Prof. Dr.-Ing Jochen H. Schiller
Inst. of Computer Science
Freie Universität Berlin
Germany

Freie Universität Berlin

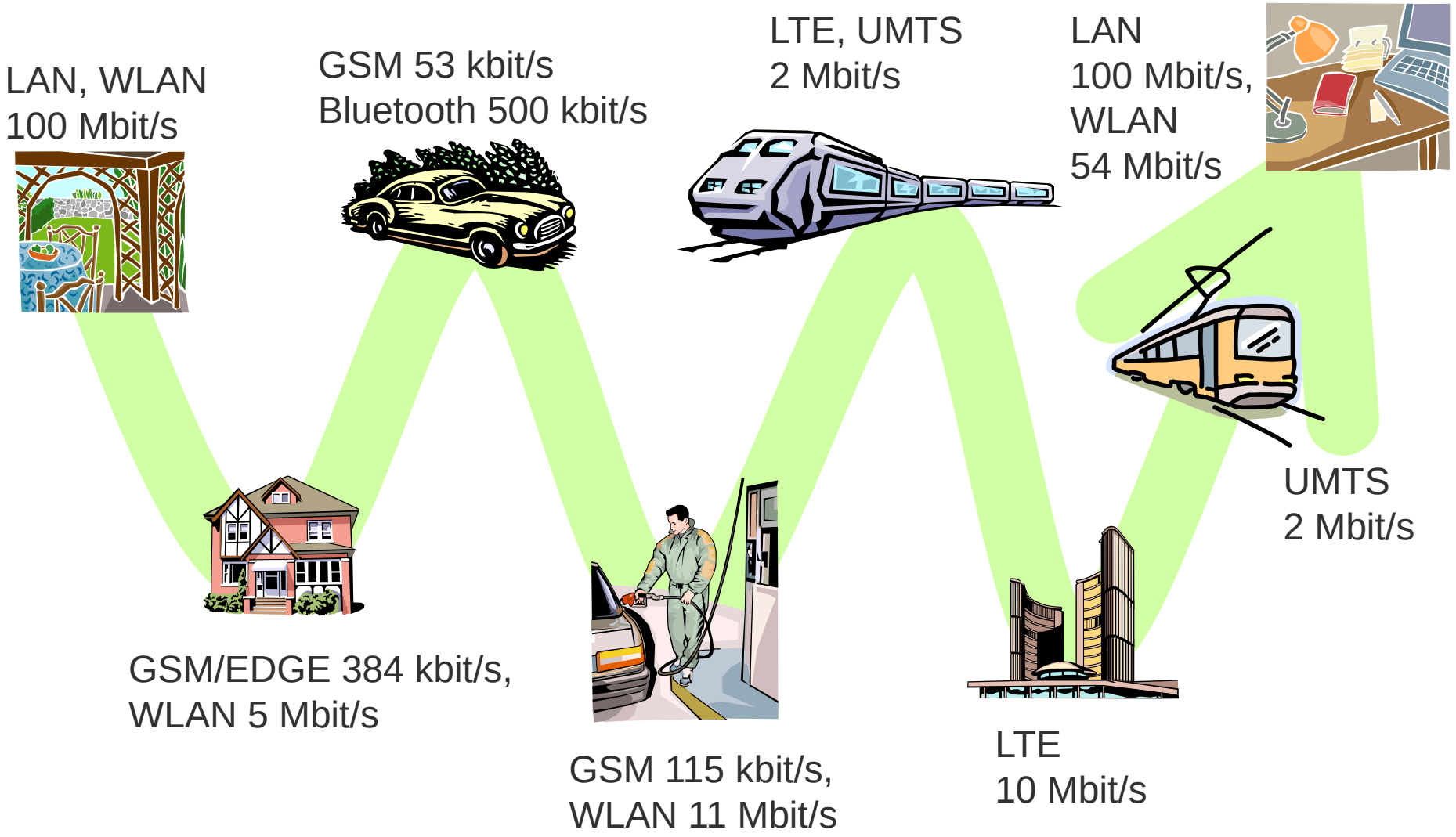
# Mobile Communications
# Chapter 7 : Outlook

**The future of mobile and wireless networks – Is it 5G/6G/…?**

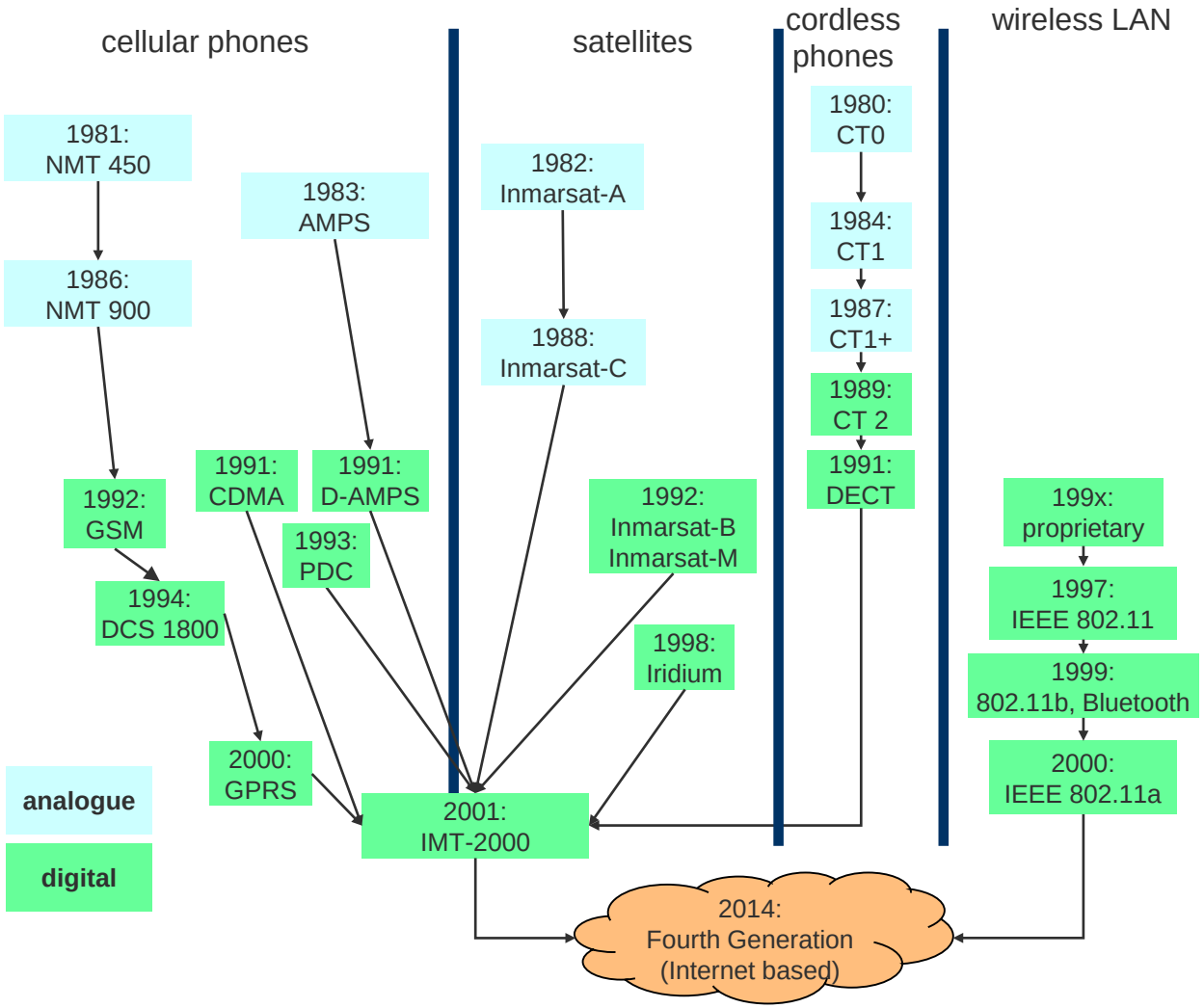
**All IP? Licensed? Public? Private? Micro-operators? Trillions of devices?**

**Tbit/s connections with sub ms latency? AI everywhere? Wireless tactile Internet?**

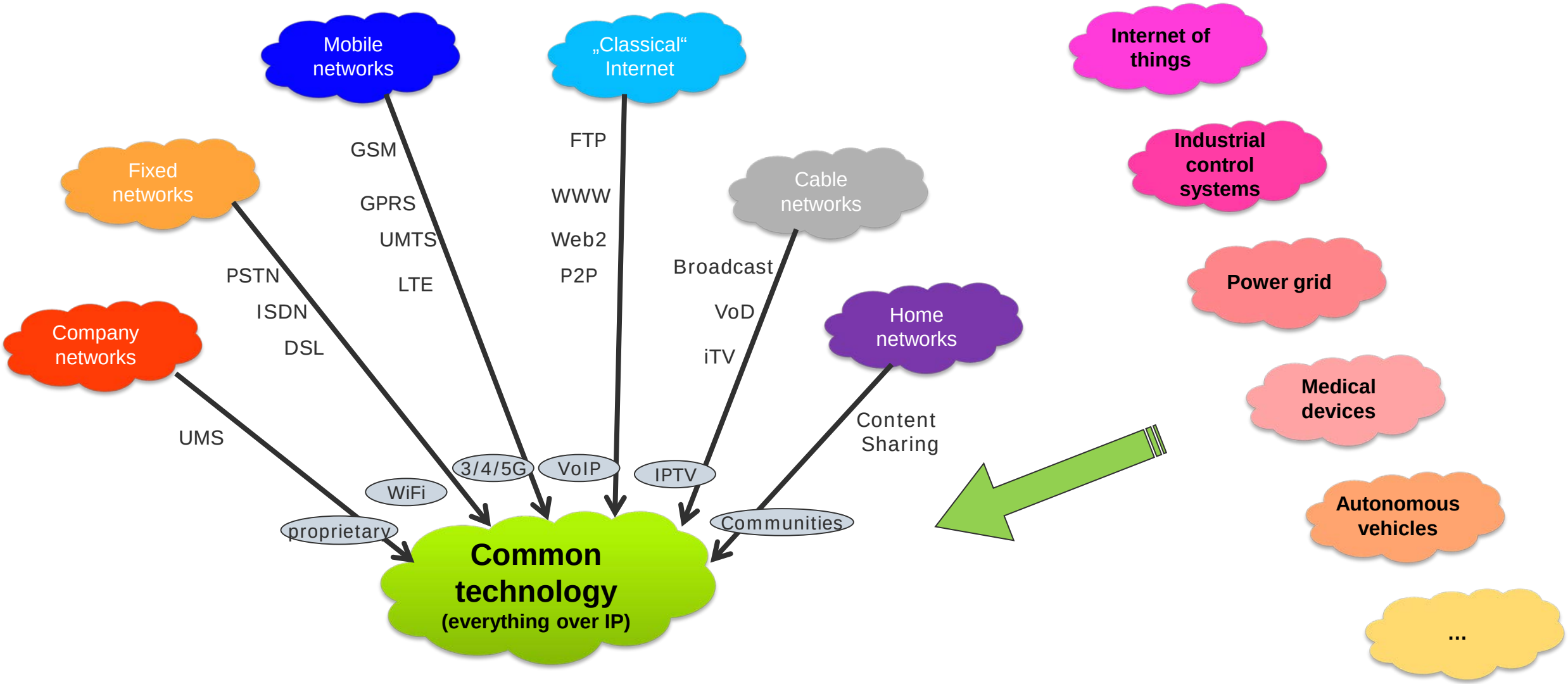
# Mobile and wireless services – Remember: Always Best Connected



