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Wireless technologies and Use Cases in Industrial IOT

Patrick Grossetete – Technical Marketing
Stephen Goodman – Industrial Solutions Architect

BRKIOT-1775

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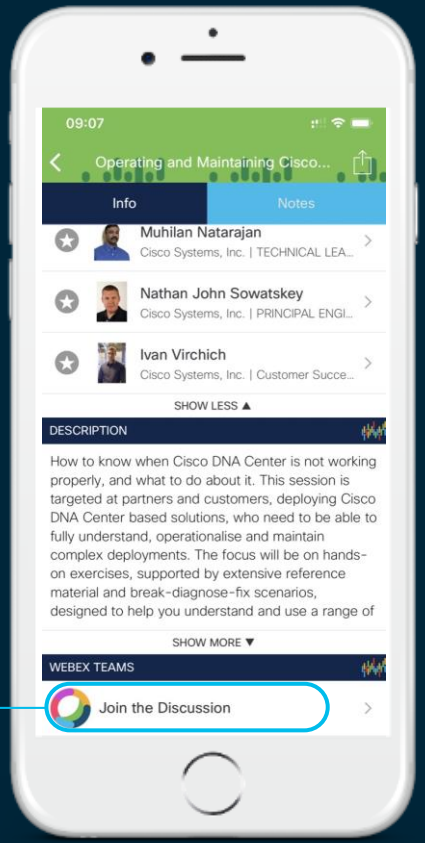


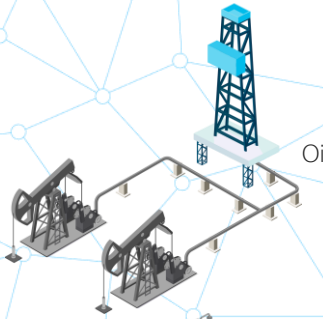
Agenda

- Introduction
- Understanding IOT wireless characteristics
- IOT Wireless technology overview
- IOT Wireless use cases
- Conclusion

Manufacturing

Warehouse

Gas Station / Kiosk



Oil & Gas

Utilities

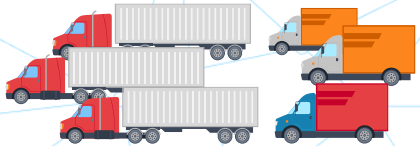
Wireless Technologies are key pillars of the Internet of Thing but...

one size doesn't fit all.

Parking Lot

Roadways

Distribution Center



Fleet

Seaport

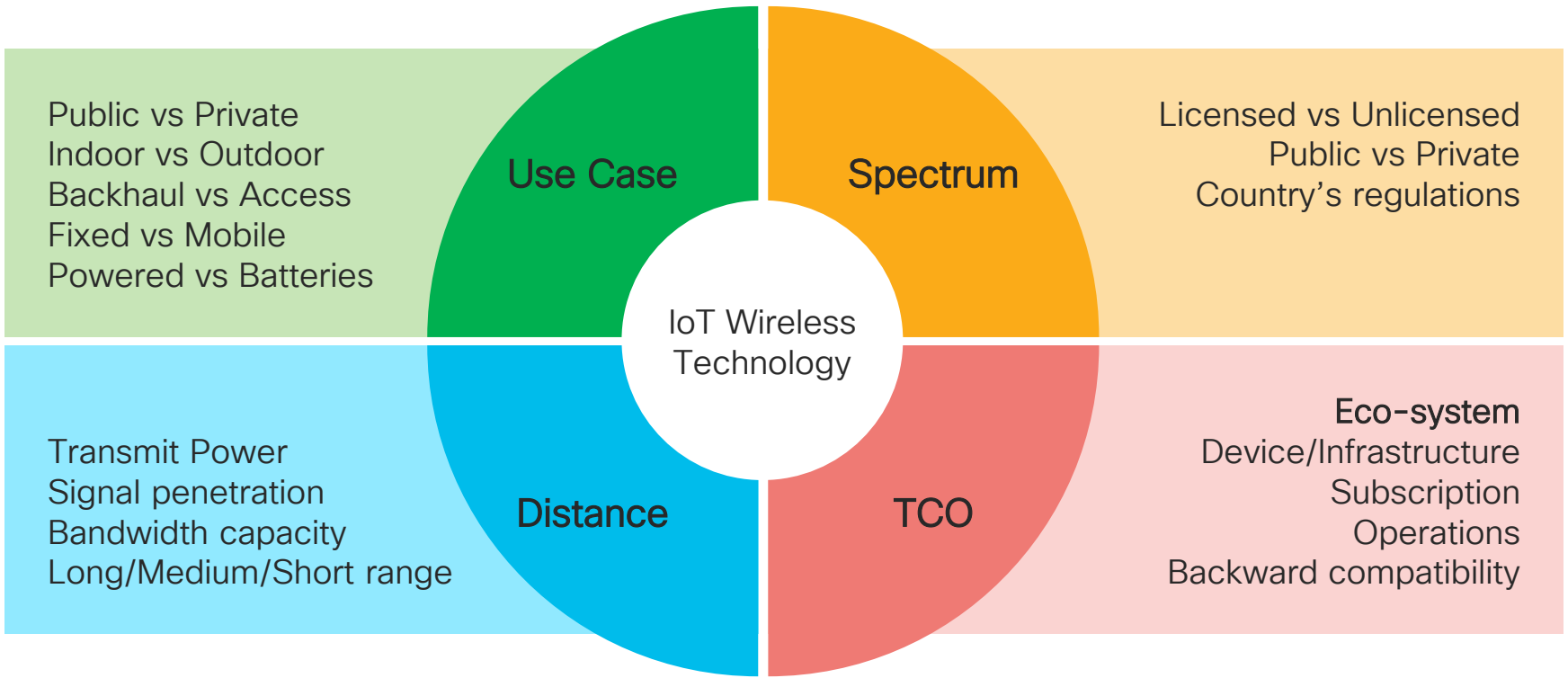
Airport

Key Learning Objectives

At the end of this session, you should be able to:

- Understand that many domain-specific wireless network technologies are available as access and backhaul for the Internet of Things.
- Articulate the challenges of spectrum's allocation, regulations, standard, architecture and use cases.
- Evaluate your Use Cases in a context of Cisco IOT Wireless portfolio and future evolution.

Industrial IOT Wireless Selection Criteria



Use Cases for IOT Wireless

Green – available today
Black – next evolution

From bits/sec to gigabits/sec

Industries	Use Cases	Wireless Technologies Access (A) or Backhaul (B)
Manufacturing, Warehouse, Distribution Center	Industrial automation, industrial security, plant efficiency, workforce enablement	LoRaWAN (A), Wi-Fi(A/B), 4G (B), 5G (B)
Transportation	Passenger experience, data operations, operational efficiency, safety and compliance, traffic operations, roadway safety, sustainable mobility, sensor modernization	LoRaWAN (A), Wi-Fi (A/B), DSRC (A) 4G (B), 5G (A/B)
Cities	Cities operations, public safety and security, citizen services, economic sustainability	LoRaWAN (A), Resilient Mesh (A), Wi-Fi (A/B), 4G (B), 5G (B)
Mining	Field operations, industrial security, workforce enablement	LoRaWAN, (A) WirelessHart (A), ISA100.11a (A), Wi-Fi (A/B), 4G (B), p-LTE (A/B), 5G (B)
Oil & Gas	Plant and field operations, industrial security, workforce enablement	LoRaWAN, (A) WirelessHart (A), ISA100.11a (A), Wi-Fi (A/B), 4G (B), p-LTE (A/B), 5G (B)
Utilities	Connected substations, distribution grid management, workforce enablement, grid safety, production plants	LoRaWAN (A), Resilient Mesh (A), Wi-Fi (A/B), 4G (B), P-LTE (B), 5G (B)

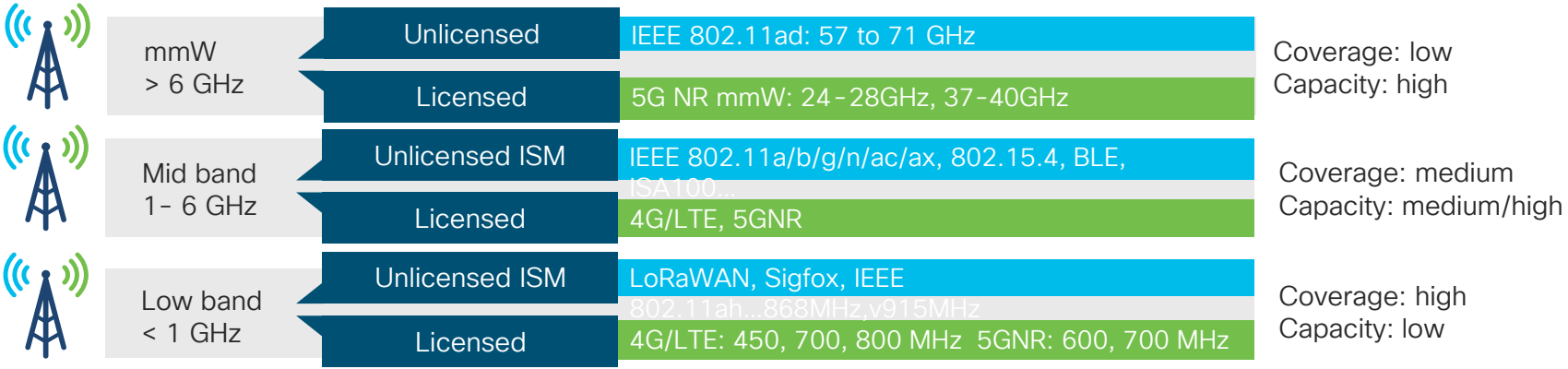
https://www.cisco.com/c/m/en_us/solutions/industries/portfolio-explorer.html

Spectrum is a Scarce Resource

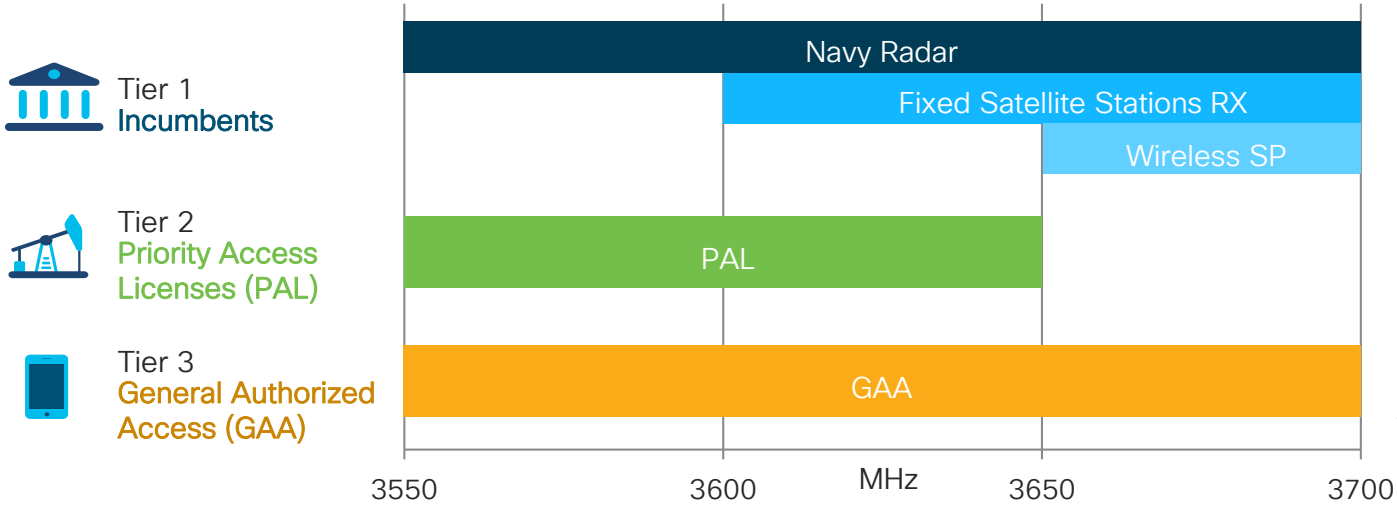
Managed by World organizations/Countries – strongly regulated: Transmit power, duty cycle…

Spectrum types in IOT Wireless

- **Unlicensed:** also refer as ISM bands, generally free of charge, public, and private infrastructures, but regulated.
  - Shared between technologies; co-existence definition in specifications
- **Licensed:** dedicated to SP (public services) or industries (private), not free, may be reallocated.
  - Introducing **Shared licensed** model.



Shared Licensed – U.S. CBRS Example



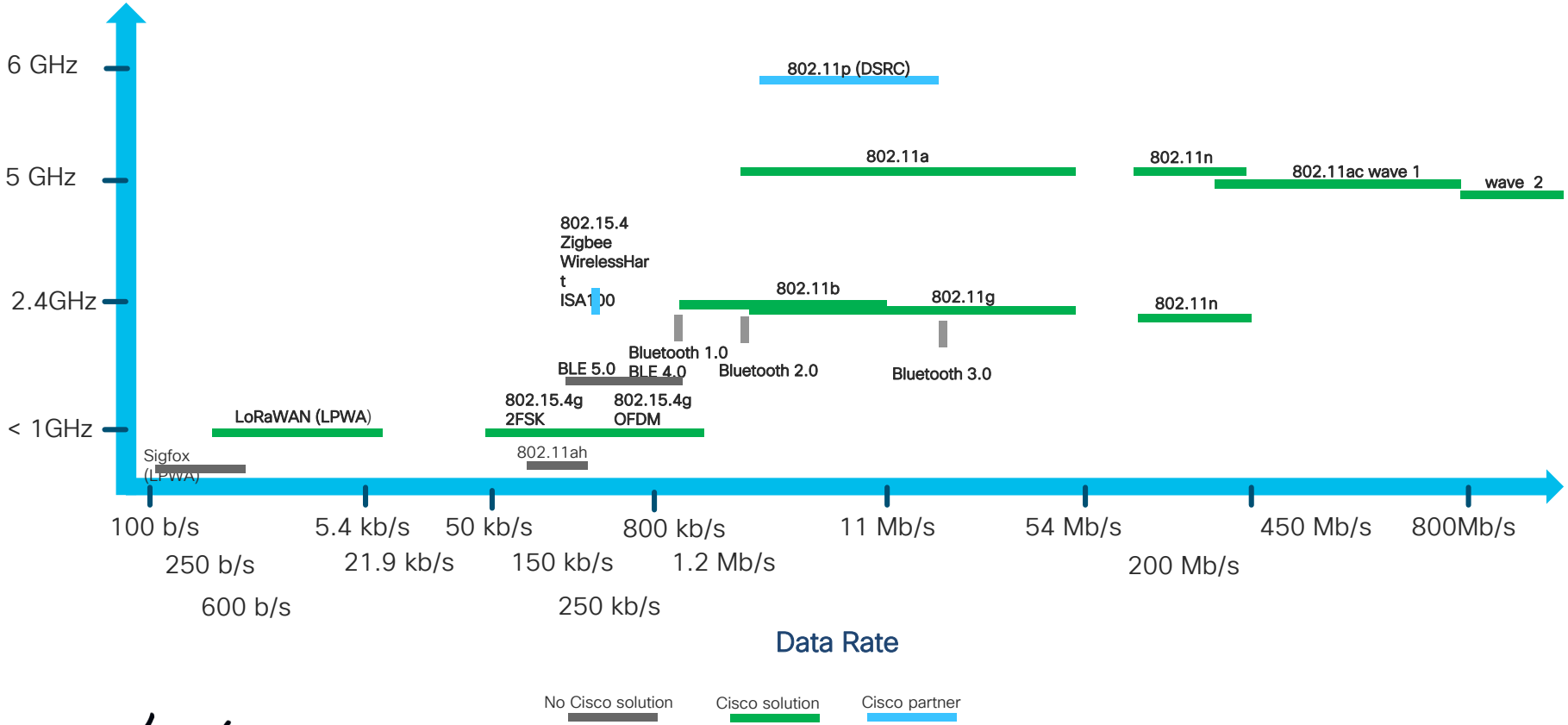
Incumbents are protected from interference from PAL and GAA

