



DesignNews

5G Tech for Industrial Automation

DAY 1 : 5G Overview

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Course Overview

In this course we will analyze the impact of 5G technology on the industrial automation space. 5G has the ability to replace all of the wireless, and most of the wired, technologies in in the IIoT (Industrial Internet of Things), providing direct connection to the cellular infrastructure. This brings with it a simplified and more robust network architecture. It allows direct connection to remote computing resources including cloud computing. We will look at how this will roll out and what the near future will bring as 5G evolves rapidly.

Class Overview

We start with an overview of the 5G technology. We will look at the standard as it has developed. Specific implementations are just now being implemented. We look at the service providers and their various approaches in the near term.

Agenda

- 5G Basics
- Modes of Operation
- Radio Technology
- Impact on IIoT
- Standards

5G Basics

- What is 5G? It is basically a new cellular radio technology that bridges the capabilities of current cellular networks and other wireless communications technologies.
- 5G covers many more use cases than previous cellular technologies.
 - It will replace many of the technologies that we currently use, including WiFi and broadband.
- 5G is just rolling out, with the standard only being formally approved recently and evolving over the next few years.

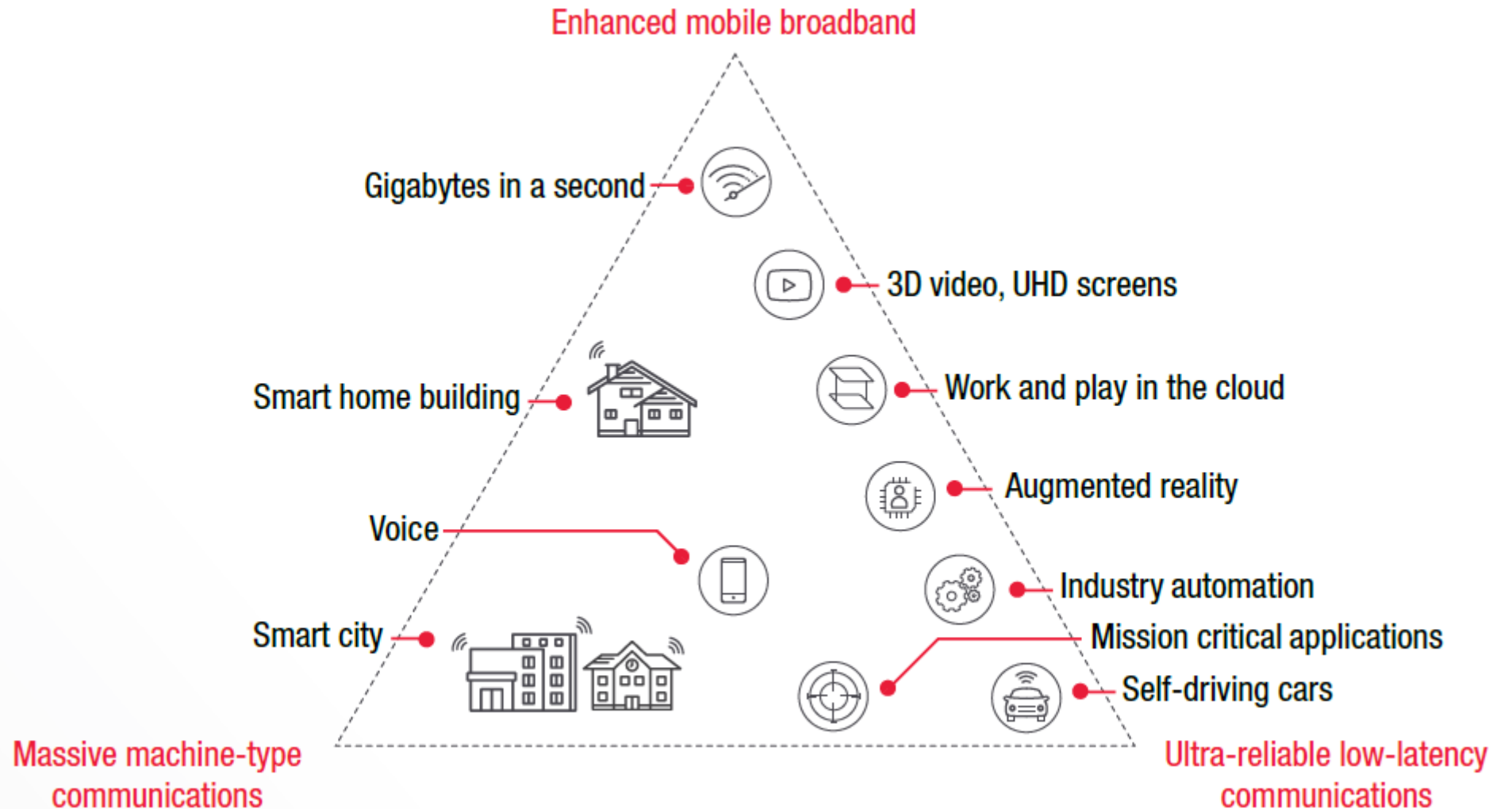
5G Basics

- 5G adds many use cases to the cellular technology space.
- The goal is the connected society, enabling a whole new range of applications.
- 5G is being implemented in public networks, as well as private networks.
 - The later is already being done by many large companies as well as some smaller firms.
- There are many features that will be available in the future as the standards settle in and vendors make equipment available.