# Wireless systems: overview of the (historical) development

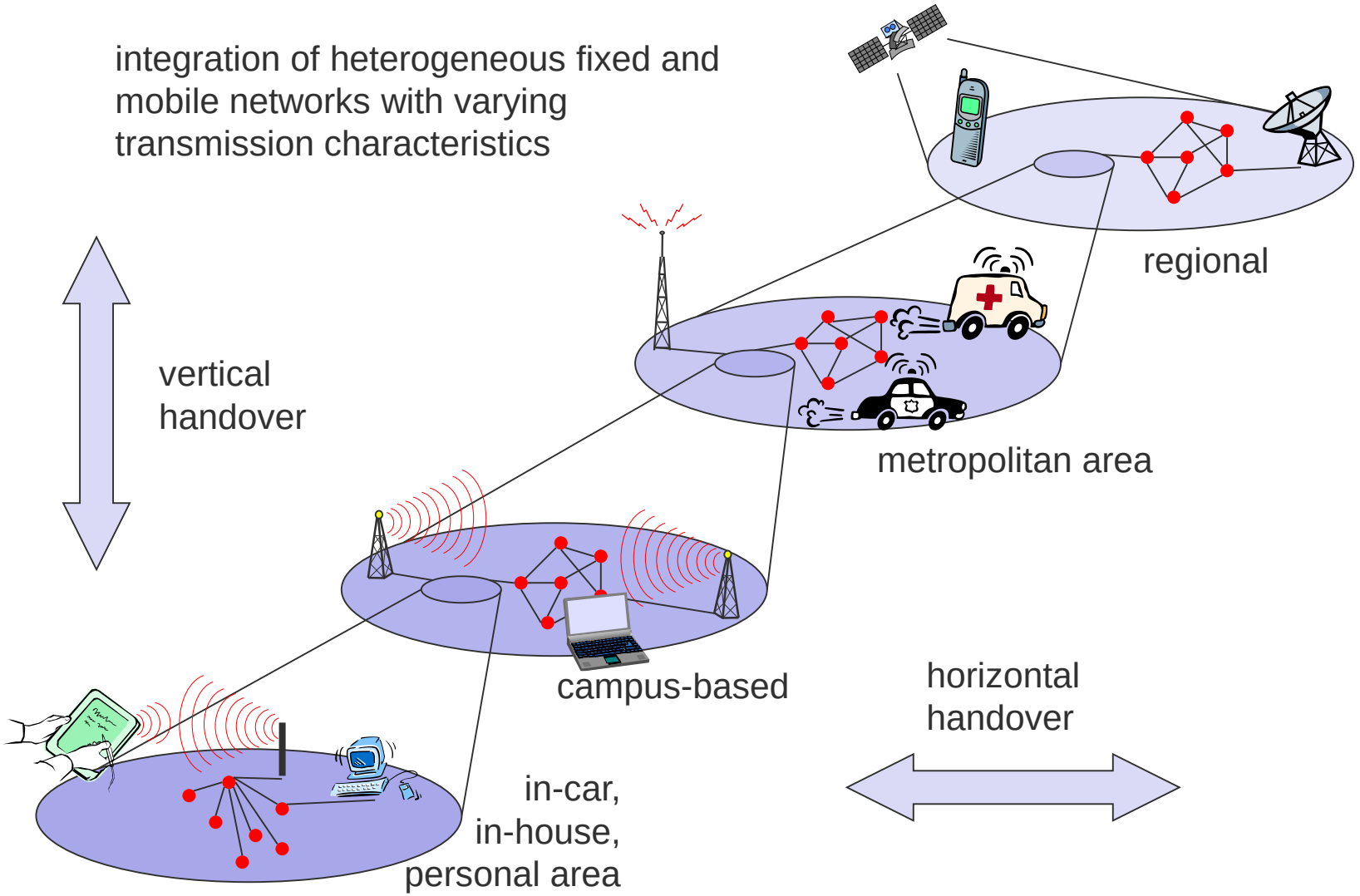


# New: Convergence with new applications

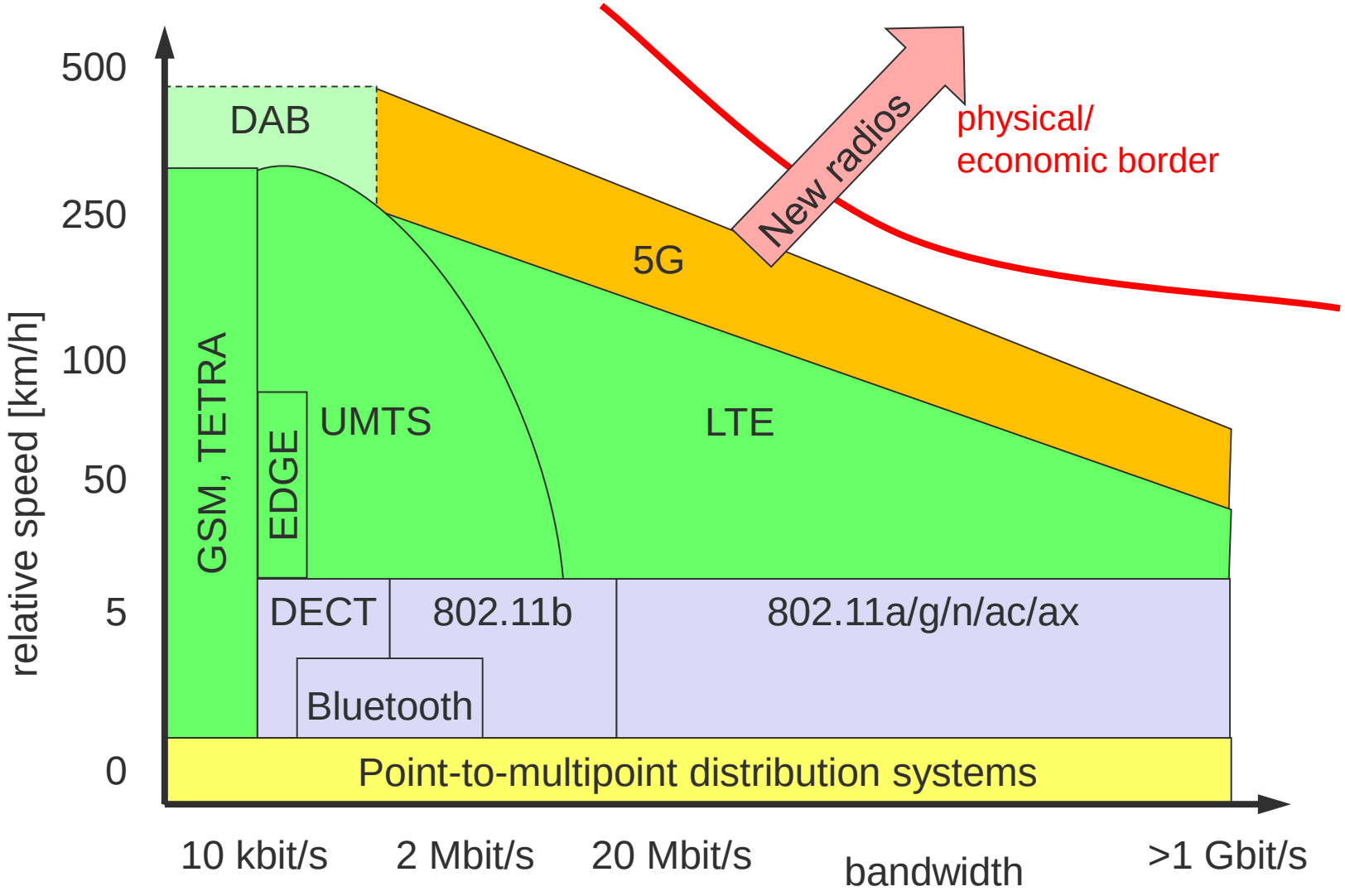


# Overlay Networks - the global goal

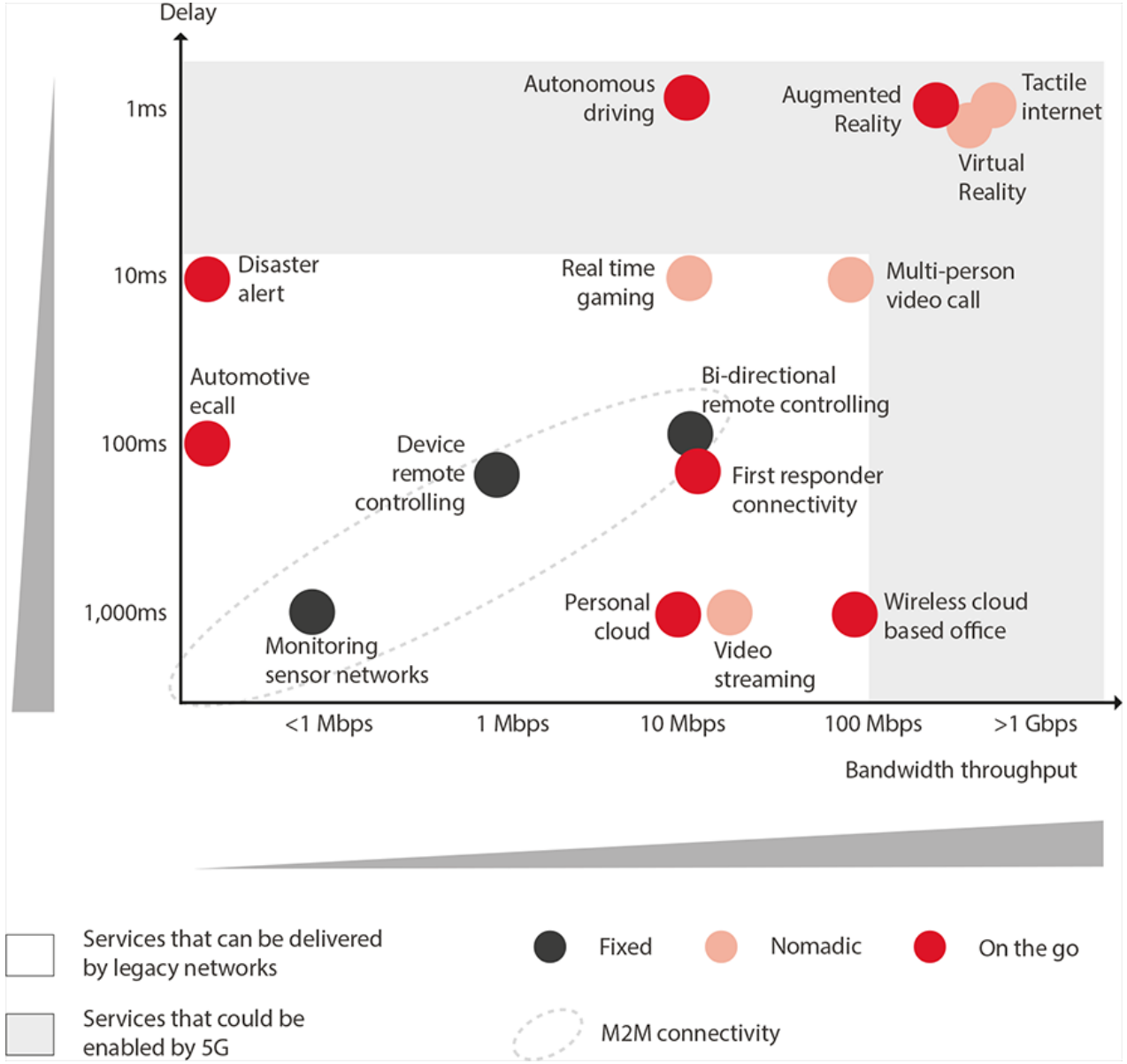
integration of heterogeneous fixed and mobile networks with varying transmission characteristics



