The bridge to possible

New Adventures in Wireless: The Journey of Wi-Fi 6 and Private 5G Networks for The Enterprise

Matthias Falkner, Distinguished Technical Marketing Engineer
Robert Barton, Distinguished Sales Architect
Filipe Rodrigues, Technical Solutions Architect

cisco Live!

TECSPG-2432

Cisco Webex App

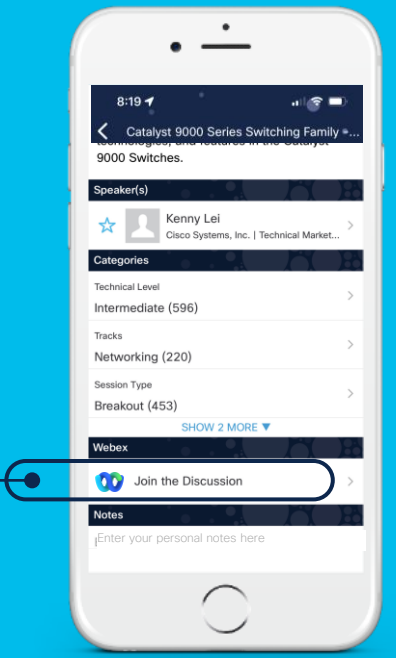
Questions?

Use Cisco Webex App to chat
with the speaker after the session

How

1. Find this session in the Cisco Live Mobile App
2. Click “Join the Discussion”
3. Install the Webex App or go directly to the Webex space
4. Enter messages/questions in the Webex space

Webex spaces will be moderated until February 24, 2023.



Agenda

Robert Barton
Distinguished Architect

Filipe Rodrigues
Technical Solutions Architect

Matthias Falkner
Distinguished Technical Marketing Engineer

Agenda Item	Speaker	Duration	Timing
Introduction to Wireless@Cisco	Rob	45	14:15 – 14:50
5G and Wi-Fi Comparative Discussion	Filipe & Rob	80	14:50 – 16:20
Break		15	16:20 – 16:30
Its all about the use-cases!	Matt / Filipe	40	16:30 – 17:15
Wi-Fi + P5G Architectures: Better-together!	Matt	60	17:15 – 18:15
Closing	Matt	15	18:15 – 18:30
Q&A	All		

cisco Live!

Introduction:
A Brief Introduction to Wireless @ Cisco

cisco Live!

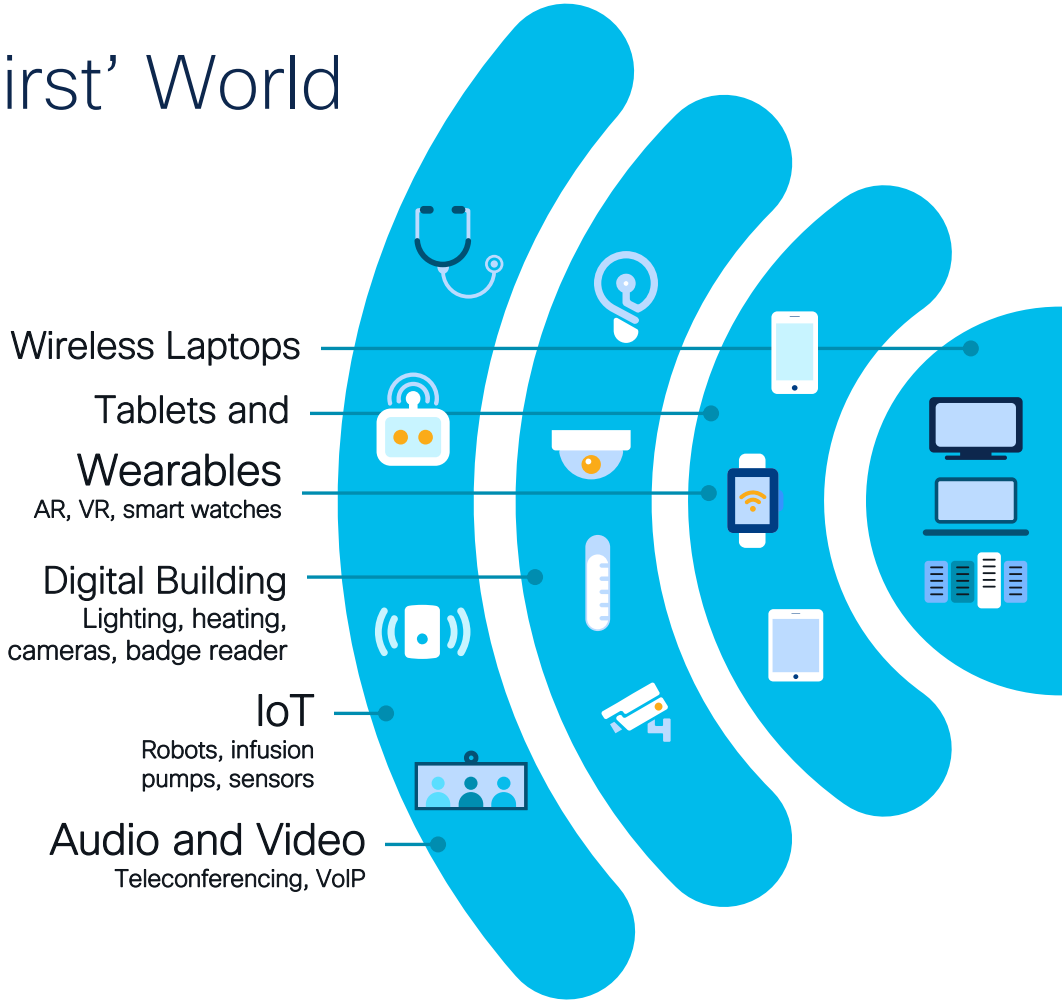
We are in a ‘Wireless-First’ World

Reliable
Always-on, low latency

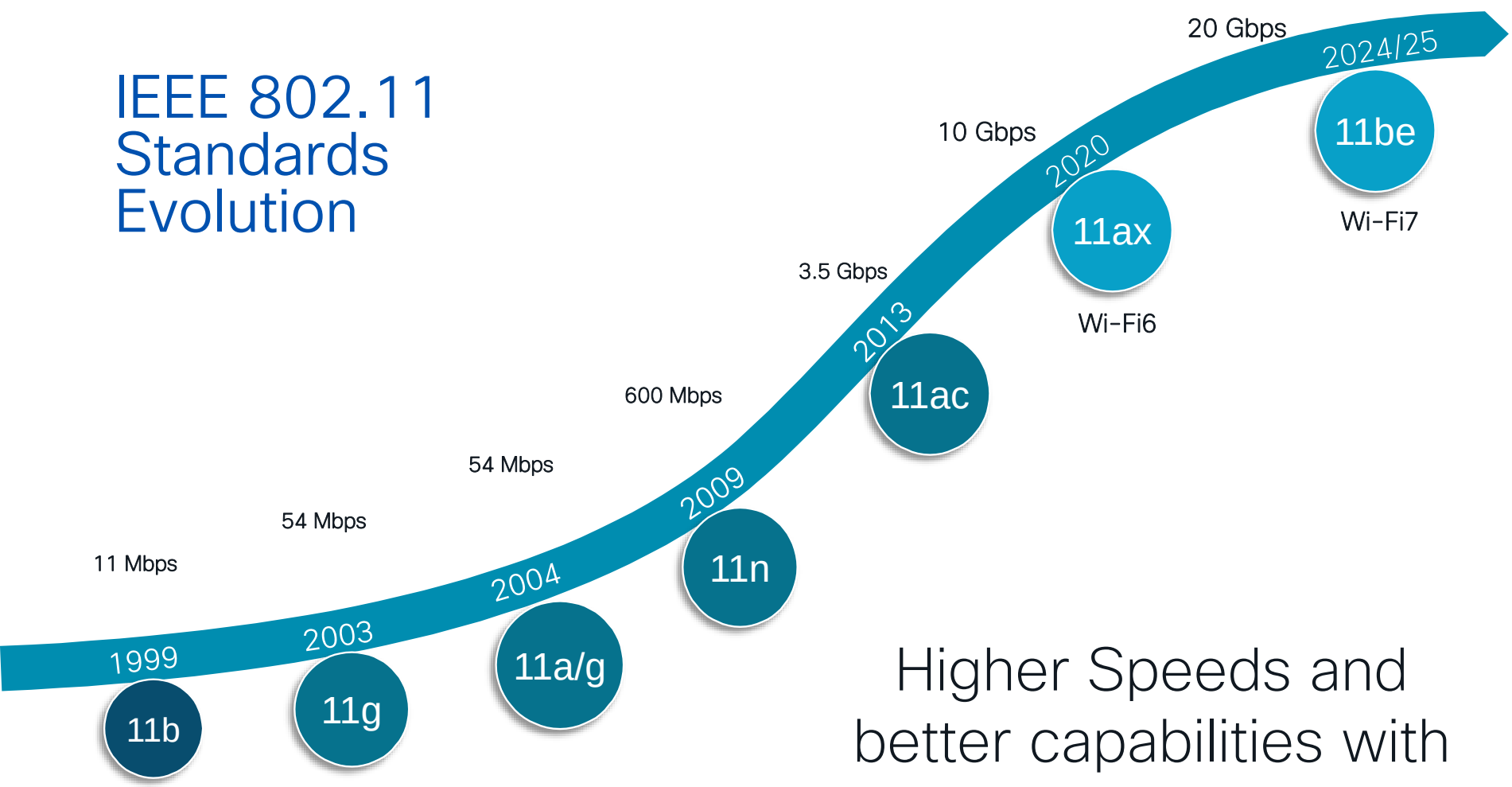
Scalable
Wired for wireless

Secure
Software-defined fabric

Everywhere & Mobile
Heterogeneous Access



IEEE 802.11 Standards Evolution



Higher Speeds and better capabilities with each New Standard

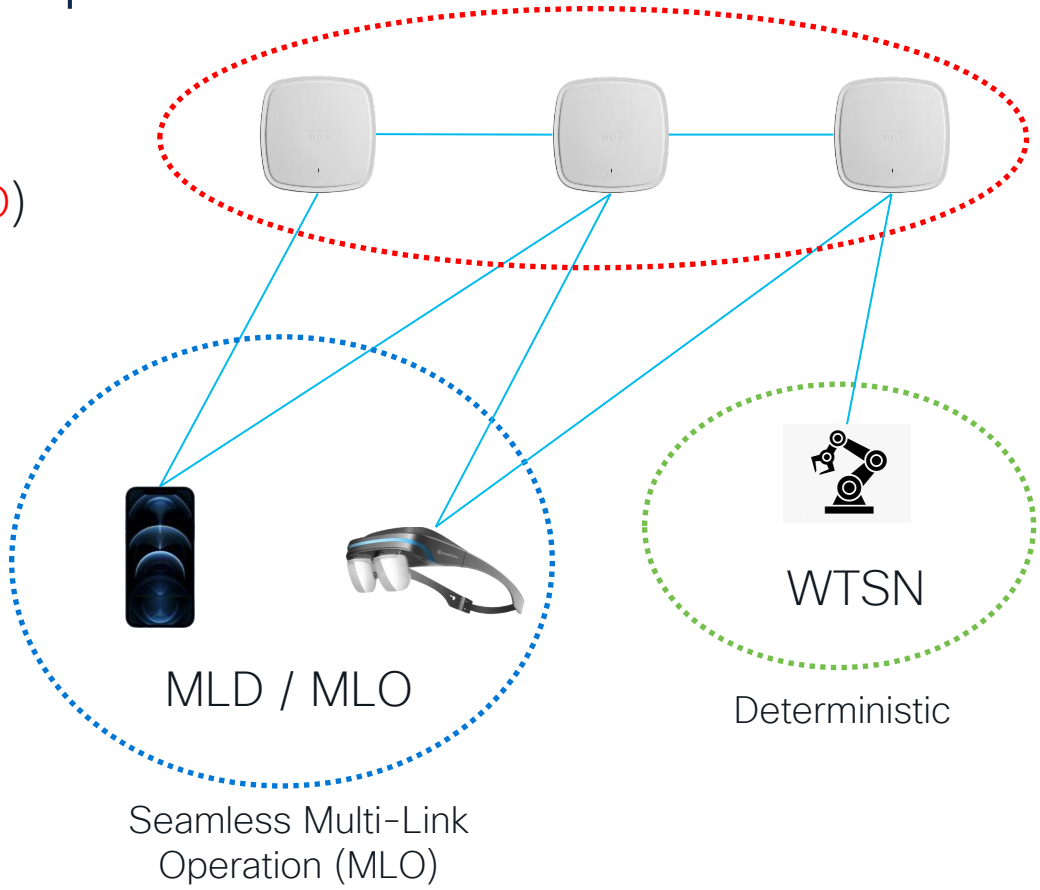
Disruptions Are Coming . . . Wi-Fi7 and beyond
Determinism and Reliability

Yellow = Deterministic Use Cases

Determinism: the ability to support predictable latency and handoff between radio stations (e.g. APs)

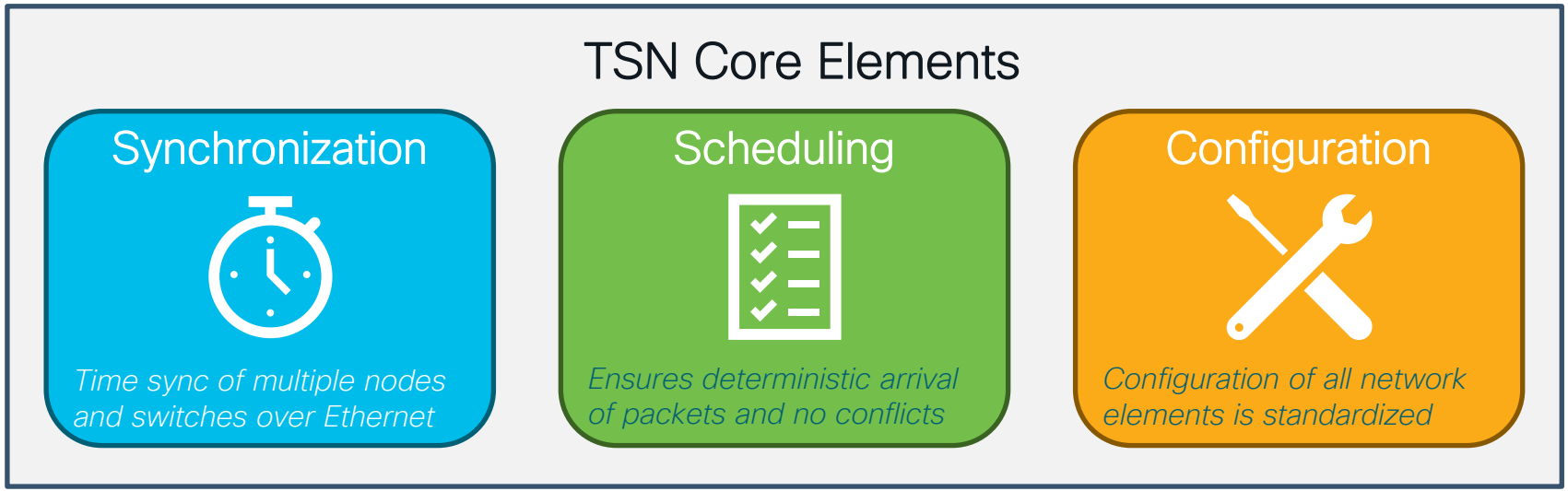
Wi-Fi7 (802.1be) Key Capabilities

1. Enterprise Multi-link Device (MLD)
2. Enterprise Multi-AP coordination (MAPC)
3. Wi-Fi TSN (WTSN)



Time Sensitive Networking (TSN)

- Comprised of ~12 IEEE 802 standards, TSN brings determinism and an enhanced quality of service to Ethernet
- Allows for different traffic types to mix on same physical network and still be deterministic



Wi-Fi7 Deterministic & Reliable Wi-Fi

No wires on this guy!

- Intel and Cisco are collaborating to enable Time-Sensitive-Network (TSN) applications like remote control of robotics for manufacturing in standard Wi-Fi networks
- These applications rely on the new **deterministic** low-delay (<5ms) capability of WiFi6! 12

AR/VR is here (almost)
… and business relevant

Facebook

Epson

Education: Educators predict a bright future for immersive VET (Virtual Environment Technology) in education because of the increasing need for tools that will help ease the process of learning and bring it closer to the student's interests

Estimate throughput and latency for VR/AR technologies

	VR Resolution	fps	Equivalent Resolution	Minimum Throughput (Mbps)	Maximum Streaming Latency (ms)	Maximum Interactive Latency
Early VR	1K X 1K	30	240p	25	40	10
Entry VR	2K X 2K	30	SD	100	30	10
Advanced VR	4K X 4K	60	HD	400	20	10
Extreme VR	8K X 8K	120	4K	1000 - 2350	10	10

Source: [Mangiante]

Apple has optimized silicon for AR

Apple, Google, Facebook, Samsung, Sony, Oculus, HTC and many new entrants all have or are developing AR/VR glasses and capabilities

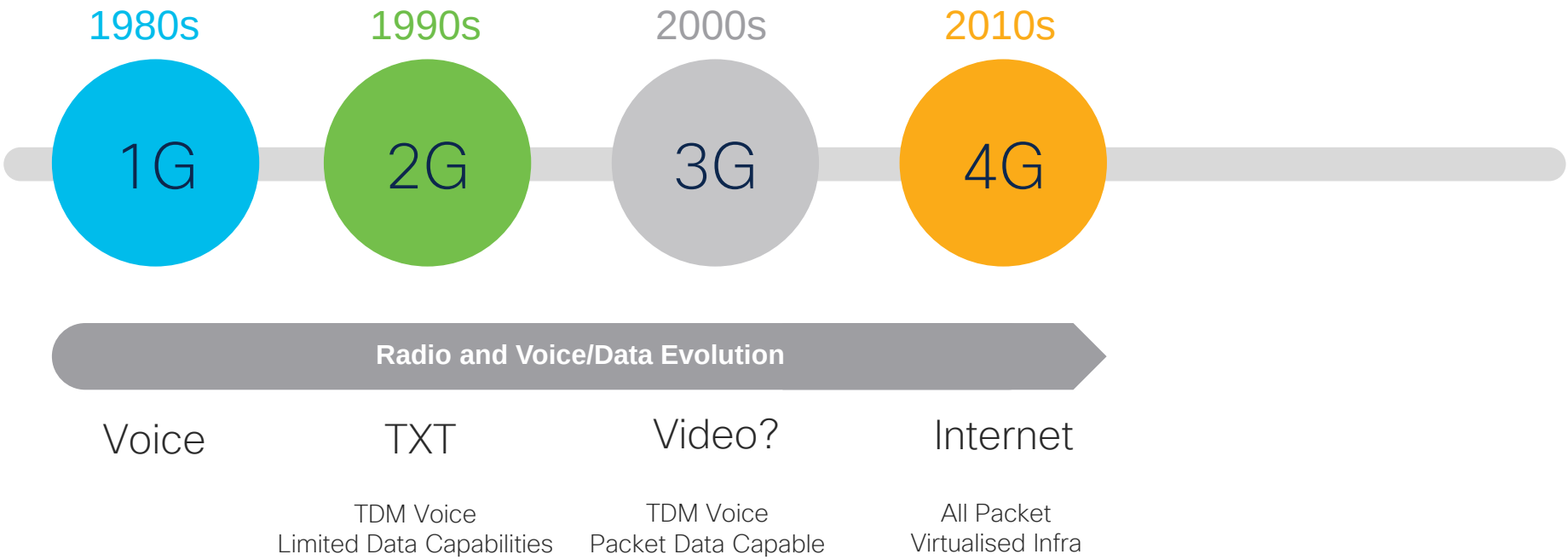
Remote rendering could improve experience and lower batter consumption

The Target

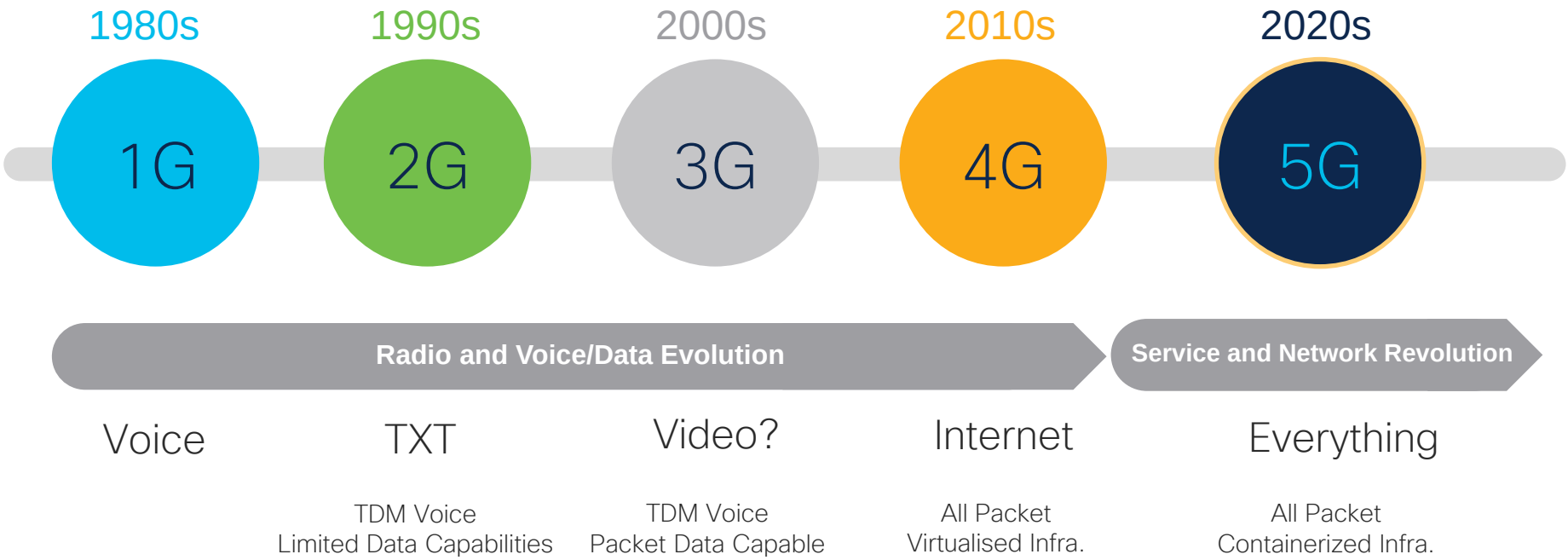
5G – A Short Introduction

cisco Live!

The Maturing World of Cellular Technology



The Maturing World of Cellular Technology



The Bold Vision of 5G
Solving a Host of Old Problems

~1ms
Latency

10+Gb/s
Data Rate

100x
Quicker Download

99.999%
Availability/Reliability

1,000,000
Devices per km²

500km/h
Service Support

Enterprise 5G – 3 Core Building Blocks

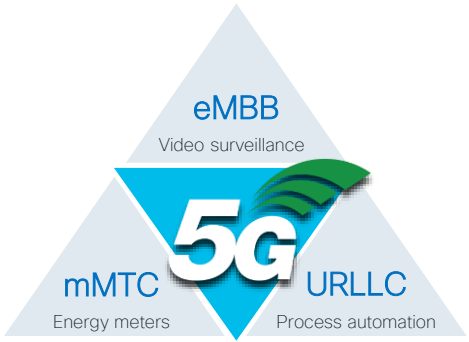
Low latency services will drive maximum 5G demand in the near-future

5G services are optimized for latency, capacity and density

URLLC and eMBB are most relevant in Enterprise

Mobile Broadband

High data rates, High traffic volumes



Massive IoT

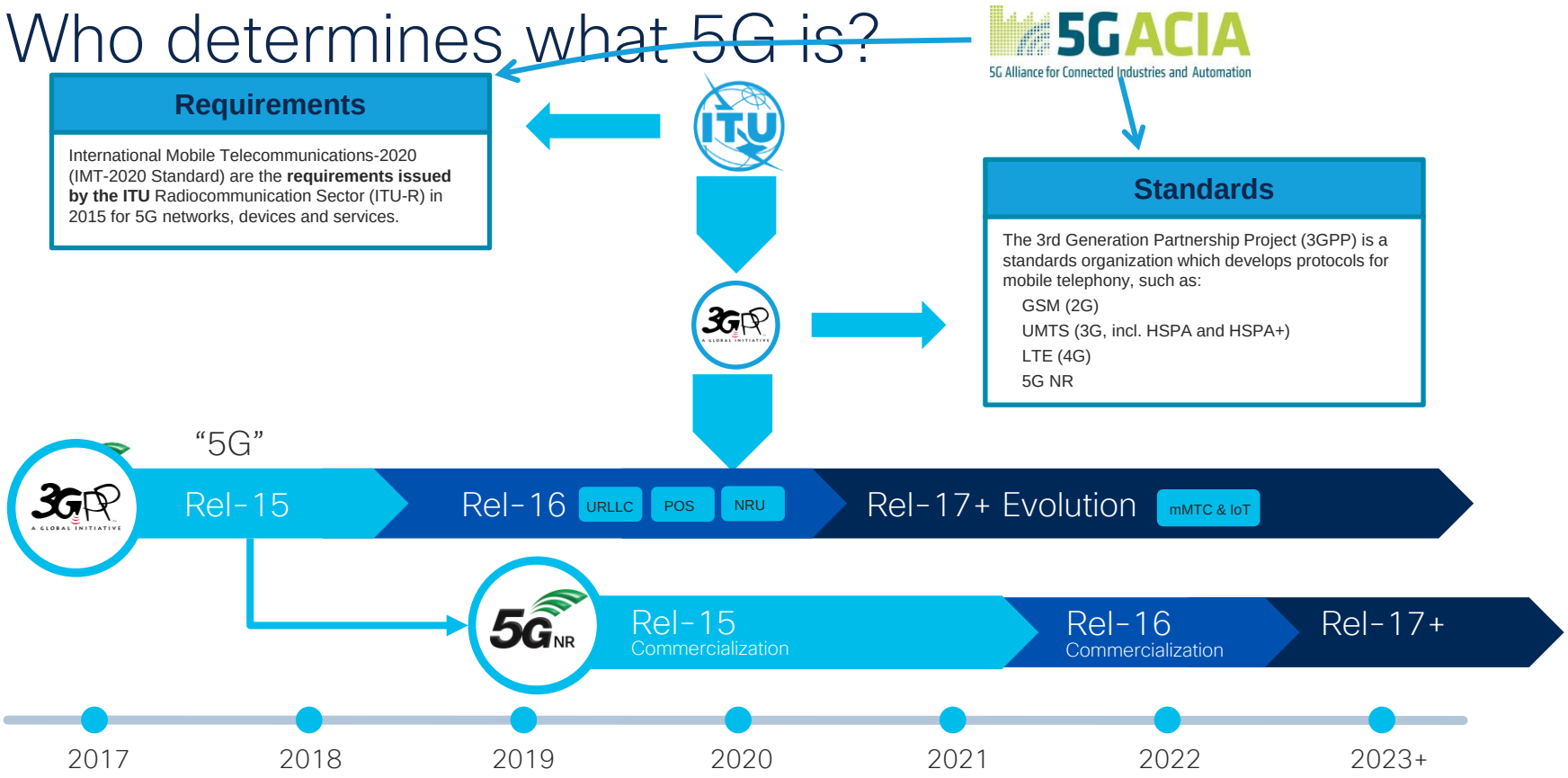
Massive number of small devices, low energy

Low Latency

Ultra-high reliability & Ultra-low latency

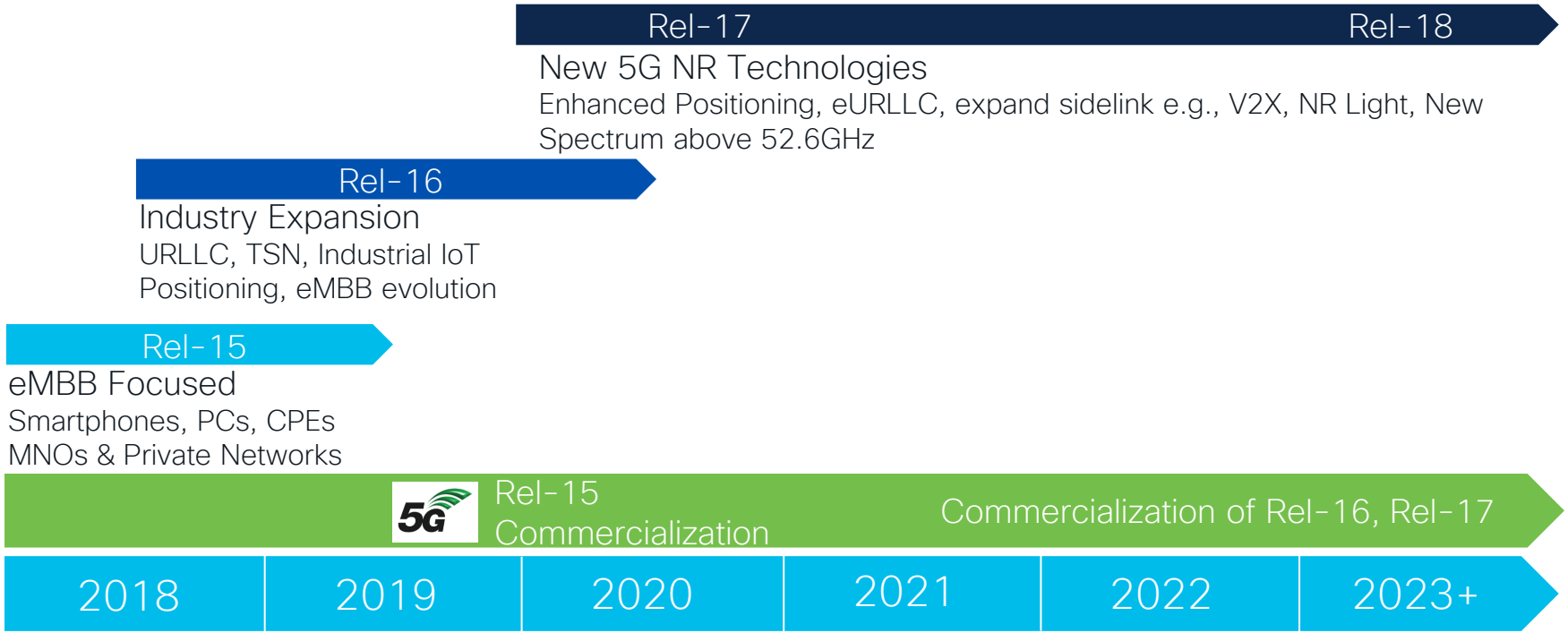
	uRLLC	eMBB	mMTC
Use Cases	Manufacturing, Industrial, Warehouses	High Bandwidth for Real Time Video, Carpeted Enterprise	Super High Density for Smart Cities, Sensors
Requirement	Optimized for Latency 1ms Latency 99.999 Aval.	Optimized for Capacity 10Gbps or more	Optimized for Density of devices 1M Per km2
N/W Needs	Timing, QoS, UPF flexibility	Bandwidth, UPF flexibility	Timing, Bandwidth

Who determines what 5G is?



3GPP 5G Standards

3GPP Releases and Private 5G Features



Low Power Wide Area (LPWA) Networks

Wireless for IoT – Connecting Things, not Humans

Water and Gas Metering

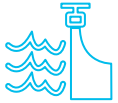
Public Security

Street Lighting

Smart Parking

Location Tracking

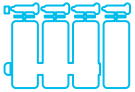
Leak Detection



Disaster Precaution

Livestock

Environment Monitoring



Smart Energy

Waste Management

Agriculture

IoT with 4G (LTE), Moving to 5G

- Two popular variants standardized by 3GPP: Cat-M1 and NB-IoT, both supporting Power Saving Mode (PSM)
- LTE-M / Cat-M1 (“M” stands for “mobility”) – 3GPP Release 13
  - Operates at 1.4 MHz bandwidth with higher device complexity
  - Supports data rates up to 1 Mbps and lower latency
- NB-IoT (Narrow-Band IoT)
  - 200 KHz bandwidth, supporting ultra-low complexity devices
  - Peak data rates of 250 Kbps

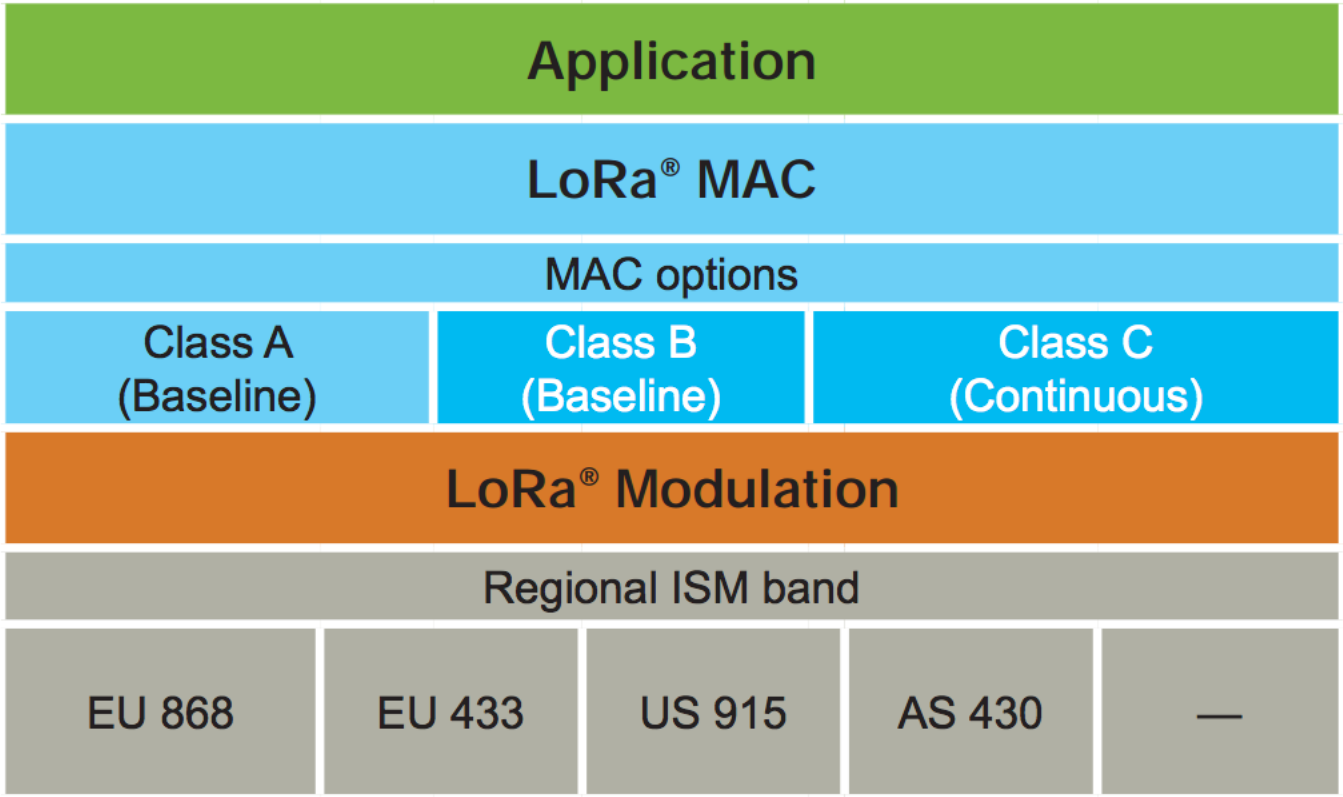
Low Power Wide Area (LPWA) Technology

- Fills the gap between short-range wireless (Wi-Fi) and cellular communication technologies
- Uses unlicensed spectrum (915 MHz in North America, 868 MHz in EU)
- Designed for low power, long range, and lightweight data collection IoT use cases
  - Devices with extended battery life 10+ years
  - Outdoor coverage of up to 20+ km
  - Low service cost and endpoint complexity

The LoRa Alliance (https://www.lora-alliance.org)

- An open, nonprofit association of members that believes the Internet of Things era is now
- Mission: To standardize LPWA networks being deployed around the world to enable Internet of Things (IoT), Machine-to-Machine (M2M), Smart City, and industrial applications
- Cisco is a founding member and serves on the Board of Directors as well as in the Technical Committee
- LoRa Alliance specifies the LoRaWAN protocol above the physical layer and network architecture, and assures interoperability between devices and operators in one open global standard

