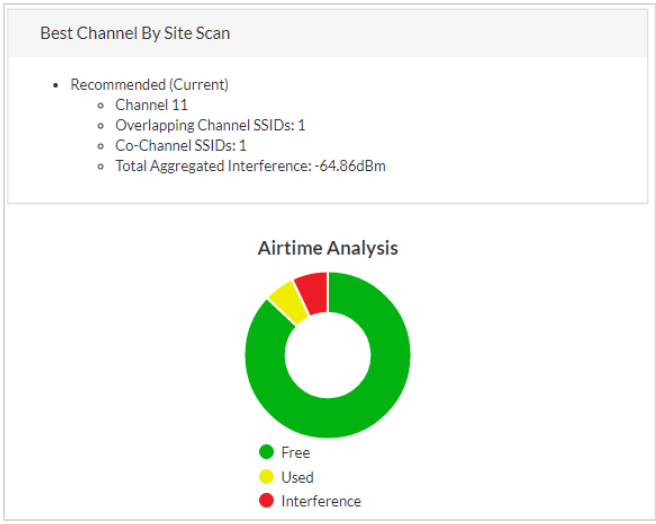
Data Element 4 - 5: Dropped and Retransmitted Packet Rates



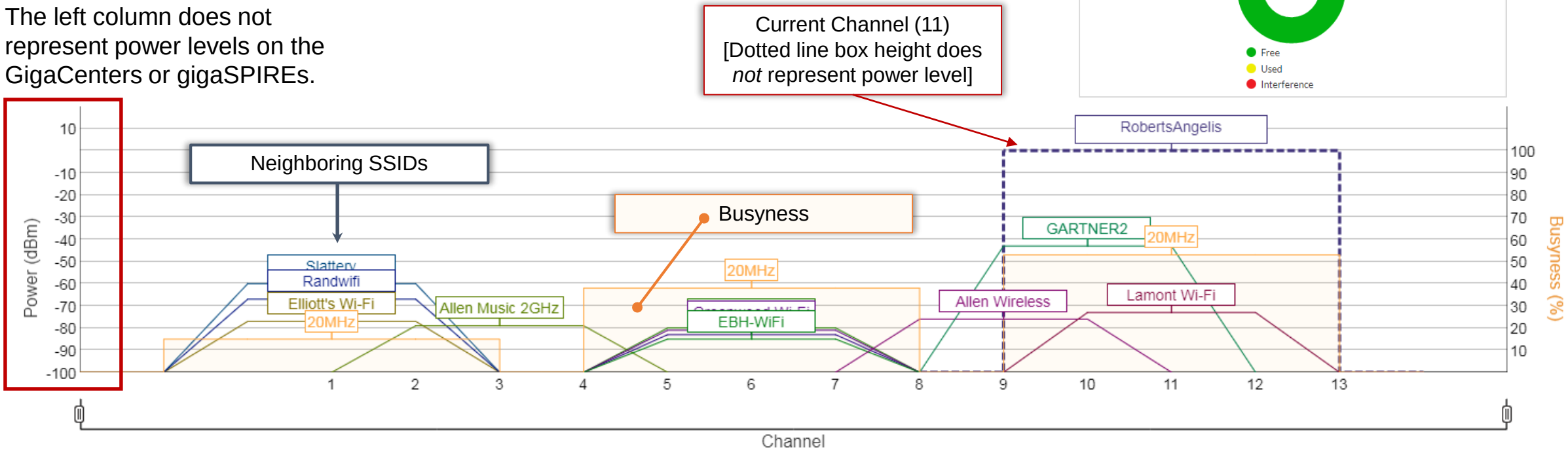
Monitor Packet Error and Retransmission rates for an indicator of the overall quality of the connection.

- High packet retransmission rates can be considered early warning signs of poor Wi-Fi connections.
- Having the ability to measure both packet error rate and retransmission rate is essential.

Data Element 6: Site Scan



The left column does not represent power levels on the GigaCenters or gigaSPIREs.



A Site Scan provides a visual representation of local Wi-Fi environment. The Calix site scan algorithm recommends the best available channel by analyzing both detected neighbors and channel busyness.

Calix Industry Initiative – Wi-Fi Alliance Data Elements

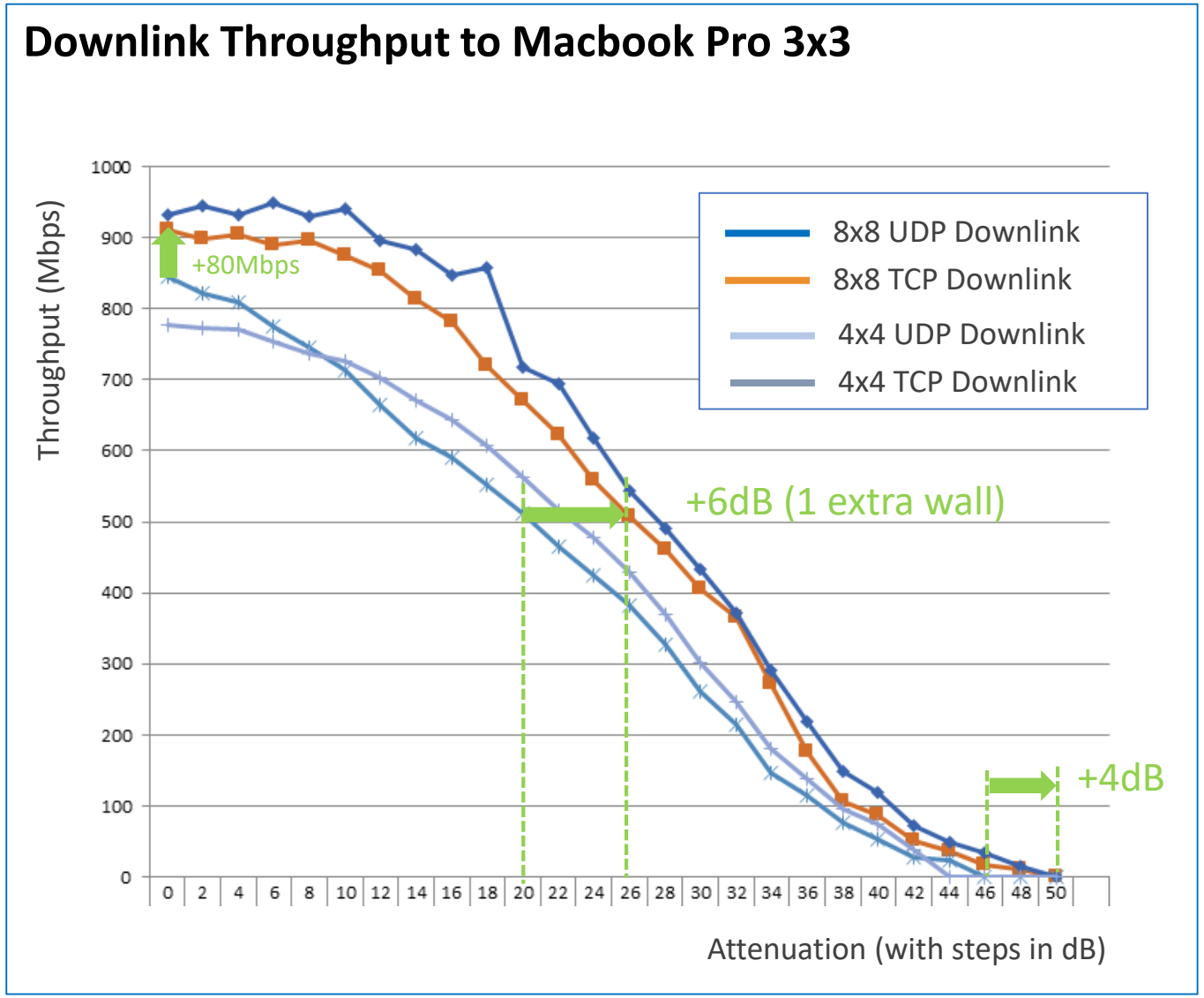
Standardize a Set of Key Wi-Fi Data Elements in the WFA:

- **Dec. 2017:** Wi-Fi Alliance starts Task Group for Data Elements based on CableLabs/Calix/Nokia proposal
- **Sept 2018:** Certification wave #4 successfully completed
- **Oct. 2018:** Data Elements Technical Specification completed
- **End 2018:** Start release 2.0 of WFA Data Elements

Why should you care? A: With a standard set of DE's an operator can ask vendors to comply and any cloud software will interoperate with the devices

Chipset Tests

- Any Wi-Fi device, including the 8x8 11ax AP, is capped by FCC transmit power limits, and a 3x3 Macbook 11ac client cannot receive more than 3 spatial streams
  - ***Can the Macbook performance still be improved with the 8x8 AP?***
- **Yes**, twice as many transmit antennas reduces the power per radio chain, improving RF fidelity at high data rates
- **Yes**, receiver benefits from 8x8 diversity vs 4x4 (no FCC limits on sensitivity)



Wi-Fi Test Chamber

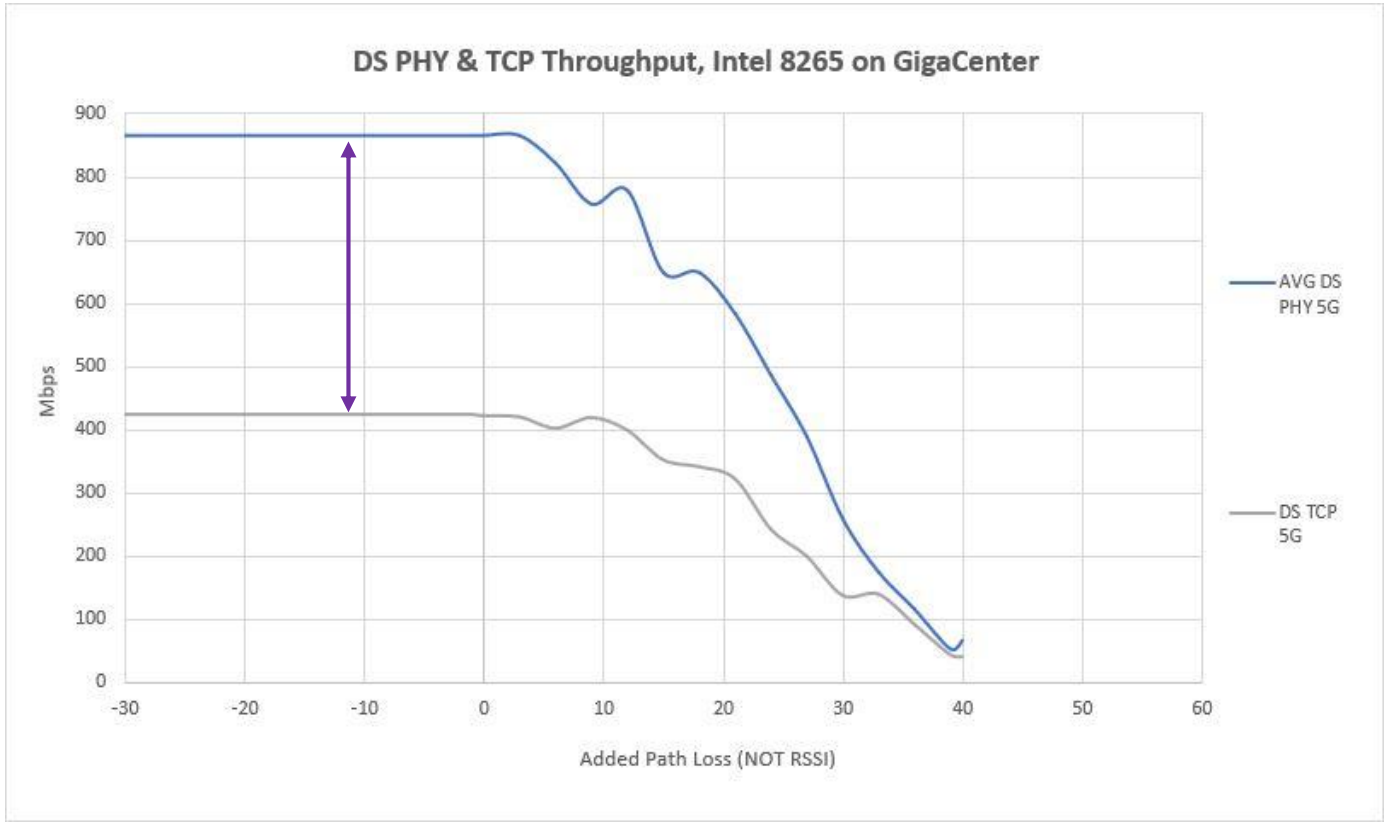
Two major ways of testing Wi-Fi performance

1. *Cabled testing from AP to client – repeatable but not realistic and requires removal of antennas on AP and client*
2. *Over the air (OTA) – Allows realistic testing with antennas but suffers from outside interference and is less repeatable*

- *Calix test environment has combined the best of both worlds, no cables yet repeatable and free of external interference*