# Wireless access technologies



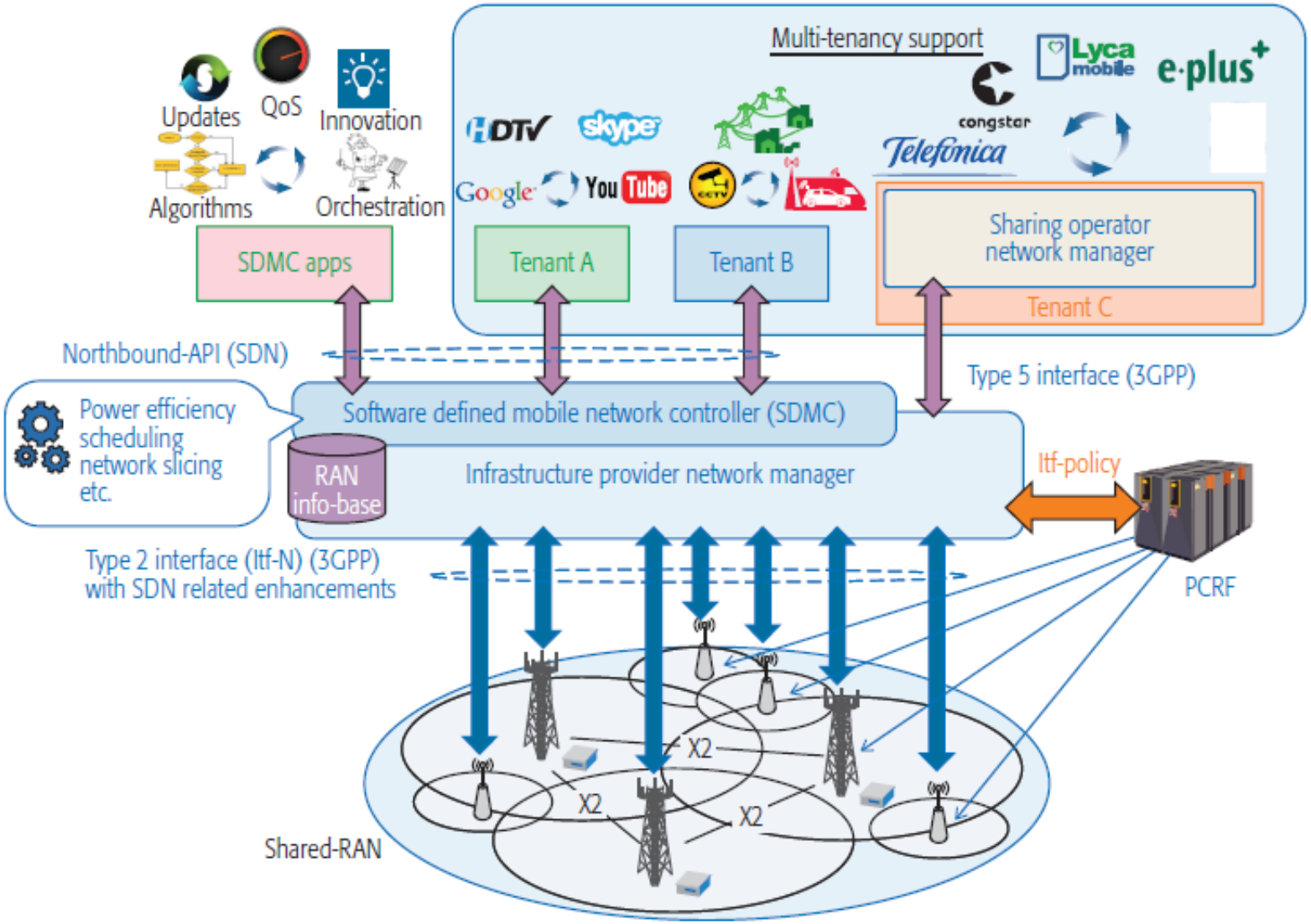
# New applications




Source: GSMA Intelligence

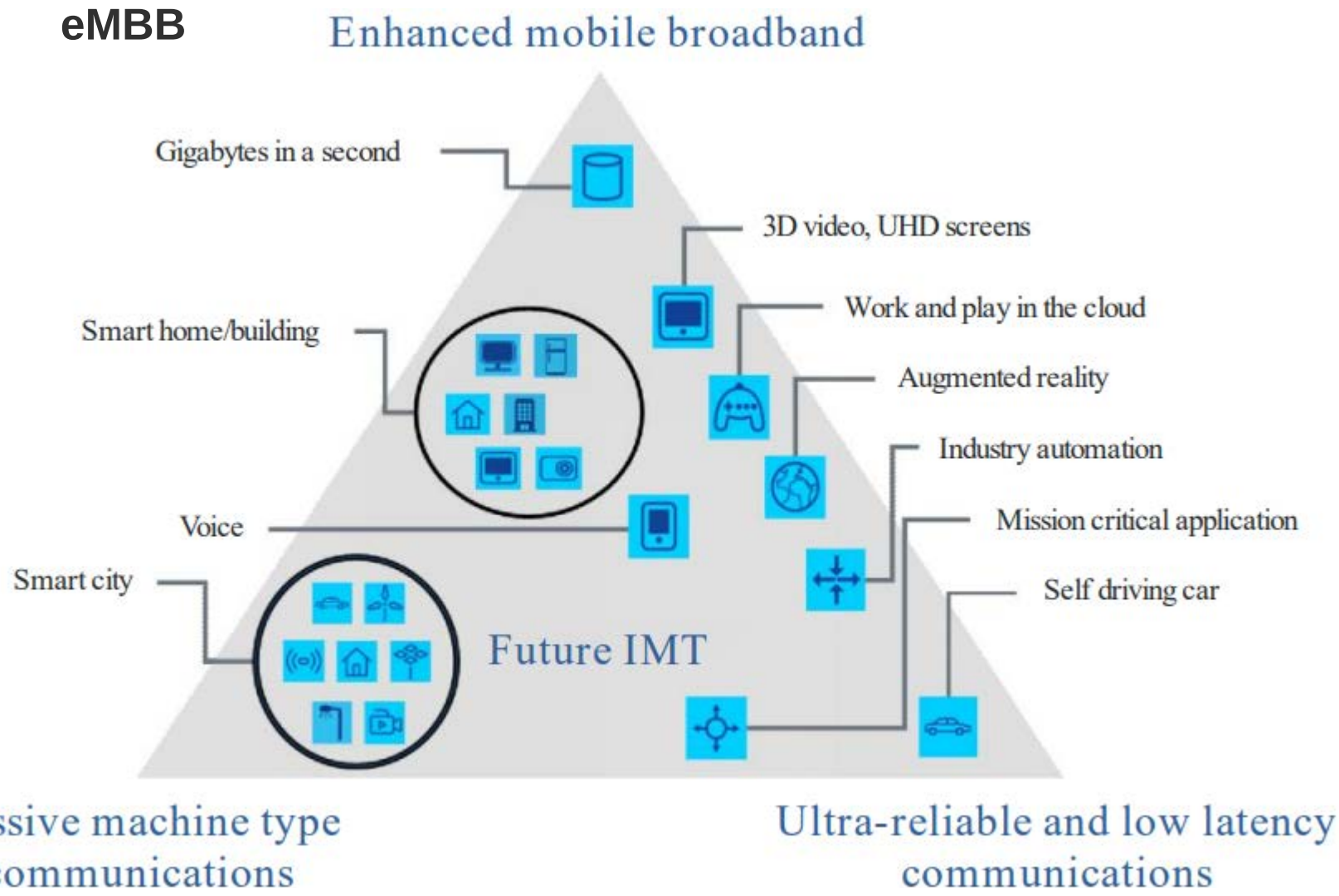
# Software Defined Mobile Networking

- Apply SDN to mobile networks
  - Dynamic, efficient network configuration
  - Improved performance
  - Separation of data (forwarding) and control (“brain”) plane
- Can be complemented by NFV
  - Network Function Virtualization
  - Virtualized network functions (SW implementations of network functions)
  - Services can be built by chaining VNFs
  - SDN could orchestrate and manage NFV



