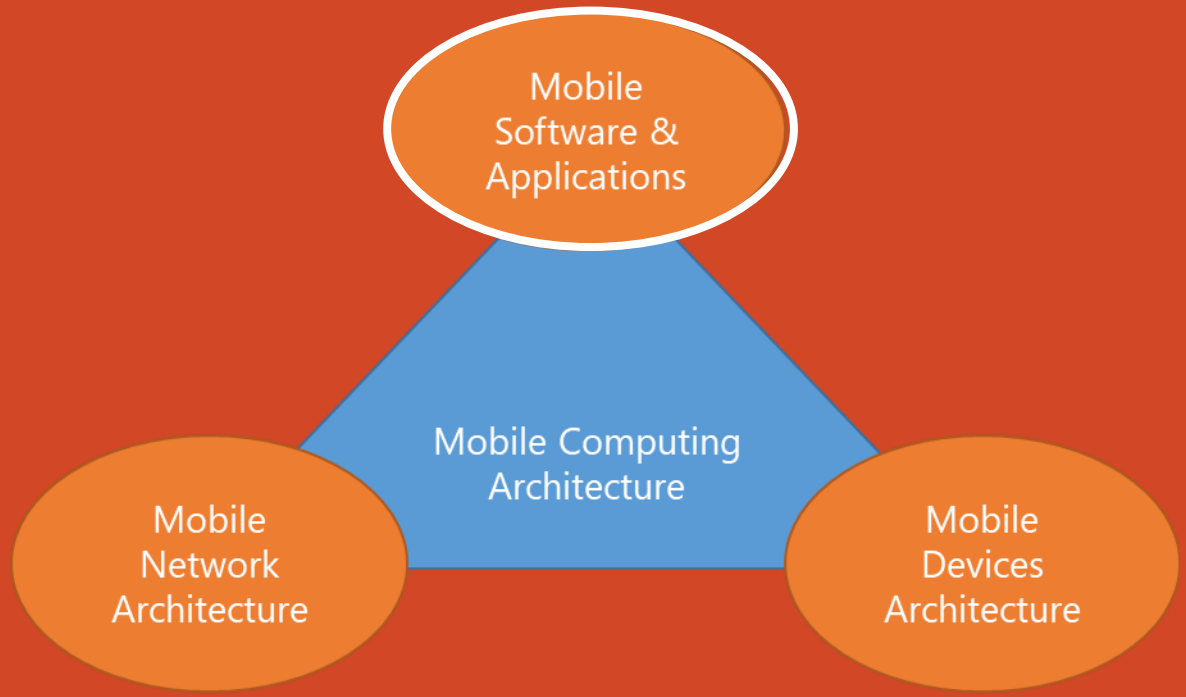
Mobile Computing Architecture

UW Bothell, WA

Internet Over Things (IoT) over 5G



IoT History

- The term "IoT" can most likely be attributed to Kevin Ashton in 1997 and his work at Procter and Gamble using RFID tags to manage supply chains.

Year	Device	Reference
1973	Mario W. Cardullo receives the patent for first RFID tag.	US Patent US 3713148 A
1982	Carnegie Mellon Internet-connected soda machine.	https://www.cs.cmu.edu/~coke/history_long.txt
1989	Internet-connected toaster at Interop '89.	IEEE Consumer Electronics Magazine (Volume: 6, Issue: 1, Jan. 2017)
1991	HP introduces HP LaserJet IIISi: the first Ethernet-connected network printer.	http://hpmuseum.net/display_item.php?hw=350
1993	Internet-connected coffee pot at University of Cambridge (the first Internet-connected camera).	https://www.cl.cam.ac.uk/coffee/qsf/coffee.html
1996	General Motors OnStar (2001 remote diagnostics).	https://en.wikipedia.org/wiki/OnStar
1998	Bluetooth Special Interest Group (SIG) formed.	https://www.bluetooth.com/about-us/our-history
1999	LG Internet Digital DIOS refrigerator.	https://www.telecompaper.com/news/lg-unveils-internetready-refrigerator--221266
2000	First instances of the Cooltown concept of pervasive computing everywhere: HP Labs, a system of computing and communication technologies that, combined, create a web-connected experience for people, places, and objects.	https://www.youtube.com/watch?v=U2AkkuIVV-I
2001	First Bluetooth product launched: KDDI Bluetooth-enabled mobile phone.	http://edition.cnn.com/2001/BUSINESS/asia/04/17/tokyo.kddibluetooth/index.html
2005	United Nation's International Telecommunications Union report predicting the rise of IoT for the first time.	http://www.itu.int/osg/spu/publications/internetofthings/internetofThings_summary.pdf
2008	IPSO Alliance formed to promote IP on objects, first IoT-focused alliance.	https://www.ipso-alliance.org
2010	The concept of Smart Lighting formed after success in developing solid-state LED light bulbs.	https://www.bu.edu/smartlighting/files/2010/01/BobK.pdf
2014	Apple creates iBeacon protocol for beacons.	https://support.apple.com/en-us/HT202880