Wi-Fi Test Chamber – 4x4 Antenna

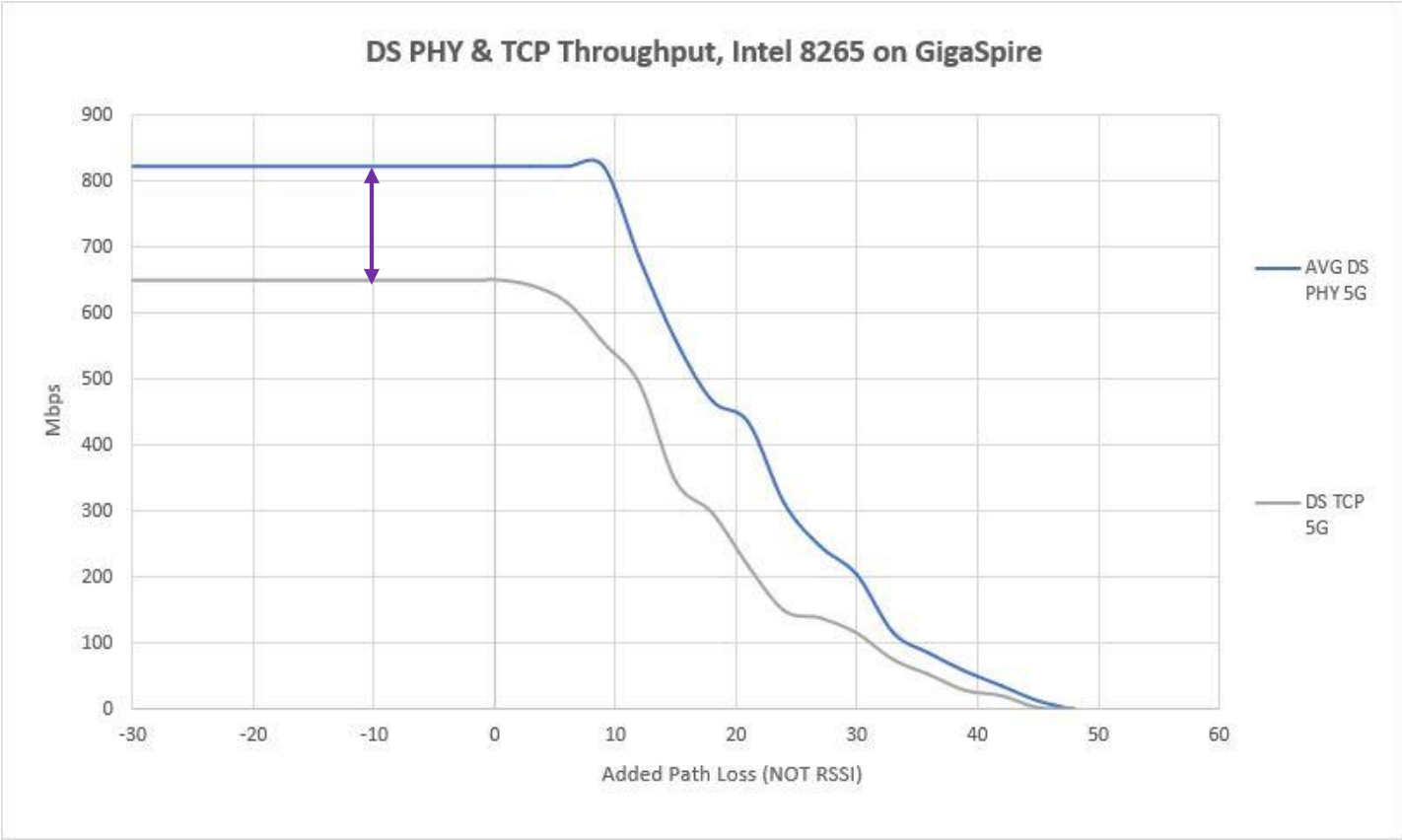
- Real data throughput rate is never has high as the PHY rate



Real Packet rate is about 50% of the reported PHY rate for the GigaCenter

Wi-Fi Test Chamber – 8x8 Antenna

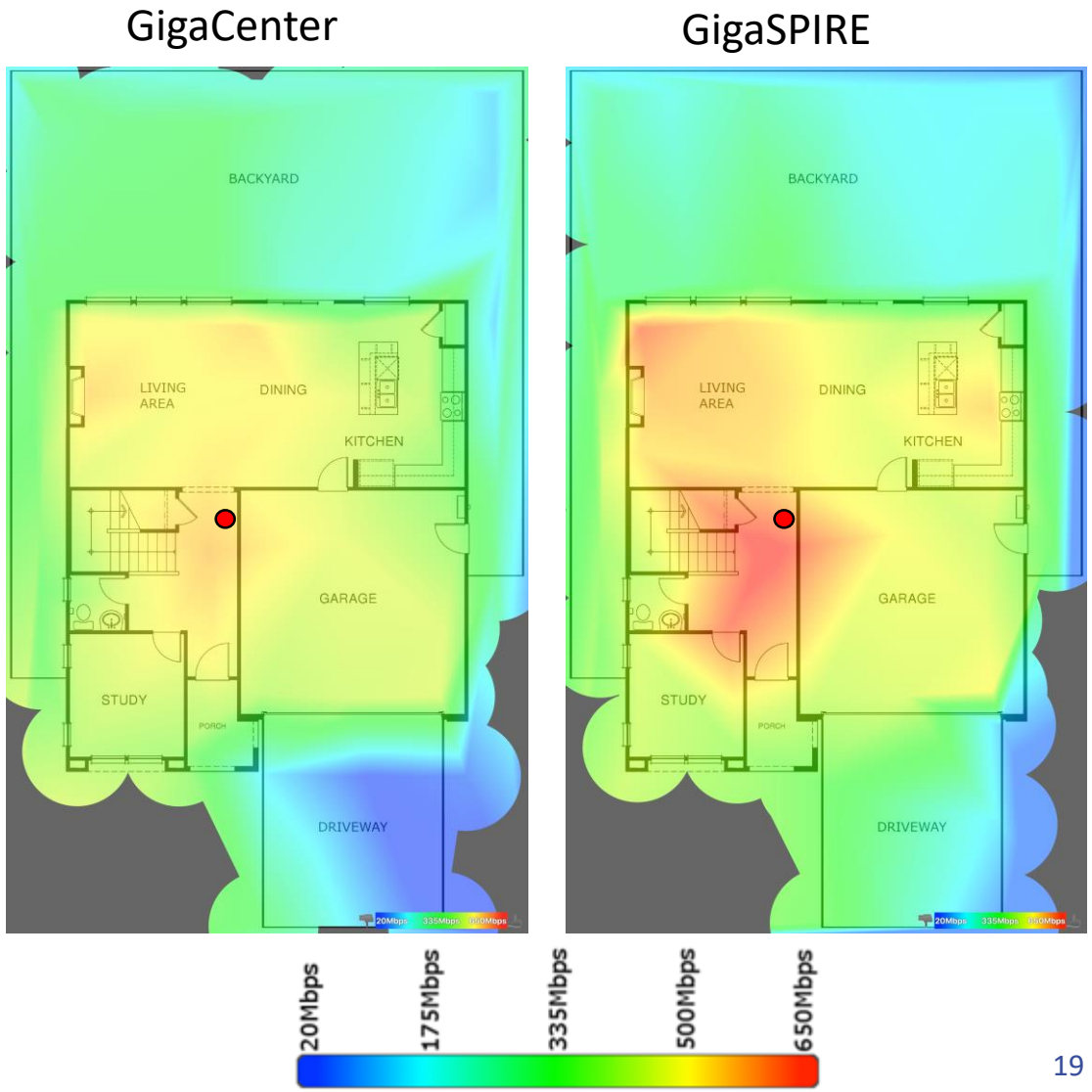
- Real data rate with 8x8 device is closer to the PHY rate



GigaSPIRE data rate is 80% of PHY rate

Wi-Fi Test Home Throughput Tests - Downstairs

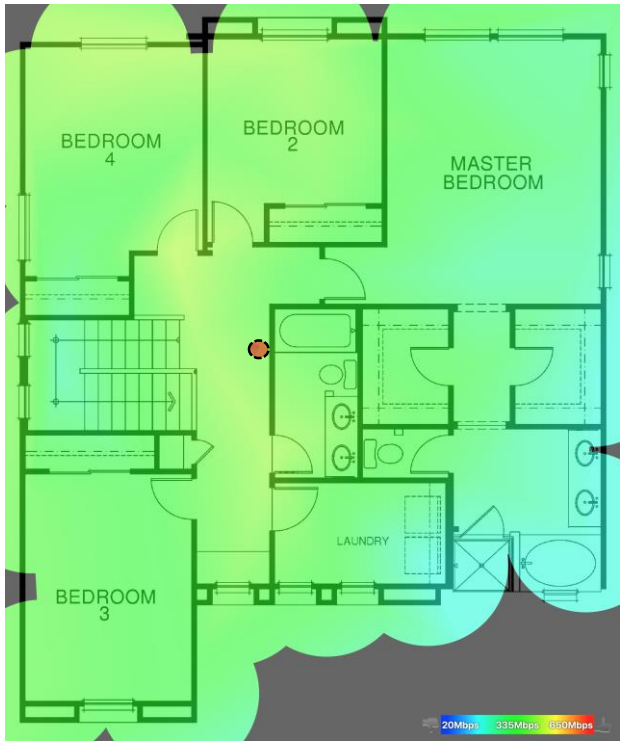
- GigaSPIRE achieves higher peak data rates of > 600 Mbps (red) and has virtually no areas of the home that are less than 100 Mbps (blue).
- Conditions
  - TCP Throughput Testing
  - Client used in testing: MacBook Pro 3x3 MIMO 802.11ac
  - Stucco on wire mesh exterior walls
  - 50-60 Test Points per floor



Wi-Fi Test Home Throughput Tests - Upstairs

- GigaSPIRE achieves upstairs peak data rates of > 500 Mbps (orange) and has virtually no areas of the home that are less than 100 Mbps (blue).
- Conditions
  - TCP Throughput Testing
  - Client used in testing: MacBook Pro 3x3 MIMO 802.11ac
  - Stucco on wire mesh exterior walls
  - 50-60 Test Points per floor

GigaCenter

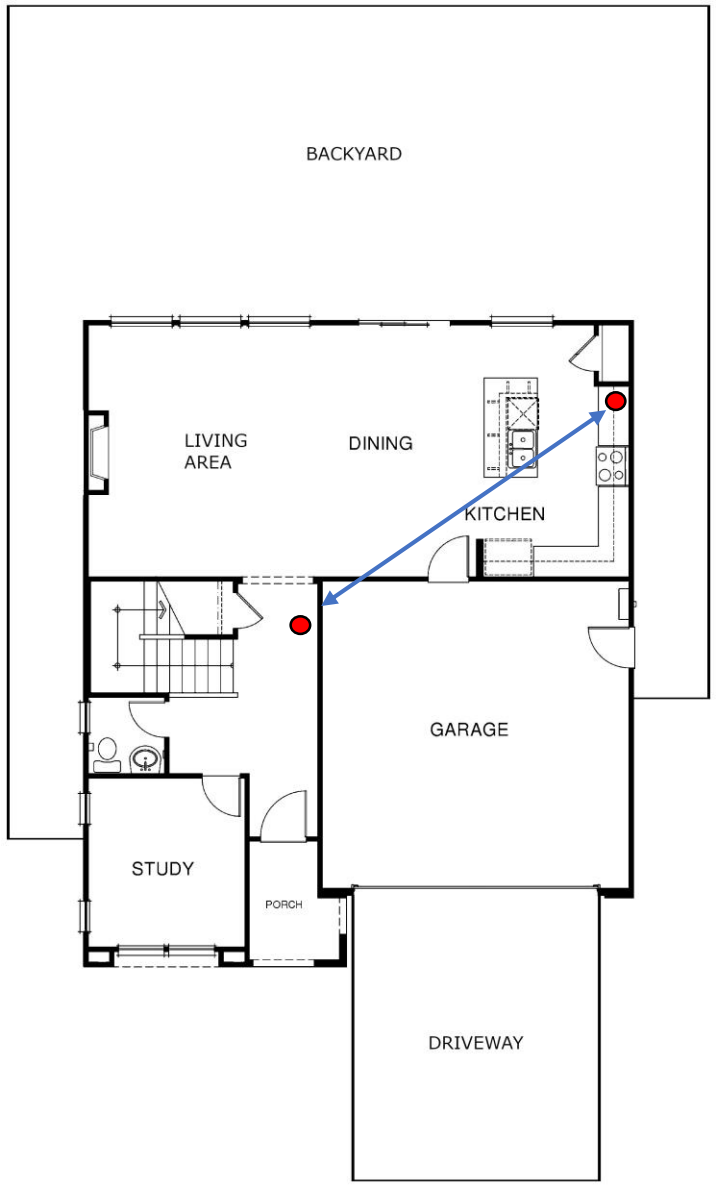


GigaSPIRE

Wi-Fi Backhaul Performance

- GigaCenter Backhaul PHY Rate – **700 Mbps**
- GigaSPIRE Backhaul PHY Rate – **1300 Mbps**

GigaSPIRE backhaul provides the closest thing yet to a "Wireless Ethernet Cable"



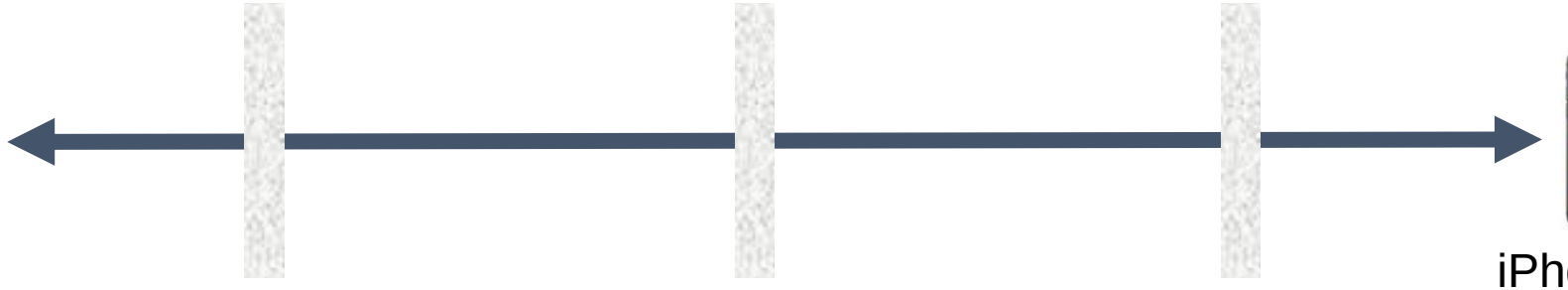
Mesh-Enhanced Carrier Class Wi-Fi

Why are more than one Access Points needed in some homes?

