Industrial Automation Wireless Networks Update – Ever More Relevant for ODVA

Bob Voss, David Brandt, Paul Didier

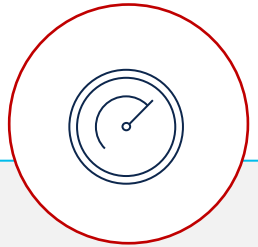
Panduit, Rockwell Automation, Cisco

Agenda

- Use Cases
- Technologies – Current State
- Key Industrial Considerations
  - Resiliency
  - Latency/Jitter
  - Time synchronization
- Architectures
- ODVA Impact

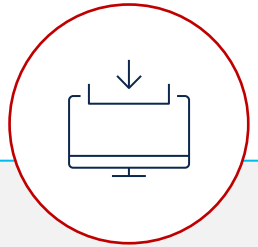
Wireless is a key enabler for digitizing operations

Applications have unique wireless requirements



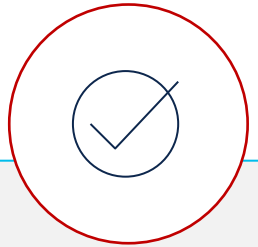
High bandwidth

HD video, AGVs, 3D sensors



Low latency

Teleremote, AGVs, AMRs



High availability

Loss of connectivity causes safety issues or loss of money

Zero-loss handoffs

Real-time control of unmanned vehicles, support for applications at high speed

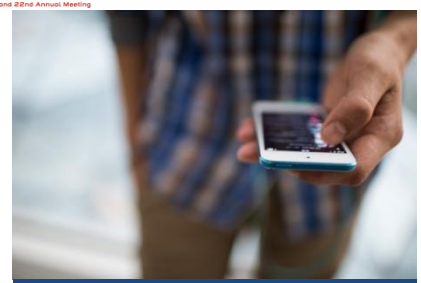
Ruggedization

IP67 protection (water and dust), hardened for shock, vibration, extreme temperatures

Use Cases

- Smart devices
- Automated Guided
- Surveillance Cameras
- Human Machine Interface
- Remote Expert
- Augmented Reality
- Sensors, Actuators
- Wireless Tooling
- Mobile Work-Cell
- Product Downloads

The Advantages of Wi-Fi 6/6E



Higher data rates

- Improved modulation for up to 9.6Gb/s per radio and single-antenna speeds of 1.2Gb/s
- 8x8:8 Spatial streams (vs. 4x4:4) increasing density – Multiple Input, Multiple Output (MIMO)

Increase in overall network capacity

- More Industry, Scientific and Medical (ISM) spectrum
- 3-4x more throughput than 802.11ac via improved modulation scheme
- Up to 4x capacity gain in dense scenarios with underlying infrastructure services