PAL has priority over GAA, licensed via auction, 10 MHz blocks, up to 7 licenses

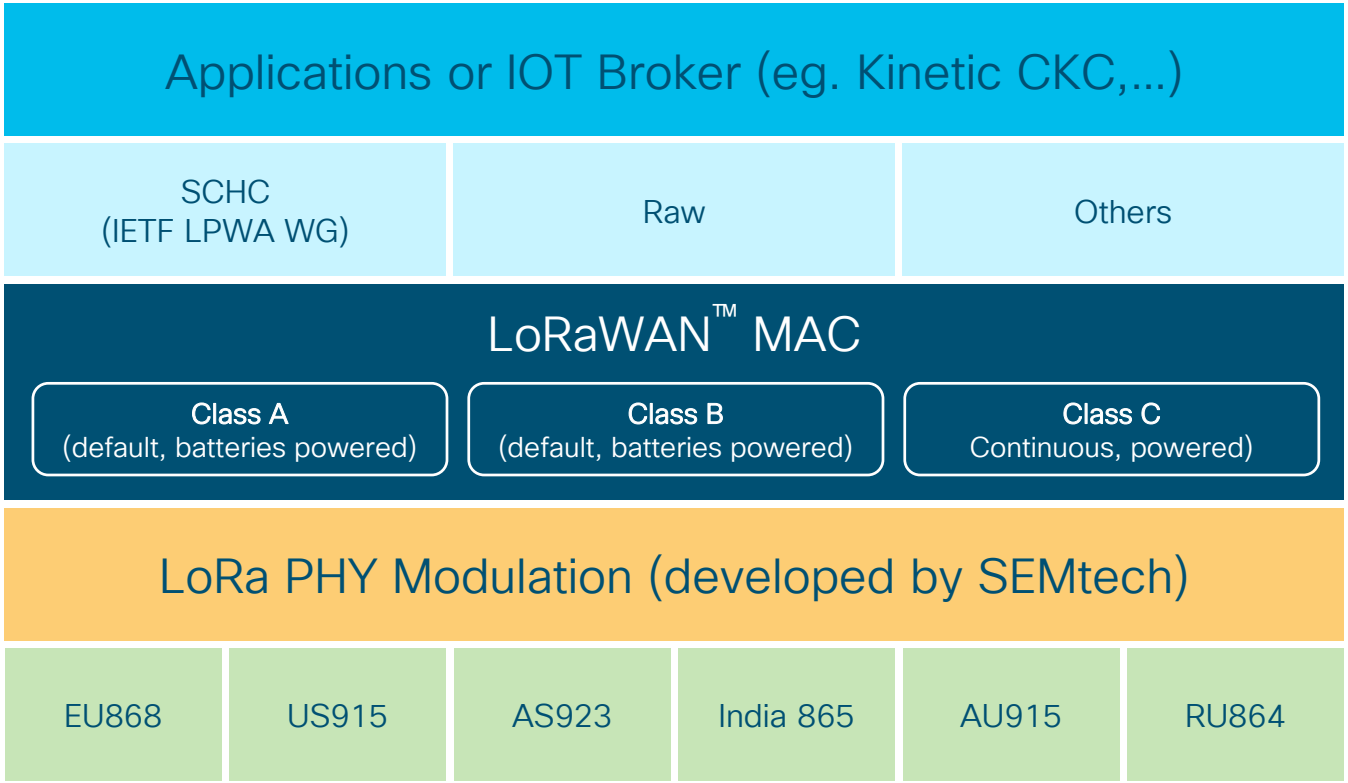
GAA can use any spectrum not used, yields to PAL and incumbents.

- Citizens Broadband Radio Service (CBRS) is a 150 MHz of the 3.5 GHz band (3550 MHz to 3700 MHz or band 48) in the U.S. – Management done through Spectrum Access System (SAS).
  - CBRS alliance https://www.cbrsalliance.org/ and OnGo certification
  - Class A (up to 1W) indoor and outdoor (antenna 6m high) and Class B (up to 50W) outdoor eNodeB.
- ETSI has similar proposal on 2 300 MHz – 2 400 MHz
  - Germany regulator (BNeztA) has set a nominal fee (€120/year) for 60MHz of 3.7-3.8 GHz, for local 'campus' coverage of up to 10,000 square metres

IOT Wireless Technologies in Unlicensed Bands

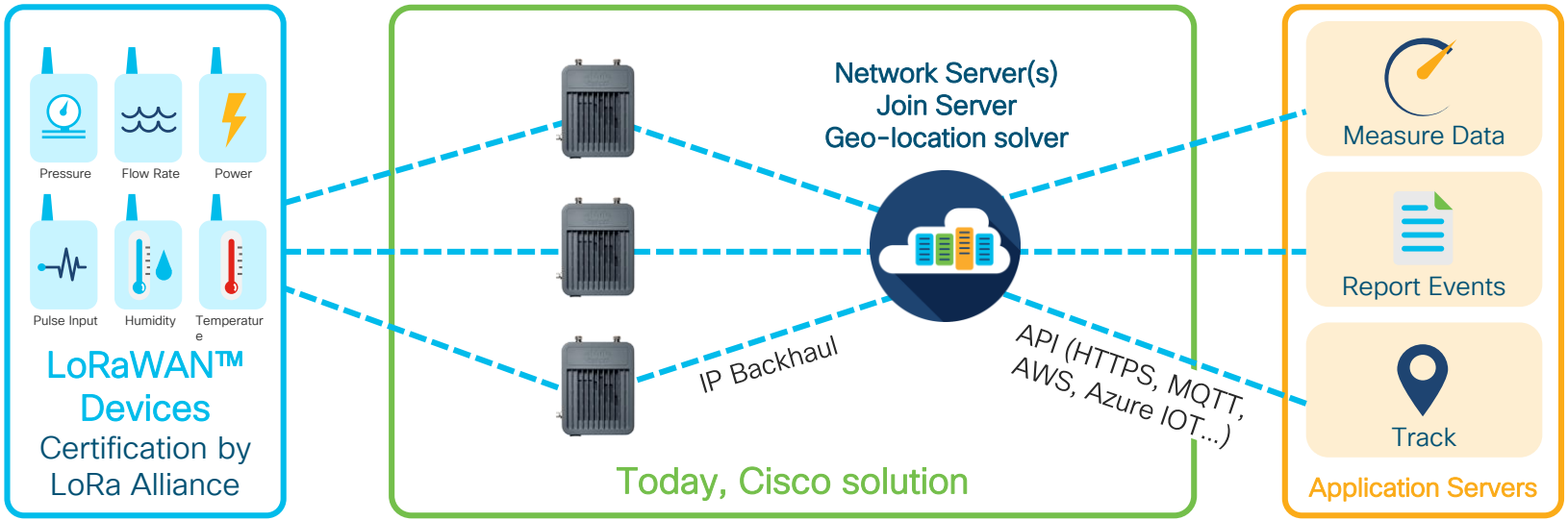


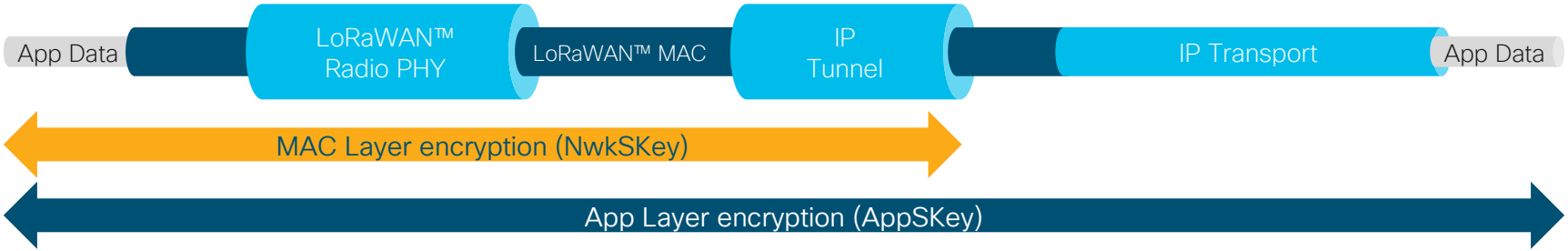
LoRaWAN Architecture



LoRaWAN

Infrastructure: Public & Private
Spectrum: unlicensed ISM bands (868MHz, 915MHz)
Data rate: 250 bit/sec – 5.4 kbit/sec (EU868), 980bit/sec – 21.4kbits/sec (US915)
Standard: LoRa Alliance specifications, Semtech LoRa PHY modulation
Features: Star Topology, limited data payload (up to 250 bytes), Adaptive Data Rate (ADR)
Use cases: batteries powered devices, all verticals

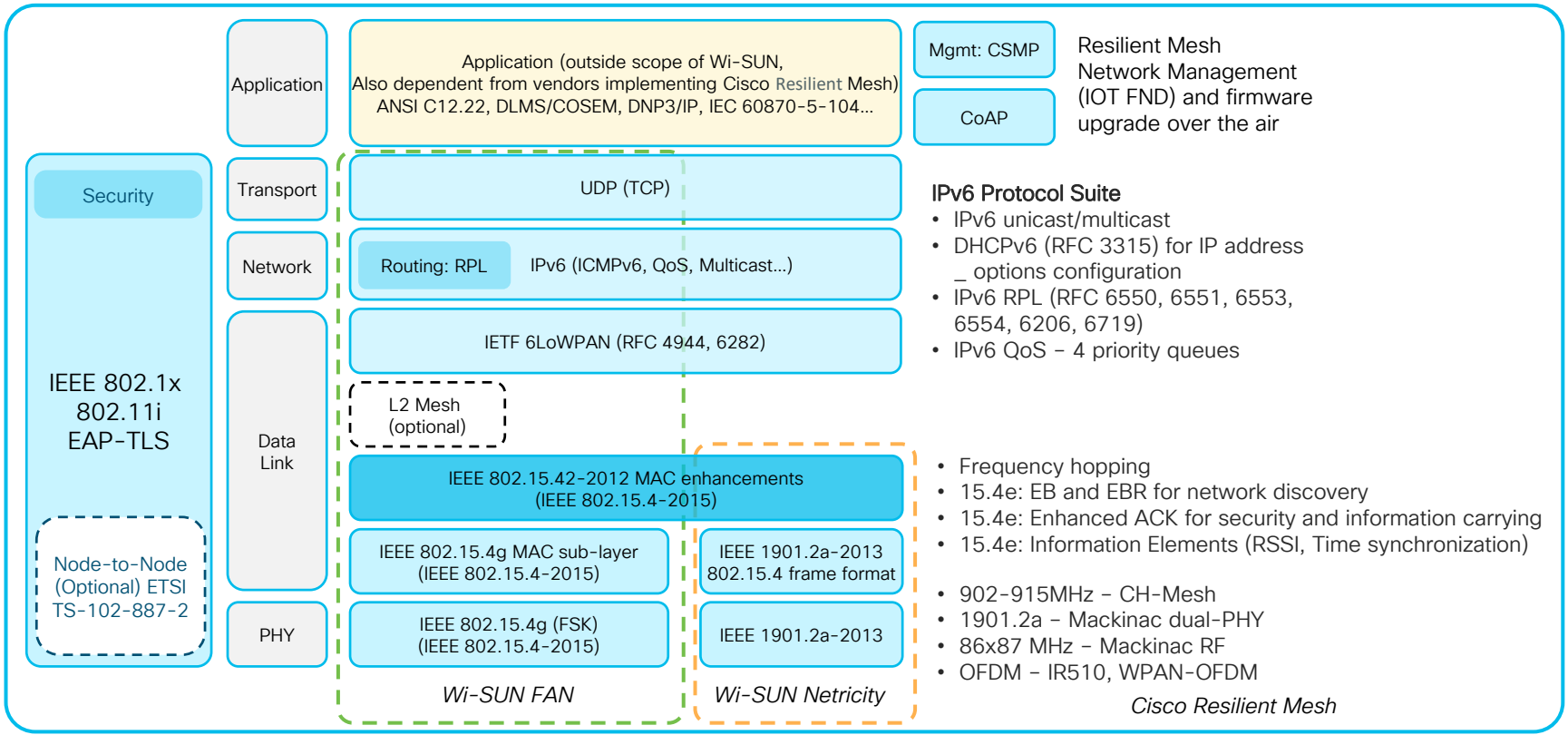




IEEE 802.15.4 vs 802.15.4g/e Amendments

	IEEE 802.15.4-2006	IEEE 802.15.4g/e SUN PHYs	Comments
Frequency bands	868 MHz 1-3 channels, 902-928 MHz 10-30 channels 2450 MHz 16 channels	In addition of 802.15.4-2011 frequency bands 169, 450-470, 470-510, 863-870, 1427-1518 MHz	• Frequency bands availability per region/country • # channels: 802.15.4-2003 – 802.15.4-2006 • 802.15-4-2011: 314-316, 430-434 and 779-787 MHz bands for China
Modulation	BPSK, ASK (Sub-GHz) O-QPSK (2.4GHz)	MR-FSK, MR-OFDM and MR-O-QPSK	BPSK/O-QPSK in 802.15.4-2003 802.15.4-2011 adds modulations 802.15.4g add 3 new PHY SUN modulation
Max. theoretical Data Rate	Up to 20, 40 and 250 kb/s	Up to 1200 kb/s (OFDM)	Frequency band and modulation dependent
Maximum PSDU size	127 bytes	2047 bytes	Better aligned with IPv6 MTU (1280 bytes)
FCS	16 bits	32 bits	Better error protection
Information Elements	No	Yes, 15.4e	Allow vendor specific information
PAN ID	0-65534	0-65534	Identifies a WPAN
MAC Address	16 bits or 64 bits	16 bits or 64 bits	16 bits = locally managed, 64 bits = EUI-64
Usage	Zigbee, WirelessHart, ISA100	Wi-SUN	

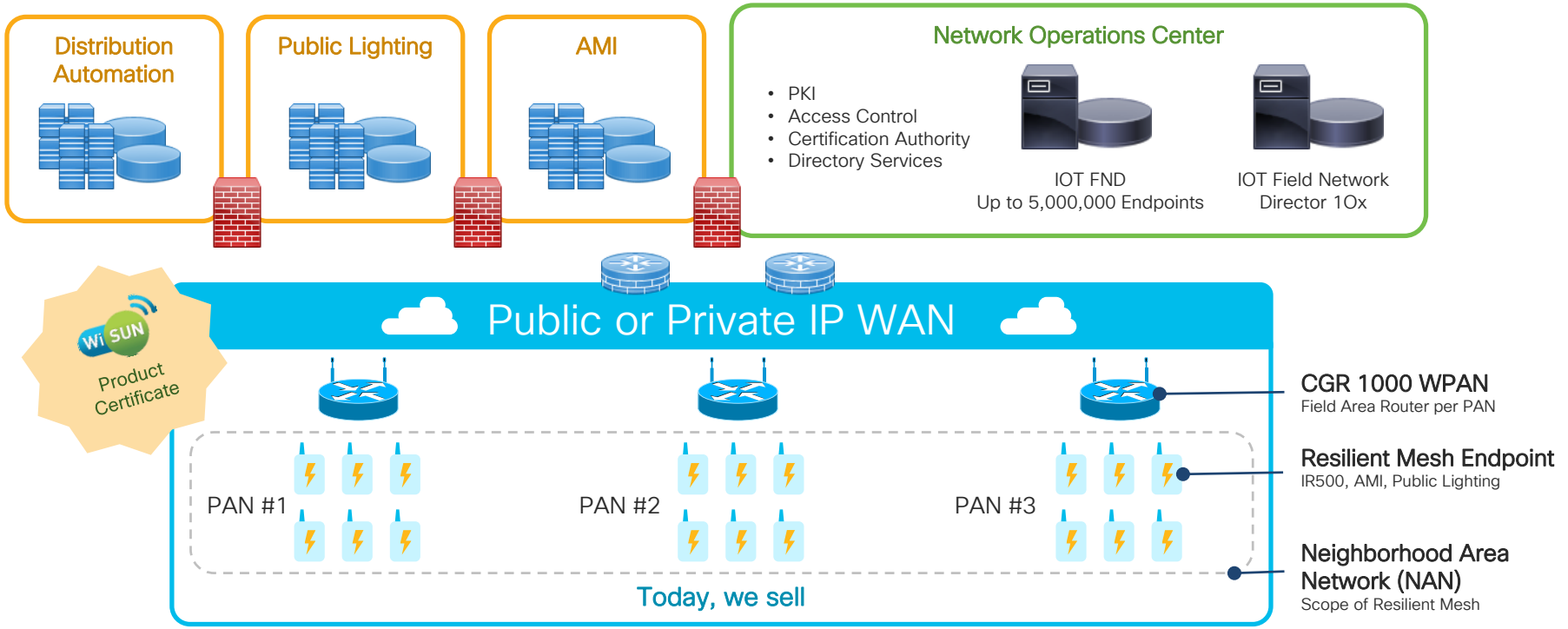
Wi-Sun 1.0 FAN and Cisco Resilient Mesh 6.1