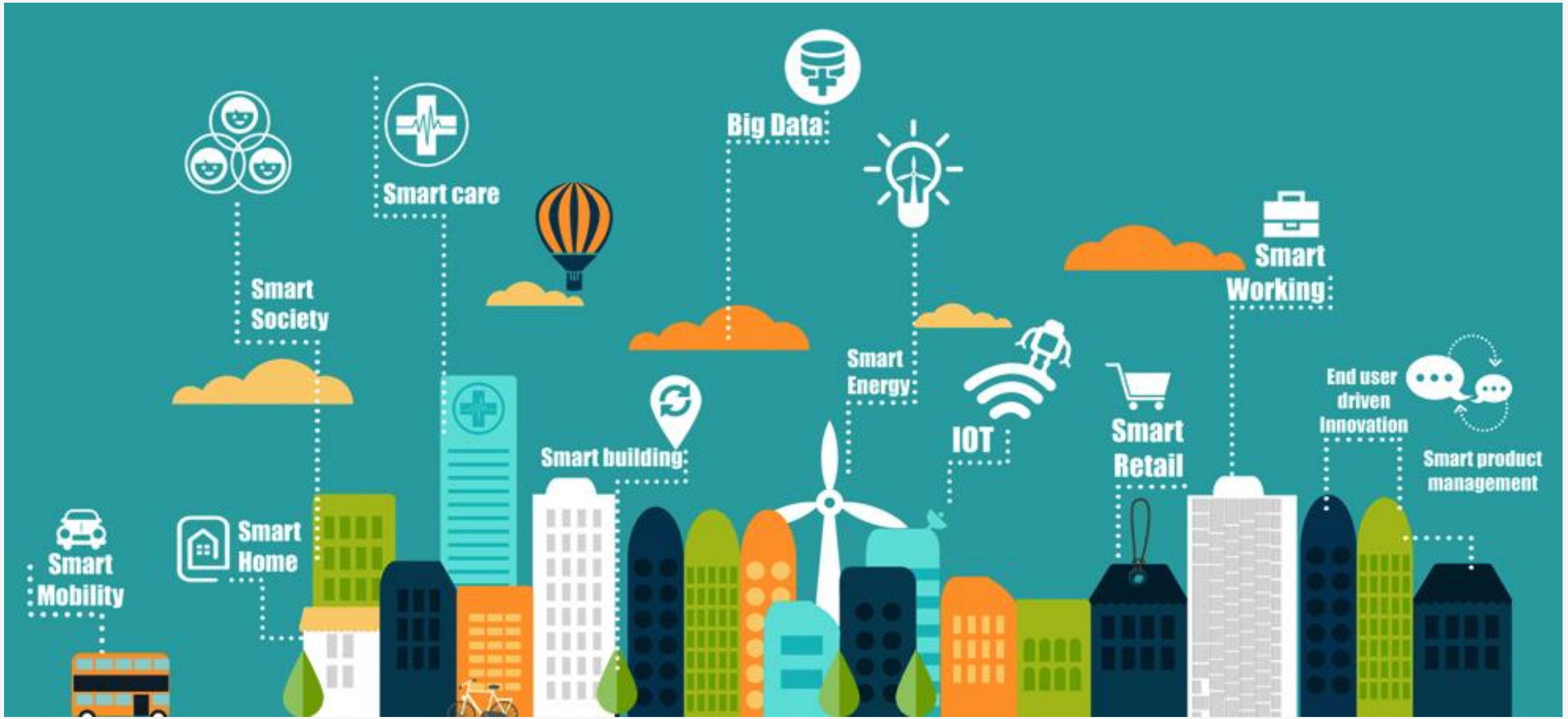
IoT Definition

The basic requirements of a device to be considered part of the IoT:

- Computationally capable of hosting an Internet protocol software stack
- Hardware and power capable of utilizing a network transport such as 802.3
- Not a traditional Internet-connected device, such as a PC, laptop, smartphone, server, data center appliance, office productivity machine, or tablet computer

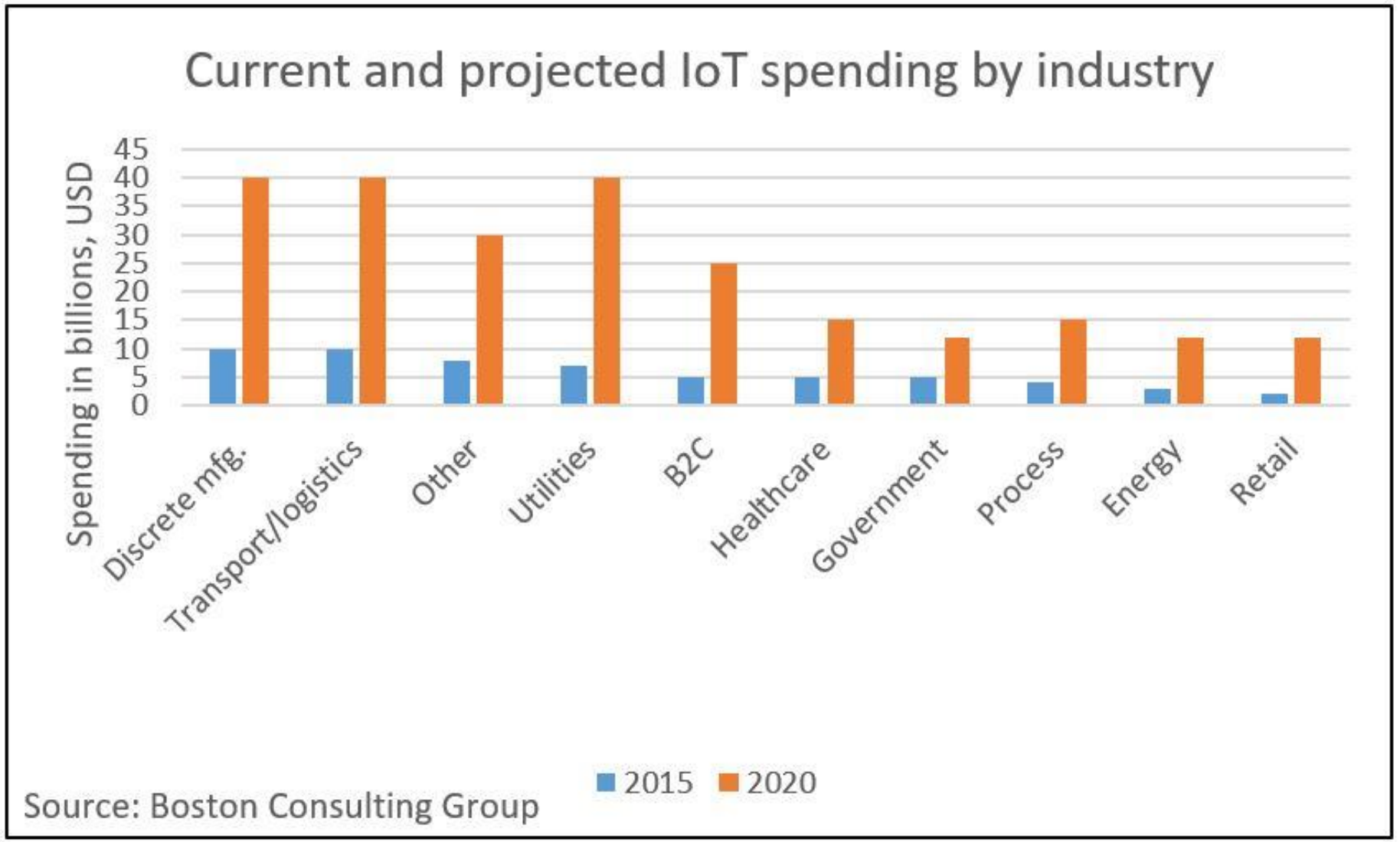
Note: Most IoT installations are not a single device that has the capabilities of running an Internet hardware and software stack. Most sensors and devices have no capabilities of reaching the Internet directly. These devices connect via gateways in a hub-and-spoke model. Connectivity is through local personal area networks, non-IP networks (Bluetooth), industrial protocols (ModBus), legacy brownfield protocols (RS232), and hardware signals.