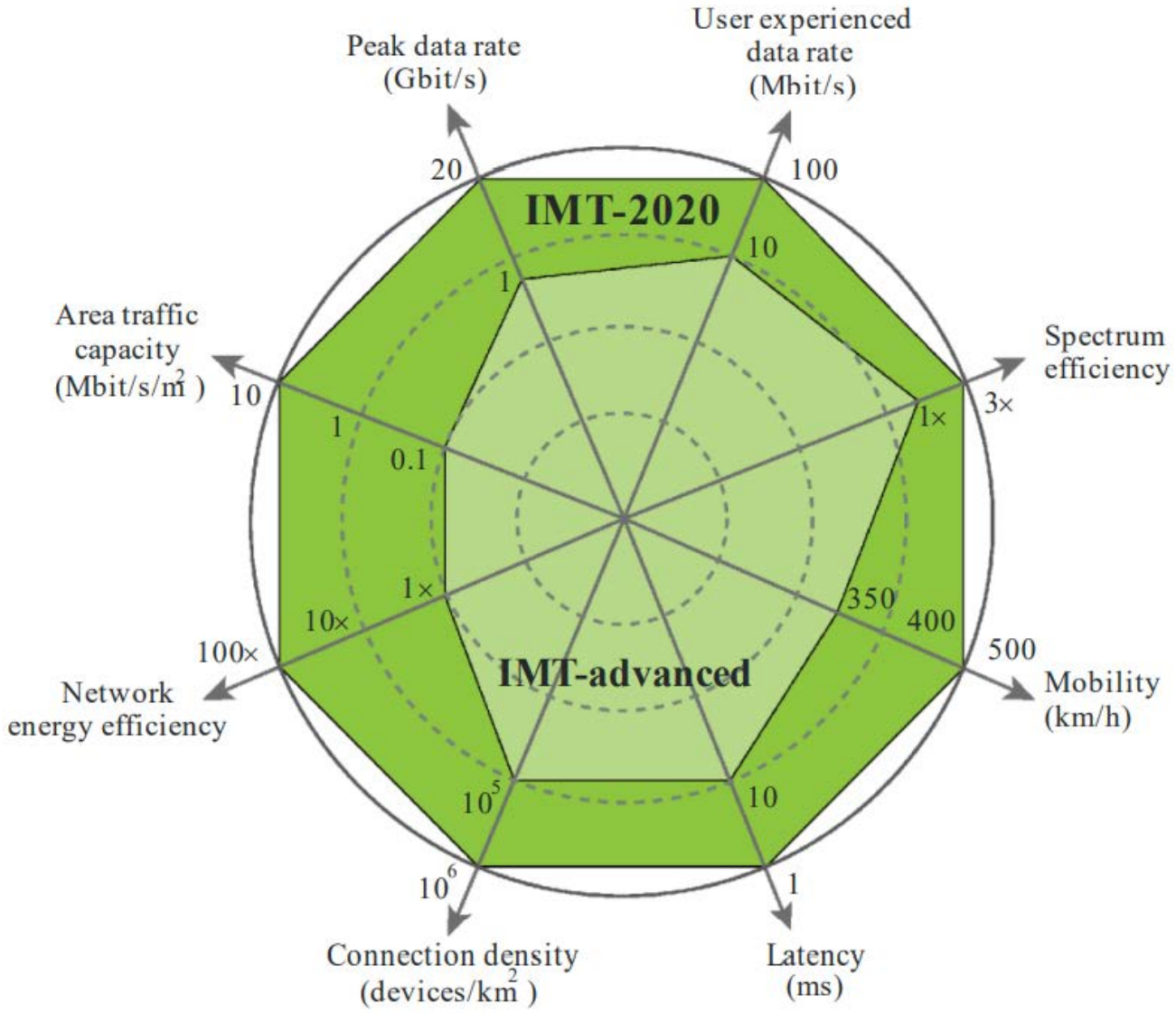

Source: Rost et. Al, Mobile Network Architecture Evolution toward 5G, IEEE Communications Magazine, vol. 54, no. 5, 2016

# ITU IMT-2020 – Applications for 5G



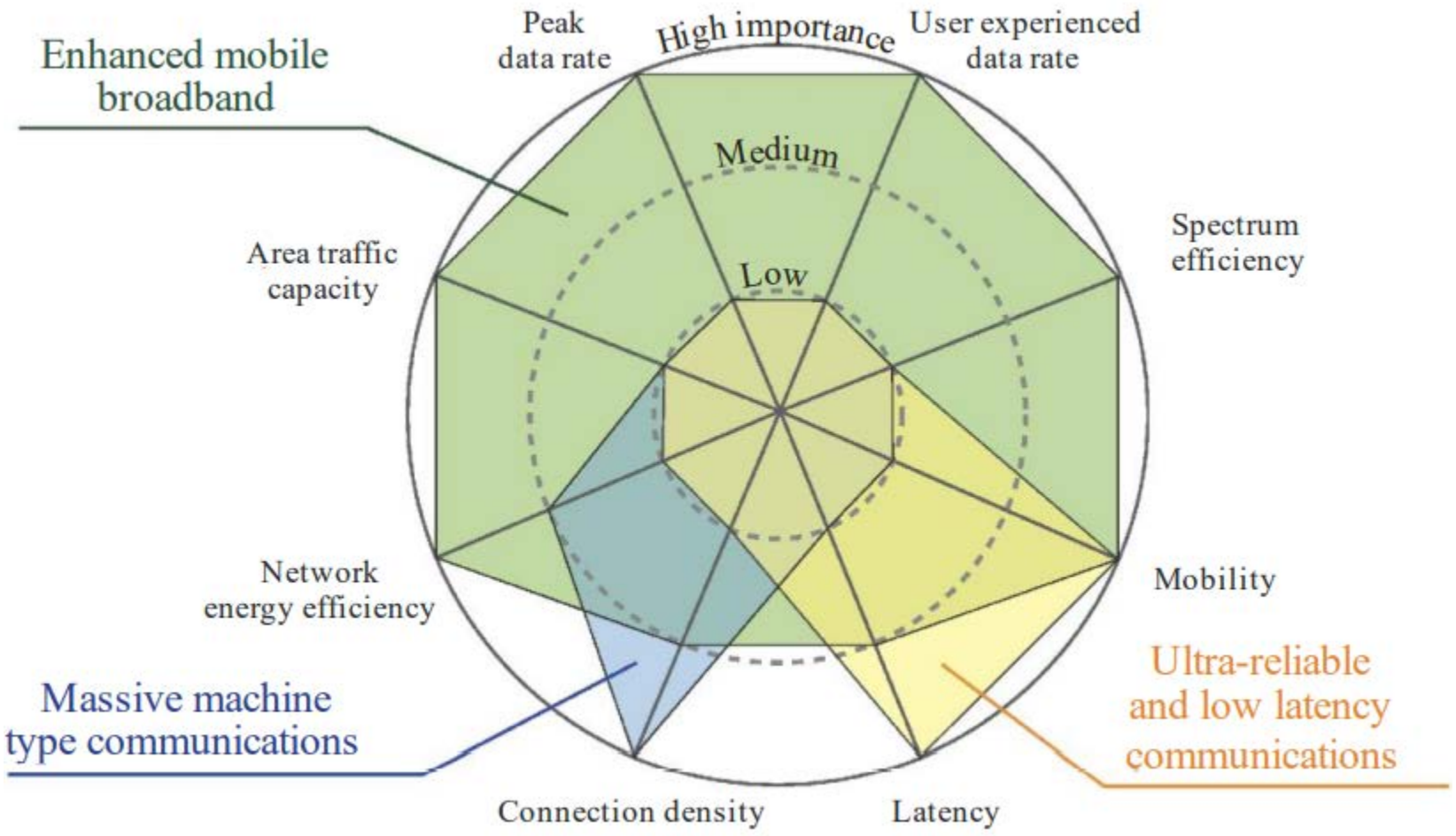

Source: ITU, M.2083

# ITU IMT-2020 – Performance Requirements



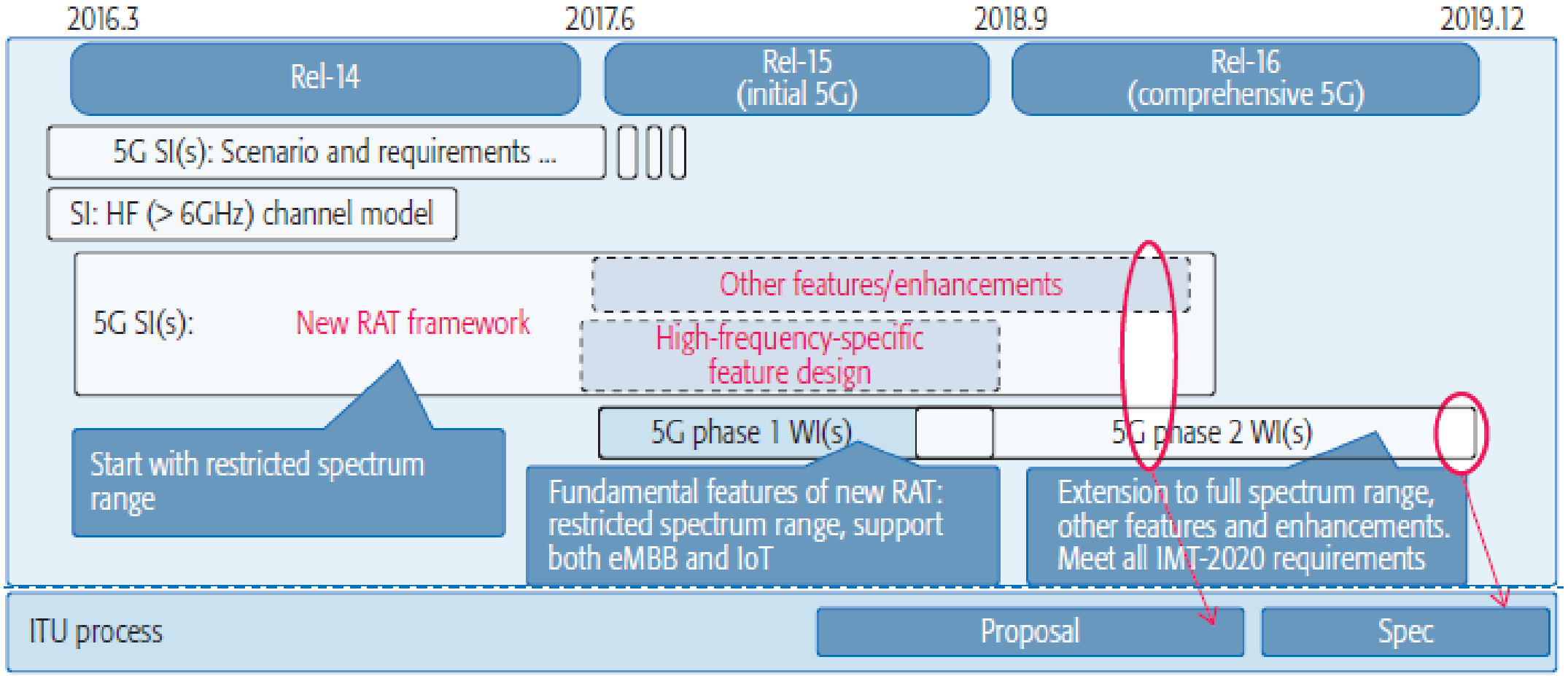

Source: ITU, M.2083

# ITU IMT-2020 – 3 main usage scenarios: eMBB, eMTC, URLL




Source: ITU, M.2083

# 3GPP LTE standardization roadmap toward 5G




Source: Rost et. Al, Mobile Network Architecture Evolution toward 5G, IEEE Communications Magazine, vol. 54, no. 5, 2016

# Some new 5G features

Using higher frequencies
- mmWave, operating bands up to 52.6 GHz, channel bandwidth up to 400 MHz, 30 bit/s/Hz down, 15 bit/s/Hz up

