Wi-Fi Network Access and Capacity Design

Shivneet Nair
Regional Technical Manager

Cambium Networks™

AGENDA

1. Welcome and Objectives
2. ONE Network Overview: Simplifying Wi-Fi Delivery
3. Coverage vs. Capacity: Key Design Concepts
4. Choosing the Right Cambium Wi-Fi APs
5. Workshop Activity – Wi-Fi Design Scenario
6. Design Pitfalls & Best Practices
7. Demo Session using Heatmap Tools

2011

Cambium Networks™

MOTOROLA SOLUTIONS

CANOPY™

Motorola Wireless Internet Platform

2011

Cambium Networks™

- Chicago HQ
- 700 Employees
- Global Coverage

2019 Acquired Xirrus

Cambium Networks™

XIRRUS
WI-FI NETWORKS

Cambium ANZ

Roy
Melbourne

Eddie
Melbourne

Shiv
Brisbane

James
Brisbane

David
Sydney

Carl
Sydney

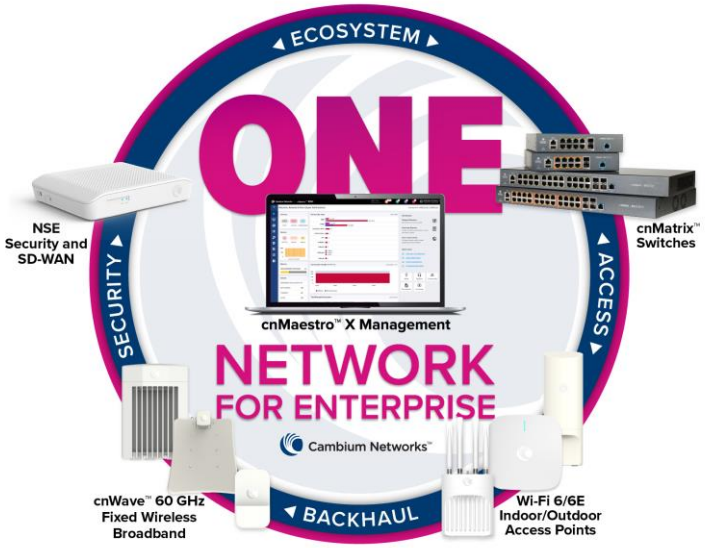
Cambium ONE Network - Resilient Networks with an Intelligent Edge

Cambium Networks™

Industry leading **Total Cost of Ownership**

Zero Touch Simplicity with
Policy Based Automation

Automated Security with
Auto Segmentation, Device
Profiling & Policy Enforcement

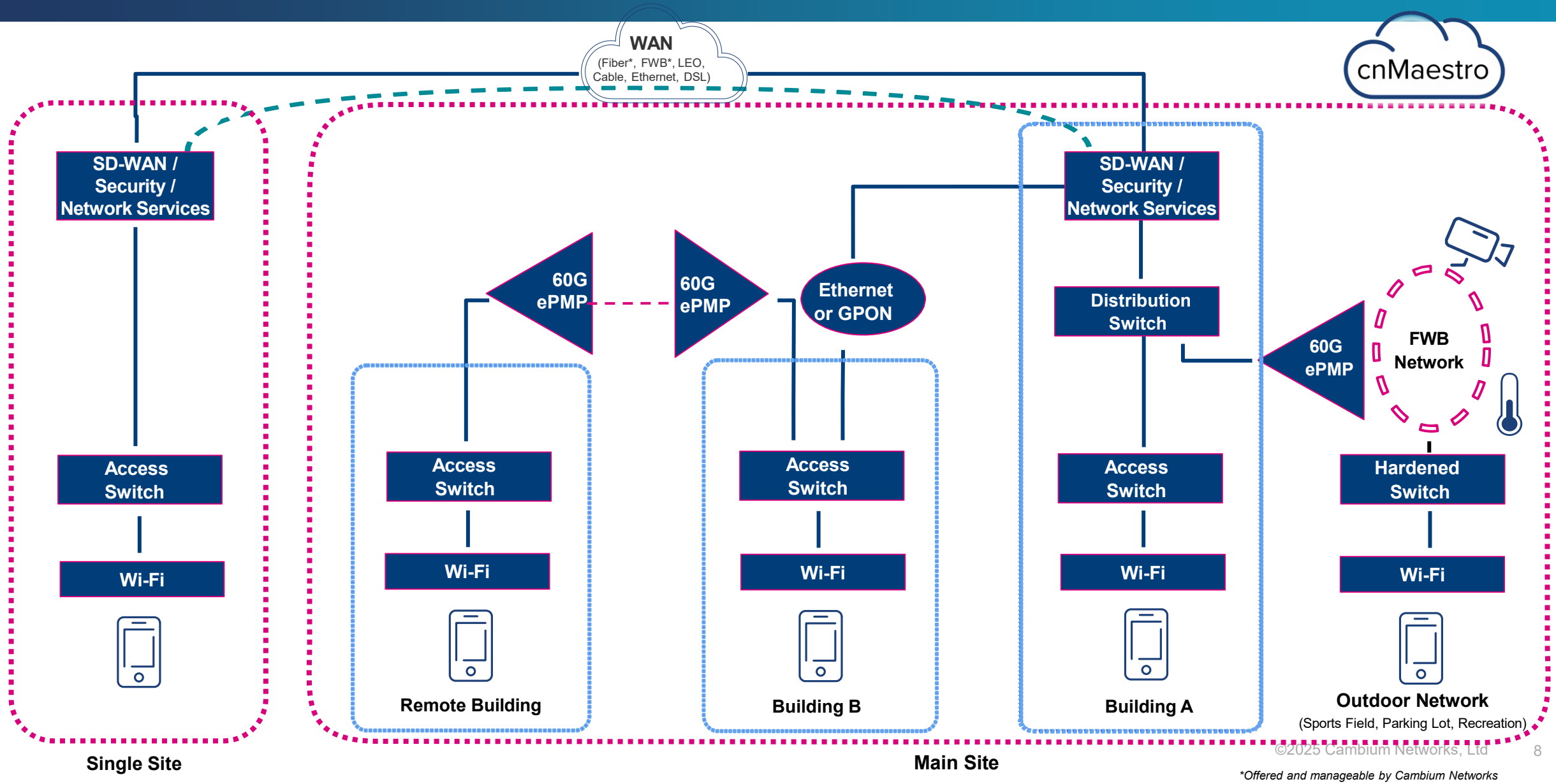


Security & SD-WAN

GPON & XGS-PON

Backhaul and Outdoor Wireless

Cambium's ONE Network for the Enterprise



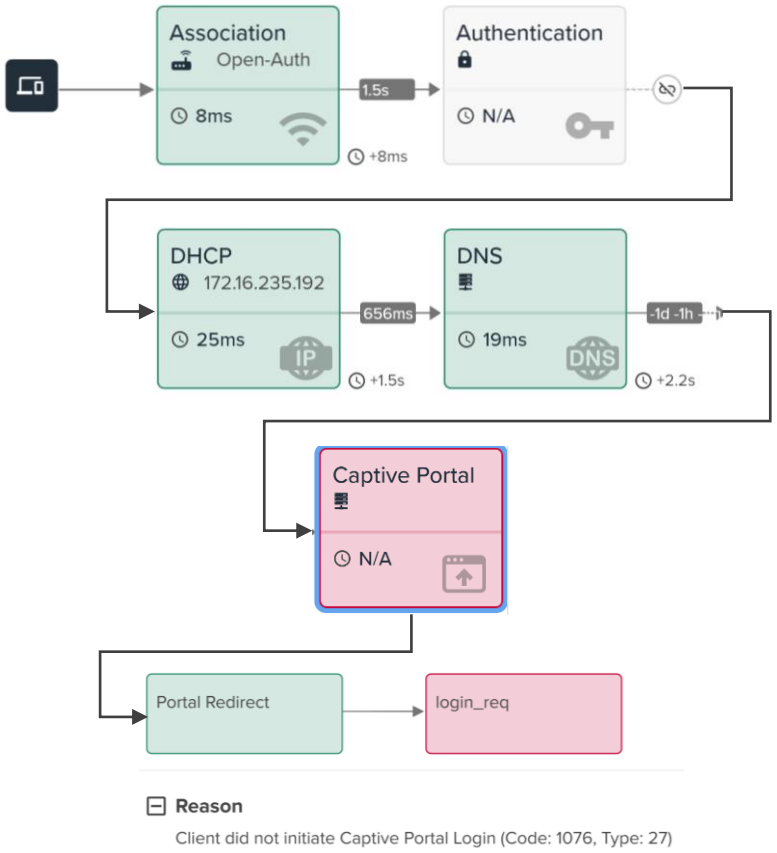
*Offered and manageable by Cambium Networks

AI Ops with cnMaestro X, Wi-Fi 6, 6E, 7

Cambium Networks™

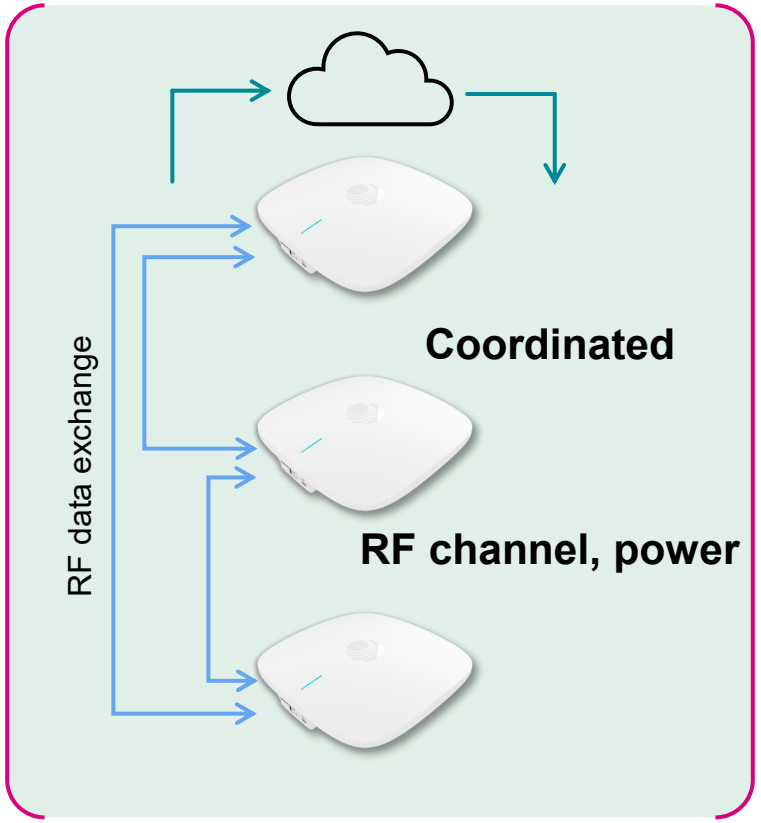
Higher Network Availability Operational Efficiency

cnMaestro X Assurance



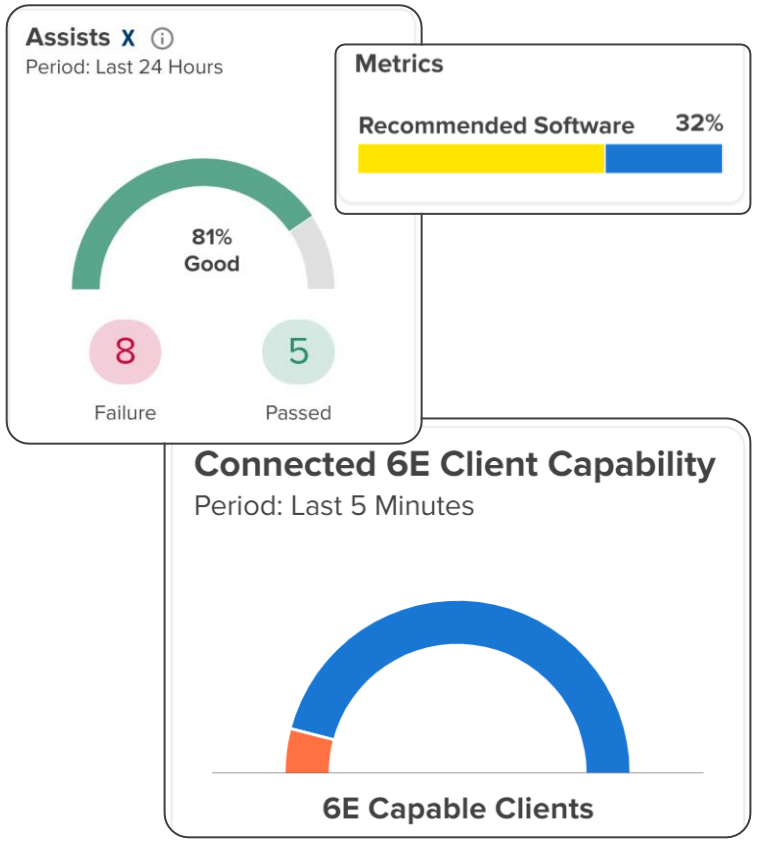
Better Performance

Runtime Self Optimizing RF



Data Driven Decisions

Device Capability Monitor Assists



cnMaestro X Assurance (AI Analytics)

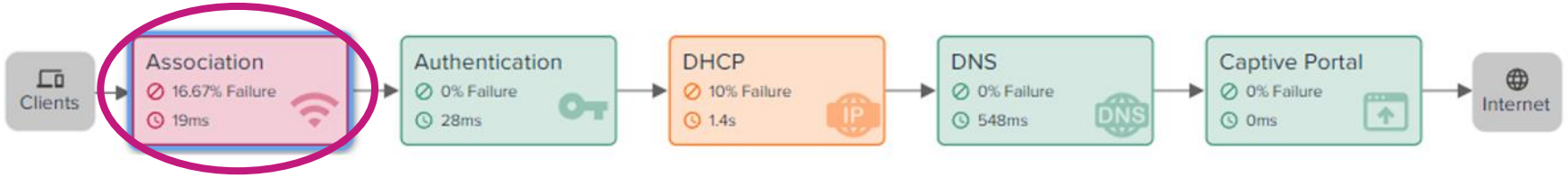
Cambium Networks™

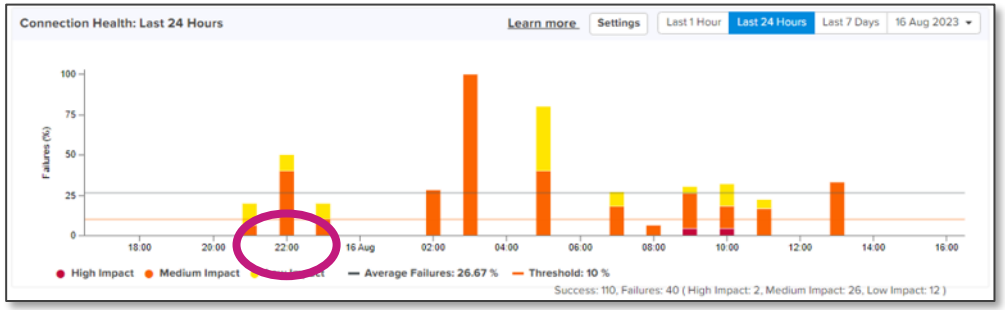
What is the issue?

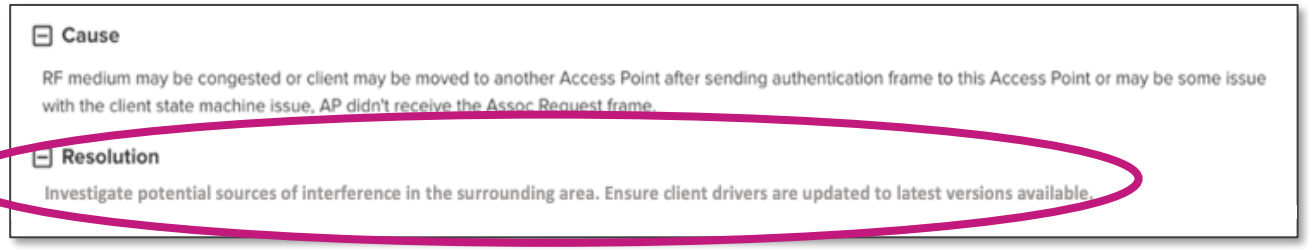
When did it occur?

Why did it happen?

How can it be fixed?