IoT In Industry



https://www.orangemantra.com/blog/iot-driving-growth-various-industry-verticals/

IoT Spending



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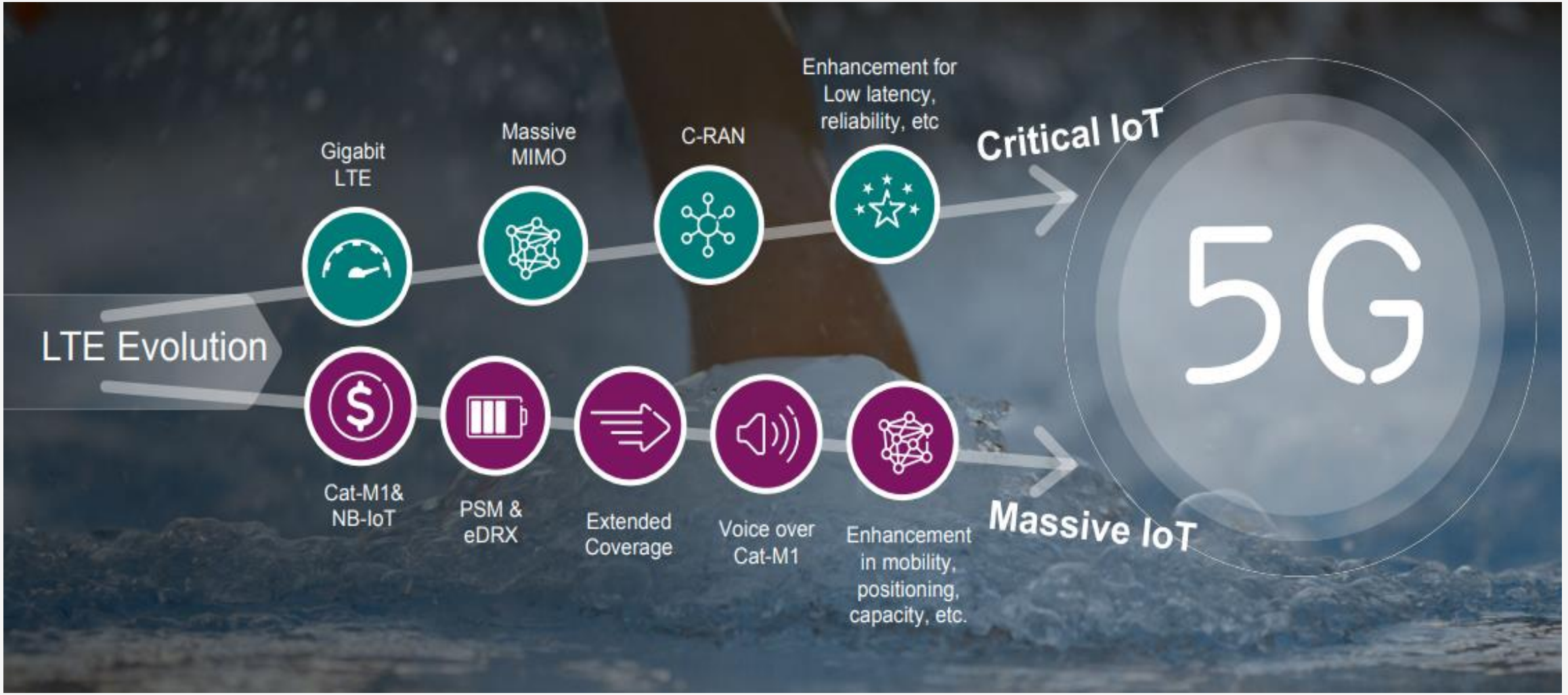
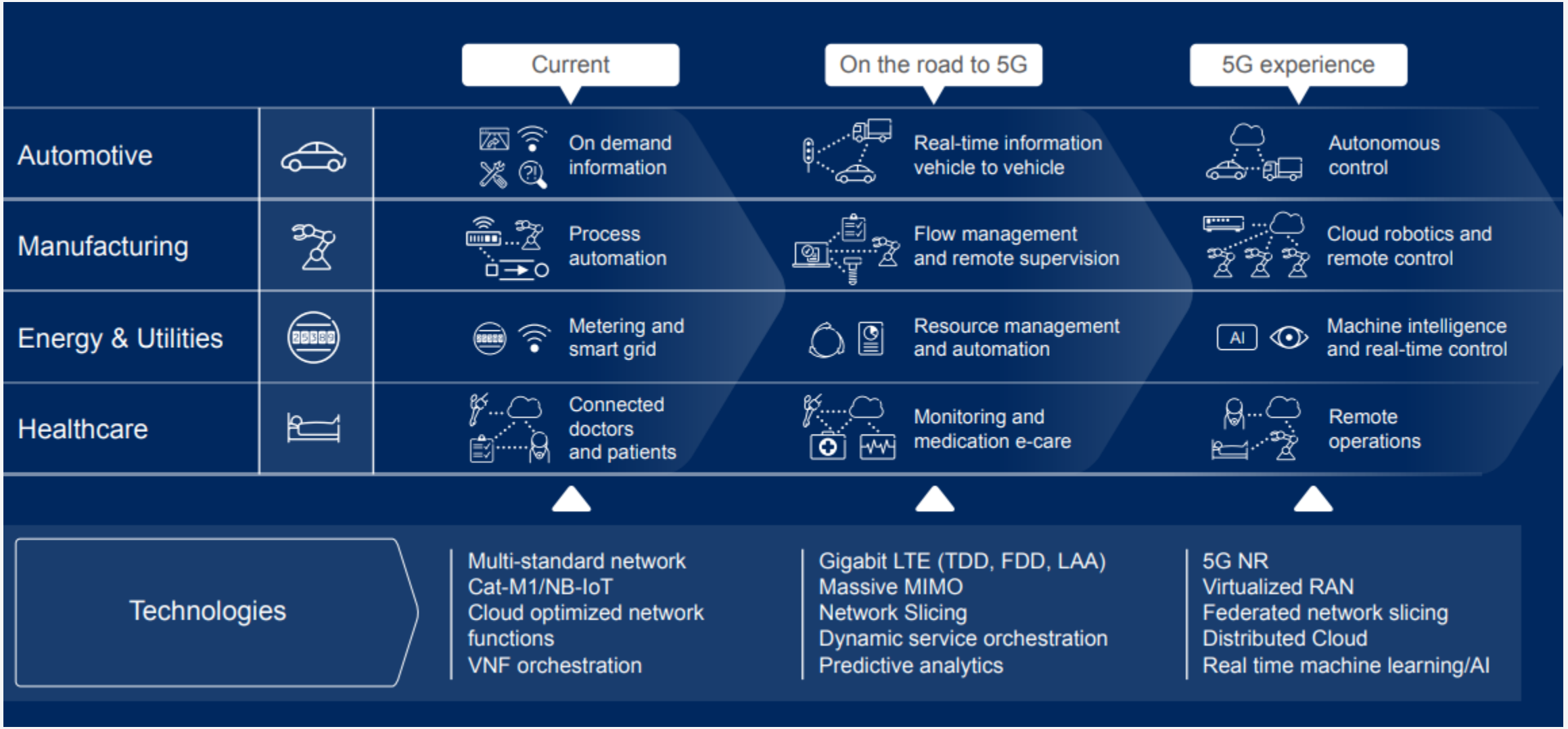
IoT Over 5G



IoT Over 5G



IoT over 5G – Low Power Wide Area (LPWA)

- Global vendors and developers are launching **NB-IoT and LTE-M** networks as an integral part of their long term 5G IoT strategies.
- Mobile IoT refers to low power wide area **(LPWA) 3GPP standardized secure operator managed IoT networks** in licensed spectrum.
- Networks designed for IoT applications that are low cost, use low data rates, require long battery lives and often operate in remote and hard to reach locations.
- Existing cellular networks are evolving to deliver service to billions of new devices providing complete IoT connectivity in the 5G era.
- NB-IoT and LTE-M are 3GPP standards that are both are set to coexist with other 3GPP 5G technologies, so fulfilling the long term 5G LPWA requirements. 3GPP has agreed that the LPWA use cases will continue to be addressed by evolving NB-IoT and LTE-M as part of the 5G specifications, so confirming the long-term status of both NB-IoT and LTE-M as 5G standards.