Not relevant for Cisco Resilient Mesh

Resilient Mesh

Infrastructure: Private
Spectrum: unlicensed ISM band: 902-928 MHz (and subset) – No EU868 support
Data rate: 50 kbit/sec – 150 kbs/sec (2FSK modulation) - 1.2 Mbs/sec (OFDM modulation)
Standards: IEEE 802.15.4g/e, IETF IPv6 protocol suite, Wi-SUN 1.0 FAN profile
Features: Mesh and Star topologies, powered devices, IPv6 (6LoWPAN, RPL, MAP-T for IPv4...)
Use cases: AMI, DA, public lighting, oil wells



WirelessHart & ISA1000 Overview

Industrial measurements use cases

	WirelessHart	ISA100.11a
Frequency bands	IEEE 802.15.4-2006 2.4GHz, 16 channels	IEEE 802.15.4-2006 2.4GHz, 16 channels
Data Rate	250kbs	250kbs
Standard	IEC 62591	IEC 62734
Topology	TDMA/CSMA based wireless mesh	TDMA/CSMA star, mesh, star-mesh topologies
Channel hopping	fixed channel hopping table 10 msec time slot	multiple channel hopping tables variable slot time, default 10 msec
	Based on HART addressing	6LoWPAN, IPv6 and UDP
Vendors	Emerson, ABB, Siemens, Endress+Hauser	Honeywell, Yokogawa, GE
Specifications	https://fieldcommgroup.org/hart-specifications	https://www.isa.org/store/products/product-detail/?productId=118261

I552SA/SD

3 Antennas (2.4/5 GHz)
AC and DC Power models
Integrated ISA100 and WirelessHART radio

I552SA/SD

6 Antennas (3x2.4/3x5 GHz)
DC Power
WirelessHART Gateway

IW6300

Mesh architecture support based on 802.11 AC Wave 2

WirelessHart and ISA100 as add-on module from partners

Wi-Fi- High Speed Ubiquitous IOT Wireless Technology

IEEE 802.11 specifications | .11ac or Wi-Fi 5 | .11ax or Wi-Fi 6

- Industrial IOT key requirement: RELIABILITY and SCALABILITY
- Wi-Fi data rate is symmetric
- All Wi-Fi versions ensure backward compatibility – in a given frequency band
- Unlicensed bands – 2.4 and 5GHz – require Access Points to comply with the local regulations, resulting in different SKUs
  - Doesn't impact Wi-Fi clients
- Next-gen under definition in IEEE 802.11be (target 2022)


Manufacturing


Transportation


Smart Cities

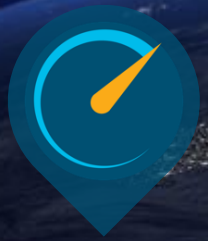

Oil and Gas


Roadways

Wi-Fi 6: New Capabilities

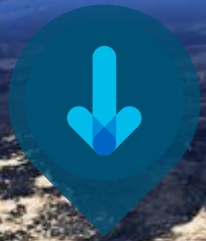
Increased data rates

Higher modulation (Up to 1024 QAM)



Reduced latency

Uplink resource scheduling (OFDMA)



Greater IoT coverage

Deterministic capacity (OFDMA)

Higher density

Efficient spectral re-use (OFDMA, BSS coloring)

Power efficient

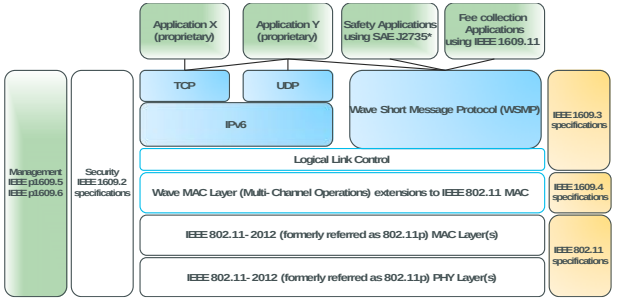
Flexible low-power scheduling (Target wake time)

Faster speeds | Optimized capacity | IoT ready

Dedicated Short Range Communications (DSRC)

Connected roads use cases

- DSRC is built on IEEE 802.11p extensions, running in 6GHz band
  - Data rate: 6-27 Mbps with 10 MHz Channels
  - Range up to 1000m (3000ft)
  - Will evolve with IEEE 802.11bd
- Profile is defined for IPv6 (layer-3) and IEEE 1609 WSMP (layer-2)
- Payload: less than 100 bytes for V2V, larger (+400 bytes) for 12V
- RSU (roadside unit) – WAVE devices that operate only when stationary and support information exchange with OBUs
- OBU (on-board unit) – WAVE devices that can operate when in motion and support the information exchange with RSUs or other OBUs
- Partnering



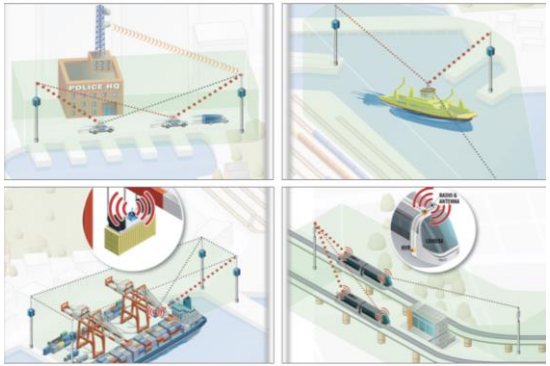
Region	Unlicensed Frequency band
North-America	5.850-5.925 GHz
Europe	5795-5815, 5855/5875-5905/5925 GHz
Japan	5770-5850 GHz
Singapore	5.855 GHz to 5.925 GHz
India	5.725 to 5.825 GHz
Australia/NZ	5,725-5,795, 5,815-5,875 MHz,
China	5,725-5,850 MHz
Korea	5,795-5,815 MHz

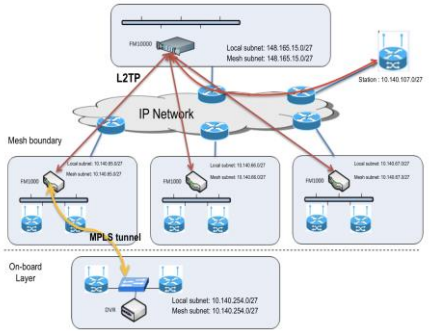
CohdaWireless™

Reliable Wi-Fi backhaul in Transportation - FluidMesh

Use cases: reliable **Wi-Fi backhaul** solution to enable seamless handoffs for on-the-move scenario in rail, mining, theme-parks, public sector markets.

- Products based on IEEE 802.11ac wave 1 (current) and wave 2 (new) products, with proprietary extensions
  - No Wi-Fi IEEE 802.11 specifications defining fast mobility
- Throughput: up to 300Mbs average and 500mbs peak, 700Mbs on new gen. @350km/h
- Fast roaming: Low latency for handover: <10 msec
- Layer-3 mobility: based on MPLS tagging
- Partnering: FLUIDMESH NETWORKS





4G/LTE Roles in Industrial IOT

Specifications – Rel.8-10-13-14 | Rel.15-16 | Rel.17+ Evolution

Low Data Rate

NB-IoT | LTE Cat M1

4G/LTE Endpoints

- Machine
- Sensors
- Meters
- Camera
- Street lighting

High Data Rate

Mbits to Gbits
Cat 1,3,4,6, 18

4G / LTE WAN backhaul on IOT gateways

- Extended enterprises
- Remote assets
- Mobile assets
- Oil and mining
- Utilities
- Transportation
- Cities and rural

4G / LTE Private Infrastructure

- Oil and mining
- Stadium
- Utilities
- Manufacturing

CGR 1240  IR807  IR809  IR829  IR1101 

Control Center – Provisioning and management

LTE UE Categories

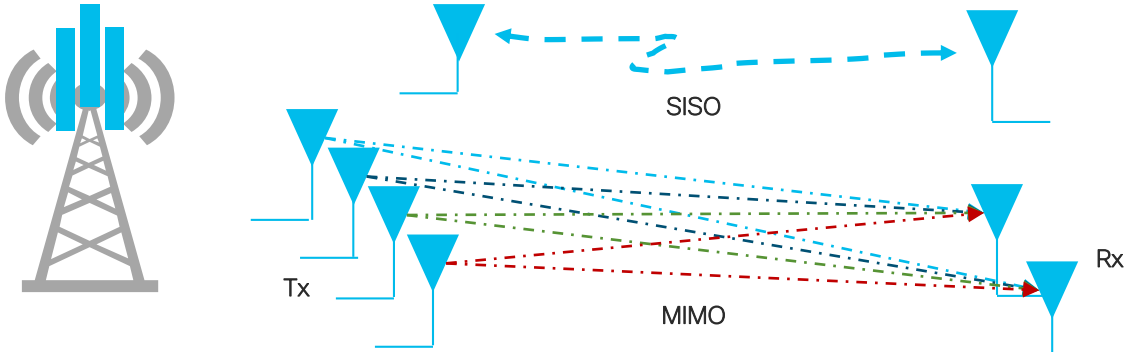
- User Element (UE) category defines a radio throughput capability (uplink (UL)/downlink (DL)).
  - Wide range in the supported parameters and performances
- Cellular is mostly asymmetric – downlink is greater than uplink data rate, which must be considered for capacity planning.
  - Mostly full-duplex (FD), but NB-IOT and CatM1 half-duplex (HD)

UE Category	3GPP release	Uplink/Downlink Data Rate (Mbs)	Cisco IOT support
NB1	Rel. 13	HD: DL: 27kbs, UL: 62kbs	
M1	Rel. 13	HD: DL: 300kbs, UL: 375kbs FD: DL/UL: 1	
1	Rel. 8	DL: 10, UL: 5	*Future*
3	Rel. 8	DL: 100, UL: 50	IR807 IR809G-LTE-*K9 IR829G-LTE-*-*K9
4	Rel. 8	DL: 150, UL: 50	IR829-2LTE-*-*K9 IR829GW-LTE-LA-*K9, IR829M-2LTE-*-*K9 IR829M-2LTE-*-*k9 P-LTE-US P-LTE-VZ P-LTE-GB *P-LTE-MNA*
6	Rel. 10	DL: 300, UL: 50	P-LTEA-EA P-LTEA-LA
18	Rel. 14	DL: 1200, UL: 211	*P-LTEAP18-GL*

LTE Bands on Cisco IOT GWs

Band	Uplink/Downlink (MHz)	Cisco IOT support	Band	Uplink/Downlink (MHz)	Cisco IOT support	Band	Uplink/Downlink (MHz)	Cisco IOT support
1	UL:1920-1980 DL: 2110-2170	IR807, 809, 829, 1101	18	UL:815-830 DL:860-875	IR809, 829, 1101	38	TDD 2570-2620	IR809, 829, 1101
2	UL:1850-1910 DL:1930-1990	IR807, 809, 829, 1101	19	UL:830-845 DL:875-890	IR809, 829, 1101	39	TDD 1880-1920	IR809, 829, 1101
3	UL:1710-1785 DL:1805-1880	IR807, 809, 829, 1101	20	UL:832- 862 DL:791-821	IR807, 809, 829, 1101	40	TDD 2300-2400	IR809, 829, 1101
4	UL:1710-1755 DL:2110-2155	IR807, 809, 829, 1101	21	UL:1447.9-1462.9 DL:1495.9-1510.9	IR809, 829, 1101	41	TDD 2496-2690	IR809, 829, 1101
5	UL: 824-849 DL: 869-894	IR807, 809, 829, 1101	25	UL:1850-1915 DL:1930-1995	IR807, 809, 829, 1101	42	TDD 3400-3600	P-LTEAP18-GL
7	UL:2500-2570 DL:2620-2690	IR807, 809, 829, 1101	26	UL:814- 849 DL:859-894	IR807, 829, 1101	43 P-LTE	TDD 3600-3800	P-LTEAP18-GL
8	UL:880-915 DL:925-960	IR807, 809, 829, 1101	28	UL:703-748 DL:758-803	IR809, 829, 1101	46	TDD unlicensed 5150-5925	P-LTEAP18-GL
12	UL:699-716 DL:729-746	IR807, 829, 1101	29	DL only DL:717-728	IR829, 1101	48 CBRS	TDD 3550-3700	P-LTEAP18-GL
13	UL:777-787 DL:746-756	IR807, 809, 829, 1101	30	UL:2305- 2315 DL:2350-2360	IR1101	66	UL:1710-1780 DL:2110-2200	P-LTEA-MNA P-LTEAP18-GL
14 Firstnet	UL:788-798 DL:758-768	P-LTEA-MNA P-LTEAP18-GL	31 450MHz	UL:452.5-457.5 DL:462.5-467.5	3rd party modem, attached through Ethernet	71	UL:663-698 DL:617-652	P-LTEAP18-GL
17	UL:704-716 DL:734-746	IR807, 809, 829, P-LTEA-MNA	32	DL only DL:1452-1496	P-LTEAP18-GL			

What is Cellular Downlink MiMo?



- SP base station transmits (downlink) on 4 antennas from the cell tower
- Cisco IR series receive on 2 antennas, hence 4 x 2 MIMO,

(or 2 x 2 MIMO if the service provider uses older infrastructure)

- Cisco IR series transmits (uplink) on a single antenna, not MIMO

- SISO: Single Input Single Output – single antenna that is only 1 input/output
  - Antenna's type such as LTE-ANTM-D or ANT-4G-OMNI-OUT-N
- MIMO: Multiple Input Multiple Output – multiple antennas are needed for MIMO, such as
  - Cisco IR with 2 x LTE-ANTM-D or ANT-4G-OMNI-OUT-N on IR series
  - Cisco IR829 with ANT-3-4G2G1-O or ANT-2-4G2-O or ANT-5-4G2WL2G1-O that incorporates multiple antenna elements inside under a single radome

IR Series with Main/Div antennas

- SISO uplink (Main antenna)
- MIMO (4x2 or 2x2) downlink

What is Carrier Aggregation ?

Modules	LTE Categaory
P-LTE-US	Conventional LTE
P-LTE-VZ	Conventional LTE
P-LTE-GB	Conventional LTE
P-LTE-EA	LTE Advanced
P-LTE-LA	LTE Advanced

20 MHz → **LTE Band A** → 20 MHz

Maximum 150 Mb/s
Typical USA: 5-12 Mbps

Conventional LTE Network

Second LTE radio channel is idle when device received on the other channel

20 MHz → **LTE Band A**

20 MHz → **LTE Band B**

Aggregated Data Pipe → 20 MHz

Maximum 300 Mb/s
Typical USA: 10-25 Mbps

LTE Advanced Network

Both LTE radio channel are utilized

The Cases for Private LTE/5G

Who?

- Utilities, ie. Nuclear plants
- Oil & Gas fields
- Mining & underground
- Defense
- Manufacturing
- Buildings
- Airport, Seaports
- Aircrafts, Ships

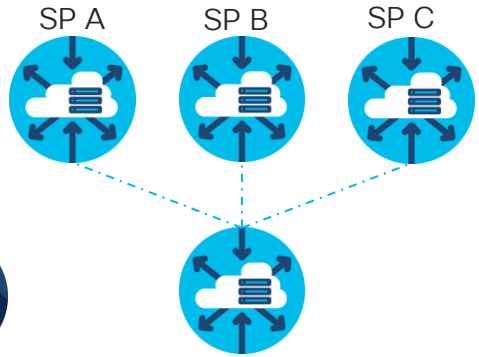
Why?