Wi-Fi Has a Physics Problem: Attenuation

GigaCenter

802.11ac
4x4 MIMO
80 MHz Bandwidth
Access Point



iPhone 6S

802.11ac
2x2 MIMO
80 MHz Bandwidth

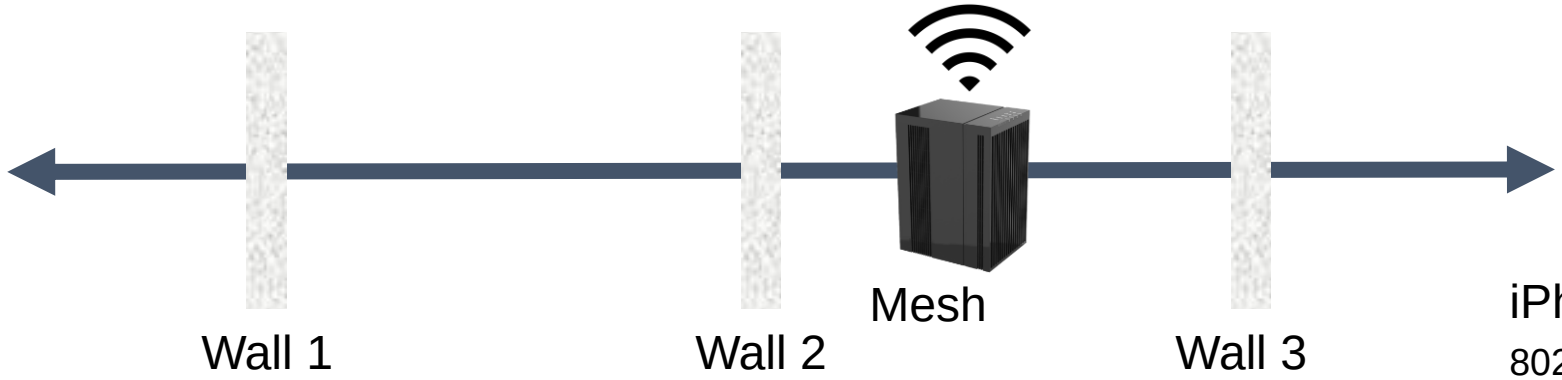
3 Walls (~27dB) attenuation
Peak PHY rate – 2x2 client

~50 Mbps Throughput

Wi-Fi Has a Physics Problem: Attenuation

GigaCenter

802.11ac
4x4 MIMO
80 MHz Bandwidth
Access Point



iPhone 6S

802.11ac
2x2 MIMO
80 MHz Bandwidth

2 Walls (~18dB)

Peak PHY rate
800 Mbps (4x4)

1 Wall (~9dB)

Peak PHY rate
400 Mbps (2x2)

~264 Mbps
Throughput

However…..

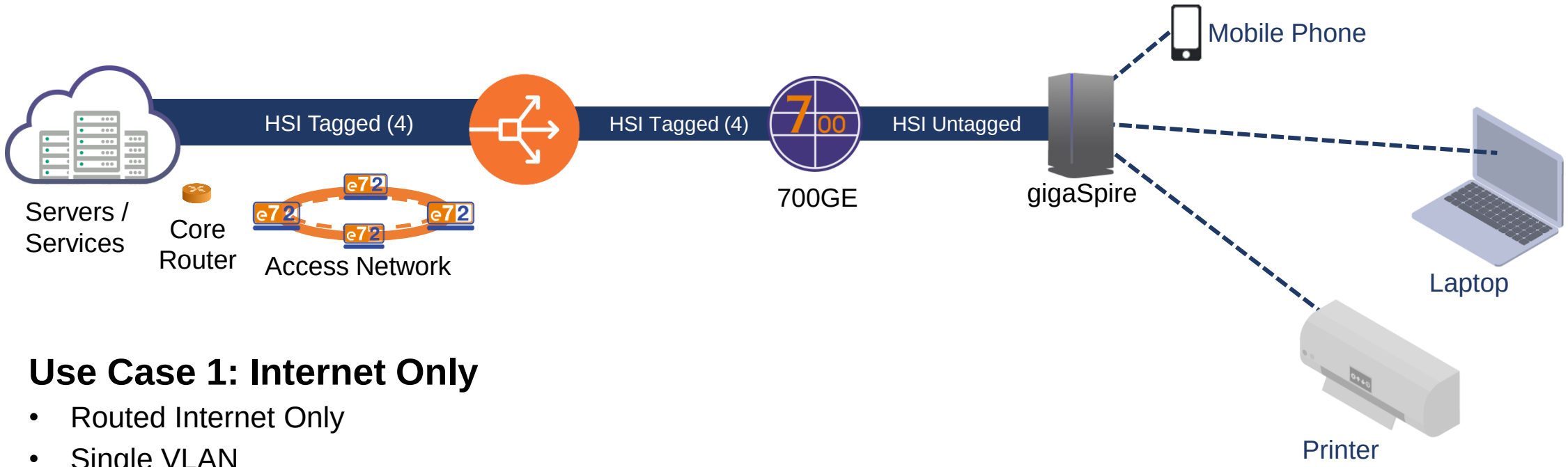
3 Walls (~27dB attenuation)

Peak PHY rate 50Mbps (2x2)

~50 Mbps
Throughput

Access Network Use Cases

High-Speed Internet Only

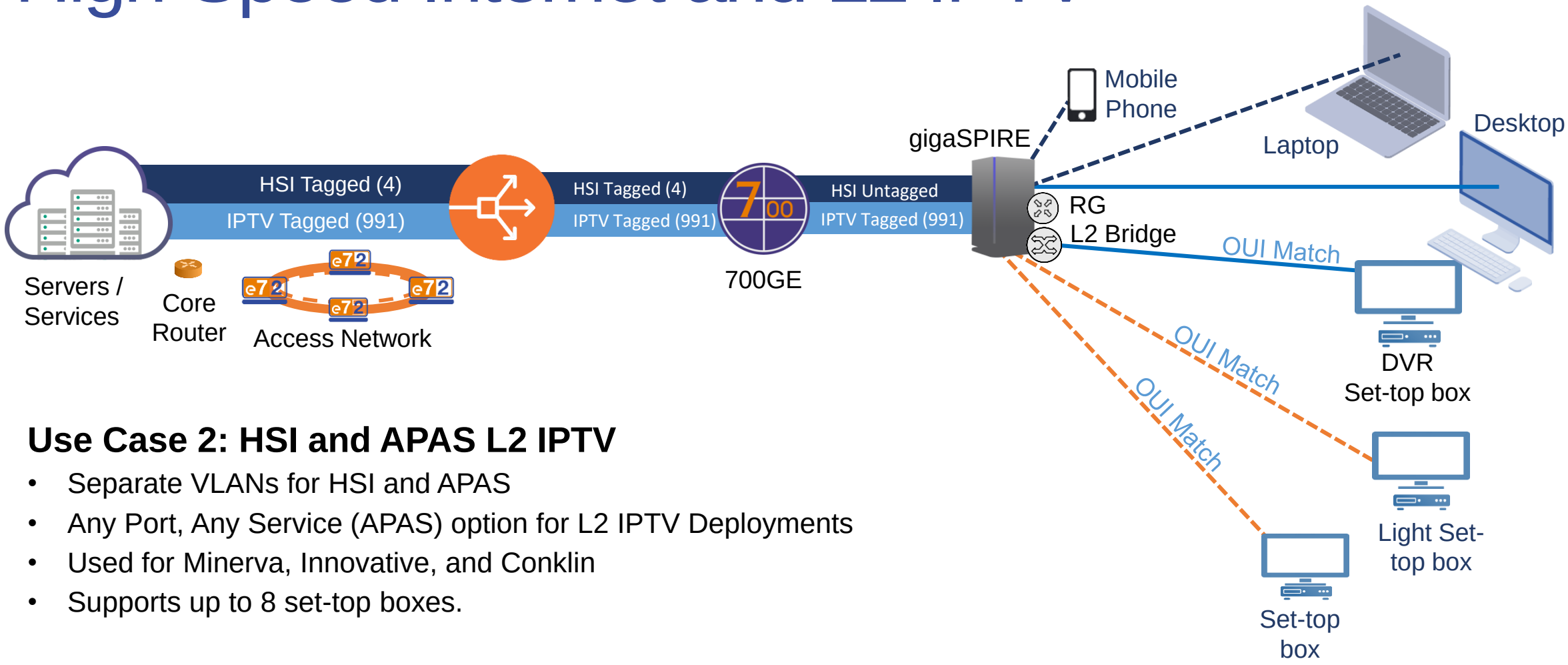


Use Case 1: Internet Only

- Routed Internet Only
- Single VLAN

Wireless Connection

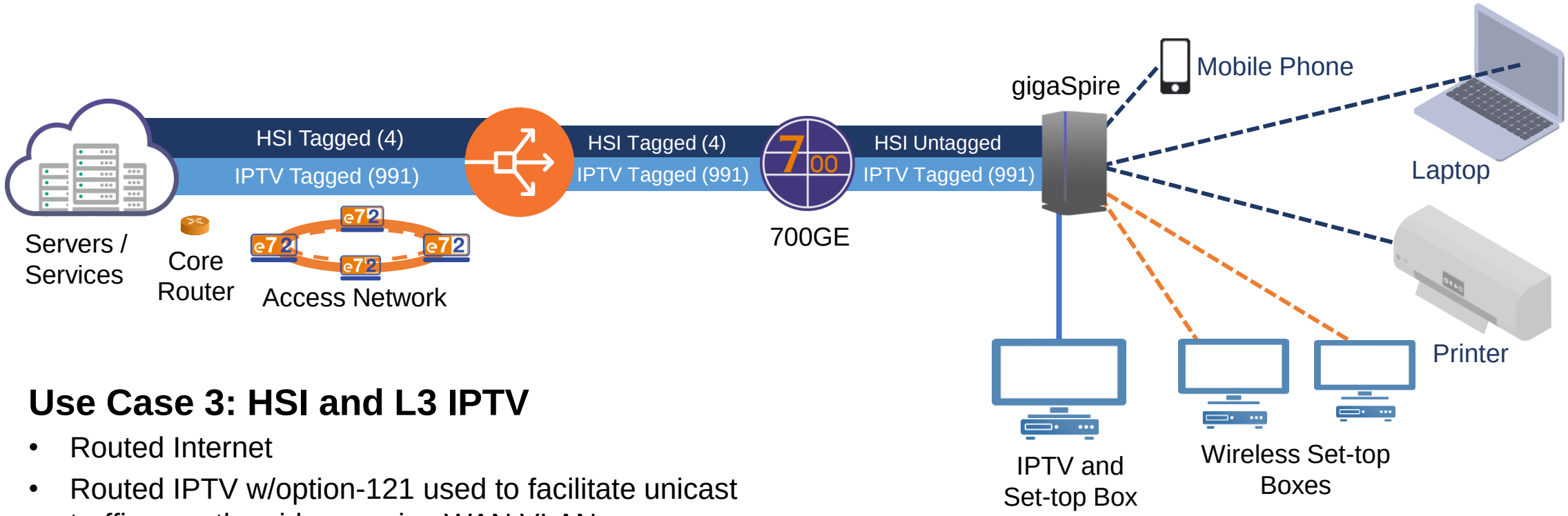
High-Speed Internet and L2 IPTV



Use Case 2: HSI and APAS L2 IPTV

- Separate VLANs for HSI and APAS
- Any Port, Any Service (APAS) option for L2 IPTV Deployments
- Used for Minerva, Innovative, and Conklin
- Supports up to 8 set-top boxes.