5G Basics

Enhanced Mobile Broadband (eMBB)	Ultra-Reliable Low- Latency Communications (URLLC)	Massive Machine- Type Communications (mMTC)
All data, all the time 2 billion people on social media	Ultra-high reliability Ultra-responsive	30 billion “things” connected Low cost, low energy
500 km/h mobility 10-20 Gbps peak data rates	<1 ms air interface latency 5 ms end-to-end latency 99.9999% reliable 50 kbps – 10 Mbps	1 million devices per km ² 1-100 kbps per device 10-year battery life

5G Basics



5G Basics: Key Performance Indicators

PEAK DATA RATE	20 Gbps in downlink 10 Gbps in uplink
PEAK SPECTRAL EFFICIENCY	30 bps/Hz for downlink and 15 bps/Hz for uplink
LATENCY	0.5 ms UL/DL (URLLC), 4 ms UL/DL (eMBB), 10 ms control plane
MOBILITY INTERRUPTION TIME	0 ms
RELIABILITY	URLLC $1-10^{-5}$ for 32 bytes with a user plane latency of 1ms V2X $1-10^{-5}$, and user plane latency = 3-10 ms
CONNECTION DENSITY	1,000,000 device/km ² in urban environments
UE BATTERY LIFE	mMTC should be beyond 10 years, 15 years is desirable
COVERAGE	164 dB
MOBILITY (UE SPEED)	500 km/h
NETWORK ENERGY EFFICIENCY	100x better than IMT-Advanced

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Modes of Operation

- Three basic modes of operation are included:
 - eMBB: Enhanced Mobile Broadband
 - URLLC: Ultra-Reliable Low-Latency Communications
 - mMTC: Massive Machine-Type Communications

Modes of Operation

- eMBB
 - This is the feature we have all heard about from the major cellular network providers.
 - Using new antennas and different bandwidths, this mode massively increases both download and upload speeds.
 - Will be able to replace wired broadband and WiFi in the home and office.
 - Increased upload speed a key feature in processing images and video generated by remote sites and users.