Reduced latency and greater reliability

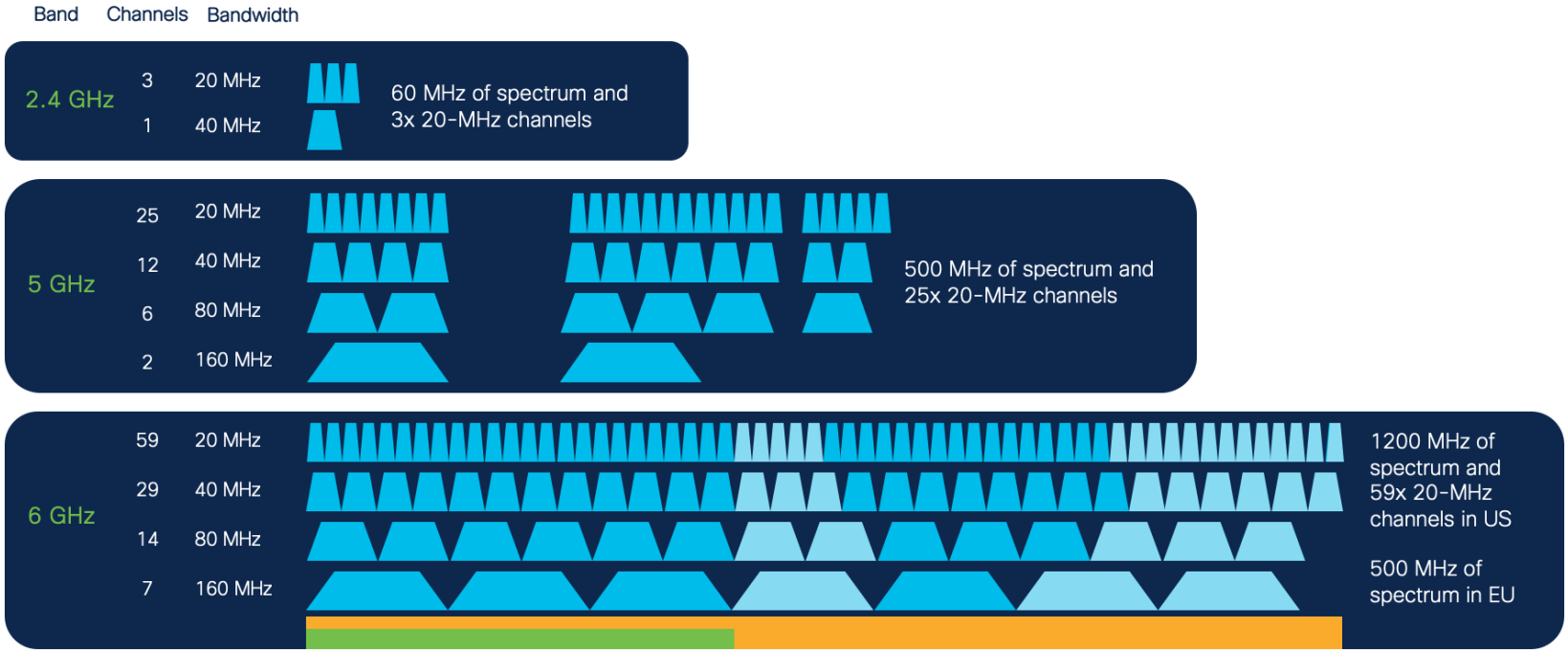
- Scheduled uplink/downlink windows for deterministic ‘cellular-like’ latency, reliability i.e. Quality of Service
- Optimized for IOT scale with 100s of devices per AP
- Spectrum w/o Listen-Before-Talk (LBT)

Improved power efficiency

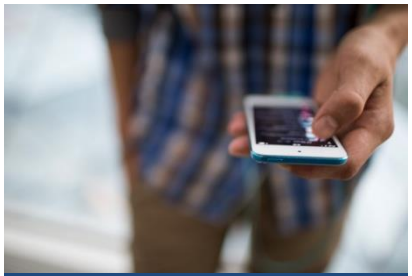
- Up to 3x better battery life with Target Wake Time (TWT)
- New coding structure and signaling procedures for better Transmit/Receive efficiency

For more information see: https://www.cisco.com/c/en/us/products/collateral/wireless/white-paper-c11-740788.html

6 GHz is the biggest Wi-Fi spectrum expansion ever



Wi-Fi 7 (802.11bn) Enhancements



Higher data rates

- Up to 4K QAM (12-bits/Hz) for 46Gb/s per radio and single-antenna speeds of 2.8Gb/s
- 320MHz channels (vs. 160MHz) and 16x16:16 spatial streams (vs. 8x8:8)

Increase in throughput and resiliency

- Multi-link operation (MLO) or “carrier-aggregation” better exploits available spectrum (e.g., simultaneous 5GHz 160MHz + 6GHz 320MHz)
- **MLO can also be used for redundancy or improved resiliency via per-packet link selection**

5G compatible QoS

- **Scheduled uplink/downlink transmissions enabled for bounded latency and reliability**
- Enables mission critical apps like AR/VR and IOT/industrial @ scale (10-100s devices per AP)
- 5QI QoS mapping via SCS/WTSN