Cambium ONE Network - Resilient Networks with an Intelligent Edge

Wi-Fi 6/6E/7 Indoor Portfolio

Cambium Networks™









	XV2-22H	XV2-21X	XV2-2X	X7-35X	XE3-4	XV3-8	X7-53X	X7-55X	XE5-8
Technology	Wi-Fi 6	Wi-Fi 6	Wi-Fi 6	Wi-Fi 7	Wi-Fi 6E	Wi-Fi 6	Wi-Fi 7	Wi-Fi 7	Wi-Fi 6E
Total Wi-Fi User Radios	2	2	2	3	3	3	2	3	5
Max 5GHz Radios	1	1	1	1	2	2	1	2	4
Max 6GHz Radios	0	0	0	1	1	0	0	1	2
Software-Defined Radio(s)					✓	✓		✓	✓
Dedicated Sensor Radio						✓			
Transmit Streams	2+2 (2x2 / 2x2)	2+2 (2x2 / 2x2)	2+2 (2x2 / 2x2)	2+2+2 (2x2 / 2x2 / 2x2)	2+2+4 | SDR (2x2 / 2x2 / 4x4)	4+8 | SDR (4x4 / 8x8)	2+4 (2x2 / 4x4)	2+4+4 | SDR (2x2 / 4x4 / 4x4)	4+8+4+4 | SDR (4x4 / 8x8 / 4x4 / 4x4)
Total RF PHY Rate	2.97 Gbps	2.97 Gbps	1.77 Gbps	9.2 Gbps	6.6 Gbps	6 Gbps	6.3 Gbps	17.9 Gbps	25.6 Gbps
Max Channel Width	160 MHz	160 MHz	80 MHz	320 MHz	160 MHz	80 MHz	160 MHz	320 MHz	160 MHz
Theoretical Max Active Devices	64	64	500	750	1500	1500	750	1200	2500
Uplinks / Downlinks	1 - 1 GigE / 2 - 1 GigE	1 - 1 GigE	1 - 2.5 GigE	1 - 2.5GigE	1 - 2.5GigE, 1 - 1GigE	1 - 5GigE, 1 - 1GigE	5GigE	5GigE	2 - 5GigE
Position Summary	Flexible Mounting	High Value	Value	All Purpose	All Purpose	High Performance	High Performance	High Density	High Density
Primary Verticals/Use Cases	Hospitality/MDU EDU Dorms SMB	SMB Hospitality/MDU	SME Hospitality/MDU Retail	General Mid-market Education Hospitality	General Mid-market Education Hospitality	Education General Enterprise High Density	MDU Education General Enterprise	Education Public Venues High Density	Public Venues Education High Density
Warranty	Limited Lifetime	Limited Lifetime	Limited Lifetime	Limited Lifetime	Limited Lifetime	Limited Lifetime	Limited Lifetime	Limited Lifetime	Limited Lifetime

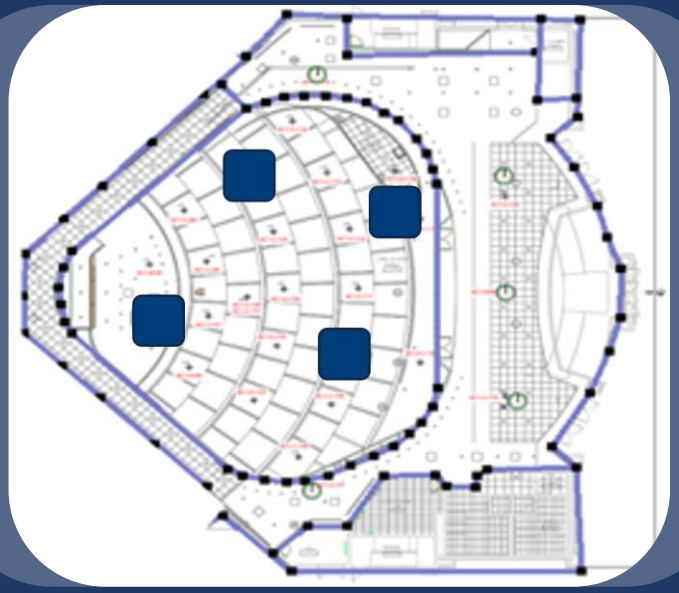
Unique in the industry

High Density Deployment Example

500 Seat Auditorium and 400+ End-user Devices

Traditional Design:

- **12** standard 2-radio APs
- **12** cables
- **12** switch ports
- 1 controller appliance



Cambium Design:

- **4** high-density 5-radio APs
- **4** cables
- **4** switch ports
- No controller appliance

Wi-Fi 6/6E Outdoor Portfolio

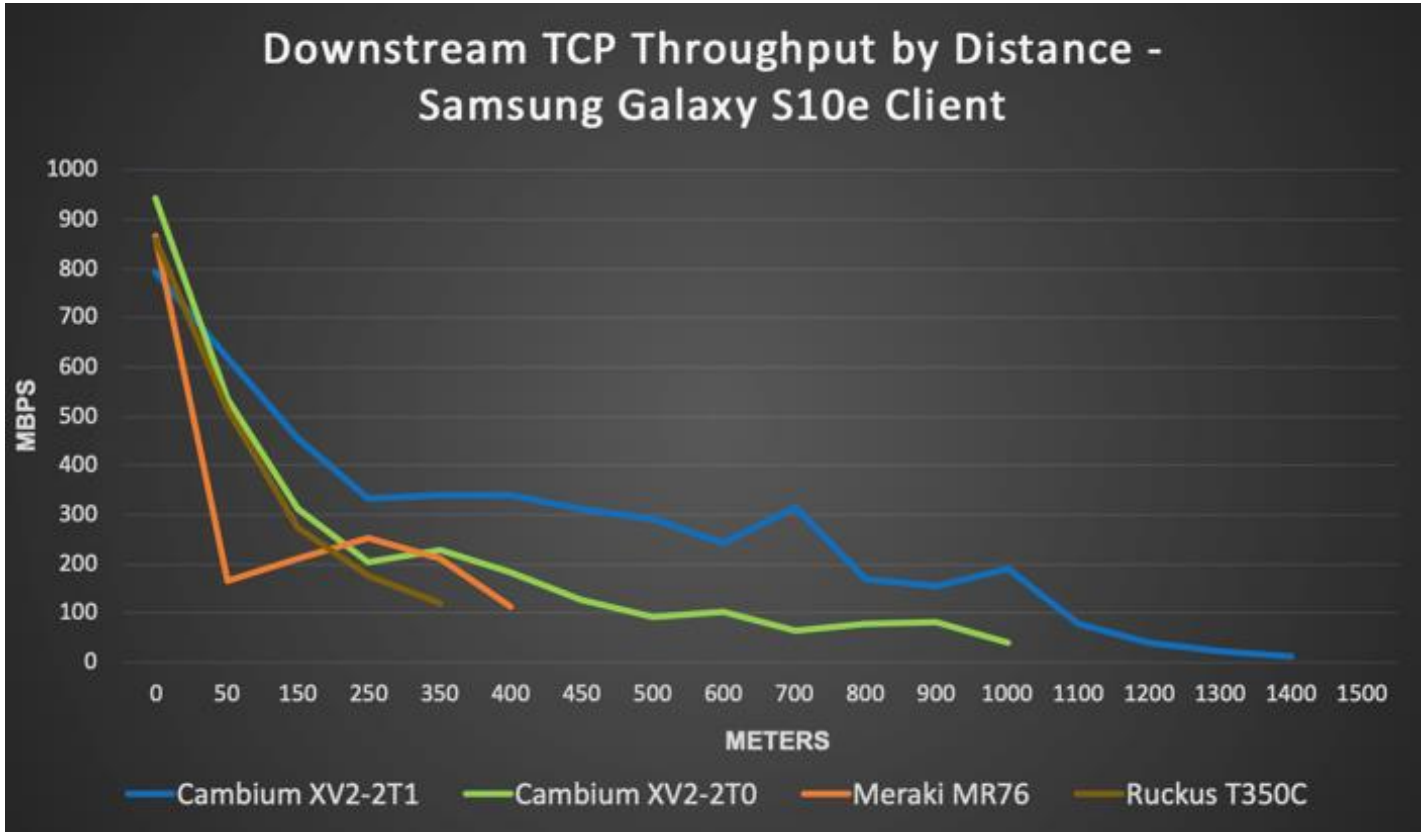
Cambium Networks™




	XV2-23T	XV2-2T0	XV2-2T1	XE3-4TN
Radios	2.4/5 GHz Wi-Fi 6	2.4/5 GHz Wi-Fi 6, BLE 4.1	2.4/5 GHz Wi-Fi 6, BLE 4.1	2.4/5/6 GHz Wi-Fi 6/6E, BLE 4.1
Max 5GHz Radios	1	1	1	2
Max 6GHz Radios	0	0	0	1
Software-Defined Radio(s)				✔
Antennas	Integrated 2x2, omni	Integrated 2x2, omni	Integrated 2x2, 120 deg sector	External 4x4/2x2 and GPS, 30, 60 deg & omni options
Total Wi-Fi Bandwidth	2.97 Gbps	1.77 Gbps	1.77 Gbps	6.6 Gbps
Max Channel Width	16 0MHz	80 MHz	80 MHz	160 MHz
Theoretical Max Devices	250	500	500	1,500
Uplinks	1–1 GigE	1–2.5 GigE	1–2.5 GigE	1–2.5GigE, 1–1GigE
PoE Out		✔	✔	
Environment	IP67 rated, -40ºC to 65ºC	IP67 rated, -40ºC to 65ºC	IP67 rated, -40ºC to 65ºC	IP67 rated, -40ºC to 65ºC
Value Propositions	Value price	Up to 1km client range with high efficiency antennas	Over 1km client range with high efficiency antennas	Flexible antenna options, 6GHz ready
Primary Verticals/Use Cases	Warehouses, Parking Lots, General Outdoor Campus	Public Wi-Fi, Venues, Logistics, Transportation, Campuses	Public Wi-Fi, Venues, Logistics, Transportation, Campuses	Large Public Venues, Logistics, Manufacturing, Campuses
MSRP (US)	$595	$774	$894	$1,795

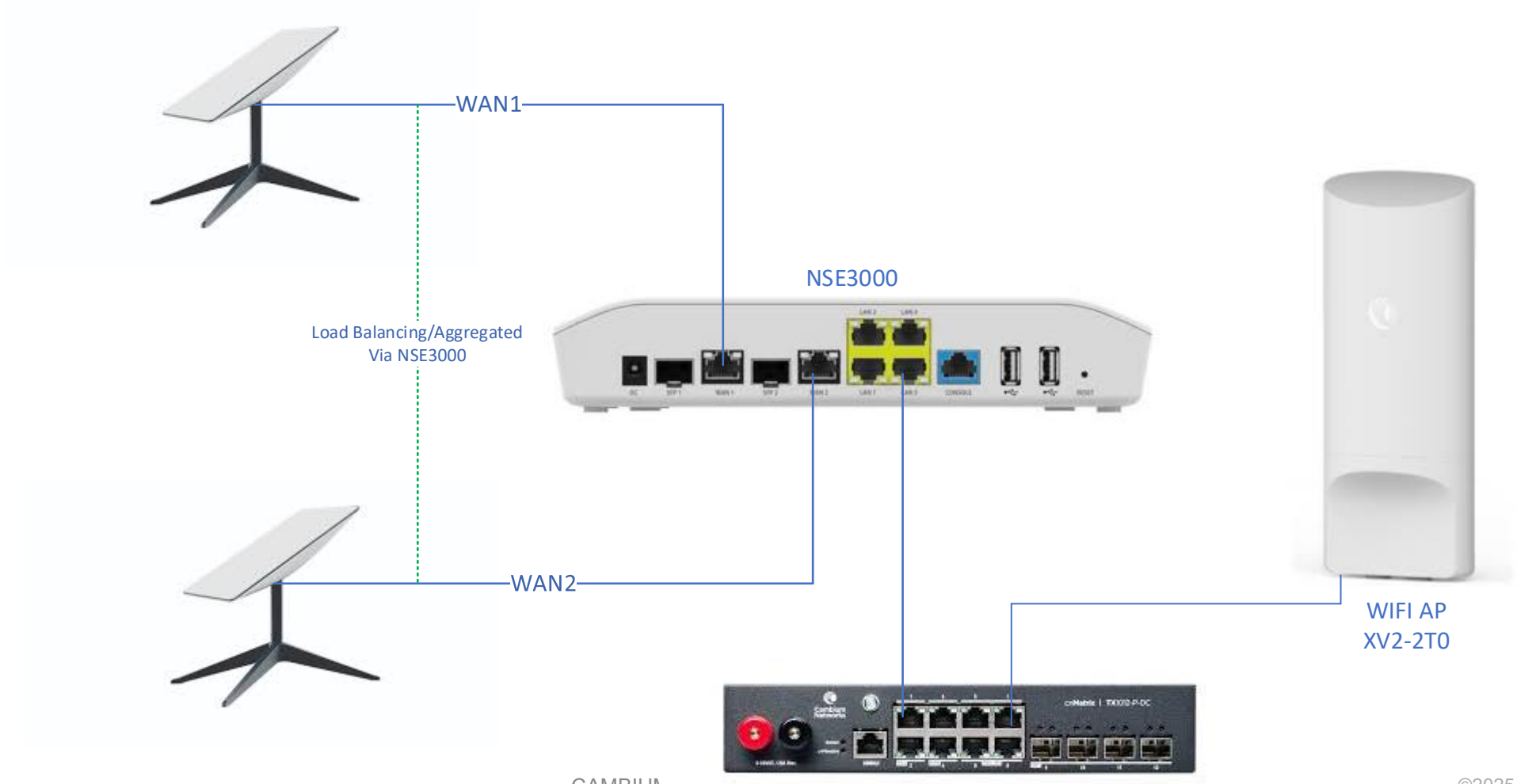
Long-Range Outdoor Wi-Fi

- **XV2-2T**
- **Highlights:**
- **Innovative high-gain antennas**
- **Integrated omni (XV2-2T0) or 120º (XV2-2T1) antennas**
- **Superior range to 1+ km**
- **2X–3X reach of conventional solutions reducing equipment by 70% or more**

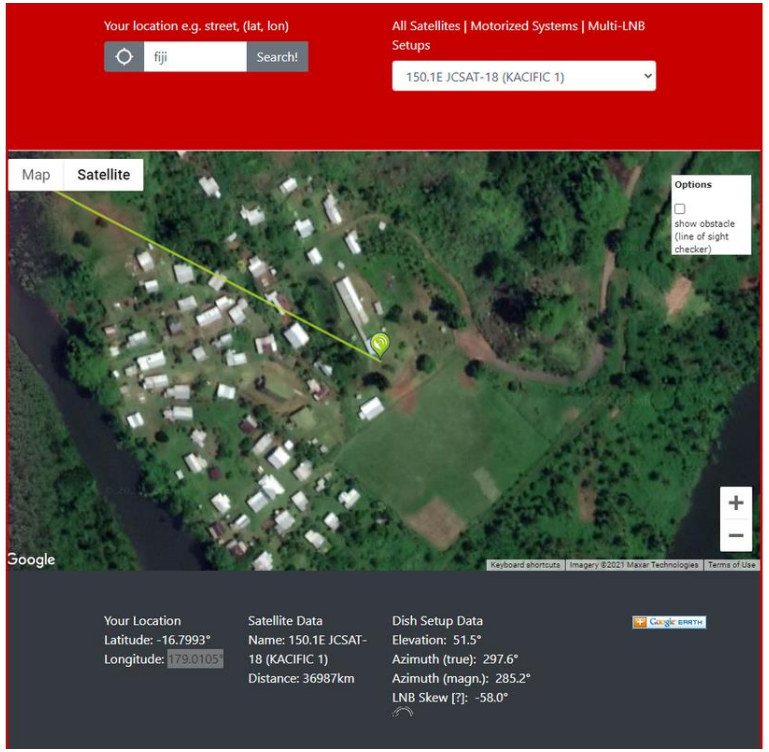


STARLINK ONE NETWORK – LONG RANGE WIFI

DUAL STARLINK SETUP USING CAMBIUM ONE NETWORK



Vodafone Fiji – 26 Remote Schools and Clinics – Wi-Fi and Satellite by Kacific



Enterprise Customer Examples

Cambium Networks™

ENTERPRISE / GOVERNMENT

Microsoft
Hormel
Bloomberg
VA Health
Chesapeake Energy
eog resources
CASVP
Centre d'Action Sociale de la Ville de Paris
Gardenspot Village
Paul Hastings
FEMA
Bar Clif
Bedford Hospital NHS Trust
USAID
Turner & Townsend

HOSPITALITY

Marriott
planet hollywood Beach Resort • Cancun
SINGLEDIGITS your business, one network.
Choice Hotels
The Venetian Las Vegas
Wyndham Hotels & Resorts
GuestTek
AccorHotels Feel Welcome
Caesars Entertainment
elewana Collection
Preferred Hotels & Resorts
B&B Hotels
Halekulani On the Beach at Waikiki