IoT Use-Cases

Massive IoT | Critical IoT | eMBB

IoT: LPWA Characteristics

LPWA technologies possess the following characteristics:

- Low power consumption that enables devices to operate for many years on a single charge
- Low device unit cost
- Improved outdoor and indoor coverage compared with existing wide area technologies
- Secure connectivity and strong authentication
- Optimized data transfer for small, intermittent blocks of data
- Simplified network topology and deployment
- Network scalability for capacity upgrade

IoT: LTE-M and NB-IoT

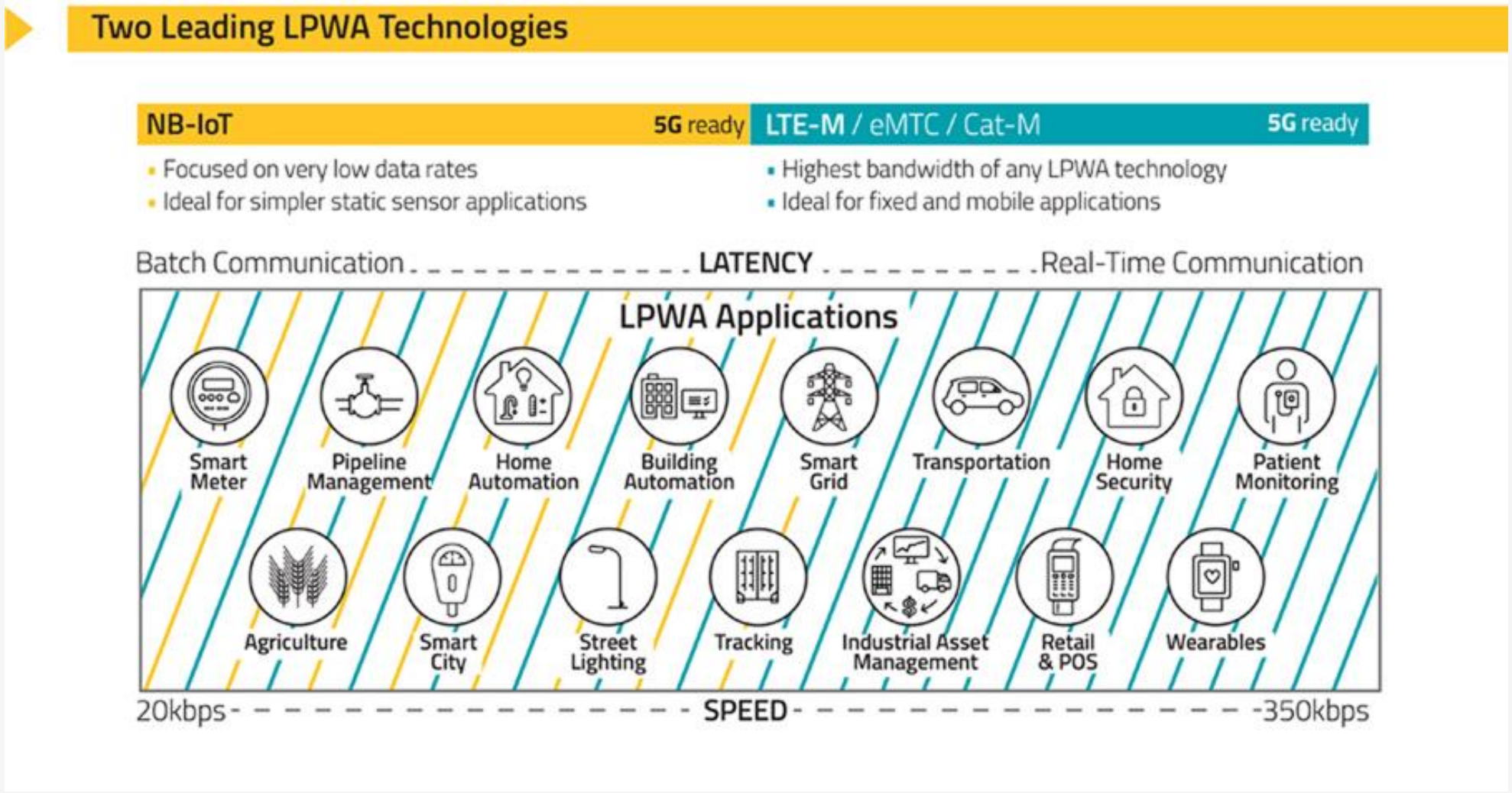
LTE-Machine Type Communication

- LTE-M supports lower device complexity, massive connection density, low device power consumption, low latency and provides extended coverage, while allowing the reuse of the LTE installed base.

Narrowband - IoT

- Narrowband IoT (NB-IoT) is a 3GPP radio technology standard introduced in Release 13 that addresses the LPWA requirements of the IoT. NB-IoT is characterized by improved indoor coverage, support of massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption and optimized network architecture.

IoT Performance



https://www.iotforall.com/cellular-iot-explained-nb-iot-vs-lte-m

IoT Devices Performance

	Release/Category			
	Release 8	**Release 12**	**Release 13**	**Release 13**
	Cat-4	**Cat-0**	**Cat-M**	**NB-IoT**
Max. system bandwidth	20MHz	20MHz	1.4MHz	200kHz
Downlink peak rate	150 Mbit/s	1 Mbit/s	1 Mbit/s	~200kbit/s
Uplink peak rate	50 Mbit/s	1 Mbit/s	1 Mbit/s	~200kbit/s
Duplex	Full duplex	Half duplex	Half duplex	Half duplex
Number of antennas	2	1	1	1
Transmit power (UE)	23dBm	23dBm	20dBm	23dBm
Estimated modem complexity	100%	40%	20%	<15%