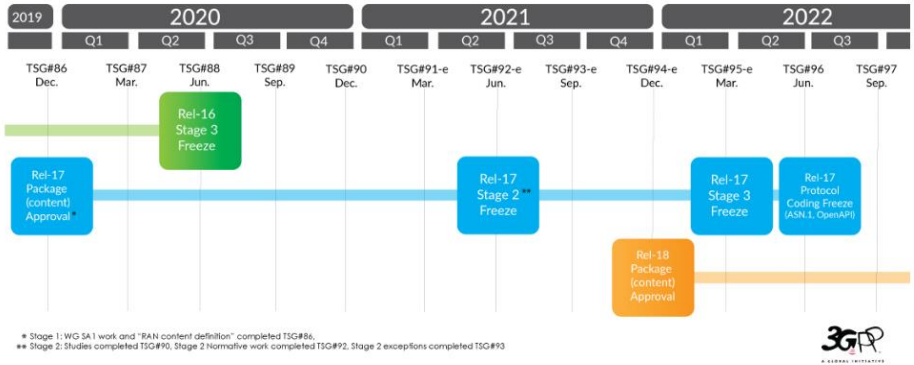
Emergency services support

- Emergency Preparedness Communication Service (EPCS) enables priority channel access (PAC) for first responders
- Combined with WBA OpenRoaming, opens guest Wi-Fi to Emergency Services.

For more information see: https://wballiance.com/road-to-wi-fi-7/

5G Release 17

- Release 17 (3gpp.org)



5G New Radio, or 5G NR, is a set of standards that replace the LTE network 4G wireless communications standard.

- Sidelink enhancements (UE to UE comms)
- Reduced capability (Redap) NR devices,
- NR operation extended to 71GHz,
- Further enhancements on MIMO for NR,
- NR over Non terrestrial Networks (NTN),
- IoT over NTN,
- UE power saving enhancements for NR,
- Enhancements to Integrated Access and Backhaul for NR,
- Enhancement of RAN slicing for NR,
- RF requirements enhancement for NR FR1,
- RF requirements for NR FR2,
- Coverage and positioning enhancements,
- NR and slicing QoE,
- Enhanced support of non-public networks,
- Support for uncrewed aerial systems,
- Support for edge computing in 5GC,
- Proximity-based services in 5GS,
- Access traffic steering, switch and splitting (ATSSS),
- Network automation for 5G (Phase 2).

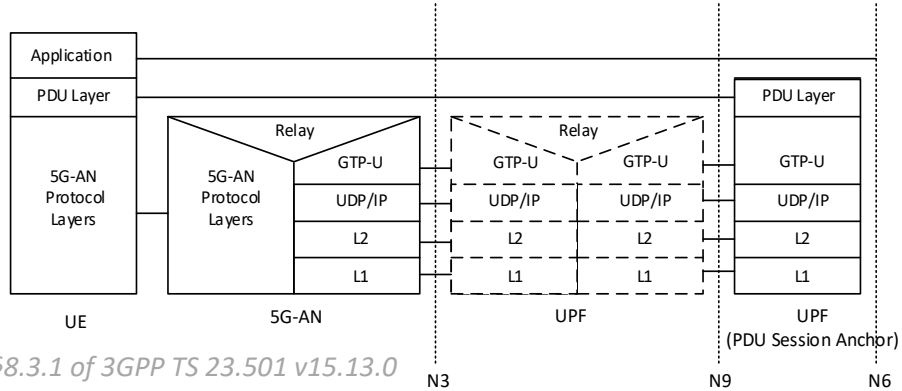
5G Feature Release

Feature	Release 15 (2018/2019)	Release 16 (2020)	Release 17 (2022)
URLLC	All basic features (for IMT-2020 compliance)	Adds redundant transmissions, QoS monitoring	No new features
Ethernet PDU	No	Yes	Yes
Time Sync Support	None	IEEE 802.1AS gPTP only	IEEE 1588 PTP (CIP Sync)
Positioning	< 50 m	< 3 m	< 1 m
Network Slicing	Basic slicing features (similar to VLAN)	Adds network slice-based authentication (NSSAA)	Adds slice groups (NSSRG), enhanced RAN support
IIoT	Relies on LTE	5G core support for NB-IoT	NR RedCap (replacement for LTE Cat 1)