EDUCATION

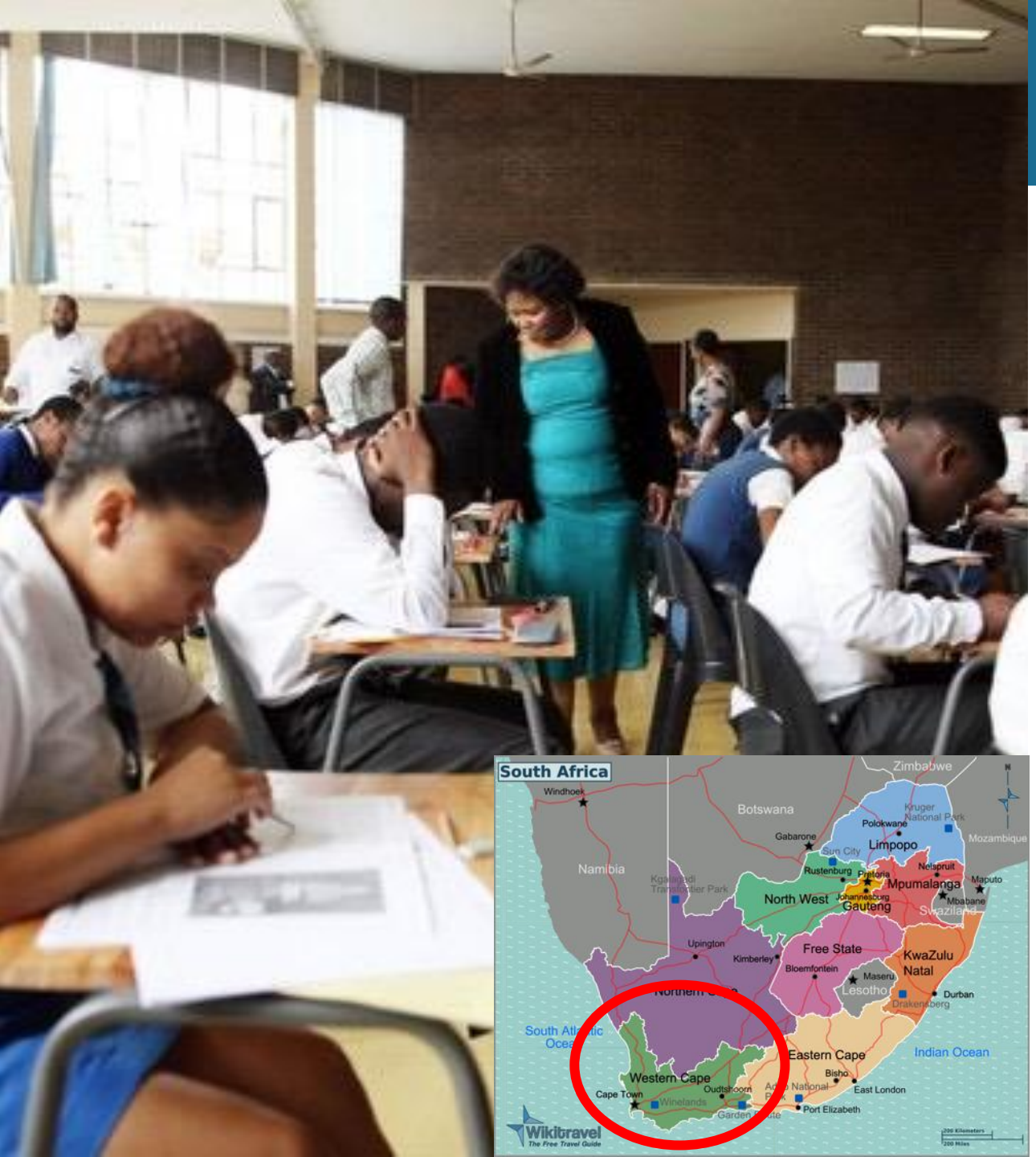
Wicomico County Public Schools
Universidad de La Sabana
New England Law Boston
SimiValleySchools Simi Valley Unified School District
Western Cape Government Education
Northwest Missouri State University
Midway University
Boulder Valley School District
KMU
Northern Michigan University
Rugby School
Hampton University
Universität Osnabrück

TRANSPORTATION / VENUES

New Orleans Ernest N. Morial Convention Center
SFMTA Municipal Transportation Agency
BNSF Railway
KORAIL
Los Angeles Chargers
Moscone Center
Liverpool Football Club
Liberty Ellis Island
Sands Expo
Melbourne Convention Exhibition Centre
the Y
The Jockey Club Since 1750

Western Cape EDU

Cambium Networks™



Government education system in South Africa with ~1M students in 1300 schools

REQUIREMENTS

- Robust connectivity for both in-class and online learning
- Support for multiple e-learning initiatives

SOLUTION

- Over 27,000 APs across 1000 schools and continuing to deploy
- Transitioned from Wi-Fi 5 to Wi-Fi 6 in 2022
- Cloud management

WHY CAMBIUM

- Scalable and flexible management
- Differentiated high density solution

Northwest Missouri State University

Cambium Networks™

7,000 student university with 135 undergrad and 36 graduate degree programs

REQUIREMENTS

- No central controllers for no single point of failure
- Reliable wireless across campus – classrooms, dorms, office spaces, sports arena, library

SOLUTION

- 2500+ APs and High Density APs covering 90% of campus across 50+ buildings, including 1300+ APs in dorms
- XMS-Cloud management
- 11,000 unique devices and 5000+ simultaneous
- Ongoing refresh to Wi-Fi 6, including XV3, XV2, XV2-22H and XV2-2T0 (outdoor)

Incheon City - Korea

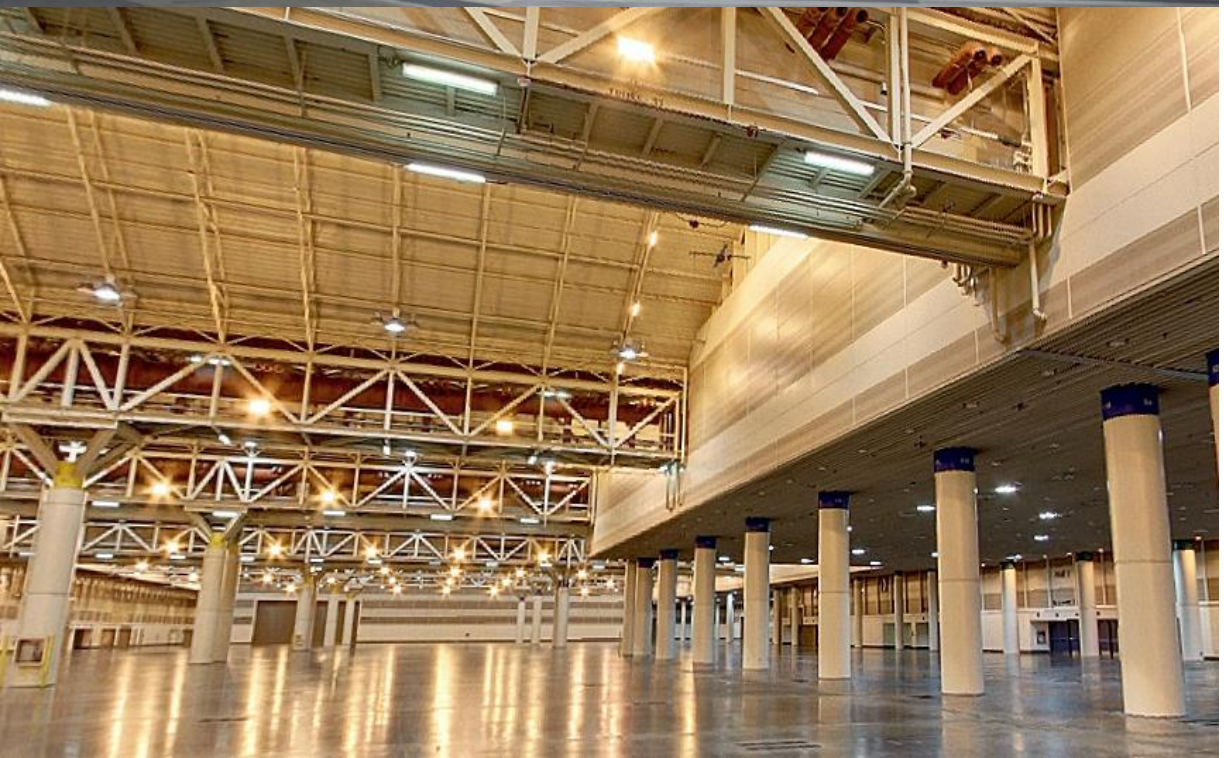
Cambium Networks™

REQUIREMENTS

- Modernize Wi-Fi infrastructure to deliver greater performance and management flexibility
- Variety of use cases – offices, city hall, public spaces
- Competitive win vs. Cisco, Aruba, Ruckus

SOLUTION

- Cambium Wi-Fi 6 solution deployed across city facilities
- Mix of standard and high density APs
- Groundwork for Smart City deployment



New Orleans Convention Center

Cambium Networks™

New Orleans
ERNEST N. MORIAL
CONVENTION CENTER

5th largest convention center in the US
3 million sq. ft with 1.1 million in exhibit space

REQUIREMENTS

- Replace aging deployment
- Keen to use 6GHz for better performance and encountering DFS issues in 5GHz (next to river)

SOLUTION

- XE5-8 and XE3-4 in hallways and meeting rooms
- XE3-4TN with directional antennas in exhibit halls
- cnMaestro X on-prem management

The Jockey Club

Cambium Networks™

Britain's Premier Horse Racing Tracks

THE JOCKEY CLUB
Since 1750

- **REQUIREMENTS**
- **Wireless coverage across 8 large race courses – up to 350 acres, up to 200,000 people capacity**
- **Mission critical Wi-Fi with sports books doing millions of pounds of business annually over the network**
- **Support spectators sharing experiences and accessing services**

- **SOLUTION**
- **1200 standard and high density Cambium APs**
- **6 years XMS-Cloud for monitoring and management**
- **Application Control**

Australian Turf Club

Cambium Networks™

Premier thoroughbred racing and hospitality venues in Sydney, Australia

REQUIREMENTS

- Deploy Wi-Fi 6 in new spectator stand with full equipment refresh planned in 2022
- High density deployments indoor/outdoor
- Wi-Fi coverage for outdoor areas, stadium seating, hospitality suites, and general use areas

SOLUTION

- 300 standard and high density APs across site
- Wi-Fi 6 deployed in new stand – high density XV3-8, outdoor XV2-2T, multi-GigE EX2016M-P switches
- XMS-Cloud managed

Melbourne Convention and Exhibition Centre

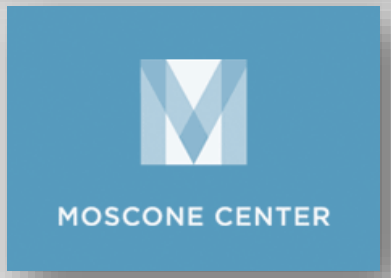
Cambium Networks™

Australia's most versatile convention facility

MELBOURNE CONVENTION EXHIBITION CENTRE

- **REQUIREMENTS**
  - High density usage accommodating thousands of users at a time
  - Easy deployment and manageability
- **SOLUTION**
  - Nearly 300 Cambium high density APs – 3 and 4 radio, Wi-Fi 5 and Wi-Fi 6
  - Tested Cambium Wi-Fi 6 AP at 2.4Gbps throughput as part of evaluation
  - Managed from XMS-Cloud
  - Won vs. Cisco/Meraki based on proven performance and ease of management

Moscone Convention Center



Largest convention complex in San Francisco

- **REQUIREMENTS**
- Wireless coverage across 2 million sq ft (106 meeting rooms + 4 exhibit halls)
- Reliable wireless access for dense user & device populations
- Highly reliable and secure environment

- **SOLUTION**
- Over 375 High Density APs plus portable APs used to augment large sessions
- Simultaneous Wi-Fi connectivity for up to 20,000 devices
- Xirrus Management System managing the network

Microsoft Events

Worldwide events team hosting dozens of events and 100,000's of attendees each year

> *We've increased our capacity and solved a problem that we've never been able to solve and we've been able to do all the other wireless needs at the event at somewhere under half of the cost for the facility side of things as we have in the past.*
>
> JOHN O'GARA
> Group Manager for Microsoft's CMG Events & Studies

REQUIREMENTS

- Simultaneously connect 10,000s of Wi-Fi users
- Temporary deployment minimizing amount of equipment
- Simple network that can be centrally managed

SOLUTION

- High performance High Density APs
- 80% less equipment and 80% less time to deploy

Fundamentals of RF

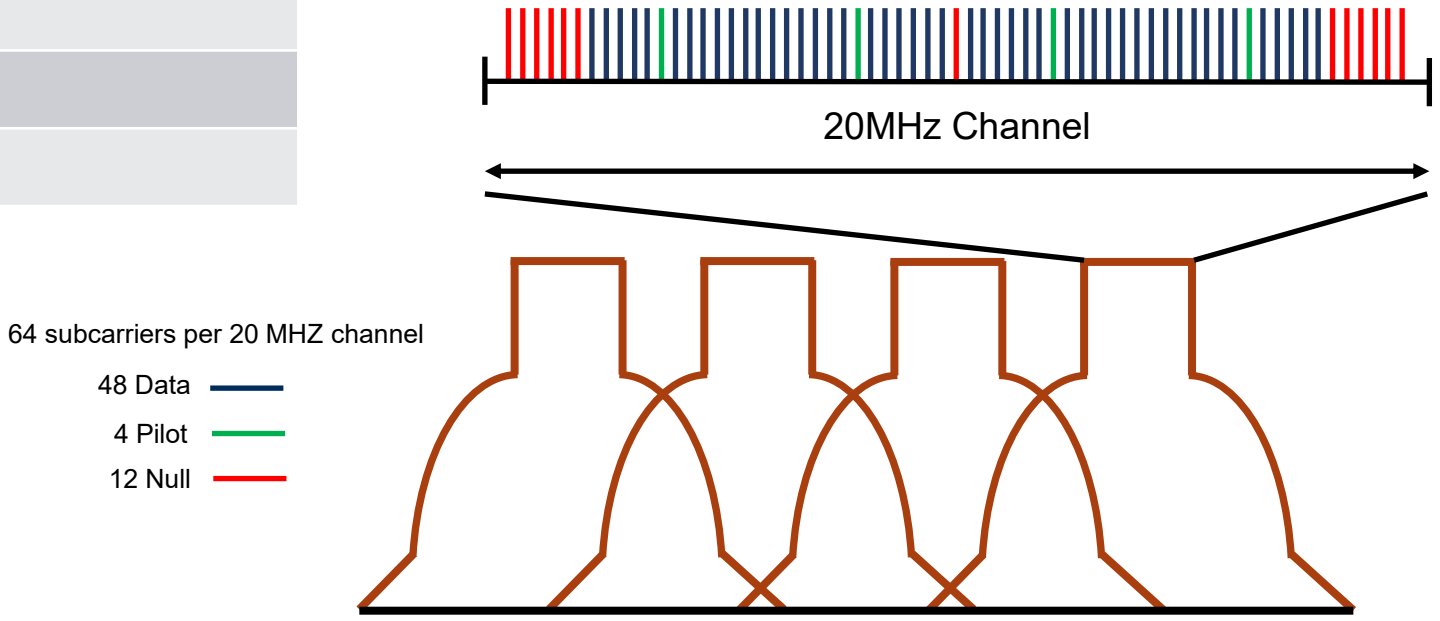
Bands and Channels

Cambium Networks™

Bands and Channels

Band	Referred As	Channels
2.4GHz	ISM	13 Channels (3 usable)
5GHz	U-NII-1	4
5GHz	U-NII-2A	4
5GHz	U-NII-2C	12
5GHz	U-NII-3	5
6GHz	U-NII-5-8	59

Wi-Fi channels operate in unlicensed wireless bands



Fundamentals of RF Spectrum

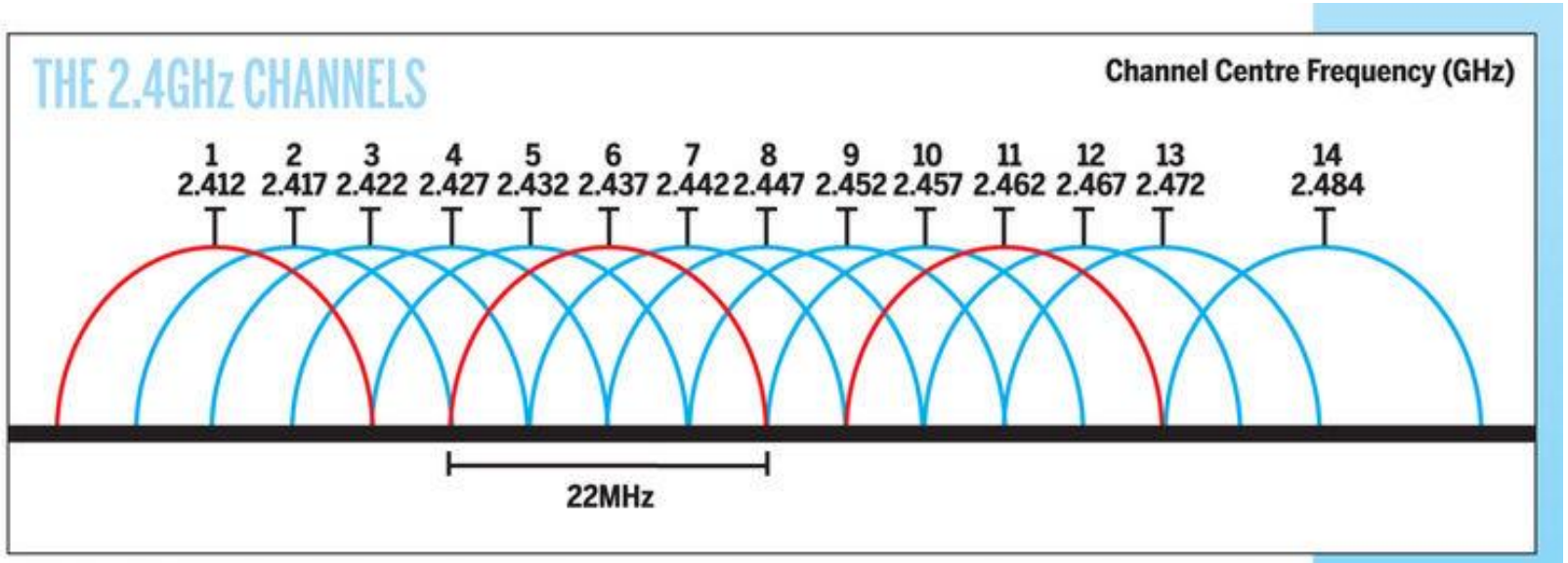
2.4GHz / 5Ghz / 6Ghz Band

Cambium Networks™

2.4GHz Band

2.4GHz – used by 802.11b/g/n/ax clients

- 3 non-overlapping channels – 1, 6, 11(differs by geo region)
- Limited bandwidth
- Prone to interference
  - Microwave ovens
  - Baby monitors
  - Bluetooth devices