- Locations with no SP cellular coverage
- Heavy disturbed environments
- Fully independent infrastructure
- Off-load SP traffic

Needs

- Spectrum – dedicated or share – costs?
- Infrastructure – operated or managed services?
- User elements – dependent of LTE band, i.e. CBRS
- Backward compatibility?
- Neutral host model or roaming?
- Automation, provisioning and management tools
- Security
- Field training – how to operate

P-LTE/5G Models



Managed by Enterprise

Managed by SP

Packet Core
Control Plane

POLICY

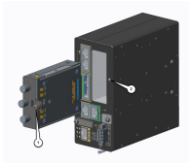
POLICY

UPF
Applications & Data

MEC

Radio Access Network with private bands
(dedicated or share licensed)

Devices with LTE/5G
Interfaces for private bands
(dedicated or share licensed)

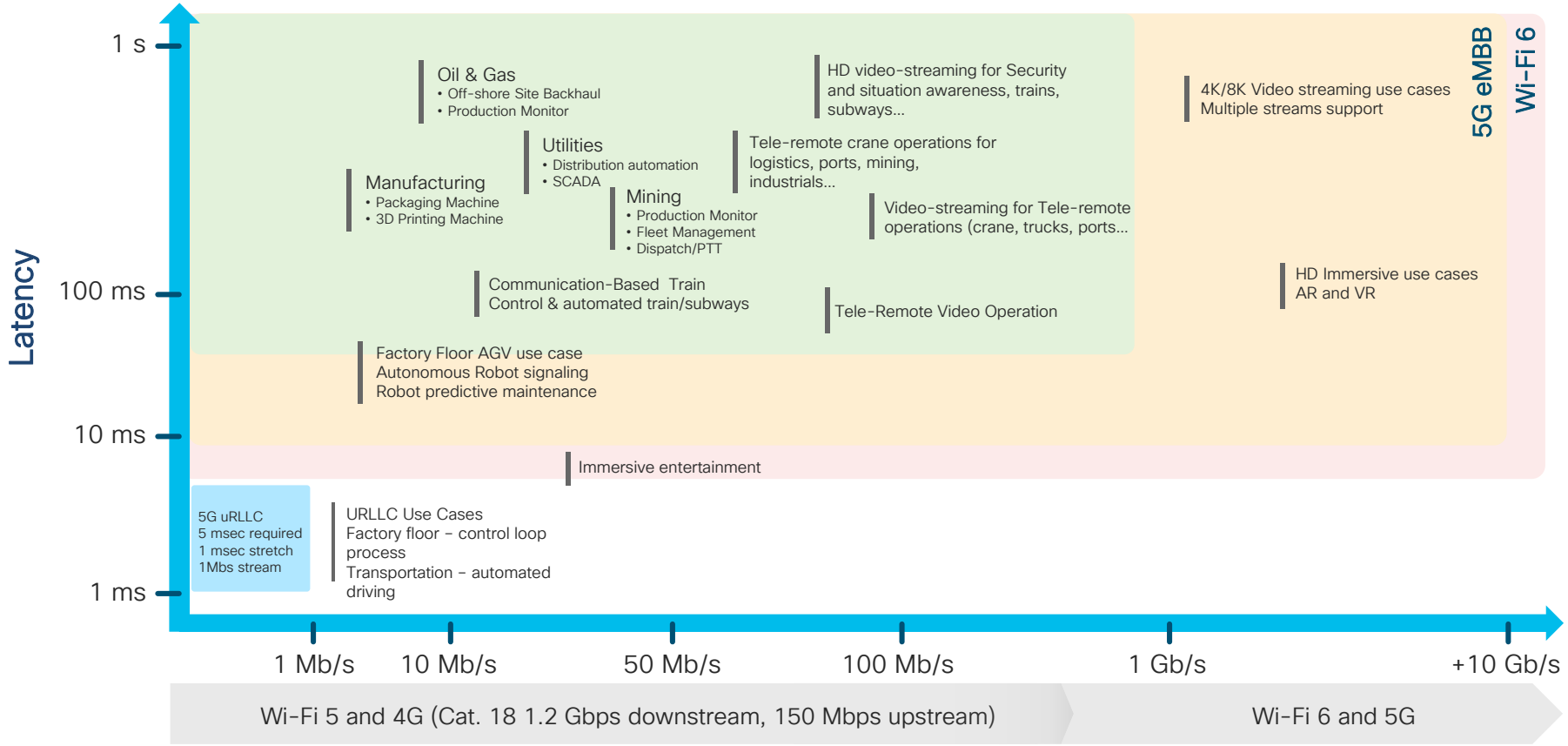


Fully Private

Managed Services

Neutral Host

Trends to Gigabit and + Wireless Technologies



Introducing a 5G IoT Network

Massive IoT (mIoT)
- Device density – up to 1M/km2
- Low power endpoints
- 5G Rel 15/16 – no change to NB-IoT & LTE Cat. M radio technologies

Enhanced Mobile Broadband (eMBB)
- High data rate: > +1Gbs –
- spectrum allocation: sub-GHz, 1-6GHz, and mmWave: countries/SP dependent
- Area traffic capacity – n x Mbs per user/Km2

Ultra-Reliable Low-Latency Communication (uRLLC)
- Low latency – 1-10 ms
- Determinism access
- Multi-Access Edge Computing (MEC)
- Network Slicing

Resilient Mesh, Thread…

802.11ac … 802.11ax (Wi-Fi 6)

Unlicensed LPWAN (LoRaWAN)

Ethernet (Wired) Access/Backhaul (from 10Mbs to TbE), Determinism (TSN))

Low power / Density | Bandwidth / Capacity | Time Sensitive Network / Edge Computing

mIoT
- V2X
- IoT sensors networking i.e. Smart Cities, Transportation, Utilities
- Scalable provisioning and monitoring through Cisco Control Center

IoT Networking
- 5G-ready IoT gateways for Enhanced Backhaul and VPN performances
- 5G SDWAN for IoT services
- Smart Cities video transition to 4K/8K and AR/VR

IoT Business Critical

Manufacturing 4.0, Logistics/Supply chain Resource separation, reserved spectrum, Edge computing
- High performances IoT infrastructure
- Automation for End-to-end SLA
- Edge computing platform/tool
- End-to-end security and QoS

Multi-Access in Enterprise IoT – End-to-End SLA, Automation & Security

Cisco Industrial IOT Wireless Summary

	LoRaWAN	Resilient Mesh	WiFi	4G/LTE – 5G
Topology	Point to multipoint	Mesh Point to Multipoint (Leaf mode)	Point to Multipoint Mesh	Point to multipoint
Coverage Range (Radio signal is the real value)	~ 2k-10km	~1.5km per hop up to 8 hops	~100m (300 feet)	~ 2k-10km (cell dependent
Data Rate	250bs-21kbs	50kbps -1.2Mbps	11Mbs (.b) 1.7 Gbs (.ac W2) 9.6 Gbs (.ax)	27kbs(DL)/65kbs(UL) NB-IOT HDx 300kbs/375kbs LTE Cat M1 300 Mbps (DL)/50Mbs (UL) LTE Cat.6 to 5G (500Mbs UL/5Gbs DL) on today's modem
Public SP vs Private Networks	Private/Public SP	Private	Private/Public SP	Public SP/Private (i.e. US CBRS)
Batteries powered devices	Optimized lifetime (+10 years)	Not in FAN 1.0	Limited lifetime (months)	NB-IOT provides good lifetime
Eco-system (endpoints)	*****	*	*****	****
TCO	Low	Low-Medium	Medium-High	Medium-High

Wireless Technologies are Fundamental to IOT

Industrial Switching

IE 1K, 2K, 3K, 3200, 3300, 3400, 3400H, 4K, 5K, CGS

IoT Gateways

819-MNA, IR807, IR809, IR829, IR1101

Industrial Routing

CGR 1000, CGR 2000

Cisco Resilient Mesh

IR500, DevNet

Low Power Wide Area Wireless

LoRaWAN
IXM Gateway

Industrial Wireless

AP1552, IW3702
IW6300, ESW6300

Industrial Security

ISA 3000

Embedded IoT

ESS, ESR, EW

Industrial Compute

IC3000

Edge Computing Software

Iox, Edge Data

Management & Automation

Field Network Director
Industrial Network Director
Control Center
Kinetic GMM

Connected Safety and Security

Video Surveillance Manager
Cisco IP Cameras

Cisco Vision

Dynamic Signage Director
Digital Media Players

Cisco Kinetic for Cities

Use cases for non-wired technologies

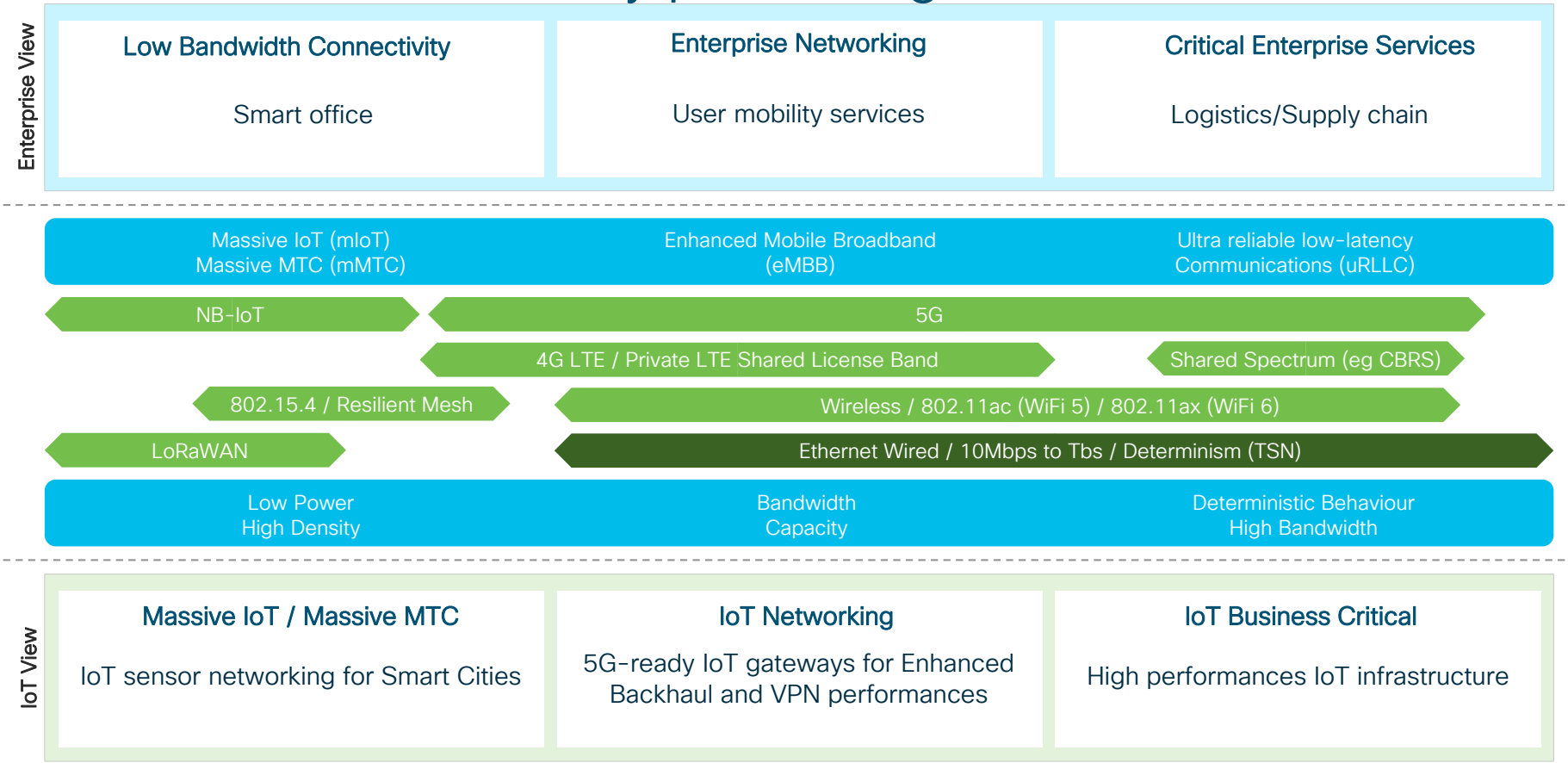
Non-wired considerations nomenclature

For Reference

Wired / Wireless communications	A wired network uses cables to connect devices to a network so that data can be transmitted between source and destination addresses. A wireless network uses radio waves to connect devices over the air without wires.
Spectrum	Spectrum refers to the invisible radio frequencies that wireless signals travel over. Portions of electromagnetic spectrum are grouped in “bands” depending on their wavelengths—the distance over which the wave’s shape repeats. Radio spectrum, we are talking about the range of radio frequencies that are used for communicating. from 30 Hertz to 300 GHz
Licensed / unlicensed spectrum	• Licensed - assigned exclusively to operators for independent usage • Unlicensed - assigned for non-exclusive usage (ie. Anyone can use) subject to some regulatory constraints, eg. restrictions in transmission power
Frequency band	A radio frequency band is a small contiguous section of the radio spectrum frequencies, in which channels are usually used or set aside for the same purpose. This is to prevent interference and allow for efficient use of the radio spectrum.
Data rate	A data rate is the theoretical maximum value that a wireless link can achieve if there were no losses or interference.
Throughput	In the real world, there will be interference and losses which will result in a lower bit rate. Throughput can be seen as a practical/realistic value that a wireless link can achieve.
Latency	Network latency is the term used to indicate any kind of delay that happens in data communication over a network. Eg. Queuing or processing times
Mobility	Mobility, or roaming, is an ability of a wireless client to maintain its association seamlessly from one access point to another securely and with as little latency as possible.
Battery/powered	Whether a sensor can be powered via battery or requires mains electrical power to operate.
Quality of Service (QoS)	Capabilities to manage the prioritization of traffic, and delay, jitter, bandwidth, and packet loss parameters on a network.
Security	Network security is any hardware or software activity designed to protect the usability and integrity of communications network performance and the data traversing it.

Wireless Considerations

Non-wired connectivity positioning overview



Non-wired technologies

So many options - where do I start?

Non-wired connectivity overview - cellular + WiFi

For Reference

Cellular ⟷ Wi-Fi

Positioning

4G/LTE

Fast, IP-based, mobile broadband

- Widespread/ubiquitous geographical coverage
- Higher data speeds, cheaper device costs
- Improved network responsiveness with lower latency and lower idle-to-active times
- High spectrum efficiency + higher network capacity
- Backwards compatibility
- Interoperability through all IP network
- Enhancements to security and Quality of Service
- Mobility support
- Country/SP dependent

Shared License Band - *CBRS Example*

Citizen broadband radio service

- Multi-technology (including WiFi) support capable
- Create own private LTE networks, replacing/ supplementing Wi-Fi
- Efficient use of wireless spectrum - less interference
- Ecosystem dependent
- Neutral host feature allows connectivity to multiple LTE providers to better support dense environments
- Potential benefits for multi-IoT application deployments
- US only, *Netherlands, UK, Germany, Sweden, Japan planning something similar*

5G

Enhanced mobile broadband, and wireless for industry

- Higher data rates and improved quality of experience for wireless broadband
- More device capacity for IoT and enterprise deployments
- Support for new high bandwidth and low latency services
- Improved performance with less spectrum interference
- Virtualization capabilities
- Connections in hard to reach areas and wired replacement
- Mobility support
- Country/SP dependent
- High b/w backhaul links

802.11ac (Wi-Fi 5)

5th generation wireless

- Current generation of wireless with speed performance comparable to standard wired connections
- Higher speeds over wider bandwidths than previous standards
- More reliable long-range transmissions over previous standards
- Improved performance in environments with obstructions
- Backwards compatibility
- Improved multi-user performance
- High b/w backhaul links

802.11ax (Wi-Fi 6)

6th generation wireless

- 40% higher data rates
- More predictable performance in dense client environments
- Simultaneous comms with multiple clients
- Real time applications, up to 75% less latency
- Increased capacity + range
- Improved power efficiency and battery of devices
- More robust outdoor performance
- Easier to guarantee near wall-to-wall indoor coverage vs 5G
- Backwards compatibility
- High b/w backhaul links

Features

- Indoor/outdoor
- Max data rate 300Mb-1Gb
- Av. user speed 15-50Mb
- 10,000 connections per Km2
- 30-50ms latency
- QoS, predictability
- Security
- Long range
- Asymmetric U/D bandwidth

- Indoor/outdoor
- Low latency and improved scale of connections vs Wi-Fi
- LTE services 1Gb indoors - 5-10x outdoor line-of-sight
- mobility/roaming across access points
- More deterministic performance for real-time
- Asymmetric U/D bandwidth

- Indoor/outdoor
- Target 10Gb UL,20Gb DL
- Target user 50Mb UL, 100Mb DL
- 1 million devices per km2
- Network slicing
- Sub-1 millisecond latency
- Predictability and QoS
- Long range
- Asymmetric U/D bandwidth

- Indoor/outdoor
- Max data rate 6.93Gb
- Multi-user access
- Medium range
- Variable latency
- Symmetric U/D bandwidth

- Max data rate 9.6Gb
- Medium range
- Multi-user access
- More deterministic behaviour
- Improved indoor + outdoor coverage
- Reduced latency up to 75%
- Split network capacity among groups of devices
- Symmetric U/D bandwidth

Non-wired connectivity overview - cellular + WiFi

For Reference

Cellular

Wi-Fi

Technical attributes

4G/LTE

- Channel bandwidths 1.4, 3, 5, 10, 15, 20Mhz
- 300km/h mobility
- Licensed and unlicensed