- Feature release for telecom providers remains 5G vendor priority
- *Significant lag* between 3GPP specification release and commercial availability (particularly of "industrial" features not needed by telecom)
  - Release 16 completed in 2020
  - No infrastructure supporting Release 16 features (e.g., time sync support) until end of 2023 / early 2024
- 5G modems more closely follow 3GPP releases
  - Some updates via firmware, many require new silicon
  - More likely to see "Release 16-compliant" 5G modem
- Infrastructure adds features from future 3GPP releases *incrementally*
  - Typically via software update
  - Follows vendor internal roadmaps
  - Features from lower-numbered 3GPP releases generally added first
  - Some features (e.g., localization) may require special hardware support in basebands

5G Carries EtherNet/IP Natively

- 5G networks natively support traffic over TCP/IP (e.g., IPv4 PDU)
- Support for Ethernet frames added in 3GPP Release 16 (Ethernet PDU)
  - Most existing 5G equipment on the market today does not support Ethernet PDU
- EtherNet/IP is carried by TCP and UDP, so **EtherNet/IP can run on any 5G!**
  - Most industrial protocols need special tunneling (e.g., VXLAN) or Ethernet PDU support
- Special support needed for: 1) Time synchronization (motion), 2) Multiple devices behind a UE

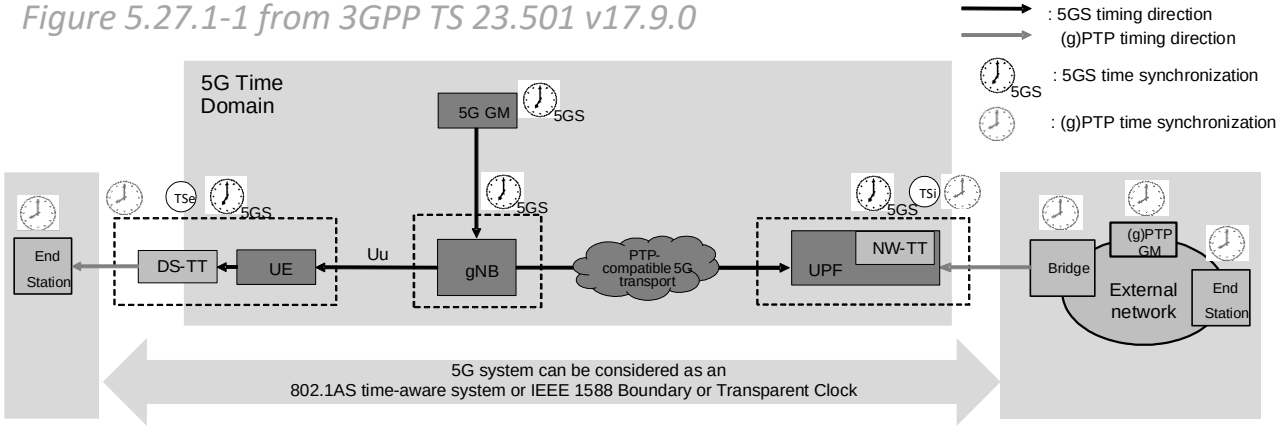


§8.3.1 of 3GPP TS 23.501 v15.13.0

- PDU layer: PDU = protocol data unit. This layer corresponds to the PDU carried between the user equipment (UE) and the data network (DN) over the PDU Session.
  - When the PDU Session Type is IPv4 or IPv6 or IPv4v6, it corresponds to IPv4 packets or IPv6 packets or both of them.
  - When the PDU Session Type is Ethernet, it corresponds to Ethernet frames.
- 5G-AN: 5G access network
- GTP-U: GPRS Tunnelling Protocol for the user plane