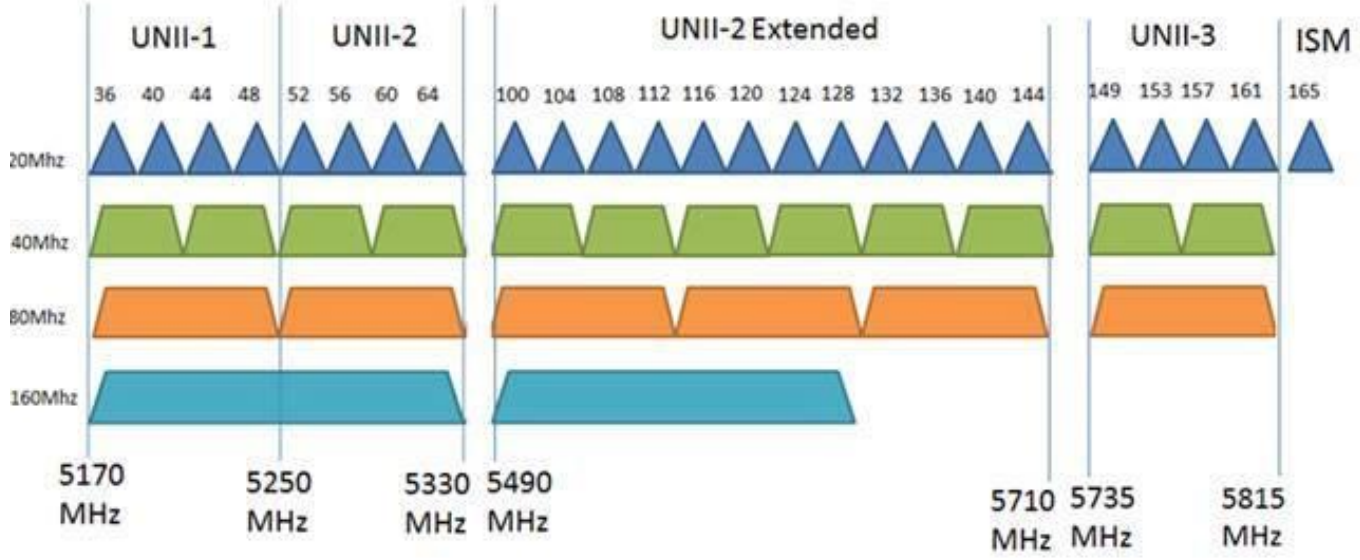
The 2.4GHz channels contain a vast amount of overlap, which is why some routers only allow you to choose from channels 1, 6 and 11. The use of channel 14 isn't permitted in the UK.

5GHz Band

25 Channels – used by 802.11a/n/ac/ax clients

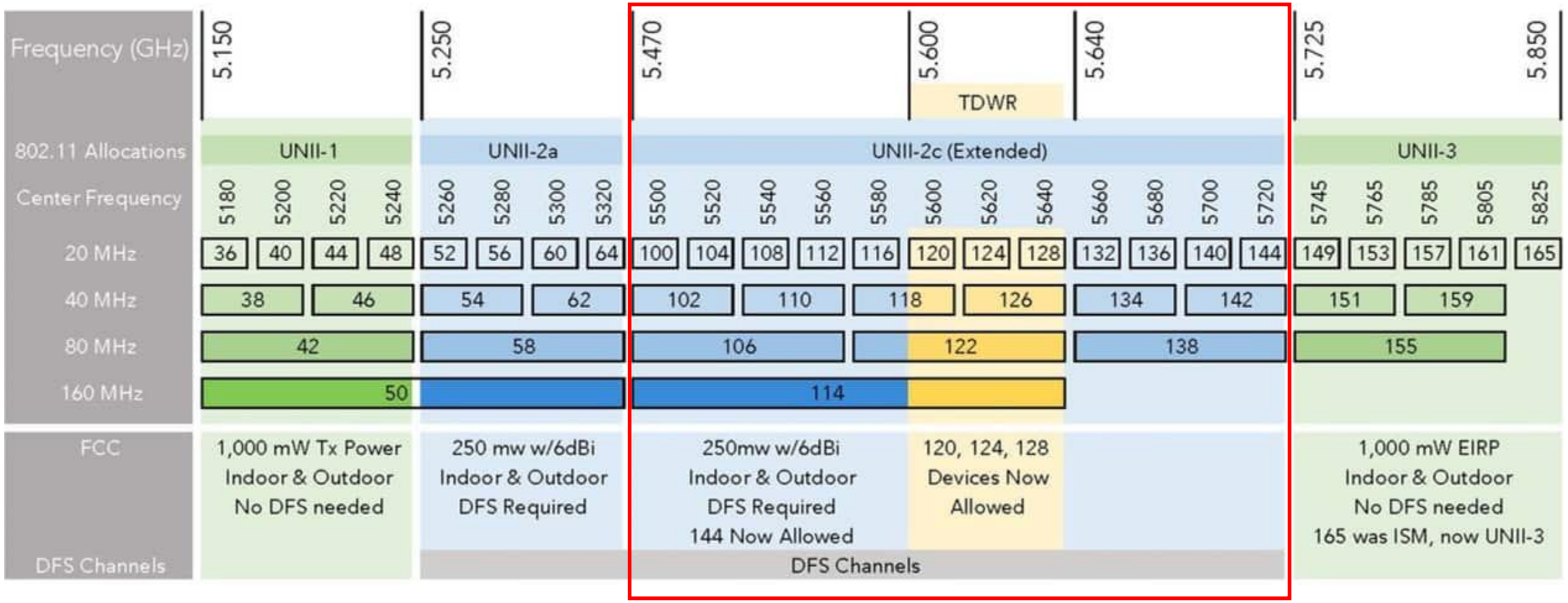
- UNII 1 - 4 Channels – 36, 40, 44, 48
- UNII 2 (U-NII-2A) – 4 Channels – 52, 56, 60, 64
- UNII 2 Extended (U-NII-2C) – 12 Channels – 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144
- UNII 3 – 5 Channels – 159, 153, 157, 161, 165

- More Channels
- Less Interference
- Must support DFS



Australia DFS - Channels

5 GHz Channel Allocations



6GHz Band

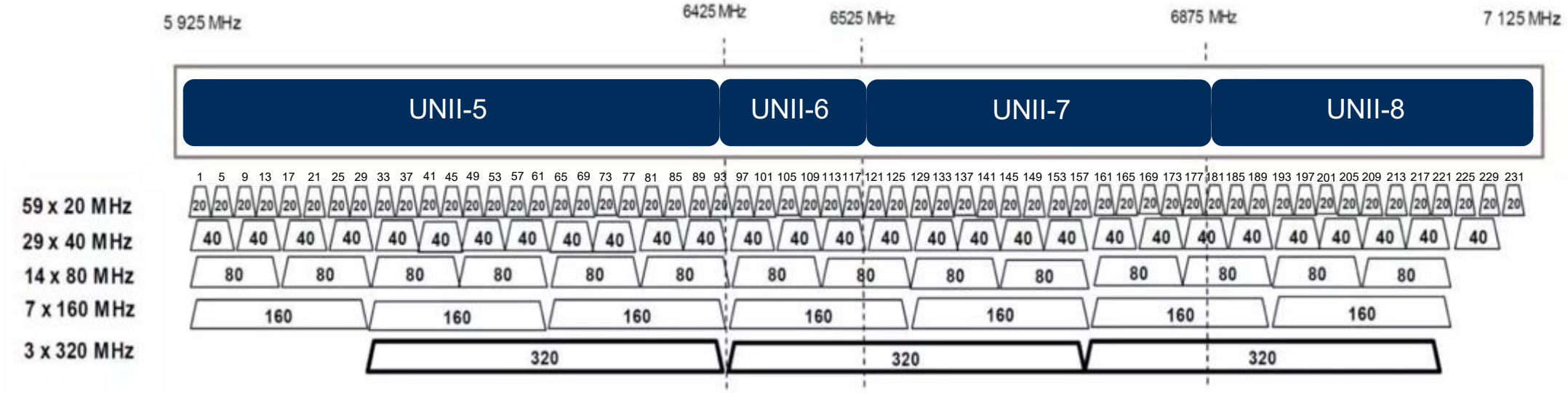
Cambium Networks™

Wi-Fi 6E - 6GHz Clients Only!

(No backward compatibility)

- 1.2 GHz additional spectrum approved by FCC
  - UNII-5, 6, 7, 8
- 500MHz additional spectrum approved in Europe
  - UNII-5

Channel width	# of channels
20MHz Channels	59
40MHz Channels	29
80MHz Channels	14
160MHz Channels	7



6GHz Band

Cambium Networks™

Expanded unlicensed use of the 6GHz band in the US

Device Class	Operating Band	Max EIRP
Low-power AP (indoor only)	U-NII 5,6,7,8	30dBm
Client connected to low-power AP	U-NII 5,6,7,8	24dBm
Standard-power (AFC controlled)	U-NII 5,7	36dBm
Client connected to standard-power AP	U-NII 5,7	30dBm

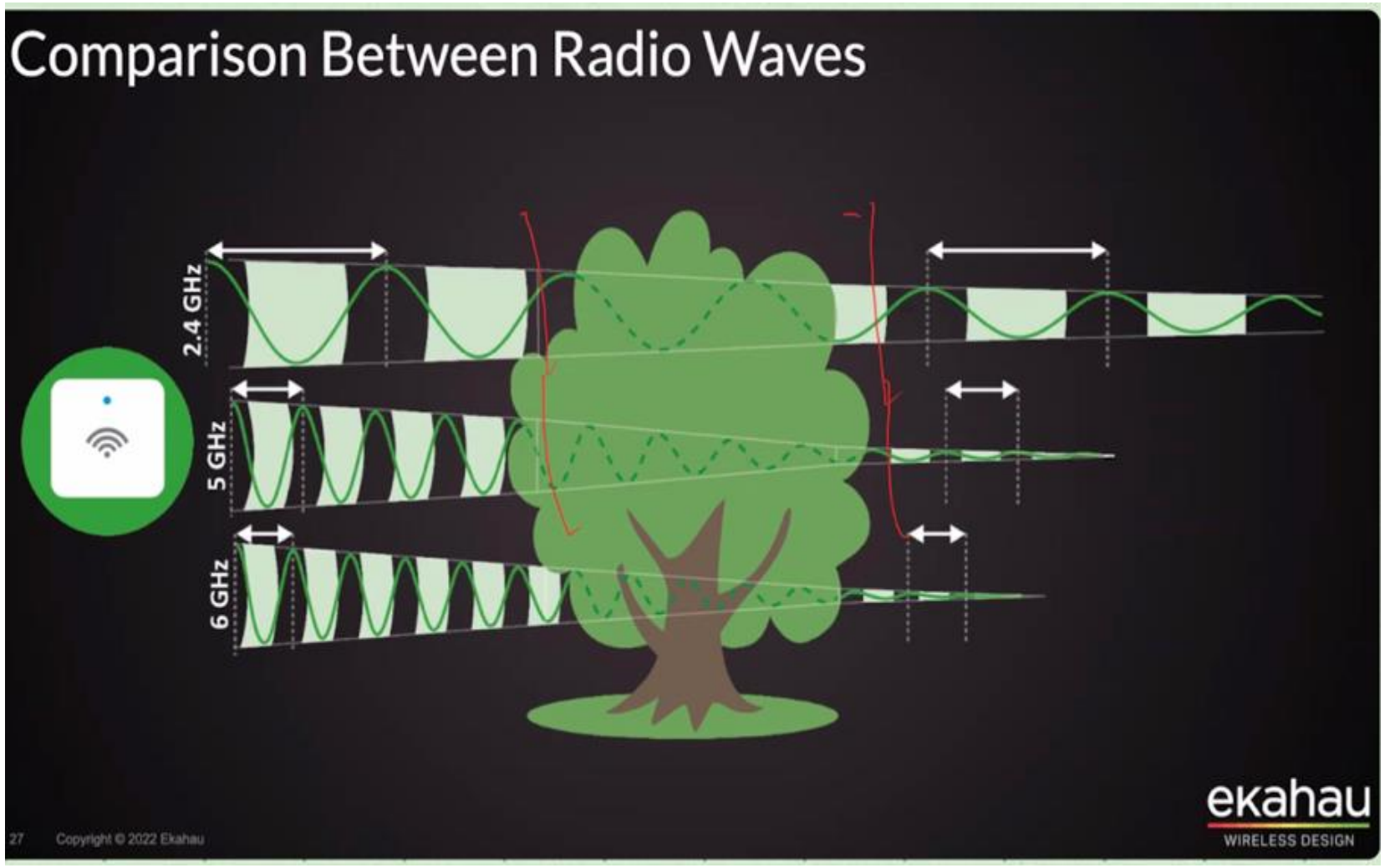
Automated Frequency Coordination (AFC)

- Protect incumbent operations from RF interference
- Required for outdoor use
- Geolocation databases to manage real-time frequency assignments

Cambium Networks™

Summary of Technical Specifications

Range



Modulation and Techniques

Wi-Fi Standard	OFDM	OFDMA	MIMO	Beamforming	TDD
802.11a	Yes	No	No	No	No
802.11b	Yes	No	No	No	No
802.11g	Yes	No	No	No	No
802.11n	Yes	No	Yes	Yes	Yes
802.11ac	Yes	No	Yes	Yes	Yes
802.11ax (Wi-Fi 6)	Yes	Yes	Yes	Yes	Yes
802.11ay (Wi-Fi 7)	Yes	Yes	Yes	Yes	Yes

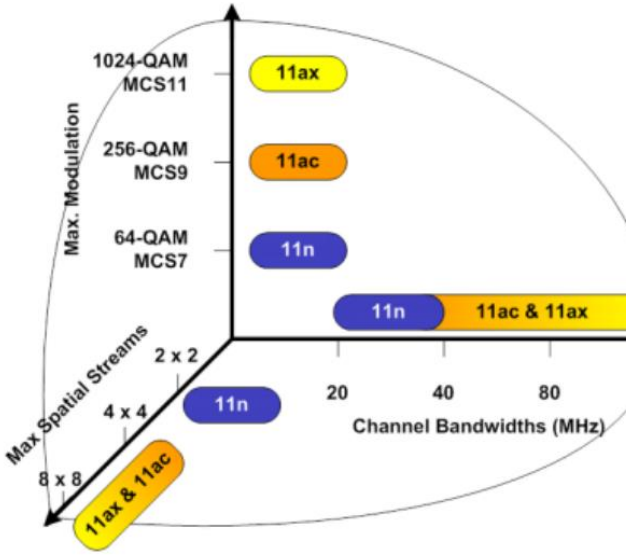
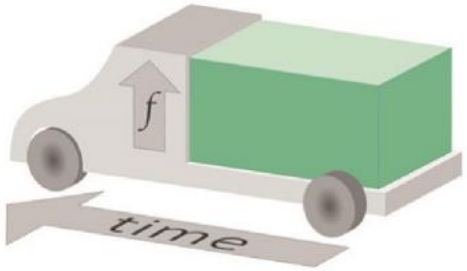
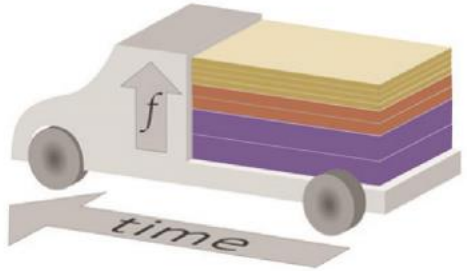


Figure 5 Evolution of Wi-Fi radio performance[15]



802.11ac, 40 MHz channel

One transmission



802.11ax, 40 MHz channel

Divide transmission by frequency into 242 sub-carriers in groups of 26.