High-Speed Internet and L3 IPTV

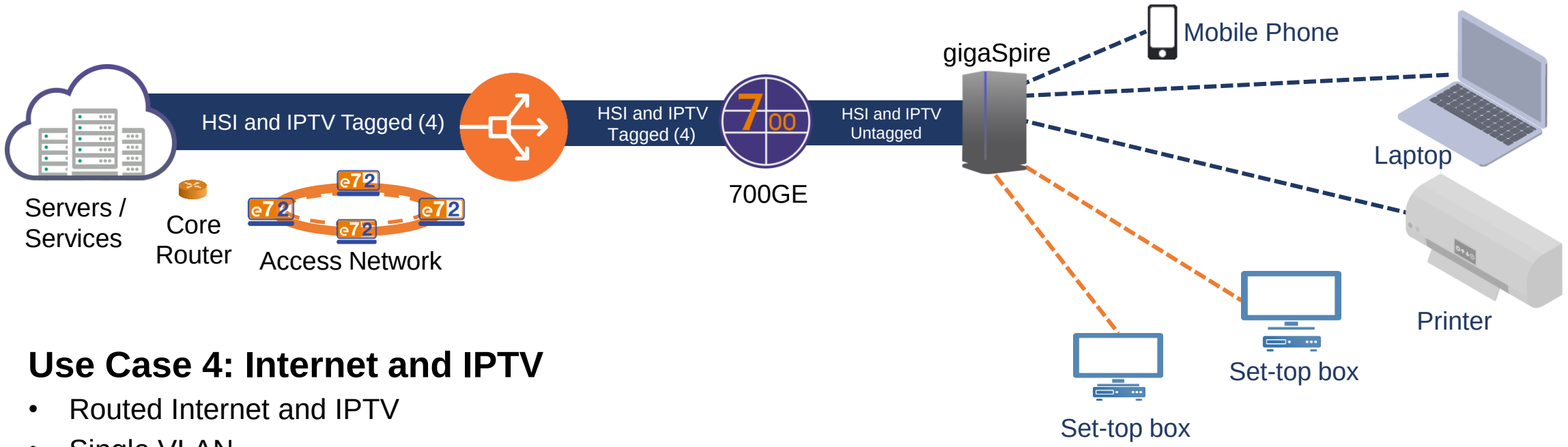


Use Case 3: HSI and L3 IPTV

- Routed Internet
- Routed IPTV w/option-121 used to facilitate unicast traffic over the video service WAN VLAN
- Used for Mediaroom and Minerva 5.7+ deployments
- Supports up to 8 set-top boxes.

Wired — 2.4 GHz Wireless Connection — IPTV SSID 5 GHz Wireless Connection

High-Speed Internet and IPTV 1 VLAN



Use Case 4: Internet and IPTV

- Routed Internet and IPTV
- Single VLAN
- Used for Internet/Mediaroom deployments

2.4 GHz Wireless Connection

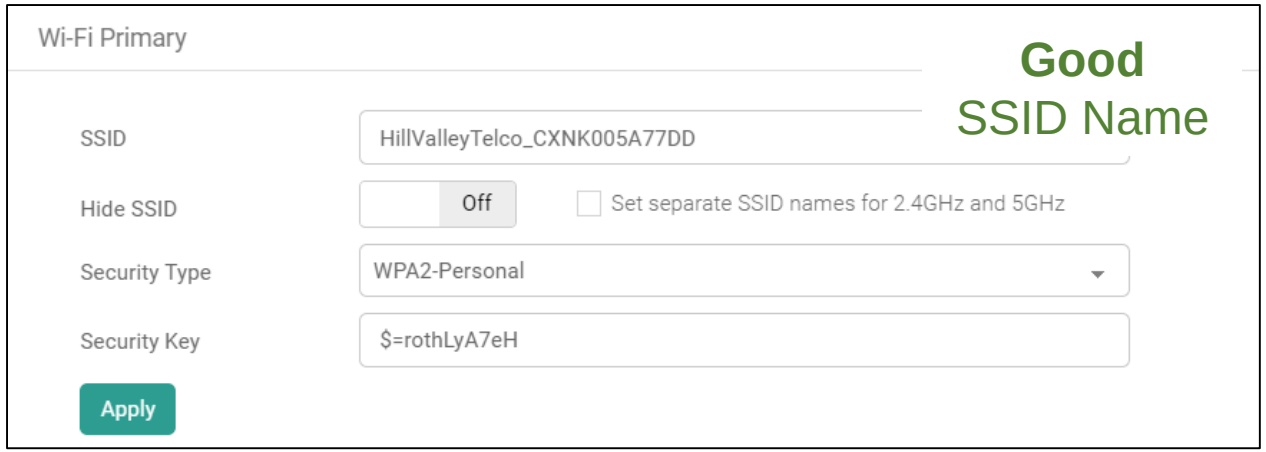
IPTV SSID 5 GHz Wireless Connection

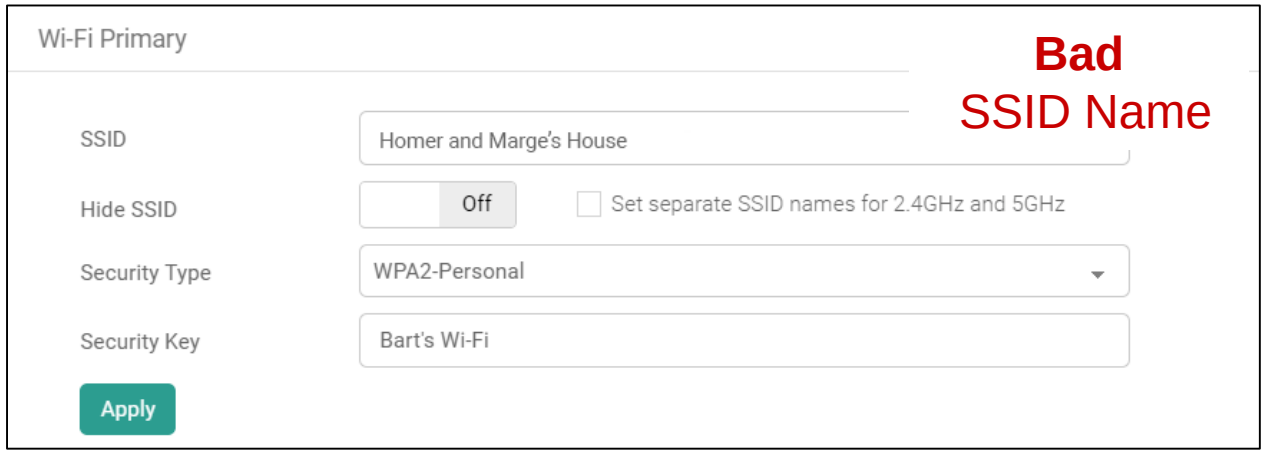
The Wireless Network

Best Practices

SSID Best Practices

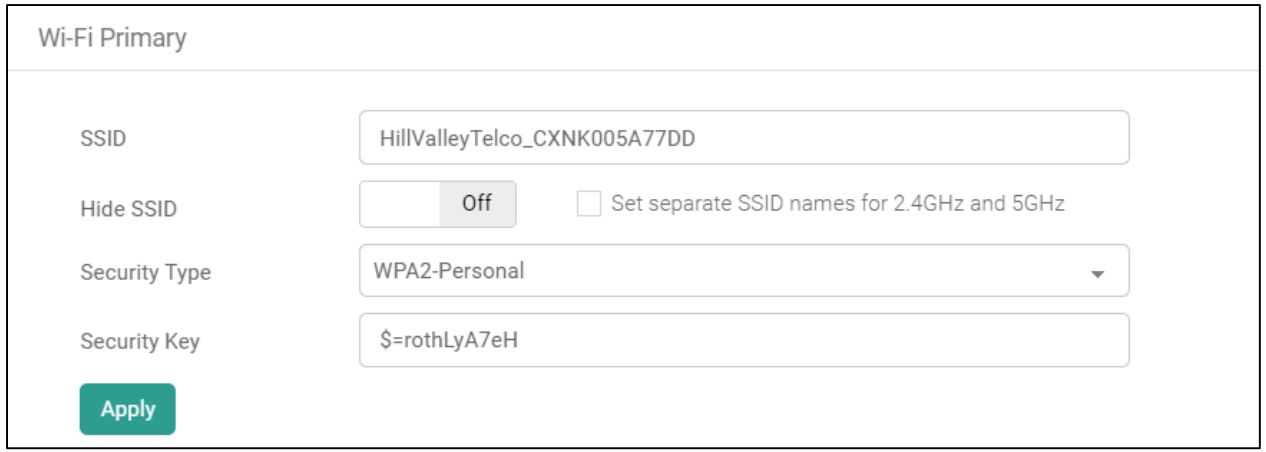
- Enable only SSIDs necessary to connect to the wireless network.
- Define a naming convention that works best in your organization.
- Hiding SSIDs does not secure the wireless network.
- Educate subscribers about naming SSIDs and how to avoid making SSIDs obvious to neighbors.
  - Example: Homer and Marge's House
  - Example: Bart's Wi-Fi
- Educate subscribers about not sharing their SSID (and passphrases) with neighbors.





Securing the Wireless Network

- WPA2 Personal provides the best security currently available.
- AES replaces TKIP as the best secure option. It uses up to 256-bit encryption to secure data.
- Create strong passphrases (passwords)
  - Use a mix of upper and lower case letters with numbers and special characters.
  - Spaces, periods, underscores, and asterisks are allowed in naming passphrases.
- MAC Authentification
  - Not enough to secure a network.

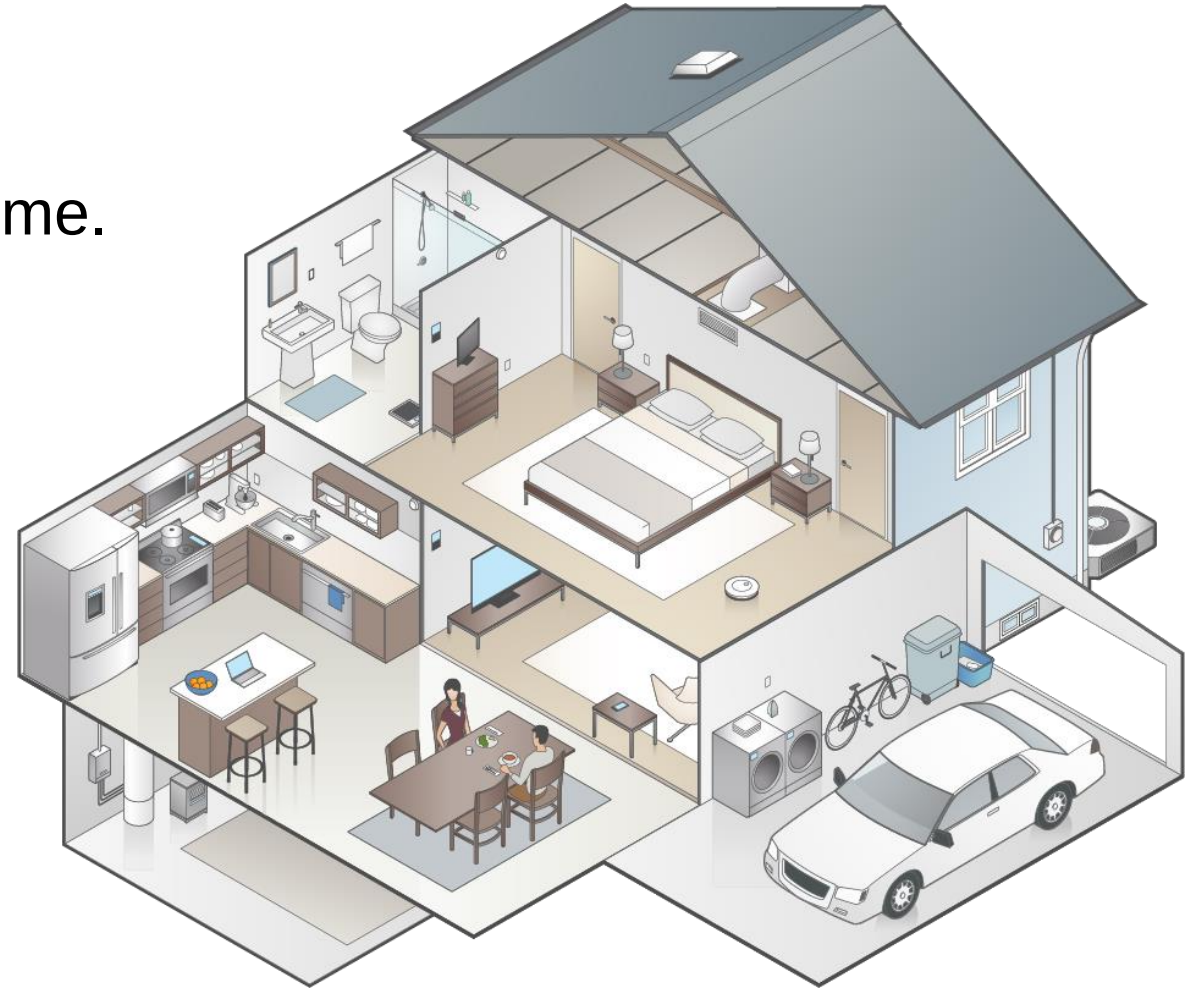


Maximizing Wireless Network Performance

- Perform Site Observations / Site Surveys
- Determine Access Point Location
- Configuring Wireless Settings on the Access Point
- Perform Wi-Fi Analysis