Variety of use cases
- scaling data rates from kbit/s up to Gbit/s

Mini-slots
- low latency response for, e.g., autonomous cars, factory automation

**eMBB**: 500 km/h mobility, 10-20 Gbit/s peak, all data all the time available

**URLL**: < 1ms air interface latency, 5 ms end-to-end latency (well, not around the globe, rather edge computing), 99.9999% reliability, 50 kbit/s-10 Mbit/s

**mMTC**: billions of things connected, ultra low cost, low energy, $10^5$ to $10^6$ devices per km², 1-100 kbit/s per device, 10 years battery life

Next Generation Core: uses SDN, NFV, SON – virtualization of network architecture

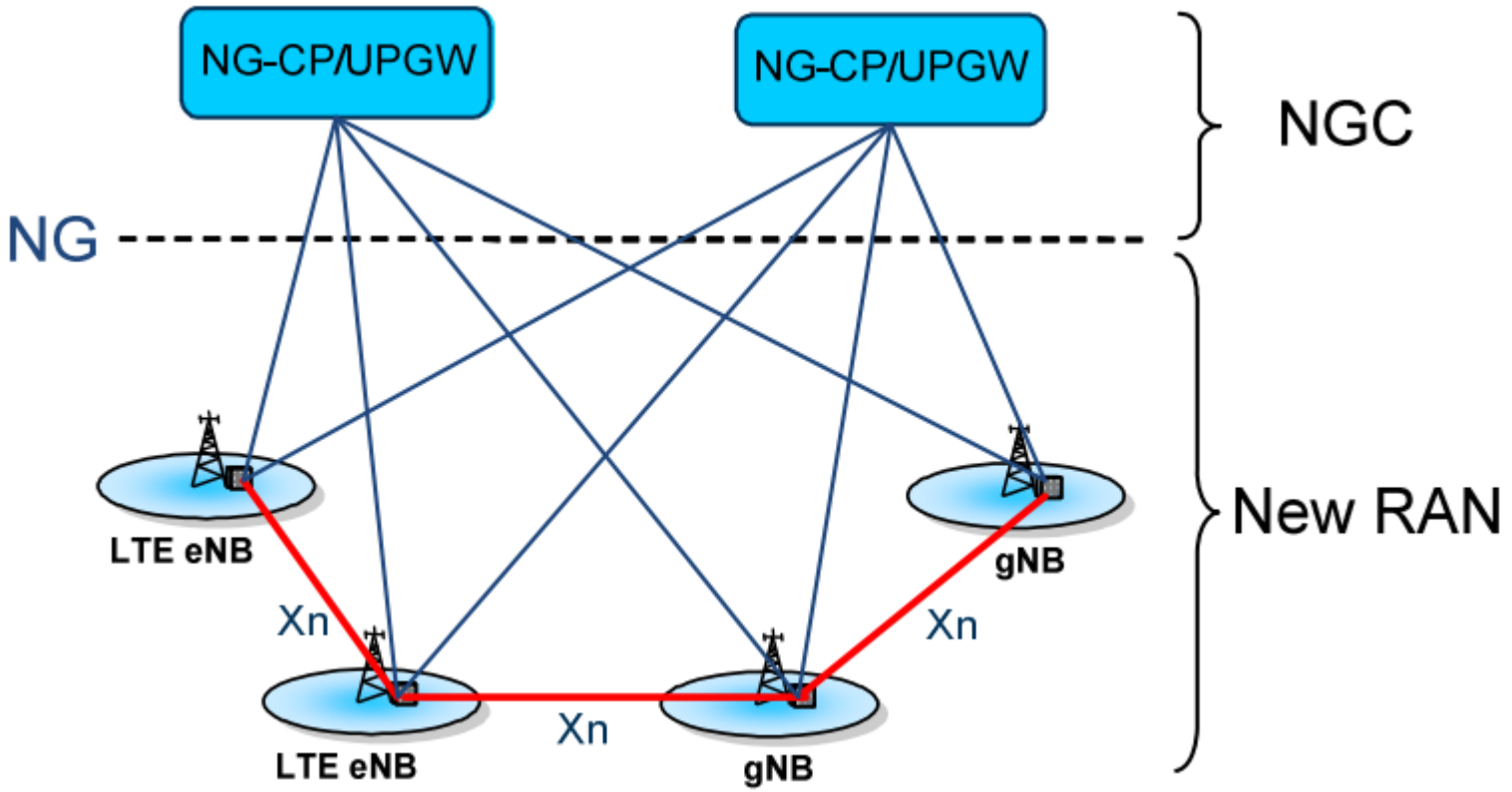
# New RAN architecture for 5G (3GPP TR 38.912)

gNodeB (gNB, next generation Node B)
- providing the New RAN U-plane and C-plane protocol terminations towards the UE

LTE eNode B (eNB)
- providing the E-UTRA U-plane and C-plane protocol terminations towards the UE.

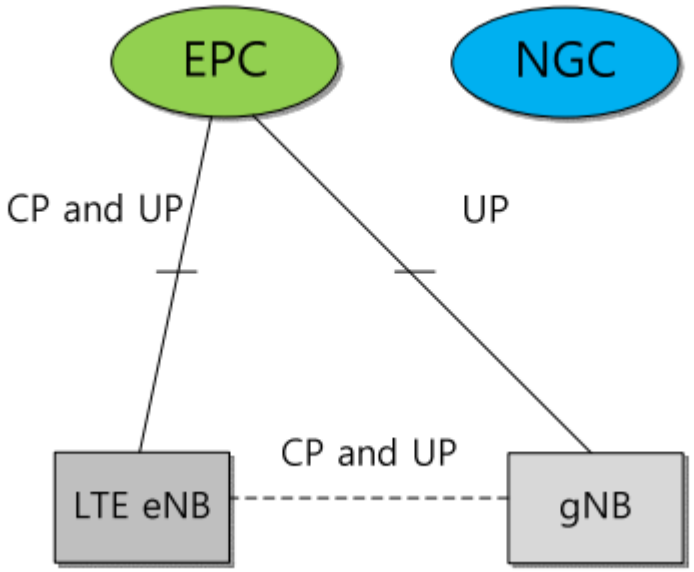
Xn interface
- interconnection of nodes in New RAN with each other

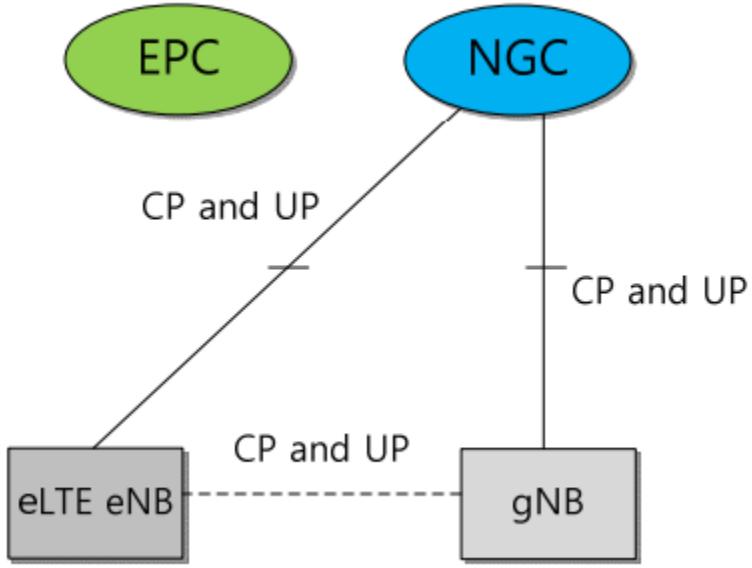
NG interface
- connections of nodes in New RAN to the NGC
- supporting a many-to-many relation between NG-CP (Control Plane)/UPGWs (User Plane Gateways) and the nodes in New RAN




Source: ETSI TR 138 912

# LTE – New Radio co-existence (ETSI TR 138 912)




Source: ETSI TR 138 912

# 5G gets real in many places 2017/2018

At least some test installations, first devices – smooth transition

More realistic expectations in industry: „no fundamental difference between 4G and 5G“, „natural evolution“ – investment in 5G, but not big hype

Products that integrate 2G, 3G, 4G and 5G are available; smartphones available since 2019

Examples:

- Berlin, 70 basestations operating at 3.7 GHz (5G New Radio), 64 antenna massive MIMO, beamforming, > 2 Gbit/s per client, RTT 7-9 ms
- https://5g-ppp.eu/ for many more 5G trials

Source: Samsung

**GSM-Band**
GSM 850 MHz, GSM 900 MHz, DCS 1.800 MHz, PCS 1.900 MHz

**UMTS-Band**
B1 (2.100), B2 (1.900), B4 (AWS), B5 (850), B8 (900)

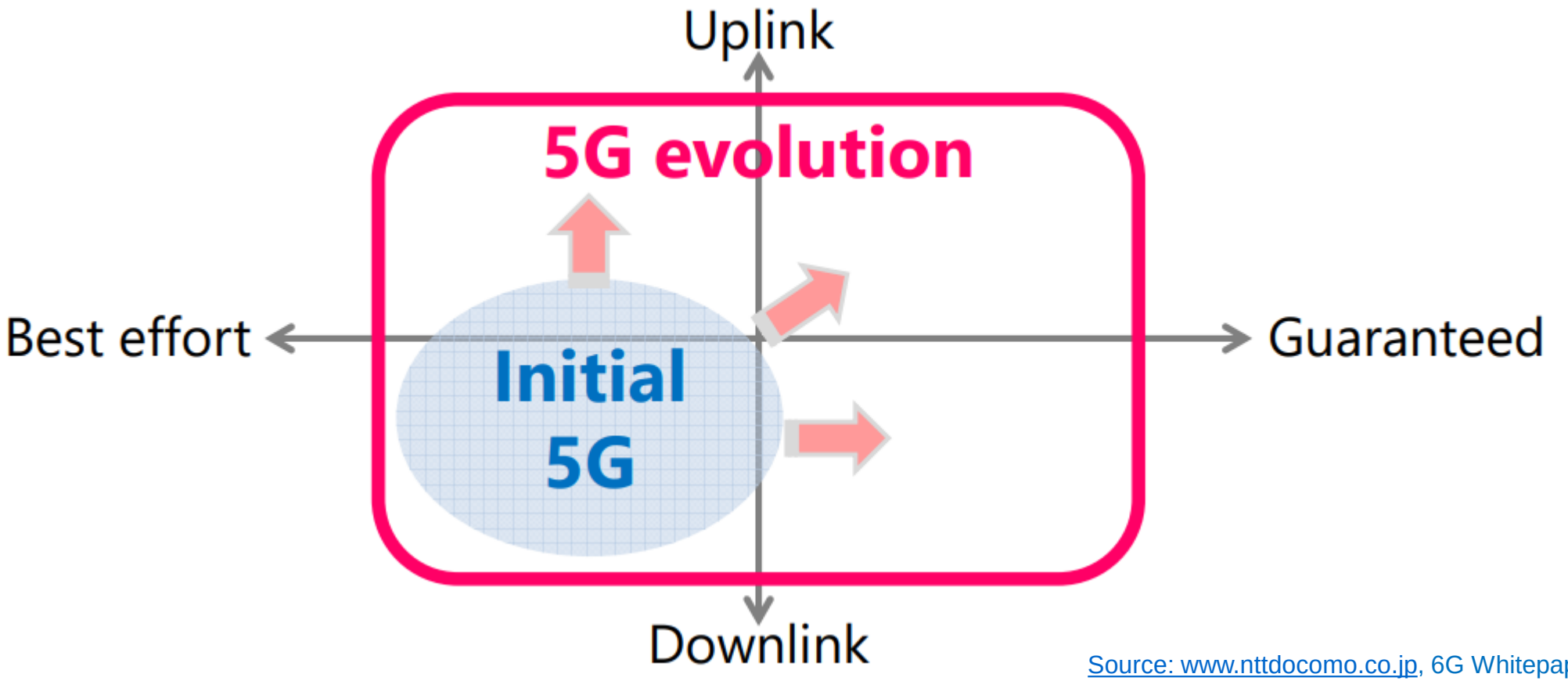
**LTE-Band**
B1 (2.100), B2 (1.900), B3 (1.800), B4 (AWS), B5 (850), B7 (2.600), B8 (900), B12 (700), B13 (700), B17 (700), B18 (800), B19 (800), B20 (800), B25 (1.900), B26 (850), B28 (700), B32 (1.500), B66 (AWS-3)