Shared License Band *- CBRS Example*

- Spectrum: 3.55 to 3.7GHz
- Licensed
- Time Division Duplex (TDD)
- Does not have to be line of sight

5G

- Spectrum: Low-band: 600M-900MHz / Mid-band: 2.5G - 4.2GHz / Millimeter wave (high-band): 24GHz - 47GHz
- Licensed
- Seamless mobility - up to 500km/h mobility
- Network slicing
- Dynamic traffic optimization
- Dynamic policy control
- Function/resource elasticity
- Granular QoS/prioritization
- Multiple-access connectivity

802.11ac (Wi-Fi 5)

- Spectrum: 5GHz
- Unlicensed
- Up to 8 spatial streams
- Standards based beam forming
- MU-MIMO
- Stronger Clear-Channel Assessment (CCA) requirements
- RTS/CTS with bandwidth indication

802.11ax (Wi-Fi 6)

- Spectrum: 2.4GHz, 5GHz (Future 1 and 6 GHz)
- Unlicensed
- OFDMA scheduling to reduce overhead and latency
- MU-MIMO
- MAC special reuse with colour codes
- Denser modulation

Example Use Cases

- Smart metering
- Distribution automation
- Smart agriculture
- Renewable/variable energy
- Smart lighting
- Mobile connectivity services

- Last mile and line of site connectivity
- Mass IoT sensor deployments
- Multi IoT application deployments
- Private LTE networks
- Private wireless
- Neutral host networks

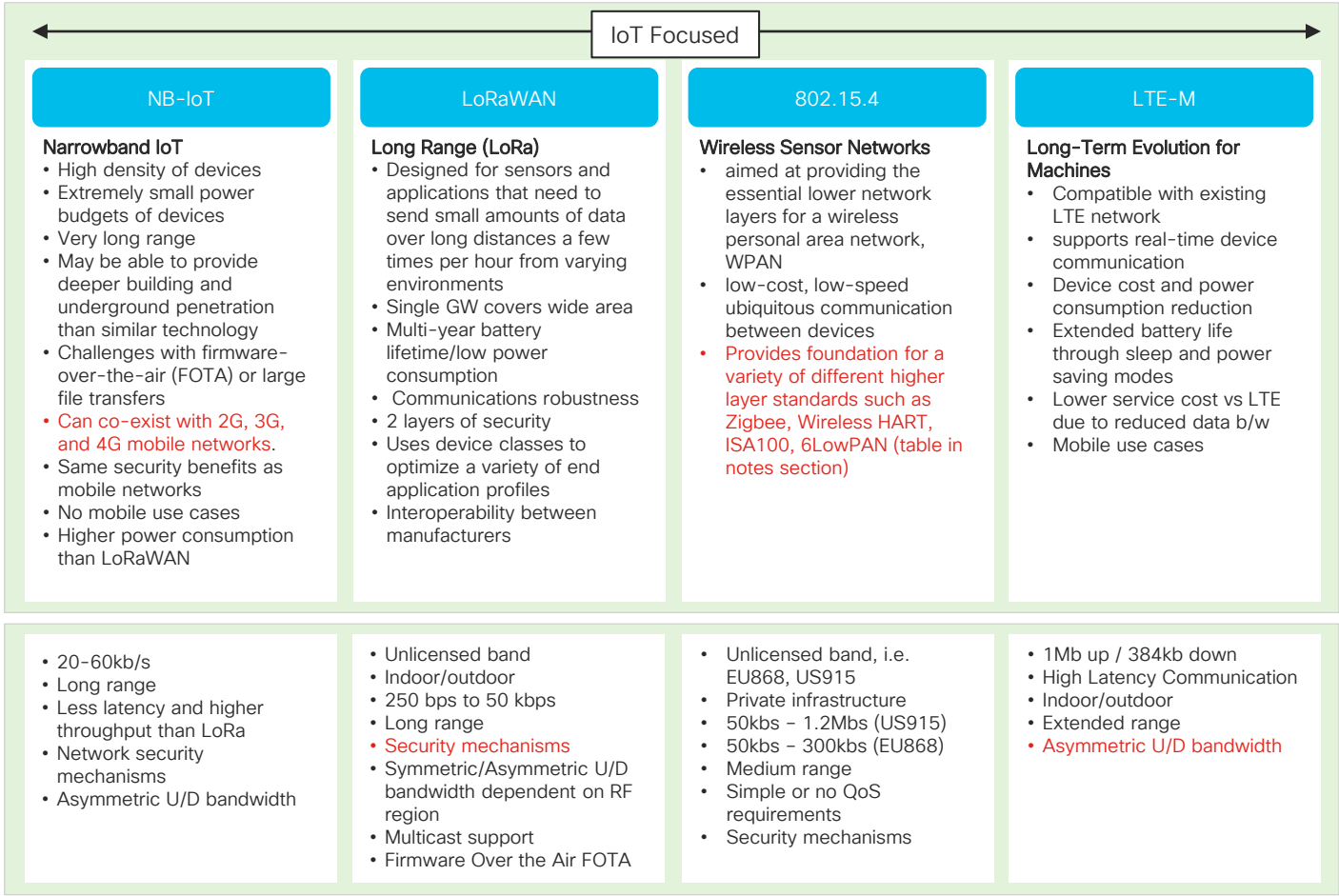
- High performance media applications
- Smart vehicle-to-X transportation/autonomous
- Dense outdoor sensor and IoT device connectivity
- Last mile and line of site connectivity
- Location based services
- Virtual + augmented reality
- Smart metering
- Distribution automation
- Renewable/variable energy
- Smart agriculture
- Edge compute

- Pervasive indoor and medium range outdoor connectivity
- User Mobility
- Location based services
- Sensor connectivity
- Smart machines - monitoring
- Virtual + augmented reality
- Smart retail + customer experience

- Pervasive indoor and medium range outdoor connectivity
- User Mobility
- Location based services
- Sensor connectivity
- Smart machines - monitoring and control
- Virtual + augmented reality
- Smart retail + customer experience
- Time sensitive applications

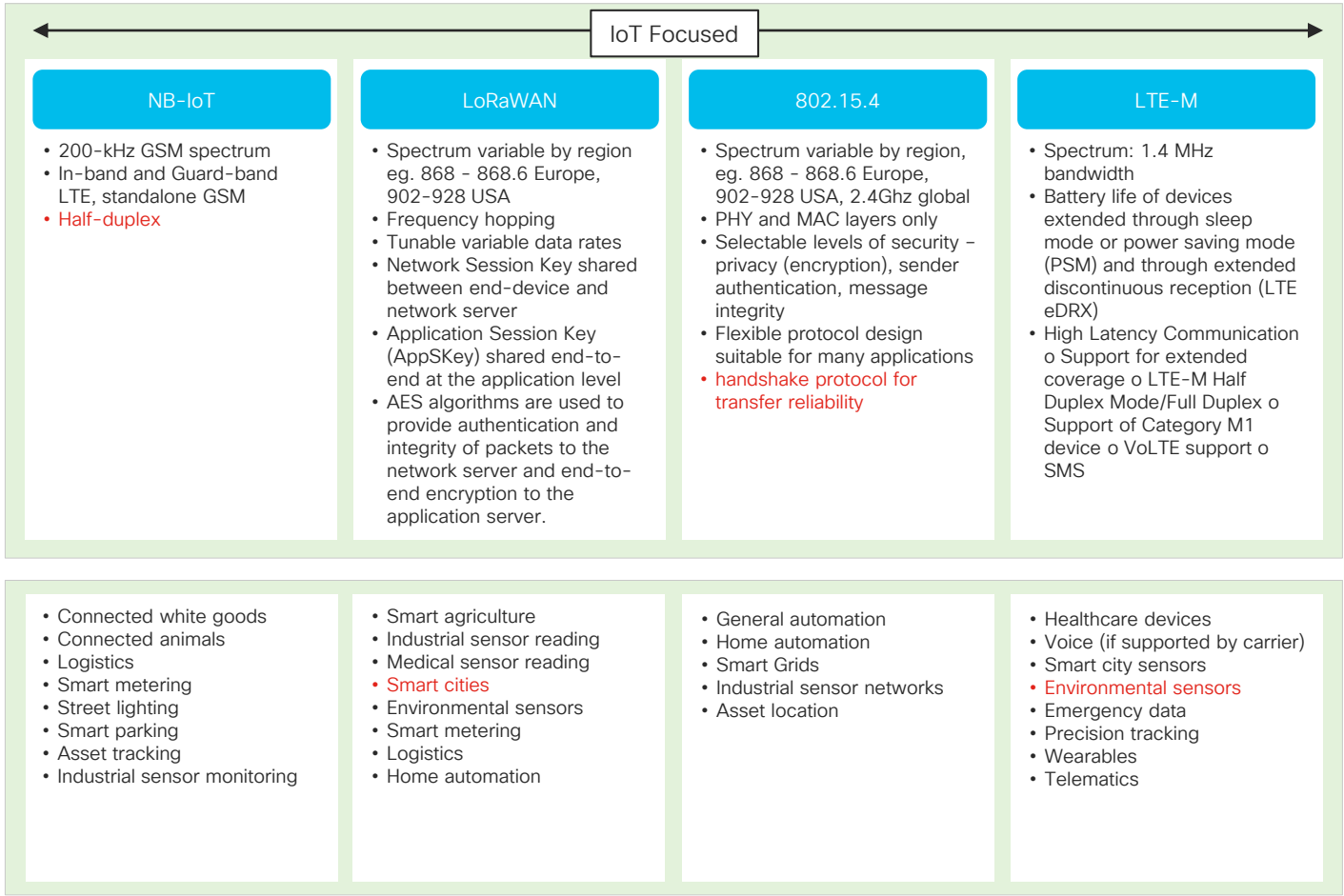
Non-wired connectivity overview - IoT

For Reference



Non-wired connectivity overview - IoT

For Reference



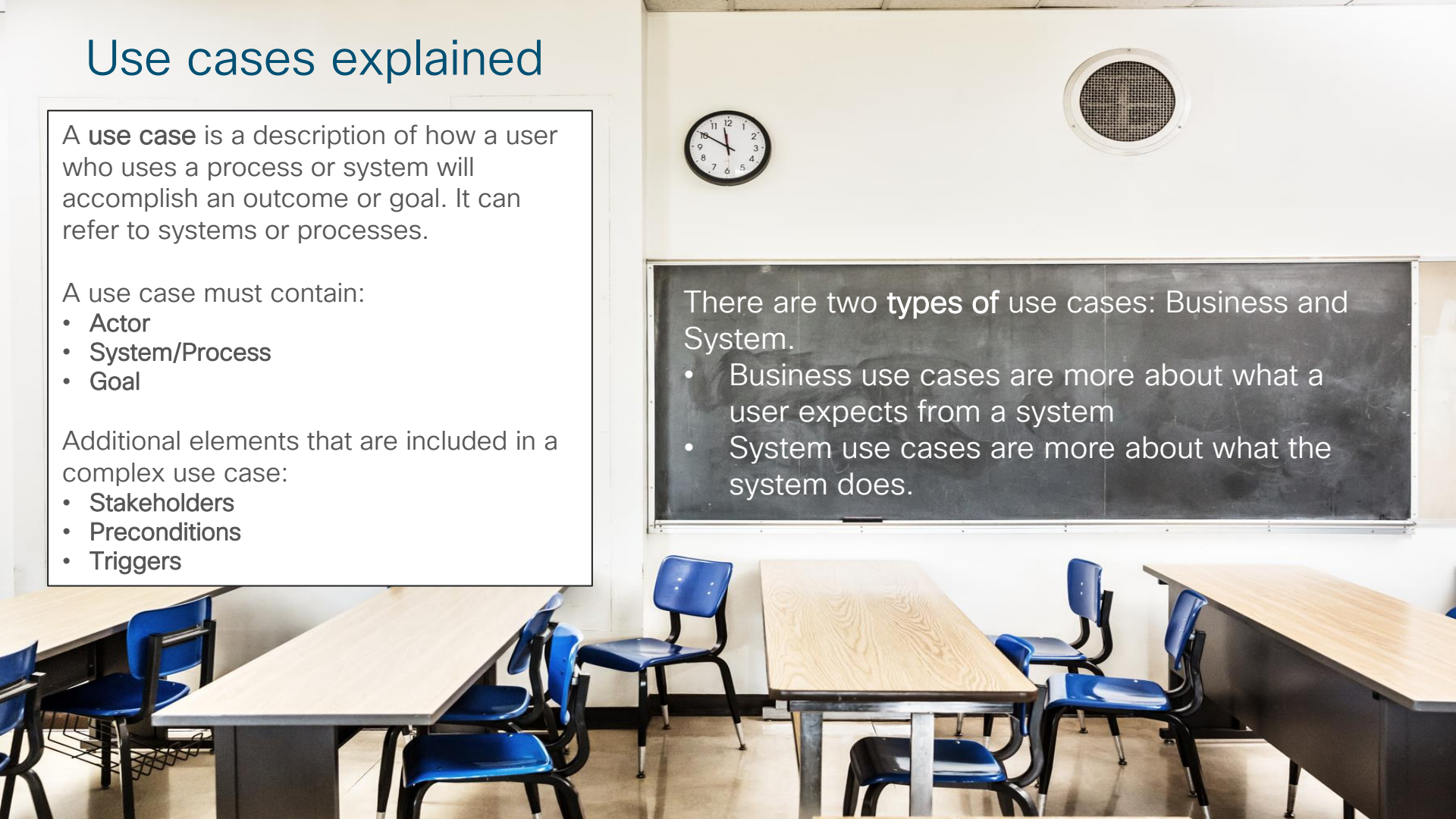
Use Cases

Use cases explained

A **use case** is a description of how a user who uses a process or system will accomplish an outcome or goal. It can refer to systems or processes.

A use case must contain:
- Actor
- System/Process
- Goal

Additional elements that are included in a complex use case:
- Stakeholders
- Preconditions
- Triggers



The confusion with “use cases”…

1. Ultra-reliable communications
2. Network slicing
3. Lifeline communications / natural disaster
4. Migration of services from earlier generations
5. Mobile broadband for indoor scenario
6. Mobile broadband for hotspots scenario
7. On-demand networking
8. Flexible application traffic routing
9. Flexibility and scalability
10. Mobile broadband services with seamless wide-area coverage
11. Virtual presence
12. Connectivity for drones
13. Industrial control
14. Tactile Internet
15. Localized real-time control
16. Coexistence with legacy systems
17. Extreme real-time communications and tactile internet
18. Remote control
19. Light-weight device configuration
20. Wide-area sensor monitoring and event driven alarms
21. IoT device initialization
22. Subscription security credentials update
23. Access from less trusted networks
24. Bio-connectivity
25. Wearable device communication

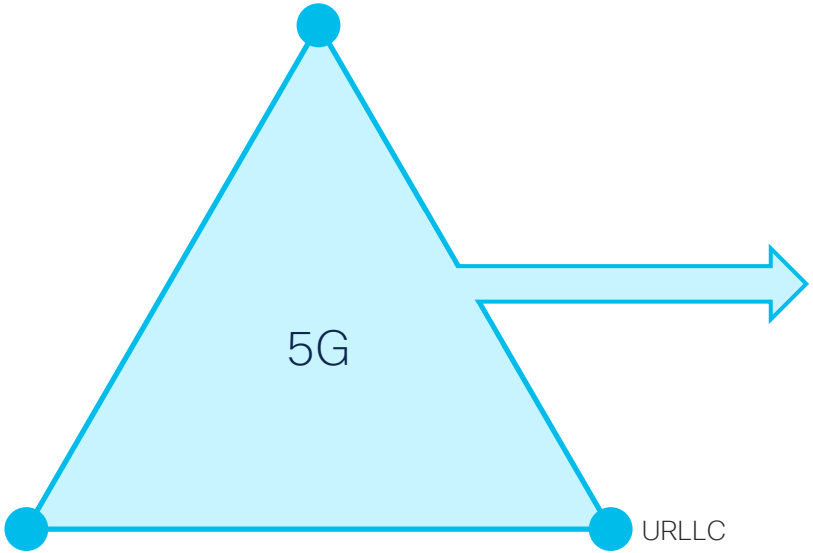
26. Best connection per traffic type
27. Multi-access network integration
28. Multiple RAT connectivity and RAT selection
29. Higher user mobility
30. Connectivity everywhere
31. Temporary service for users of other operators in emergency case
32. Improvement of network capabilities for vehicular case
33. Connected vehicles
34. Mobility on demand
35. Context awareness to support network elasticity
36. In-network and device caching
37. Routing path optimization when server changes
38. ICN based content retrieval
39. Wireless brief-case
40. Devices with variable data
41. Domestic home monitoring
42. Low mobility devices
43. Materials and inventory management and location tracking
44. Cloud robotics
45. Industrial factory automation
46. Industrial process automation
47. SMARTER service continuity
48. Provision of essential services for very low-ARPU areas
49. Network capability exposure
50. Low delay speech and video recording