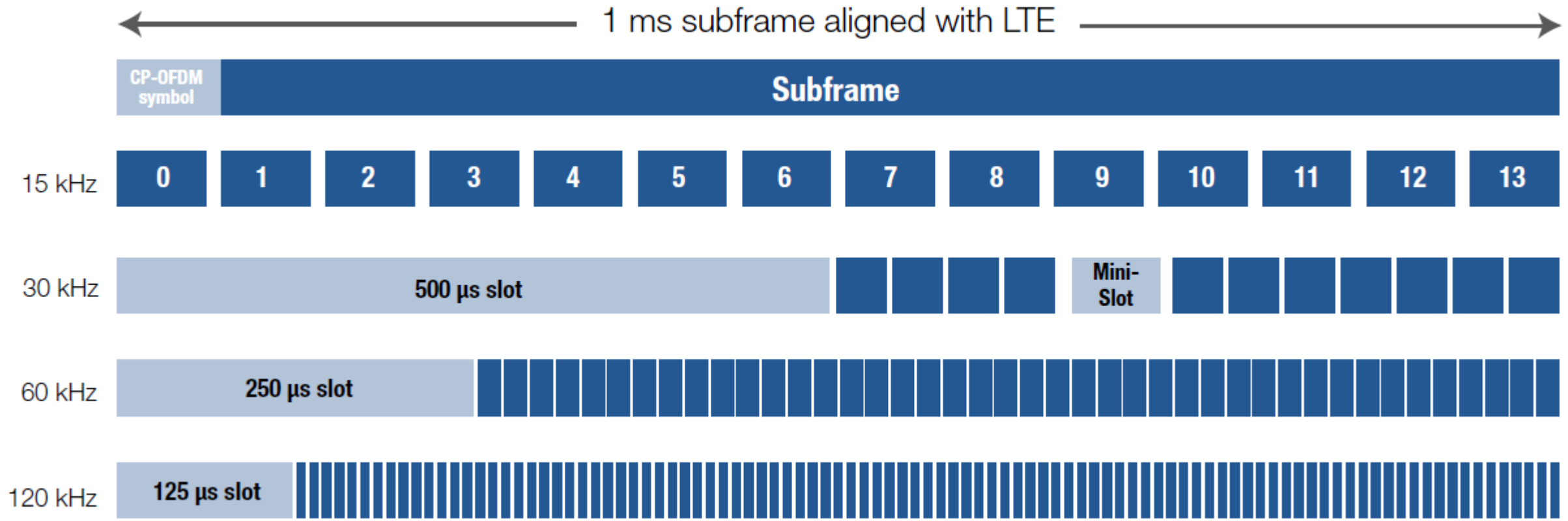
Modes of Operation

- eMBB
 - Uses mmWave spectrum with up to 52.6 GHz.
 - Current standard allows up to 16 component carriers with a maximum carrier bandwidth of 400 MHz resulting in a total bandwidth of 800 MHz.
 - Other technologies contributing to high throughput are:
 - Massive MIMO (Multiple-Input, Multiple-Output)
 - Beam Steering

Modes of Operation

- URLLC
 - This mode is geared to applications which require low latency
 - Self driving cars
 - Industrial automation
 - Mission critical applications
 - Similar to and complementary to real-time applications in CPUs.
 - Enabling feature is the flexible slot structures, especially mini-slots which do not have to start at slot boundaries.

Modes of Operation: URLLC Slots



Modes of Operation

- mMTC
 - Supports massive numbers of devices all connected
 - 1M per square kilometer
 - Lower data rates
 - 1 – 100 kbps per device
 - Lower power consumption for long battery life
 - Lower cost devices