The LoRaWAN Stack

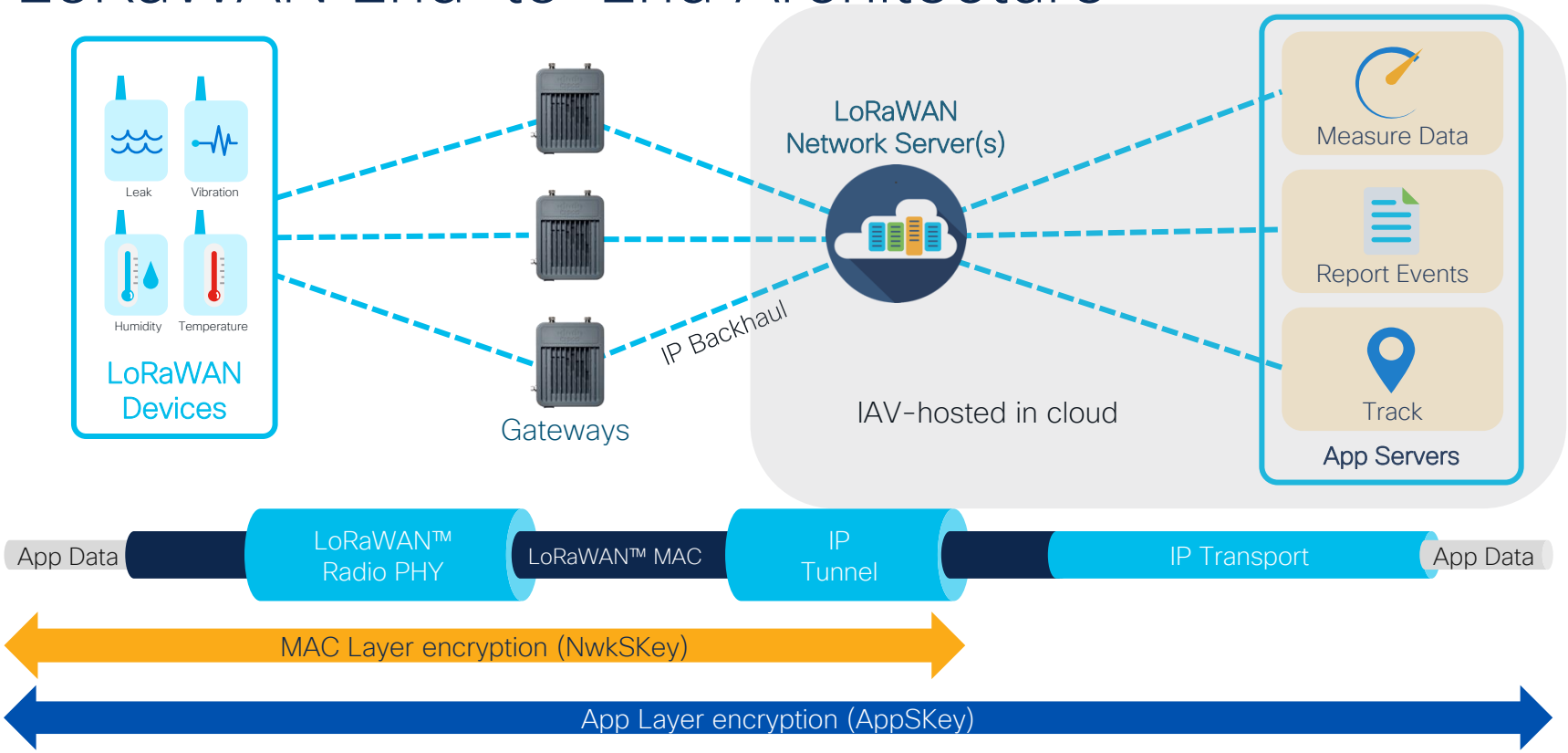


LoRa Alliance Specifications

Semtech modulation

LoRa Alliance Regional Profiles

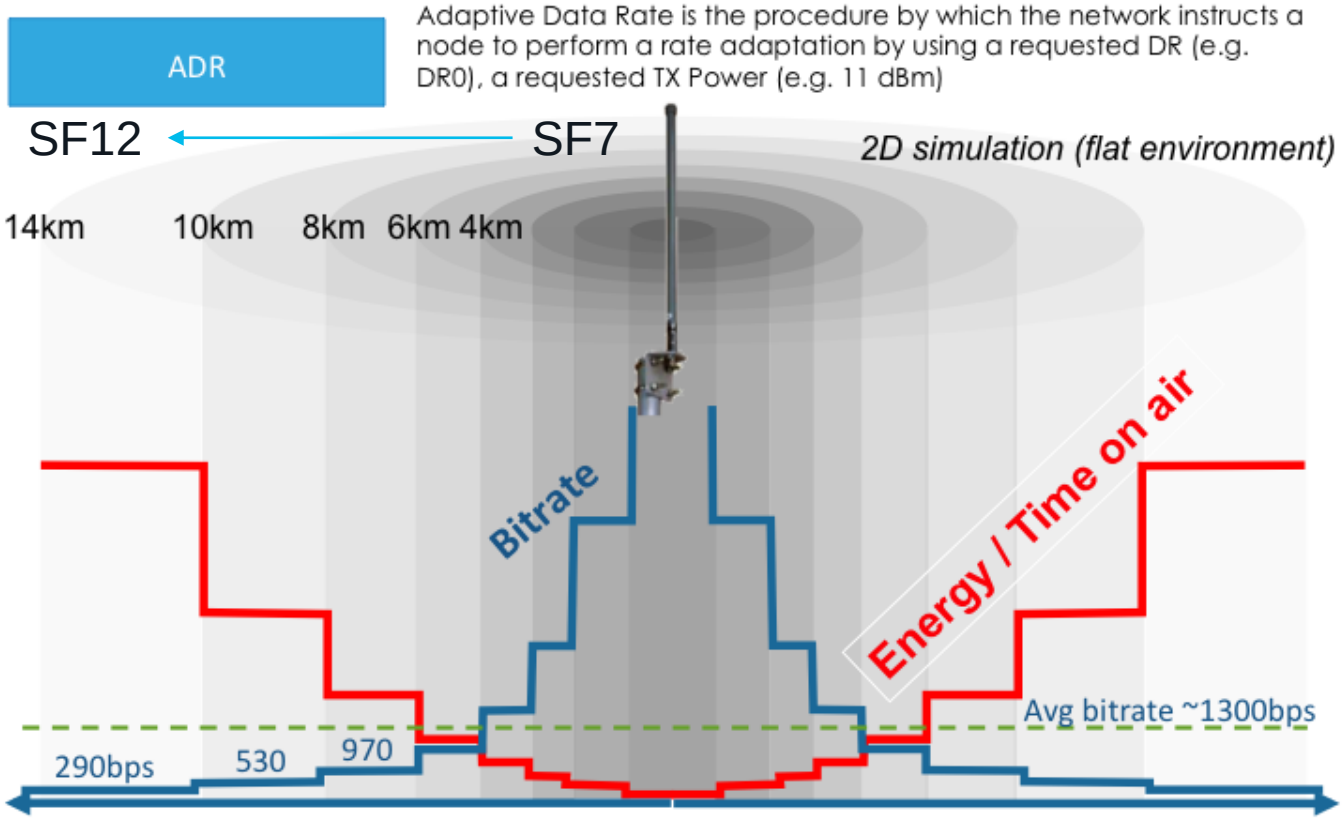
LoRaWAN End-to-End Architecture



Cisco LoRaWAN Gateway

- IP67 Ruggedized IP67
- Dual Power Inputs
- TDOA Geolocation (GPS-free)
- 868/915MHz ISM band

LoRaWAN Data Rates and Range

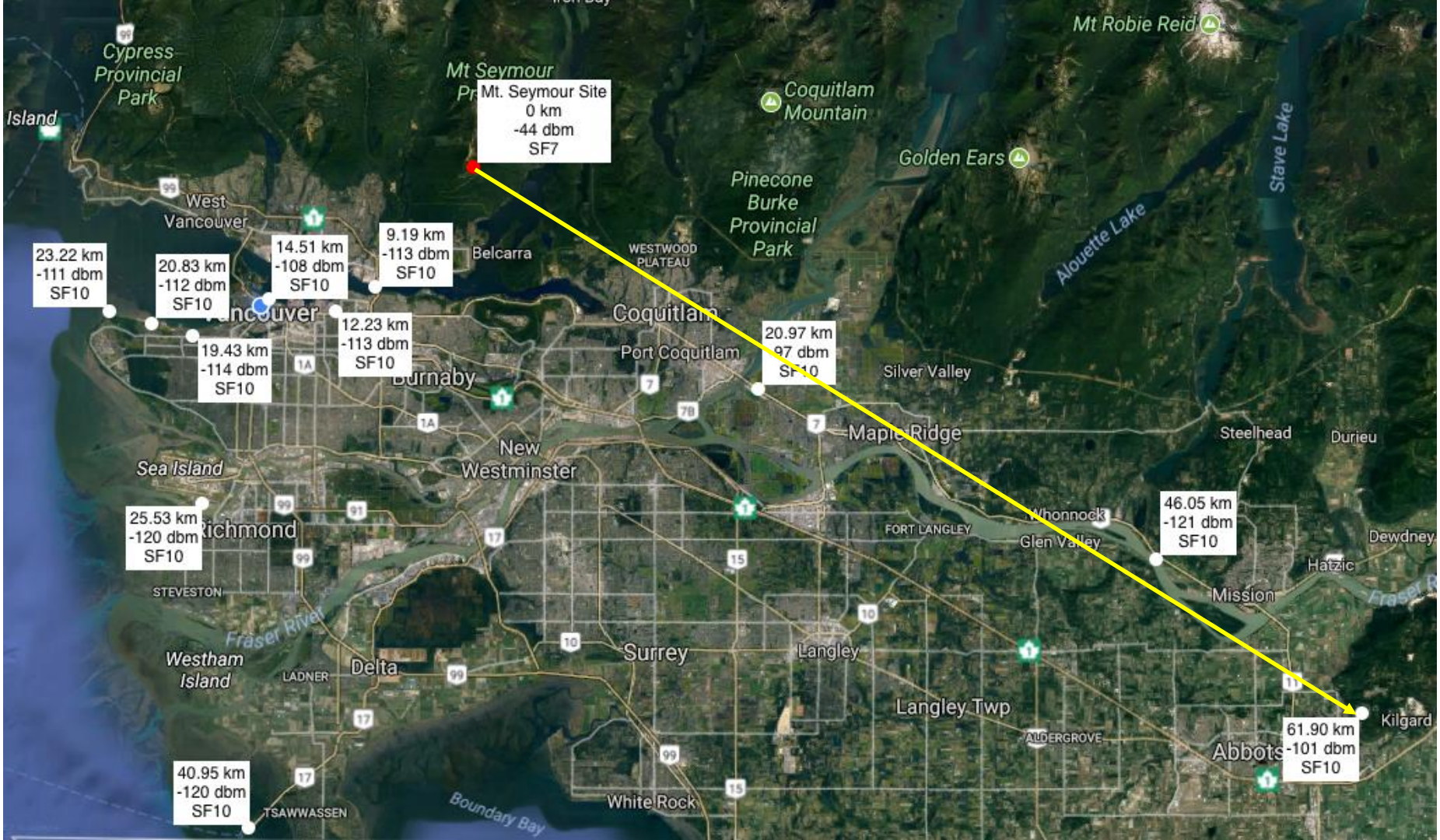


Spreading Factors (SF) 7 – 12 are orthogonal modulation schemes used by LoRaWAN

Each SF has a unique range and bitrate associated with it

LoRaWAN Data Rates vary Depending on Spreading Factor

SF	LoRa BW (KHz)	Coding Rate	Data Rate (bps)	Sensitivity (dBm)
7	125	4/5	5,469	-125
8	125	4/5	3,125	-127.5
9	125	4/5	1,758	-130
10	125	4/5	977	-132.5
11	125	4/5	537	-135
12	125	4/5	293	-137.5
7	500	4/5	21,875	-119
8	500	4/5	12,500	-121.5
9	500	4/5	7,031	-124
10	500	4/5	3,906	-126.5
11	500	4/5	2,148	-129
12	500	4/5	1,172	-131.5


Mt. Seymour Site
0 km
-44 dbm
SF7
23.22 km
-111 dbm
SF10
20.83 km
-112 dbm
SF10
14.51 km
-108 dbm
SF10
9.19 km
-113 dbm
SF10
19.43 km
-114 dbm
SF10
12.23 km
-113 dbm
SF10
20.97 km
97 dbm
SF10
46.05 km
-121 dbm
SF10
25.53 km
-120 dbm
SF10
40.95 km
-120 dbm
SF10
61.90 km
-101 dbm
SF10
Mt Robie Reid
Cypress Provincial Park
Mt Seymour
Coquitlam Mountain
Golden Ears
Stave Lake
Pinecone Burke Provincial Park
Alouette Lake
West Vancouver
Belcarra
WESTWOOD PLATEAU
Coquitlam
Port Coquitlam
Burnaby
Silver Valley
Maple Ridge
Steelhead
Durieu
New Westminster
Sea Island
Richmond
STEVESTON
Whonnock
Glen Valley
FORT LANGLEY
Dewdney
Hatzic
Mission
Fraser River
Westham Island
LADNER
Delta
Surrey
Langley
Langley Twp
ALDERGROVE
Abbotsford
Kilgard
TSAWWASSEN
Boundary Bay
White Rock

Cisco Industrial Asset Vision sensors

A variety of options for telemetry and location tracking

Monitoring environments

Light

Outdoor Temp

Humidity

Door/Window

Occupancy

Water Leak

Monitoring assets

Machine Temp

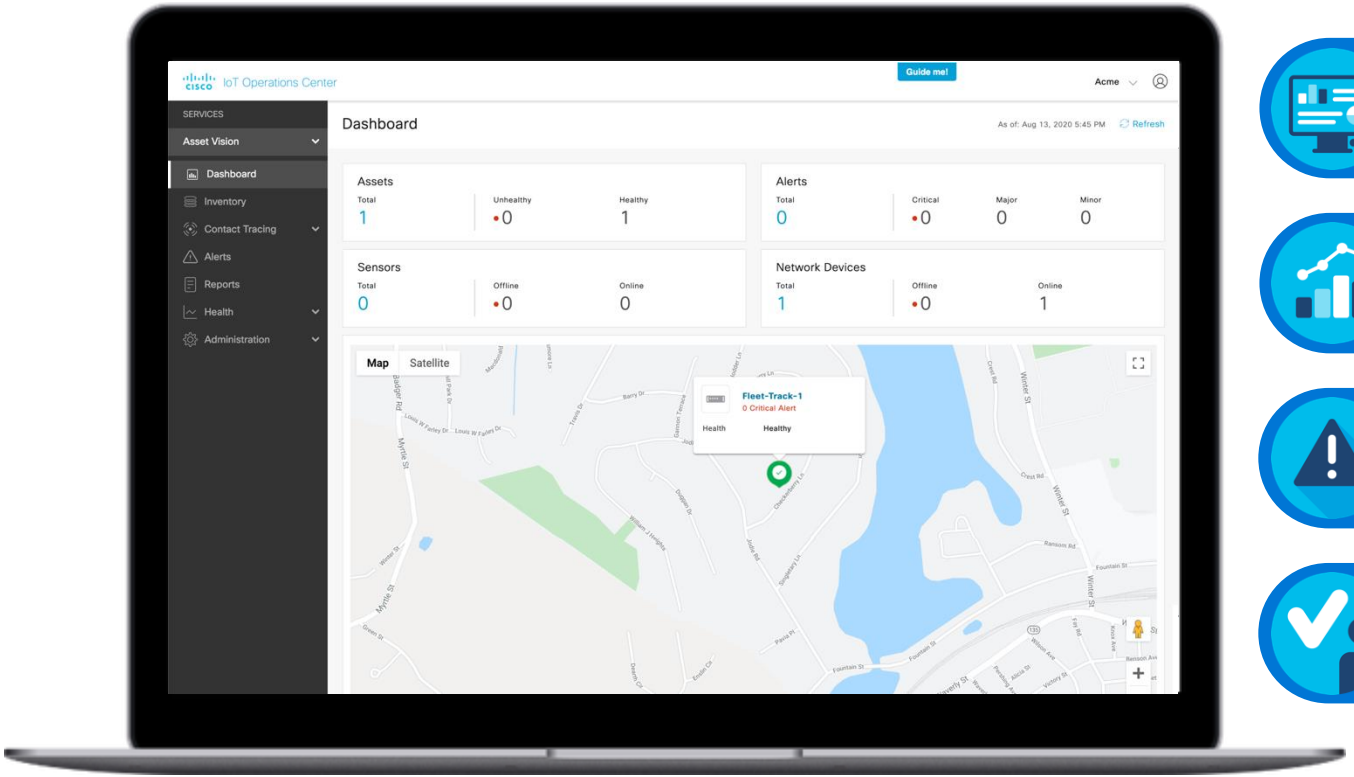
Geolocation

Product Temp

Refrigeration

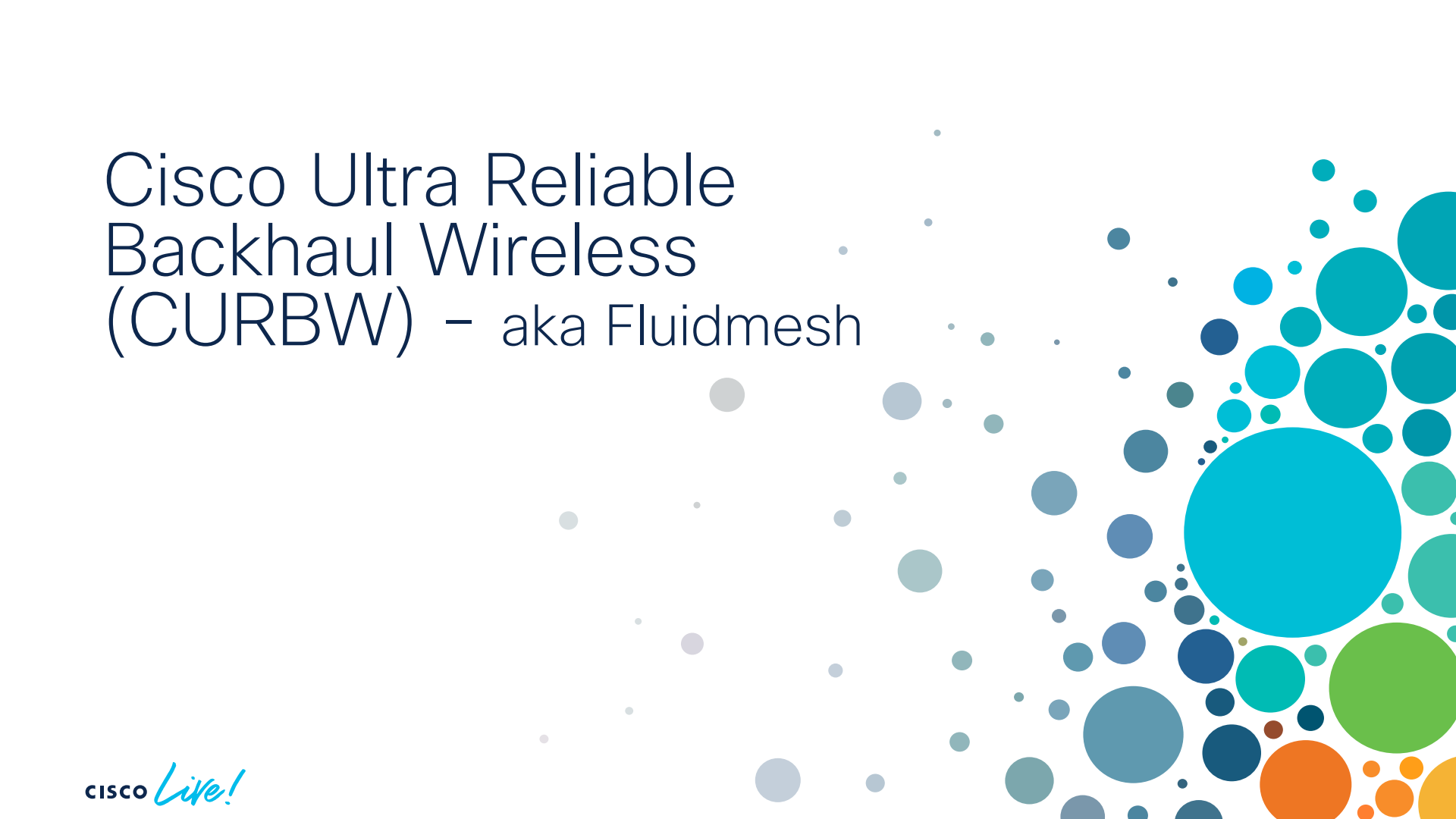
Ruggedized. IP65, IP67 rated for outdoor or industrial indoor environments

Asset Vision Powerful visibility across your business



- Single pane of glass visibility by asset and location
- Simple, automated reporting
- Flexible alerting – includes email and mobile notifications
- Role-based access and insights

Cisco Ultra Reliable Backhaul Wireless (CURBW) – aka Fluidmesh



cisco Live!

Cisco Ultra-Reliable Wireless Backhaul (CURWB)
Supporting Ultra Reliable Communications Today

Industrial devices

Reliable Network

Cisco Ultra-Reliable Wireless Backhaul

Fixed and mobile wireless backhaul

Ultra-low latency
Ultra reliable
High bandwidth
Fast mobility
Easy to deploy
Custom to your needs

Critical applications

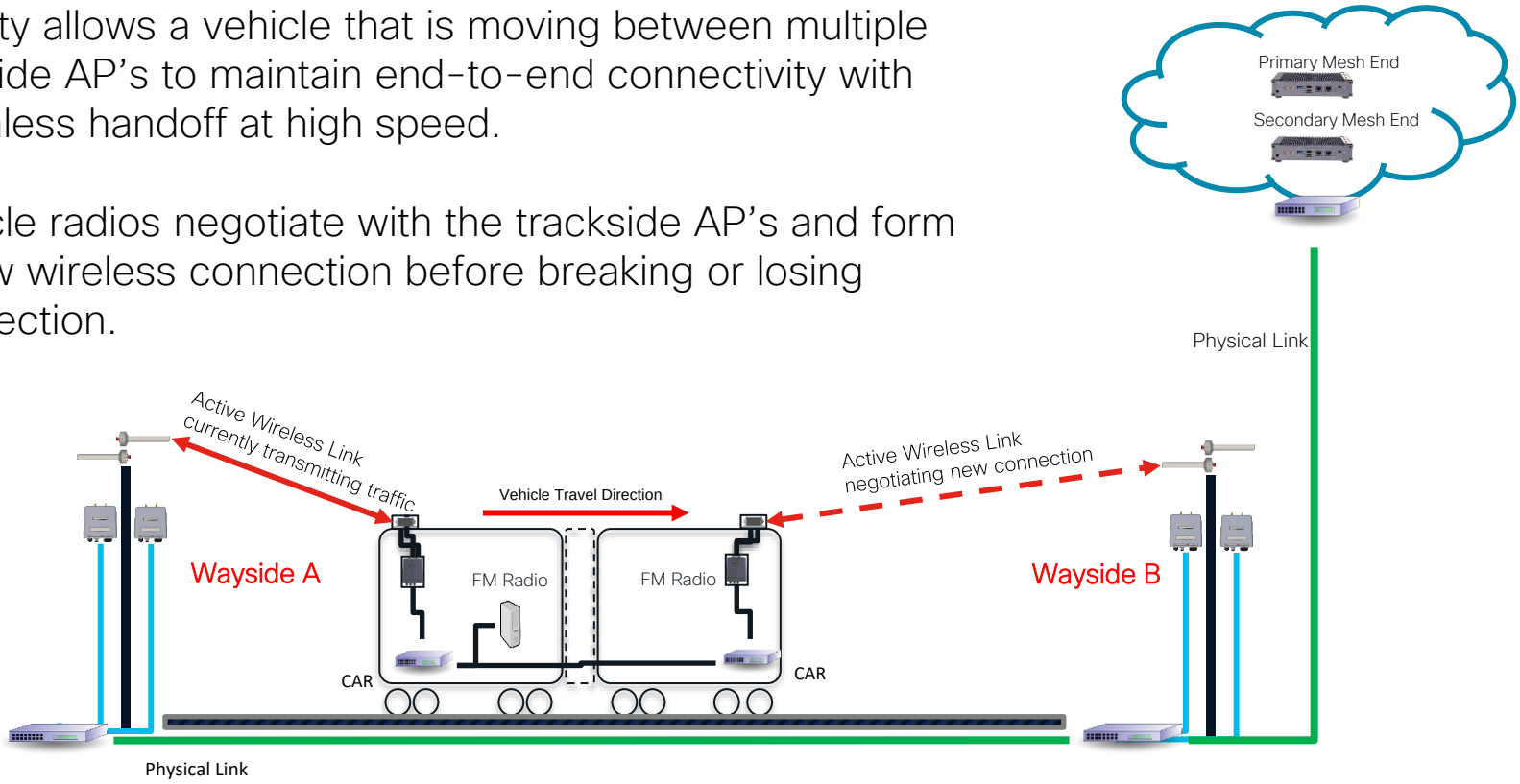
Autonomous vehicles control
Tele-remote machine operations
Communications-based train control
Train-to-ground communications
Terminal operations systems (TOS)
Live HD video-surveillance
Emergency response systems

cisco The bridge between moving devices and business-critical applications

Fluidity

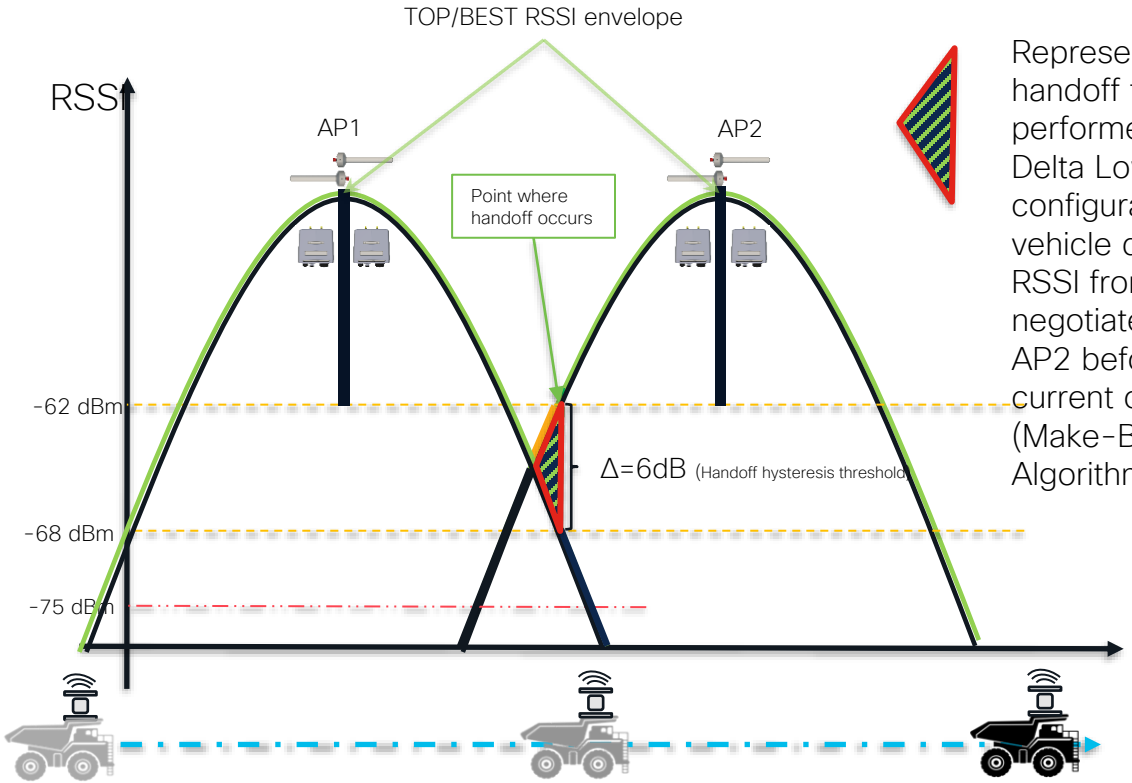
- Fluidity allows a vehicle that is moving between multiple wayside AP's to maintain end-to-end connectivity with seamless handoff at high speed.

- Vehicle radios negotiate with the trackside AP's and form a new wireless connection before breaking or losing connection.



Fluidity Seamless Handoff – How it Works

Radios always operate on the top line (RSSI Envelope), handing over to the next available AP as soon as the RSSI level is better than a designated delta value (Hysteresis Threshold).

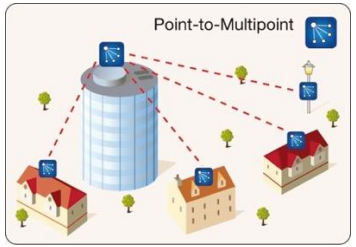


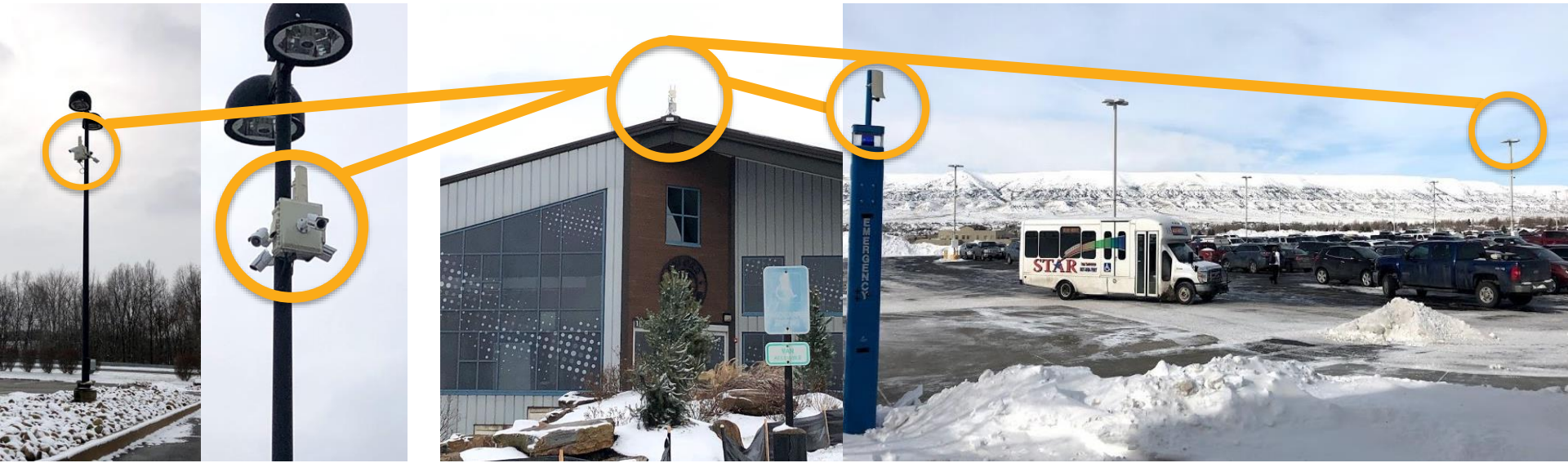
Dynamic Handoff Decision

Represents area where handoff to a new AP is performed according to the Delta Low and Hi configuration. Radio on the vehicle detects an increase in RSSI from AP2, where it negotiates a connection with AP2 before breaking the current connection with AP1 (Make-Before-Break Algorithm).

CURBW Use Case Examples

Use Case Example: Extending Wi-Fi, CCTV, E-VoIP





Introducing Cisco Catalyst IW9167 Series

One hardware, two wireless technologies

Industrial and outdoor

Wi-Fi 6E access point

OR

Cisco Ultra-Reliable Wireless Backhaul

Improved data rate: up to 7.8Gpbs
Improved availability: up to 99.999%

- IP67, shock/vibration, extreme temperatures
- Cisco secure
- Flexible and sustainable

Tri-radio
2.4 GHz, 5GHz, 5/6GHz

4x4
4 spatial streams

Multigigabit
RJ45, M12 or SFP+

PoE and DC power

GNSS, BLE, Scanning Radio

Learn more, see product and demo at the WoS

Catalyst IW9165E Rugged access point and wireless clie

The 6 GHz-ready wireless client that connects mobile industrial assets

NEW

Autonomous robots and vehicles for manufacturing, ports, logistics

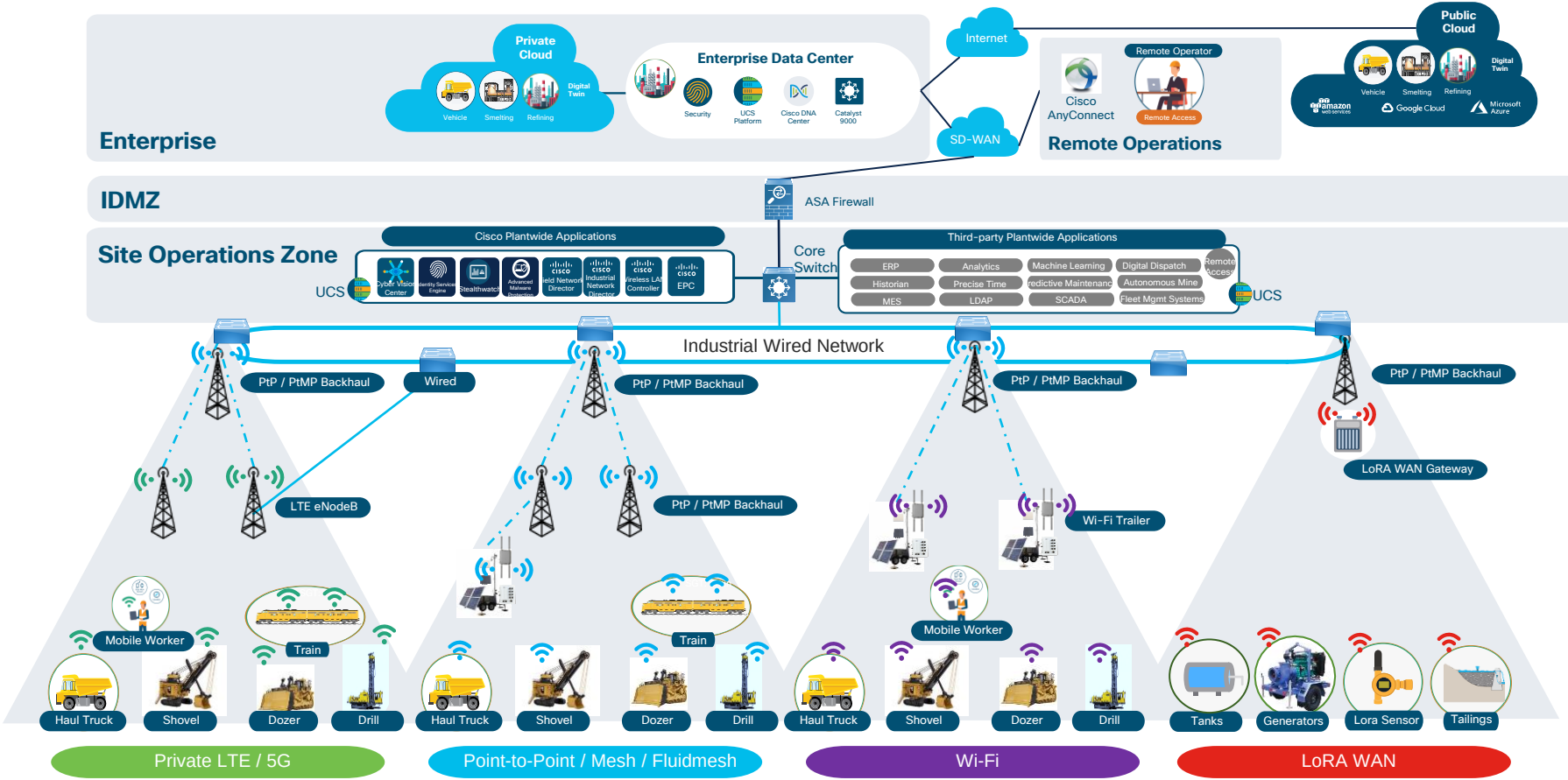
Rail and light-rail rolling stock

EN50155 certified for rail operations

- **Connect more machines to your network**
  Compact form factor for integration in existing assets
- **Get more from your industrial assets**
  BLE, GNSS, GPIO capabilities for advanced use cases
- **Connect moving vehicles to your systems**
  Ultra low latency and zero packet loss during handoff
- **High performance and modular wireless**
  Dual 802.11ax radio with wide choice of antenna
- **Works with your Wi-Fi infrastructure**
  Supports WGB or URWB. Evolve as your needs change

Ultra-reliable broadband wireless connectivity for moving machines and vehicles

Different Wireless Solutions, Different Problems



Wi-Fi and 5G Comparative Discussion

What changed in Wi-Fi 6/6e?

For your reference

6GHz Spectrum: 1.2 GHz of additional unlicensed spectrum to support high-bandwidth applications with Wi-Fi 6e	Bandwidth improvements
Uplink and Downlink Orthogonal Frequency Division Multiple Access (OFDMA): Increases network efficiency and lowers latency for high demand environments	Packet latency improvements
Multi-User Multiple Input Multiple Output (MU-MIMO): allows more data to be transferred at once and enables an access point to transmit to a larger number of concurrent clients at once	Parallel transmissions
Parallel processing: enables greater capacity by allowing MU-MIMO and OFDMA to function in parallel and then adding channel reuse with BSS coloring	Channel Reuse With BSS Color
1024 Quadrature Amplitude Modulation Mode (1024-QAM): increases throughput in Wi-Fi devices by encoding more data in the same amount of spectrum	Faster Speed more Radios and 1024 QAM
Target Wake Time (TWT): significantly improves battery life in Wi-Fi devices, such as Internet of Things (IoT) devices	Better Battery Life
Mandatory WPA3: protection of the management frames and simultaneous authentication on both sides	Improved Security

What does 5G offer (as of Release 16)?

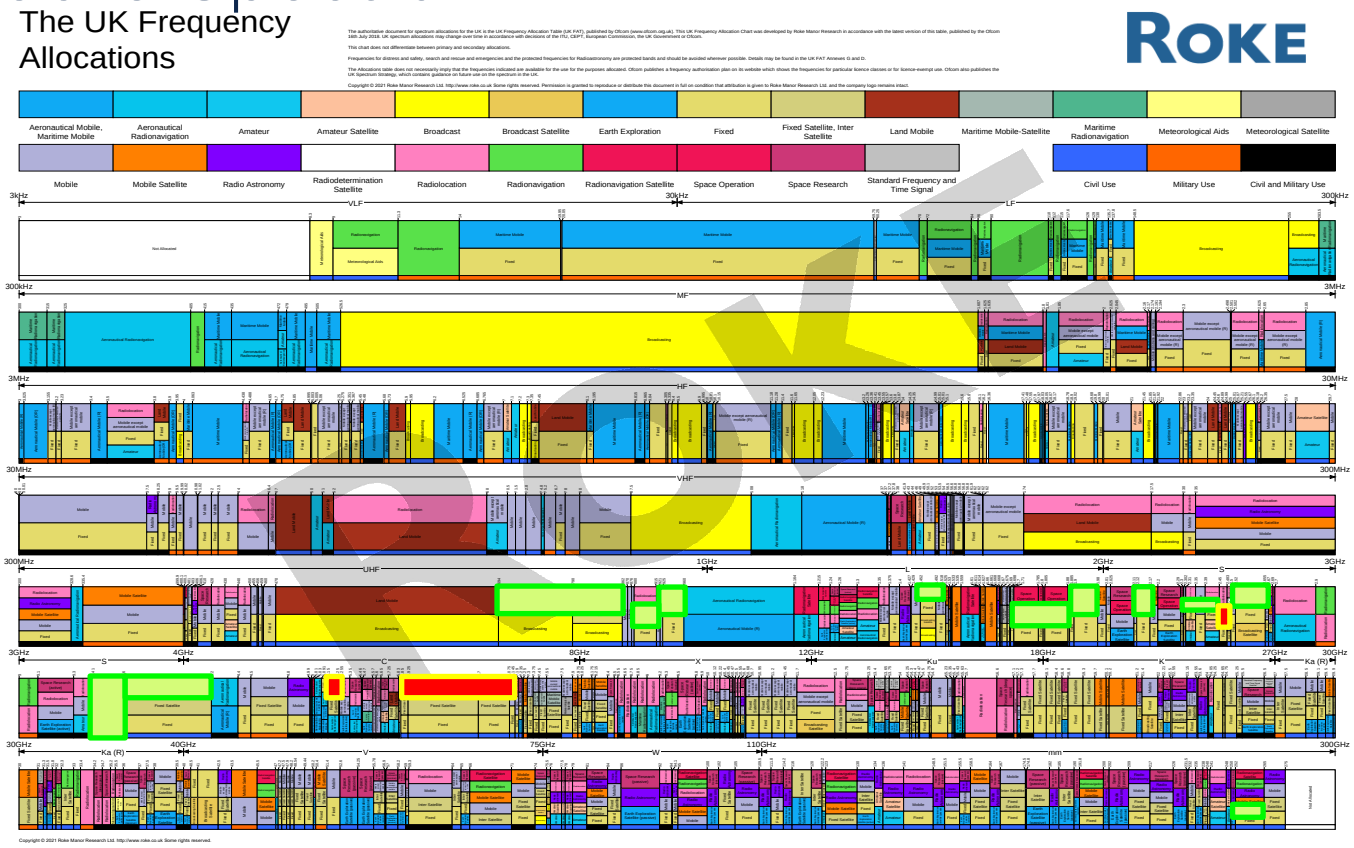
For your reference

New Spectrum Bands: 3.5 GHz and mmWave *licensed* spectrum to support high-bandwidth enhanced mobile broadband applications	Bandwidth improvements
Uplink and Downlink Orthogonal Frequency Division Multiple Access (OFDMA): Efficient use of spectrum to support ultra-low latency (URLLC) applications	Packet latency improvements
Multi-User Multiple Input Multiple Output (MU-MIMO): allows more data to be transferred at once and enables an access point to transmit to a larger number of concurrent clients at once	Parallel transmissions
Spectrum Efficiency: Ability to aggregate different carriers (frequency bands) into higher-capacity channels and simultaneous use of 4G and 5G Radios (dynamic spectrum sharing)	Higher throughput
256 Quadrature Amplitude Modulation Mode (256-QAM): efficient encoding of data in the same amount of spectrum	Faster Speed more Radios and 256 QAM
Architecture Flexibility: cost-efficient RAN architectures with flexible placement of network functions enabled by ORAN, slicing, and multi-access edge compute (MEC)	Operational efficiency
Slicing: Ability to create different virtual topologies for specific services (e.g. Gaming)	Dedicated resources for services

Spectrum Considerations

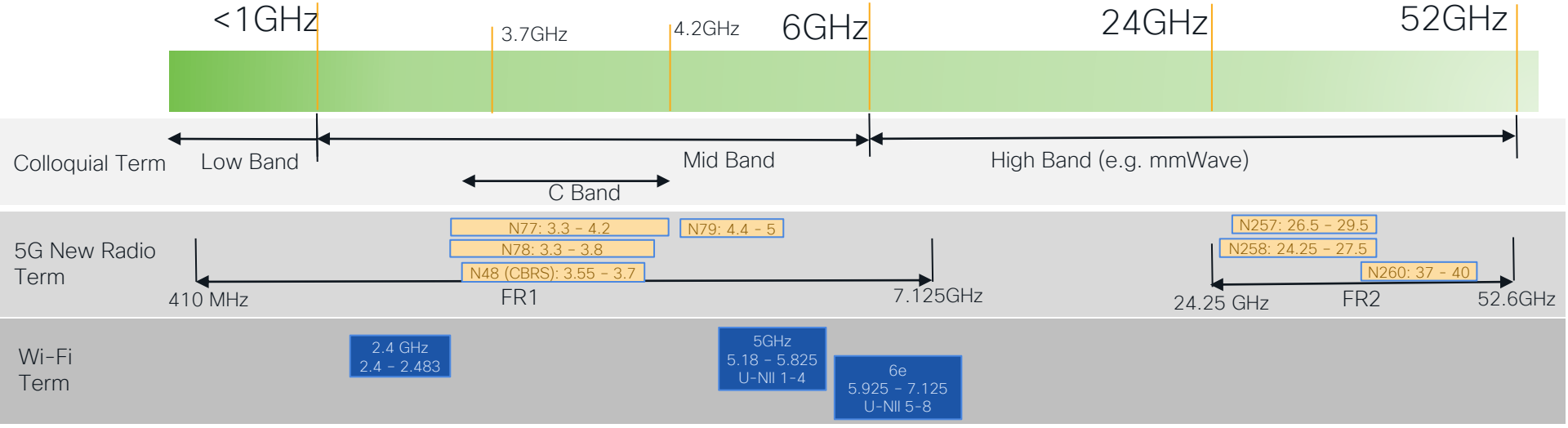
Where is the Mobile Spectrum???