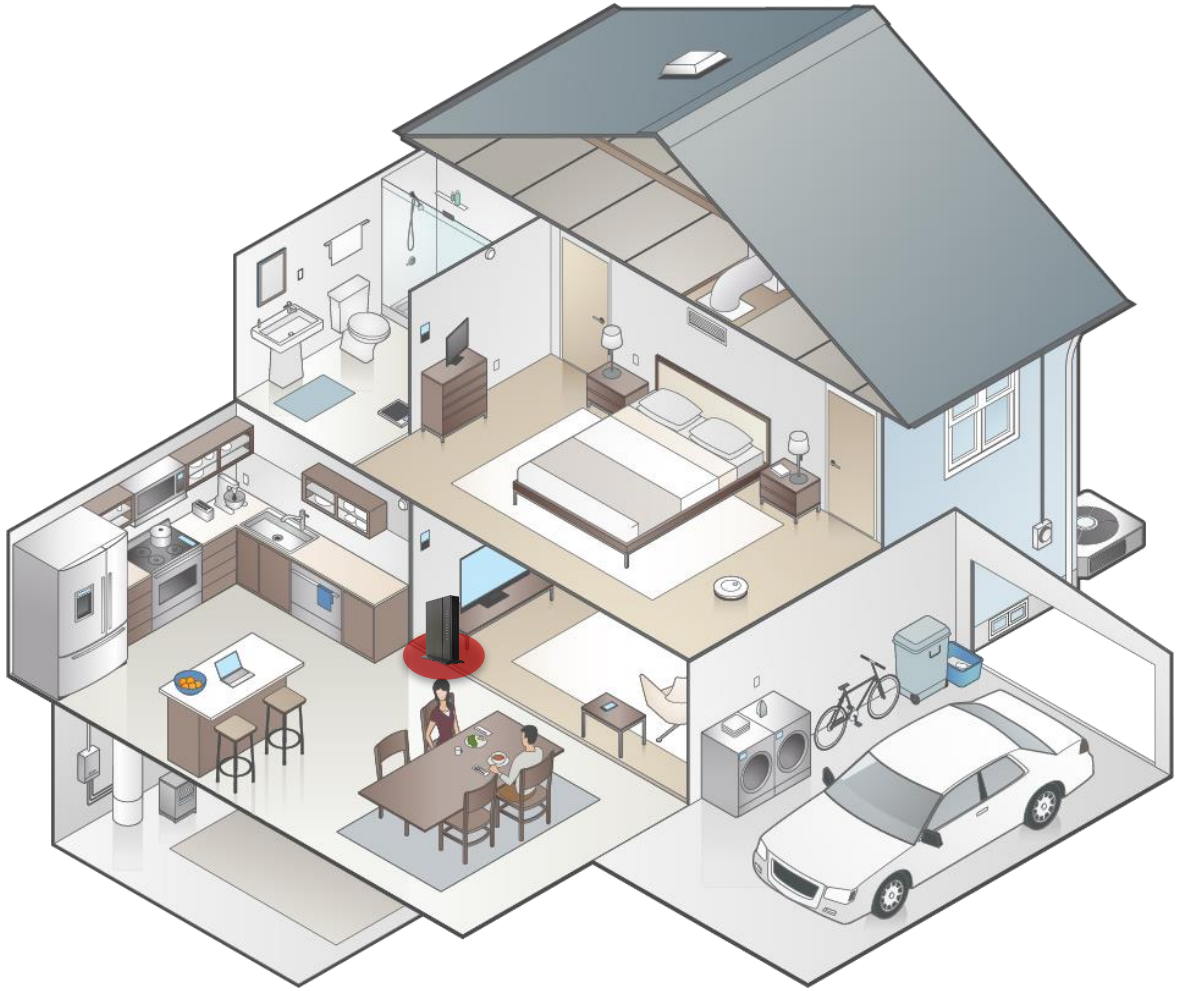
Site Observations

- Locate the fiber/coax cable in the home.
- Look for interferers in and around the home.
  - Cement and brick material
  - Double-pane and tinted glass
  - Mirrors
  - Wireless sound bars
  - Baby monitors



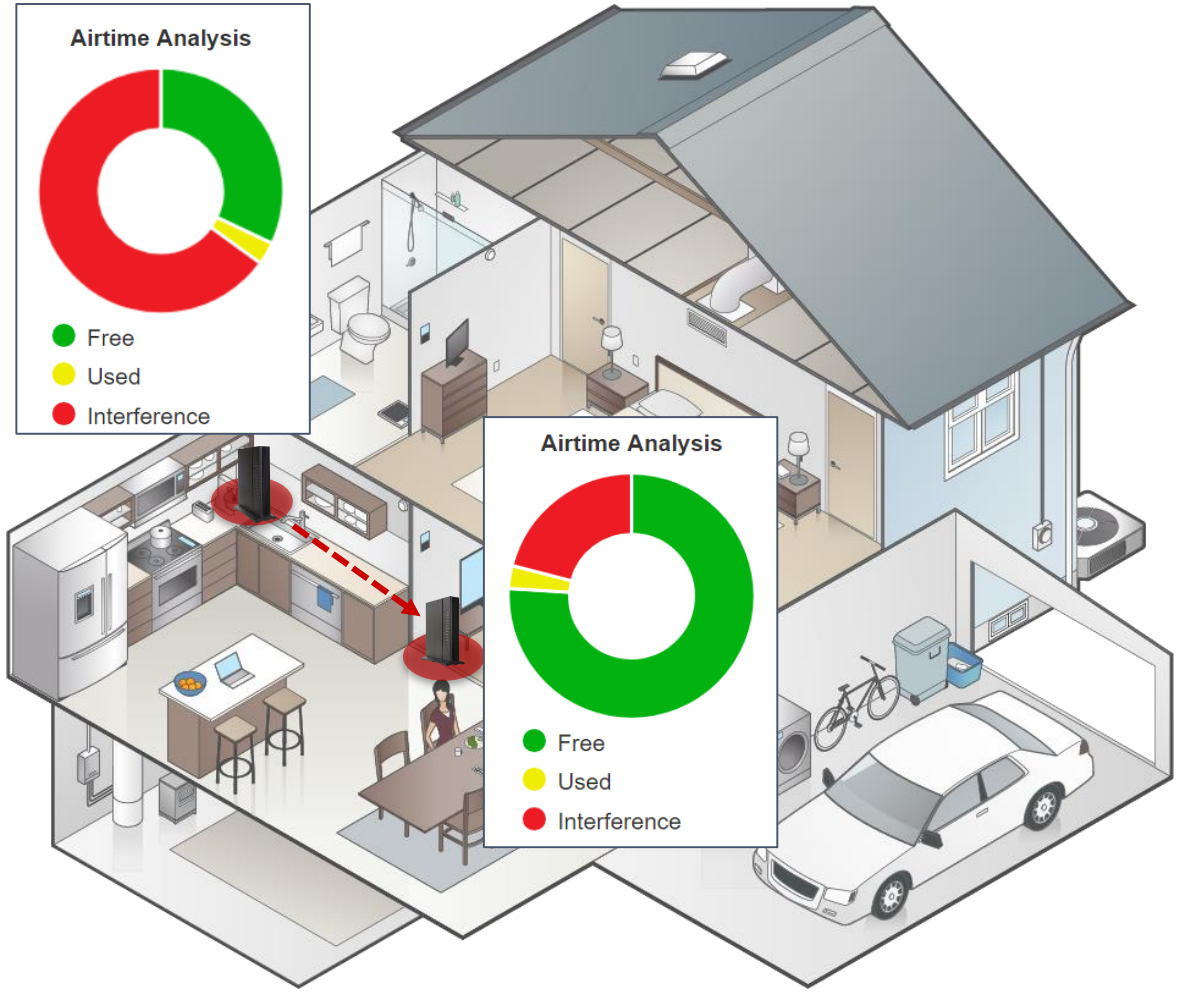
Access Point Location

- Place access points high and in the center of the home whenever possible.
- Avoid placing the main access points in the basement.
- View Wi-Fi Analyzer tools to check Wi-Fi usage.
  - Example: Wi-Fi Analyzer
  - Example: Wi-Fi Smart Check and current Air Time Analysis in Calix Support Cloud



Determine the Best Location

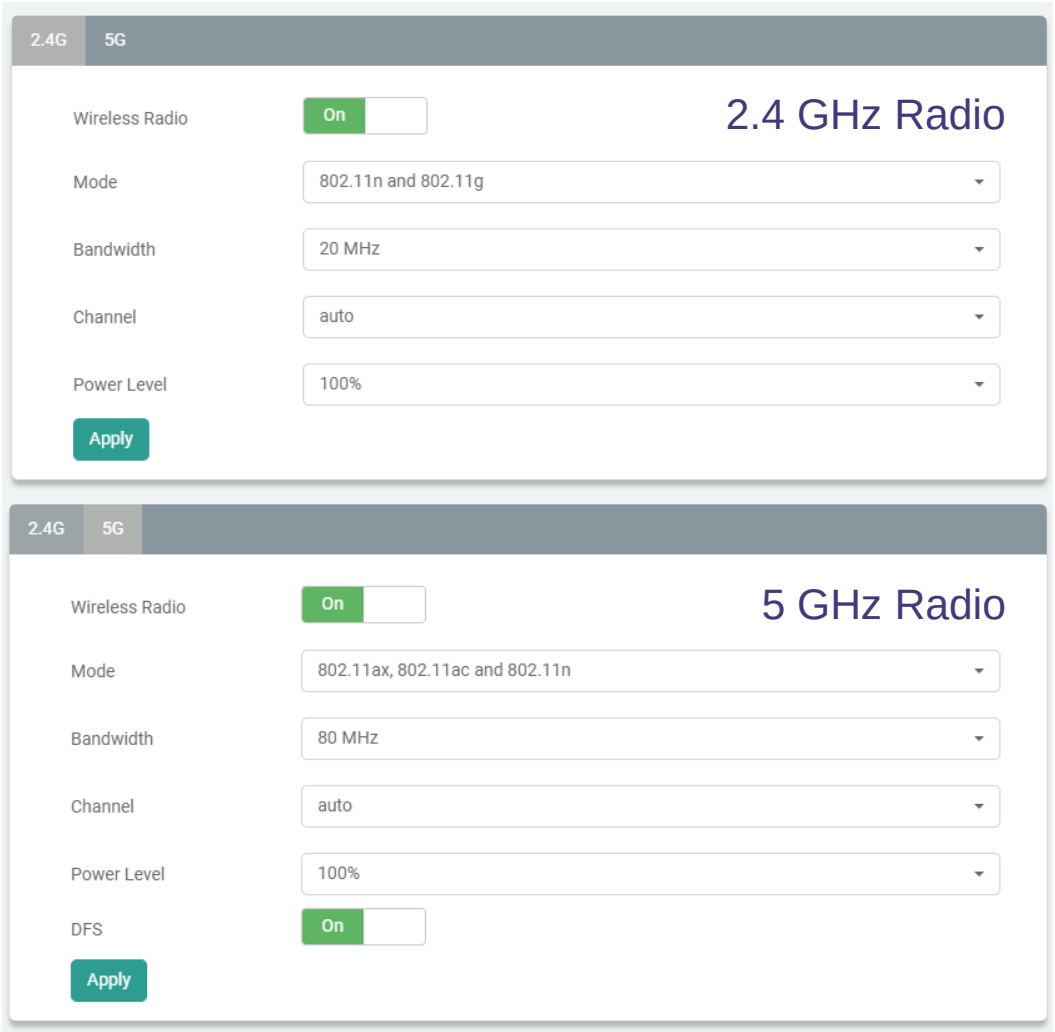
- Use Wi-Fi Analyzer to determine the best location.
- View real-time air time utilization as you move the device around.
- View air time utilization for both 2.4 and 5 GHz.