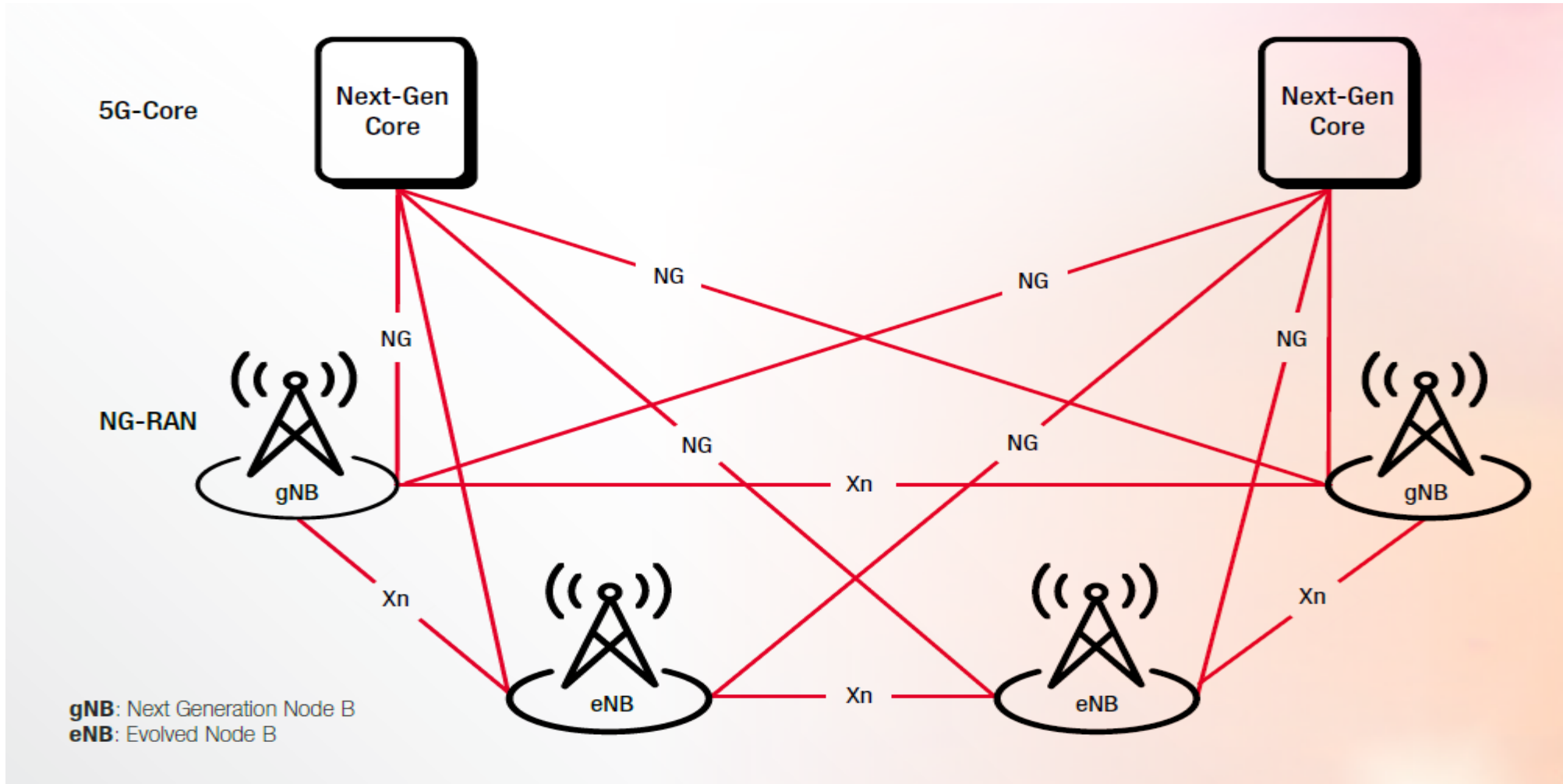
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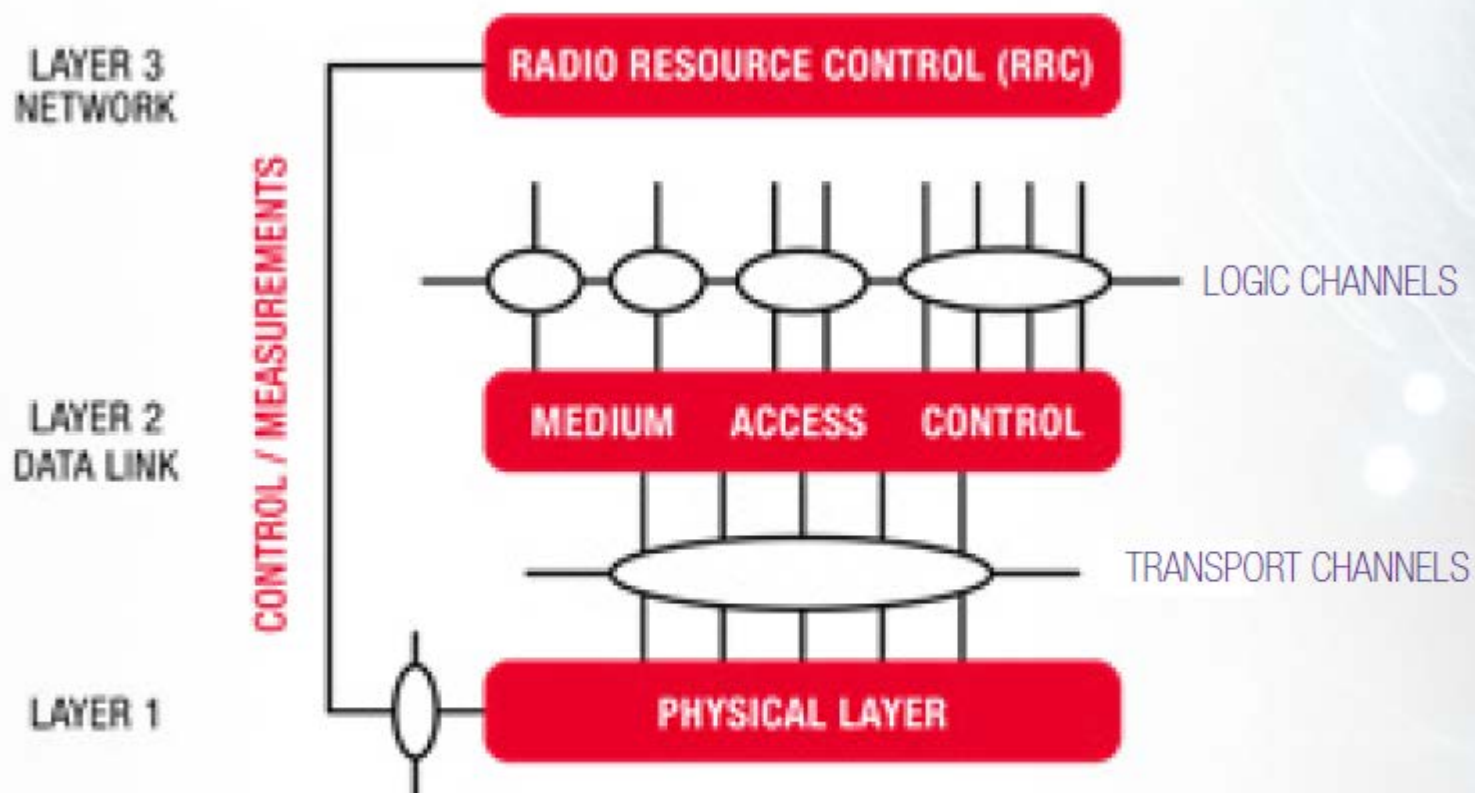
Radio Technology