- Spectrum is a national regulated resource
  - Auctioned off
- There is no free spectrum in most countries
  - E.g.3.5 GHz band needed to be freed up in the UK



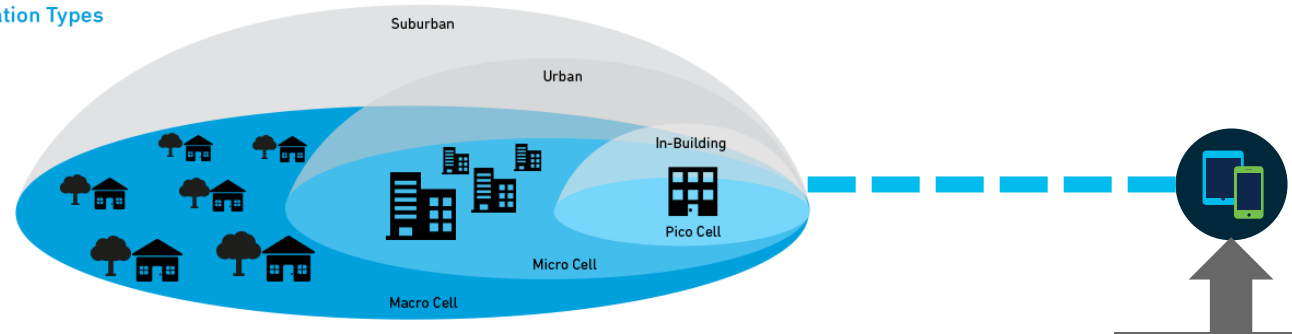
Cellular Wi-Fi Source: Roke Manor Research Ltd

Spectrum Nomenclature & Properties



Power impacts Reach and Endpoint Handoffs

Notes:
- Typical data for licensed spectrum service.
- Tx power limited by regional regulator for “shared spectrum”
- **For Enterprise use throughput per cell is important and this may reduce overall practical cell radius further**
- Actual values will depend on exact environments – we cannot change the laws of physics



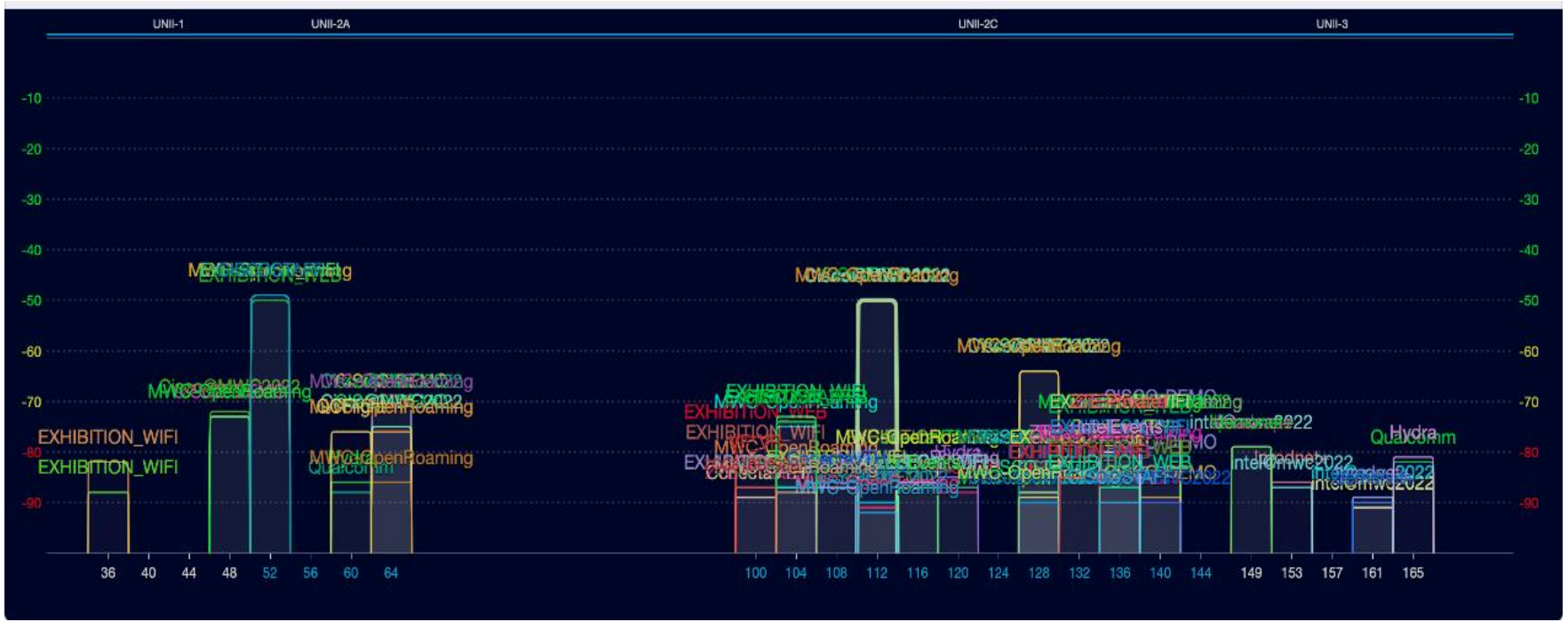
Cell Type	Output Power (w)	Theoretical Cell Radius (m)	Practical Cell Radius (m)	Typical active / Max Users per AP / RU	Typical Locations
Wi-Fi 2.4 GHz	0.1	75 Limited by max client Tx power)	<70	30/256	Indoor
Wi-Fi 5 GHz	0.2 to 4*		<35	30/512	Indoor
Wi-Fi 6 GHz	0.2 to 4*		<30	30/400-1024	Indoor
Femtocell	0.001 to 0.25	10-100	8 - 15	1 to 30	Indoor
Picocell	0.45 to 1	100-200	<200	30 to 100	Indoor/Outdoor
Microcell	1 to 10	200-20000	<2000	100 to 2000	Indoor/Outdoor
Macrocell	10 to >50	30000 to 80000	1000 to 20000	>2000	Outdoor

* Higher transmit powers not typically used as devices have limited Tx range

Variable Tx power.
e.g. 4G:
- Typical 0.1W or less but can go higher typically to 0.2W
- Cat 0 (M2M) max 0.2W

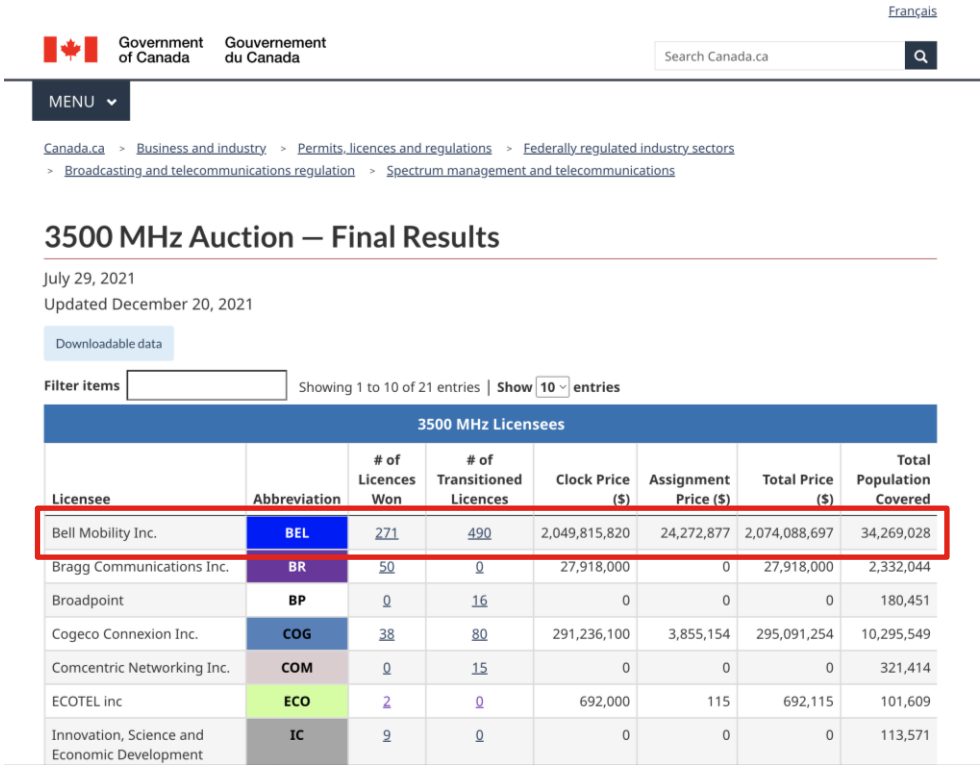
E.g. Wi-Fi6:
- Support for Dynamic Transmit Power Control (DTPC)
- Average 0.01W or less

… And don’t forget about Interference in Wi-Fi on 2.4 / 5GHz!



So how do I get Licensed 5G spectrum?

- Option 1: Catch the Auction!
  - And for national licenses, bring lots of $$$
- Option 2: Talk to someone who has the license
  - Likely a Tier 1 SP
  - Some spectrum owners ‘lease’ spectrum (e.g. Dish)
- Option 3: go unlicensed!



Français

Government of Canada | Gouvernement du Canada

Search Canada.ca

MENU

Canada.ca > Business and industry > Permits, licences and regulations > Federally regulated industry sectors > Broadcasting and telecommunications regulation > Spectrum management and telecommunications

3500 MHz Auction — Final Results

July 29, 2021

Updated December 20, 2021

Downloadable data

Filter items | Showing 1 to 10 of 21 entries | Show 10 entries

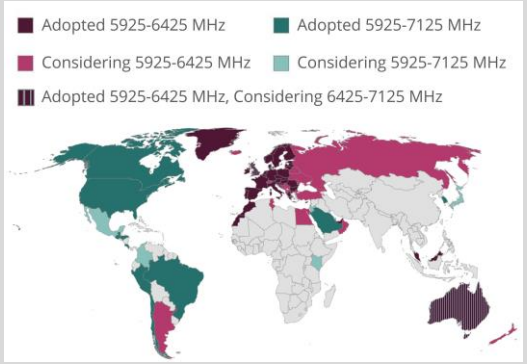
3500 MHz Licensees

Licensee	Abbreviation	# of Licences Won	# of Transitioned Licences	Clock Price ($)	Assignment Price ($)	Total Price ($)	Total Population Covered
Bell Mobility Inc.	BEL	271	490	2,049,815,820	24,272,877	2,074,088,697	34,269,028
Bragg Communications Inc.	BR	50	0	27,918,000	0	27,918,000	2,332,044
Broadpoint	BP	0	16	0	0	0	180,451
Cogeco Connexion Inc.	COG	38	80	291,236,100	3,855,154	295,091,254	10,295,549
Comcentric Networking Inc.	COM	0	15	0	0	0	321,414
ECOTEL inc	ECO	2	0	692,000	115	692,115	101,609
Innovation, Science and Economic Development	IC	9	0	0	0	0	113,571

Who owns Spectrum Today?

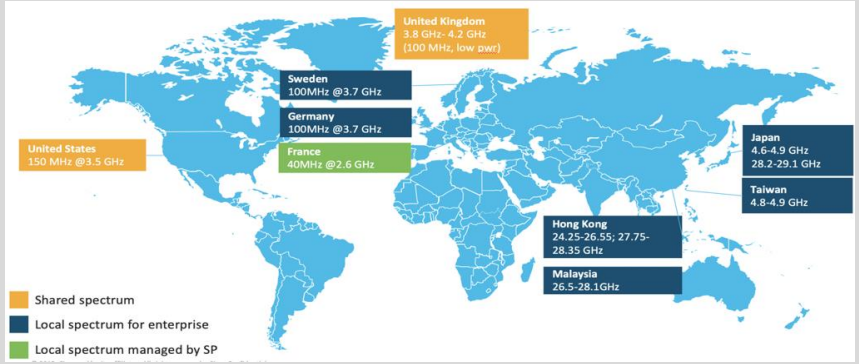
Wi-Fi Spectrum

- Unlicensed! Anyone can use!
- Wi-Fi 6e available in selected Countries



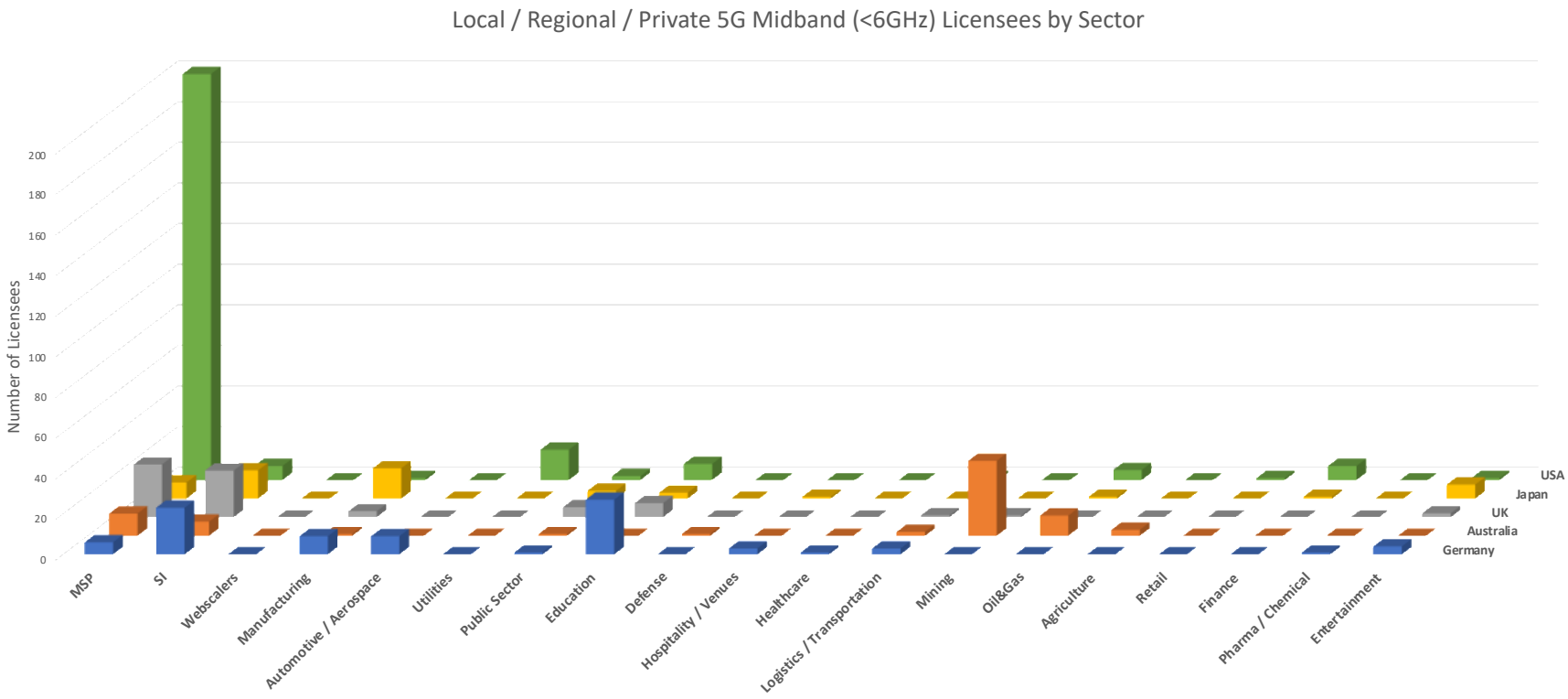
5G Regional / Enterprise / SP Managed Spectrum

- Mostly Tier 1 SPs / MNOs
- Shared Licenses: US, UK
- Local Enterprise Licenses:
  - Germany, Australia, Japan, Sweden, France, Hong Kong, Taiwan, Malaysia
- Local SP Managed



See also: https://spectrummonitoring.com/frequencies.php?market=D

Sample Local / Regional 5G Midband Licensees by Vertical



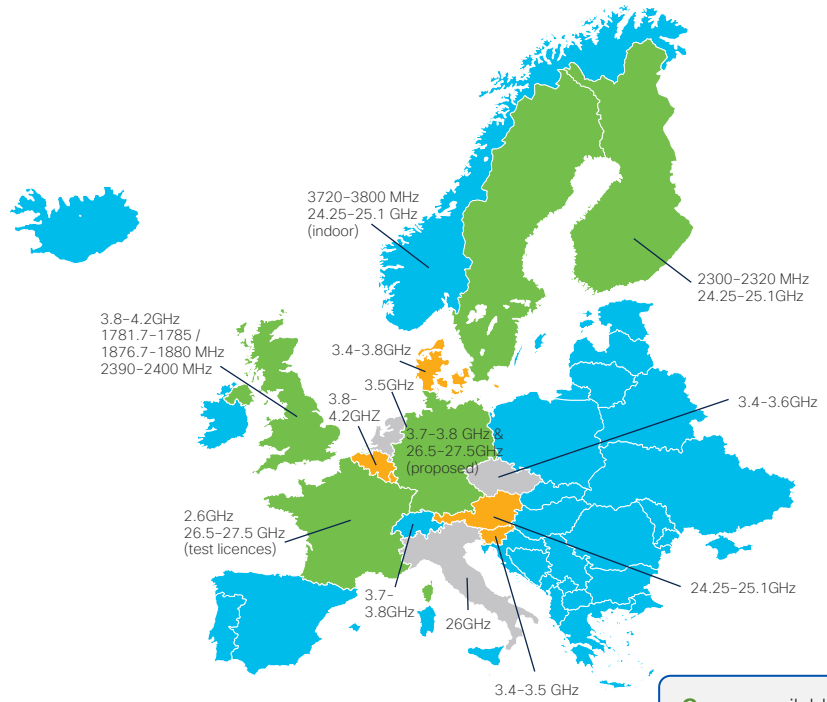
P5G Spectrum
Availability in EMEA

Country	Frequency Band	Frequency	Auction Status
Finland	n78	3.41 – 3.8 GHz	Auctioned (Oct 2018)
	n258	25.1 – 27.5 GHz	Auctioned (Jun 2020)
France	n78	3.4 – 3.8 GHz	Auctioned (Sep 2020)
	n257	26.5 – 27.5 GHz	Upcoming
Germany	n1	1920 – 1980 MHz (Uplink) 2110 – 2170 (Downlink)	Auctioned (Aug 2019)
	n78	3.4 – 3.7 GHz	Auctioned (Aug 2019)
	n78	3.4 – 3.8 GHz	Upcoming (Planned)
	n258	24.25 – 27.5 GHz	Upcoming (Planned)
Ireland	n78	3.4 – 3.8 GHz	Auctioned (May 2017)
	n258	26 GHz	Upcoming
Italy	n78	3.6 – 3.8 GHz	Auctioned (Oct 2018)
	n258	26.5 – 27.5 GHz	Auctioned (Oct 2018)
	-	700 MHz	Auctioned (Oct 2018)
Russia	n40	2.3 – 2.4 GHz	Upcoming
	n41	2.57 – 2.62 GHz	Upcoming
	n79	4.4 – 4.99 GHz	Upcoming
	n248	24.25 – 27.5 GHz	Upcoming (Planned)
	-	694 – 790 MHz	Upcoming (Planned)
Spain	n78	3.4 – 3.6 GHz	Auctioned (Jul 2018)
	n78	3.6 – 3.8 GHz	Upcoming (Planned)
	-	700 MHz	Upcoming (Planned)
	n258	26 GHz	Upcoming (Planned)
United Kingdom	n78	3.4 – 3.6 GHz	Auctioned (Apr 2018)
	n78	3.6 – 3.8 GHz	Upcoming (In 2020)
	n258	24.25 – 27.5 GHz	Upcoming (Planned)

Preferred Radio Partner

Air span
support@airspan.com

Source: GSMA, Date November 2021



CBRS Licensing (CBRS band 48 – US Only)

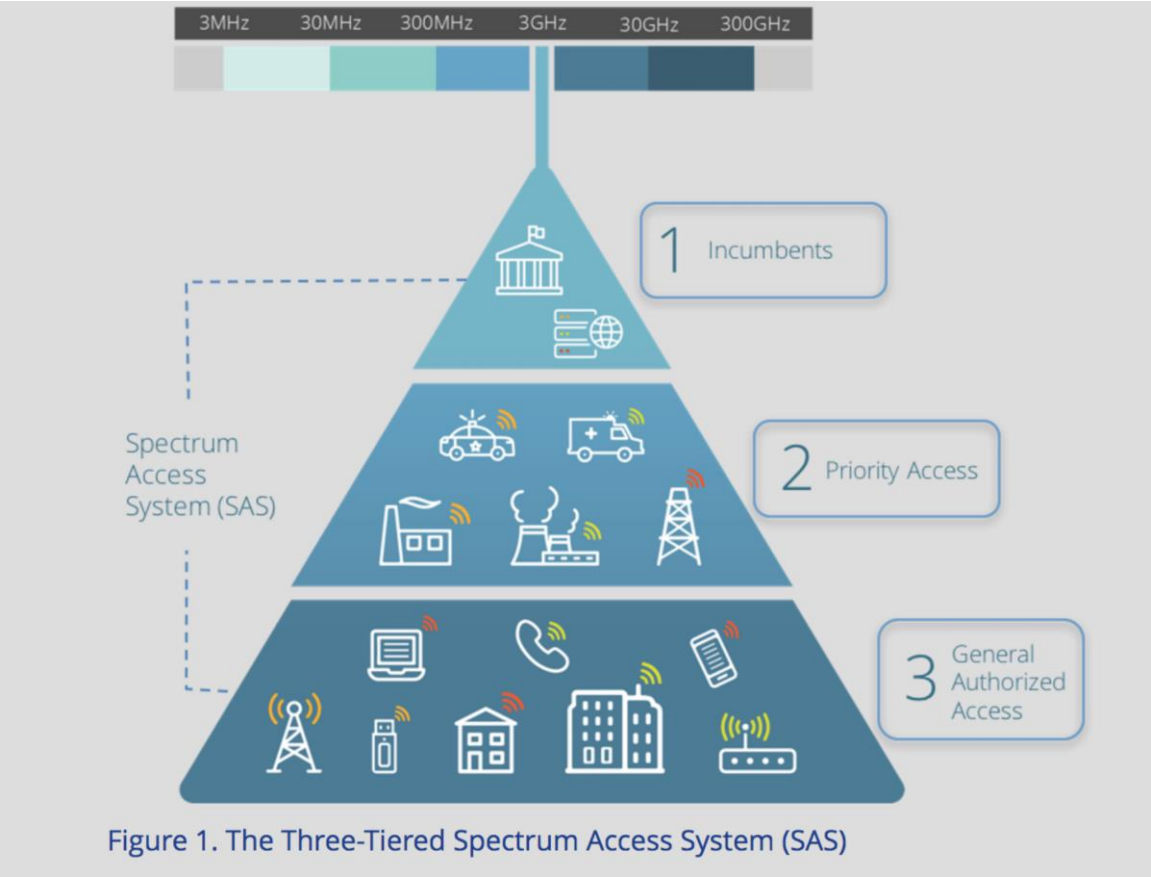


Figure 1. The Three-Tiered Spectrum Access System (SAS)

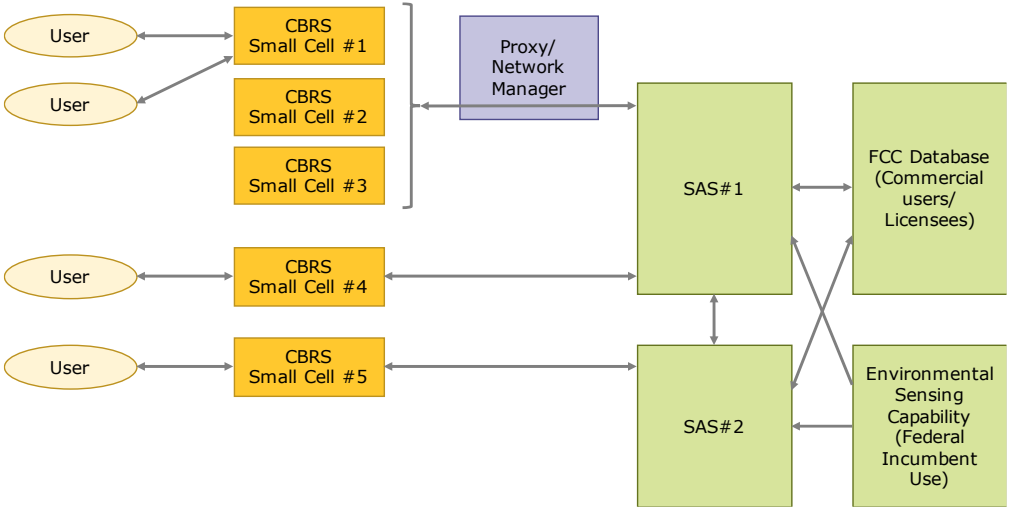
1) Incumbents:
Existing users (e.g. US Naval Radar, DoD personnel) get permanent priority as well as site-specific protection for registered sites.

2) Priority Access Licenses (PAL):
Organizations license up to four (10MHz) PALs in a limited geographic area (county) for three years. Only the lower 100 MHz of the CBRS band will be auctioned off; with a max of seven concurrent 10 MHz PALs allocated within the same region, max 40MHz/licensee: interference protection in 3.55GHz band. Guaranteed spectrum at a location

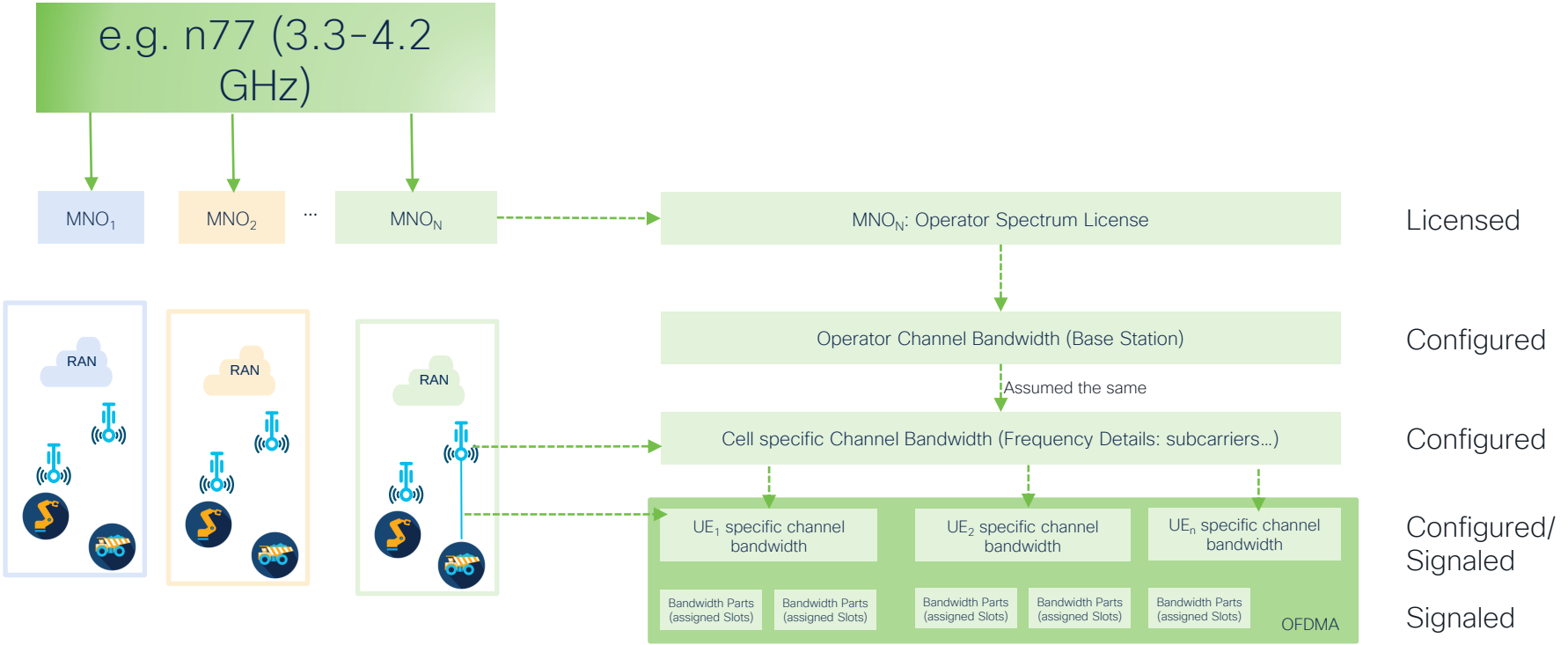
3) General Authorized Access (GAA):
The rest of the spectrum will be open to GAA use and coexistence issues will be determined by SAS providers for spectrum allocation. (min 80 MHz), 5MHz channelization (CBRSA/WinnForum).

A note on CBRS Spectrum in the US

- 150MHz for outdoor/indoor small cells, has its own 3GPP band class (Band 48), for LTE or 5G-NR
- PAL/GAA are regulated by Spectrum Access System Administrators (SAS), who also coordinate assignments for GAA
- PAL licenses are auctioned/purchased, GAA access is not; SAS-fees apply to both
- Many use-cases (Esp. indoor) can be realized using GAA!



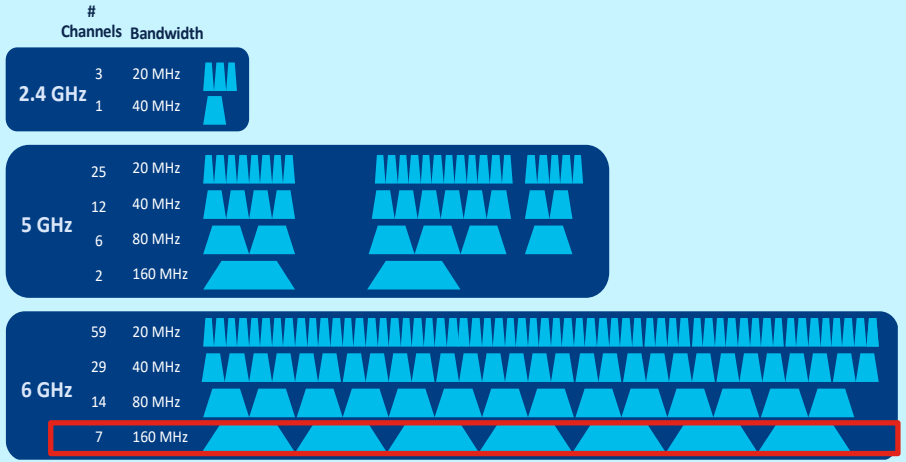
How does the Spectrum get used by Endpoints in 5G?



How does this spectrum help me get more bandwidth

Both 5G and Wi-Fi can have flexible spectrum channel widths (i.e. more bandwidth on the air!)

- Wi-Fi
  - Configure channel widths for APs



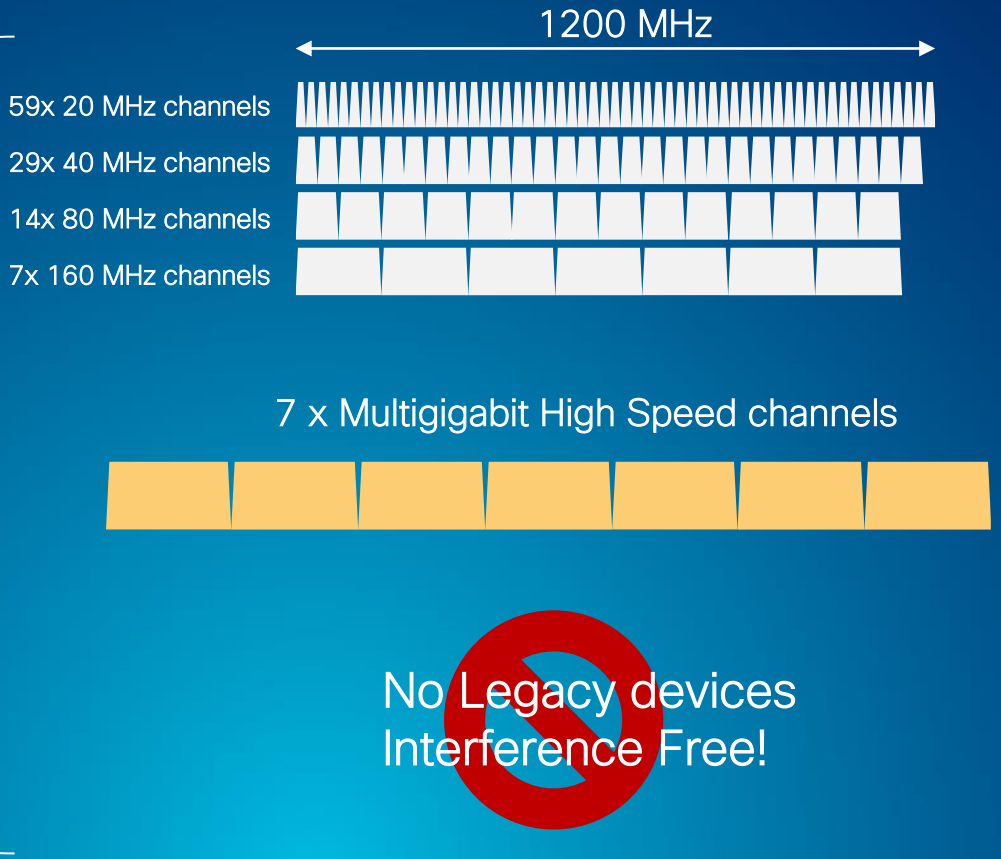
- 5G:
  - Allow for flexible bandwidth allocations over time
  - Varies by frequency band (e.g. n78) and Numerology (= sub-carrier spacing aka. 'μ')
  - Ranges from 10 MHz – 100 MHz
  - A Base station can support *multiple* channel widths per endpoint (c.f. UE bandwidth parts)
  - Also support for Carrier Aggregation (CA) and Dual Connectivity (DC)

Band	SCS	FR	UL band [MHz]		DL band [MHz]		BW [MHz]	Duplex	Possible channel bandwidth
			F_{UL_low}	F_{UL_high}	F_{DL_low}	F_{DL_high}			
n78		1	3300	3800	3300	3800	500	TDD	15: [10, 15, 20, 25, 30, 40, 50]
									30: [10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100]
									60: [10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100]

Source: https://www.nrexplained.com/bandwidth

A Word on Wi-Fi Spectrum Evolution

6E =



Extending the Capabilities of Wi-Fi 6

6GHz is wider channels – 80 is the new 20!

Less interference, higher throughput & density = Reliable Wireless

5GHz channel width feasibility				
Environment	20 MHz (25)	40 MHz (12)	80 MHz (6)	160 MHz (2)
High Density [1200 ft^2]				
Typical Density [2500 ft^2]				
Low Density [6000 ft^2]				

6GHz channel width feasibility				
Environment	20 MHz (59)	40 MHz (29)	80 MHz (14)	160 MHz (7)
High Density [1200 ft^2]				
Typical Density [2500 ft^2]				
Low Density [6000 ft^2]				

Note: Experience based on relative amount of AP co-channel interference at the AP based on Max EIRP power and channels available.

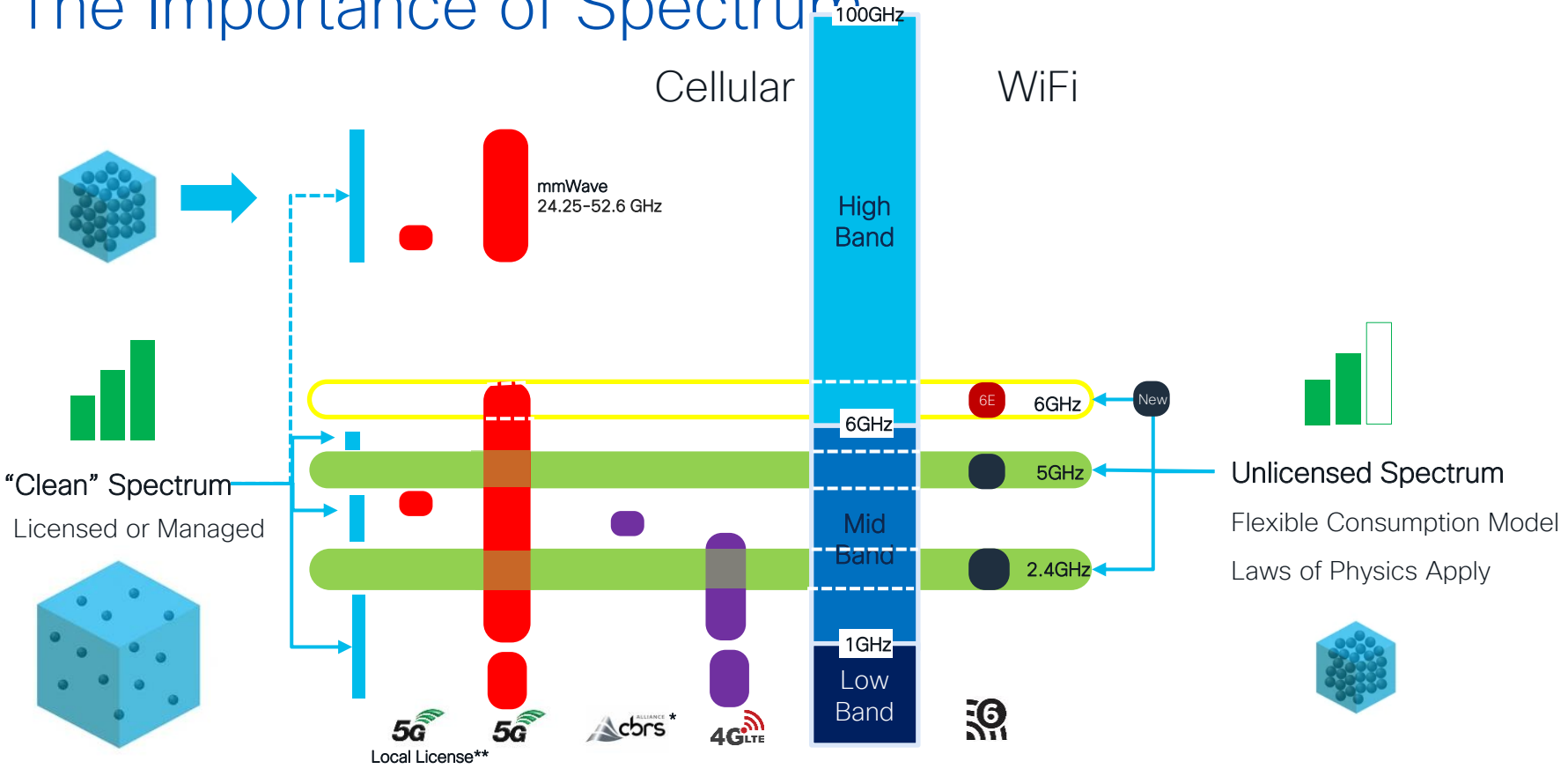
Wi-Fi6 Brings 2.4GHz Back!!