5G Support for Time Synchronization

Figure 5.27.1-1 from 3GPP TS 23.501 v17.9.0

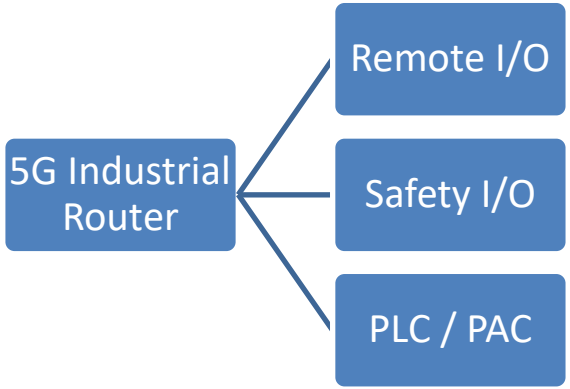


- 5G system (5GS) supporting Release 16+ will correct residence time via **TSN Translators (TTs)**
- Two types of TTs: device-side TT (DS-TT; TSN master), and network-side TT (NW-TT)
  - Grandmaster may be internal or external to the 5G system; at most one NW-TT can be a TSN slave
- 5G system uses its own synchronization mechanisms internally, adds residence time to correction field
- Release 16 supports IEEE 802.1AS gPTP; Release 17 adds support for standard PTP (CIP Sync)
  - Vendors may choose when to implement features according to their own product roadmaps

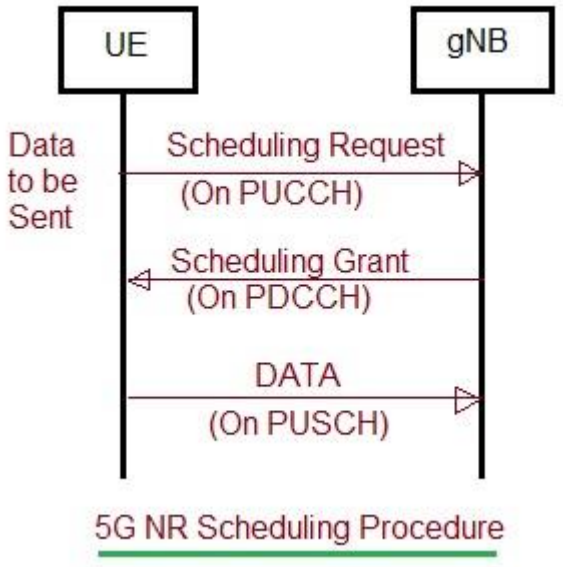
Support for Multiple Devices Behind Single UE

- Advantageous if single UE can support multiple automation devices
  - 5G user equipment (UEs) are expensive
  - Many automation devices will not integrate 5G radios
- 5G is designed to connect single device (i.e., phone)
- Tunneling / VXLAN can be used to support multiple devices behind UE
  - May need “extra box” behind UE to act as tunnel endpoint
  - Some UEs can run containers (e.g., with OpenVPN)
- 5G also supports “framed routing” (TS 23.501 §5.6.14)
  - Originally developed as part of RADIUS (RFC 2865)
  - Also called “Routing Behind Mobile Station” or “Routing Behind UE”
- Example of how framed routing works:
  - Allocate small subnet (/27 or smaller) behind UE
  - This subnet is associated with a user name and password, stored in 5G core, specifically unified data management (UDM) service
  - 5G UE attached to network using SIM credentials (primary authentication)
  - 5G UE may also authenticate to data network using EAP (typically via PAP or CHAP) – this is called secondary authentication
  - When UE performs secondary authentication, route created in core to subnet associated with secondary authentication credentials

https://www.industrialnetworking.com/pdf/HMS-anybus-wireless-bolt.pdf



Grant-Free Scheduling



5G NR Scheduling Procedure

https://www.rfwireless-world.com/5G/5G-NR-Scheduling-Request-Procedure.html

- End devices (UEs) typically must request permission (grant) to send uplink data
- Delay caused by scheduling request procedure unacceptable for low-latency applications
- Grant-free scheduling (also called transmission without grant, TWG) possible
  - Base station reserves resources for uplink for each UE; UE can transmit on these at any time
  - Lowers latency, but reduces throughput
- Periodicity of grant-free uplink resources is adjustable