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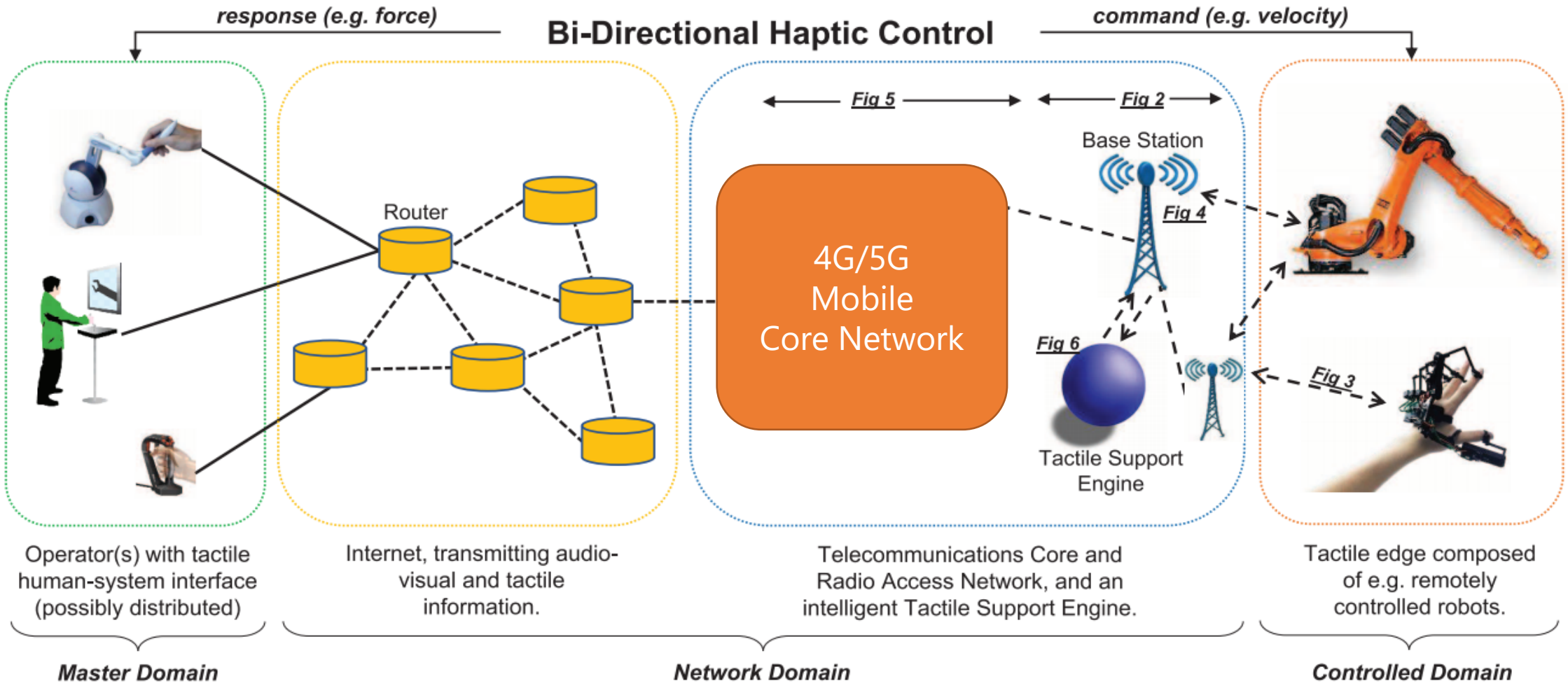
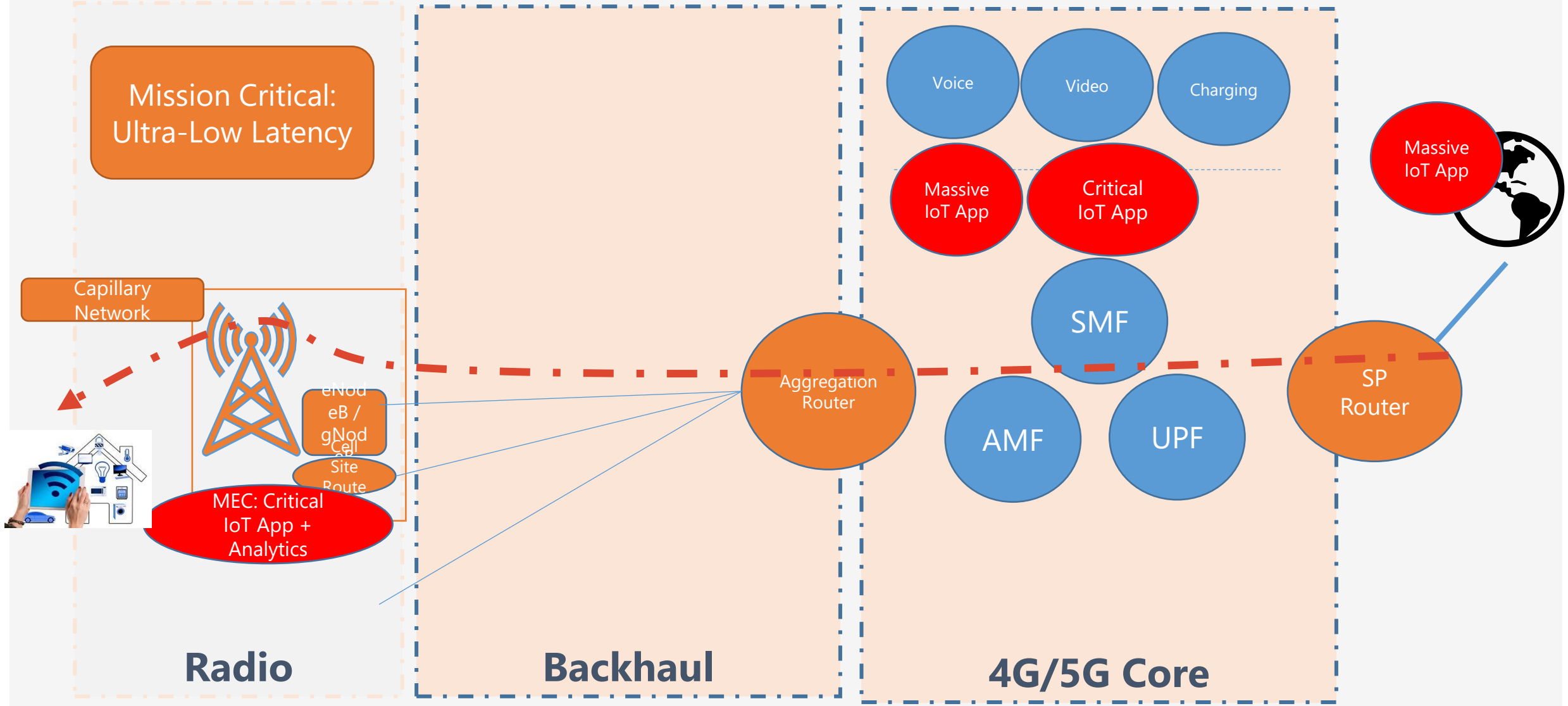
IoT Devices Roadmap