2.4 GHz

5 GHz

Both Bands are Back in 802.11ax

The Importance of Spectrum

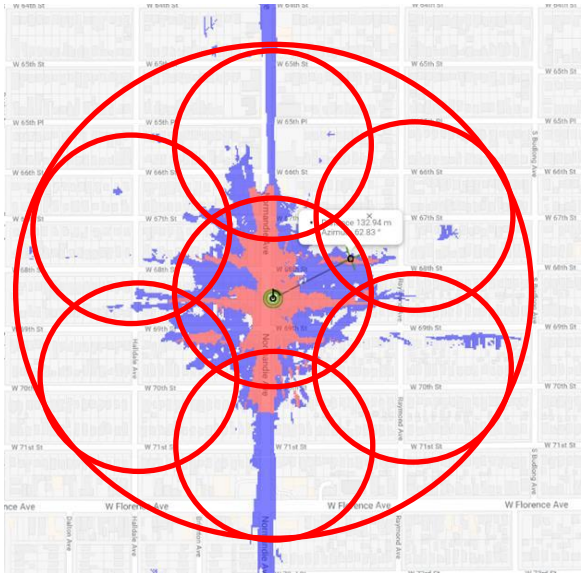


* USA Only

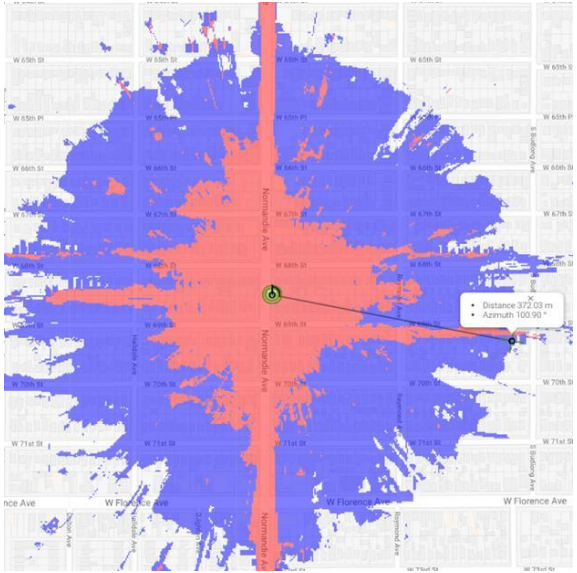
** Not available in all countries and typically only subset available

What about mmWave vs. Sub-6GHz?

Modeled at same pole height in a relatively flat part of Los Angeles



mmWave Propagation



Sub-6 Propagation

100 Mbps

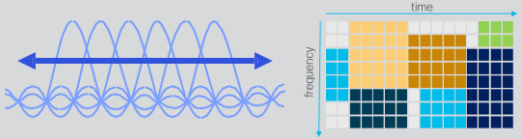
1 Gbps

Source: Defense Information Board 5G Study

Radio Dynamics

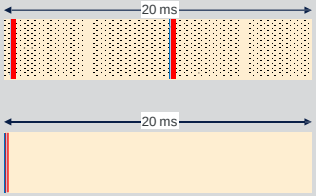
5G New Radio – Improvements

Flexible NR Protocol



- Mixed numerology: Flexible TTI,
- Bandwidth parts – mixed numerology within a carrier (RAN slicing)

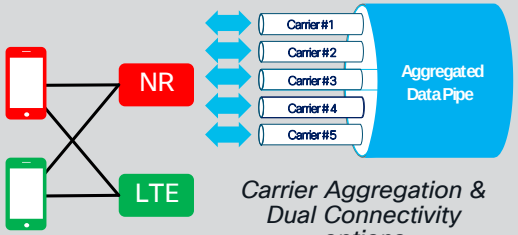
Lean Frame Design



Eliminating LTEs Cell-Specific RS gives capacity & efficient power

Better Frame Structure: about 20% improvement in spectral efficiency

Higher Data rates with Multi-connectivity



Carrier Aggregation & Dual Connectivity options

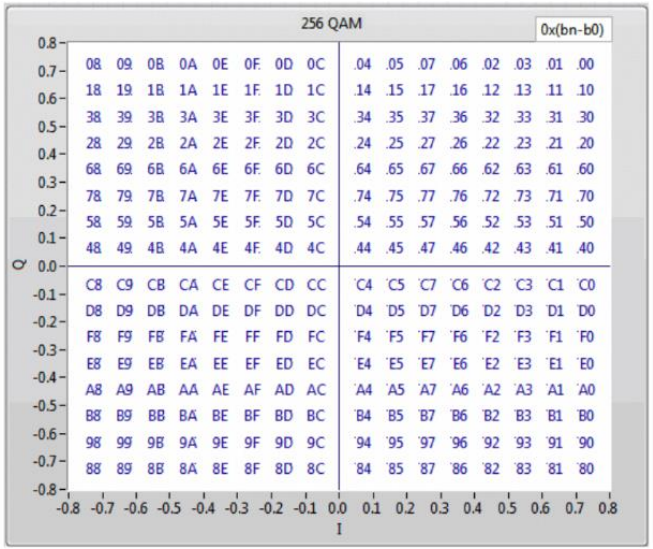
Massive MIMO & Beamforming

Better Spectrum Management: Improvements in capacity and reach across multiple bands reduce need for densification

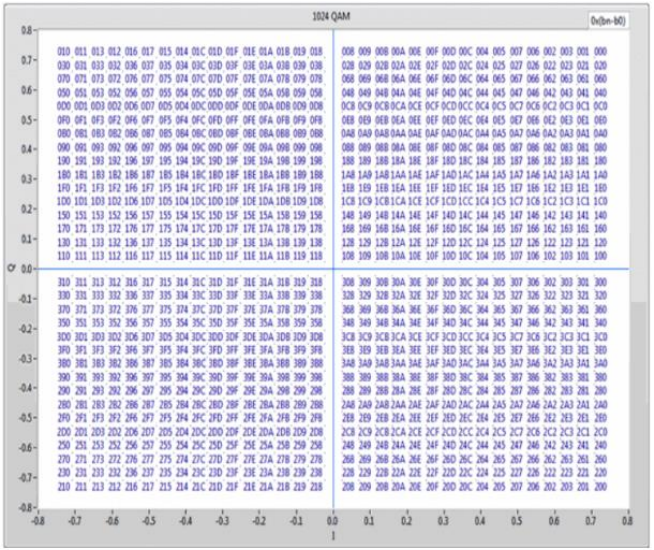
256 vs1024 QAM

25% Increase in PHY Data Rate, but more is not always better

11ac – 256 QAM
8 bits per symbol



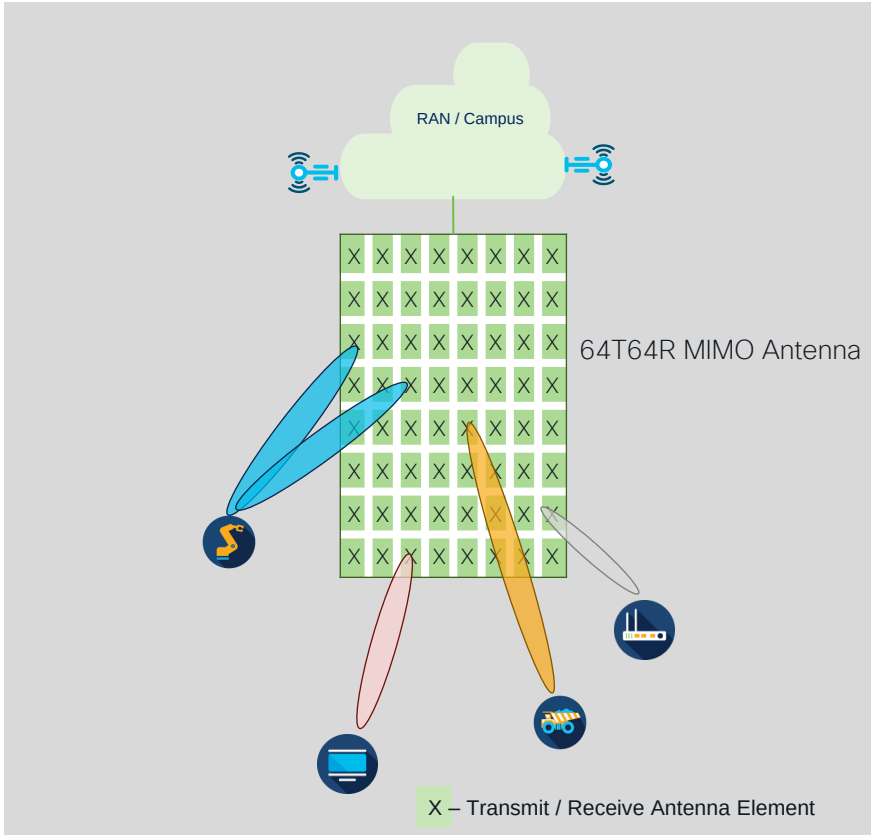
11ax – 1024 QAM
10 bits per symbol



Wi-Fi6 and 5G release 16 support 256 QAM, but BER increases with added spectral complexity

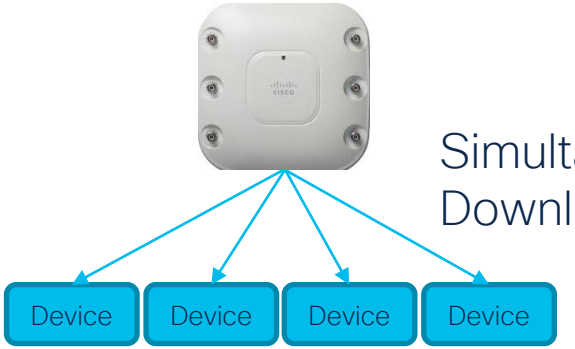
MU-MIMO & Beamforming
More bandwidth to Endpoints!

- Both Wi-Fi and 5G utilize sophisticated Beamforming techniques
  - Wi-Fi: Beam Steering. Can configure the radius and direction of the beam ‘cone’
  - 5G: Beamforming
- Based on Multi-user Multiple-input / Multiple-output antennas (MIMO)
- Facilitated by Multiple Array Antennas in the Radios and Endpoints
- Allows multiple simultaneous transmissions (multi-user, MU) – spatial muxing
- E.g. 4T/4R – can use 4 transmit and 4 receive antennas for simultaneous transmission



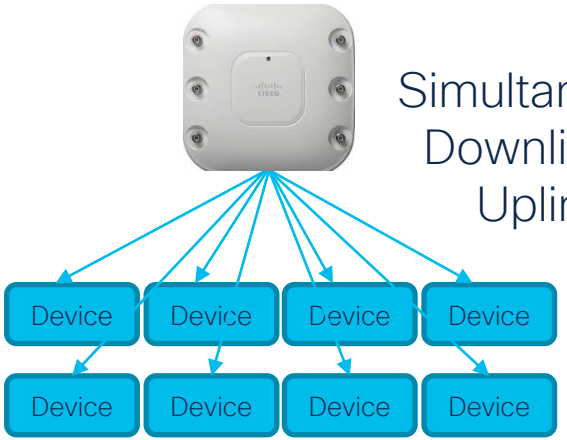
Downlink MIMO (example: Wi-Fi6/6E)

11ac (4 Spatial Streams)



Simultaneous Downlink

11ax (8 Spatial Streams)

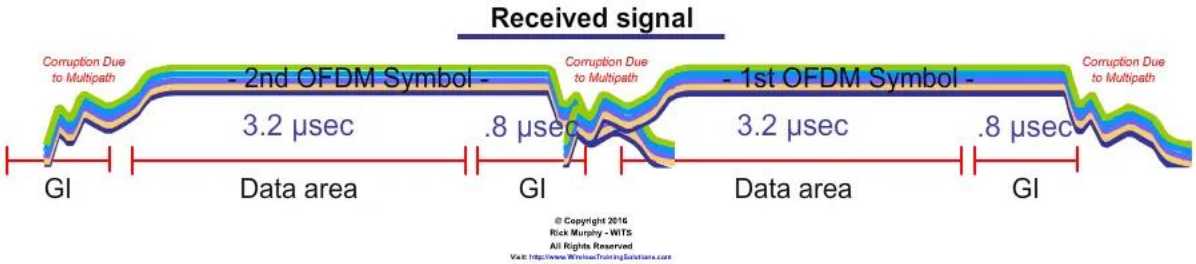


Simultaneous Downlink + Uplink

Spatial Streams enable Simultaneous Connections and now for both UL & DL

802.11ax Adjustable Guard Intervals

- Guard Intervals are the spaces between signals (shorter = more performance)
- Great for indoors, but what about industrial IoT settings?
- 802.11ac supported 0.8us only
- 802.11ax introduces 3 guard intervals: 0.8us, 1.6us, 3.2us (formerly 0.4us and 0.8us)
- Improves delay spread protection (better resiliency for outdoor/industrial wireless)



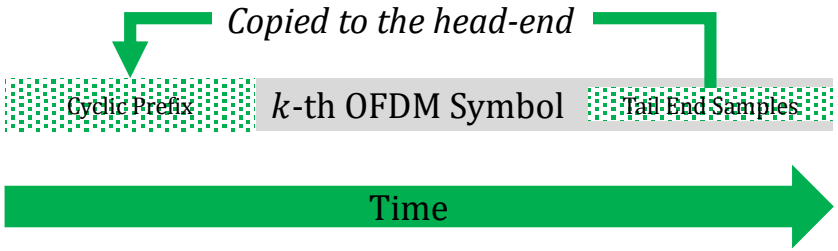
5G Cyclic Prefix

Problem

- Because of multipath, the delayed version of a symbol can overlap with the adjacent symbol and cause unter-symbol Interference (ISI)

Solution is the Cyclic Prefix

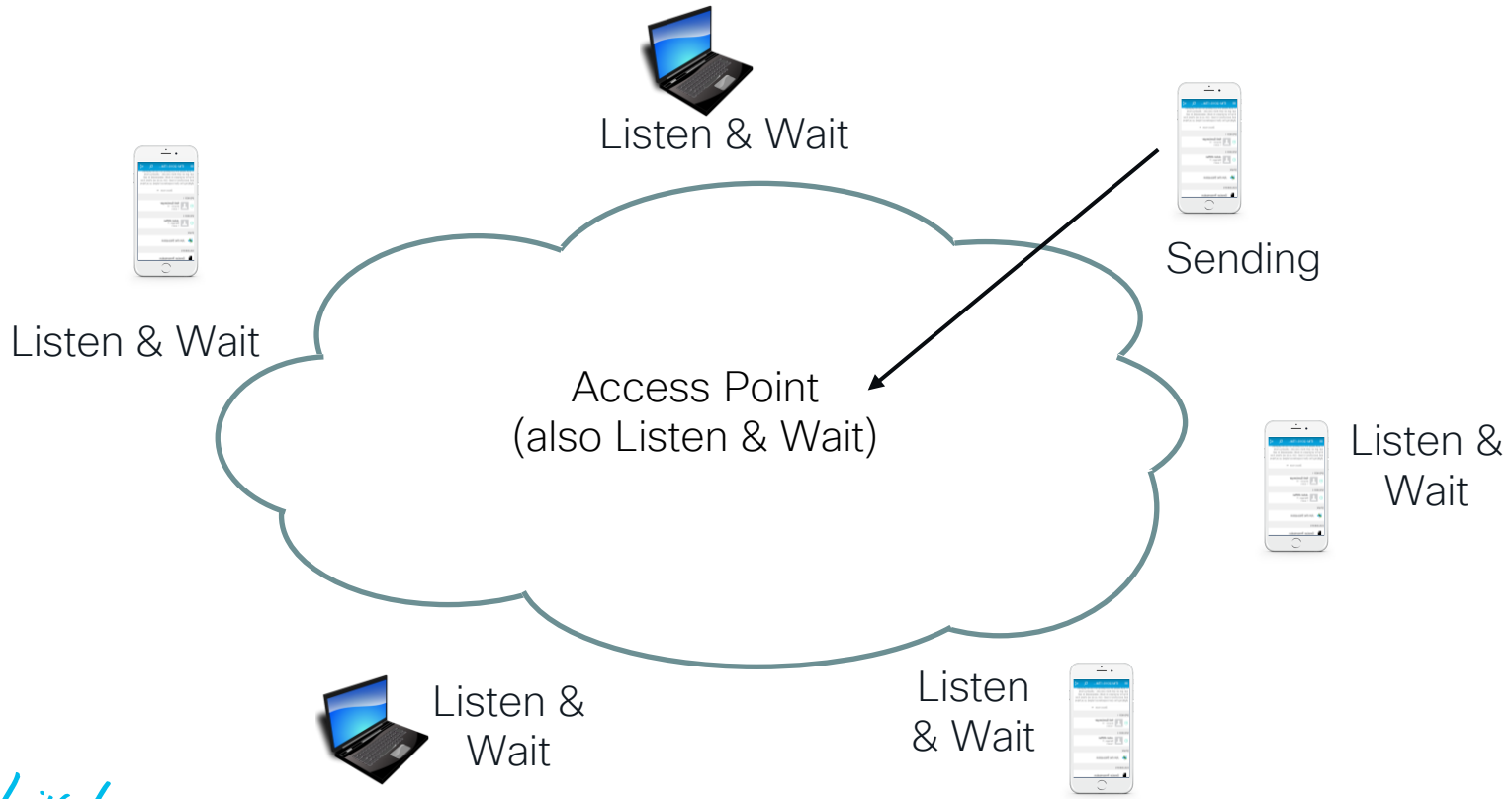
- Extends the symbol into a guard interval at the beginning of the symbol by copying part of the tail and gluing it into the front.
- This is a trick. The mathematics is not complicated but outside the scope
- If the delay spread is within the CP, subcarriers are orthogonal and no ISI



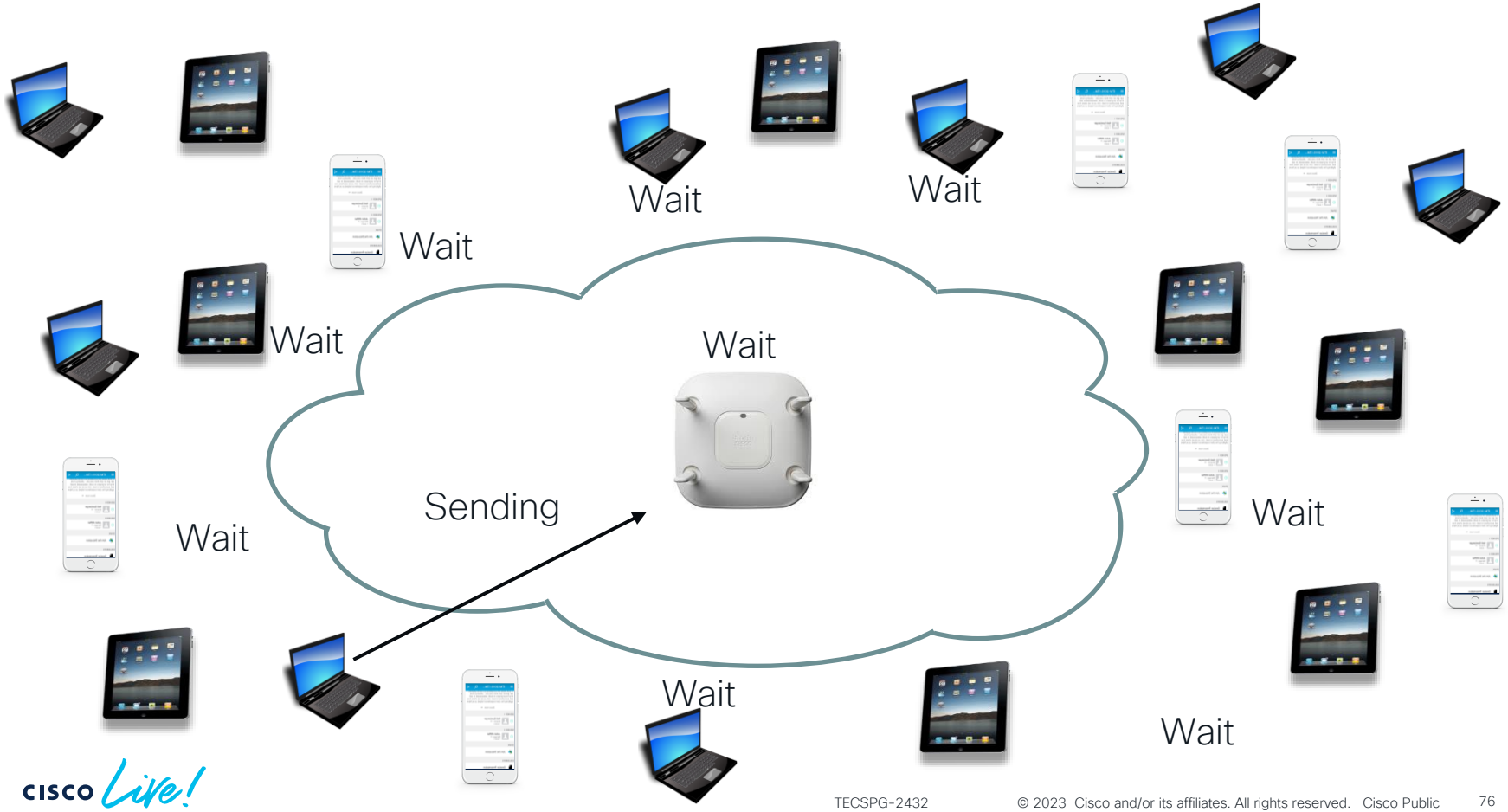
The point of the cyclic prefix is to address multipath at the expense of overhead.

Comparing Wi-Fi and 5G Media Access

Traditional 802.11 / Wi-Fi is Contention-Based

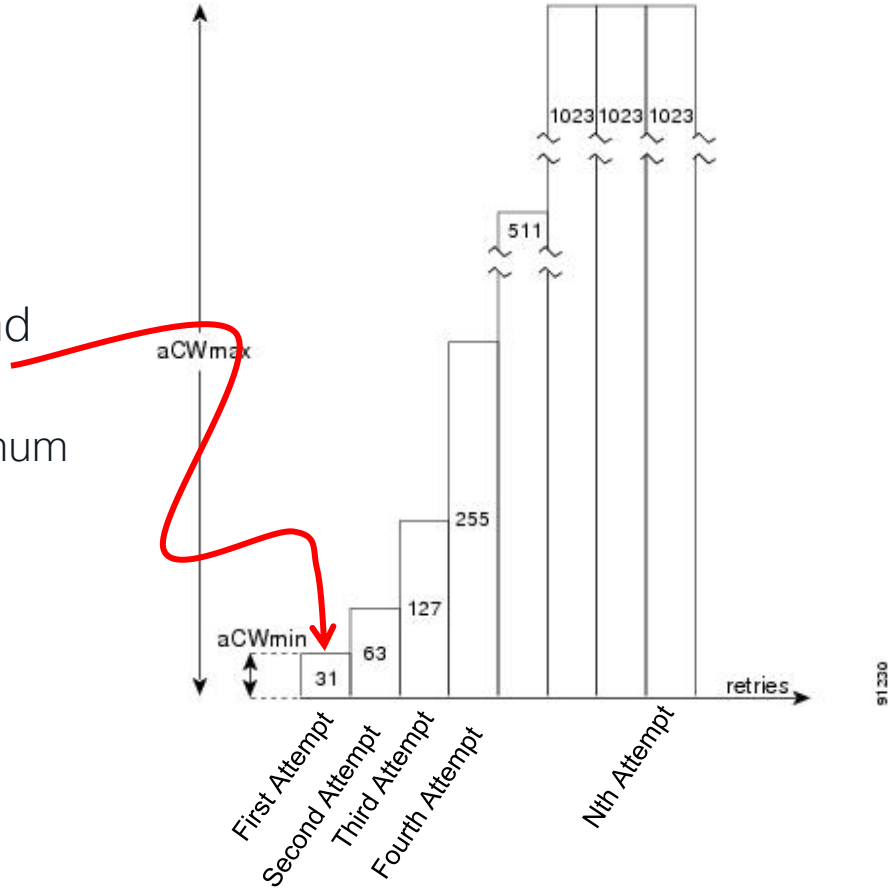


What Happens When the Client Density Increases?

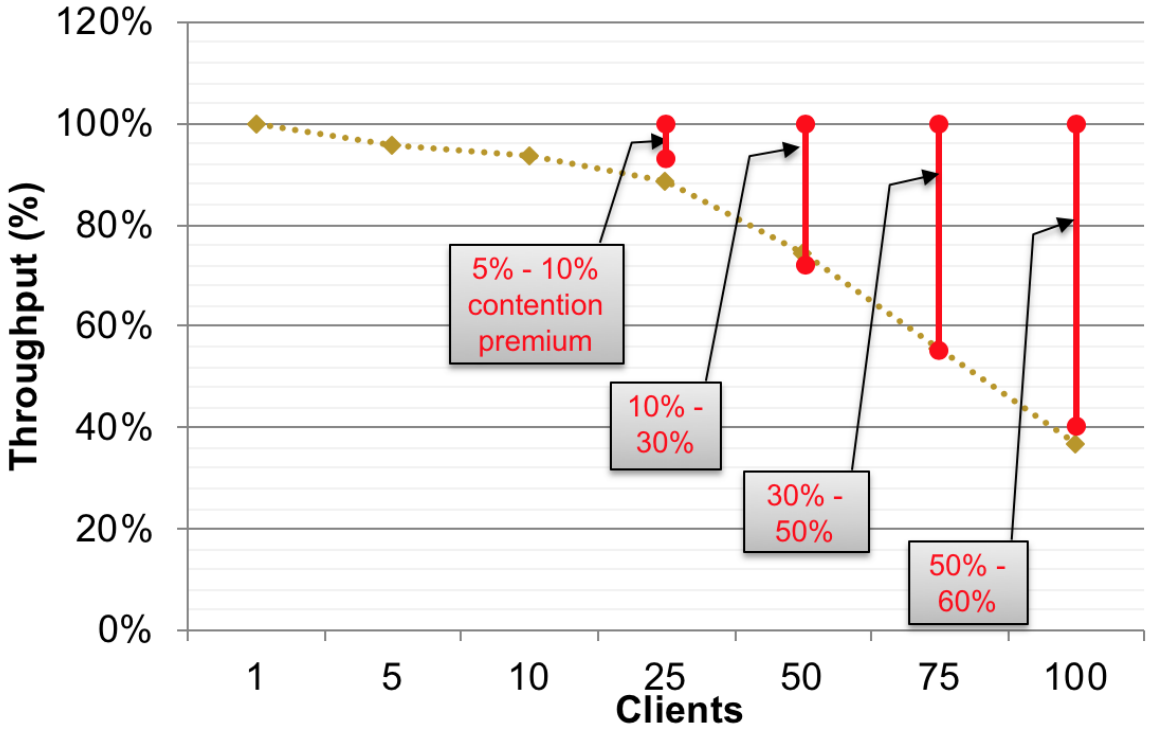


Every Wi-Fi Frame MUST be Ack'd, or Else, Retry

- How do you know the transmission got through okay? The receiving station must send an acknowledgment.
- If the first attempt didn't work (no ACK received), double the previous CW size and pick a new random number.
  - Keep doing this until the CW reaches a maximum size of 1023 slot times.
- How many times should the station keep trying?



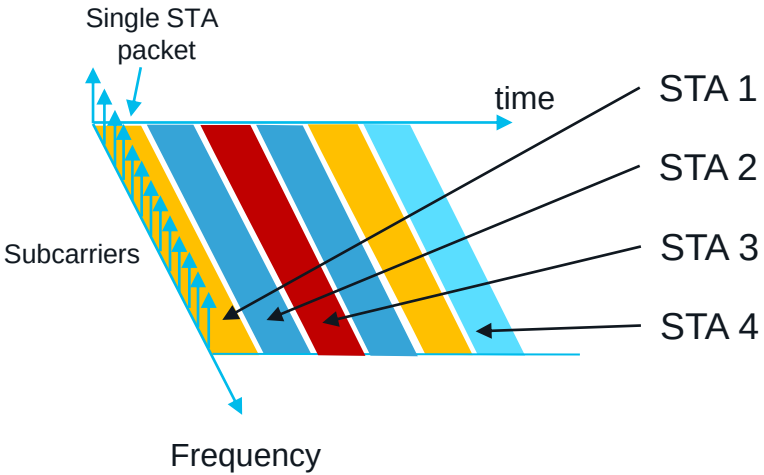
The Contention Breaking Point (802.11ac)
(source: IEEE 802.11-15/0351r2)



As more clients associate and transmit, WLAN contention increases for all clients, degrading performance for all

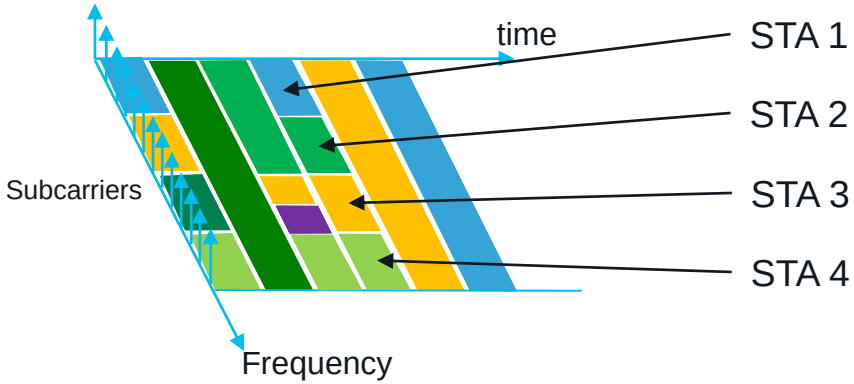
Legacy Wi-Fi's Problem is that only One Client Can Transmit at a time)

- Each Station occupies the whole channel for it's transmission time, regardless of how much of the actual spectrum is actually being used (very inefficient)



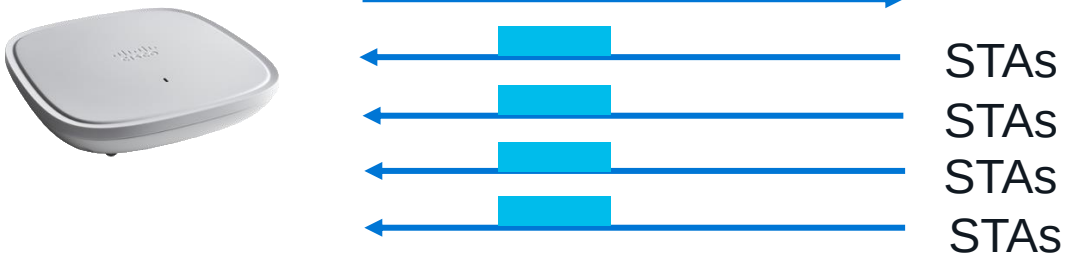
802.11ax / Uses OFDMA
(Orthogonal Frequency Division Multiple Access)

- With 802.11ax, a single wireless channel is sub-divided into Resource Units (RUs) that allow more than one station to communicate at a time
- Multiple STAs get to transmit at the SAME TIME – maximizing available bandwidth for each timeslot!

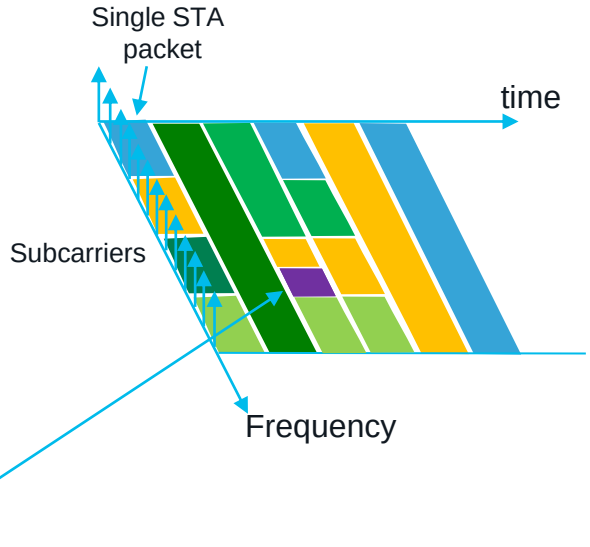


How Does Uplink Multi-User MIMO Work?

- AP checks which STAs can send together
- AP sends a trigger frame and STAs respond all at the same time
- Like a track and field race – when the judge fires the gun, all runners start running



Single Resource Units Mean Smaller Bands and Better Range for IoT



Combining TWT and single RU assignments an AP can have as many as 4000 clients associated at a given time

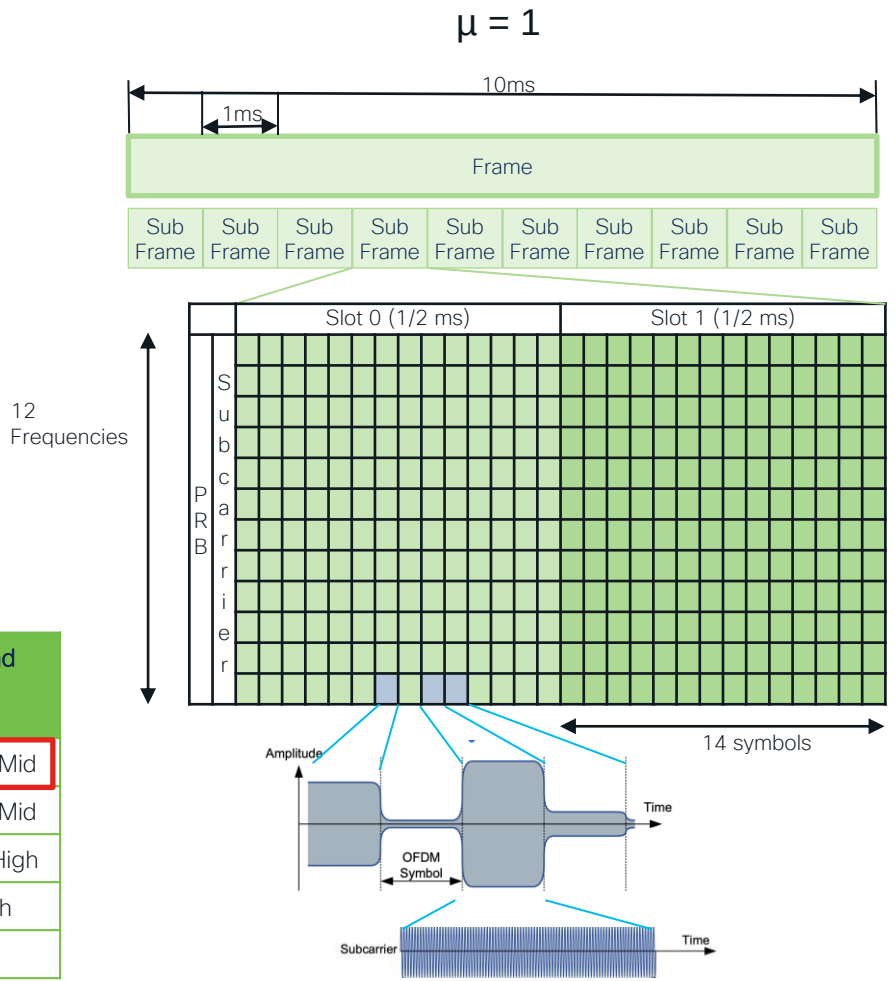
- With a single 2 MHz RU, AP and client can exchange at 375 kbps (improves link budget by 8dB – means much better range)
- 802.11a/g allowed only 6 Mbps minimum, 802.11n/ac 6.5 Mbps (higher power consumed, wasted bandwidth)

5G Wave form

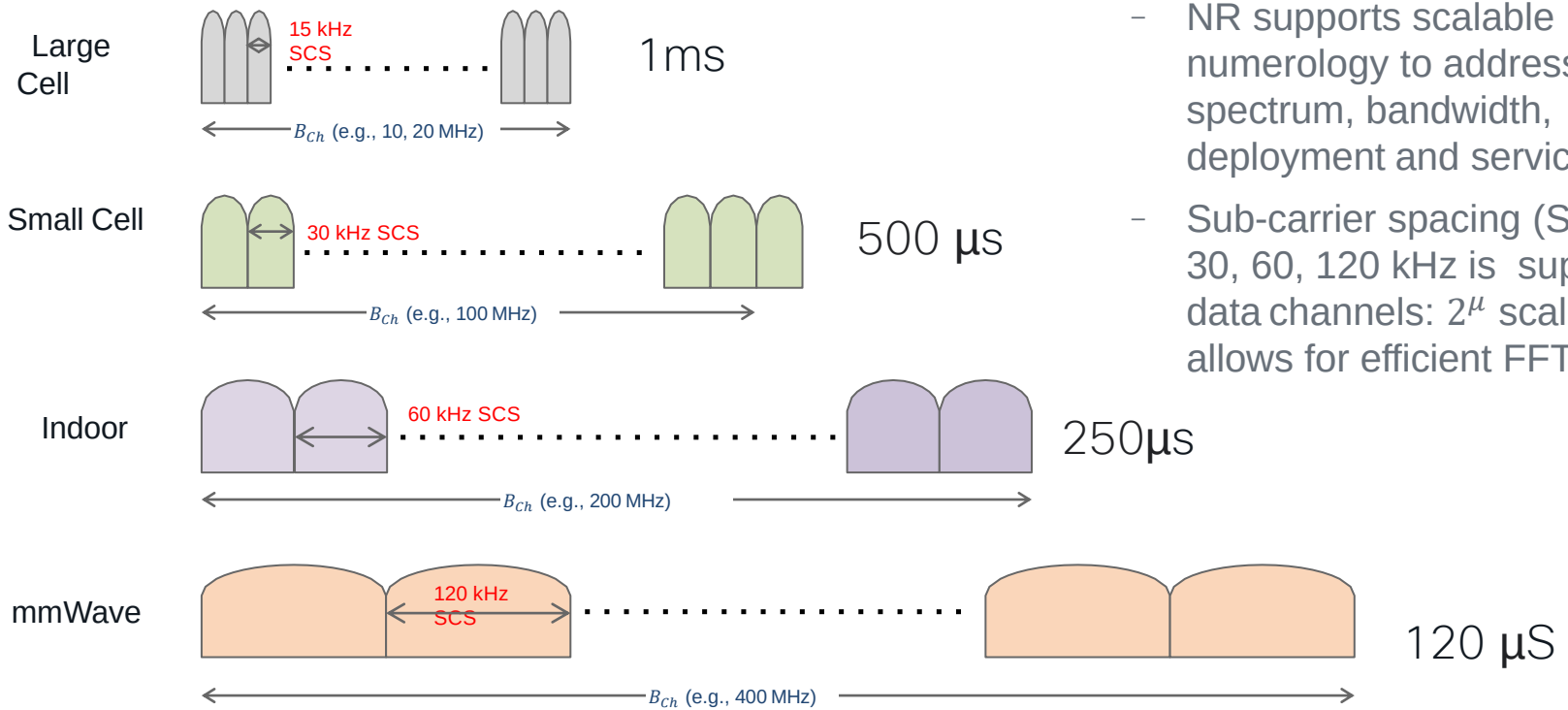
- A Key part of 5G is waveform flexibility:
  - Different options for Subcarrier spacing.