Wi-Fi Analyzer is located in the Support area of the EWI of GigaFamily Devices

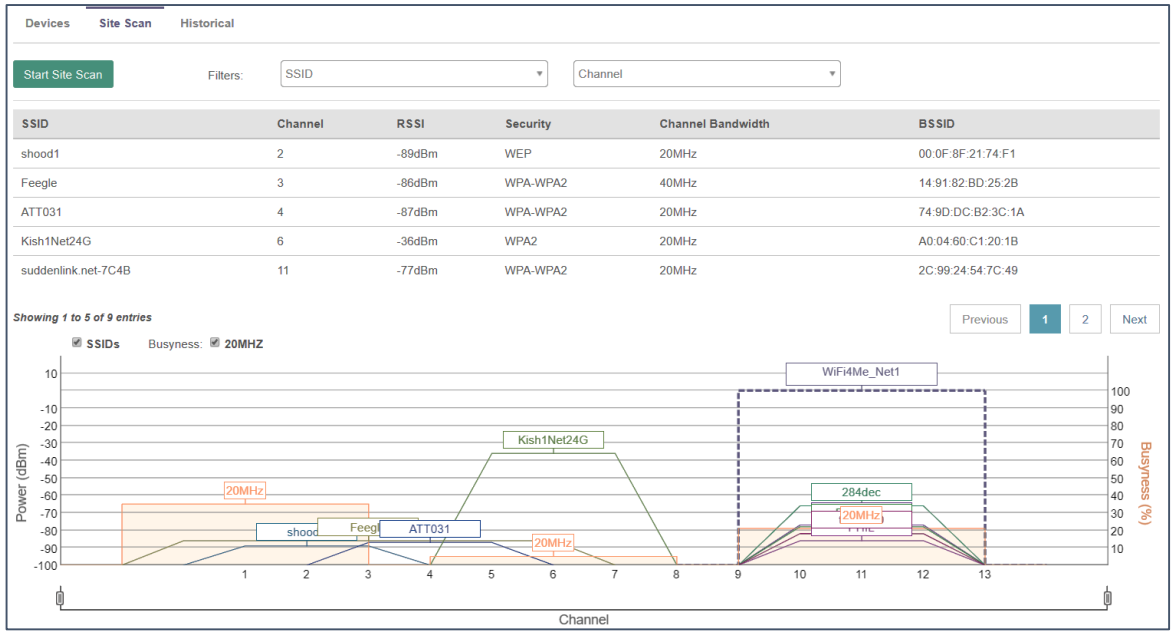
Configuring Wireless Settings on the Access Point

- Isolate legacy devices from hogging air time away from modern devices by removing 802.11b from the **Mode** to prevent old devices from connecting.
- In some rare cases, it's optimal to reduce the 5 GHz bandwidth since the wider the signal bandwidth, the shorter the distance covered.
- Allow devices to **auto-select** the best **channel** that is less crowded with the least interference.
- For the 5 GHz radio, when possible allow use of additional channels in the 5 GHz band (**DFS Channels**).

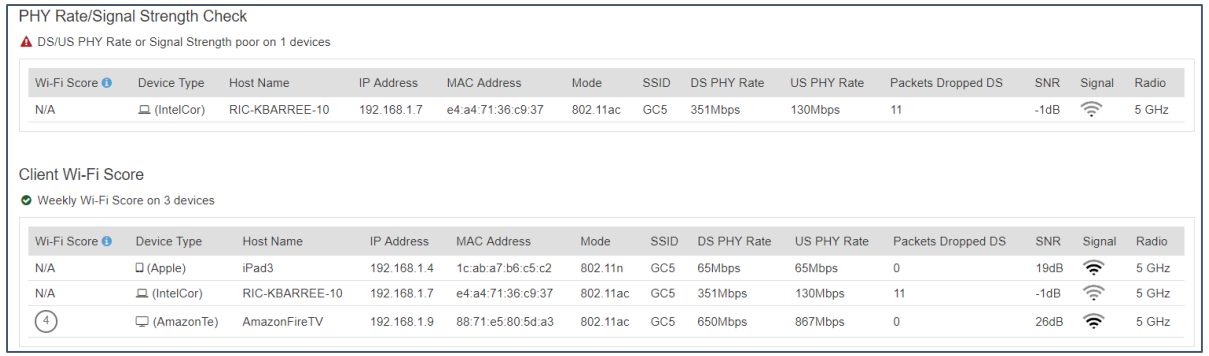


Ex. gigaSPIRE EWI

Wi-Fi Analysis – Today

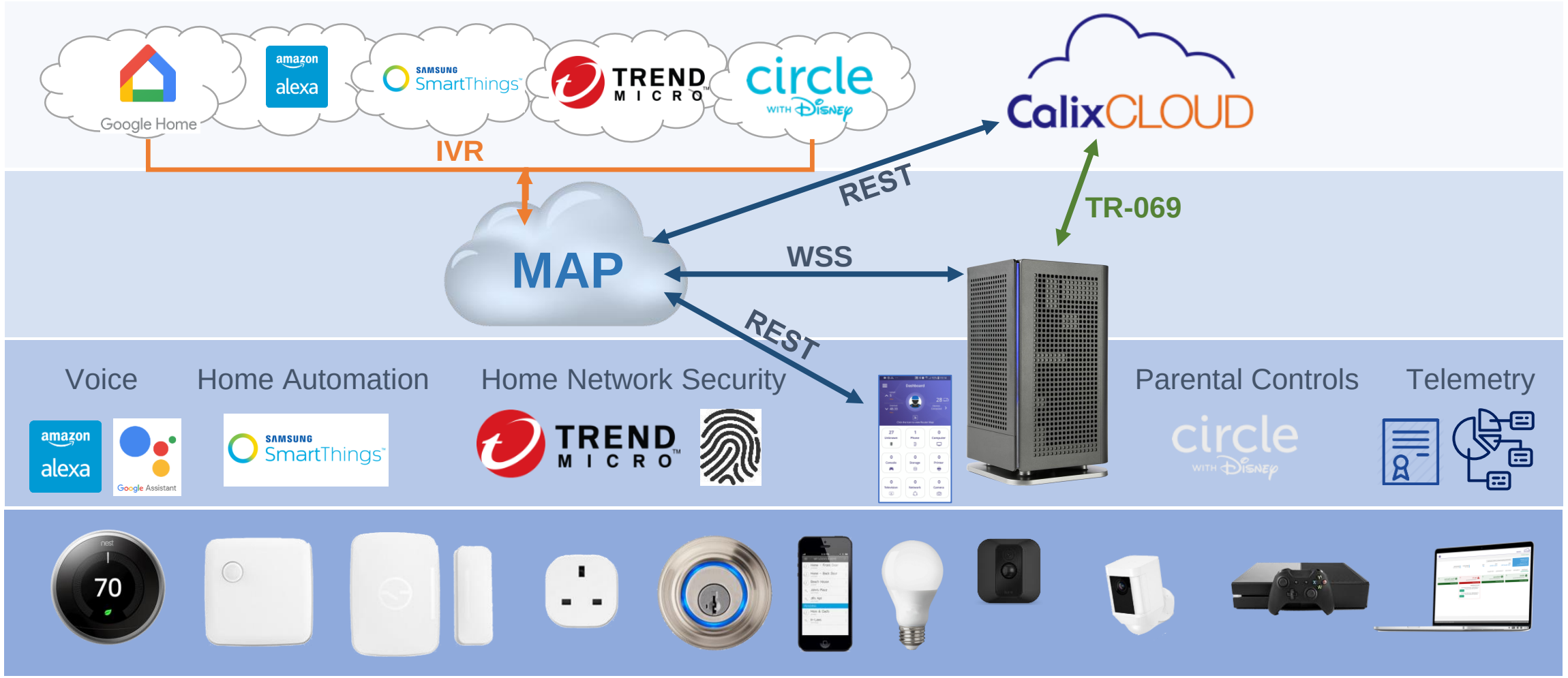


View neighboring devices using Calix Support Cloud.



View subscriber devices and Wi-Fi performance using Smart Check Client Devices in Calix Support Cloud.

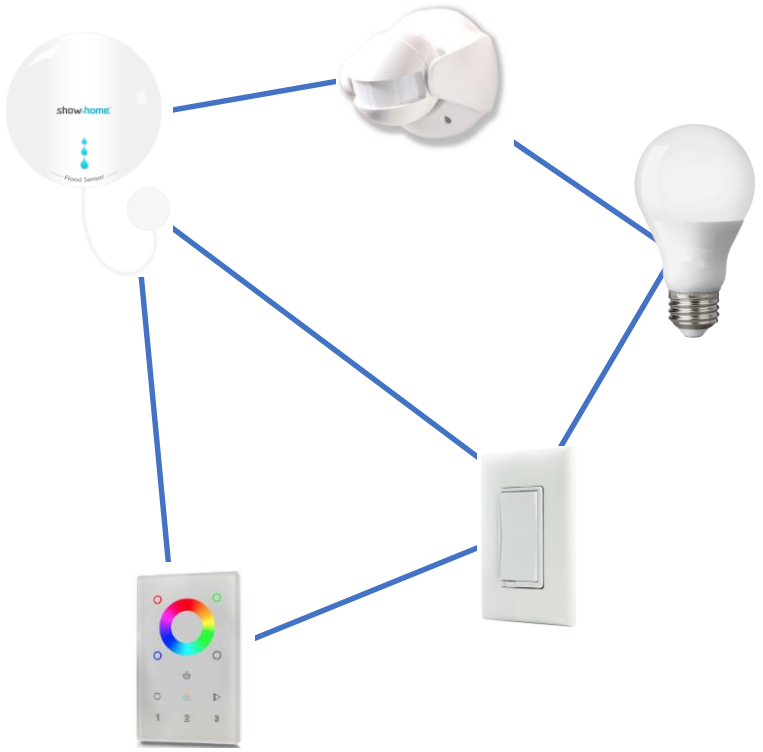
Wi-Fi Analysis – Tomorrow



MAP - Micro-services Aggregation Platform IVR – Interactive Voice Response

Get to Know Smart Home Technologies

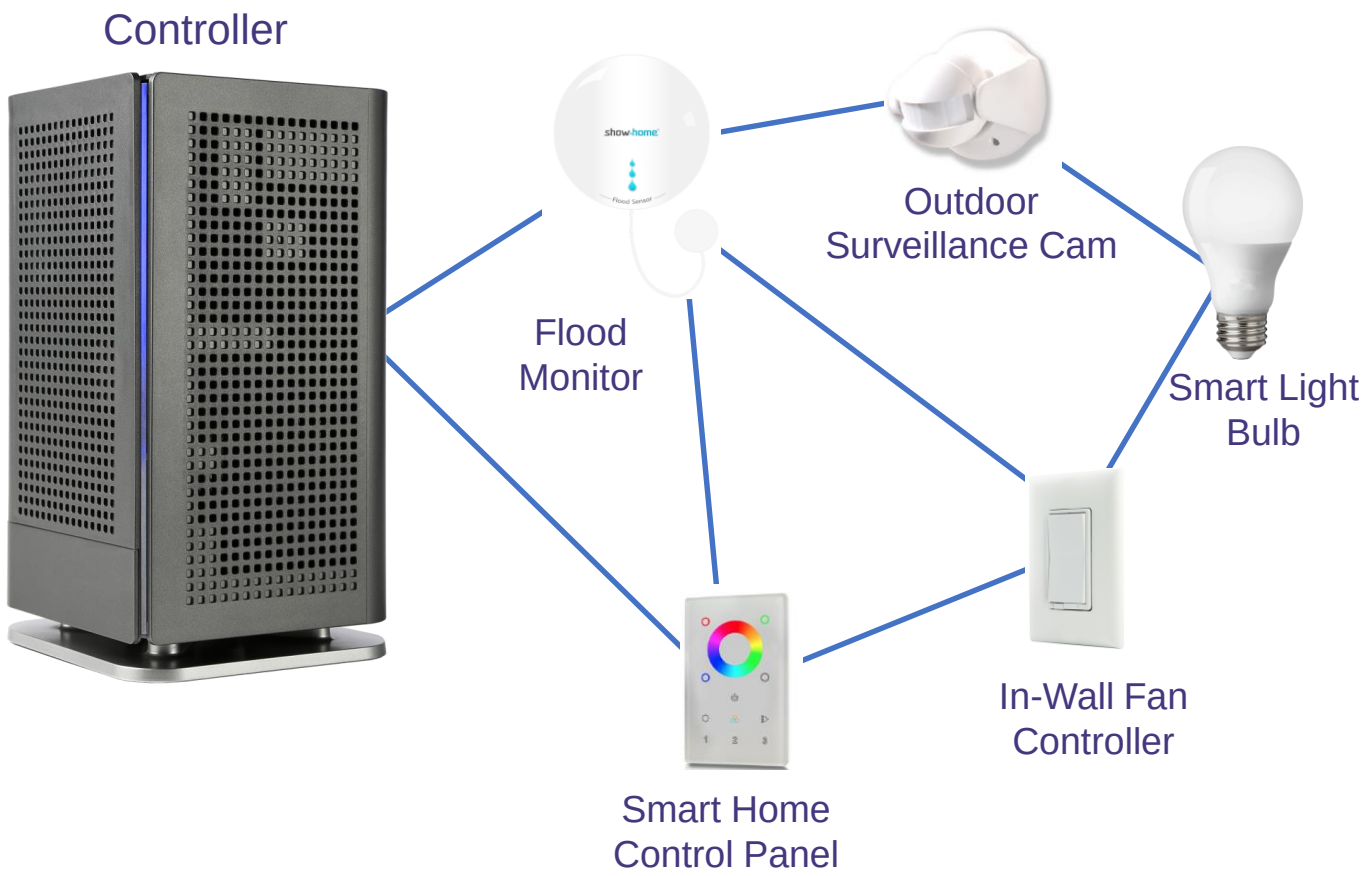
- **ZigBee and Z-Wave** are low-bandwidth communication protocols designed for controlling smart home devices.
- ZigBee and Z-wave uses radio frequencies.
  - ZigBee – 2.4 GHz
  - Z-Wave – 908.42 MHz
- Devices must be compatible with ZigBee or Z-Wave to leverage the smart home technology.
- The estimated range for Z-Wave/ZigBee enabled devices is up to 100 meters (328 ft).
  - Ideally – 100 feet for no obstructions and 50 feet with walls in between with no signal hopping.



Note: ZigBee and Z-Wave are not compatible with each other.