**4G TDD LTE**
B38 (2.600), B39 (1.900), B40 (2.300), B41 (2.500)

**5G FDD Sub6**
N1 (2.100), N3 (1.800), N5 (850), N7 (2.600), N8 (900), N28 (700)

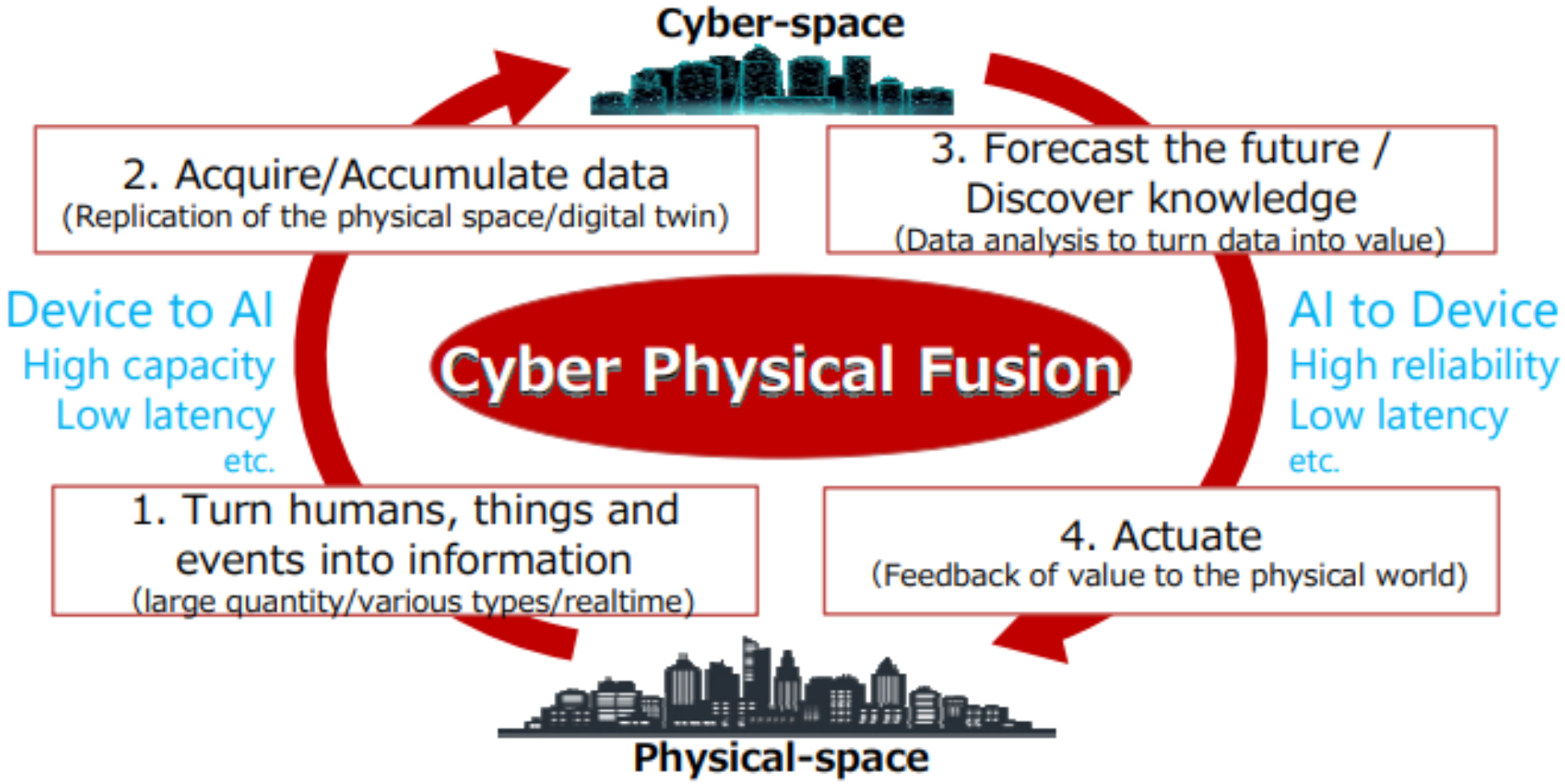
**5G TDD Sub6**
N40(2300),N77(3700),N78(3500)