μ	$\Delta f = 2^{\mu} \cdot 15[\text{kHz}]$	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal
5	480	Normal
6	960	Normal

Numerology μ	N symbols / Slot	N Slots / subframe (2^{μ})	N slots / frame	Band
0	14	1	10	Low, Mid
1	14	2	20	Low, Mid
2	12/14	4	40	Mid, High
3	14	8	80	High
4	14	16	160	



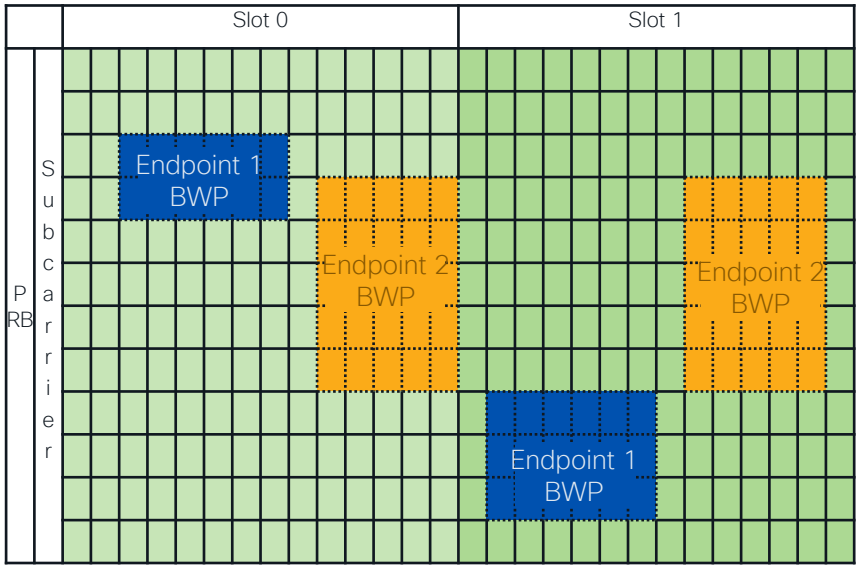
Scalable NR Numerology gives flexibility to different environments



- NR supports scalable numerology to address different spectrum, bandwidth, deployment and services
- Sub-carrier spacing (SCS) of 15, 30, 60, 120 kHz is supported for data channels: 2^{μ} scaling of SCS allows for efficient FFT processing

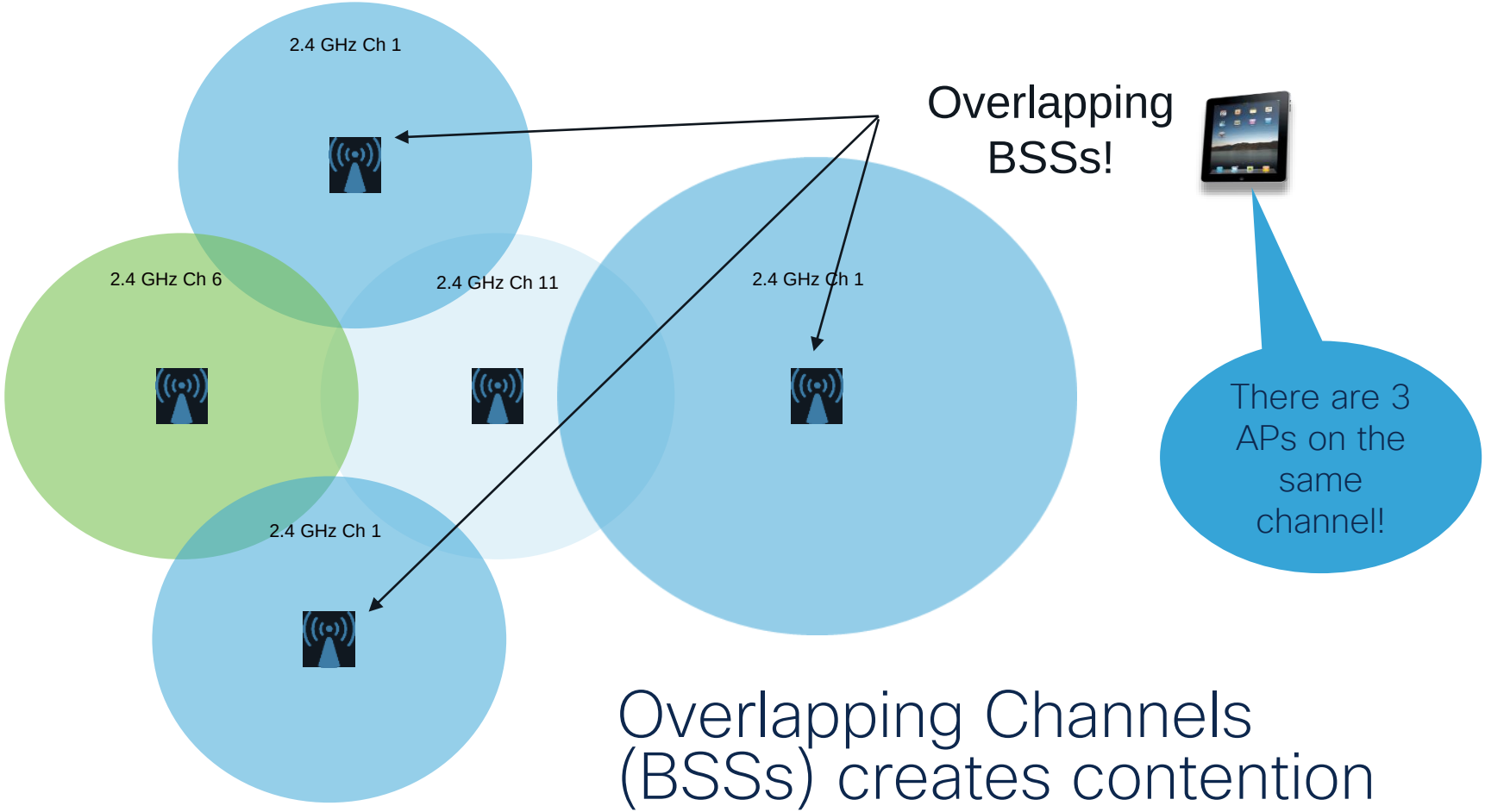
OFDMA Scheduling – Why is this important?

- 5G Endpoints can request bandwidth dynamically
- Endpoint is Schedule on the best slot.

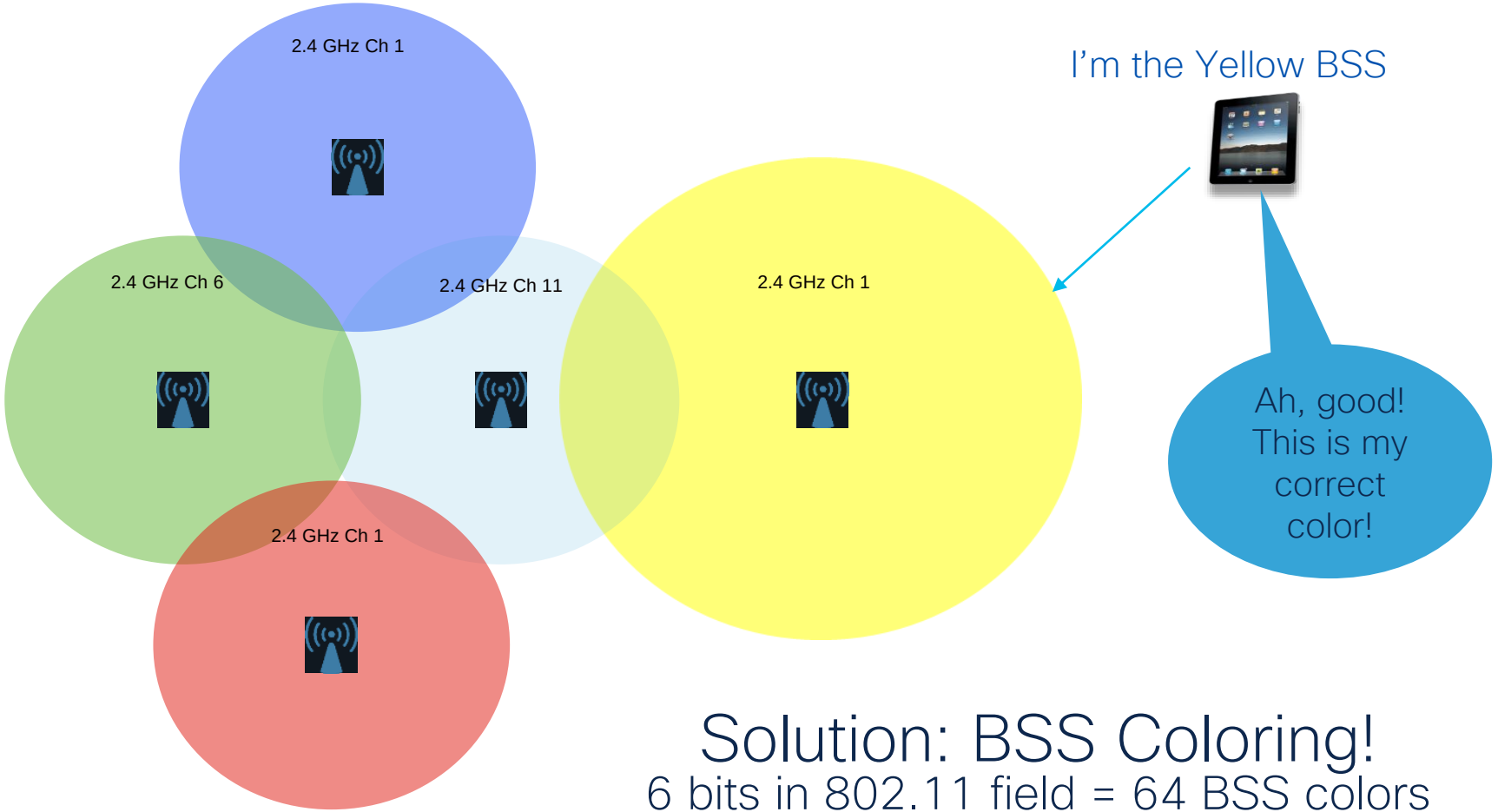


BWP: Bandwidth Part

Intelligent Frequency Reuse



Overlapping Channels (BSSs) creates contention

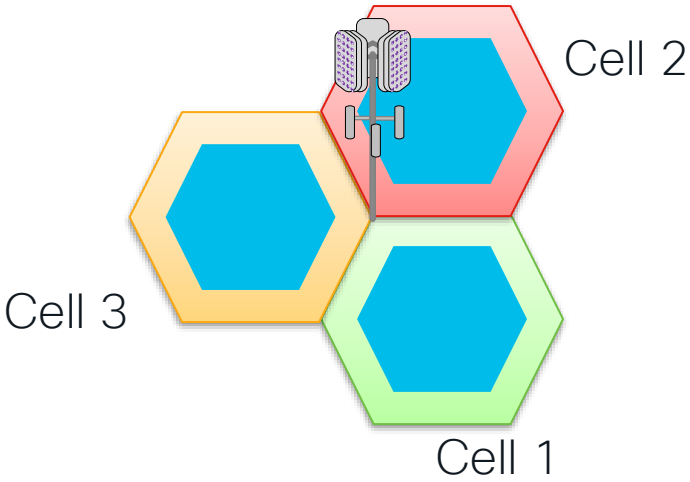


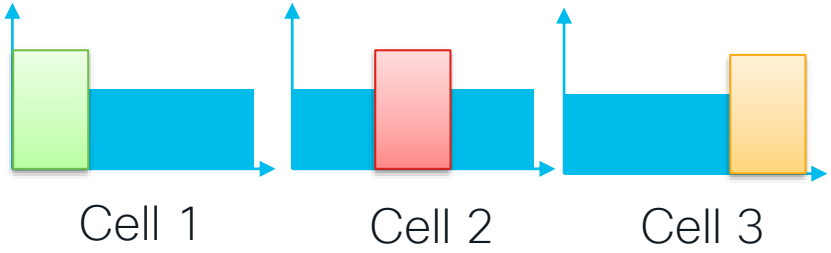
Solution: BSS Coloring!

6 bits in 802.11 field = 64 BSS colors

5G- Intelligent frequency reuse (eICIC)

- NR can use a frequency re-use of 1 (i.e) same bandwidth is use in all cells.
  - This allow maximum spectrum efficiency.
- gNB can managed the TX power as a matrix (time and frequency) and coordination over Xn interface





Wireless Radio Security Considerations

Security Aspects

	5G	Wi-Fi 6 /6e
Air Interface Security	Encrypted – 256 Bit Integrity checked	
Subscriber Security	SIM Identity	Enterprise identity Framework with flexible authorization
Roaming Interface	Clearly Standardised with bi-lateral agreements	OpenRoaming

Mandatory
Security framework **defined** by 3GPP (see TS 33.501) – mainly driven by **SIM/eSIM use cases**

Some Aspects Up To Customer
With WPA3 Enterprise **can** integrate security and policy framework with enterprise policy (e.g. IBN with ISE/DUO etc)

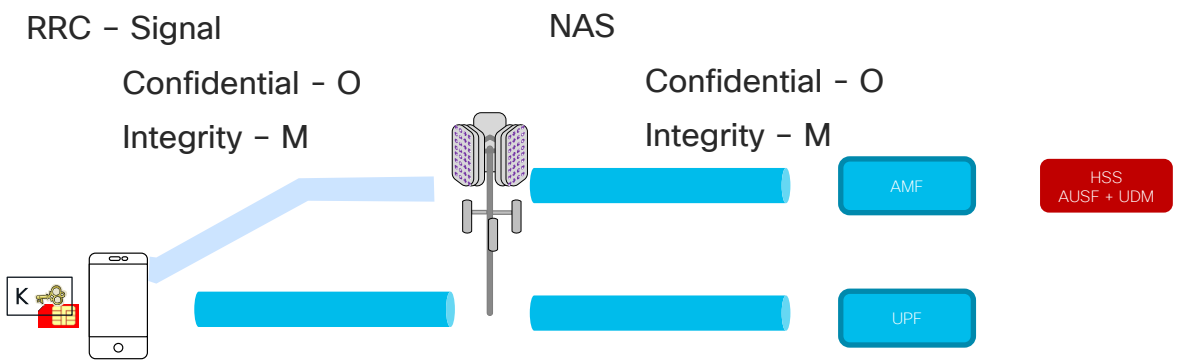
Wi-Fi Protected Access 3 (WPA3)

WPA	· A snapshot of the 802.11i Wireless Security Standard · Commonly used with TKIP encryption
WPA2	· Final version of 802.11i Wireless Security Standard · Commonly used with AES encryption
Authentication Mechanisms	· Personal (PSK – Pre-Shared Key) · Enterprise (802.1X/EAP)
WPA3	· Wi-Fi Alliance security update · Includes new capabilities and new certification requirements

WPA3 Highlights

- Mandatory for Wi-Fi 6 Certification
- Remove insecure legacy protocols
  - WEP
  - TKIP
  - SHA1
- Negative Testing
  - KRACK (Key Reinstallation Attack)
- Protected Management Frames (802.11w)
- Simultaneous Authentication of Equals (SAE)
- Wi-Fi Certified Enhanced Open
- Opportunistic Wireless Encryption (OWE)

Security in 5G – New Radio Security



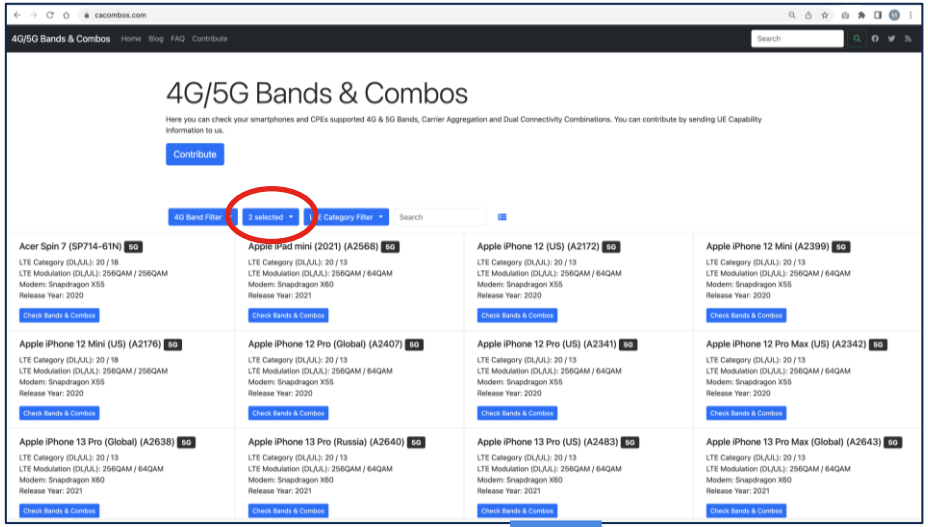
M- Mandatory
O – Optional

128-NEA1	128-NIA1	SNOW 3G
128-NEA2	128-NIA2	AES
128-NEA3	128-NIA3	ZUC

Endpoint Considerations

What about Endpoints?

- To leverage new spectrum bands with either Wi-Fi 6e or P5G, need respective support in Endpoints
- 5G interfaces in endpoints up and coming, but not as pervasive as Wi-Fi
- P5G backhaul allows endpoints to. Remain Wi-Fi connected



Apple iPhone 12 Mini (US) (A2176) 4G/5G Bands and Combos

Modem Specification

Modem Model	Snapdragon X55
Release Year	2020
LTE DL/UL Modulation	256QAM / 256QAM
LTE Bands	1, 2, 3, 4, 5, 7, 8, 12, 13, 14, 17, 18, 19, 20, 25, 26, 28, 29, 30, 32, 34, 38, 39, 40, 41, 42, 46, 48, 66, 71
LTE 4x4 Bands	1, 2, 3, 4, 7, 25, 30, 34, 38, 39, 40, 41, 42, 48, 66
LTE Category (DL/UL)	20 / 18
LTE Max Speed (DL/UL)	2000 / 200 Mbps
NR NSA Bands	1, 2, 3, 5, 7, 8, 12, 20, 25, 28, 38, 40, 41, 66, 71, 77, 78, 79, 260, 261
NR SA Bands	41, 71, 78, 79

Source: https://cacombos.com/

What about 5G devices?

138
(181 Identified)

Mobile form factor:

QC: Snapdragon 865 / X55 chipset
Samsung: Exynos 990
MediaTek: Dimensity 1000
MediaTek: Helio M70

12

Hotspots and CPEs	Askey	HTC	Netgear	WNC
	Inseego	Netcomm	Nokia	ZTE
5G modules	Compal	Longsung	Sierra	SIMcom
	Fibocom	Quectel	Wireless	Telit

35
(123 Identified)

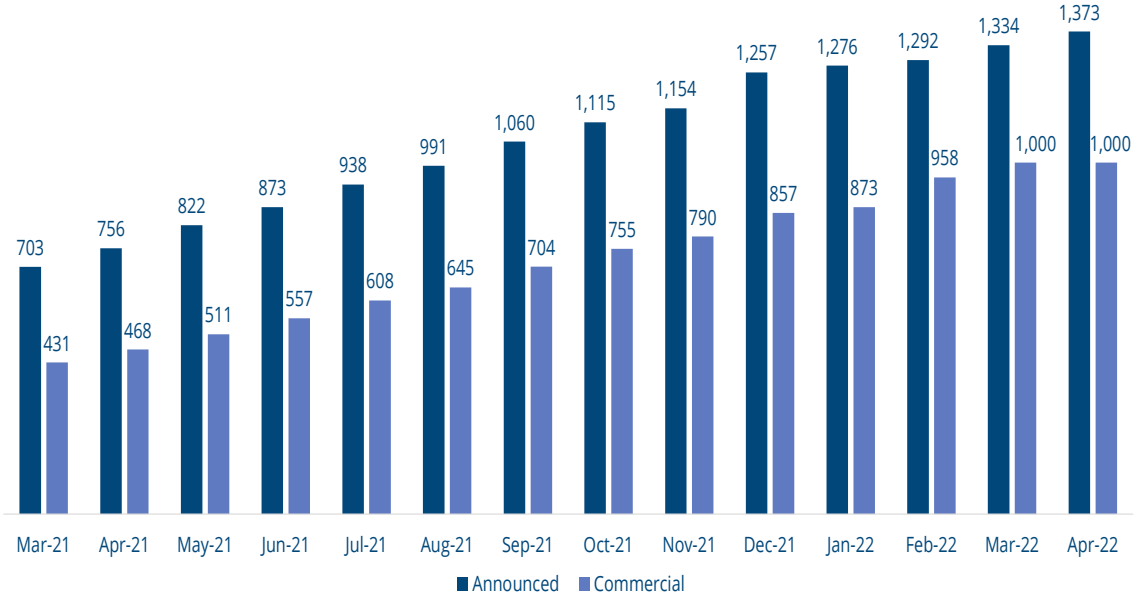
11
(64 Identified)

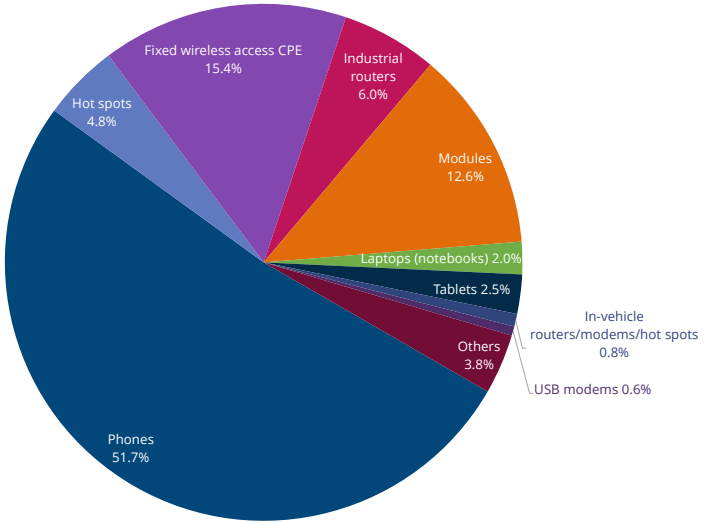
CPE & other:

Snapdragon 865 chipset & variants

Source GSA Intelligence: September 2020

What about 5G devices?

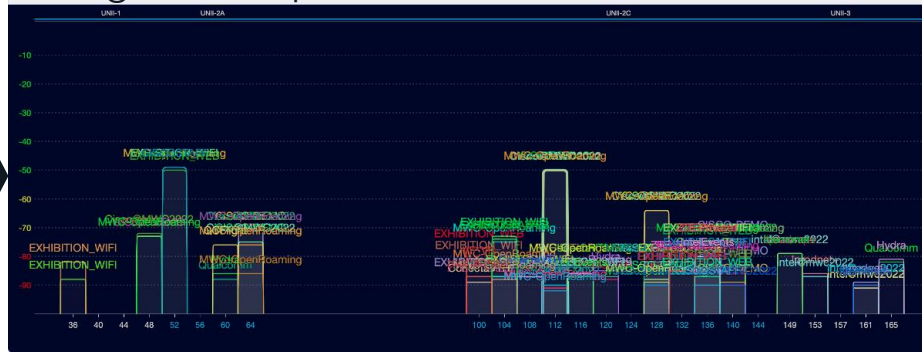




Source GSA Intelligence: May 2022

MWC 22 – First Production Wi-Fi 6E network!

Congested spectrum in 2.4 and 5Ghz



Speed test in 2.4 and 5Ghz:
126 Mbps UP
186 Mbps DW

Vs.

Speed test in 6 GHz:
1016 Mbps UP

Coffee Break

Recap – 5G vs. Wi-Fi

To Summarize

- Wi-Fi 6 and P5G have many similarities
- Spectrum is the key difference!
  - Implications on bandwidth, reach, cost
- Private 5G optimizes 5G technology for Enterprise uses
- Both Wi-Fi6 and P5G have a place to support Enterprise use-cases
  - Don’t attempt to find a clear winner in all categories!
- .. So let’s talk about use-cases!

5G and Wi-Fi (as it stands today)

	Wi-Fi 6/6e	P5G
Spectrum (economics)	Unlicensed: 2.4 GHz, 5 GHz, 6 GHz International with regional regulations	Licensed: 3.5 GHz Midband, mmWave Local License & rules but not always available
Channel Width (bandwidth)	2.4 GHz: 20, 40 MHz 5 GHz & 6 GHz: 20, 40, 80, 160 MHz	mixed numerology within carrier Midband: 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 MHz mmWave: 50, 100, 200, 400 MHz
Radio (# Radios)	OFDMA, MU-MIMO, Beamforming	
	1024 QAM Antennas: 8T8R, 12T12R	256 QAM Indoor Antennas: 4T4R Outdoor Antennas: 64T64R
	Reach: 30-40m	Femto: 8-15m Pico: 200m Micro: 2000m
Infrastructure (operations)	WLC Self contained Access Points no complex transport	5G Packet Core both control and user plane (offered as-a-service) RUs with complex sync requirements on transport (PTP)
Identity / AAA	Typically enterprise ID and Authentication	ID: SUPI & SUCI mechanism (address 3/4G vulnerabilities) Auth: EAP-AKA or 5G-AKA
Security	Encryption: Galois/Counter Mode Protocol(GCMP-256) Key HMAC-SHA-384	Encryption: SNOW 3G, AES-CTR, and ZUC Key AHMAC-SHA-256
Endpoint Availability	Pervasive	Improving
Endpoint Mobility	Endpoint controlled/initiated	Network Initiated / Controlled
Target use-case	High Data Rates, Massive IoT, Low Latency	Macro Mobility, EMBB, mmTC, URLLC

Typical Drivers to 5G

A Note on TCO Comparisons

- Evaluating Wi-Fi and P5G from a TCO perspective is tricky!
- Many variables – almost impossible to generalize

Mobility

Endpoint availability

Application Requirements
(bandwidth, Jitter..)

Number of Radios / APs

Adjacent Operations

Environmentals (penetration,
building layout…)

Coverage Area

Spectrum
(type, availability, interference)

Traffic patterns

- BEWARE!

Its all about the use-cases!

Manufacturing

Warehouse

Gas Station / Kiosk

Oil and Gas

Roadways

Wireless technologies are key pillars of the Internet of Things although…
No single technology fits all.

Distribution Center

Fleet

Seaport

Airport

Coverage
Wide area coverage

Clean spectrum
Eliminate interference

Mobility
Reliable handover for AGVs

Power of 5G
Latency, throughput, scale

Security
Cellular Security

Enterprise led
Freedom of choices

Industry and Use-Case Driven Technology Selection Criteria


MFG


Transportation


Mining


Utilities


Roadways

Customer Use Case:
AGV/AMR, Train to Trackside, Autonomous mining, Remote Crane operations

1 What are the devices to connect?

Devices

Local and global Eco-system

Handhelds, AGV/AMR, Dozer, Cranes, Rail

2 What are the applications requirements?

Resiliency

Latency, Reliability, Scalability, Ease of operations, throughput…

3 Deployment Scenarios?

Deployment

Regional regulations: spectrum ?
Specify Environment: Indoor / Outdoor
Access / backhaul
Cyber-security

4 What are the potential technology options?

Technology

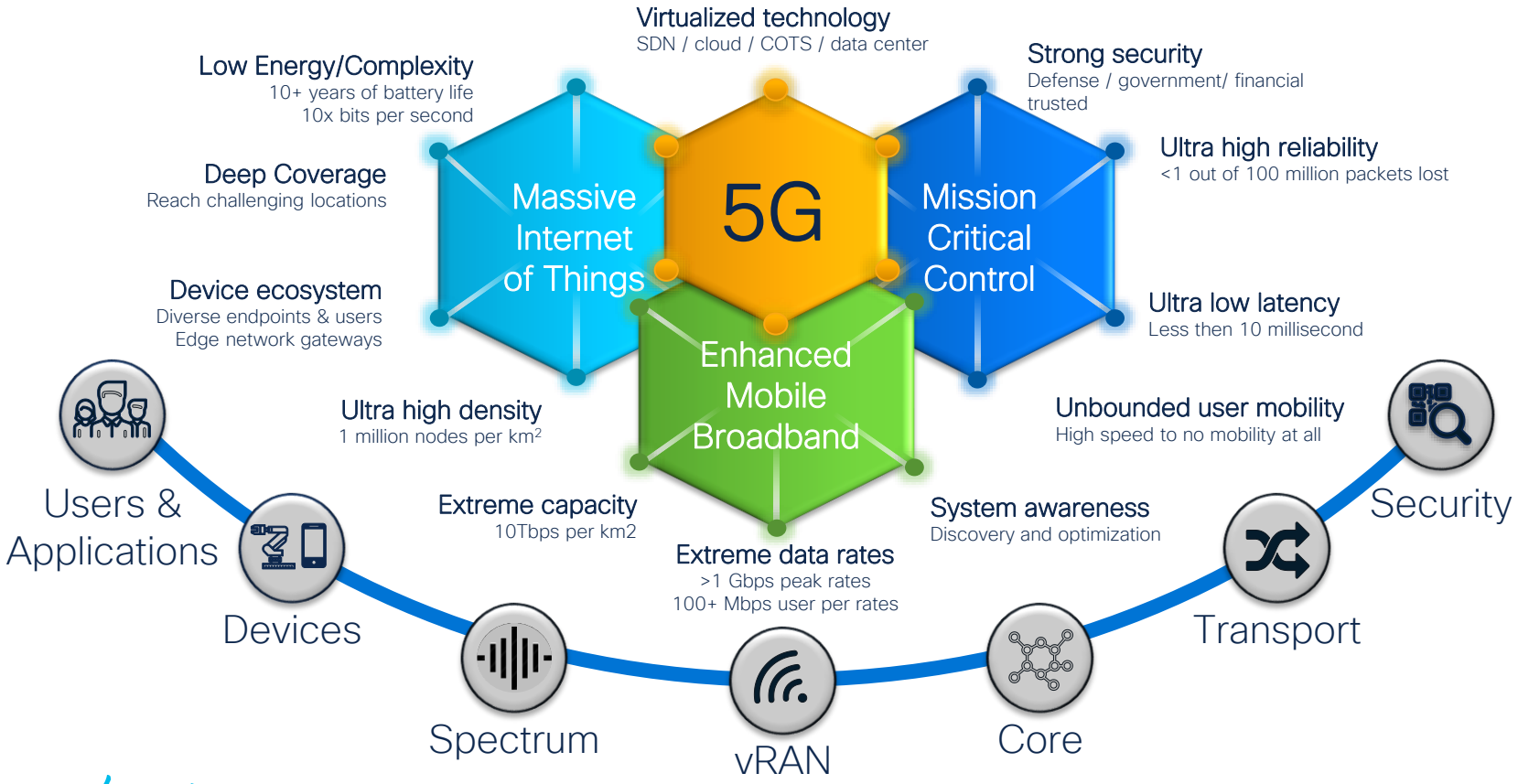
Wired: Ethernet, serial, DSL
Wireless: Wi-Fi & Ultra-Reliable Wireless Backhaul, Cellular, Wi-SUN, LoRaWAN,…
Spectrum:
Unlicensed, Licensed: Private, Public, Shared

5 What are the CapEx and OpEx Implication?

TCO

Product costs?
Operational costs?
Complexity?
Training?
Backward compatibility?

Building the End-to-End Solution to Achieve 5G Outcomes

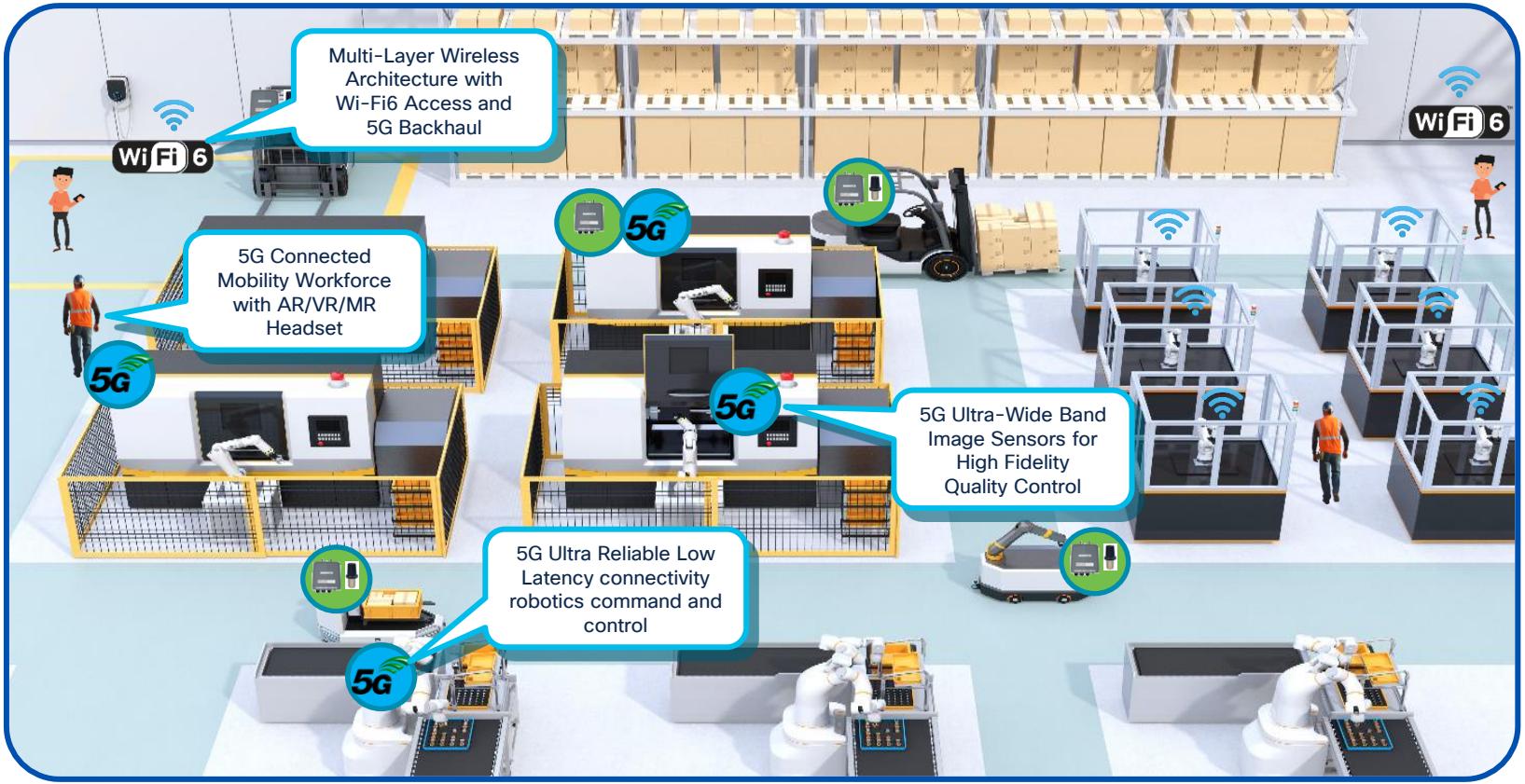


Emerging Government Use Case Examples
Wireless Mobility Technology and Solutions Required

- Demands Secure Private Network and Mobility
- Market Agility
  - → Defense
  - → Government
  - → Industry
  - → Commercial

* Matrix content adopted from DoD/OUSD 5G-to-Next G use cases

Multi-Access Wireless Examples in Manufacturing



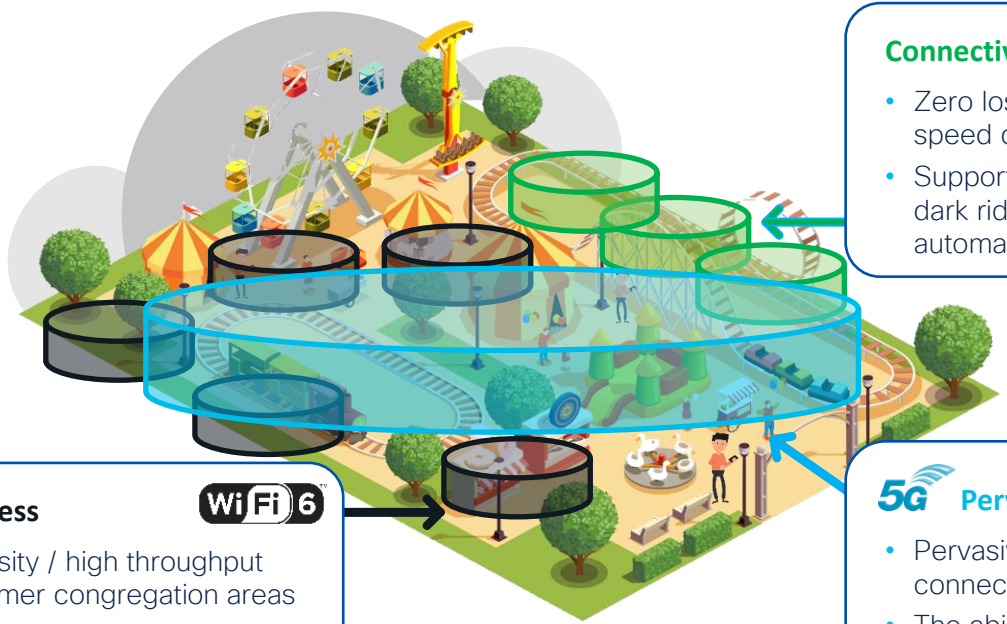
Multi-Wireless Access in Theme Parks and Venues

Better Together

5G

CURWB

Wi Fi 6



Connectivity in motion

CURWB

- Zero loss – low latency – high speed connectivity
- Support for rides in motion and dark ride connectivity with automated people movers