51. Network enhancements to support scalability and automation
52. Wireless self-backhauling
53. Vehicular Internet and infotainment
54. Local UAV collaboration
55. High accuracy enhanced positioning (ePositioning)
56. Broadcasting support
57. Ad-hoc broadcasting
58. Green radio
59. Massive Internet of Things, M2M and device identification
60. Light-weight device communication
61. Fronthaul/Backhaul network sharing
62. Device theft preventions / stolen device recovery
63. Diversified connectivity
64. User multi-connectivity across operators
65. Moving ambulance and bio-connectivity
66. Broadband direct air-to-ground communications (DA2GC)
67. Wearable device charging
68. Telemedicine support
69. Network slicing – roaming
70. Broadcast/multicast services using a dedicated radio carrier
71. Wireless local loop
72. 5G connectivity using satellites
73. Delivery assurance for high latency tolerant services
74. Priority, QoS, and policy control

Technology is required to enable use cases

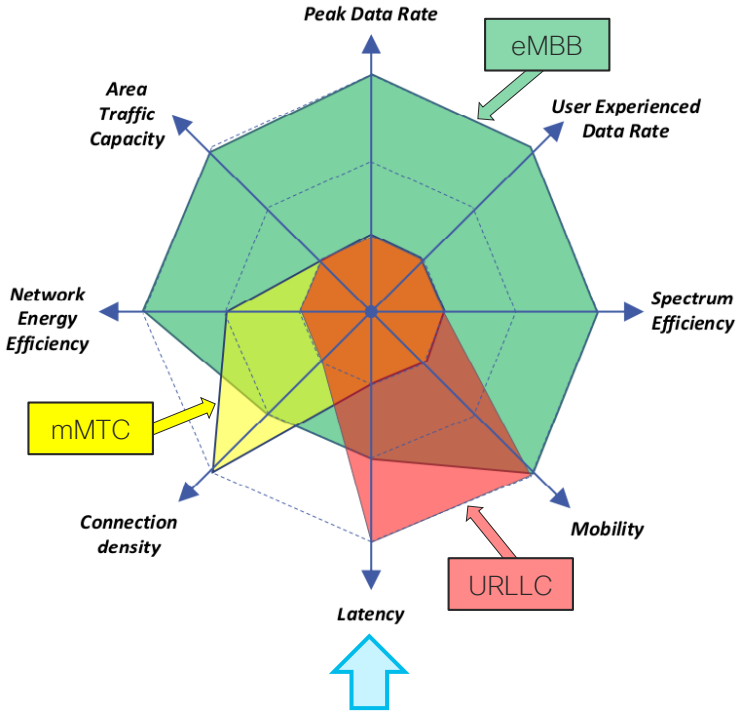
Communication characteristics: 5G example

enhanced Mobile Broadband (eMBB)
Extreme high data rates, low latency and high coverage



massive Machine Type Communications (mMTC)
Large amount of connections, low volume of data, long battery life

URLLC
Ultra-reliable and low latency communications (URLLC)
High availability, very-low / predictable latency



These characteristics are applicable to all non-wired technologies

Each scenario has different characteristics

For Reference

Indoor hotspot
- Small coverage per site / TRP
- High user density
- High capacity
- High user throughput
- Consistent user experience
- Frequencies: around 4Ghz, 30Ghz, 70Ghz
- ISD: 20m
- Users: 100% indoor, 3kmh

Dense urban
- Macro TRPs with or without micro TRPs
- High user density
- High traffic loads
- Dense urban areas and city centers
- Outdoor and outdoor to indoor coverage
- Interference limited
- Frequencies: Around 4Ghz, 30Ghz
- ISD: 200m
- Users: 80% indoor-3kmh, 20% outdoor-30kmh

Rural
- Large and continuous coverage
- Support for high speed vehicles
- Noise and/or interference limited
- Macro TRPs
- Frequencies: around 700MHz, 2GHz, 4Ghz
- ISD: 1732m or 5000m
- Users: 50% outdoor vehicles (120kmh), 50% indoor (3Kmh)

Urban macro
- Large cells and continuous coverage
- Interference limited
- Macros TRPs
- Frequencies: around 2GHz, 4GHz, 30GHz
- ID: 500m
- Users: 20% outdoor in cars (30kmh), 80% indoor in houses (3kmh)

High speed
- Continuous coverage along tracks in high speed trains
- Consistent UX and train communication reliability
- Dedicated linear deployment along railway line, UEs in train carriages
- TRP to relay and relay to UE
- Frequencies: around 4Ghz, 30Ghz (BS to relay) / around 4Ghz, 70Ghz (relay to UE)
- ISD: 1732m (BBUs), 580m (RRH), 25m (SCs in carriages)
- Users: 100% in train - 500kmh

Long distance coverage in low density areas
- Services for very large areas with low density of users
- Macro cell with very large coverage area
- Low to moderate user throughput
- ·Frequencies: around 700MHz, 1GHz, 3GHz
- ·ISD: 100km
- ·Users: 100% outdoor or in cars, up to 160kmh

Urban coverage for massive connections
- Large cells and continuous coverage
- Very high connection density
- (mMTC)
  ·Frequencies: around 700MHz,
- 2100MHz
  ·ISD: 500m or 1732m
  ·Users: 20% outdoor in cars (100kmh)
- or outdoors (3kmh), 80% indoor (3kmh)

Highway
- Vehicles with high speed
- Reliability and availability
- under high speed ·Frequencies: below/around
- 6GHz
  ·ISD: 1732m or 500m
  ·Users: 100% in vehicles, 100-
- 300kmh

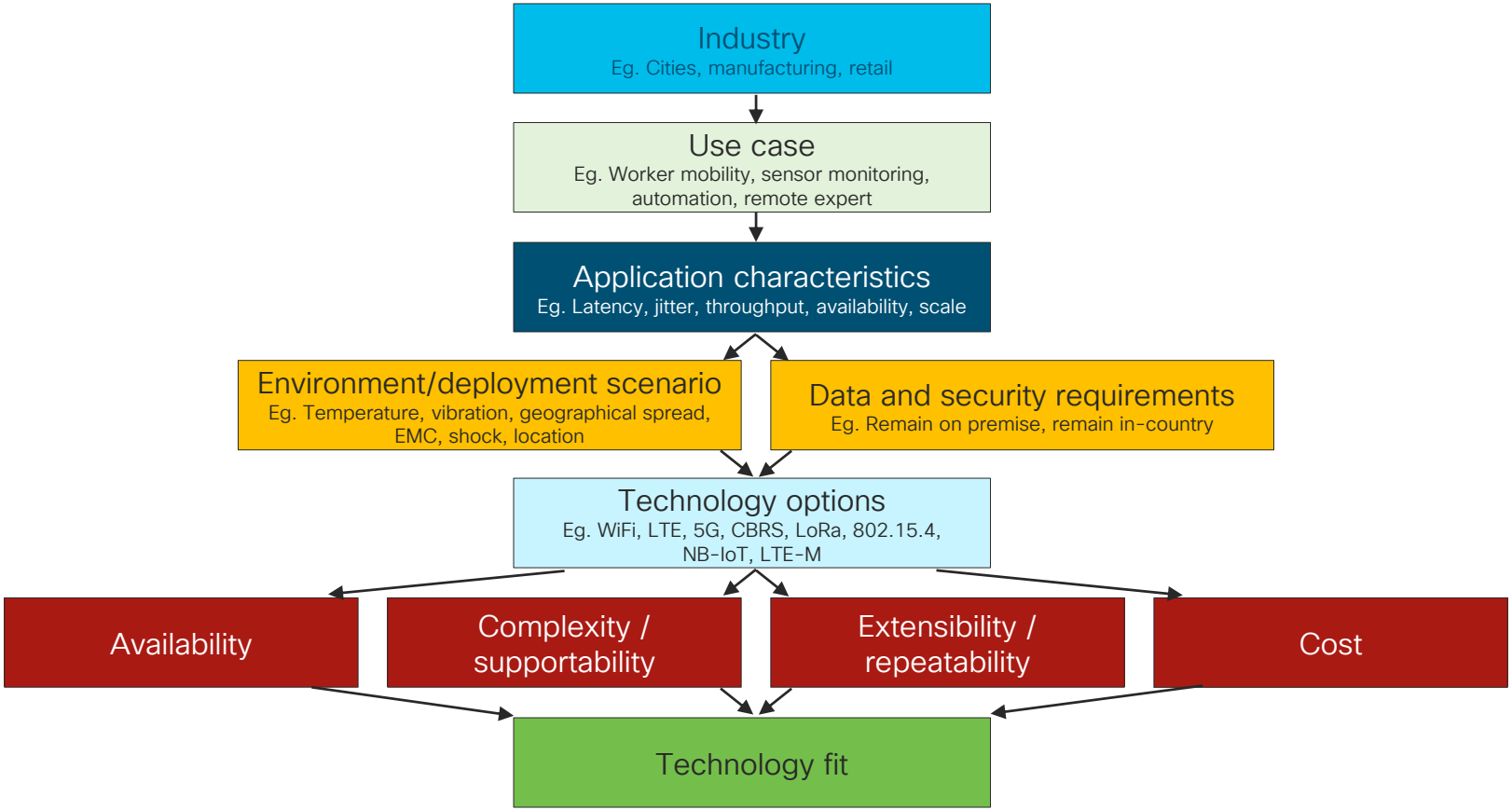
Urban grid for connected car
- Highly densely deployed vehicles in urban area or freeways leading to urban grid
- ·Reliability, availability, latency in high network load and high user density
- ·Macro only or macro+RSU
  ·Frequencies: below 6GHz
  ·ISD: 500m
  ·Users: urban grid, cars, 15-20kmh

Commercial air to ground
- Services for commercial aircraft for humans and machines aboard
- ·Upward pointed macro cells with very large area coverage
- ·Moderate user throughputs and high speeds
- ·Aircrafts with relays and macro sites ·Frequencies: below 4GHz
  ·Cell range: 100km
  ·Users: 100% in plane, < 1000kmh

Light aircraft
- Services for general aviation aircrafts for humans and machines aboard helicopters and small air planes
- Upward pointed macro cells with very large area coverage (no relays)
- Moderate user throughputs ·Low user density and moderate altitude
- Frequencies: below 4GHz
- Cell range: 100km
- Users: 100% in aircrafts, < 370 km

Satellite extension to terrestrial
- Services for areas where terrestrial service is not available and broadcasting
- Fill in on roadways and rural areas
- Data, voice, mMTC, broadcast
- Frequencies: around 1.5-2.0GHz, 20- 30GHz, 40-50GHz
- Satellite as access or backhaul
- Users: 100% outdoors, fixed, portable, mobile

Making the use case technology choice



Industry example 1 – manufacturing

Cisco for manufacturing

https://www.cisco.com/c/m/en_us/solutions/industries/portfolio-explorer/portfolio-explorer-for-manufacturing.html

Advanced manufacturing operations

- Overall equipment effectiveness
- Data collection and management
- Asset visibility and control
- Remote access and troubleshooting

Workforce enablement

- Industrial collaboration
- Remote experts
- Augmented reality
- Worker mobility

Industrial security

- Cybersecurity
- Physical security

The Industrial Wireless Challenge

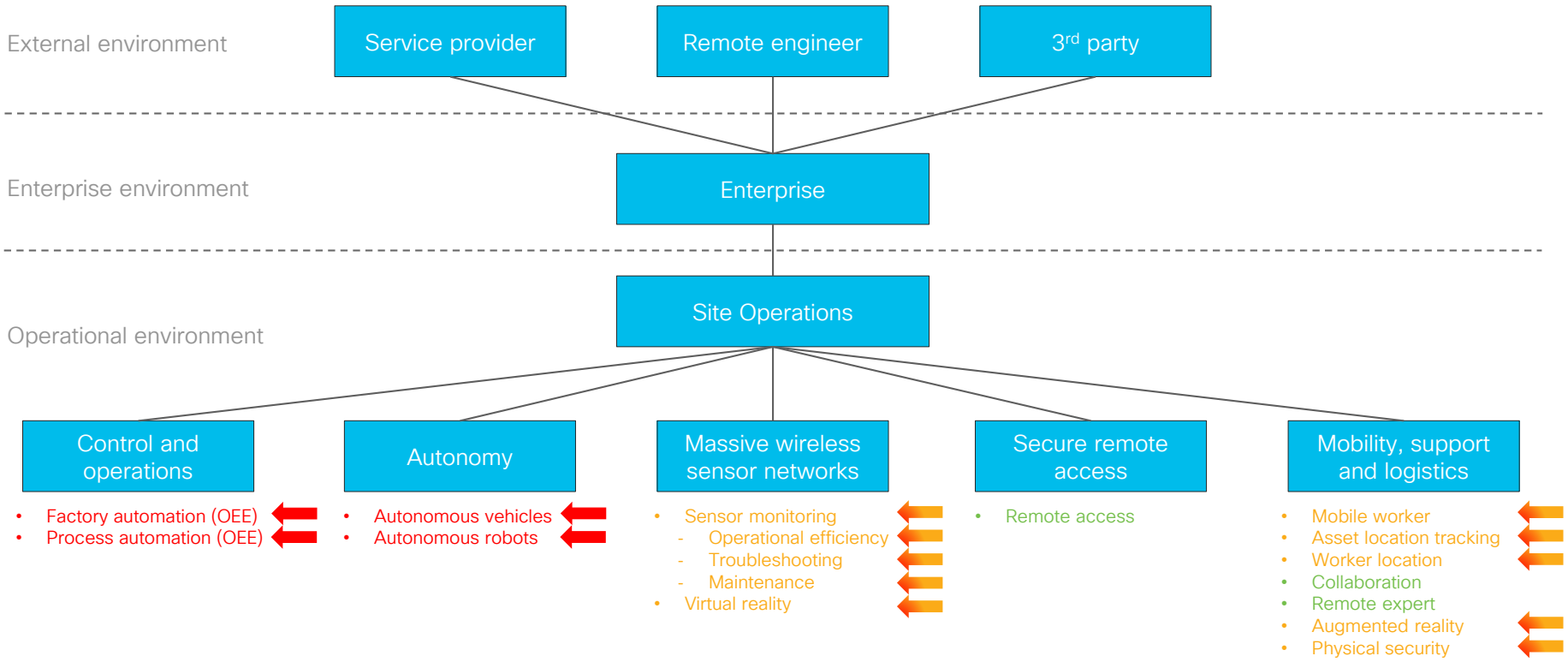
It’s not the office.