# 5G Evolution continues



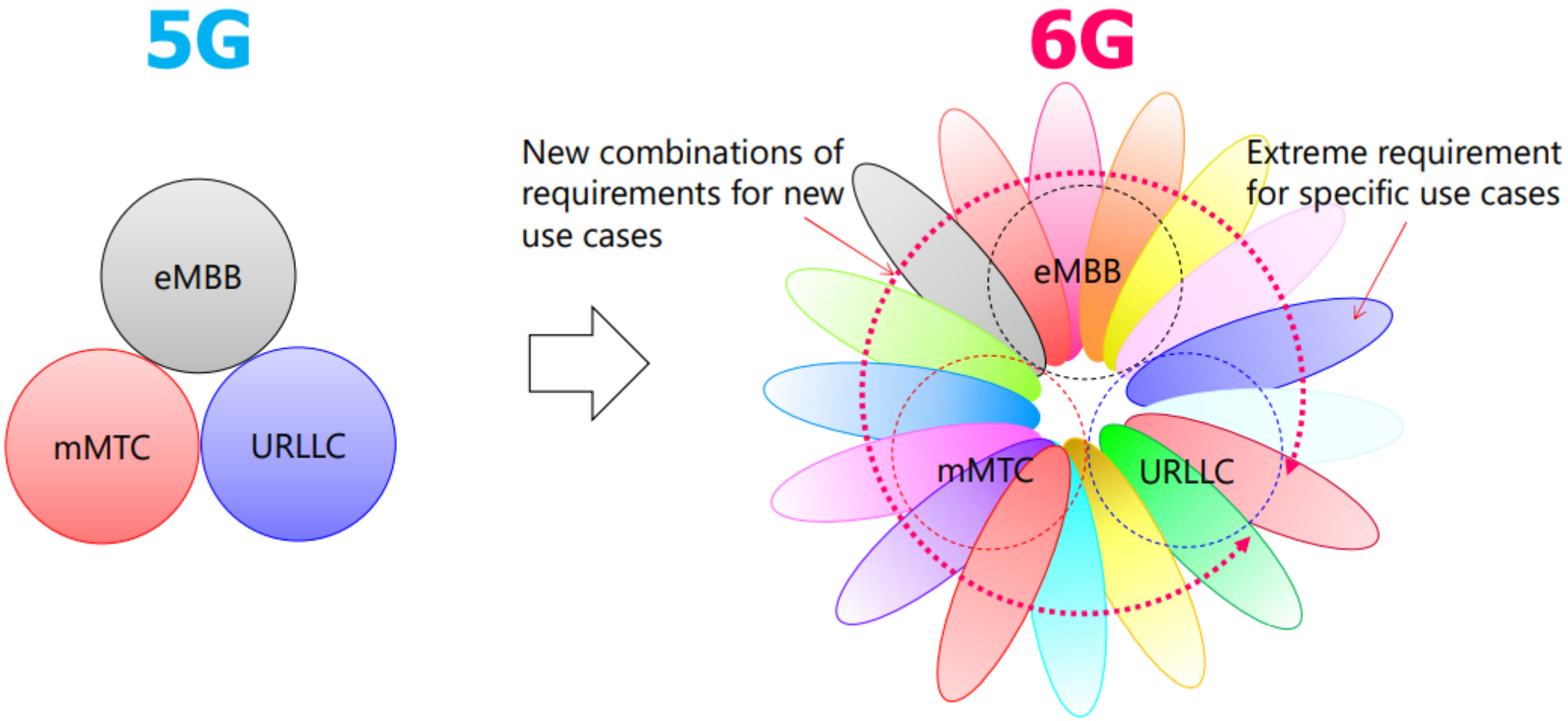

Source: www.nttdocomo.co.jp, 6G Whitepaper

# Why needing more than 5G?



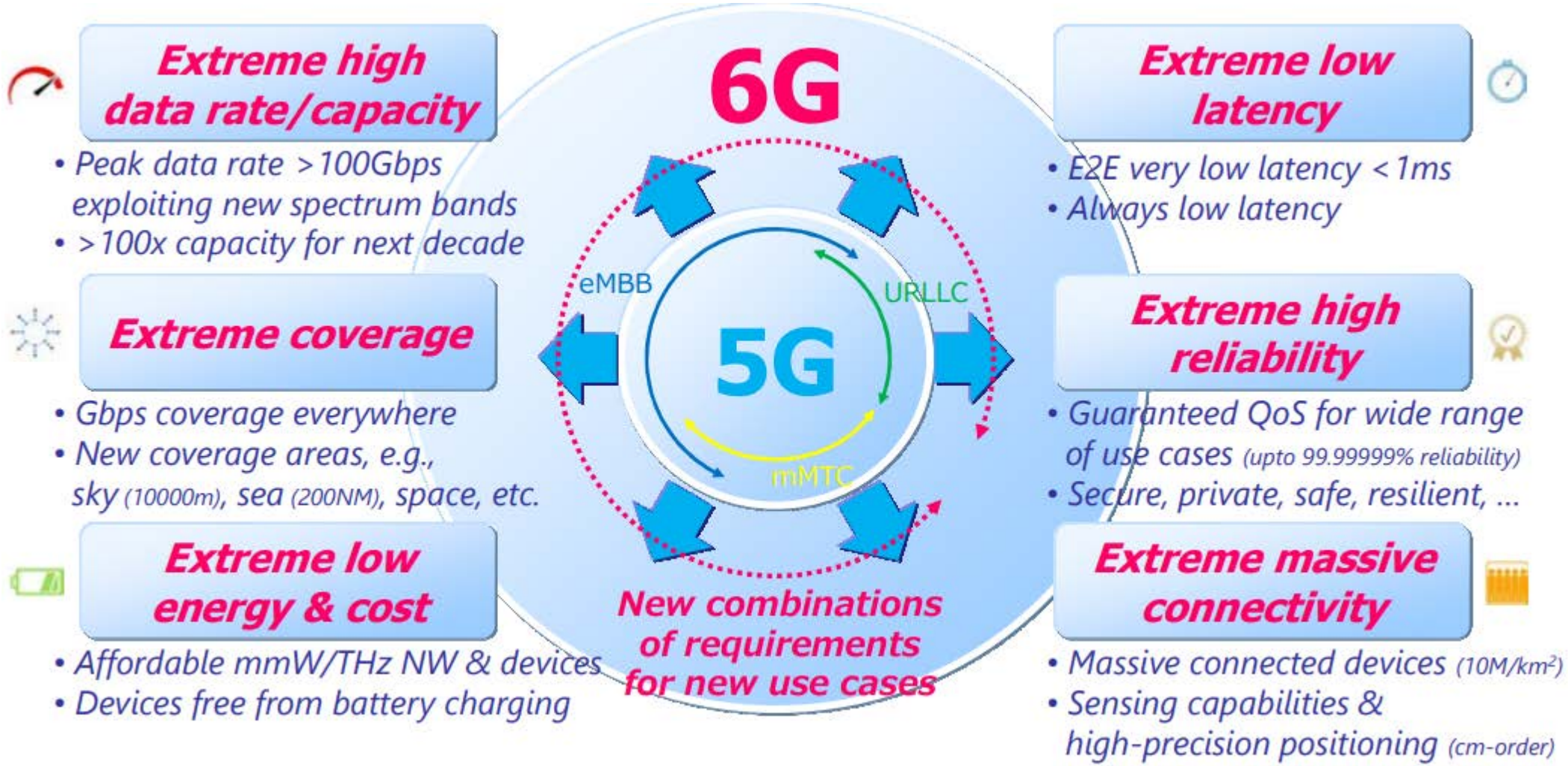

Source: www.nttdocomo.co.jp, 6G Whitepaper

# Extreme requirements for specific scenarios



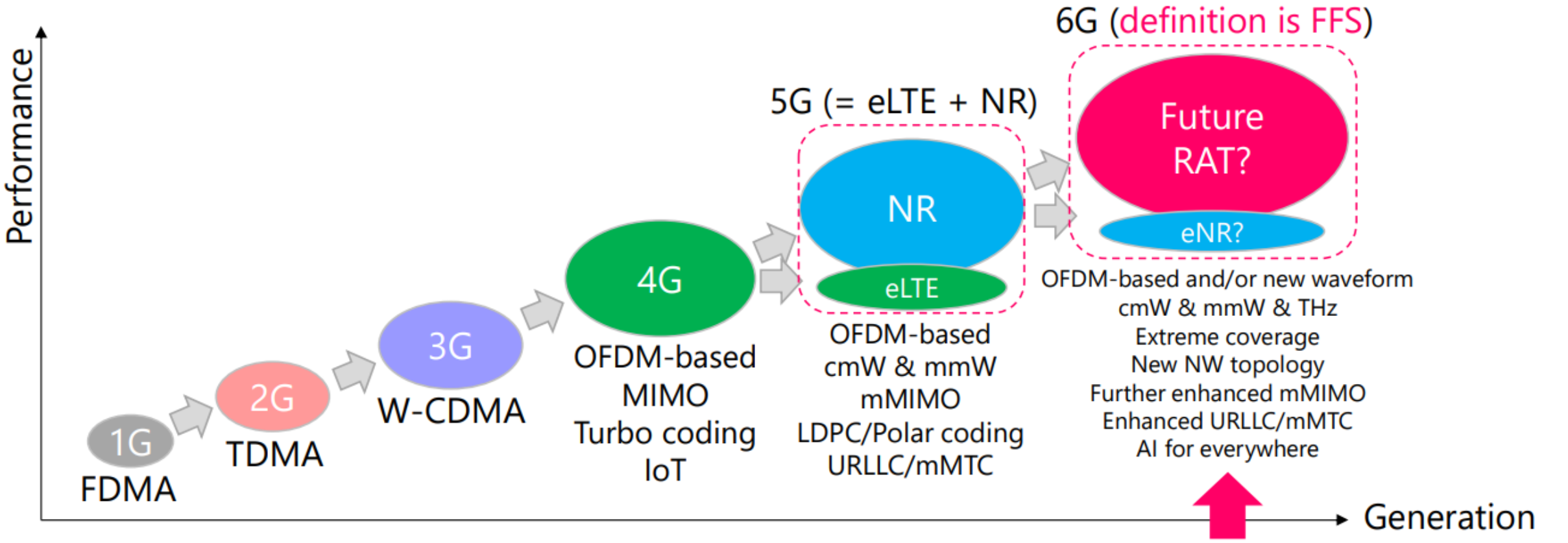

Source: www.nttdocomo.co.jp, 6G Whitepaper

# 6G – The next step for 2030 and beyond - IMT-2030




Source: www.nttdocomo.co.jp, 6G Whitepaper

# Roadmap through the generations



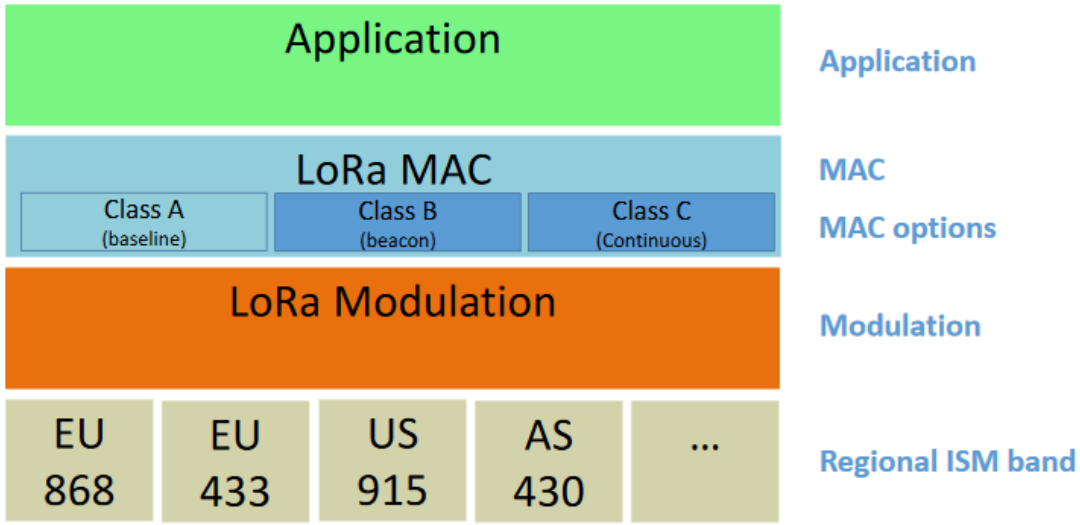

6G will be a combination of new technologies and enhancements to bring "Big gain"

Source: www.nttdocomo.co.jp, 6G Whitepaper

# LoRaWAN – a wireless technology for IoT I

**LoRaWAN**

- Max. 250 mW, max. 1% duty cycle, ISM/SRD band (e.g. 433, 868 MHz)
- Open specification, based on proprietary chirp spread spectrum technology (LoRa, Semtech Corp.)
- Asymmetric, > 10km range, up to 50 kbit/s, star topology




LoRaAlliance

- 500+ member companies, solutions, products, services based on LoRaWAN
- https://www.lora-alliance.org/

Open issues

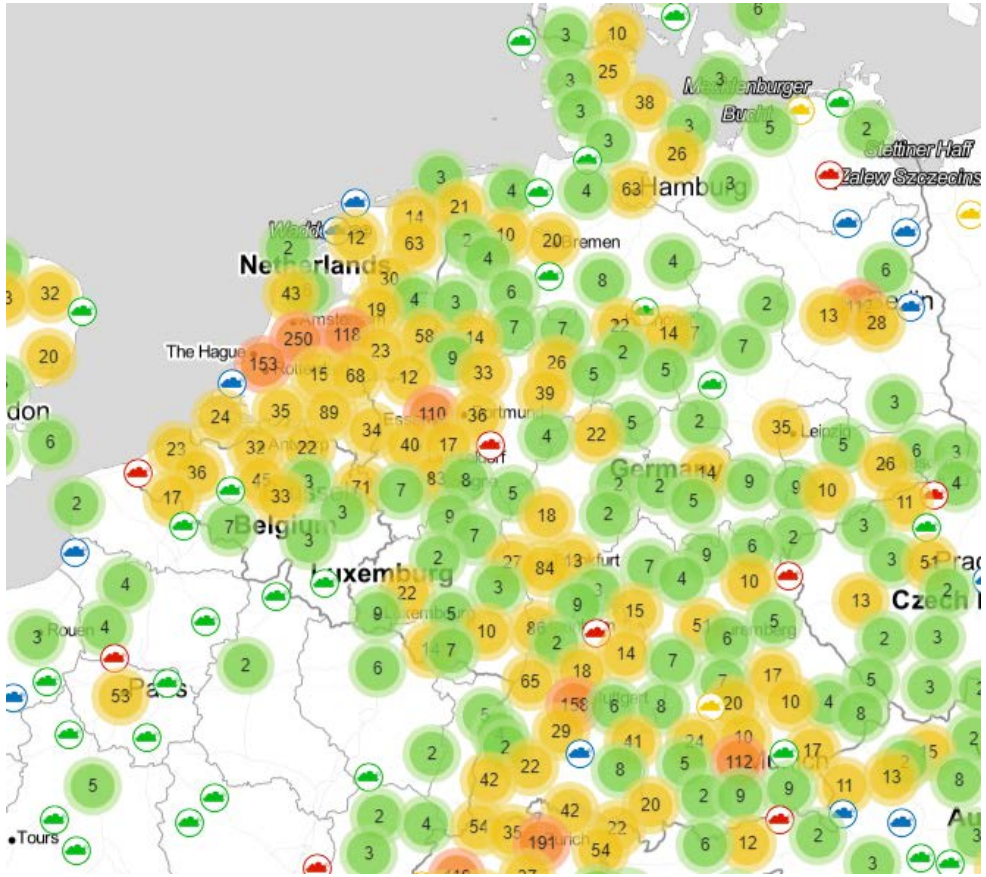
- LoRa closed, no open documentation
- Doubts regarding scalability: “Do LoRa Low-Power Wide-Area Networks Scale?” (Bor et. Al, MSWiM’16)
  - Typical smart city deployment supports only 3-4 nodes per 1000m² (20 byte packet every 16 min)
- No hard guarantees for QoS