IoT Generic Architecture

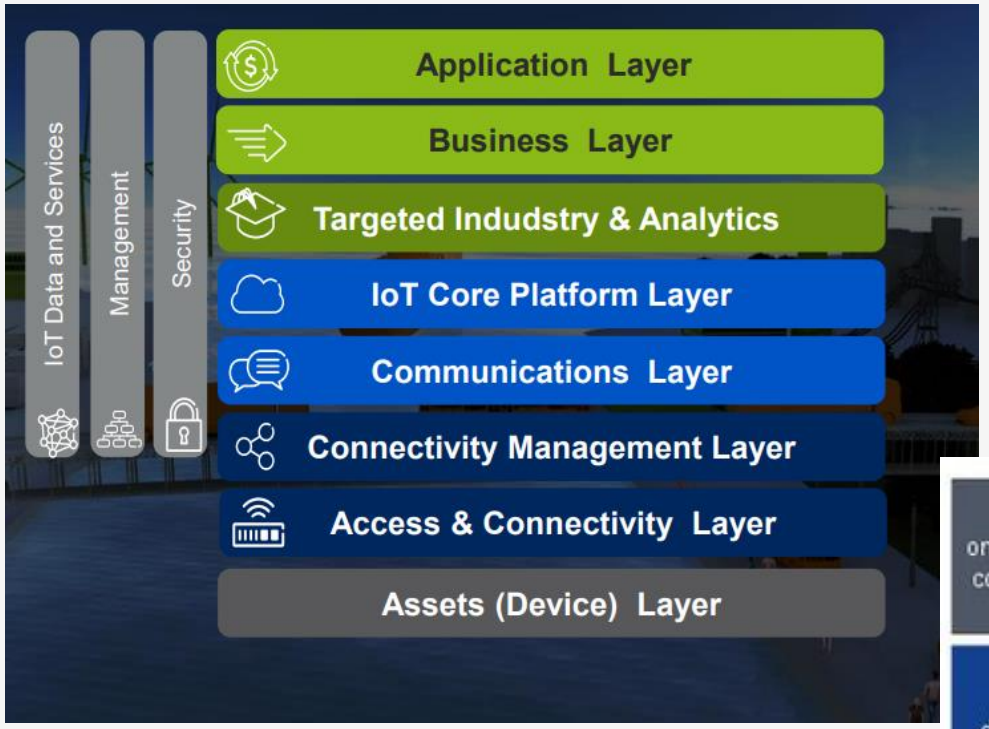


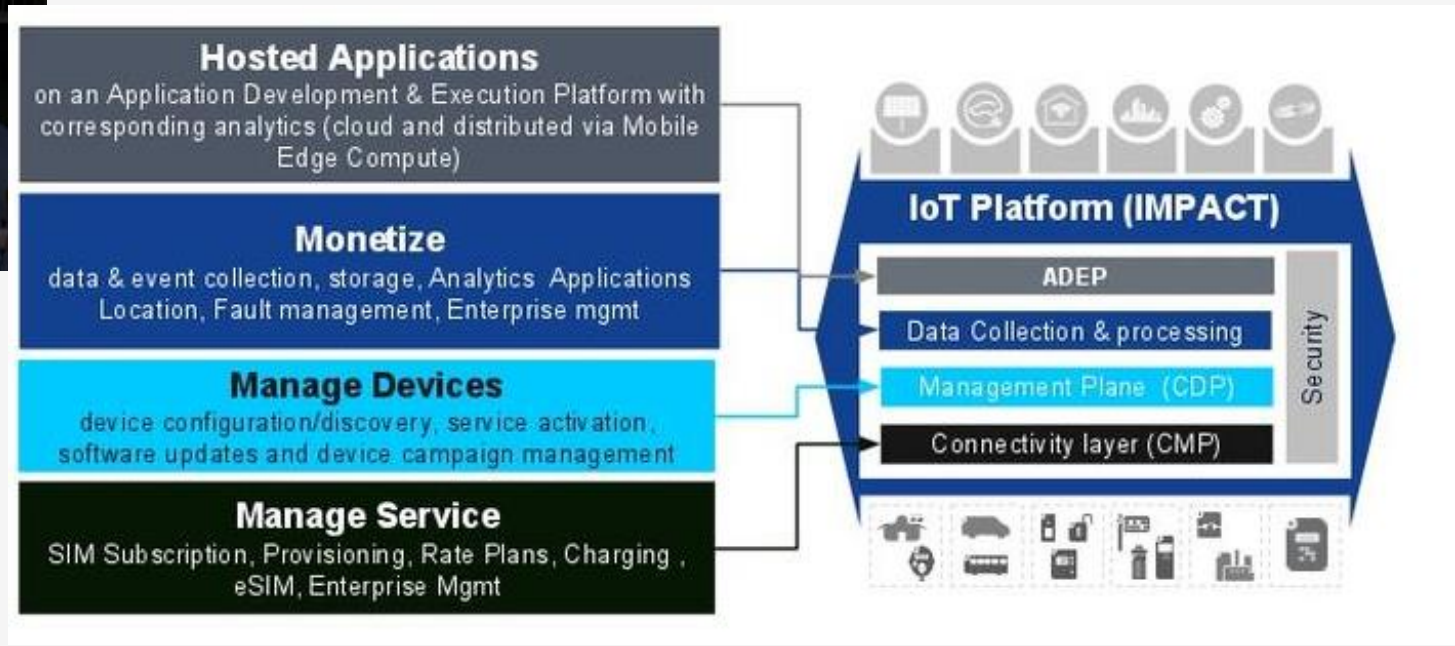
5G-Enabled Tactile Internet
Simsek, Meryem ; Aijaz, Adnan ; Dohler, Mischa ; Sachs, Joachim ; Fettweis, Gerhard
Institute of Electrical and Electronics Engineers (IEEE)
IEEE journal on selected areas in communications, 2016, Vol.34 (3), p.460-473