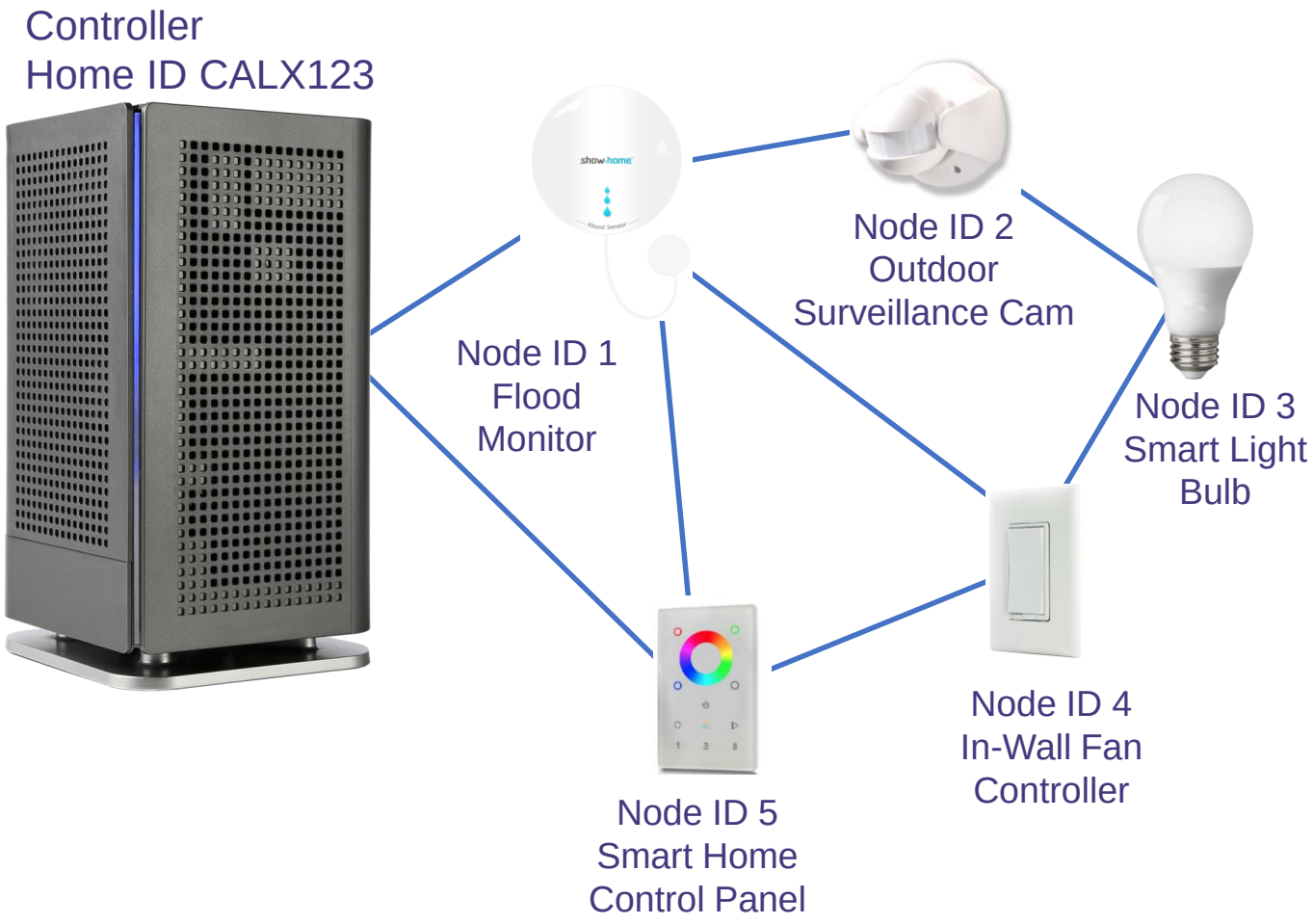
Smart Home Topology

- A Z-Wave network contains at least one controller.
- Devices connected to the controller are called nodes.
- The controller allow devices (nodes) to join or be removed from the network.
- All non-battery powered devices are used to create a wireless self-organizing network.
- Up to 232 devices, nodes can be added to the Z-Wave Network.
  - ZigBee has no concrete limit.



Calix Smart Home Topology

- Controllers contain unique IDs that are not labeled the same. The unique IDs are called Home IDs.
- Home IDs prevent you from being able to control your neighbor's devices.
- Nodes contain unique IDs.
  IDs cannot be labeled the same.
- Node IDs ensure that the signal goes to the device it is intended for.
- AES 128-bit encryption.



Recommended Installations

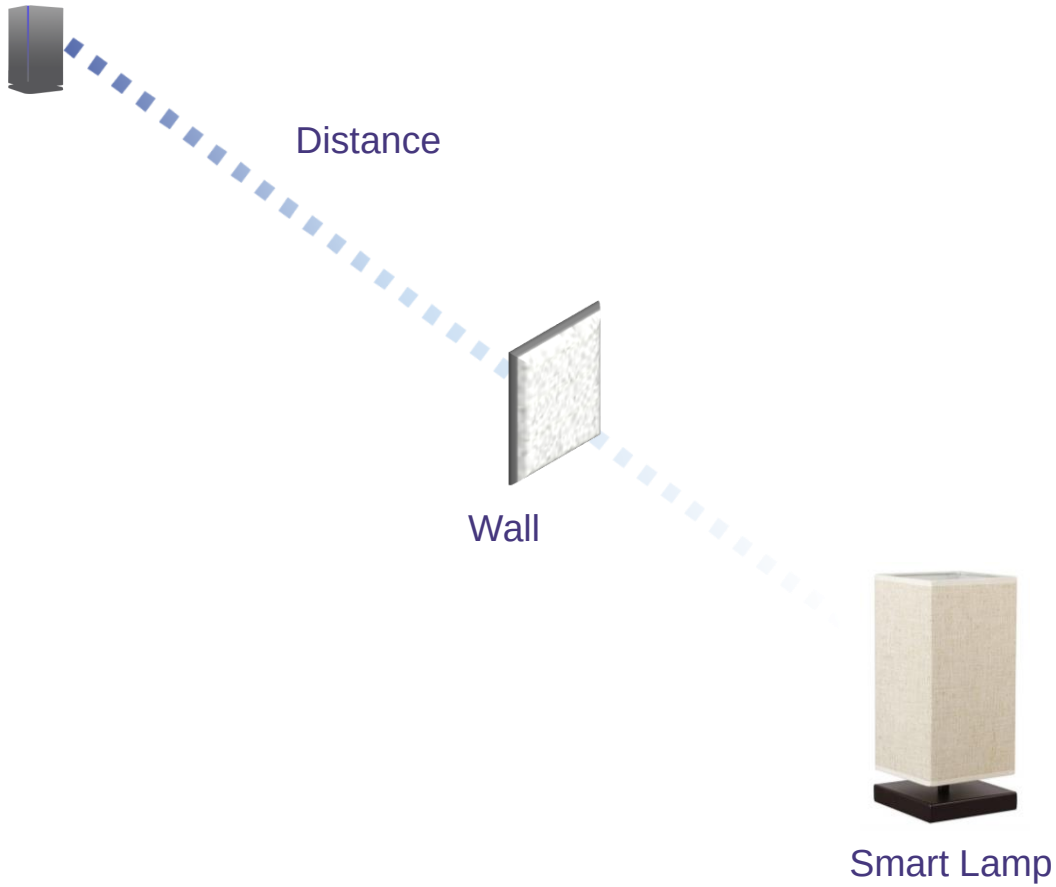
- Calix Smart Home is intended for single-family units.
- Calix Smart Home can be deployed in multi-dwelling units, but separate networks must be setup for each family.
  - If used in a high-rise, the building materials are often not RF-friendly.
- Calix Smart Home is not recommended for large commercial or industrial networks.

Single-Family Units

Multi-Dwelling Units

What can Impact Smart Home Performance?

- Path loss is the loss of signal. It is also known as attenuation.
- Causes of path loss:
  - Distance
  - Obstacles and the materials they are made of.
  - Performance of the radio frequency (RF) signal
- Key Smart Home scenarios installers should know.
  - Vacuum Fade
  - Shadow
  - Reflection



Building Materials and Path Loss

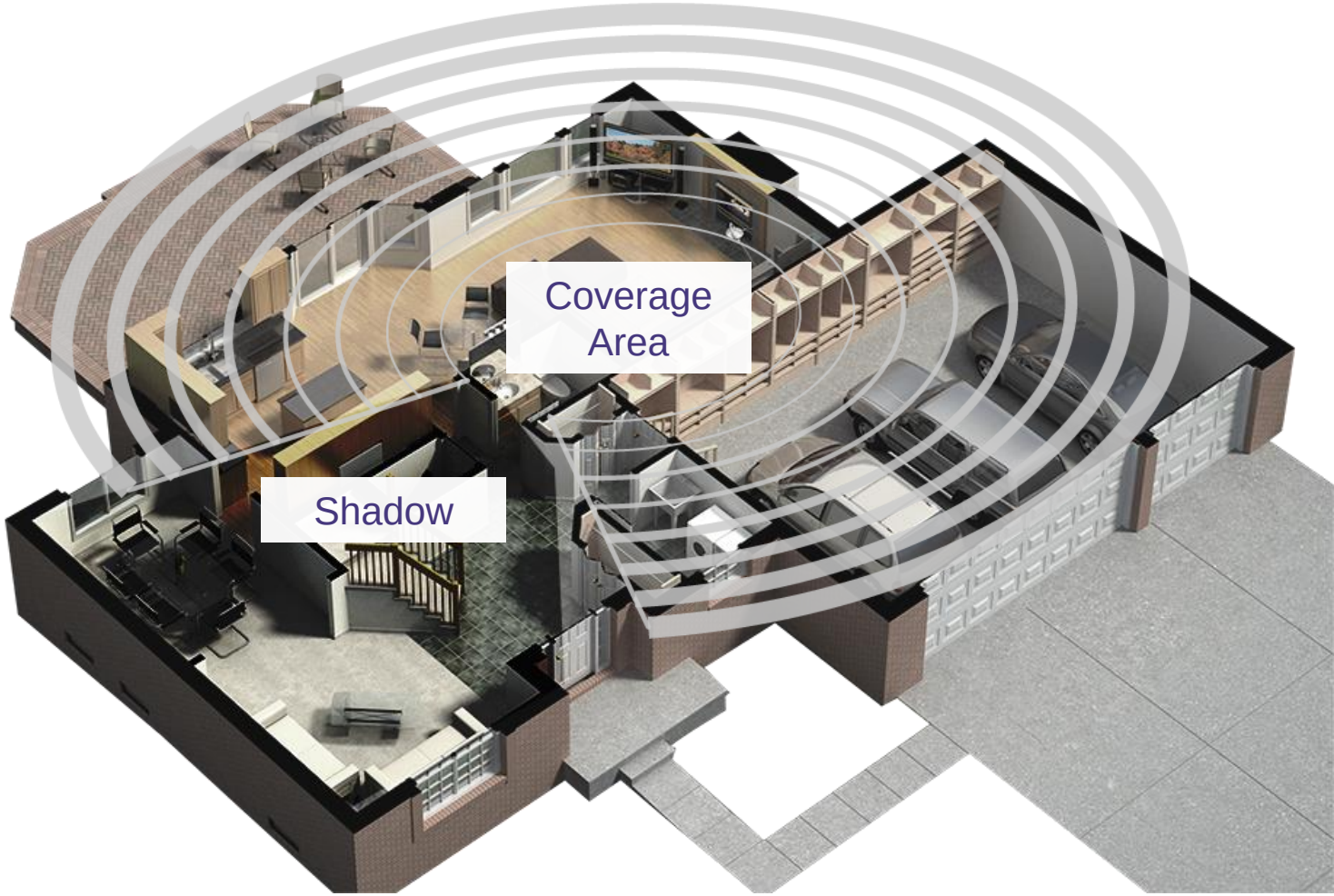
Material	Thickness	Worst Case Signal Attenuation
Glass	.25 inch	10%
Drywall	< 4 inch	30%
Wood	3 inch	30%
Stone	10.5 inch	70%
Concrete	4 inch	70%
Concrete	8 inch	90%
Reinforced Concrete	4.5 inch	95%
Concrete	12 inch	98%

Vacuum Fade

- Vacuum Fade occurs when a device fails or if a device was plugged into a switch outlet and someone turned off the switch.
- There are two stages used to address vacuum fade.
  - Anticipate
    - Detect problem areas beforehand.
    - For new home instructions, determine if an outlet can be added.
    - Can a Z-Wave/ZigBee outlet be added instead of a plug-in module?
    - Can you find a module with a pass-through plug?
  - Diagnose
    - Ask the subscriber about any failures and what changes they made before the failures.