- As we have seen, 5G uses new radio technologies and a variety different bandwidths
- Massive MIMO and beam steering are key technologies.
- Compatible with 4G devices.
 - Can be configured without this feature for dedicated, non-public networks operating independently of the 4G core network.
- Independent networks can be connected to the Internet via various technologies:
 - Wired or wireless backhaul

Radio Technology



Radio Technology

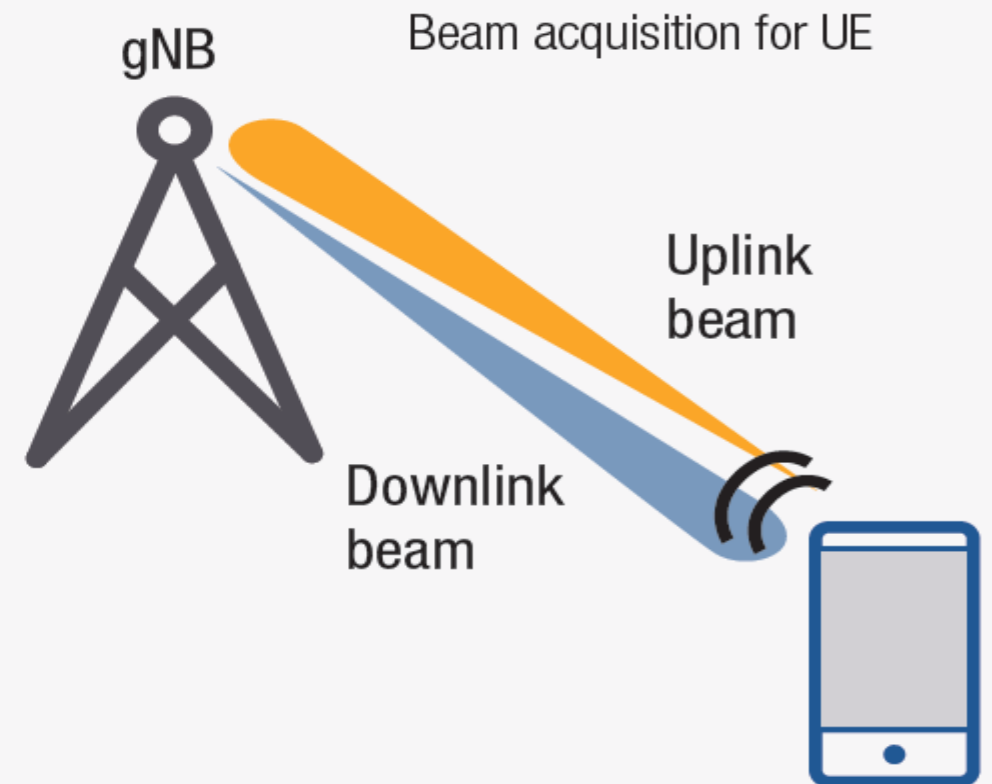
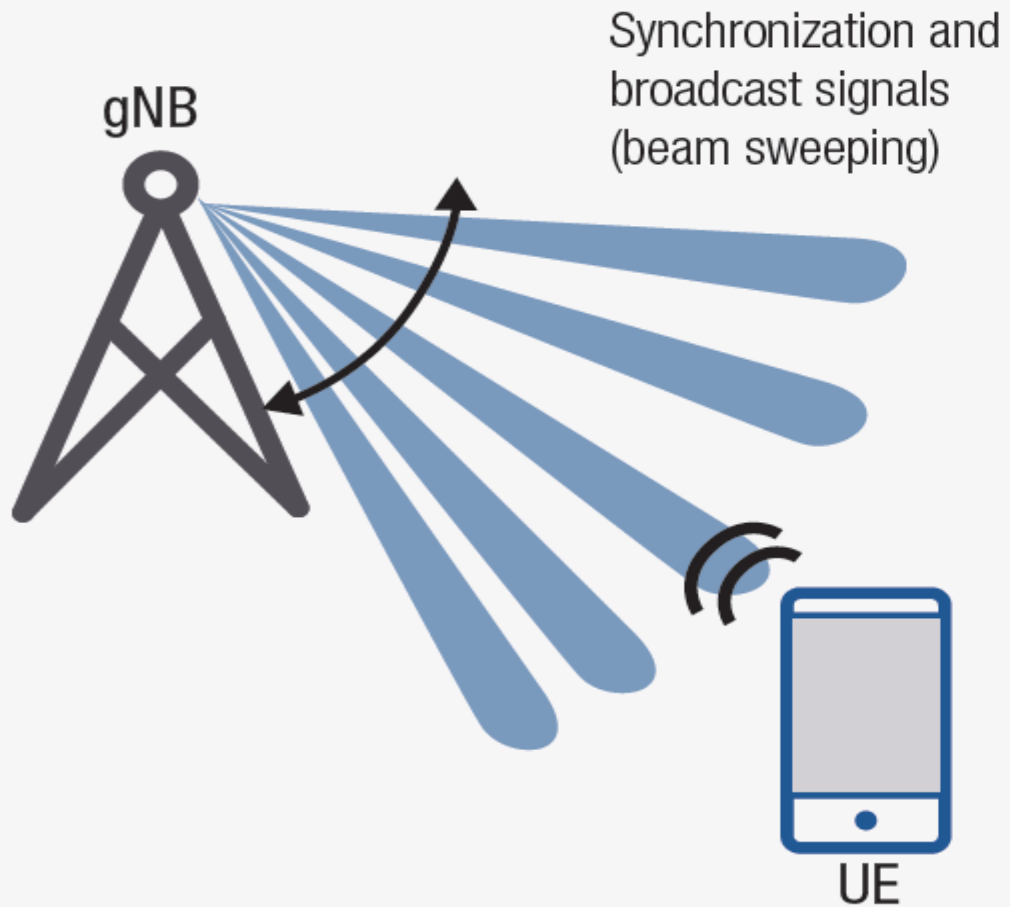