IoT over 5G Mobile Network – Capillary Network

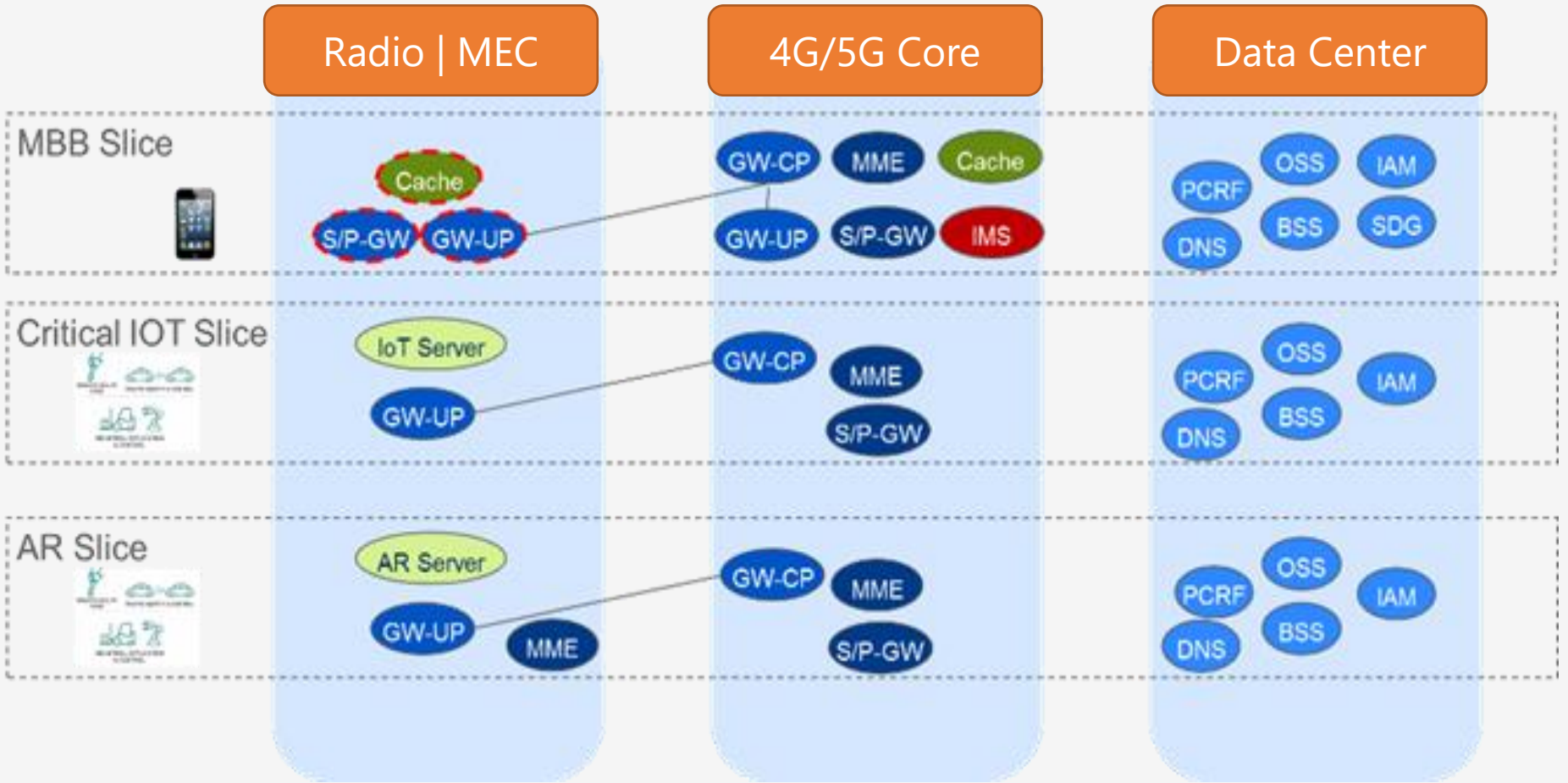


IoT Deployment – Automation Stacks
Two Examples





IoT Slice



Reading Material

GSMA-5G-Mobile-IoT.pdf

5G enabled Tactile Internet.pdf