High density wireless

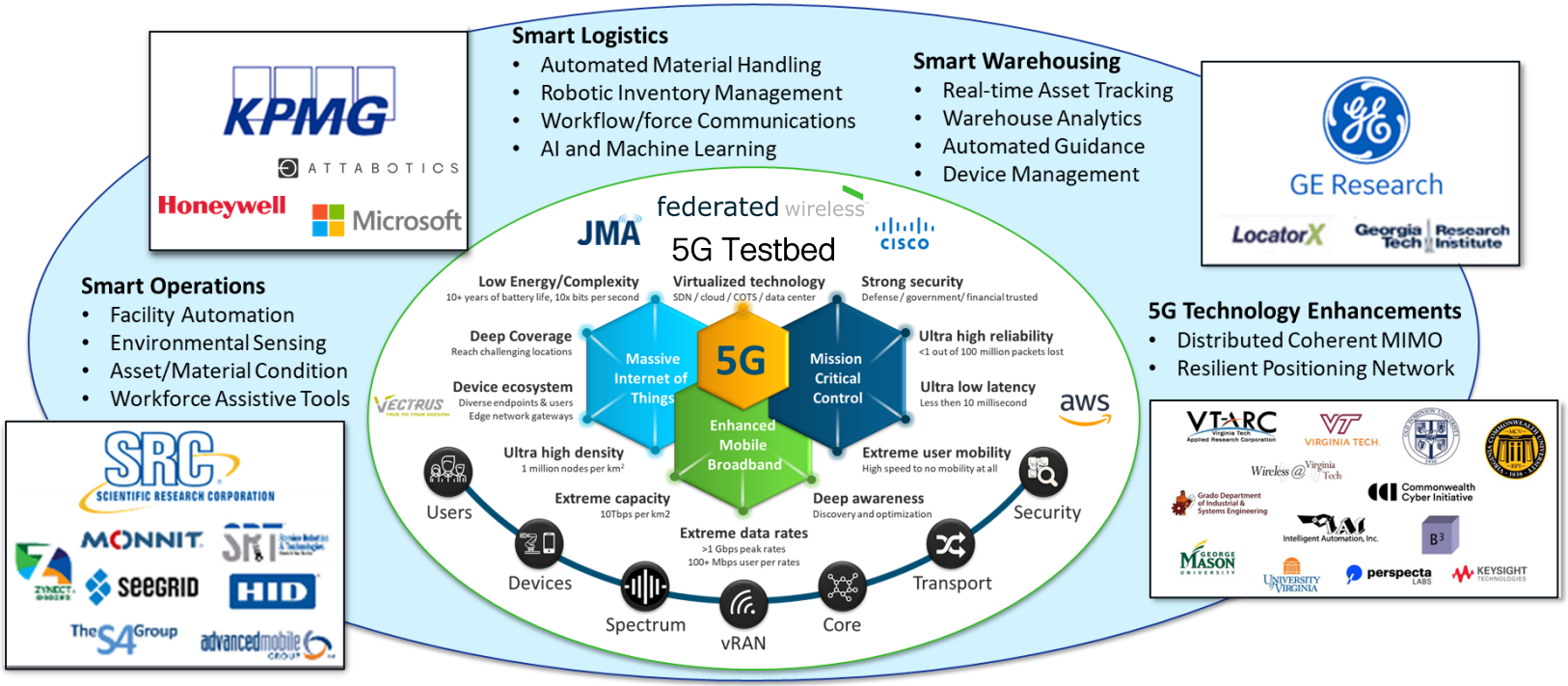
Wi Fi 6

- Leverage hi-density / high throughput wireless in customer congregation areas
- Supports application pushes across private networks
- Supports non-5G devices via 802.11

5G Pervasive 5G connectivity

- Pervasive private 5G for customer connectivity
- The ability to push application data to customers across private network
- Leveraging CURWB for 5G edge devices without cabling

US Marine Corps Logistics Base Albany 5G Smart Warehouse Applications and Use Cases

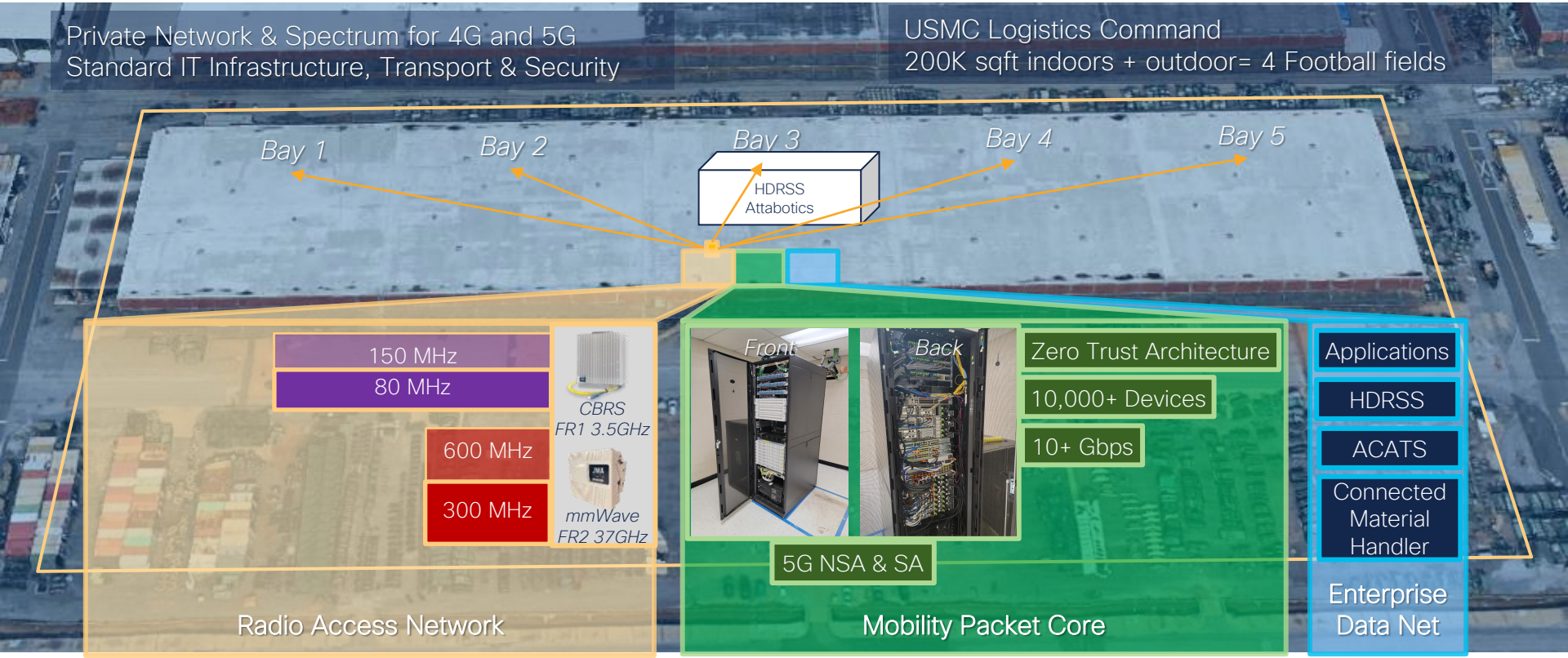


5G Native Features Improve Inventory Management through **Massive IoT** for sensor/location networks, **ultra-low latency** for precision automation, and **resilient advanced analytics** for AI/Big Data

Private 5G Business Architecture Analysis: Smart Warehouse

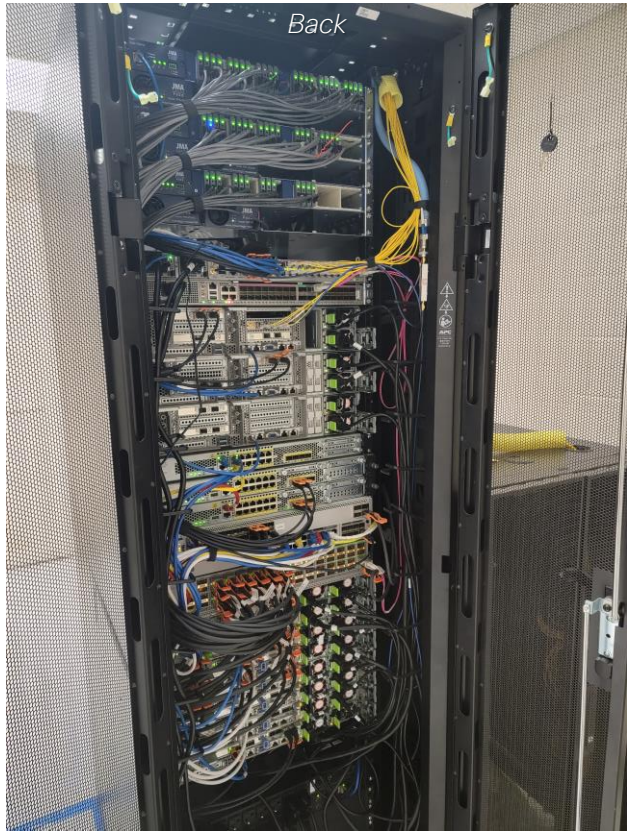
Priorities	Capabilities	Solutions	Outcomes
Digitization, Telemetry, and Visibility			
• Increase inventory accuracy and accountability • Reduce time to count • Reduce human error • Increase tracking of warehouse floor resources	• Generate telemetry from everything possible • Define multiple asset tags, trackers, data loggers to match asset profile • Real-time tracking & inventory mgt • Analog data capture (Bar/QR Code, OCR) and integration of passive RFID	• **5G** infrastructure and gateways to expand network to support **5G , Wi-Fi, LoRa, RFID, BLE**, etc. tags, beacons, and trackers • **5G** smart trackers and gateways in vehicles and large assets • **5G** GUI devices with operations data • **5G** bar/QR code reader and OCR scanners	• **Total asset visibility, quantity, location, and status** • **Real-time speed to count and inventory management** • **Digitization of received, stored, issued, and shipped material**
Guidance and Automation			
• Reduce time to receive, issue, and kit • Reduce workload on humans • Reduce manual transport operations • Reduce manual processes • Reduce cost to maintain warehouse • Decrease assembly and repair time	• AGVs and Robots performing routine tasks • Guided inventory put and pick locations • Forklift driver assistance systems	• **5G** Automated / Robotic Storage and Distribution Systems • **5G** robotic forklifts, pallet jacks and tuggers • **5G** AR/VR/MR assisted picking/kitting • **5G** light-based guided pick or put • **5G** connected AR/VR/MR assisted maintenance and repair	• **Increase material distribution capabilities** • **Increase supply chain efficiency** • **Reduced wait times for loading and unloading goods** • **Automation of material retrieval** • **Optimization of warehouse space**
Data Fusion, Analytics, and Optimization			
• Optimized warehouse processes • Reduce disparate information stores • Prioritize workloads	• Capacity planning • Predict material availability • Supply Chain Forecasting • Warehouse modeling & predictive analytics	• **AI/ML** Predictive Analytics • **Data Fusion** and Service Broker • **Digital modeling** • **Position** triangulation from static and mobile beacons	• **Autonomous daily inventory** • **Data Driven Decisions** • **Data management and visualization** • **Converged data collection, analysis, and data driven inventory management**
Safety and Security			
• Improve safety and security	• Physical security and access control • Personnel tracking • Environmental Controls and Monitoring • Automated inventory results, storage history, tamper alerts	• **5G** security cameras, sensors and actuators • **5G AR/VR/MR** assisted workers • **5G** air quality monitoring, building management, and HVAC control systems • **5G** building automation and door controls • Blockchain ledger of asset status	• **Safer workplace avoiding accidents and reducing potential for malicious intent** • **Asset assurance, prevention, detection, and alert to unauthorized access & movement**

US Marine Corps Logistics Base Albany 5G Smart Warehouse Private 5G On-Prem Deployment

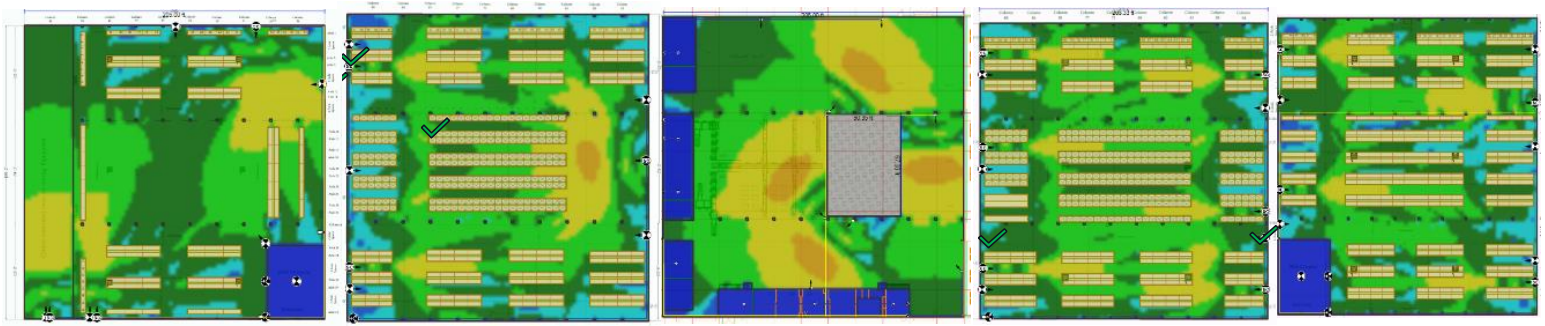


US Marine Corps Logistics Base Albany 5G Smart Warehouse Private 5G RAN, Core, Security, Management, and Apps

- Small Modular Footprint
- Nx 15GE Capacity
- Nx 5k Subscribers
- Integrated with Cisco Zero Trust Architecture
- Scalable Distribution System: Combined Low Voltage + Fiber to the Radios

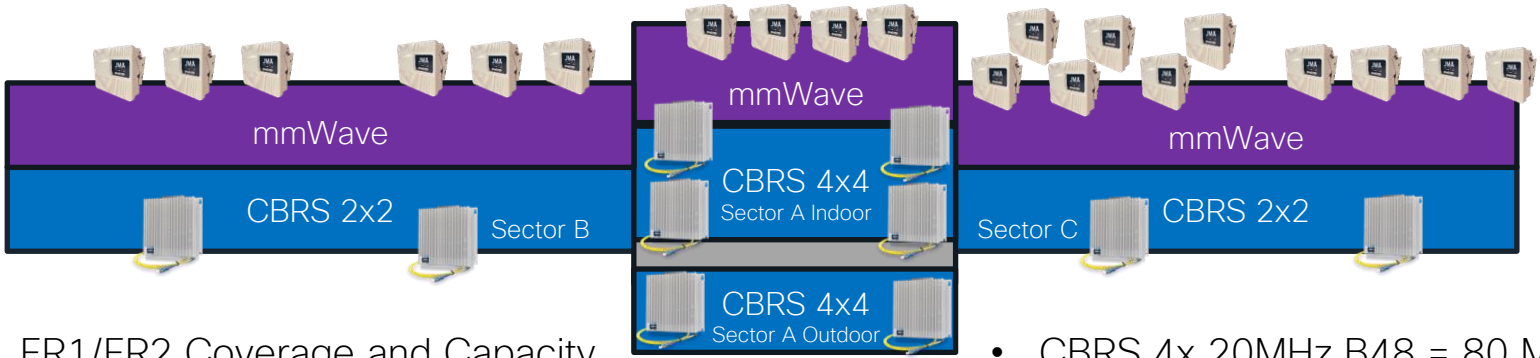


US Marine Corps Logistics Base Albany 5G Smart Warehouse Warehouse Radio / Frequency Design



200'x200' Per Bay

~ 3.7 football fields in total



- FR1/FR2 Coverage and Capacity
- 20 mmWave Radio Units
- Bay 3 is Main Area of Receipt and Shipping

- CBRS 4x 20MHz B48 = 80 MHz
- n260 interleaved 37.0-37.3 GHz Even RUs, with 37.3-37.6 GHz Odd RUs

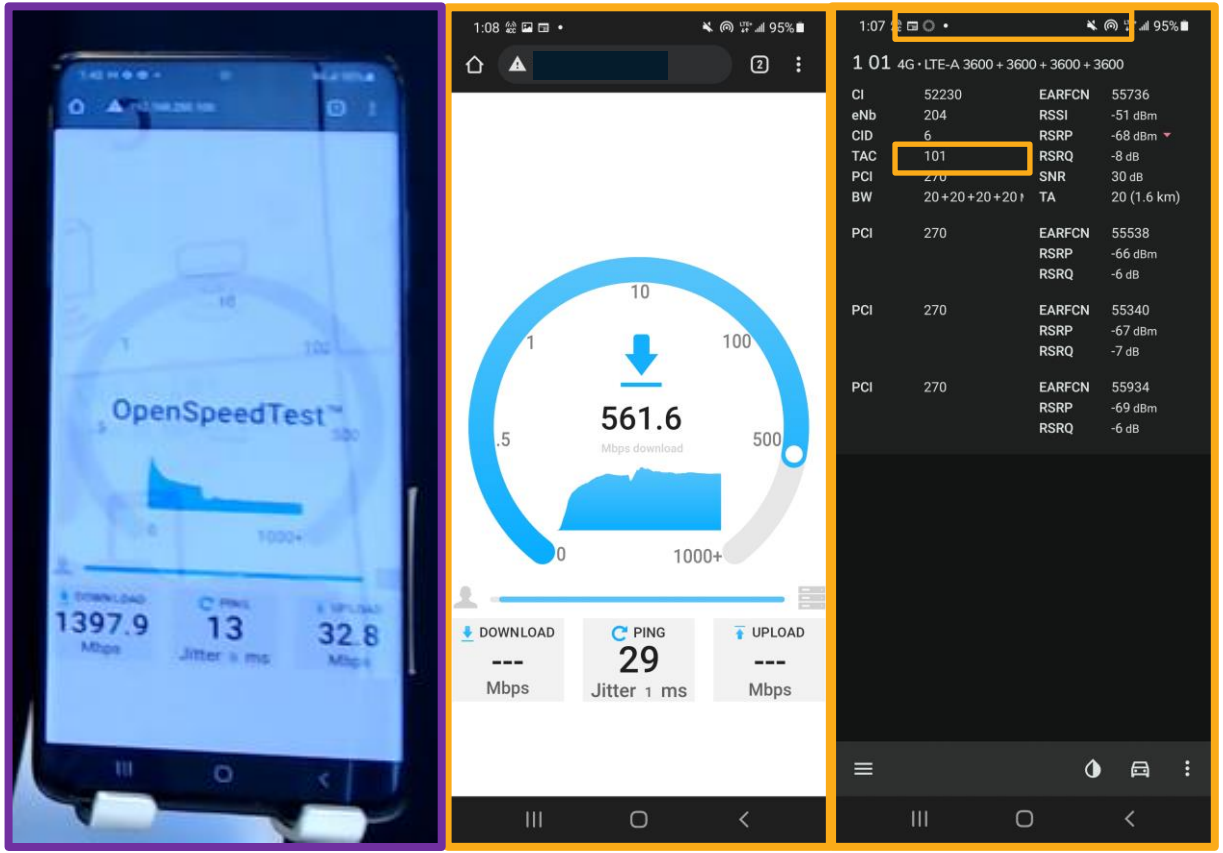
US Marine Corps Logistics Base Albany 5G Smart Warehouse Private 5G User Experience

mmWave n260 27GHz

- 1.5 Gbps
- 3x 100 MHz Carrier Aggregation
- Extremely Low Latency

CBRS b48 3.5GHz

- 500+ Mbps
- 4x 20 MHz Carrier Aggregation
- Low Latency



US Marine Corps Logistics Base Albany 5G Smart Warehouse Defense Logistics Modernization

The cost effectiveness of smart warehouses has significantly improved over the past decade, such that retrofitting existing facilities or buildings should be a real consideration for Defense leaders.

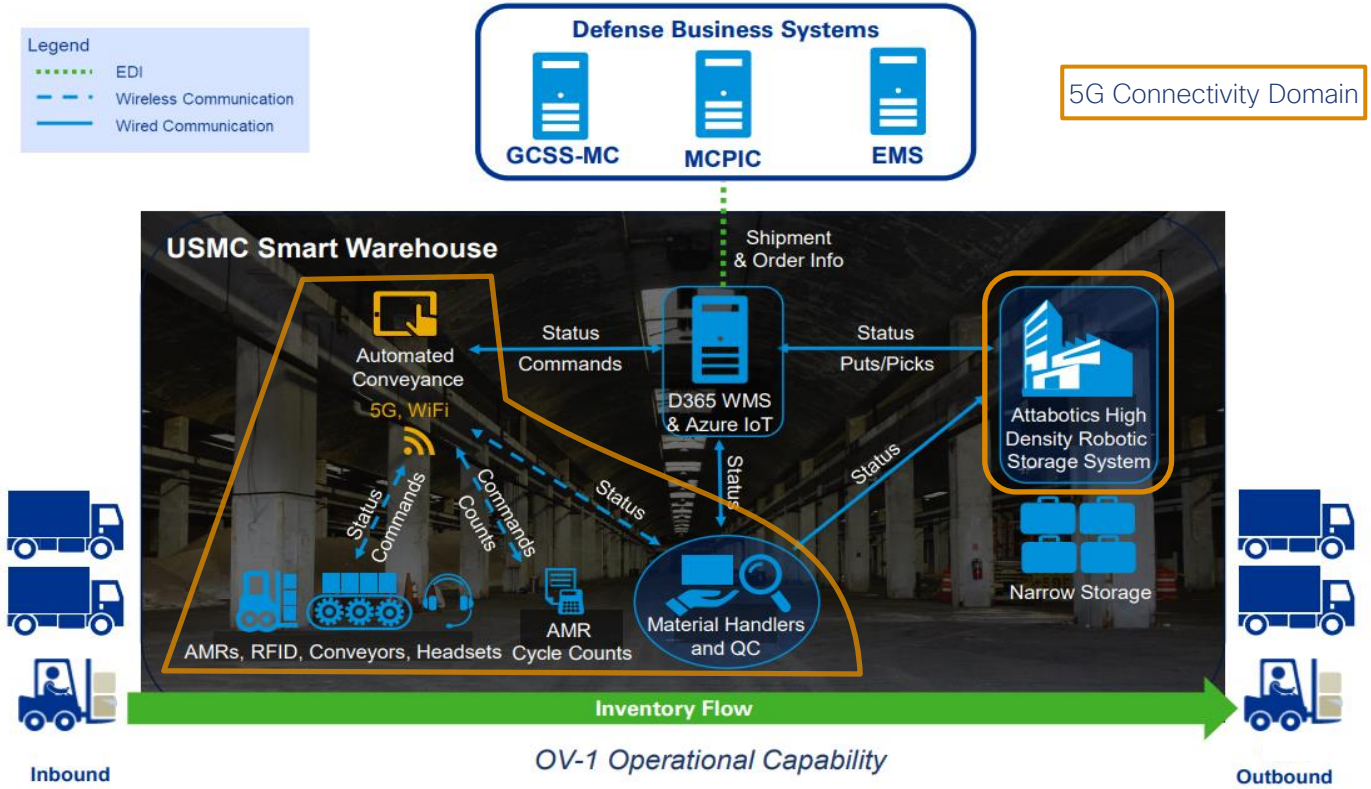
High Density Robotic Storage System (HDRSS)

Automated Conveyance and Tracking

Enable a 5G Smart Warehouse by creating an integrated, automated, and digitized environment in which gear and product move efficiently through the warehouse to support the Defense mission.

The four primary goals: Innovation; Usability; Accuracy; Accountability (Auditability)

US Marine Corps Logistics Base Albany 5G Smart Warehouse Defense Logistics Modernization

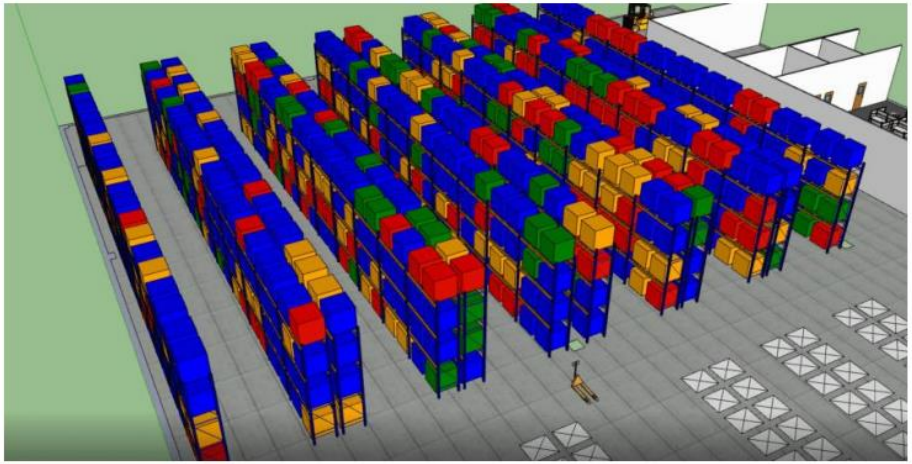


OV-1 Operational Capability

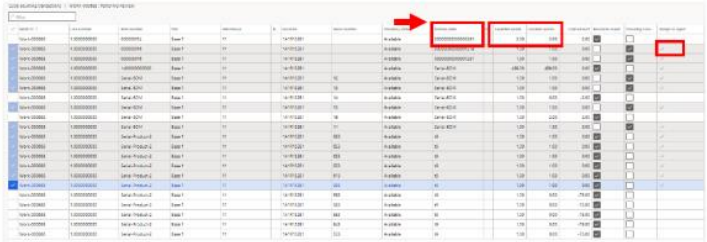
US Marine Corps Logistics Base Albany 5G Smart Warehouse High Density Robotic Storage System

US Marine Corps Logistics Base Albany 5G Smart Warehouse Inventory Visualization

- Generate a warehouse **heatmap in 3 dimensions** with volume frequency data and dynamic storage locations
- Determine **inventory path of operators** with inventory location list and count list information
- Operations will **visualize the locations** of the NIINs and easily perform the inventory
- Enable the **calculation of the time required** to inventory NIINs at different storage locations
- Create the ability to demonstrate the difference in time **comparing as-is to to-be situations**
- Inventory will be easily **auditable, traceable, under a level of control**, and induce efficiencies and security. An electronic trail will be developed for digitization of processes.



Mobile Application



WMS aligned through an API or BOT for real-time communication and causative research

US Marine Corps Logistics Base Albany 5G Smart Warehouse Digitizing the Connected Material Handler

Initial UX Development

Digital Enablement

- Material Handlers and Supply Techs are able to work across multiple different digital touchpoints for a consistent user experience

Operations Engagement

Health Measurements

- Warehouse managers are able to measure and evaluate performance both as individual users and as an aggregate warehouse

Real Time Integration

Network Integration

- Users are able to indirectly pull information from the APSR and other systems to evaluate assets in real time to streamline the experience of gear processing

APSR Integration

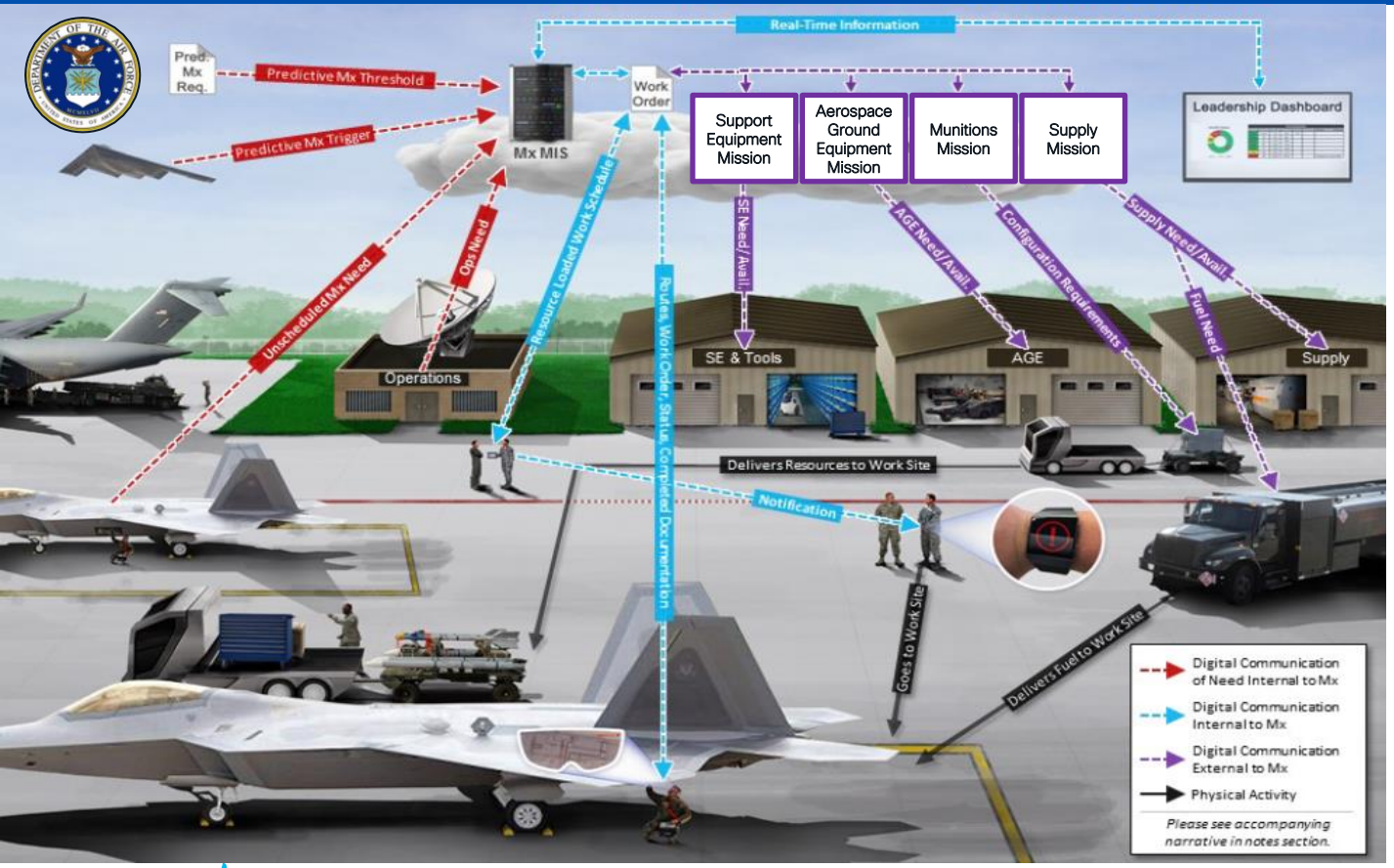
Voice to Text

Fully Integrated Network

Connected Material Handler - User Experience in a Digitized Environment

- Develop Validation / **Performance Measurements** reports
- Develop **Activity level report** for monitoring progress for warehouse processes
- Incorporate the usage of monitors in Operations to display health **performance and status of processing**
- Create support documentation for **common used features** to minimize hand key data input

Flightline Maintenance 2030: Linked, Lethal…Ready!



U.S. Air Force Base Information Transport Infrastructure (BITI)

Base Area Network (BAN) Modernization Program

Wireless Coverage

- Public/Private
- 802.11, 4G LTE, 5G NR

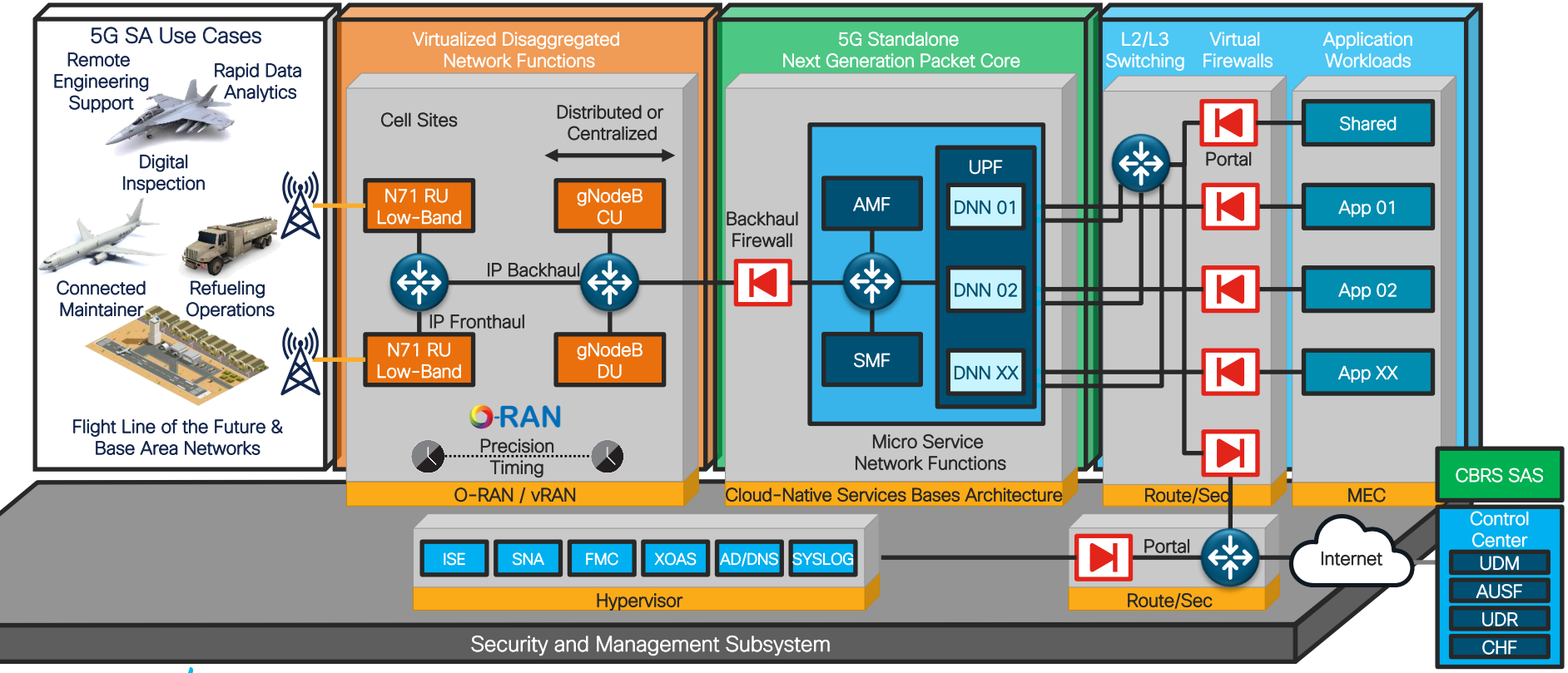
Spectrum

- Unlicensed
- Licensed CBRS, mmWave

Scope

- Indoor/Outdoor Use Cases
- Guest WLAN, AAA, Performance, Zero Trust Security, First Responder Support

Naval Air Station 5G Flightline of the Future



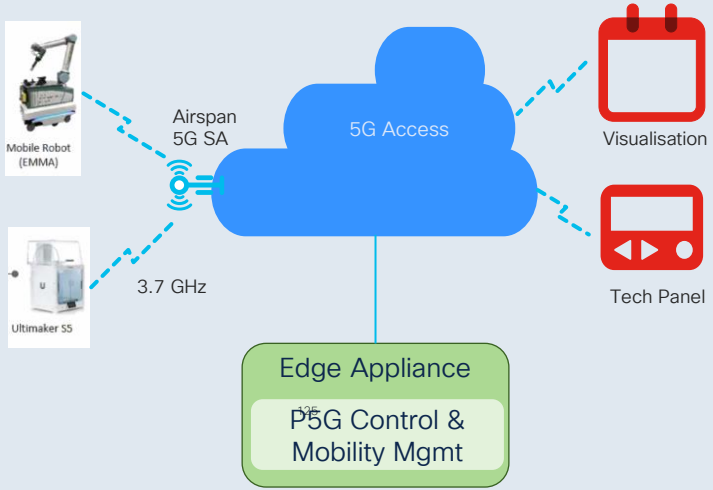
Private 5G Use Case: Manufacturing

Use case description

- Industry 4.0 manufacturing
  - Experimentation / training for robots
  - Closed loop manufacturing (sensors, controlling mobile robots, automated pickup of 3D printed components)
  - Safety: remote services, shop floor monitoring
- Key requirements
  - Private / protected spectrum
  - Reliable communication incl. slicing
  - Location accuracy
- Applications: AGV, CAD drawings, 3D printing

Architecture

Automated robot delivery of 3D printed components

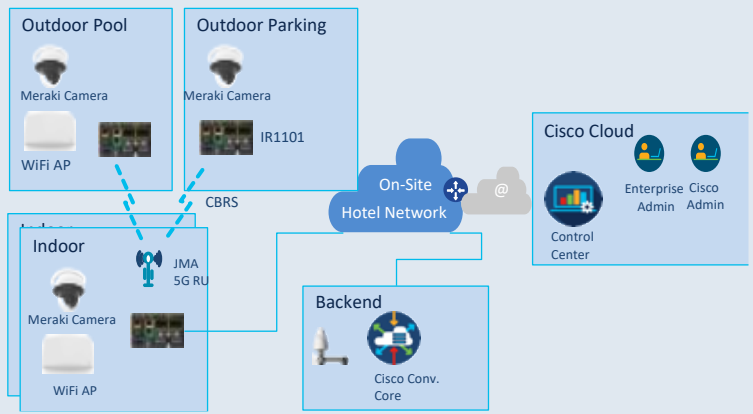


P5G Use-Case: Hotel Dallas

Use Case Description

- Improved network access, Wireless backhaul for hotel network connectivity to simplify operations
  - HOTEL is a protected building, so difficult to install cabling
- Connect Cameras, APs, sensors etc. to the Hotel network
- Key Requirements
  - Private / protected spectrum
  - Indoor/outdoor coverage
  - Integration with existing hotel network

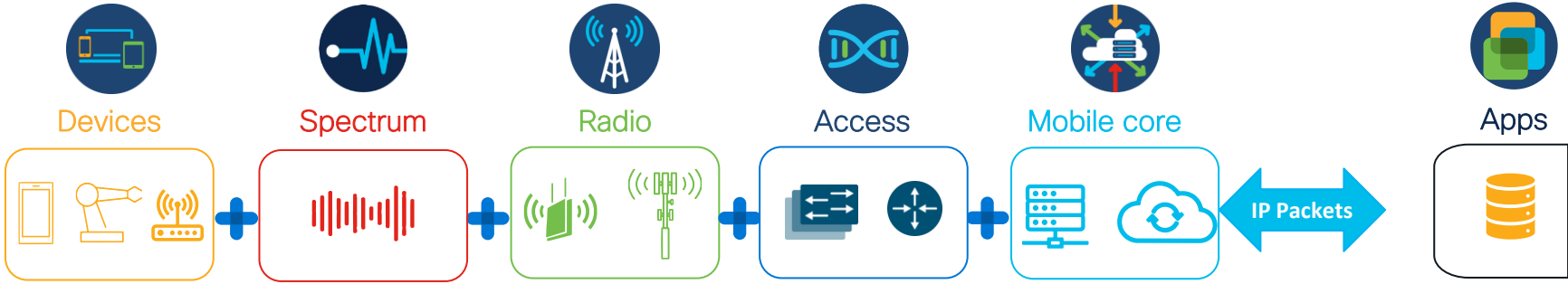
Architecture



Wi-Fi and *Private* 5G Architectures: Better Together!

cisco Live!