- Larger spaces
  - Typically 6-10m height, not 3m
- Different construction
  - Radio reflective surfaces
- Potential RF interference sources
- Large moving metallic objects
- Sensitive industrial applications
  - Safety or process control

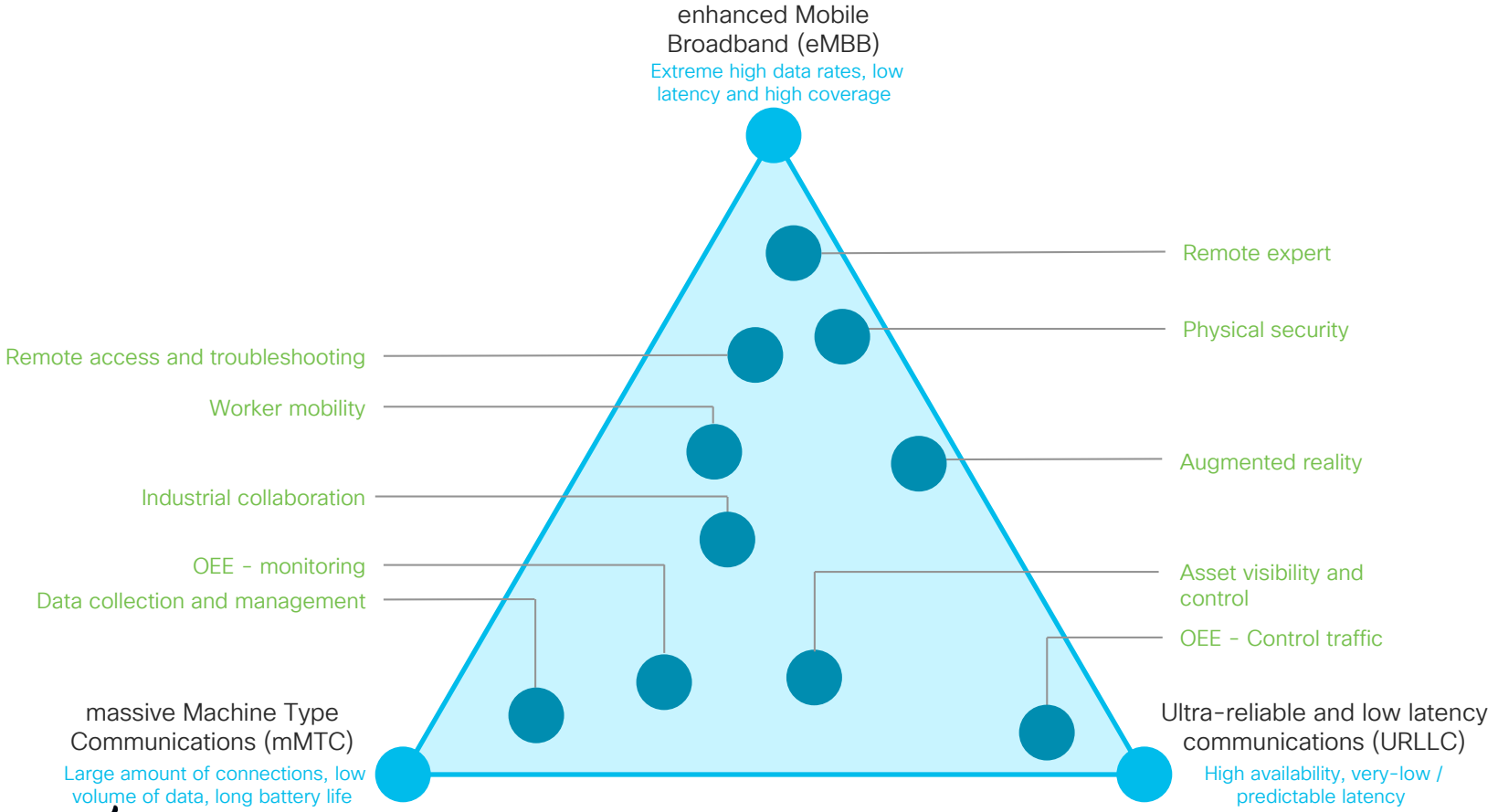
Application characteristics

Use case (high level)		Availability	Latency	Jitter	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms		20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms		50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms		40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms		40-250 bytes	100	< 1 km^2
	Video-operated remote control	>99.9999%	10 – 100 ms		15 – 150 kbytes	100	< 1 km^2
Mobile control panels with safety functions	Assembly robots or milling machines	>99.9999%	4-8 ms		40-250 bytes	4	10 m x 10 m
	Mobile cranes	>99.9999%	12 ms		40-250 bytes	2	40 m x 60 m
Process automation (process monitoring)		>99.99%	> 50 ms		Varies	10000 devices per km^2	

Manufacturing high level architecture



Manufacturing use cases mapped to ITU triangle



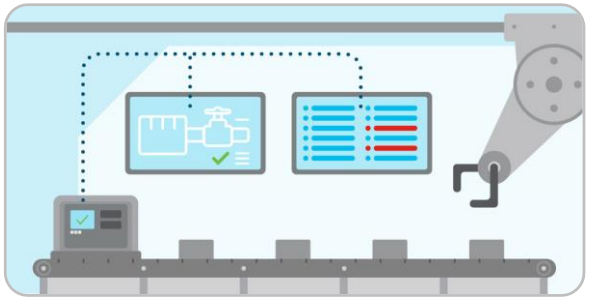
Manufacturing use cases non-wired mapping

ISG use case	Description	4G/LTE	Shared spectrum *eg. CBRS*	5G	Wi-Fi 5 (802.11ac)	Wi-Fi 6 (802/11ax)	NB-IoT	LoRaWAN	802.15.4	LTE-M
Overall equipment effectiveness	Provide automation, monitoring and security with rapid and repeatable machine connectivity through enterprise and industrial networking									
Data collection and management	Capture compute information from point of acquisition to target systems for faster decision-making, real-time insights and machine learning.									
Asset visibility and control	Apply asset status, condition, and/or location to improve utilization									
Remote access and troubleshooting	Gain visibility and insights, stop manual troubleshooting, and reduce time spent on issues									
Industrial collaboration	Provide Subject Matter Expertise wherever and whenever needed									
Remote experts	Empower with the critical information you need, when you need it, to ensure your operations run seamlessly without interruption									
Augmented reality	Implement hands free capabilities to monitor the factory, summon assistance, and solve problems in real-time.									
Worker mobility	Build a smart workplace environment for optimized communication and collaboration while improving employee productivity and asset utilization									

Note: *this demonstrates which technologies could* ***potentially*** *be used. It does not indicate the best choice*

Overall equipment effectiveness (OEE)

Provide automation, monitoring and security with rapid and repeatable machine connectivity through enterprise and industrial networking.



Industry drivers

- Reliable operations to reduce unplanned downtime
- Efficient operations to lower operating costs and maintain a productive working environment
- Optimize operations to drive excellence and create a competitive differentiation
- Connect to increasing number of factory devices

Business needs

- Robust connectivity environment
- Reduced overall costs and maximized uptime
- Real-Time multi-site asset management
- Reduced costs and downtime through predictive and remote maintenance
- Adaptability and support for next generation systems

Capabilities

- Connectivity deployed on key equipment transmitting process data
- Real-time edge processing and forwarding of critical data
- Secure Remote Access
- More robust connectivity for an increasing number of devices and machines
- Visualization of sensor data to anticipate failures
- Predictive analytics for infrastructure and systems

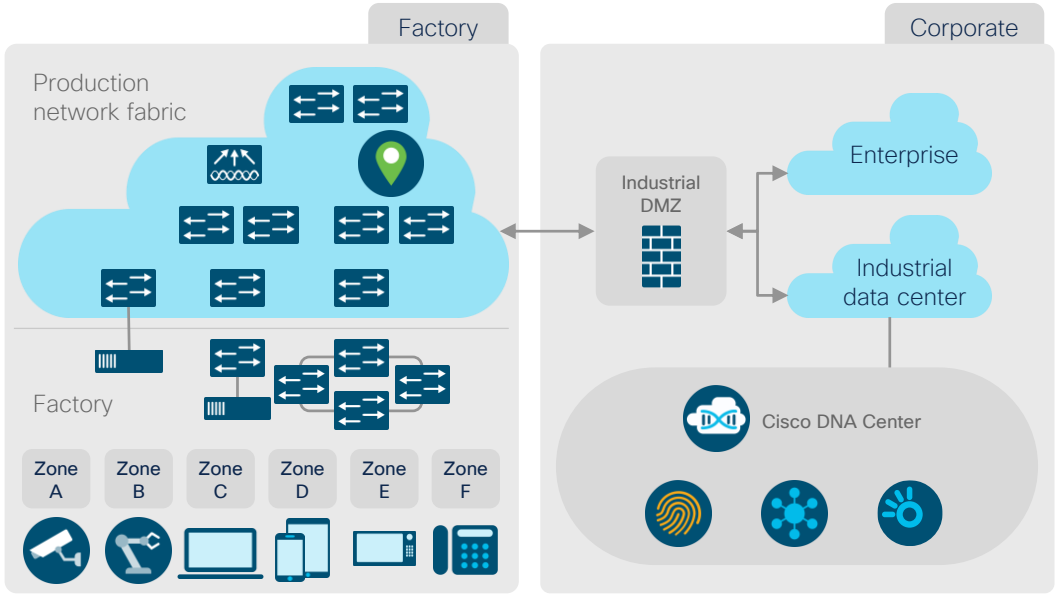
Business outcomes

- Improved business operations
- Real-time production management
- Maximize uptime and lower costs with reduced turnaround time
- Improved labor productivity
- Lowered operating costs
- Improved Asset Management,

Stakeholders

- CFO
- VP of Manufacturing and Operations
- Plant Manager
- Industrial Network Architect
- Reliability Manager
- Process Engineer
- Facility manager
- Engineering Director
- Control engineer
- Director of IT

Overall equipment effectiveness (OEE)



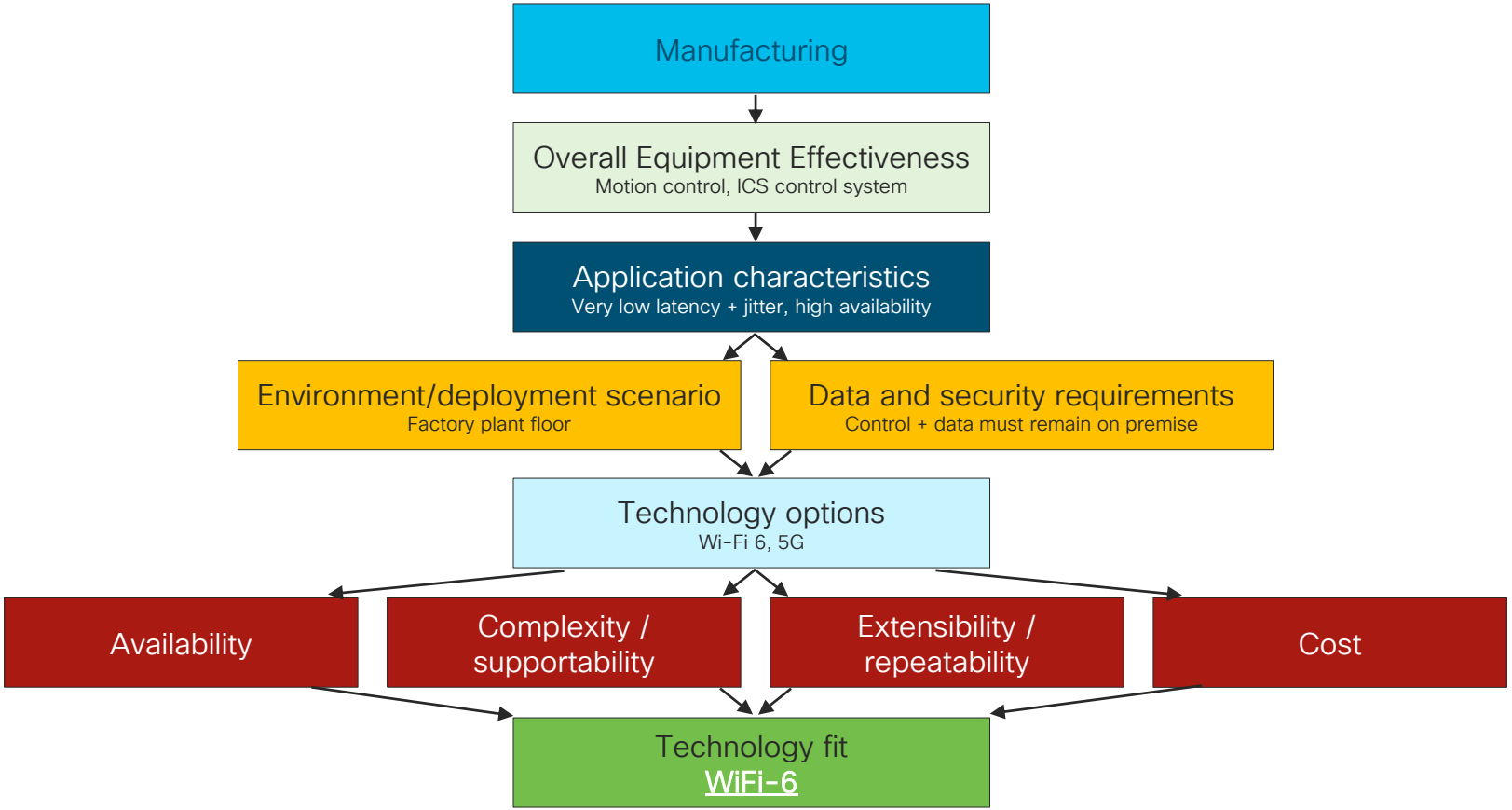
Communication requirements

Component	
Availability	>99.9999%
Latency	<0.5 - 12ms depending on specific sub-use case
Jitter	x
Payload	15-250 bytes depending on specific sub-use case
Number of devices	2 to 100+ depending on specific sub-use case
Coverage area	Both L x W and L x W x H need to be considered. Scenarios such as 10 x 10m, 10 x 5 x 3m, 100 x 100 x 30m, 1 KM_2

Deployment environment

- Highly metallic environment
- Dust, EMC, vibration and shock
- Data must stay on premise
- Availability and uptime essential

Use case deployment example(s)



Factory Wireless at Continental Tire

Challenge

Long Tire Assembly Search Times by Operators Increased Cycle Times, Decreased Labor Optimization, and Noncompliance with Production Schedules. High Scrap Rate Associated with Lost Carriers.

Solution

Implement LBS Solution to Track All Carriers in Real-time Using T2 Tags and Cisco Unified Wi-Fi network

Allow Material Handlers/Truckers and Managers to Search for Component by ID, Tread Number, Material Code (FIFO)

Business Outcomes

Continuous Real-time Visibility Across Entire Plant

20% Reduction of Breaker Component Tire Loss

Increase in tire machine utilization ensuring increased production and overall equipment efficiency (OEE)

Industry example 2 – cities

Cisco for cities + communities

https://www.cisco.com/c/m/en_us/solutions/industries/portfolio-explorer/portfolio-explorer-for-cities-and-communities.html

City operations

- Cross-agency collaboration
- Modernize critical infrastructure
- Digital readiness

Public safety and security

- Physical safety and security
- Network segmentation and access control
- IoT endpoint visibility

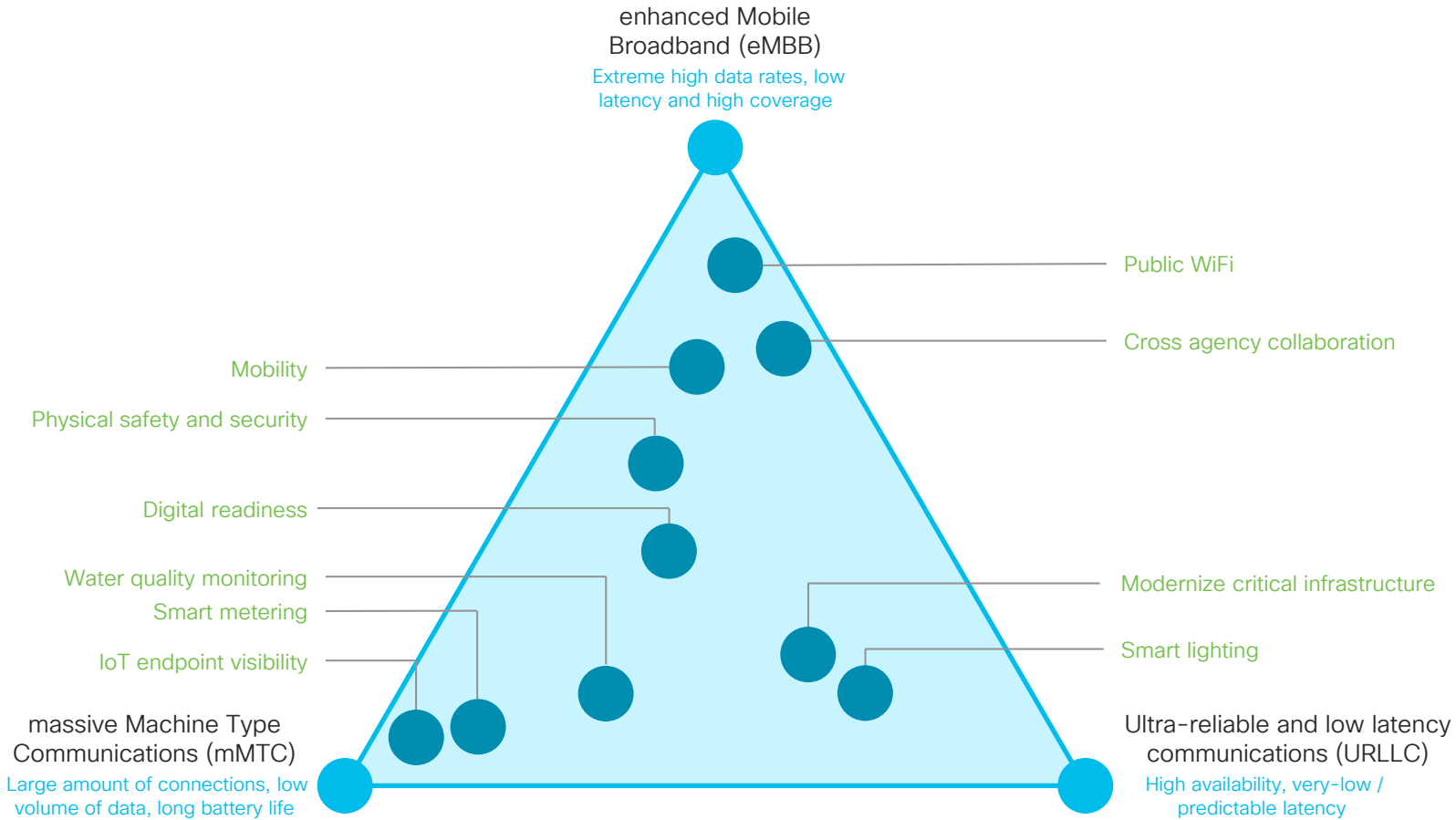
Economic sustainability

- Smart lighting
- Public Wi-Fi
- Open IoT data

Citizen services

- Smart metering
- Water quality monitoring
- Mobility

Cities + communities mapped to ITU triangle



Cities + communities use cases non-wired mapping

ISG use case	Description	4G/LTE	Shared spectrum *eg. CBRS*	5G	Wi-Fi 5 (802.11ac)	Wi-Fi 6 (802/11ax)	NB-IoT	LoRaWAN	802.15.4	LTE-M
Cross agency collaboration	Better data management across all functions for more informed policy decisions									
Modernize critical infrastructure	The use of real time data and analytics to improve aging systems and extend the life of the underlying assets									
Digital readiness	The digitization of city and citizen services to enhance public services and safety									
Physical safety and security	High performing, high quality video that that increases public safety									
IoT endpoint visibility	The proper and efficient delivery of digital services to constituents									
Smart lighting	A common platform that monitors and applies all city lighting policies									
Public WiFi	Secure, effective Wi-Fi infrastructure that drives economic development									
Open IoT data	The use of sensors and IoT devices to drive short and long-term planning for citizen experience and safety									
Smart metering	Deep, IoT driven insights into water consumption and maintenance issues									
Water quality monitoring	Leverage real time data to improve response time to water quality issues									
Mobility	Actionable insights into road + traffic conditions that increase pedestrian + driver safety									