Radio interface protocol architecture around the physical layer (38.201)

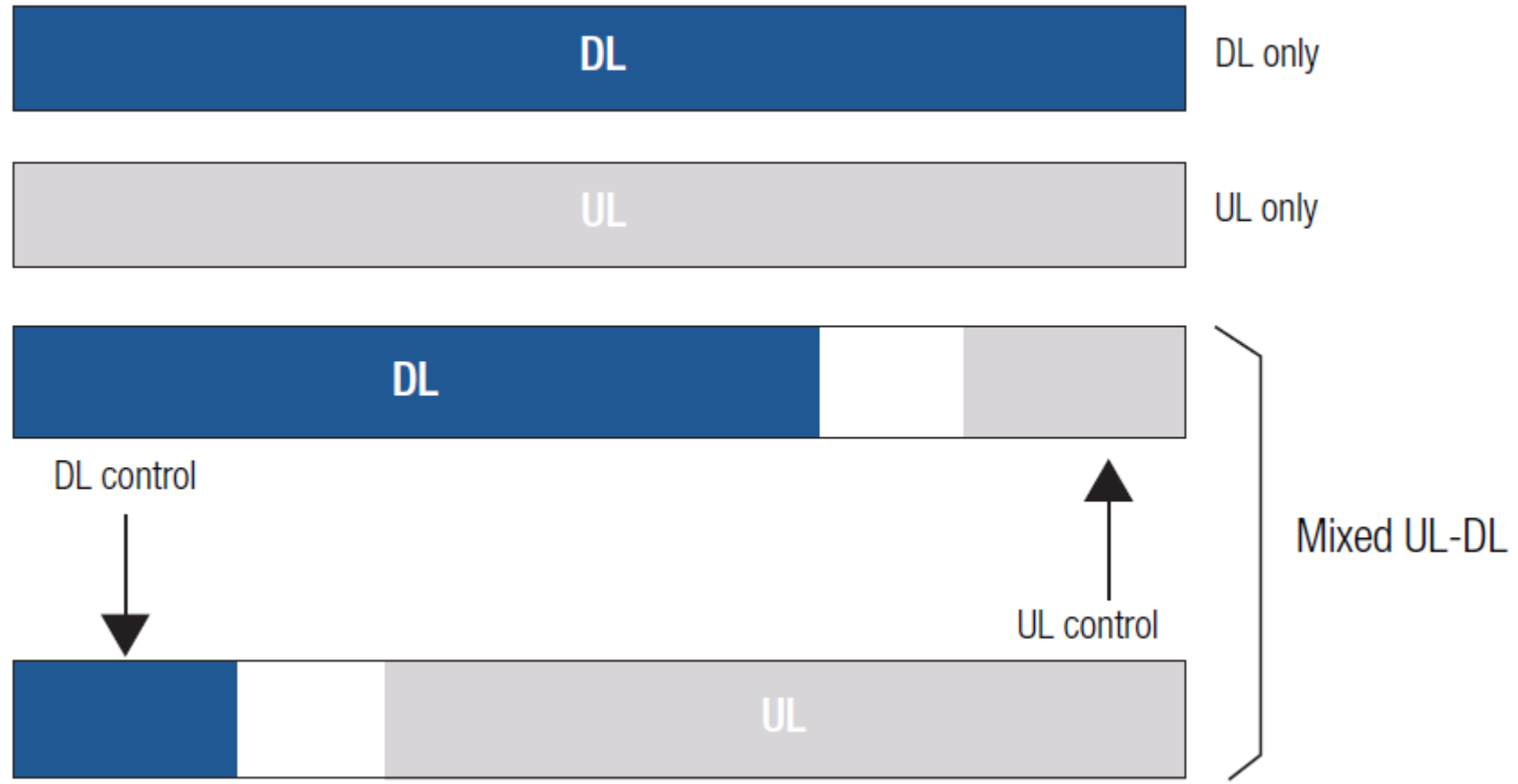
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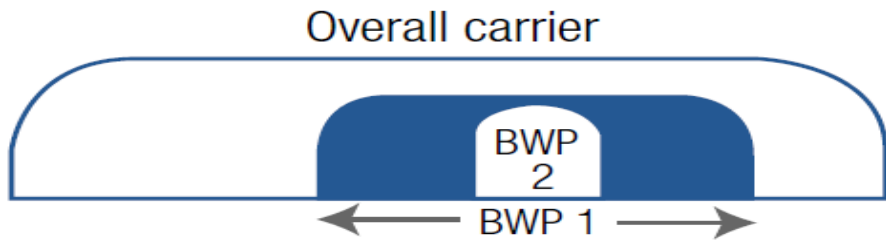
Radio Technology