Wi-Fi 7 Headline Feature : MLO

Cambium Networks™

Multi - Link

Alternating or simultaneous

Choice of Links

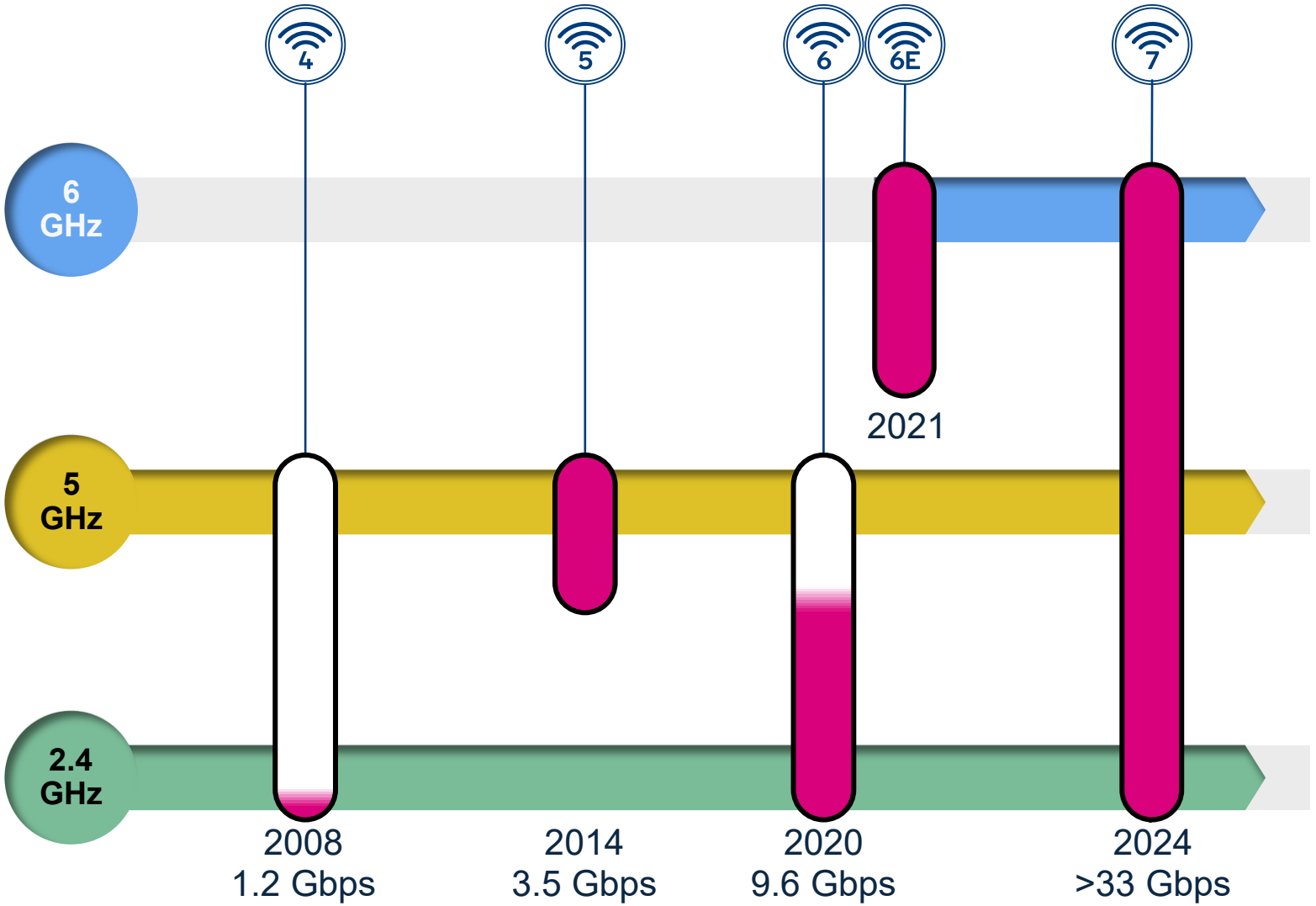
Between router and client
2.4 GHz or 5 GHz

One Link

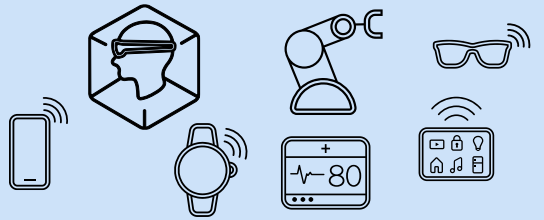
Between router and client

Faster Wi-Fi, More devices, Lower Latency

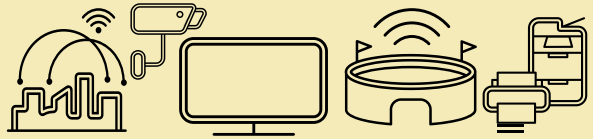
Cambium Networks™



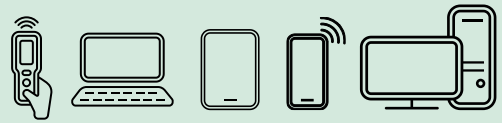
AR/VR, AI applications, IOT



Streaming video/audio
All wireless office, LPV

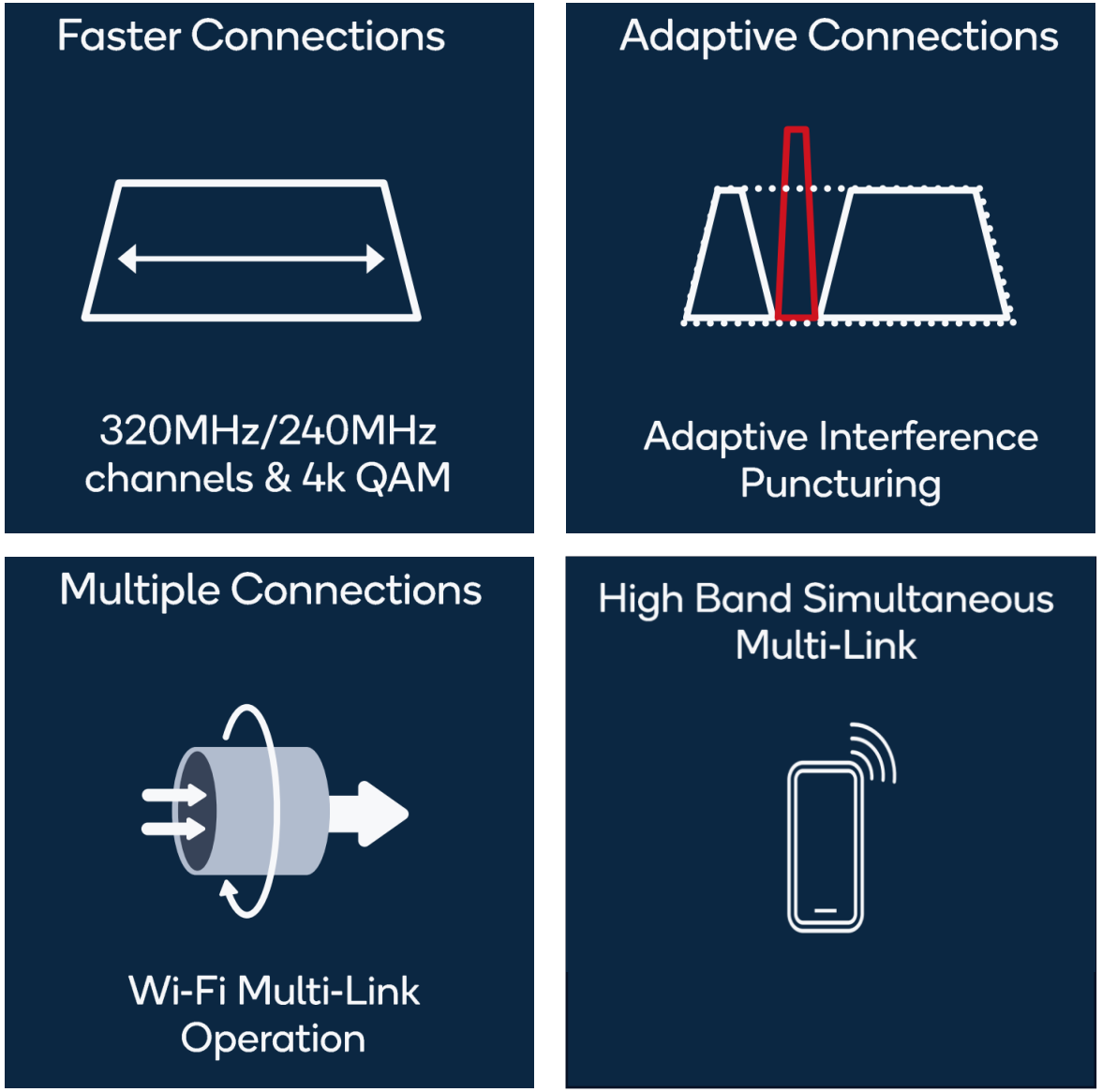


Smartphones, Tablets
25% YoY growth 2010-2013



Wi-Fi 7 Headline features

Cambium Networks™



Key Concepts that Drive Wi-Fi 6E and 7 adoption and deployment decisions

Wi-Fi must keep pace with client devices

- New features require client support, some new features are proprietary e.g., Qualcomm HBS Multilink
- 96% of AR/VR/Spatial Computing will ship with Wi-fi 6E/7

6 GHz operation is the key to massive speed

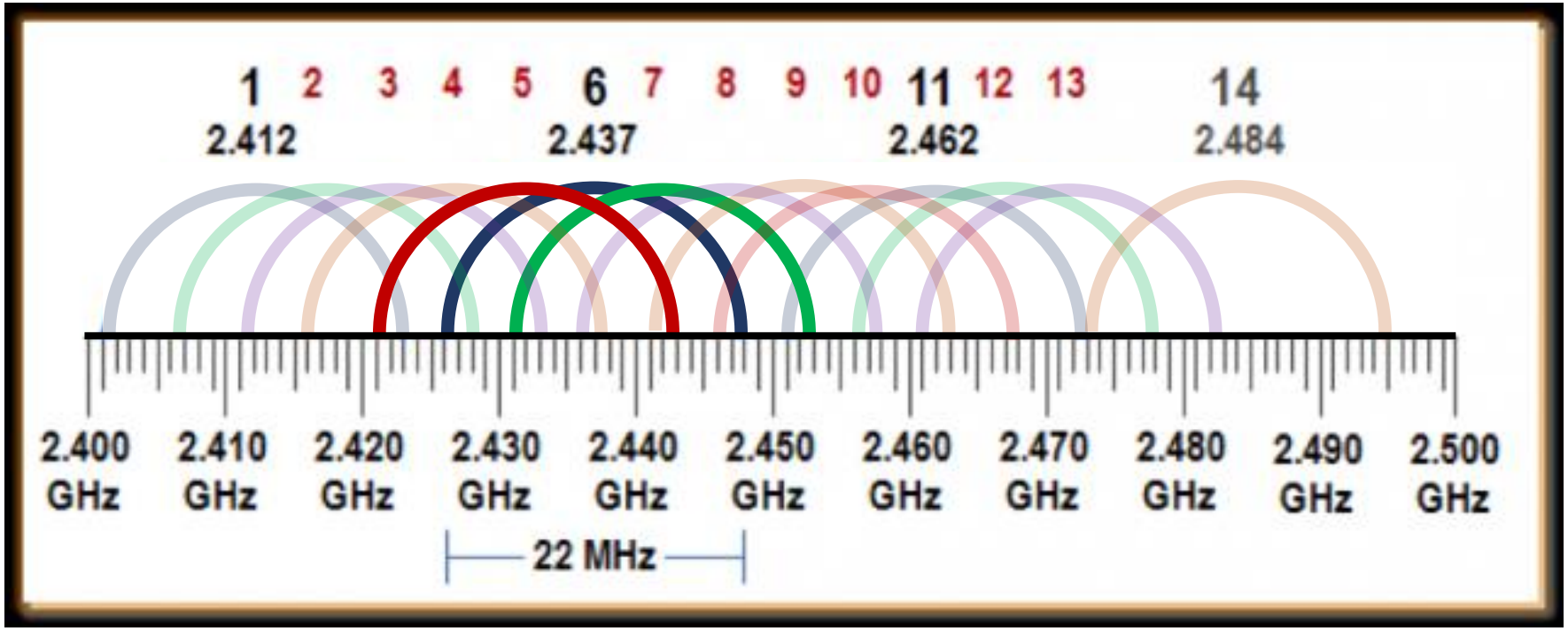
- Not all countries support 6 GHz, but many do
- Most countries use similar rules for indoor 6 GHz


Cambium Networks™
Channel Interference

Channel Interference

Adjacent Channel Interference – 2.4GHz

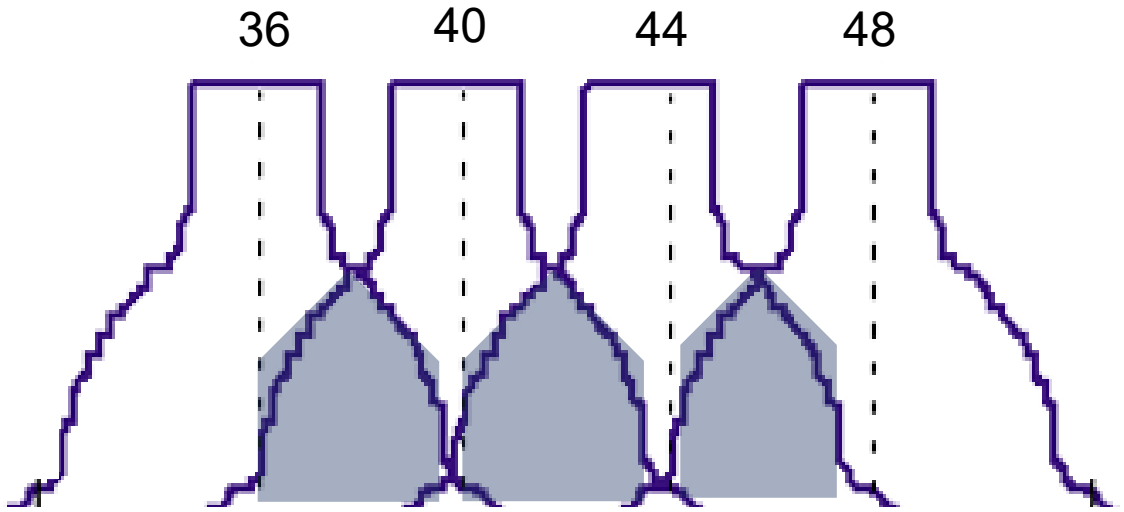
- Previous or next channel number (ie. 5,6,7)
- Insufficient channel separation causes interference from neighboring channels



Channel Interference

Adjacent Channel Interference – 5GHz

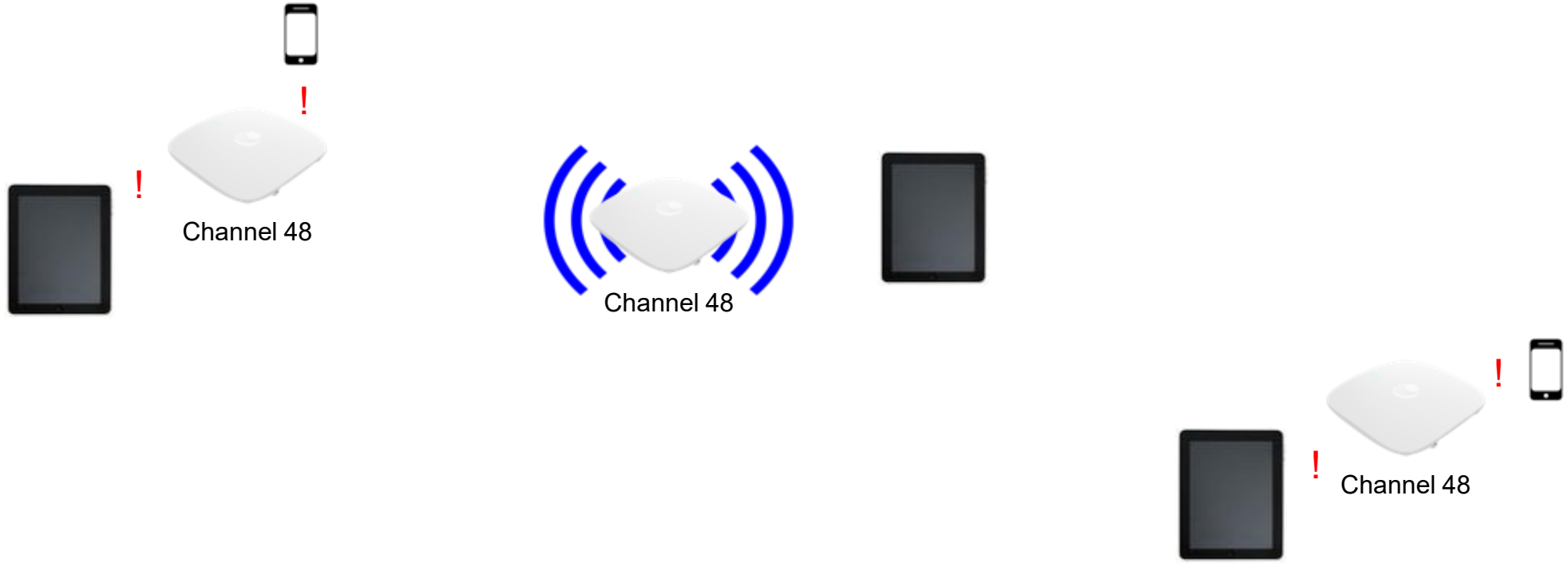
- Previous or next channel number (ie. 36,40,44)
- Even though the 5GHz channels have separation built into them, it is possible to get a little interference from the side bands