Wi-Fi and 5G Comparable Architectures



Wi Fi ALLIANCE
IEEE
IETF

User Equipment
Device with a Wi-Fi Radio Interface

Unlicensed Spectrum
2.4 GHz
5 GHz
6 GHz

Access Points (AP)
Radio Antennas and Control Functions
Wi-Fi6 = OFDMA

Enterprise
IBN / DNA
SD-WAN
SD-Access

Wireless LAN Controller
User session Policy and Control
Scale to Thousands of Devices

Enterprise

10s to 50 Thousand

10s of Feet to 100s of Miles

5G
3GPP
A GLOBAL INITIATIVE

User Equipment (UE)
Device with a 5G Radio Interface

Licensed Spectrum
Shared or Private
20-50 GHz
1 – 7 GHz
Sub 1 GHz

Radio Access Network (RAN)
Radio Antennas and Control Functions
5G = OFDMA

Service Provider or Enterprise
Optical
Segment Routing
MPLS L2/L3 VPN

Mobile Packet Core
User session Policy and Control
Scale to Millions of UEs

Internet / Enterprise

10s to > 1 Trillion

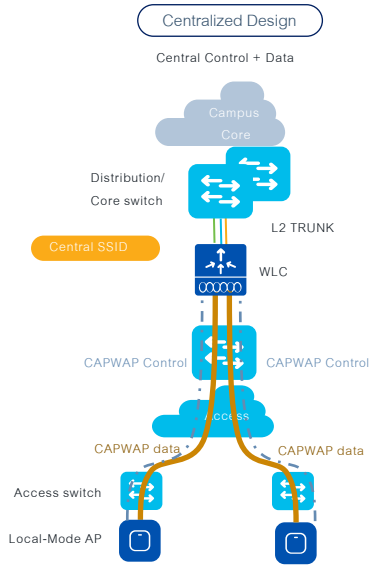
10s of Feet to 10,000s of Miles

Open Architecture with Cloud Native Decentralized and Distributed Network Functions

Distributed Application Architectures

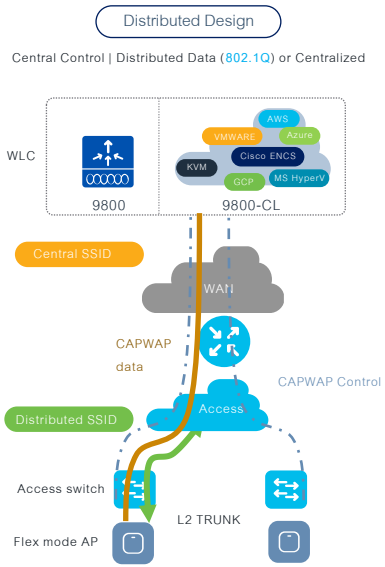
Review of Wi-Fi Architectures

Review: Wireless Deployment Options



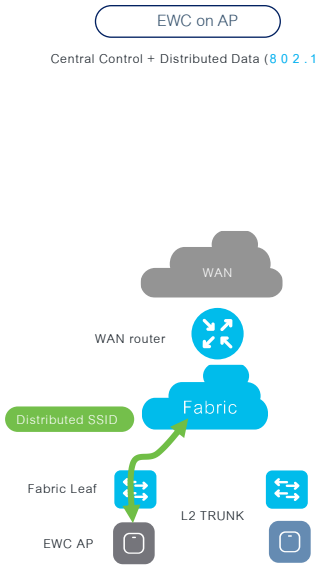
Local mode

- Mid to Large size Campus
- APs are in local mode
- Client traffic bridged at WLC in a L2 trunk
- Single point of entry into wired network
- Roaming is supported across all APs
- Latency < 20ms between AP and WLC



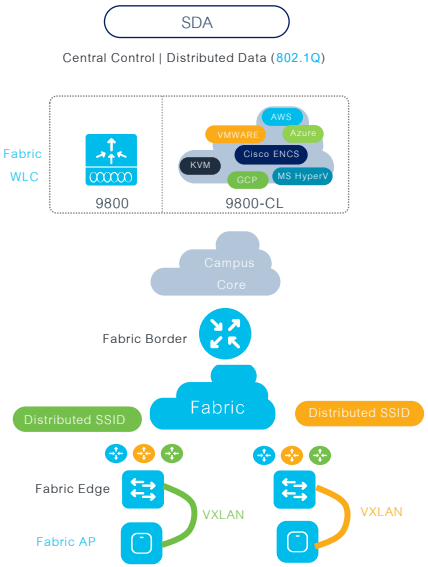
FlexConnect

- Distributed Enterprise design choice
- APs in Flex mode, across a WAN from WLC
- Per SSID: Client traffic is distributed at AP in L2 trunk or centralized via CAPWAP
- Roaming limited to APs in a Flex domain



Embedded Controller in AP

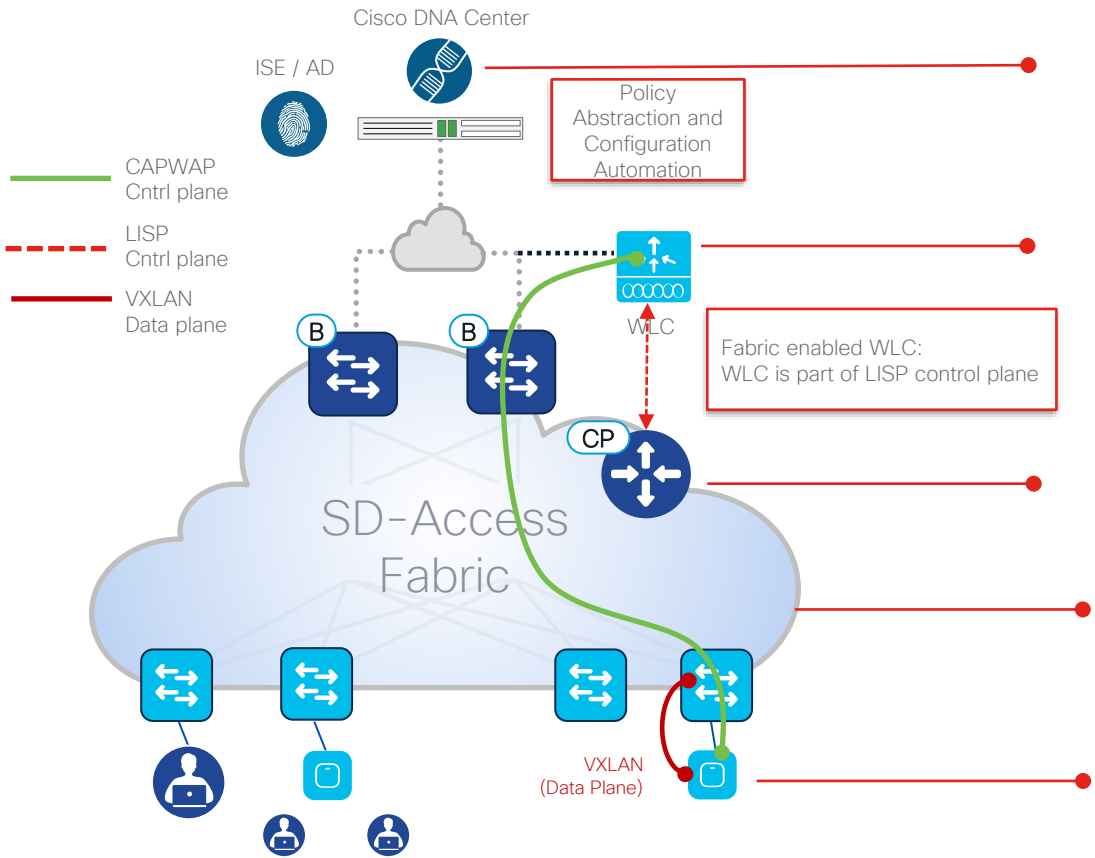
- Standalone small site
- Master AP runs EWC
- Other APs are in Flex mode
- Client traffic is switched locally
- Roaming limited to APs in a Flex domain



SDA Wireless

- Mid to Large size Campus
- APs are in Fabric mode
- Traffic distributed at AP via VXLAN
- Roaming is supported across all APs
- Latency < 20ms between AP and WLC

Cisco SD-Access – Wireless Architecture



Automation
- Cisco DNA Center simplifies the Fabric deployment
- Including the wireless integration component

Centralized Wireless Control Plane
- WLC still provides client session management
- AP Mgmt, Mobility, RRM, etc.
- Same operational advantages of CUWN

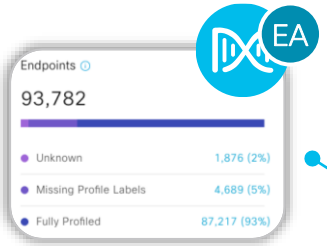
LISP control plane Management
- WLC integrates with LISP control plane
- WLC updates the CP for wireless clients
- Mobility is integrated in Fabric thanks to LISP CP

Optimized Distributed Data Plane
- Fabric overlay with Anycast GW + Stretched subnet
- VLAN extension with no complications
- All roaming are Layer 2

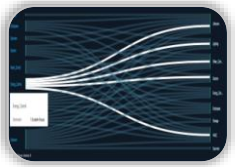
VXLAN from the AP
- Carrying hierarchical policy segmentation starting from the edge of the network

Catalyst Stack Innovation Advantage

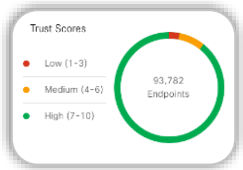
Endpoint Analytics (EA)



Policy Analytics

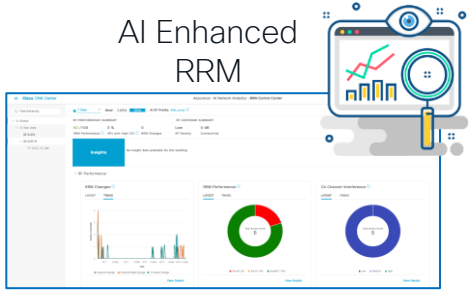


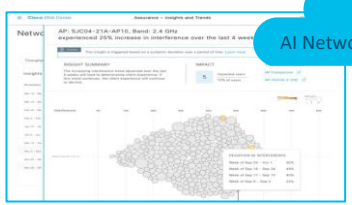
Trust Analytics



AI Driven Scanning Radio

AI Enhanced RRM





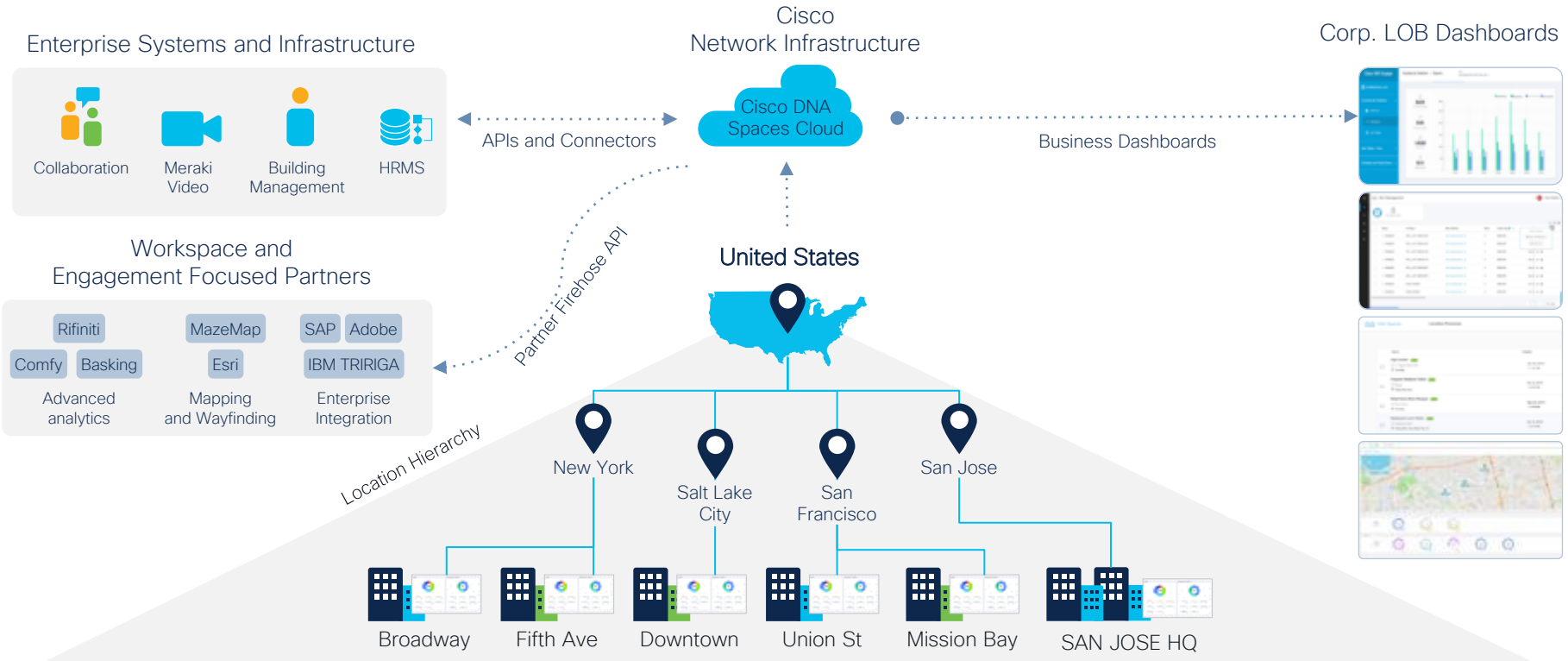
AI-driven at every layer of the stack

Cisco DNA Center assurance

The confidence that the infrastructure is doing what you intended it to do

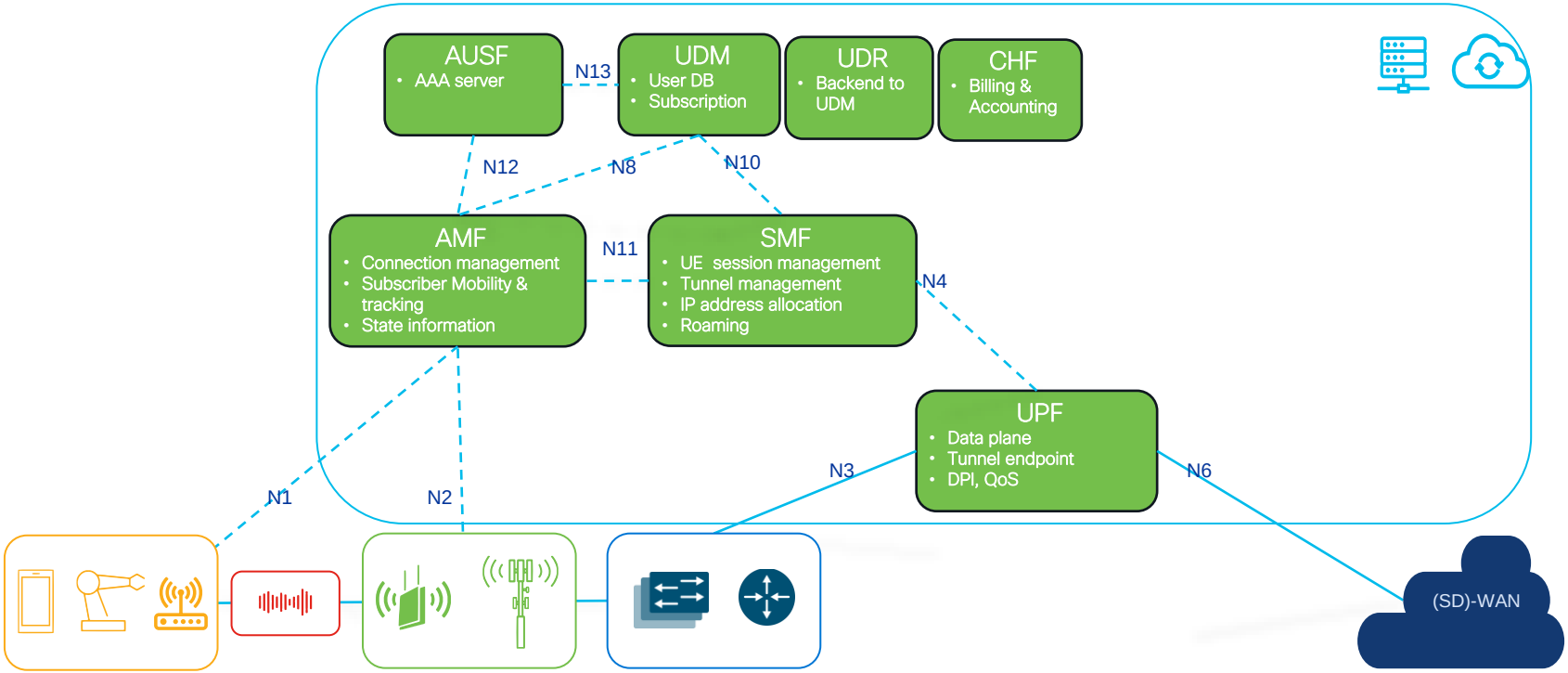
Insights and visibility	Proactive troubleshooting	Corrective actions
360-degree visibility, context, historical insights, iOS analytics, user location	Anomaly-based Intelligent Capture, sensor tests, and on-demand analytics	Guided remediation, automated updates, system optimization
Best-in-class user experience	Minimize downtime, increase user productivity	Increase IT productivity

Cisco DNA Spaces – Middleware to deliver Wi-Fi based business outcomes

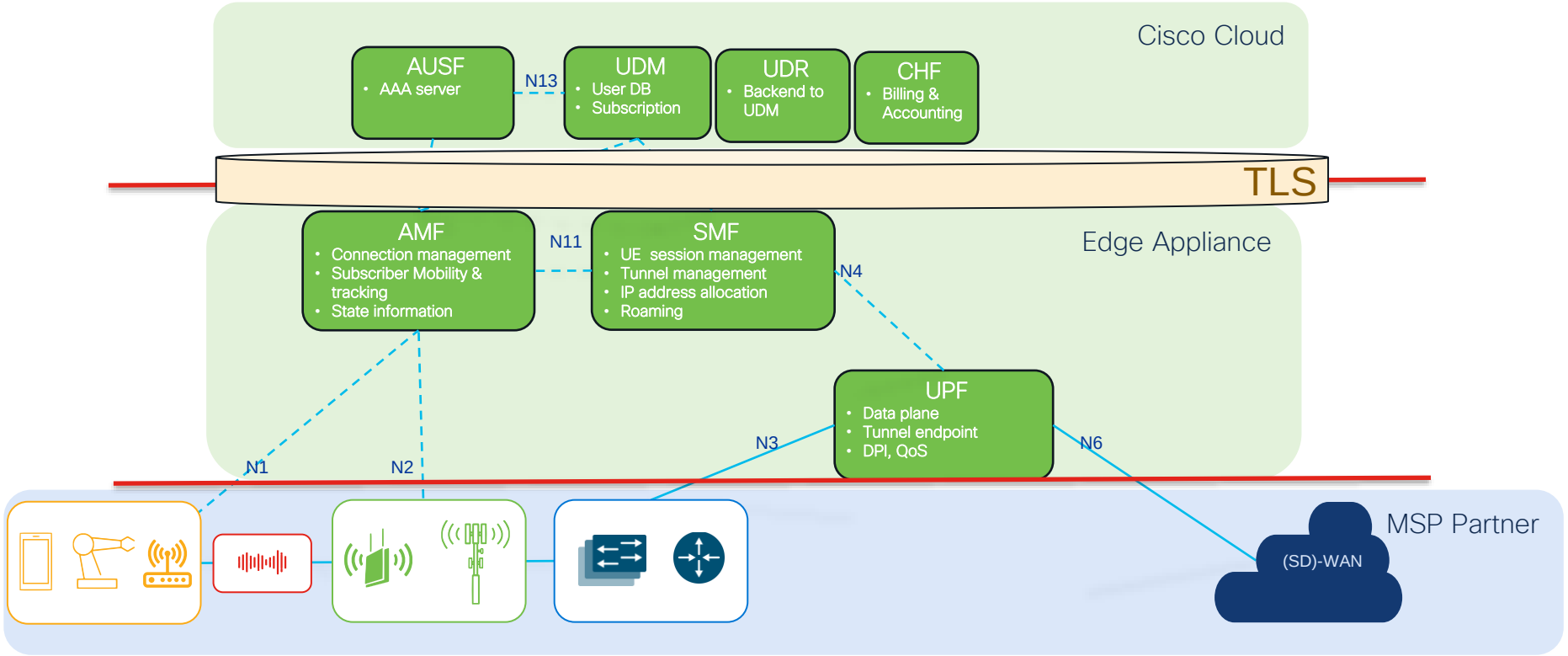


Private 5G Architectures

The Cisco Converged Core Governs the P5G Access



Cisco Converged Core: Hybrid Deployment Model



5G Architecture enables splitting of RAN Functions

Centralized Unit (CU)

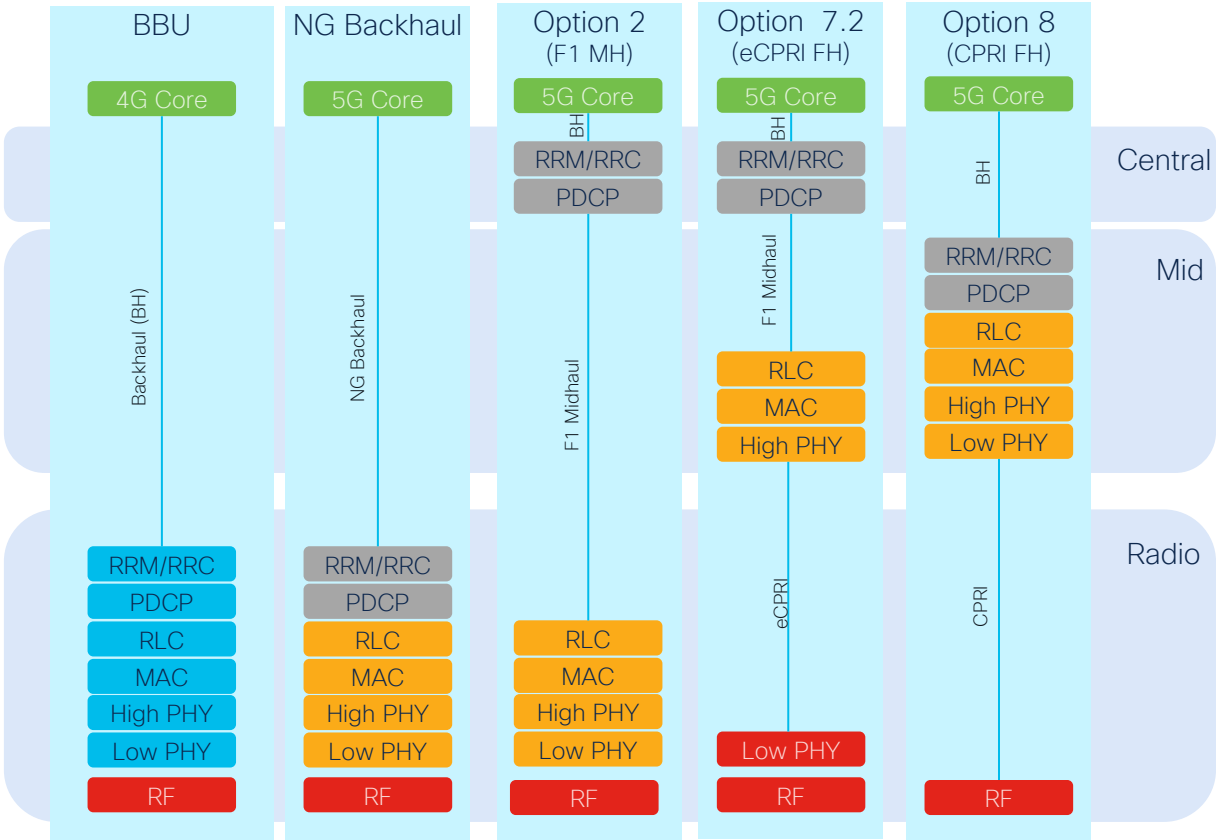
- Radio Resource control / management
- Packet Data Convergence Protocol
- Description, details

Distributed Unit (DU)

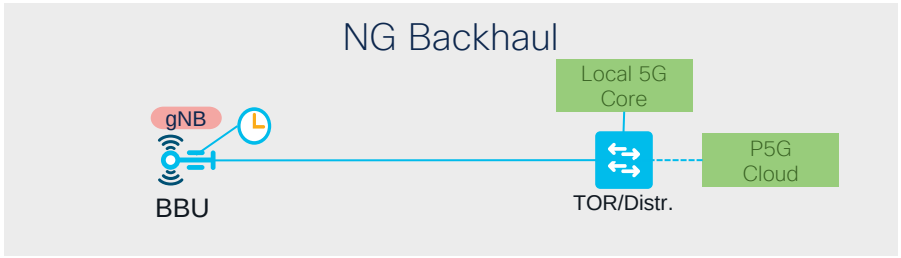
- Radio Link control, MAC
- Subset of eNB/gNB (depending on functional splits

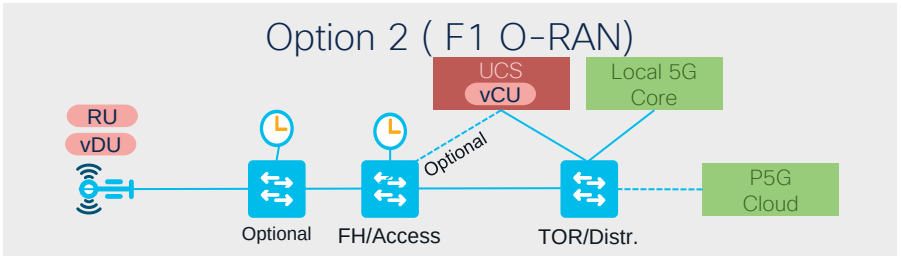
Radio Unit (RU)

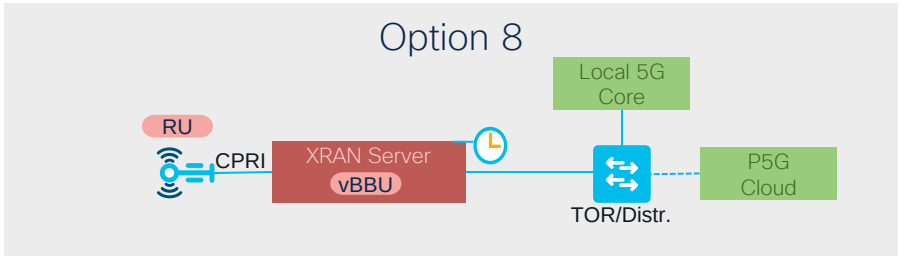
- Radio signal (digital <-> analog)
- Beamforming
- Physical layer

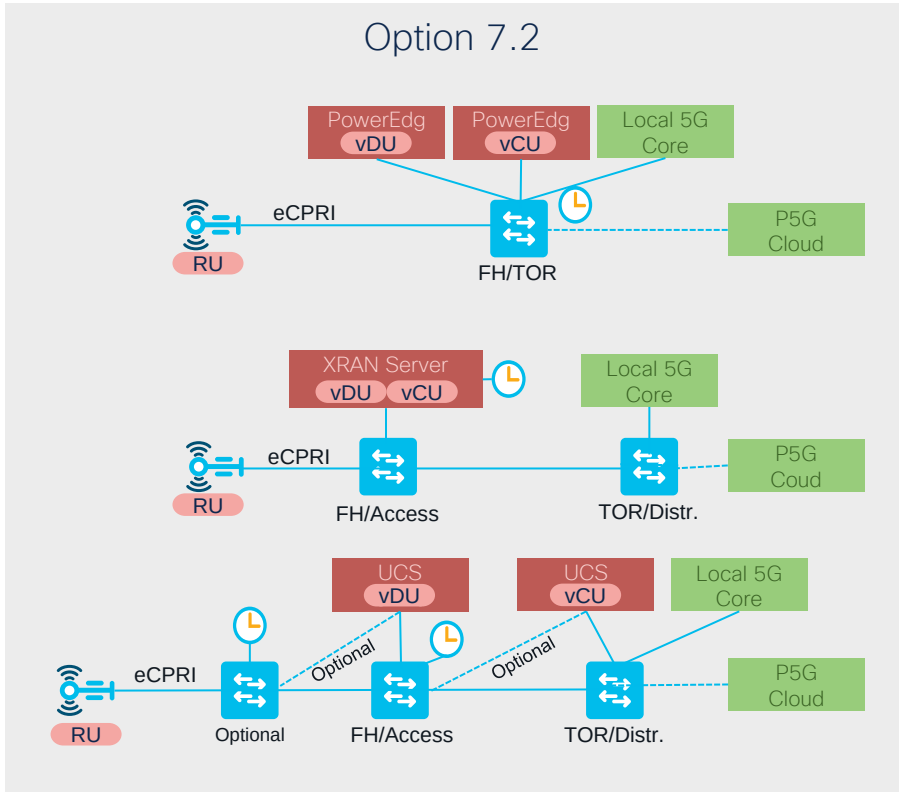


There are many RAN Architecture Variations





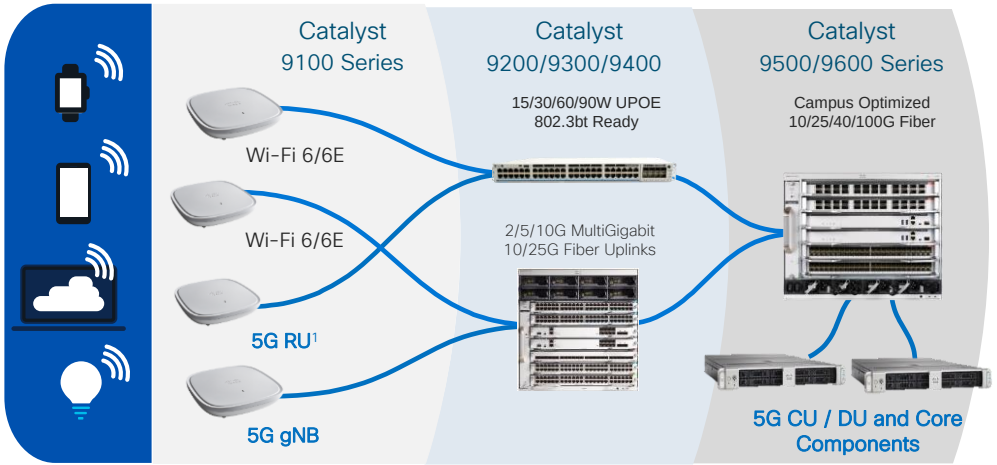




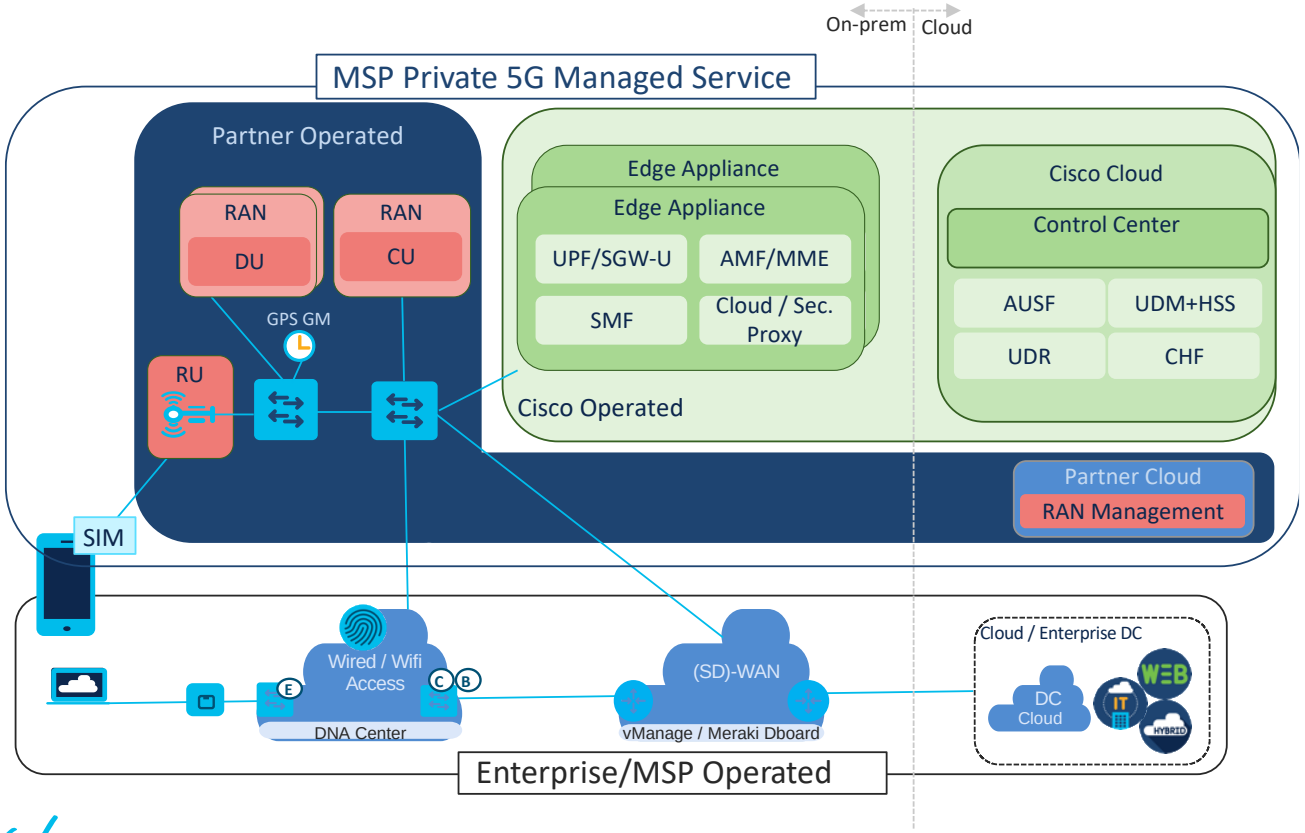
5G Converged Enterprise Transport Vision

Reduce Infrastructure Costs and Simplify Operations

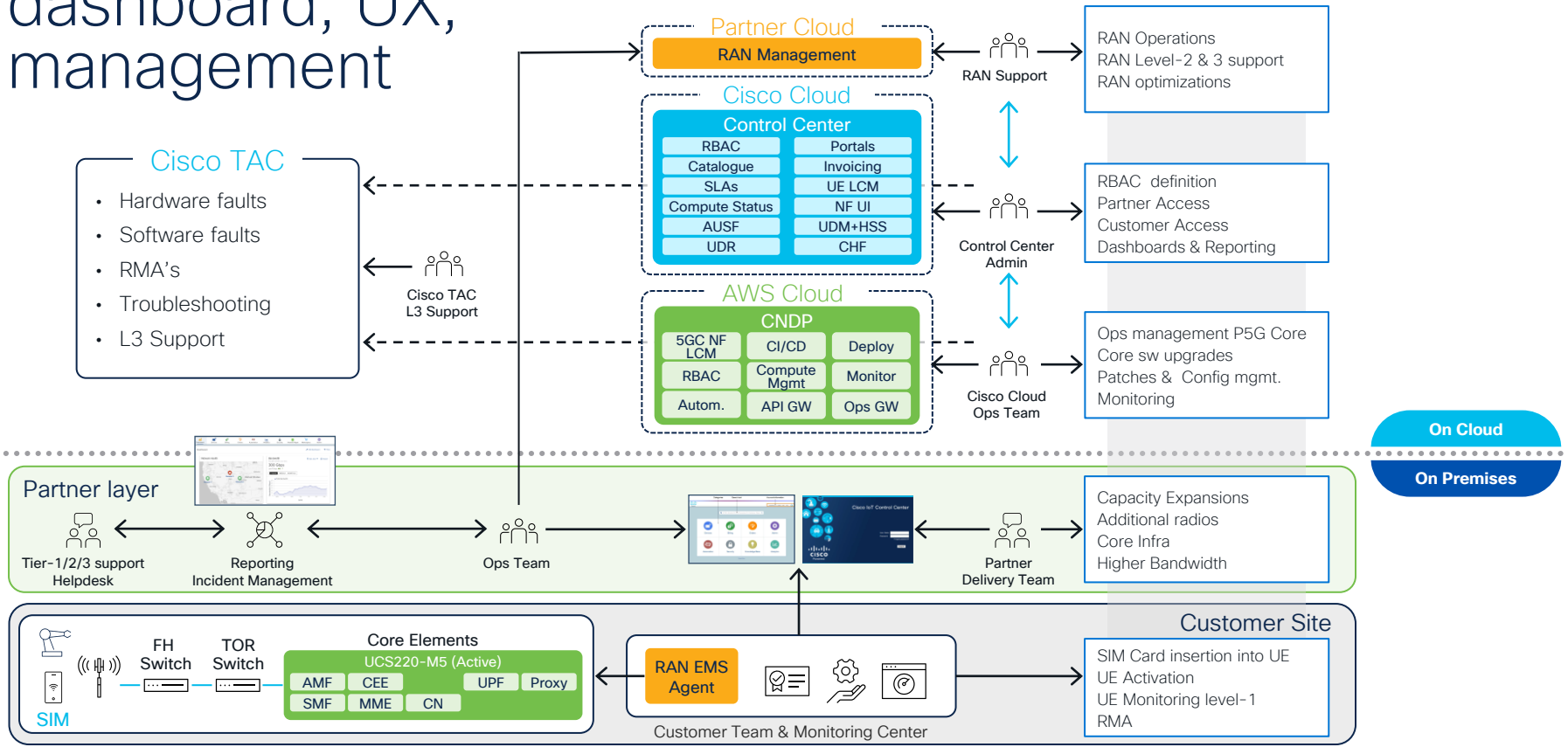
- Converged Infrastructure for all Services
- Common Technology End-to-end: using campus SW
- Open, Programmable SDN-based
- On-prem & Cloud-based (Hybrid Cloud)



The Cisco P5G Architecture in Detail



CC/enterprise dashboard, UX, management

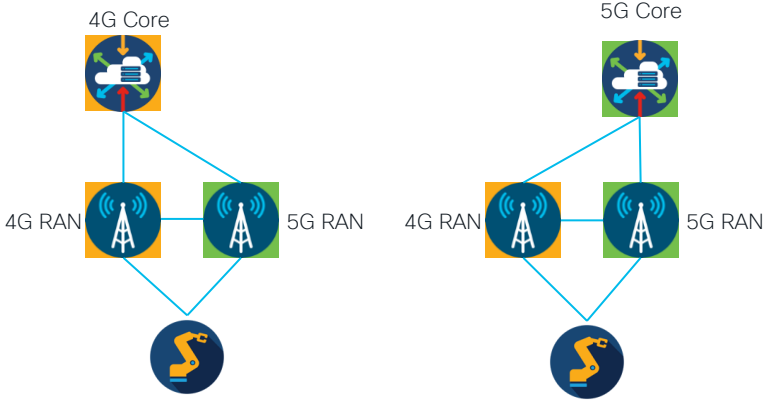


Demo: Control Center

Evolving to a 5G Network

5G Standalone & Non-Standalone Architecture

- 5G Standalone (SA): 5G RAN paired with a 5G Packet core
- 5G Non-Standalone (NSA): 4G and 5G RANs paired with either a 4G or a 5G Packet Core simultaneously
  - Endpoints are dual-connected to both a 4G RAN and a 5G RAN (requires device support)

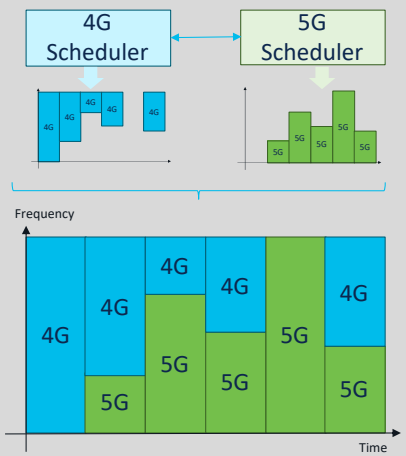


Option	Core	Control	Data
3/3a/3x	4G	4G	4G+5G
4/4a	5G	5G	5G+4G
7/7a	5G	4G	4G+5G
8/8a	4G	5G	5G+4G

Facilitating 4G to 5G Evolution

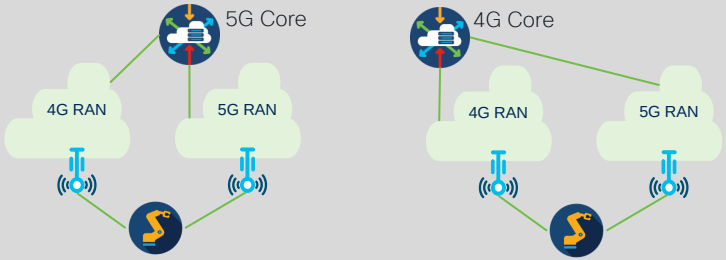
Dynamic Spectrum Sharing

- The same spectrum bands are sometimes used for 4G and 5G
- Radio Equipment can dynamically change RAN between 4G/LTE and 5G NR
- Parallel use of 4G and 5G of the same UE