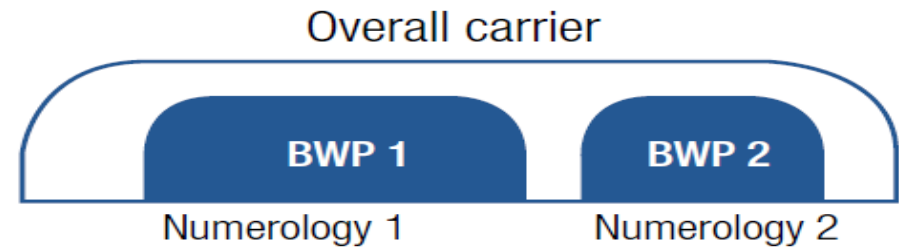
Radio Technology: Mixed Slot Structure



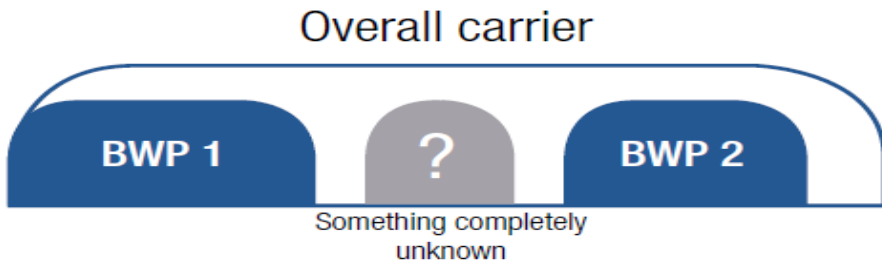
Radio Technology: Multiplexing Services on the Same Carrier



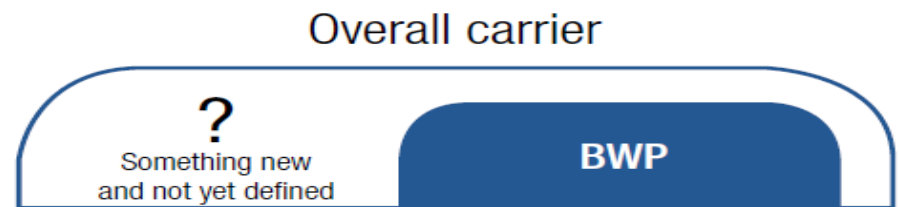
Using a smaller part of the overall carrier reduces device energy consumption for each separate user



Overall carrier contains two non-contiguous bandwidth parts with different numerologies



Non-contiguous spectrum that can have an unknown service inserted



Open bandwidth to support something new or not yet defined

Impact on IIoT

- Many of the new features of 5G are geared to the Internet of Things (IoT) overall, and some specifically target the Industrial Internet of Things (IIoT).
- For the IIoT this contains a mixture of needs
 - High bandwidth for applications like robotics and inspection
 - Sensors, including the ability to deploy massive numbers
 - Low latency for time critical control applications
- 5G will simplify networking and communications
 - Obviates the need for multiple network types and gateways devices between them.