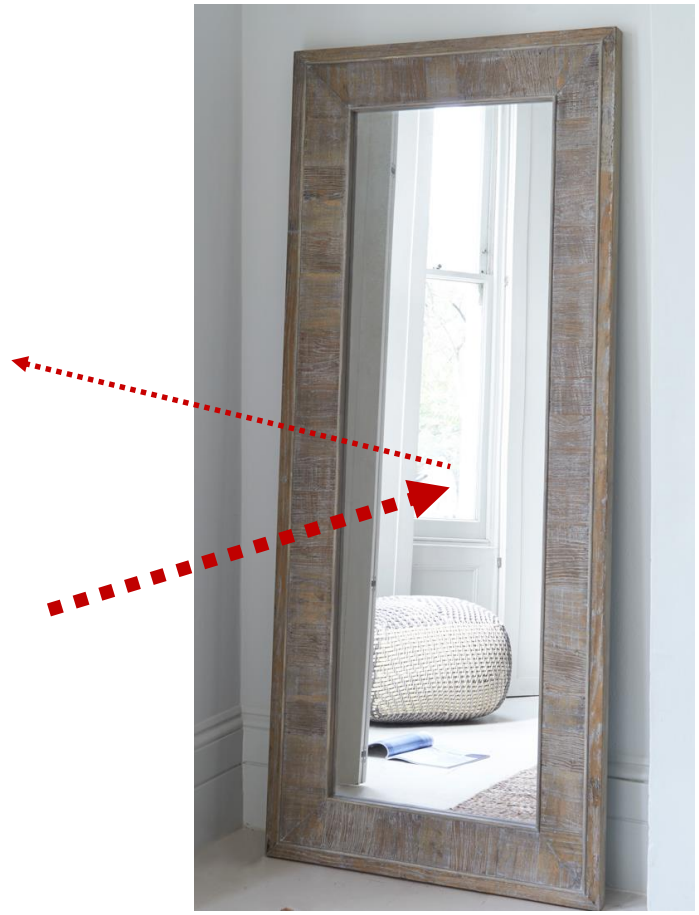
Shadows

- A shadow occurs when the attenuation of a signal going through building material create an RF dead spot.
- Installers should identify shadows.
- Installers can add repeaters to strengthen Z-Wave mesh networks to eliminate shadows.



Reflection

- Reflections occur when the wireless signal bounces off an object.
- Reflections are not avoidable and can cause interference due to time delays of the reflection, also known as multi-path or phase interference.
- The solution is to add always-on devices to strengthen the self-organizing mesh network.



Reflection

Calix Wireless Network Solution Overview

Calix GigaFamily

gigaCENTER™

800G

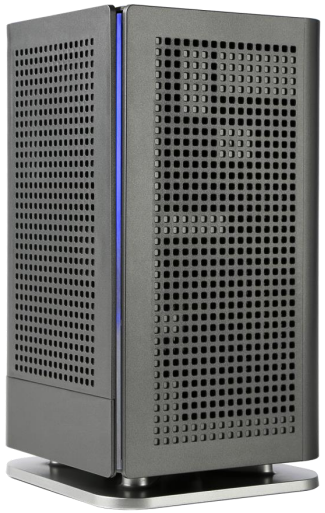
804MESH™

804M

gigaSPIRE MAX

GS2026E

gigaSPIRE BLAST

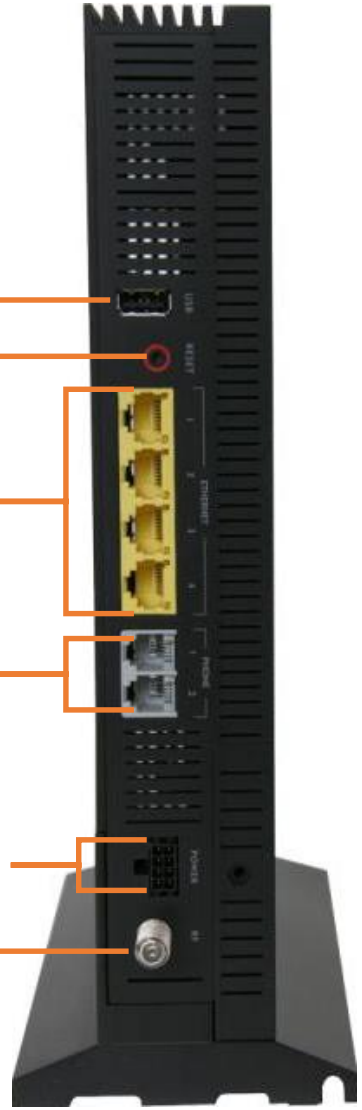


GS2020E

gigaMESH™

GM1020

800G GigaCenter



2.4 GHz and 5 GHz Wi-Fi

The image shown is an 854G GigaCenter.
The 844G does not contain an RF overlay.

804Mesh Satellite Specifications

Dual Band Wi-Fi Range Extender

- 2.4 GHz 802.11 b/g/n 2x2 MIMO, high-power
- 5 GHz 802.11 a/n/ac 4x4 MU-MIMO, implicit/explicit dynamic beamforming
- IEEE 802.11v BSS Transition Management
- Wired: 10/100/1000 BASE-TX Ethernet Port, RJ-45 connector

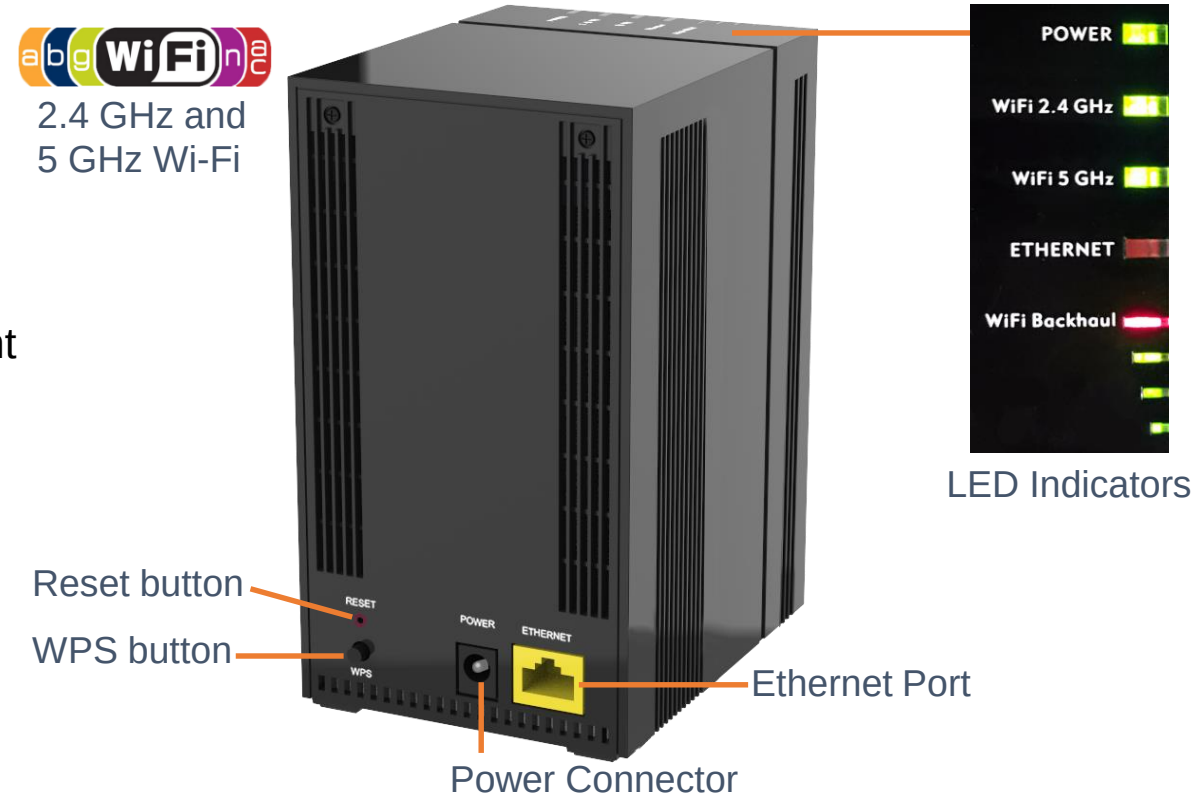
Interoperability

- 800G, 844GE, and 844E

TR-069 remote management

- TR-098 Internet Gateway Device Data Model

Wi-Fi Alliance Certified



gigaSPIRE

Top View


Action Button


Volume Up


Volume Down


Mute

gigaSPIRE MAX

Wi-Fi 802.11ax, alexa, ZigBee, Z-WAVE, Bluetooth

gigaSPIRE BLAST

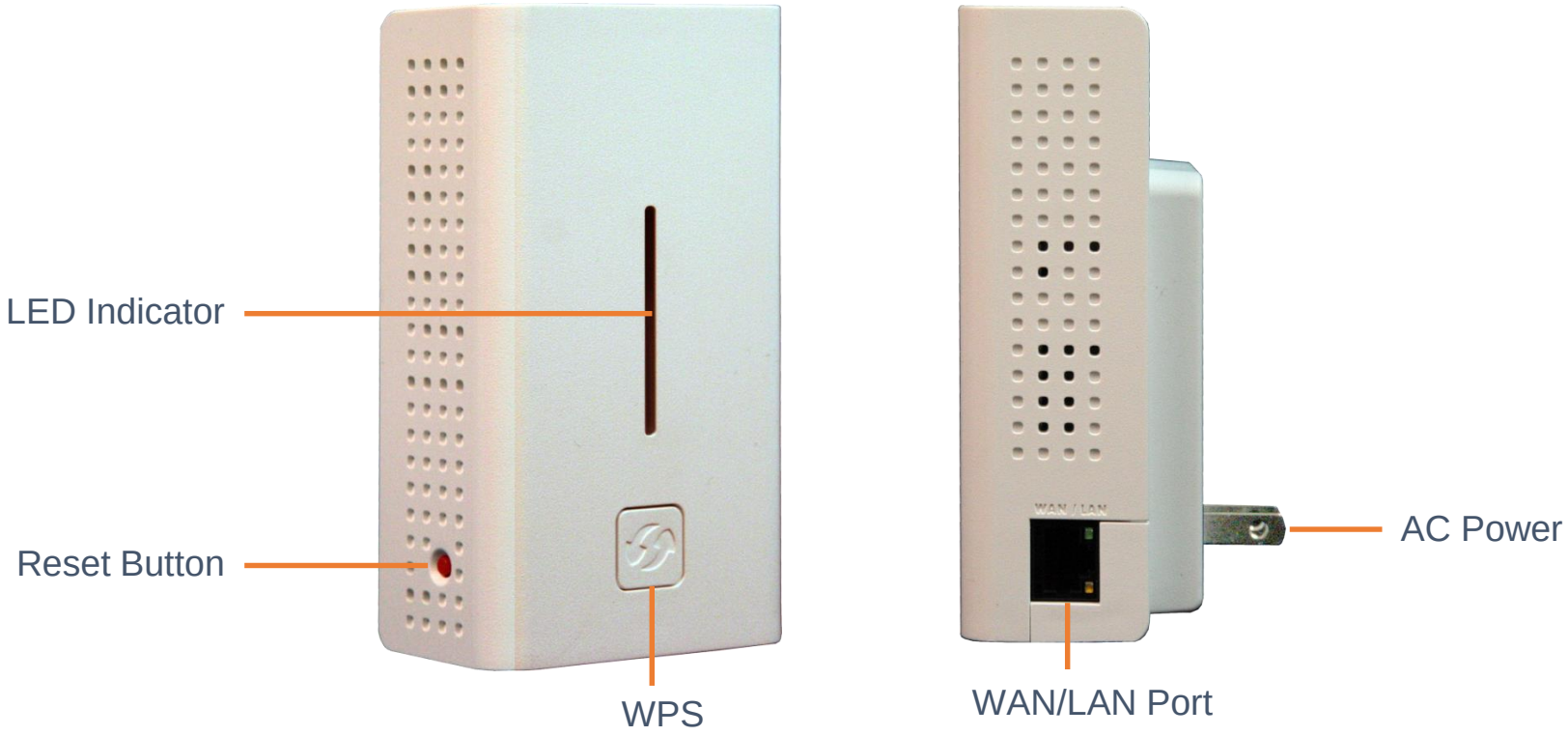
Wi-Fi 802.11ax

The gigaSPIREs Blast and Max share the same physical features except the Blast does not have a sound jack and there are no controls at the top.

gigaSPIRE Comparison

	GS2026E	GS2020E
WAN	10/100/1000 Ethernet or Wi-Fi	10/100/1000 Ethernet or Wi-Fi
LAN	10/100/1000 Ethernet	10/100/1000 Ethernet
Wi-Fi	5 GHz – 802.11ax/ac/n - 8x8 MIMO 2.4 GHz – 802.11ax/g/n - 4x4 MIMO	5 GHz – 802.11ax/ac/n - 8x8 MIMO 2.4 GHz – 802.11ax/g/n - 4x4 MIMO
IVR (Interactive Voice Recognition)	Yes	N/A
IoT	ZigBee / Z-Wave	N/A
Bluetooth	BT / BLE	N/A
POTS	N/A	N/A
Dimensions	5” x 5” x 9”	5” x 5” x 9”

gigaMESH



gigaMESH Specifications

Dual-band Wi-Fi Range Extender

- 2.4GHz 802.11b/g/n
  - 2x2 MIMO
- 5GHz 802.11a/n/ac
  - 2x2 Downlink (DL) MU-MIMO
  - Implicit/explicit high-power, dynamic beamforming

Wired

- 10/100/1000 /Base-TX Ethernet Port
- RJ-45 connector

Wi-Fi multimedia (WMM)

Power: 2-pin wall socket plug-in

Wi-Fi Alliance Certified

GM1020

Questions?