Note: *this demonstrates which technologies could* ***potentially*** *be used. It does not indicate the best choice*

Water quality monitoring

Leverage real time data to improve response time to water quality issues

Industry drivers

- Impact of poor water quality on health
- Leverage IoT technologies to improve water quality based on real time data
- Gain a better understanding of trouble zones
- Ability to quickly respond to emergencies and natural disasters

Business needs

- Improve water quality to assure health of the ecosystem
- Prioritize and reduce infrastructure spending based on real time quality monitoring
- Identify poor water quality zones
- Better emergency response time
- Real-time insight for operations and maintenance staff

Capabilities

- Automate water quality monitoring
- Pinpoint trouble zones that pass the required quality thresholds
- Timely identification of trouble zones and ability to mitigate issues quickly through automation
- Respond to incidents efficiently by using situational predictive modeling and monitoring

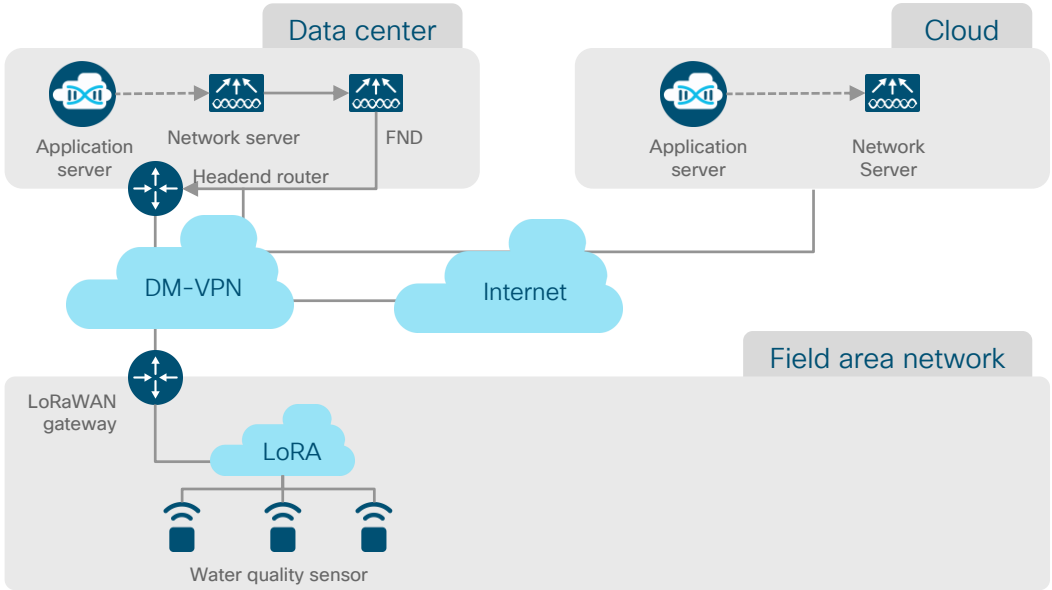
Business outcomes

- Improved water quality
- Shorter response time to emergencies and natural disasters
- Ability to leverage existing infrastructure more efficiently and reduce capital costs
- Better real-time insight for operations and maintenance staff

Stakeholders

- Elected and appointed municipal leaders
- City CIO/CTO
- Utility Director/Deputy Director

Water quality monitoring



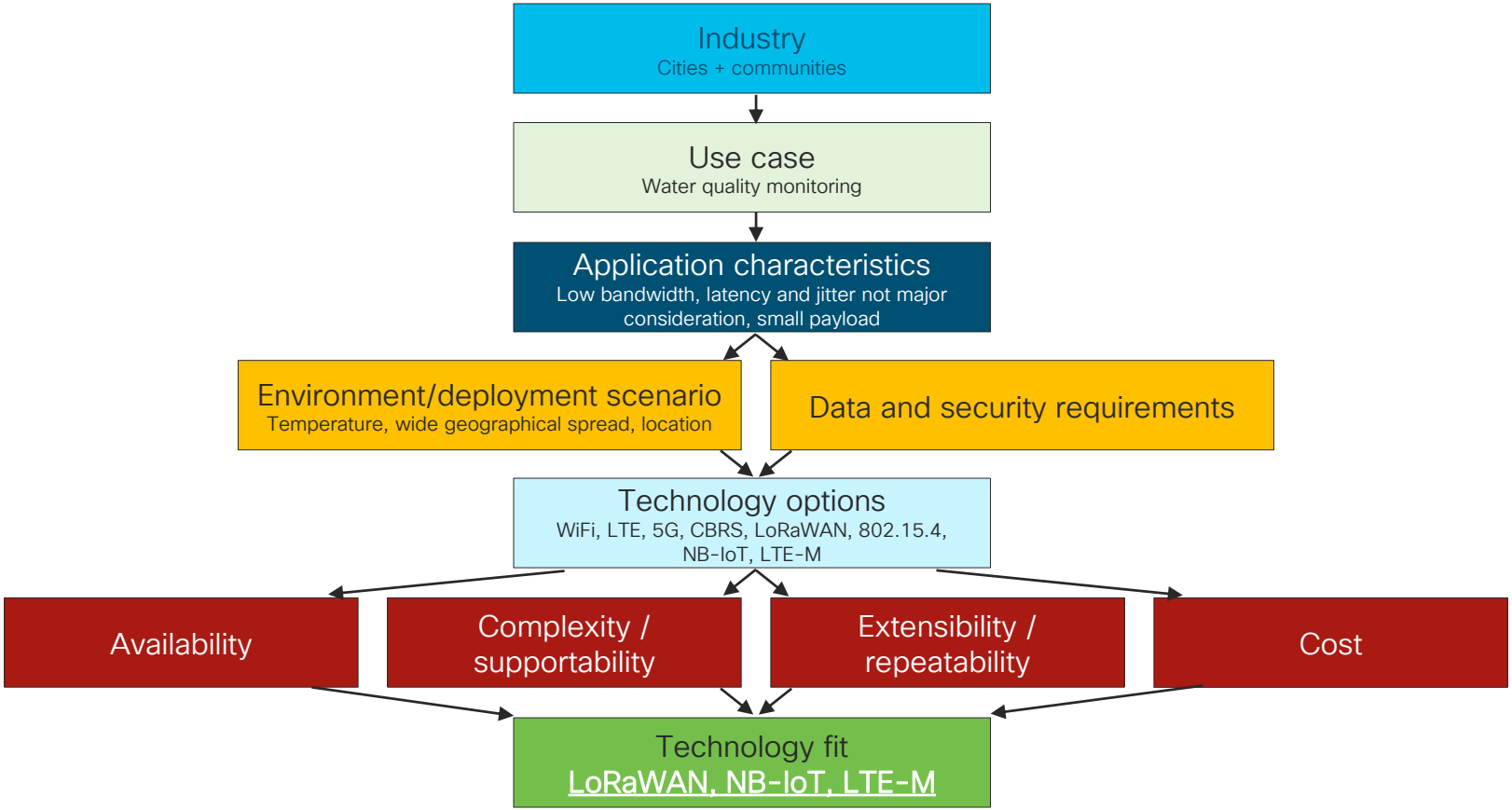
Communication requirements

Component	
Availability	>99.9999%
Latency	<0.5 - 12ms depending on specific sub-use case
Jitter	x
Payload	15-250 bytes depending on specific sub-use case
Number of devices	2 to 100+ depending on specific sub-use case
Coverage area	Both L x W and L x W x H need to be considered. Scenarios such as 10 x 10m, 10 x 5 x 3m, 100 x 100 x 30m, 1 KM_2

Deployment environment

- Highly metallic environment
- Dust, EMC, vibration and shock
- Data must stay on premise
- Availability and uptime essential

Making the use case technology choice



Caldas da Rainha

Caldas da Rainha, Portugal
51,729 population

Caldas da Rainha has improved their citizen's quality of life, reduced water management costs, and ensured that water quality meets their high standards.

"Our Cisco network is an important new chapter of our magical city and the future." – Fernando Manuel Tinta Ferreira, Mayor of Caldas da Rainha

Actility

Customer Story

Challenge

Monitor how much water is consumed, ensure water quality, and alert management if there are any water leaks or abnormalities.

Solution

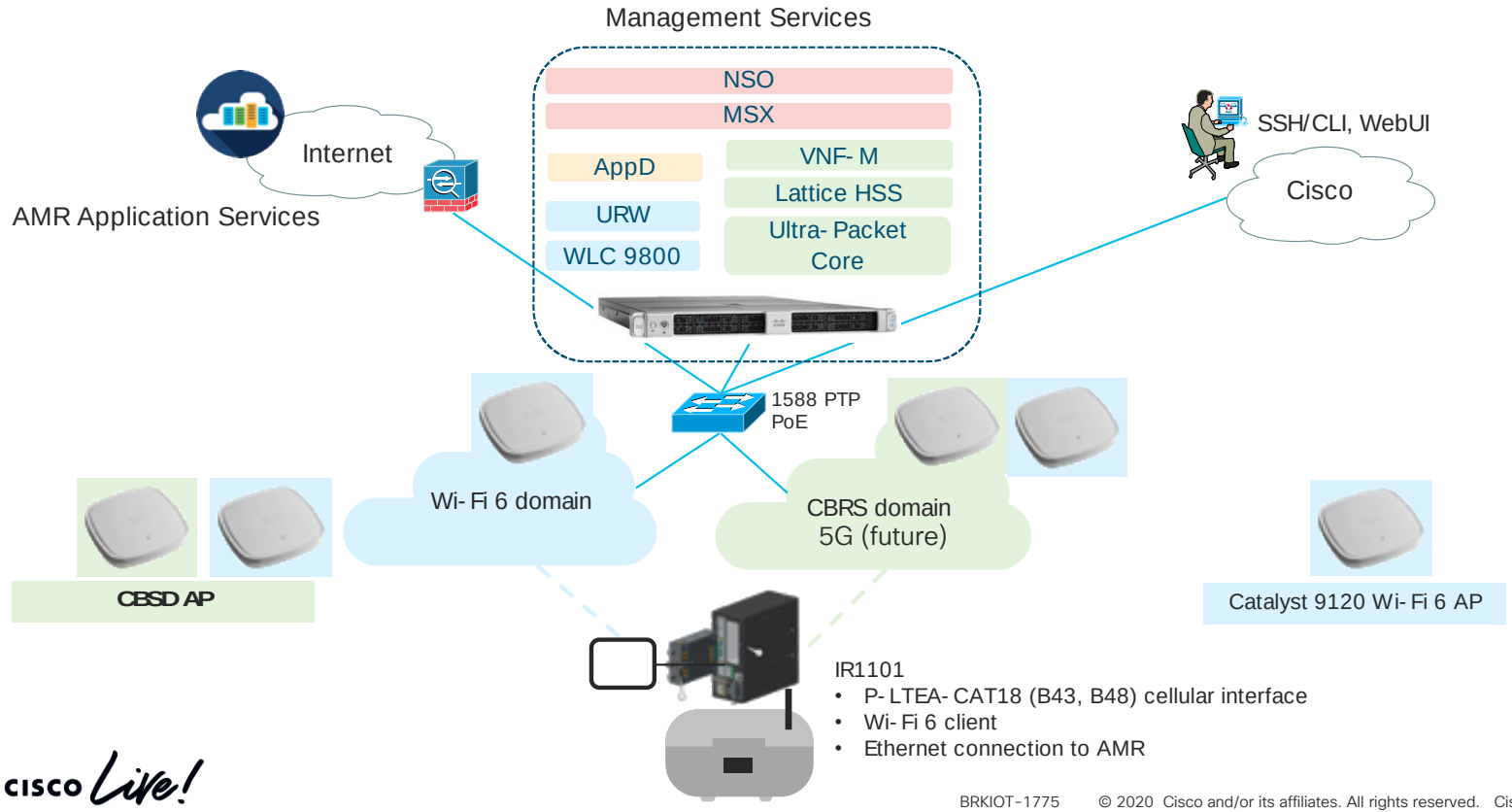
Deployed low-battery sensors and Cisco LoRaWAN gateway network powered by Actility network server across the entire 250-square kilometer city to power multiple smart cities use cases, including smart water.
https://youtu.be/QlXM-qJeOII

Impact

- Save thousands of gallons of water through leak detection and reduced management costs by 33 percent.
- Improve water quality
- Minimize water monitoring and repair costs

Summary

Call to Action – Cisco Wireless Testbed



Additional Resources

Salesconnect Collaterals

- LoRaWAN
- Cisco Resilient Mesh
- Industrial Wi-Fi

5G and Wi-Fi 6 IOT Papers

- Demystifying 5G in Industrial IOT

  Wi-Fi 6 and Private LTE/5G Technology and Business Models in Industrial IoT

Alliances

- LoRa https://lora-alliance.org/
- Wi-Fi https://www.wi-fi.org/
- Wi-SUN https://www.wi-sun.org/
- CBRS https://www.cbrsalliance.org/

Cisco Webex Teams

Questions?

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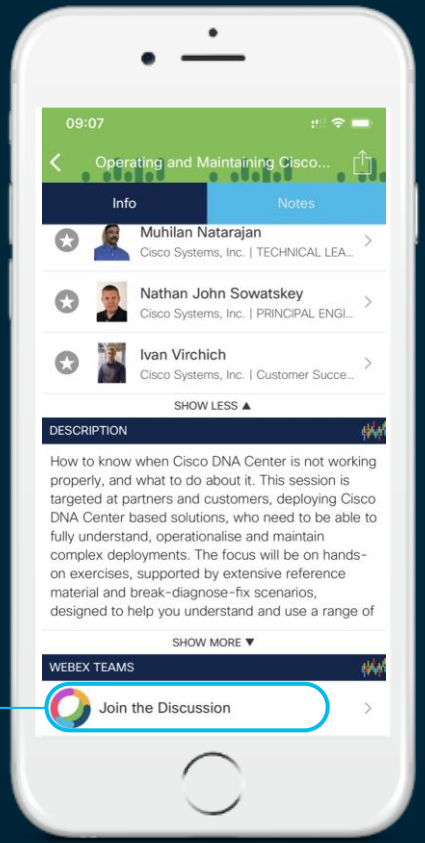

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