Channel Interference

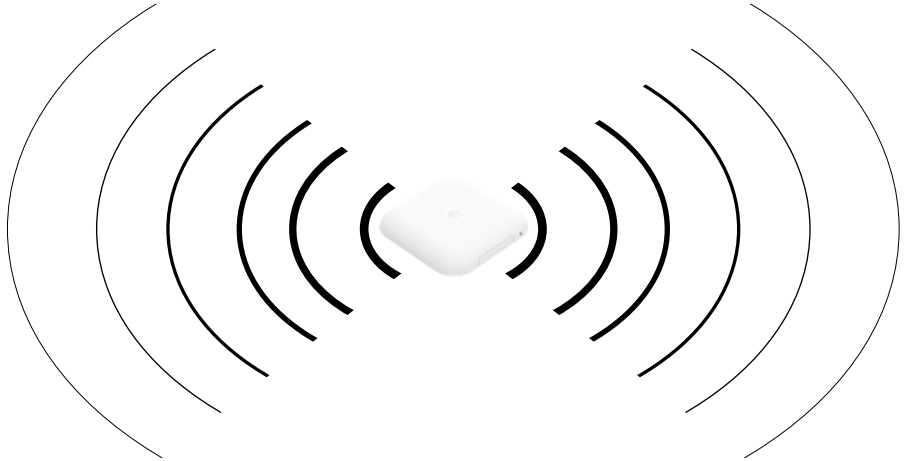
Co-Channel Interference

- 2 or more APs within range of each other share same channel
- Only 1 device allowed to transmit at a time, others wait their turn



Behaviors - Inhibitors

- Wave propagation
- Propagation loss



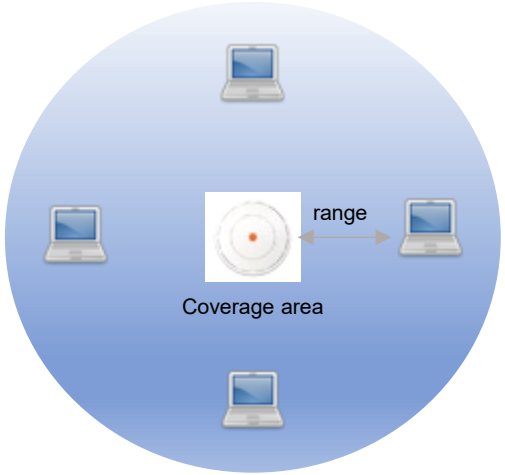
Range Inhibitors

- Multi-path
- Interference
- Attenuation

Element	Materials/Physical Elements	Impact on WiFi Signal
Diffraction	Walls, furniture, corners, and other obstacles	Can cause signal loss or attenuation, especially when the obstacle is comparable in size to the wavelength.
Reflection	Glass, metal surfaces, mirrors, and other reflective materials	Can cause signal interference or multipath fading, leading to signal degradation.
Absorption	Concrete, metal, water, and other absorbent materials	Can absorb significant amounts of WiFi signal, reducing its strength.
Scattering	Cluttered environments, irregular surfaces, and objects with complex shapes	Can cause signal attenuation and interference.
Fading	Moving objects, changing environmental conditions, and multipath interference	Can lead to fluctuations in signal strength.
Multipath Fading	Reflective surfaces, multiple paths between router and receiver	Can cause rapid fluctuations in signal strength.
Polarization	Metal objects, certain types of antennas	Mismatched polarization can reduce signal strength.
Frequency Interference	Other electronic devices operating on the same frequency band (e.g., cordless phones, microwaves)	Can cause signal degradation and reduced throughput.

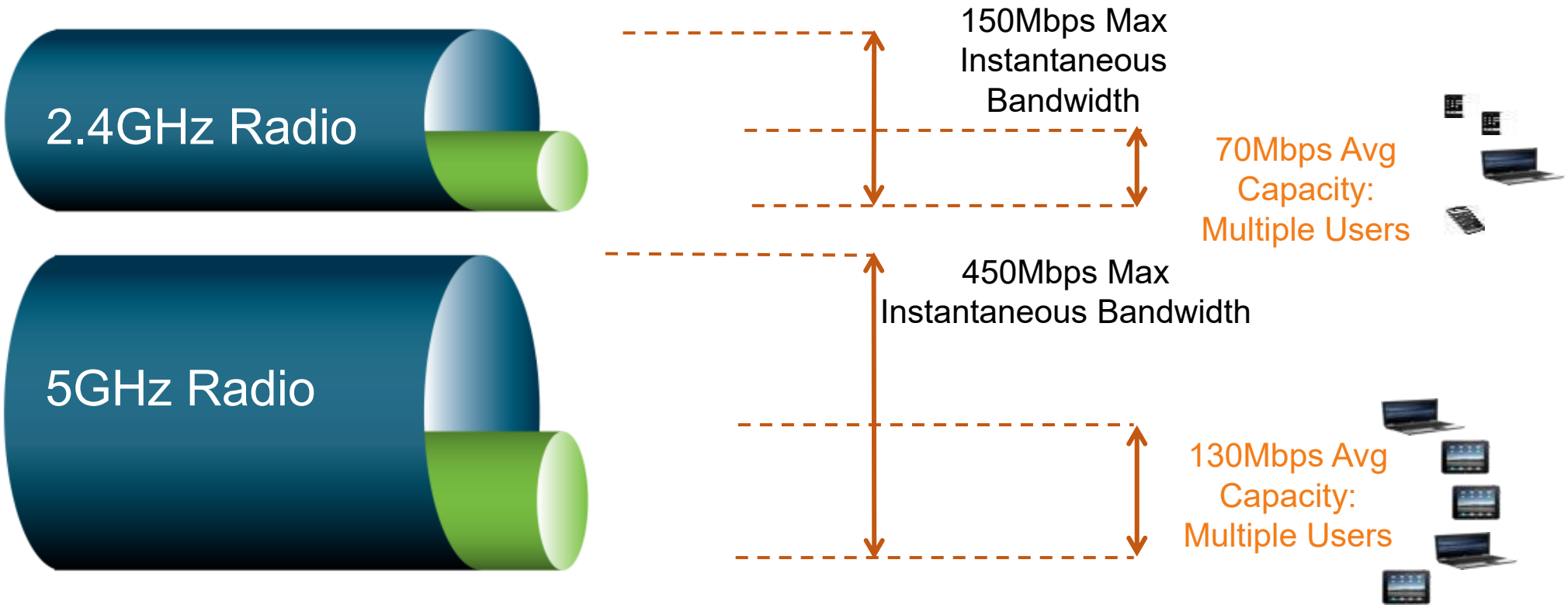
Range / Coverage / Capacity

- Transmission Basics
  - Range
    - Operating distance between two radios that wish to communicate
      - Access Point to Station
      - Station to Station
  - Coverage
    - Total area wherein radios can maintain connection to Access Point
  - Range vs. Capacity - The greater the coverage area…
      - …the more wireless stations can be covered
      - …the less bandwidth available to each user
      - …the lower data rates will be at the edge
      - …the more likely the chances of “hidden nodes”




Cambium Networks™
Bandwidth / Clients

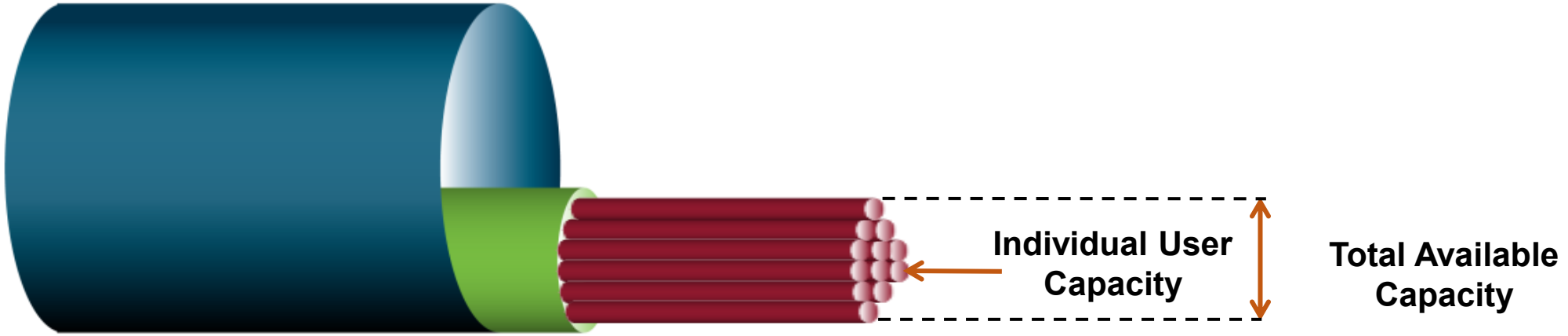
Understanding Radio Capacity



In a Wi-Fi network, radio capacity is reduced by **half duplex transmissions**, **protocol overhead and is shared by multiple users**

https://mcsindex.com/

Understanding Radio Capacity



5GHz radio: 450Mbps / 20Mbps = ~22 users per radio

2.4GHz radio: 150Mbps / 20Mbps = ~7 users per radio

Devices Per AP

Public Wi-Fi – General Usage (~5 Mbps/device)			
	XE3	**XV3**	**XE5**
Devices Per AP	100	200	400

Office/Classroom – Critical App Usage (~15 Mbps/device)			
	XE3	**XV3**	**XE5**
Devices Per AP	40	80	160

File Transfer – High Capacity Usage (~60 Mbps/device)			
	XE3	**XV3**	**XE5**
Devices Per AP	12	25	50

- These numbers factor in both capacity (varies by table) and density (varies by AP model)
- These are general guidelines, many factors to consider they may impact these:
  - Specific applications
  - Physical environment
  - RF environment
  - Client types
  - Wi-Fi bands
- These numbers are based on 5GHz radio usage specifically
  - 6GHz usage on XE models which will increase capacity
  - Does not factor in 2.4GHz radios which have lower capacity and in many cases may be disabled

Application Throughput Requirements*

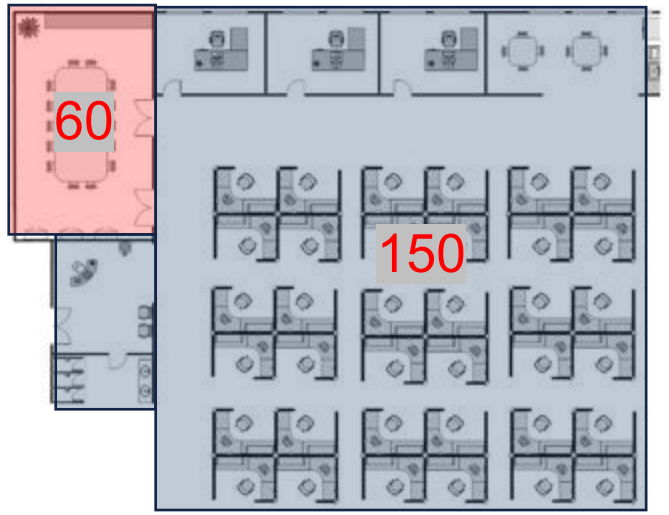
Activity	Download Speed (Mbps)		Activity	Download Speed (Mbps)
General Browsing/Email	1		Personal Video Call Std	1
Streaming Online Radio	0.5		Personal Video Call HD	1.5
VoIP Calls	0.5		HD Video Teleconferencing	6
Student	5 – 25		Game Console	3
Telecommuting	5 – 25		Online Multiplayer	4
File Downloading	10		File Transfer	100
Social Media	1			
Video Streaming Std	3 - 4			
Video Streaming HD	5 - 8			
Video Streaming 4K	25			

* FCC Broadband Speed Guide (www.fcc.gov/consumers/guides/broadband-speed-guide)

Throughput Requirements – Office Example

Application	Throughput Requirement (Mbps)
Email	1
Zoom calls	3
File Downloading	10
MS Office	5
Other network traffic	1
Future growth	25%
Throughput requirement	25

Office Network



Aggregate Throughput

Throughput requirement * number of connected devices * oversubscription ratio

Office: 25 * 150 * 0.20 = 750Mbps

Conf Room: 26 * 60 * 0.20 = 312Mbps

Cambium Networks™

Wi-Fi Network Design

Best Practices

Before You Start the Design

- Business Requirements / User Requirements
- Existing WAN / LAN / WLAN
- Areas requiring wi-fi coverage
- Client Devices
  - What type (phones - 1 antenna, tablets – 2 antennas, laptops – 3 antennas)
  - How many client devices
  - Application usage
  - Bandwidth requirements
- Latency Requirements
- Signal Strength Requirements
- Coverage Requirements
- Capacity Requirements
- Security Requirements
- Roaming Requirements (Layer 2 & Layer 3)
- WIPS / MDM / NAC
- Guest Access
- Design Constraints and Restrictions

Wi-Fi Design Principles

Network Design = Is Getting the Math Right

- Coverage is a given, focus on Capacity and Performance
- Design for all bands - 2.4GHz, 5GHz and 6GHz
- Determine signal criteria required based on device usage:
  - -72 dBm RSSI *was* 'Good Enough' for laptops
  - -65 / -62 dBm RSSI is required for Smartphone/Tablet/VoWiFi
  - Stronger RSSI values (-60) may be required for some devices, …
- Understand the impact of device density per radio
  - High performance = <20
  - Medium performance = <40
  - Low performance = <80
- Plan coverage with all locations seeing multiple radios/APs
- Make sure the customer appreciates the need for and buys 802.11a/b/g/n/ac/ax/be enabled clients!!!

Means 5GHz!

WAN / LAN Capacity

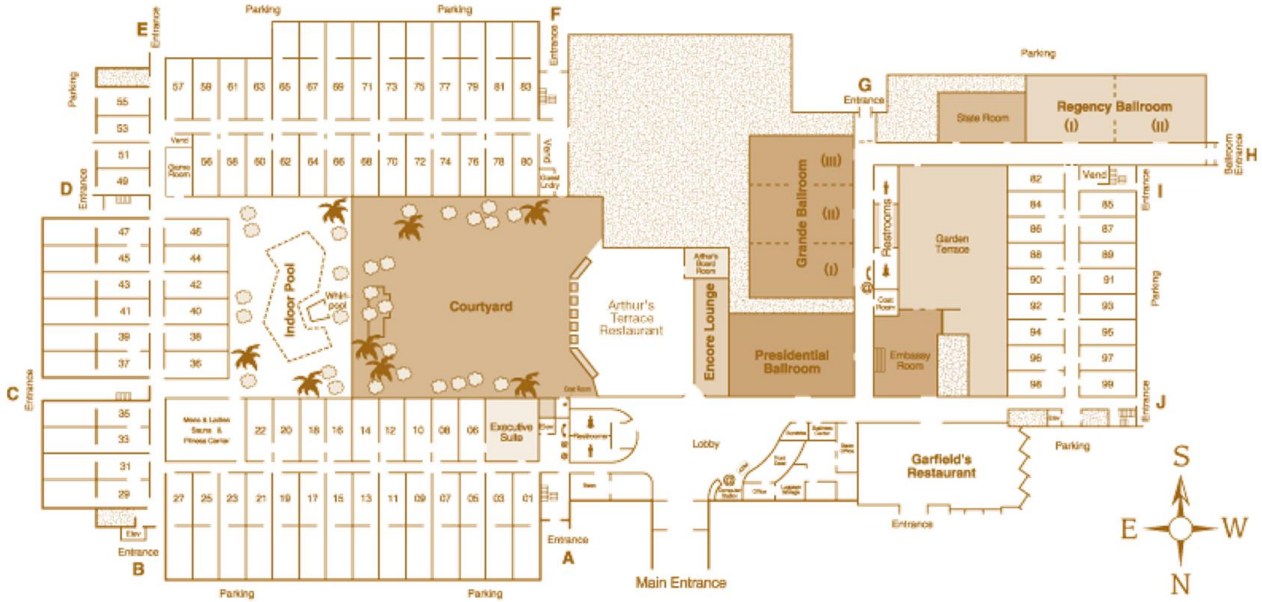
- Existing switching infrastructure
  - Available ports
  - Port speeds supported
  - PoE
  - Available PoE switch power budget
- Cable drops
  - Cable rating
  - Locations
- WAN
  - Router port speed
  - WAN connection speed
- DHCP – IP address availability
  - Existing LAN
  - WLAN infrastructure
  - WLAN clients
- One facility – multiple environments
  - Storage areas – little to no wi-fi coverage
  - Warehouse – scanners, limited client usage
  - Congested office areas – Desktops, laptops, tablets, phones, BYOD
  - Cafeteria, auditorium - Tablets, phones, BYOD

Cookie cutter designs

No two environments are exactly the same

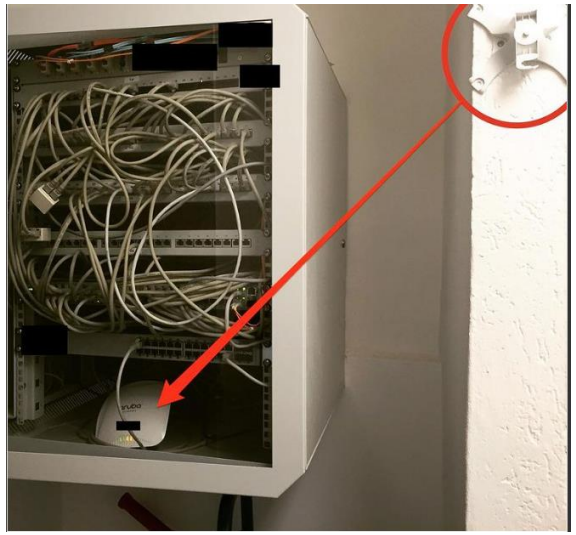
Taking shortcuts rises potential for:

- Missed interferers
- Too many devices or too few devices
- Poor performance



Ugh!!!