1:1 Slot Ratios

- **EtherNet/IP typically has approximately equal traffic in each direction**
- Typical cellular use cases are downlink heavy (e.g., streaming video)
- 5G divides resources in time into frames, subframes, slots, then symbols
  - Individual symbols can be allocated for downlink, uplink, or flexible
  - Takes time to switch radios between downlink and uplink
- With time-division duplexing, slots (each containing 14 symbols) are typically allocated as downlink (D), uplink (U), or special (S; mix of symbols)
- Slot patterns set ratio of uplink to downlink traffic, as well as retry delay
  - 5G base stations and UEs initially offered only a few fixed slot ratios
  - Closest to symmetric was 4:1 downlink to uplink, such as DDDSUUDDDD
  - Current 5G equipment may offer nearly 1:1 slot ratio, e.g., DDSUU
- Even with 1:1 slot ratio, downlink throughput is typically better
  - E.g., due to MCS differences, such as higher-order QAM in downlink

5G-ACIA

- ***5G Alliance for Connected Industries and Automation***
  - Working Party of ZVEI (German Electrical and Electronic Manufacturers' Association)
- ***Industrial + Telecom members***
- ***Industrial use case development***
  - Whitepapers
  - Contributions to influence 3GPP, ETSI, etc.

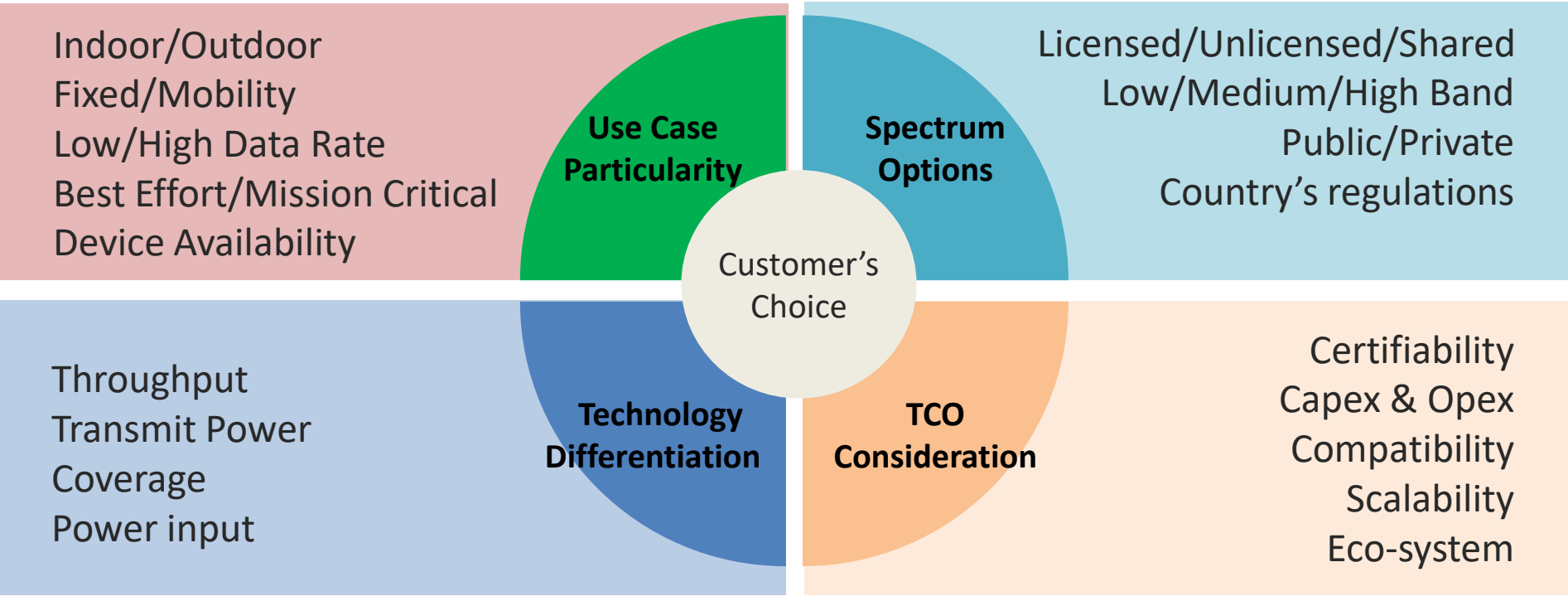
Use case (high level)		Availability	Cycle time	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km²
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km²
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 km²	

Source: ZVEI

[10]

Six Nines (99.9999%) is wired Ethernet reliability

Key Considerations



Considerations for wireless technology decision

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?