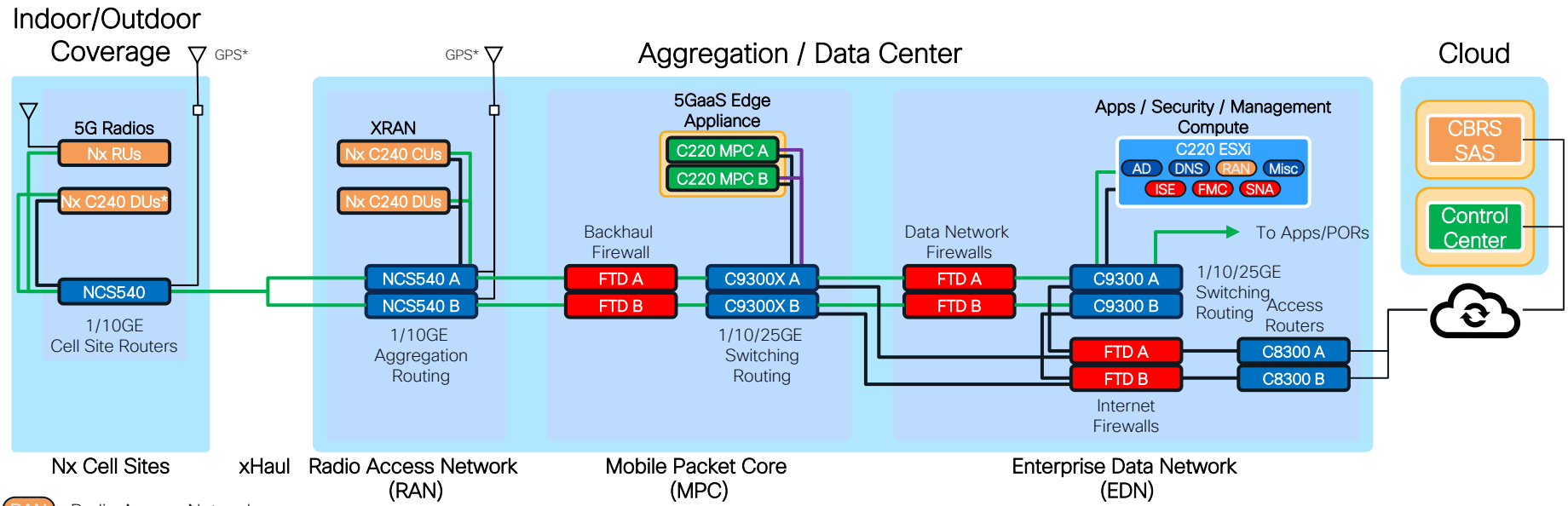


Dual Connectivity

- Allow a UE to use two air interfaces to different radios
  - E.g. midband 4G and 5G mmWave frequencies
  - Using both data planes OR
  - Using 4G for control plane and 5G for data plane
- Typically Assumes 5G Non Standalone (NSA)



Cisco Government 5G Reference Architecture

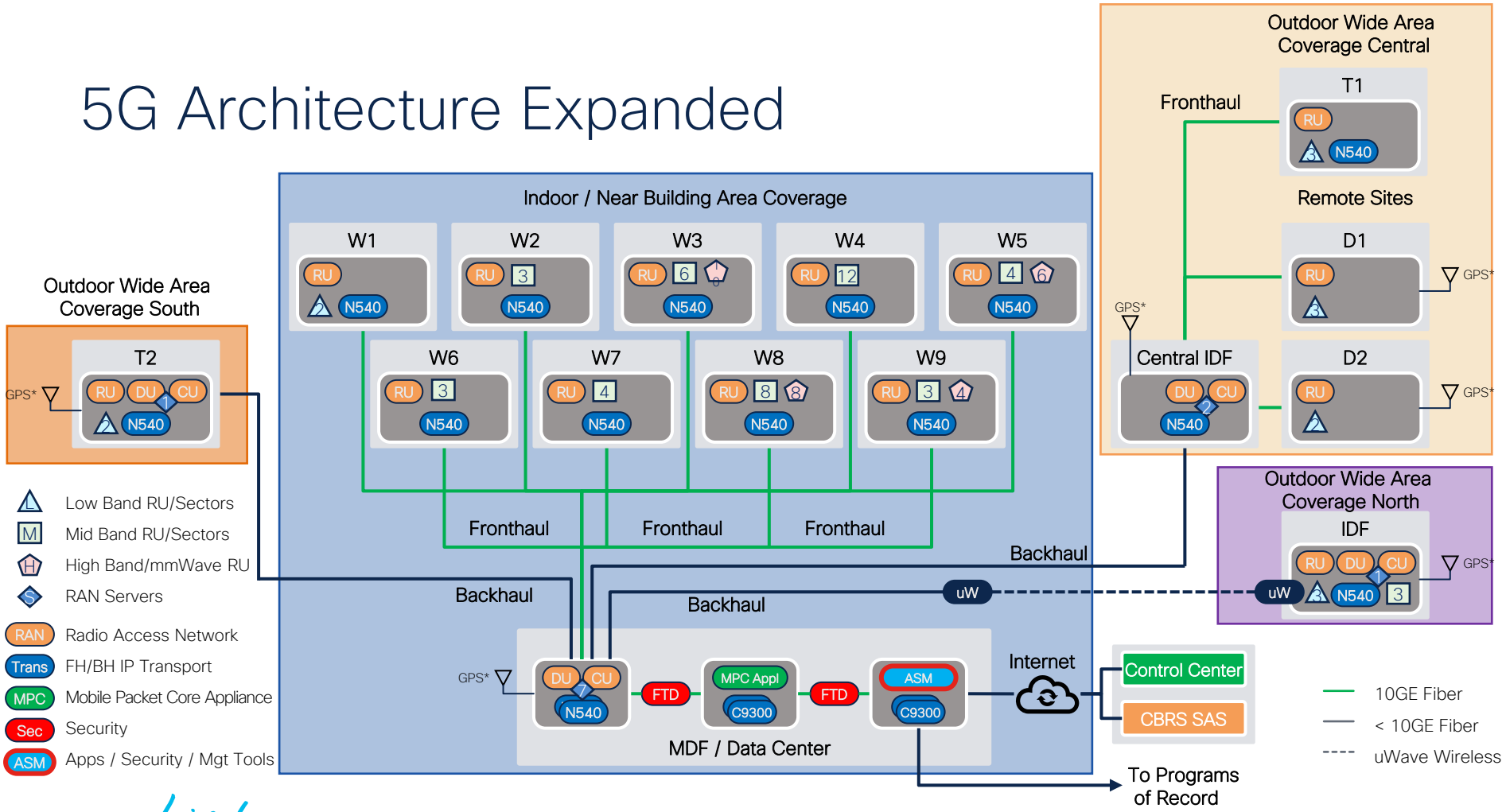


- RAN — Radio Access Network
- Trans — IP Transport
- MPC — Mobile Packet Core
- Sec — Security
- SaaS — 5G Software as-a-Service

- High Availability / Redundancy
- Next Generation O-RAN
- 4G and 5G device support
- 5k sessions
- 15 Gbps throughput

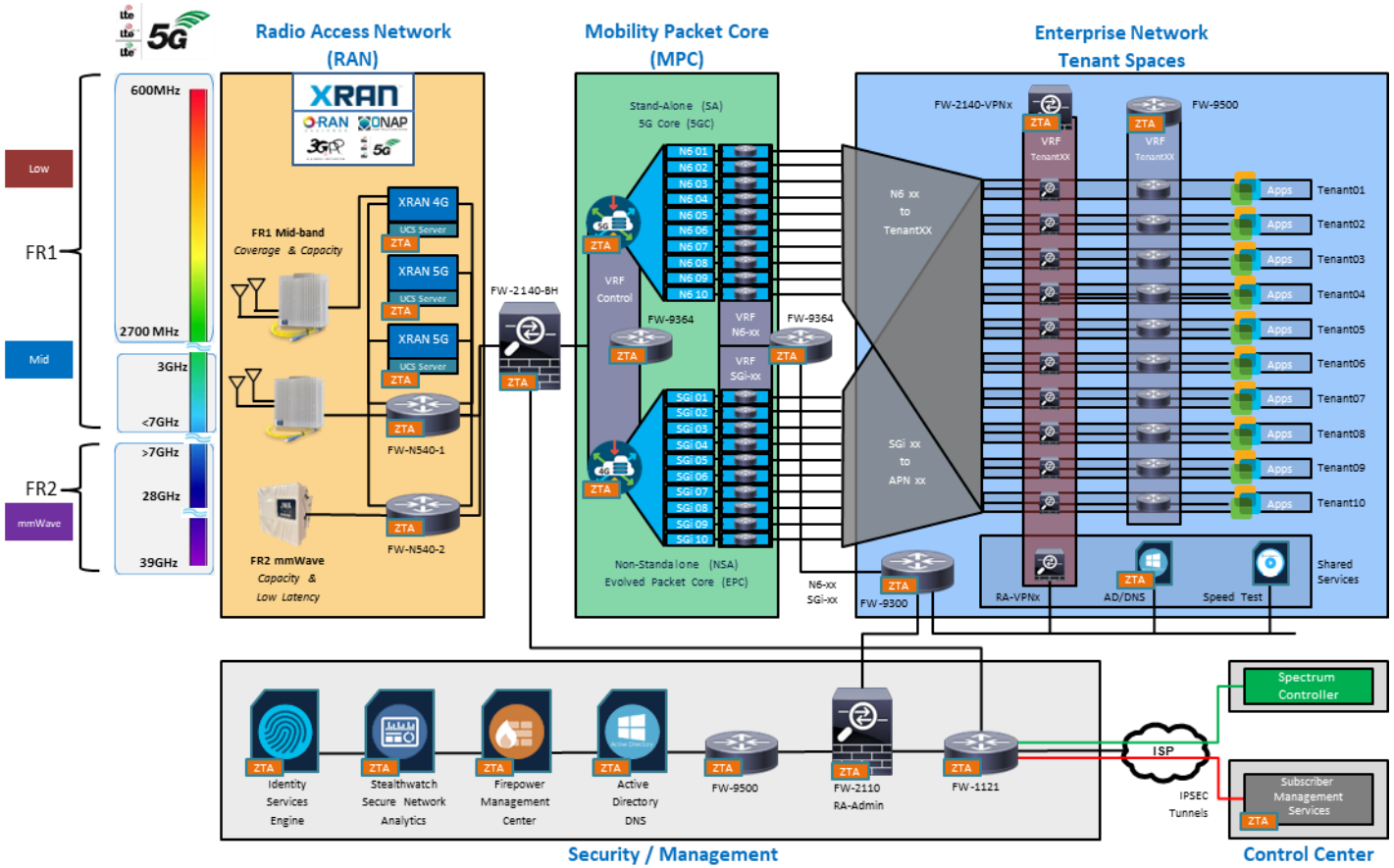
- 25GE Fiber
- 10GE Fiber
- 1GE Fiber
- 1GE or less

5G Architecture Expanded



US Marine Corps Logistics Base Albany 5G Smart Warehouse Private 5G Network Architecture

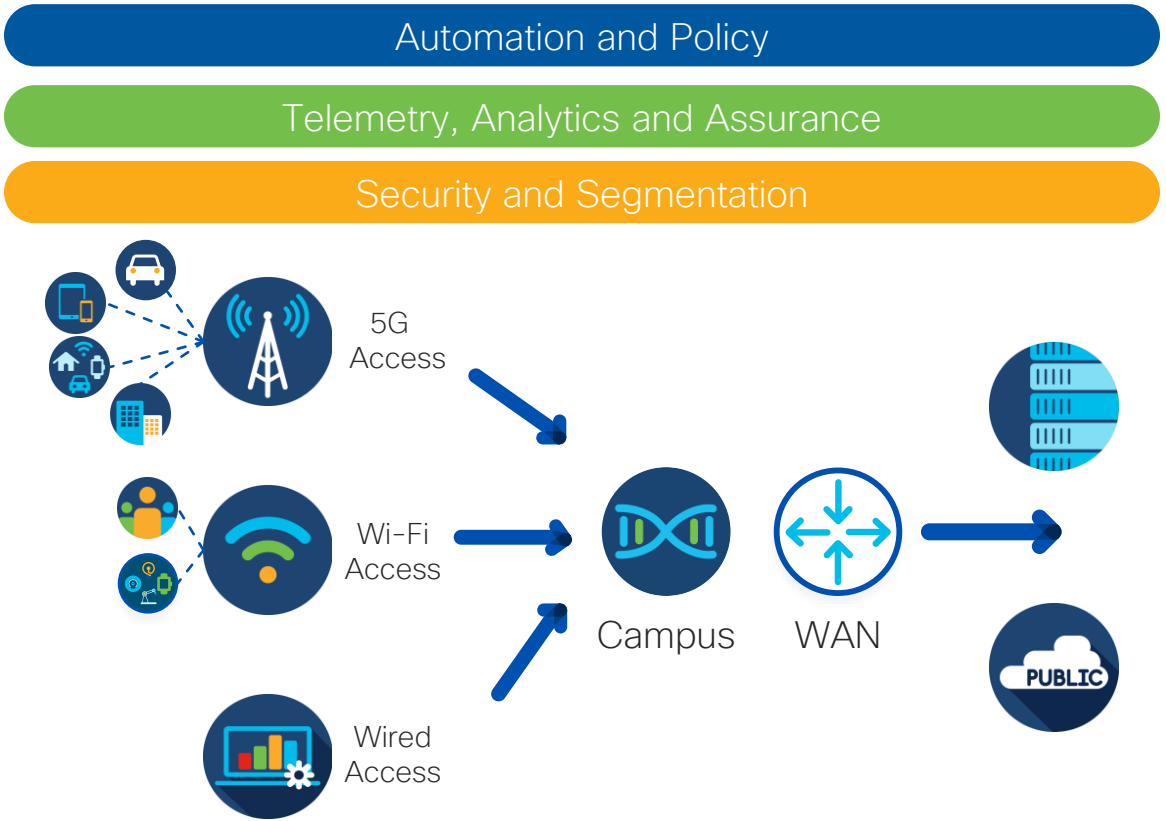
- 5G NSA Today
- 5G SA in 2 Months
- Modular Subsystem Design
- Multiple security zones
- Zero Trust Architecture
  - Confidentiality
  - Identity Mgt
  - Detection / Analytics
  - Automation / Response
  - Policy Mgt



The Vision of Private 5G Enterprise Network Integration
Private 5G as an extension of the Enterprise Network

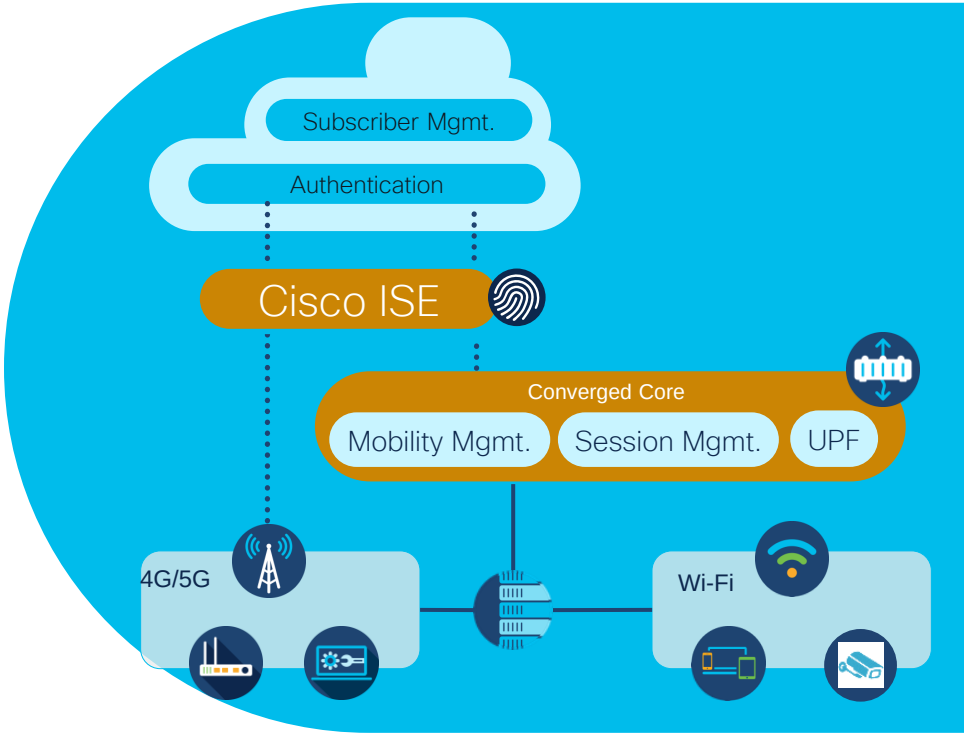
Cisco Private 5G Vision

- Unified Identity Framework
- Common Enterprise Policy
- Private Mobility
- Enterprise Security Integration
- Leverage Existing Campus Transport
- Unified EN Operations
- Consolidated Insights & Analytics
- Cisco Endpoint/IoT GW Integration
- Public Mobility



Unified Identity Framework Vision

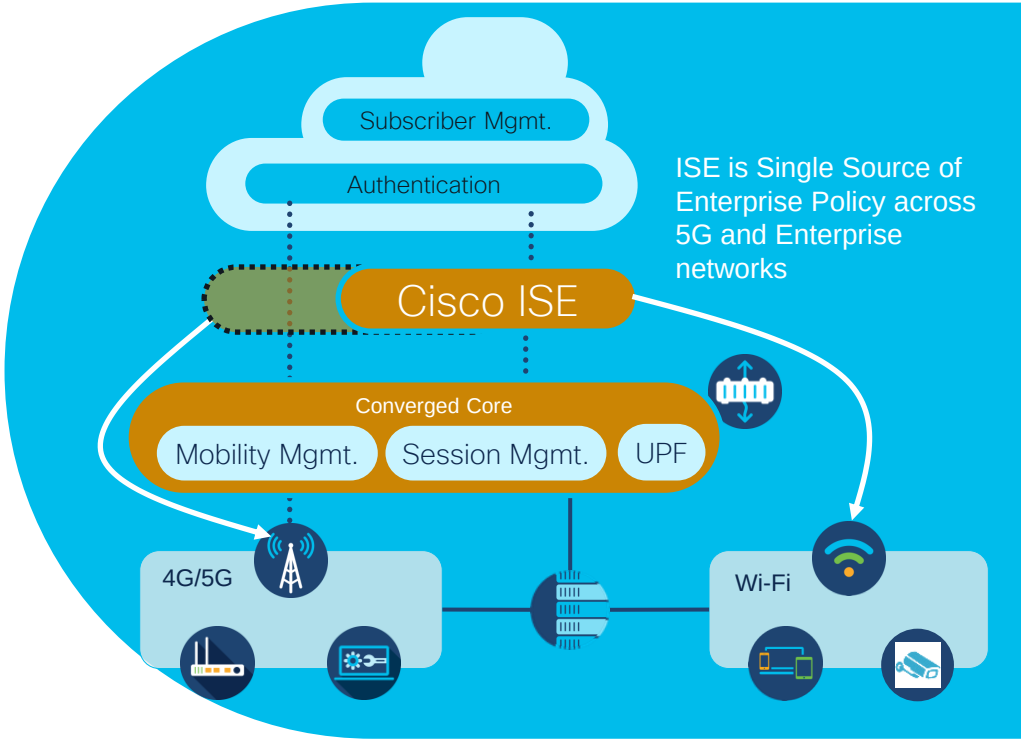
- Identity and authentication is often a patchwork of solutions, meaning consistent identity and policy control of users or devices between Wi-Fi and Cellular networks is not possible.
- Cisco's Private 5G solution uses a common identity framework based on ISE
  - SIMs/eSIM & SIM-less auth mechanisms are coupled with a user's enterprise identity for policy decisions
  - This capability will lead to consistent identity and policy management across all domains



Foundation for common enterprise policies:
Access / Macro & Micro Segmentation / App Experience

Common Enterprise Policy – Access
(Partially Available in Phase 1)

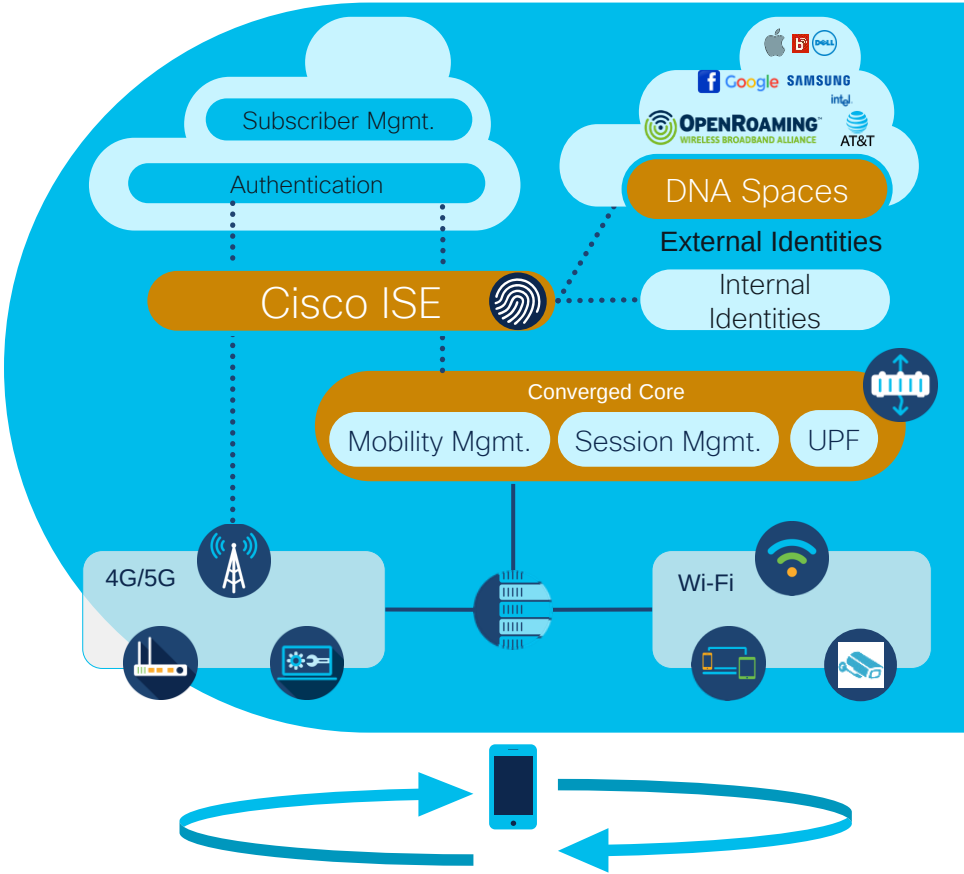
- Private 5G needs to have user and network policies that are consistent with the Enterprise
- Cisco ISE will be the single point for enterprise-wide access policies based on unified identity management
- Common Access Policies allow Enterprise operators to govern what endpoints can and cannot do (authorization) in the P5G network



Common Enterprise Policy – Private Mobility
(Partially Available in Phase 1)

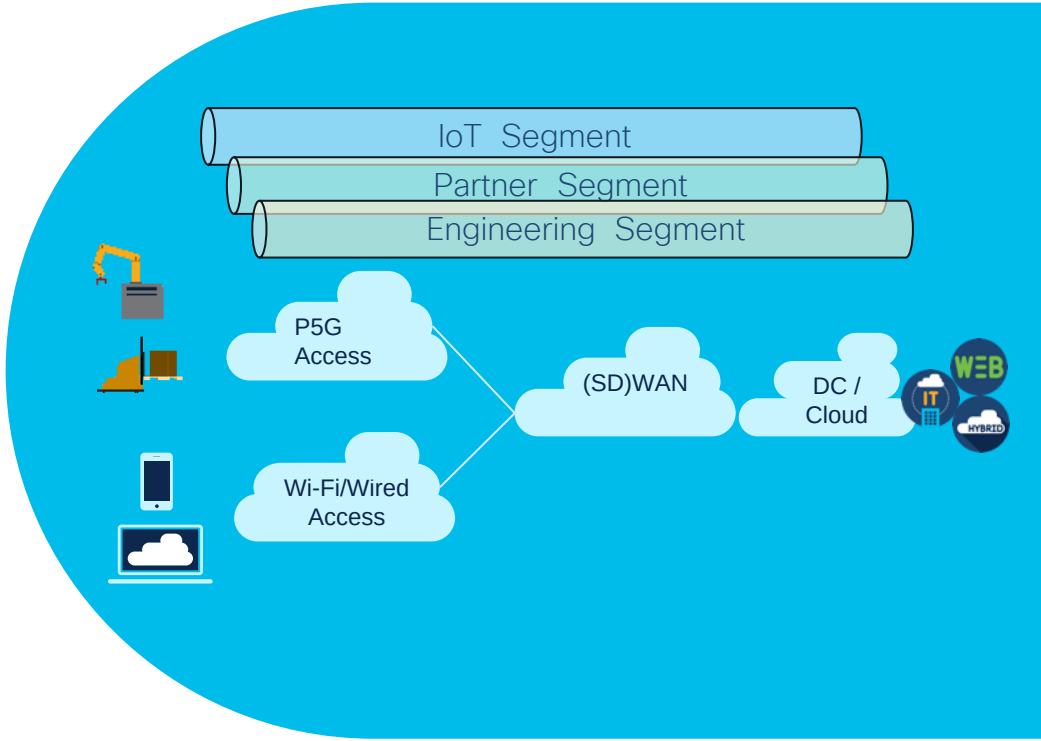
- Wi-Fi & 5G Mobility happens today, controlled to a great extent by the device and the application
- Cisco's vision enables devices to select any bearer based on Policy
  - Consistent and centralized user / device policy based on ISE
  - Apps seamless reconnect @ bearer change if necessary
  - Devices can leverage external identities via Open Roaming federation.

Movement across private wireless networks (P5G, Wi-Fi) is constrained only by business needs, business relationships and regulatory obligations. Not by technological constraints.



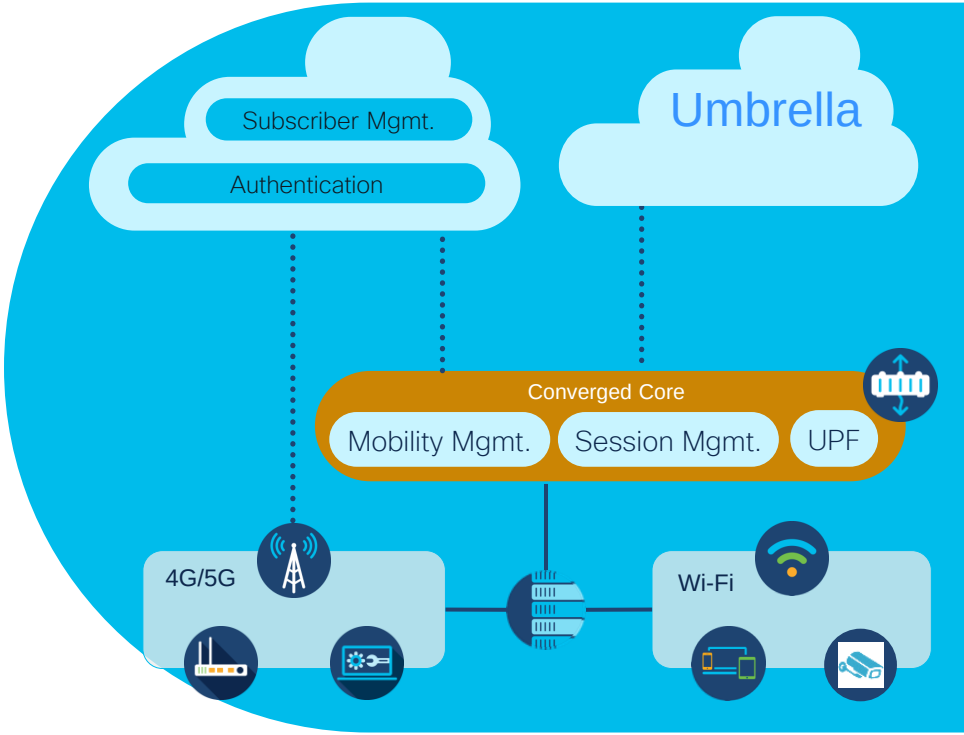
Common Enterprise Policy - Segmentation
(Longer-term Vision)

- As Private 5G devices connect to the enterprise fabric there is a need to segment the two domains in a uniform way according to network policy
- Cisco's Private 5G solution will support identity and policy-based segmentation between the cellular and enterprise fabric domains (e.g., SDA, EVPN, etc.)



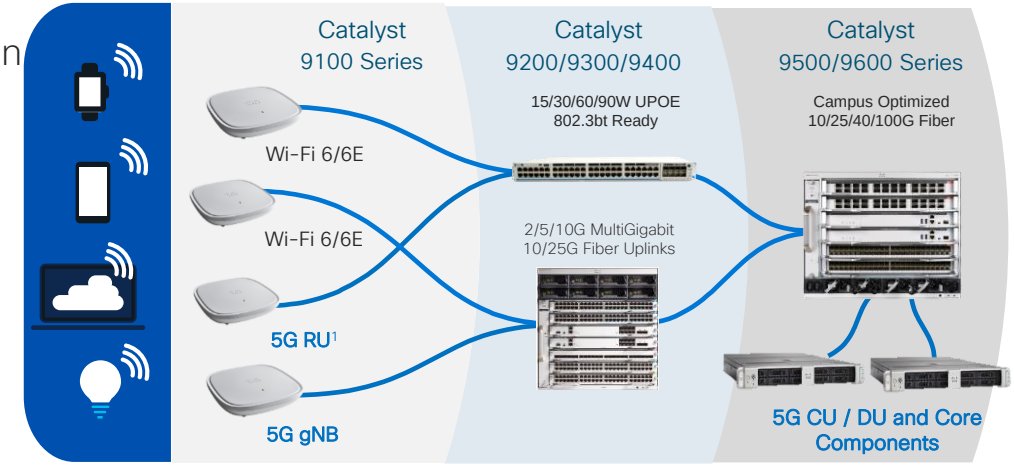
Common Enterprise Policy – Umbrella Security

- Umbrella-based DNS offers cloud-based security for the Enterprise
- Integration of Cisco P5G with Umbrella DNS extends security policies to 5G access networks
- Benefits:
  - Ability to define policy once and apply every where – including Network
  - Correlation of endpoints across managed P5G and Wired/Wi-Fi access networks
  - Operational cost savings
  - New use-cases

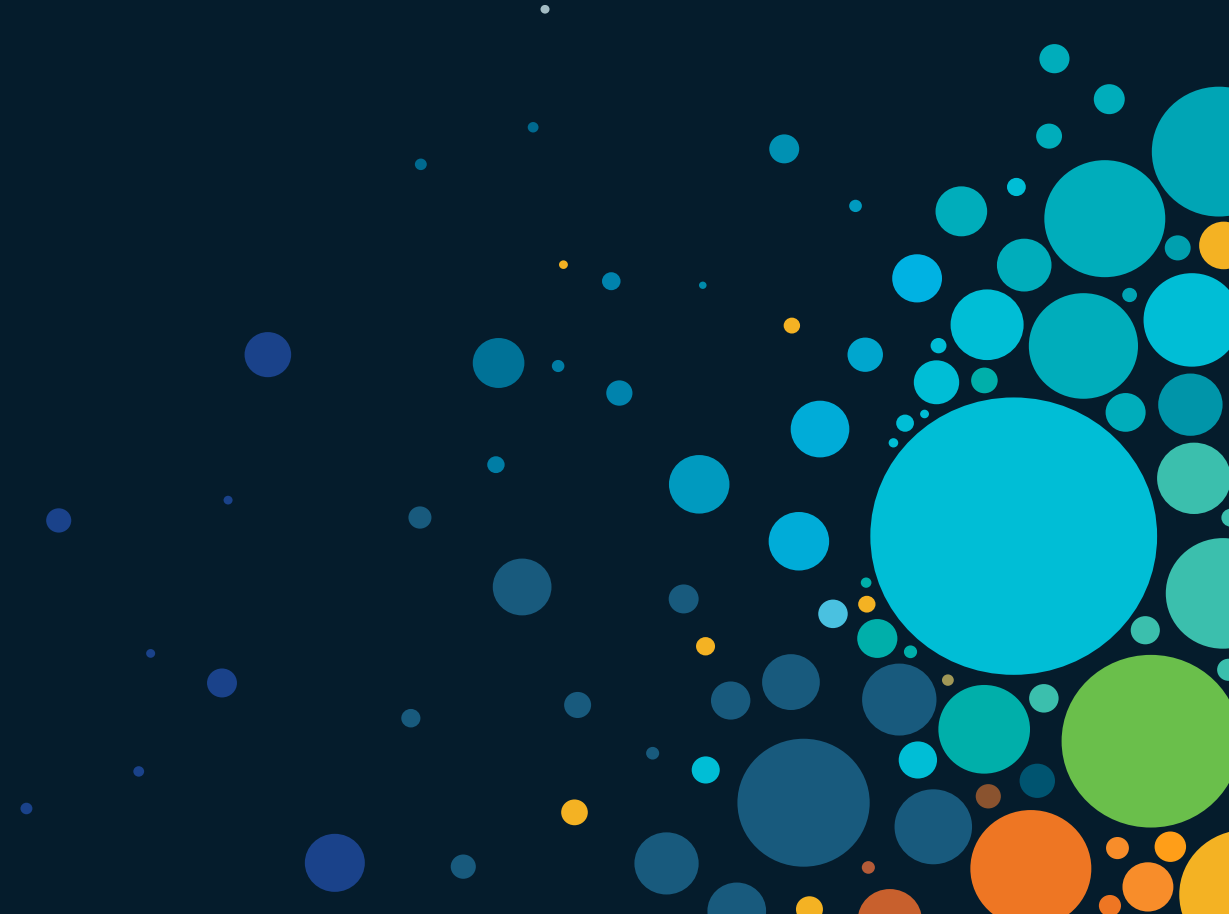


Leverage Existing Campus Transport
(Partially Available in Phase 1)

- P5G access networks have strict X-haul switching requirements to connect radios and 5G core / RAN functions (precision timing requirements, etc.)
- Cisco's Catalyst switching products will allow enterprise network operators to deploy Private 5G components on common enterprise infrastructure.
  Benefits include:
  - Common operations
  - Simplified inventory management
  - Reduction of network elements
- Catalyst IOS-XE enhancements will support advanced 5G timing requirements, making the platform a candidate for Front-haul.



Conclusion



Topics Covered Today

Agenda Item	Speaker
Introduction to Wireless@Cisco	Rob
5G and Wi-Fi Comparative Discussion	Filipe / Rob
Break	
Its all about the use-cases!	Matt / Filipe
Wi-Fi + P5G Architectures: Better-together!	Matt
Closing	Matt
Q&A	

Key Take Aways

- Use-cases drive best technology choice
- Cisco is executing on the vision of P5G + Wi-Fi = better together
  - ISE integration
  - Consistent Security
  - Operational synergies
- Don’t dwell on doing a Wi-Fi vs. P5G technology comparison
- P5G and 5G are still emerging!
  - Device availability
  - Spectrum availability

Summary – Wireless Truly is an Adventure

- No one wireless technology solves all the problems – Cisco will continue to develop solutions to meet the right needs
  - Wi-Fi6E
  - Private and Public 5G
  - LoRaWAN
  - CURBW
- Private 5G is a new paradigm in enterprise access, but needs to be unified with existing enterprise networking capabilities
  - Consistent policy and security
  - Common management framework

Additional Private 5G Sessions @ CL Live

Start

February 6 | 2:15 pm

TECSPG-2432

New Adventures in Wireless: The Journey of WiFi6 and Private 5G Networks for the Enterprise

February 6, | 5:20 pm

PSOSPG-1002

It's More Than Just a Connection: How Cisco makes 5G private networks simple to buy, employ, and operate

February 7 | 8:30 am

BRKXAR-1433

The New Era of LTE and 5G – Cisco Catalyst Cellular Gateways

February 7 | 11:30 am

BRKSPM-1006

The 5G System as a Spectrum Management Solution

February 7 | 3:45 pm

IBOSPG-2010

Getting Started with Enterprise Private 5G: An Interactive Design Workshop

February 8 | 10:30 am

BRKSPM-2672

Managing IoT Connectivity in a 5G World

February 9 | 10:10 am

BRKSPM-2917

Monolithic or Polylithic packet cores? The case for specialized use-case based Mobile Packet Cores

February 9 | 2:15 pm

BRKSPM-2386

Getting Ready for Private 5G Deployments

February 9 | 3:45 pm

BRKEWN-2030

WiFi6 and Private 5G for the Enterprise – a 'Better Together' Journey

Finish

Networking

Wireless Solutions

Learn from experts on wireless topics such as wireless security and location based services including Wi-Fi and BLE technologies, extending to IoT use cases. You will learn some key fundamentals on leveraging your Cisco Wi-Fi investment to deliver smarter workspaces.

START

Feb 5 | 16:00
LABEWN-1661
Cisco DNA Spaces lab for Hybrid Workspace

Feb 7 | 14:45
BRKMER-2514
10 Things You Don't Know About Meraki Wireless

Feb 7 | 17:00
BRKOPS-2416
Seven Habits for a Successful Cisco DNA Center Deployment

Feb 8 | 08:30
LTREWN-2020
Cat 9800 Powered DNA Spaces Wireless Solutions Lab

Feb 8 | 14:45
BRKOPS-2402
Automate the Deployment of a Wireless Network with the Help of Cisco DNA Center

Feb 8 | 16:30
BRKEWN-3004
Understanding Wireless Security and the Implications for Secure Wireless Network Design

Feb 8 | 17:00
BRKEWN-1538
Internet of Things on the Next Generation Catalyst Wi-Fi 6E Access Points

Feb 9 | 08:45
BRKMER-2399
Meraki Wireless from a Troubleshooter Perspective

Feb 9 | 12:00
BRKEWN-2042
Cisco Spaces: How to Turn your Wi-Fi Network into Location Based Intelligence

Feb 9 | 15:45
FINISH
BRKEWN-2658
Implement Smart Workspaces and deliver Intelligent, Sustainable Buildings with Cisco Spaces

If you are unable to attend a live session, you can watch it On Demand after the event

cisco Live!

Technical Session Surveys

- Attendees who fill out a minimum of four session surveys and the overall event survey will get Cisco Live branded socks!
- Attendees will also earn 100 points in the Cisco Live Game for every survey completed.
- These points help you get on the leaderboard and increase your chances of winning daily and grand prizes.

Cisco Learning and Certifications

From technology training and team development to Cisco certifications and learning plans, let us help you empower your business and career. www.cisco.com/go/certs

Pay for Learning with Cisco Learning Credits

(CLCs) are prepaid training vouchers redeemed directly with Cisco.

Learn

Cisco U.
IT learning hub that guides teams and learners toward their goals

Cisco Digital Learning
Subscription-based product, technology, and certification training

Cisco Modeling Labs
Network simulation platform for design, testing, and troubleshooting

Cisco Learning Network
Resource community portal for certifications and learning

Train

Cisco Training Bootcamps
Intensive team & individual automation and technology training programs

Cisco Learning Partner Program
Authorized training partners supporting Cisco technology and career certifications

Cisco Instructor-led and Virtual Instructor-led training
Accelerated curriculum of product, technology, and certification courses

Certify

Cisco Certifications and Specialist Certifications
Award-winning certification program empowers students and IT Professionals to advance their technical careers

Cisco Guided Study Groups
180-day certification prep program with learning and support

Cisco Continuing Education Program
Recertification training options for Cisco certified individuals

Here at the event? Visit us at **The Learning and Certifications lounge at the World of Solutions**

Complete your Session Survey

- Please complete your session survey after each session. Your feedback is important.
- Complete a minimum of 4 session surveys and the Overall Conference survey (open from Thursday) to receive your Cisco Live t-shirt.

- All surveys can be taken in the Cisco Events Mobile App or by logging in to the Session Catalog and clicking the "Attendee Dashboard" at https://www.ciscolive.com/emea/learn/sessions/session-catalog.html

Continue Your Education

Visit the Cisco Showcase for related demos.

Book your one-on-one Meet the Engineer meeting.

Attend any of the related sessions at the DevNet, Capture the Flag, and Walk-in Labs zones.

Visit the On-Demand Library for more sessions at ciscolive.com/on-demand.


cisco
The bridge to possible
Thank you
cisco Live!


CISCO Live!
ALL IN