Cambium Networks™



Number of Radios

A Network Design Checklist

Cambium Networks™

Number of radios

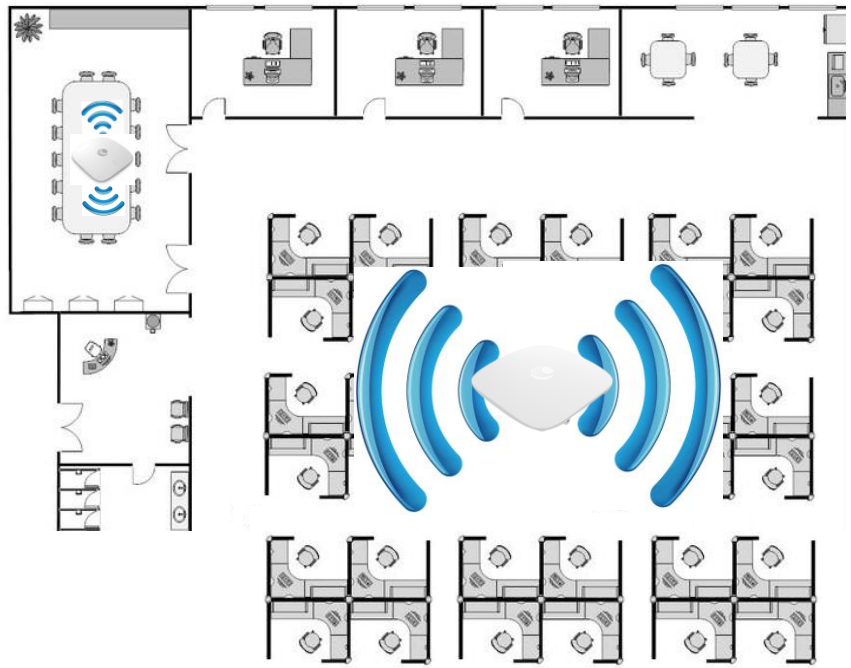
Enterprise			
XV3, XE3, XE5	Low	Medium	High
Mbps	1–25	25–60	60+
Clients per 5GHz 4x4 radio	40+	25-40	1-25
Clients per 6GHz 4x4 radio			

Office Area
40 Clients / 26Mbps each
1,040Mbps aggregate bandwidth

Conference Room
12 Clients / 26Mbps each
312Mbps aggregate bandwidth

1 – 2 radios required in office
1 radio in conference room

Office Network



Number of radios

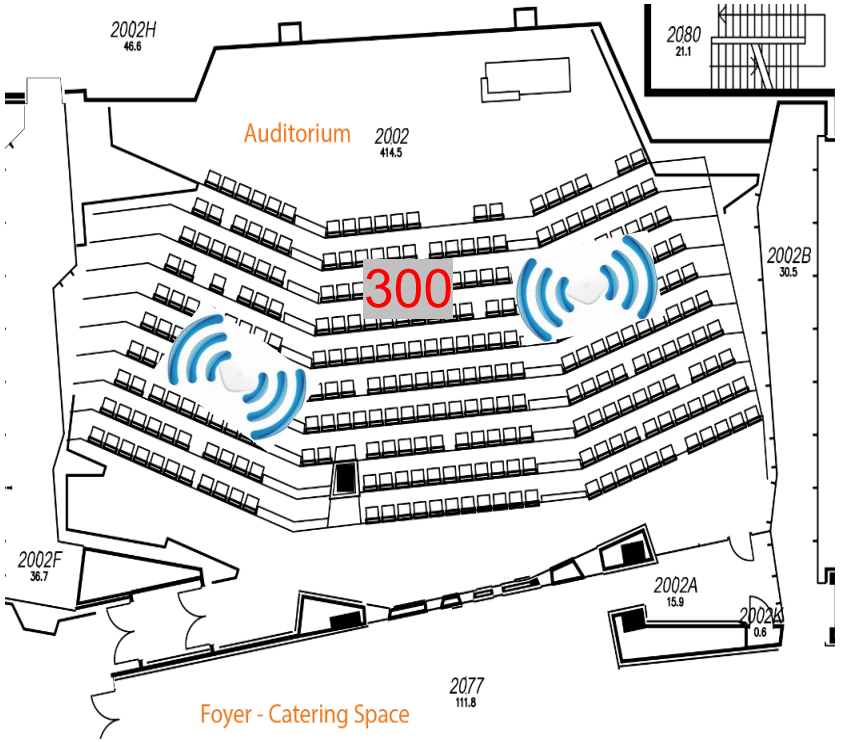
High Density			
XV3, XE3, XE5	Low	Medium	High
Mbps	1–40	40–75	75-100
Clients per 5GHz 4x4 radio	25-50	15-25	10-15
Clients per 6GHz 4x4 radio			

300 students / 40 students per radio

=

8 - 5/6Ghz radios

Auditorium Network



300 Clients / 20Mbps

1,500Mbps aggregate bandwidth

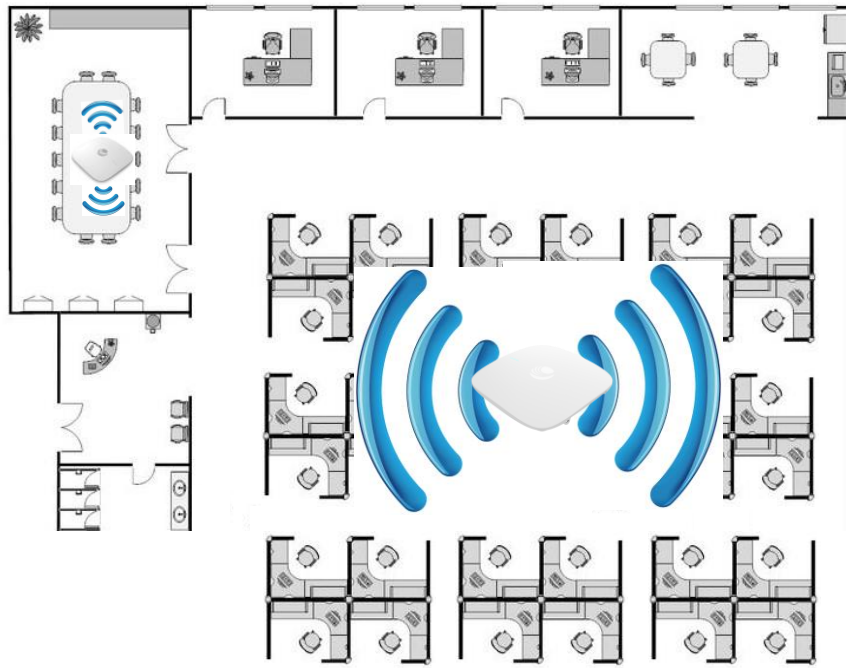
Type of Access Point

Design Office area for performance with one XE3-4

	Number of 5GHz radios	Number of 6GHz radios
XV2-2	1	0
XV3-8	2	0
XE3-4 (SDR)	1/2	1
XE5-8 (SDR)	2/4	2

	Rate with 40MHz channels 1024QAM (in Mbps)
XV2-2 5GHz (2x2)	574
XV3-8 5GHz (4x4)	2,294
XE3-4 5/6GHz (4x4)	1,147
XE3-4 5GHz (2x2)	574
XE5-8 5/6GHz (4x4)	1,147*2
XE5-8 5GHz (4x4)	1,147*2

Office Network



40 Clients / 26Mbps each
1,040Mbps Aggregate throughput

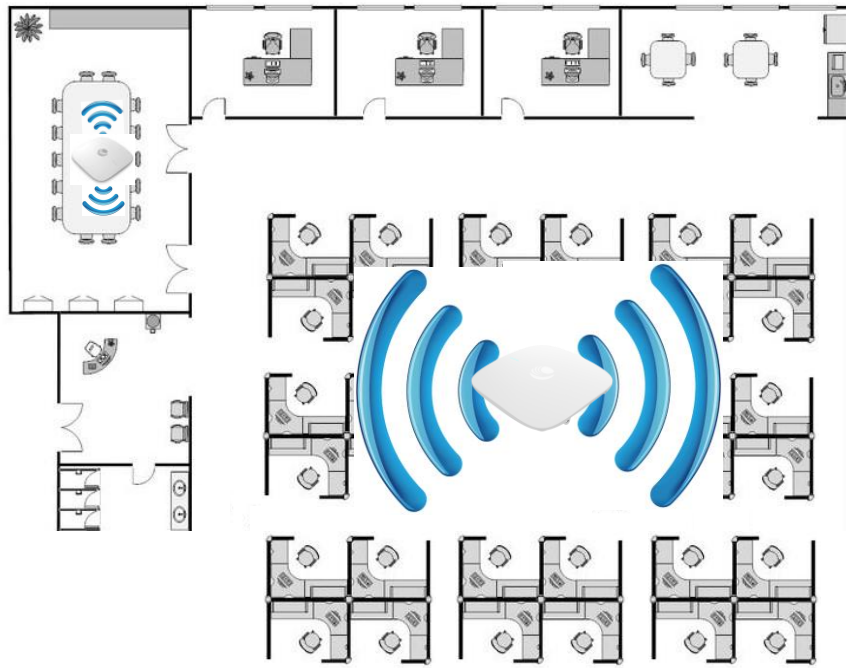
Type of Access Point

Design Office area for performance with one XE3-4

	Number of 5GHz radios	Number of 6GHz radios
XV2-2	1	0
XV3-8	2	0
XE3-4 (SDR)	1/2	1
XE5-8 (SDR)	2/4	2

	Rate with 40MHz channels 1024QAM (in Mbps)
XV2-2 5GHz (2x2)	574
XV3-8 5GHz (4x4)	2,294
XE3-4 5/6GHz (4x4)	1,147
XE3-4 5GHz (2x2)	574
XE5-8 5/6GHz (4x4)	1,147*2
XE5-8 5GHz (4x4)	1,147*2

Office Network



40 Clients / 26Mbps each
1,040Mbps Aggregate throughput

Type of Access Point

	Number of 5GHz radios	Number of 6GHz radios
XV2-2	1	0
XV3-8	2	0
XE3-4 (SDR)	1/2	1
XE5-8 (SDR)	2/4	2

	Rate with 40MHz channels 1024QAM (in Mbps)
XV2-2 5GHz (2x2)	574
XV3-8 5GHz (4x4)	2,294
XE3-4 5/6GHz (4x4)	1,147
XE3-4 5GHz (2x2)	574
XE5-8 5/6GHz (4x4)	1,147*2
XE5-8 5GHz (4x4)	1,147*2

Design for density

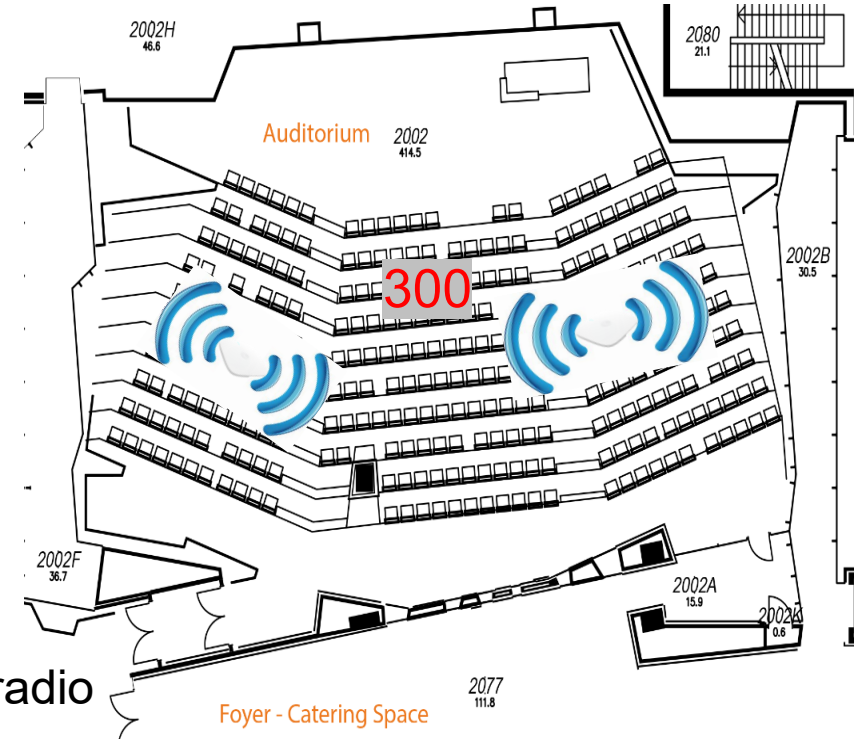
Two XE5-8's

Four 5Ghz radios

Four 6Ghz radios

- 300 Clients = 38 clients per radio

Auditorium Network



300 Clients / 20Mbps

4,800Mbps aggregate bandwidth


Cambium Networks™
Wi-Fi Network
Deployment
Best Practices

Deployment Best Practices

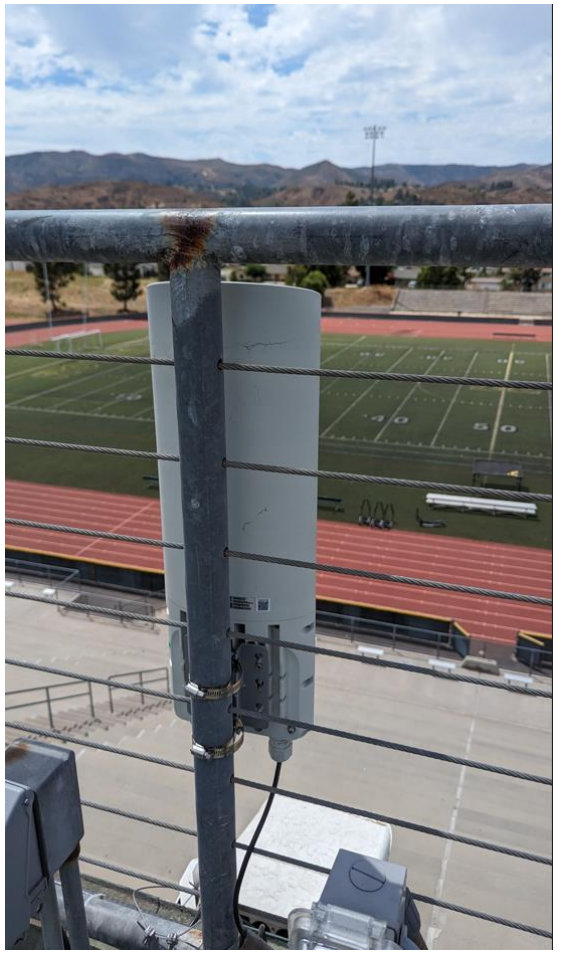
- General Guidelines
- AP Placement
- Education
- Large Meeting Rooms
- Locationing Services
- MDU
- Outdoors / RV Parks
- 2.4GHz vs 5GHz vs 6GHz design impact

AP Placements – General Guidelines

- Select clean/simple mounting options
  - Balance RF coverage with simplicity of deployment
- Consider cable runs to closet / power for PoE injector if used
- Leverage existing cable pulls if possible
- Omni-directional antenna APs should not be mounted higher than 15ft. Performance degradation will happen above this threshold
- Directional APs are typically recommended to direct signal to designated areas and avoid co-channel interference.