Application requirements

Latency, Reliability, Scalability, Ease of operations, device and system 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 and Ultra-Reliable Wireless Backhaul, 5G Cellular, Wi-SUN, LoRaWAN,…
Spectrum: Unlicensed, Licensed: Private, Public, Shared

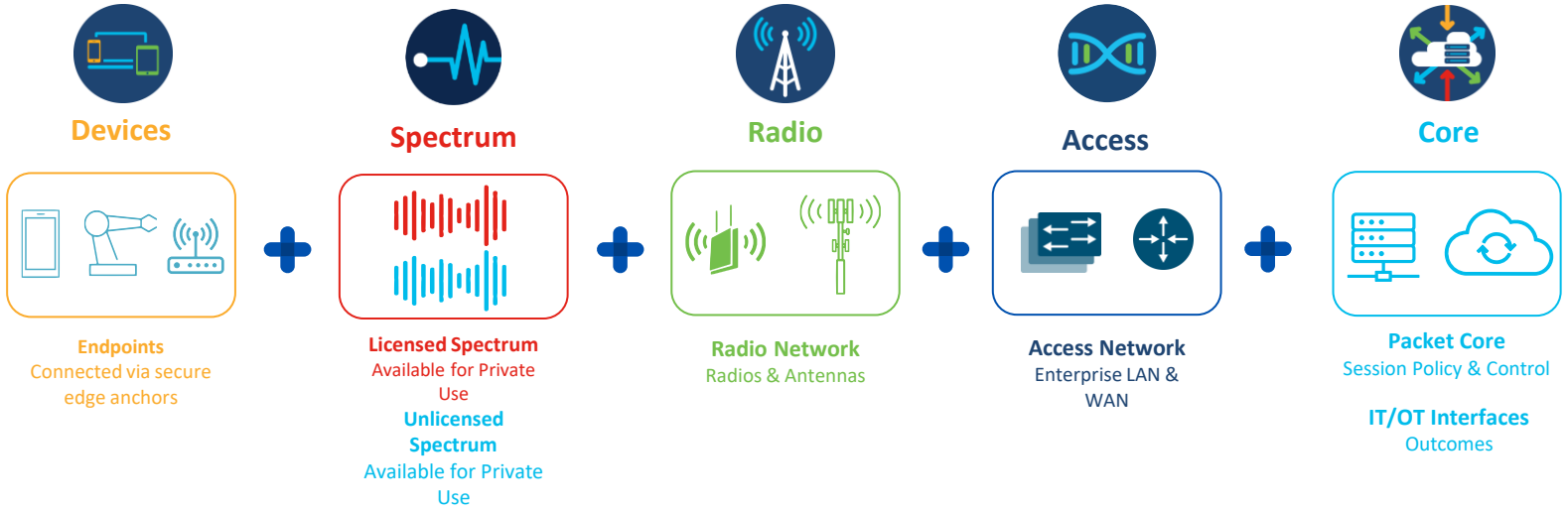
5 What are the CapEx and OpEx Implication?