Impact on IIoT

- There is already an impact on the vendors of chipsets. Qualcomm credits good results to handsets, but also to growth in IoT devices (WSJ, Nov. 5, 2020).
- The creation of private 5G networks is aided by the new device technologies and by inherent mesh networking capabilities.
- 5G is also adds levels of security and resilience.
- There is even an open-source network management system available
 - Magma, put out by engineers at Facebook

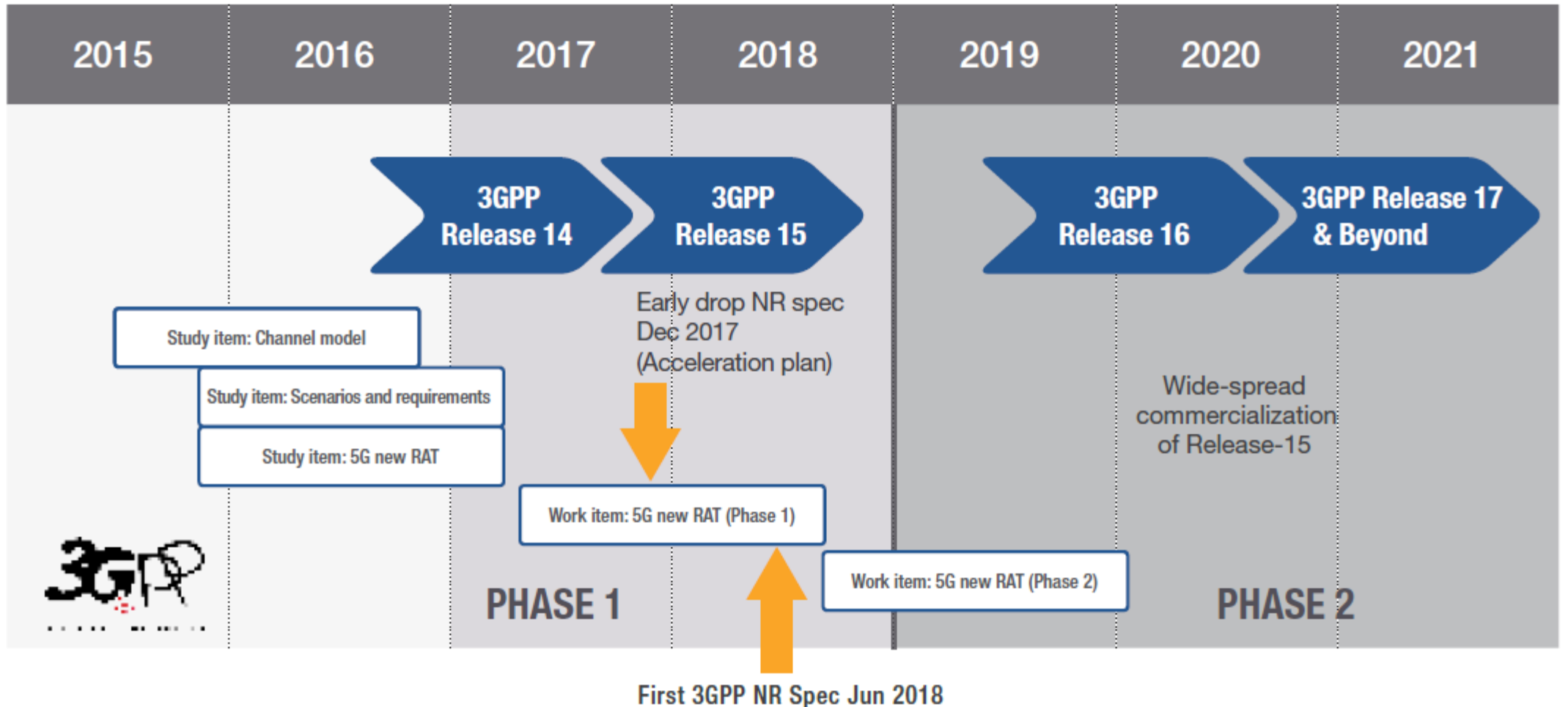
Impact on IIoT

- When creating a private network, there are three basic options
 - Roll your own.
 - Most risky, but most flexible.
 - Use a third-party vendor
 - Less risk but constrained by the vendor's capabilities.
 - Use a cellular network provider
 - They will build you a private network
 - Leverage their existing equipment
 - Easy connection to their network
 - Provide monitoring and management services, if wanted

Standards

- The overall standard that defines 5G is developed by the ITU (International Telecommunication Union)
 - The 5G NR Release 15 was approved in June 2018
- There is significant activity within the IEEE as well.
 - This consists of extensions to existing standards that define wireless technologies, such as the 802.11 series
- New standards are also being developed in areas such as vehicular applications.

Standards



Thank you for attending

Please consider the resources below:

- 3GPP Website
- IEEE Standards Website
 - List of standards activities at:
 - <https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/5G.pdf>



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