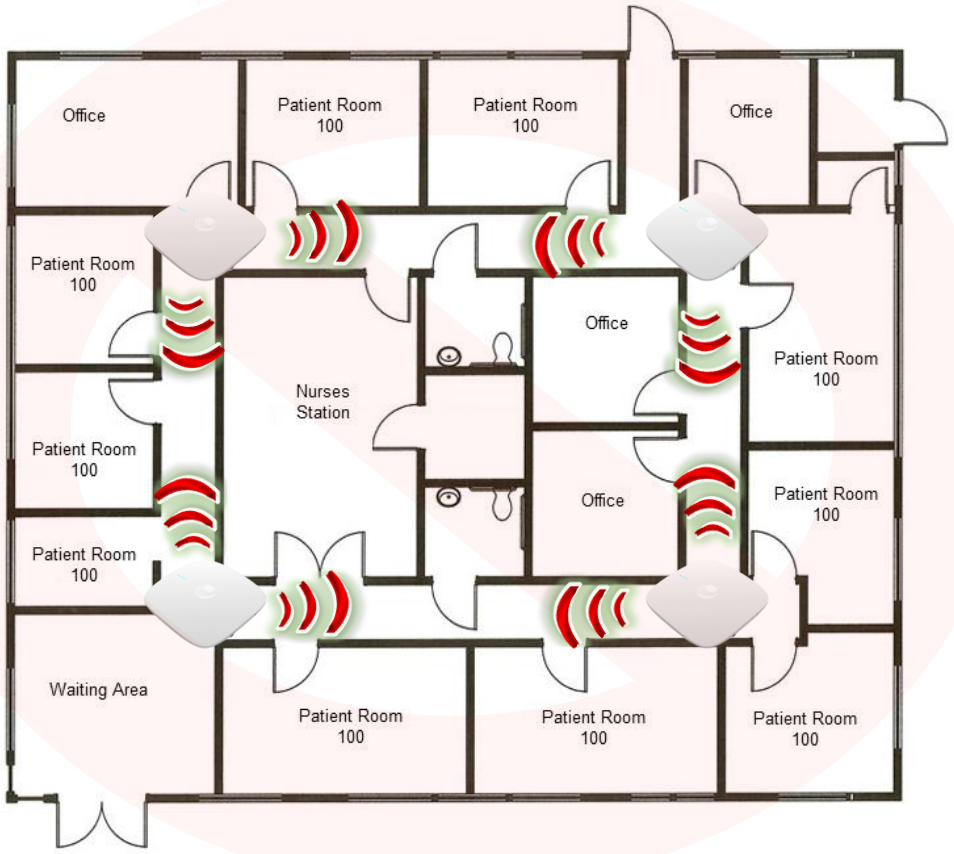
AP Placements

- Ensure the correct degree of tilt to be used, based on height of APs.
- Isolate APs (RF energy) as much as possible.
- Avoid APs having direct line of sight of each other when possible
- Plan for minimum 20-30% overlap in cell overlap



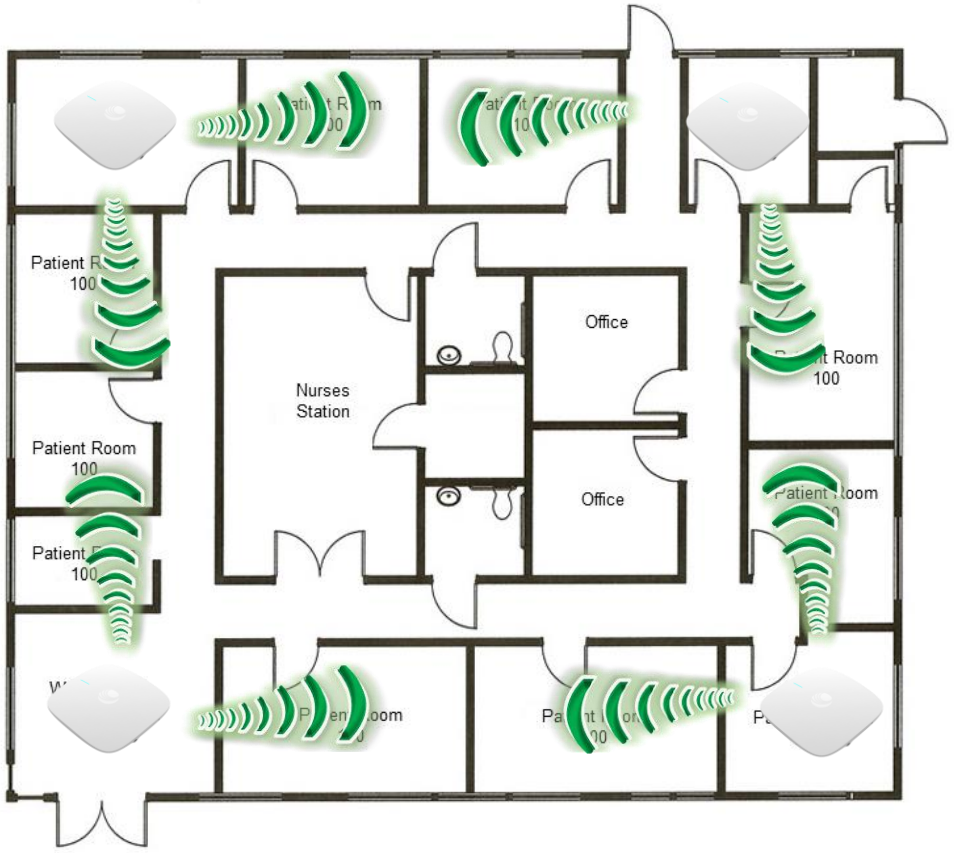
AP placement – Hallway deployment

- Avoid placing APs in hallways and with line of sight of each other
- RF interference, especially in 2.4Ghz band
- RF has harder time penetrating walls at 45° angles
- More prone to multi-path
- More drywall to pass through



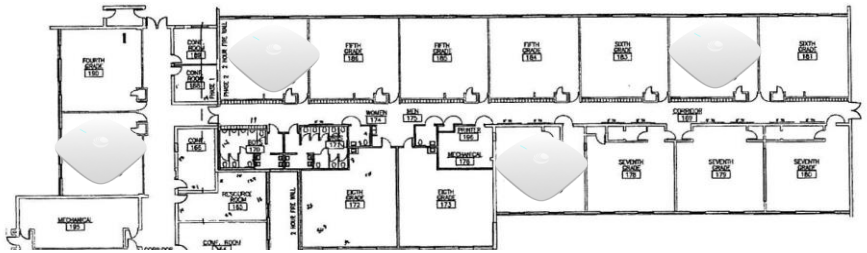
AP placement – In room

- Placing the AP in the room is a better option
- Walls will provide attenuation, and better protection against interference

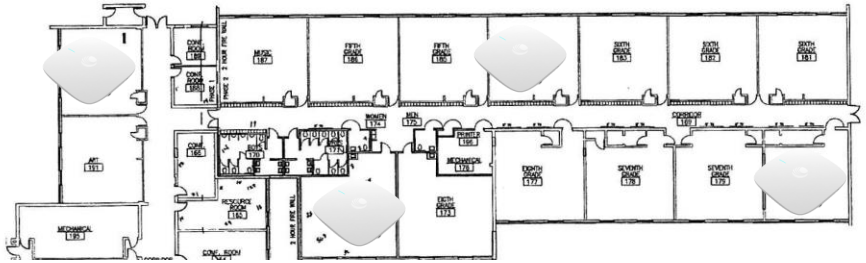


Multi-Level Building Deployment

Stagger APs in adjacent floors

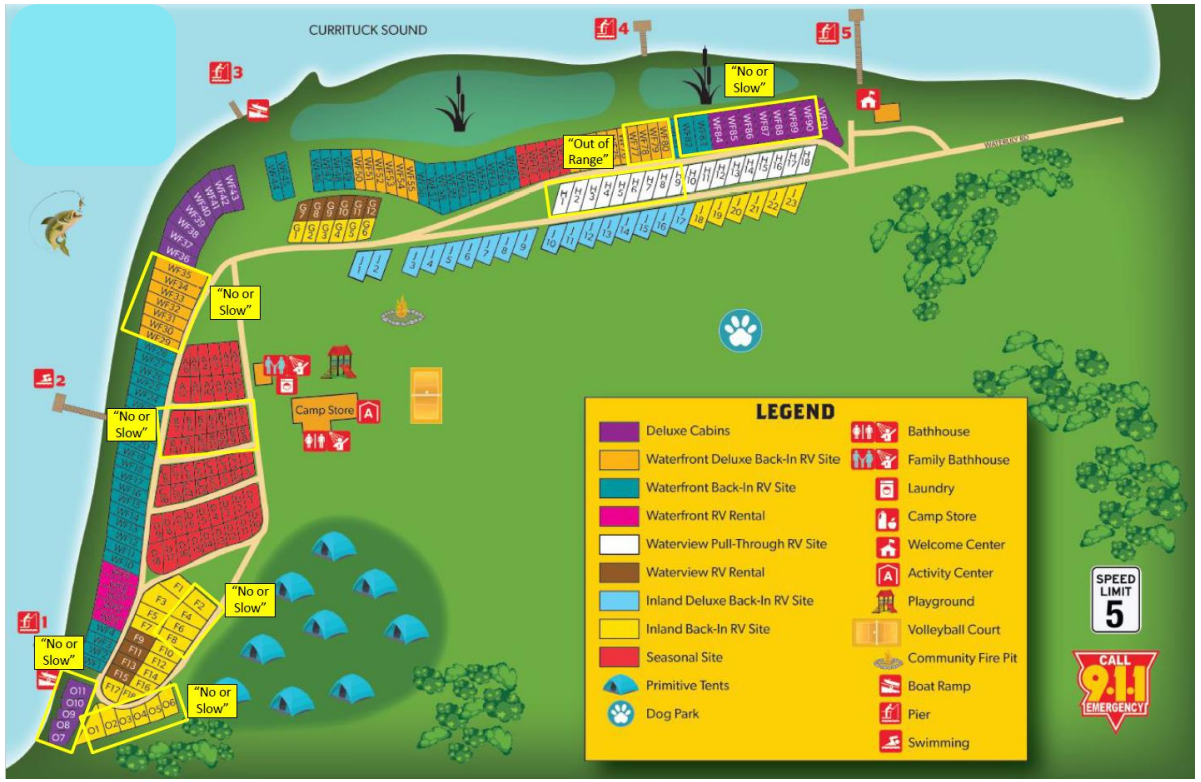


Floor 1



Floor 2

Outdoor Design – Resorts



- Mobile devices include smartphone and tablets. Both low powered devices.
- Network used by guests and staff
- Cabling restrictions, MESH is an option
- Directional antennas are common
- Capacity is generally low to moderate with increasing expectations

Outdoor Design – Antenna Considerations

- AP antenna selection
  - Omni versus Directional
    - Usually comes down to if you need to "target" the signal to specific areas
    - If targeted coverage is required, then directional is usually the choice


Wi-Fi Network Optimization
Cambium Networks™

Wi-Fi network optimization

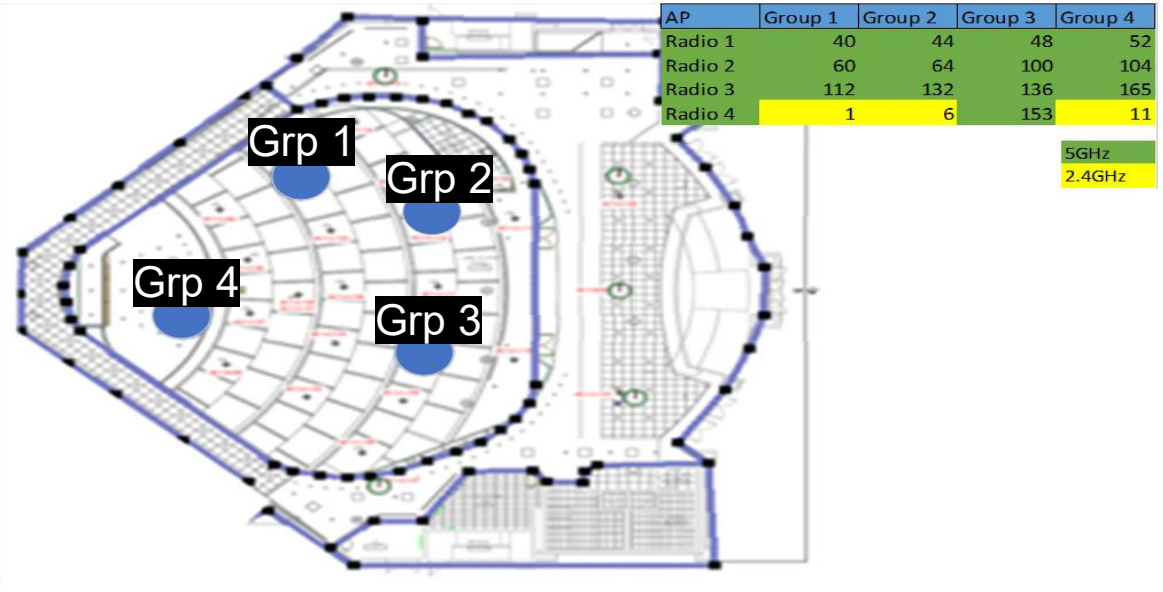
- Channels
- Channel Plans
- Channel Groups
- Power Settings
- Optimization

Channel Planning Best Practices

- Careful channel planning is a big factor of ANY Wi-Fi design, especially a high-density network design
- Use Auto-RF when possible, when necessary, use manual channel assignments to avoid ACI & CCI
- Channel reuse patterns may be necessary
- Disabling 2.4GHz radios may be necessary if more than 3 APs are located near each other
- Create as much channel separation as possible (minimum 3 channels, ex. 36 and 48)
- 40Mhz Channels are typical in most environments
- Channel bonding is typically not recommended in high density to minimize co-channel interference and because channel re-use becomes critical

Channel Planning with Channel Groupings

- Channel Plan Groups are used to simplify the process of manually channel planning a wi-fi network where auto-channel is not recommended
- 2 – 5 radios (depending on the AP model), each with a channel assignment
- Channels are selected to create as much separation possible
- 2.4GHz channels should be assigned manually after the 5GHz & 6GHz groups have been assigned



AP	Group 1	Group 2	Group 3	Group 4
Radio 1	40	44	48	52
Radio 2	60	64	100	104
Radio 3	112	132	136	165
Radio 4	1	6	153	11

5GHz
2.4GHz

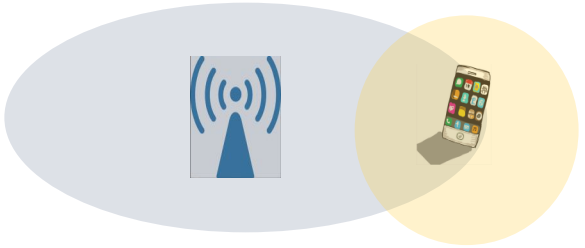
Power Settings Best Practices

- Critical to the performance of the network
  - Too high – roaming/sticky clients, CCI
  - Too low – poor device performance, coverage area
- Cambium APs are defaulted to “Auto”. This is the highest power allowed for that radio

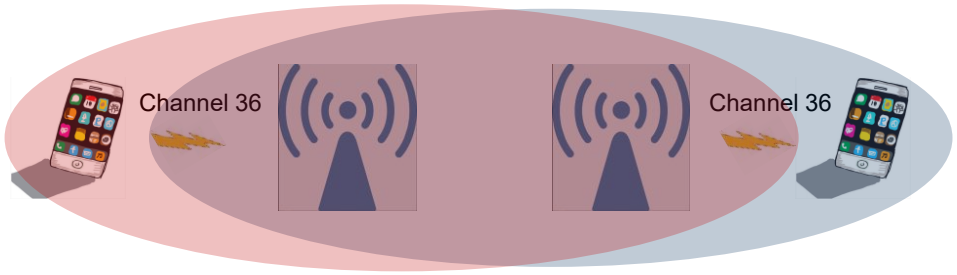
Environment	2.4GHz	5GHz	6GHz
Classrooms	Small (4-9dBm)	Medium (10-16dBm)	Medium (10-16dBm)
Hallways	Medium (10-16dBm)	Large (17-24dBm)	Large (17-24dBm)
Enterprise	Small (4-9dBm)	Medium (10-16dBm)	Medium (10-16dBm)
Outdoor	Max (25-30dBm)	Max (25-30dBm)	Max (25-30dBm)
Auditorium with APs in line of sight Based on # of APs and height of AP. The lower the AP is deployed, the lower the power setting will be.	Preferably Off. Otherwise, 9	Medium (10-16dBm)	Medium (10-16dBm)

Power Settings – Too High

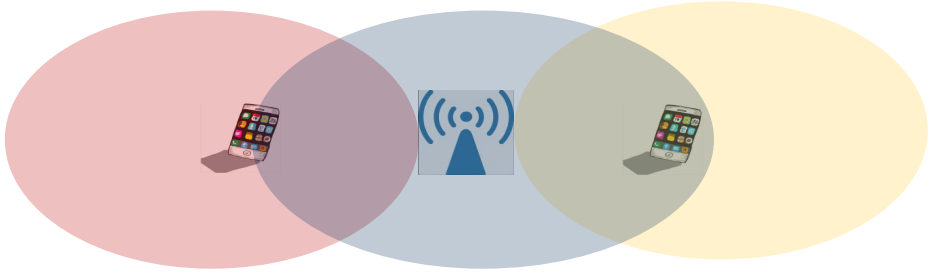
- High CCI
- Hidden nodes
- Asymmetric power – Power from AP exceeds power from client device
- Data corruption from smaller device due to distance from AP - common result is invalid password message
- Very large coverage areas
- Sticky clients and odd roaming behavior



Asymmetric power



Co-Channel Interference



Hidden Nodes

Optimization

Automatic channel selection when booting up

- AP scans surrounding RF environment and selects the cleanest channel available
  - For best results, do this during the day, when network is being used. False readings occur when run off production hours because all channels look clean.
  - Unlikely customer will agree to this due to down time during production hours affecting clients. Therefore, when auto channel is performed during off-peak hours it is not taking into account interferers and attenuation from people throughout the building.
  - Will work for 90% of our customers

Optimization

Automatic channel selection when booting up

- Trust but verify!
- Run report to verify –
  - cnMaestro - Monitor & Manage > Site > Report > Devices >Type – Enterprise Wi-Fi

When NOT to use Automatic channel selection and use a manual channel plan

- Complex designs require manual channel plans and power/RX settings
  - High-Density environments
  - Dense AP deployments
  - High capacity

THANK YOU