TCO

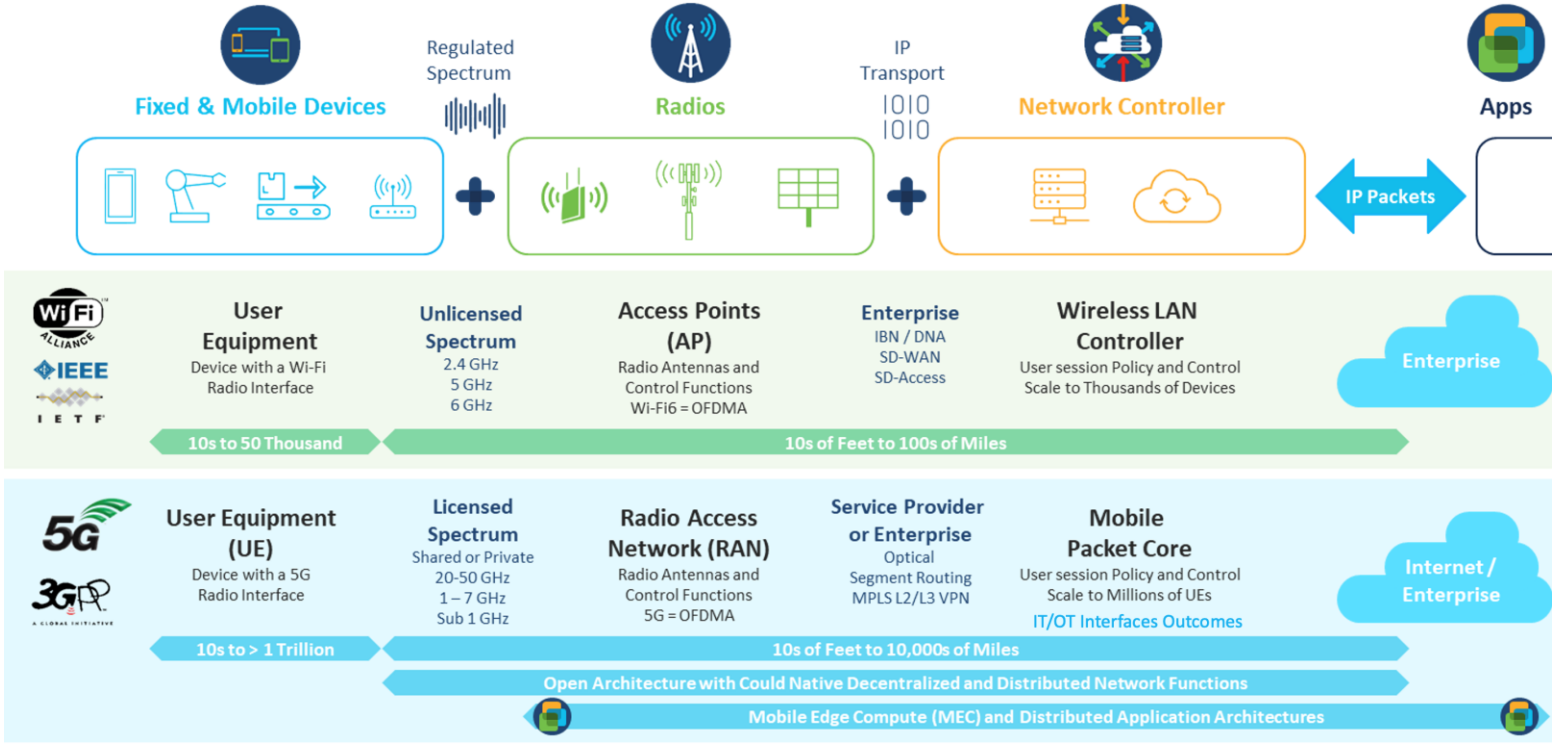
Product costs?
Operational costs?
Complexity?
Training?
Backward compatibility?

What is Private Wireless?

A private network that is built using **fit-for-purpose technology, dedicated** to carrying **traffic from a specific entity** (e.g., an enterprise) in **licensed** or **unlicensed** radio spectrum



Wi-Fi & 5G Comparable Architectures



Impact on CIP and EIP

- RA/Ericsson blog – CIP can be carried – as a routed protocol or tunneled protocol, Safety and I/O ready to go, Release 16/17 for CIP Sync 16-.1AS 17-PTP default option, TSN –capability (802.1AS, Scheduling) - TBD a bigger
- CIP/EIP runs natively on WiFi networks. WiFi enhancements improve resiliency, latency and performance. WiFi still not PTP aware.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