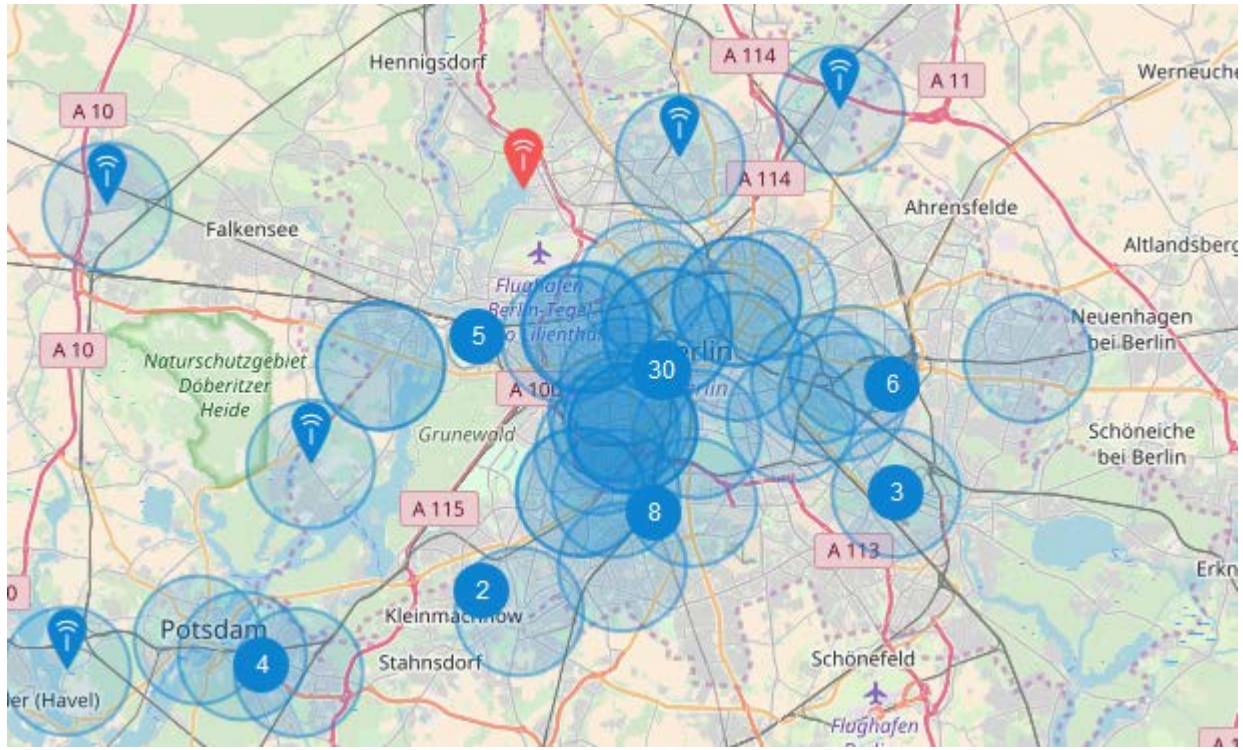
# LoRaWAN – a wireless technology for IoT II

LoRaWAN

https://www.thethingsnetwork.org/

https://www.ttnmapper.org/

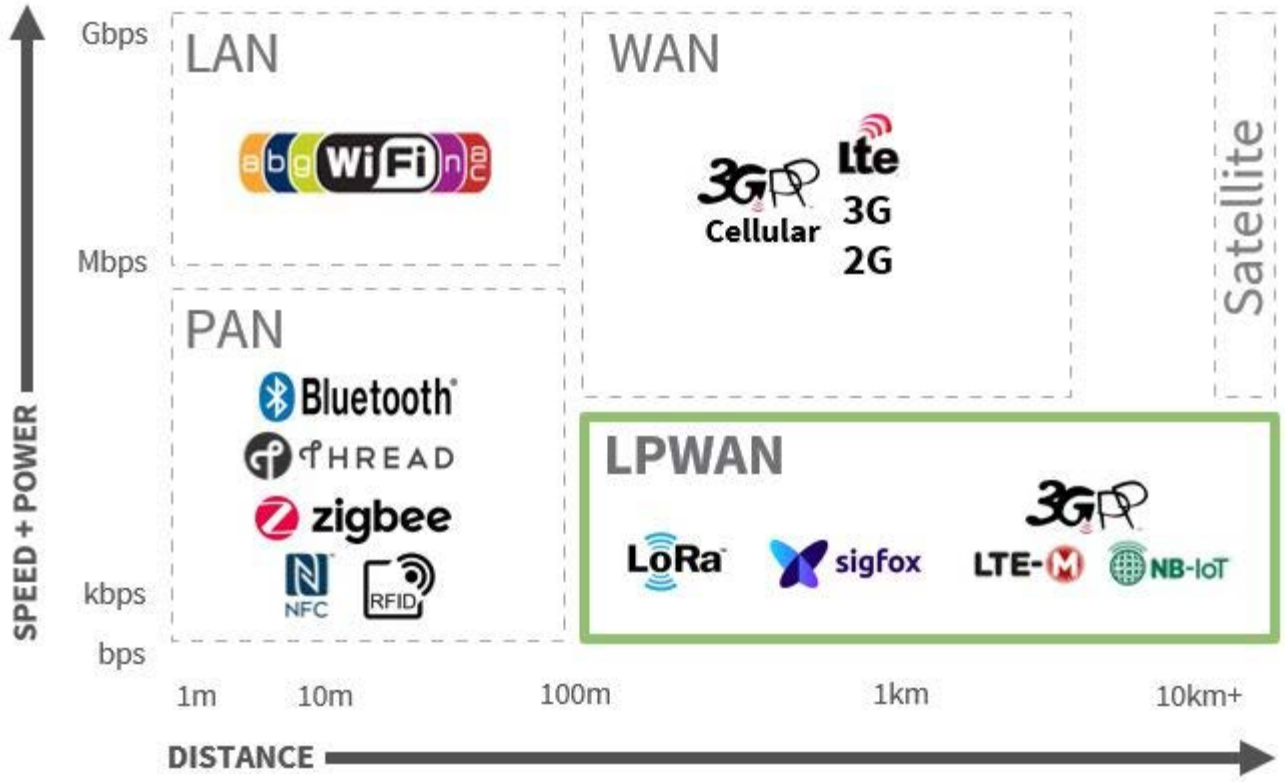



THE THINGS NETWORK BERLIN

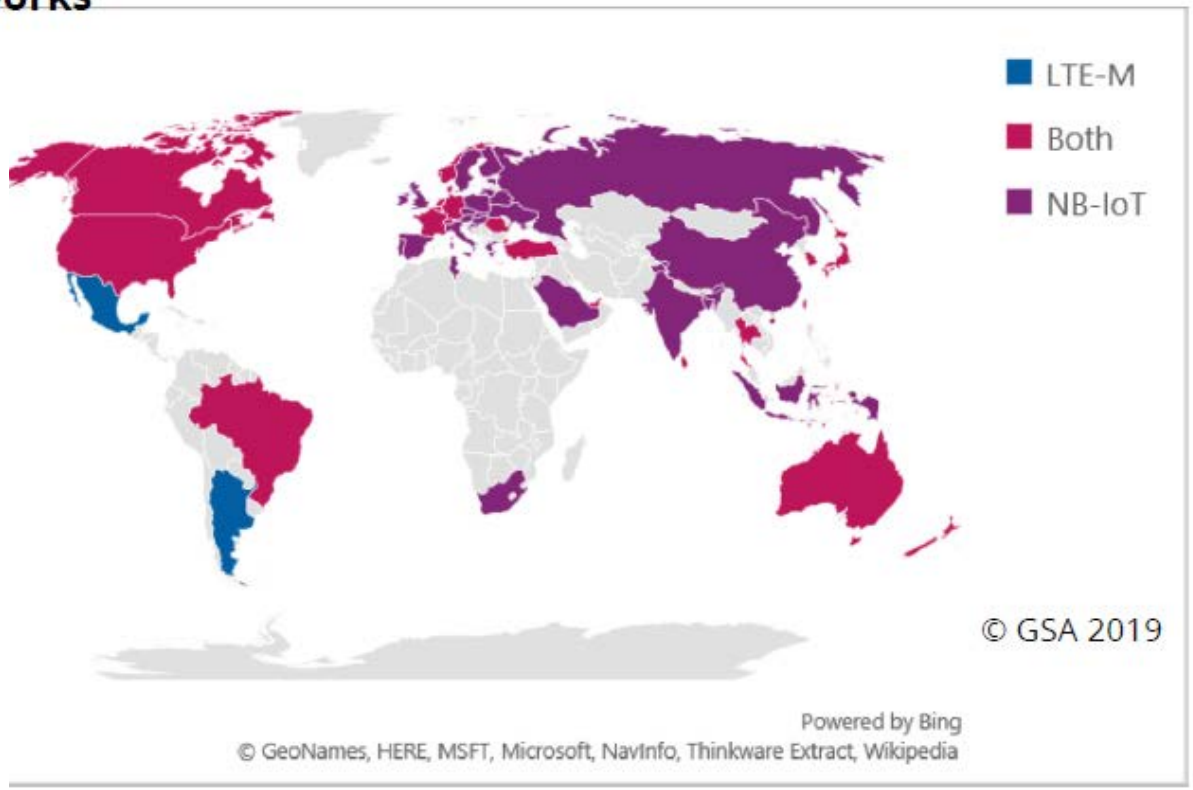
DB DIGIMONDO Telekom Innovation Laboratories Fraunhofer FOKUS BEUTH HOCHSCHULE FÜR TECHNIK BERLIN University of Applied Sciences element14 Berliner Wasserbetriebe Technische Universität Berlin htw Hochschule für Technik und Wirtschaft Berlin TECHNOLOGIE STIFTUNG BERLIN BSR Freie Universität Berlin

# Many more wireless networks for IoT are evolving – who will make it?




www.electronicspecifier.com

**Countries with deployed/launched NB-IoT and LTE-M networks**



# …and what about security? Availability?

„The Internet of Things (IoT) will present **new attack surfaces** as most of the IoT devices do not offer integrated security and, furthermore, it is **often not possible to update** security mechanisms later on. If compromised, these devices may serve as a backdoor for hackers to enter clinical IT systems – undiscovered for months.“ (DarkReading, www.informationweek.com, 22.12.16)

- Large variety of systems (hardware, interfaces, operating systems), typically “weak”
- Real interaction with the environment (CPS)
- Longer (but also much shorter!) life cycles, deeply embedded
- Complete unclear patching/updating strategy, responsibility
- How to integrate today the security needed in 30 years?

Software bugs do happen

- Even using the best software engineering principles
- Quite often due to unforeseeable interdependencies, new features, short innovation cycles

Often only one/very few vendors

- Even simple bugs may affect many networked systems


Source: www.heise.de

Result: very simple to affect millions of users

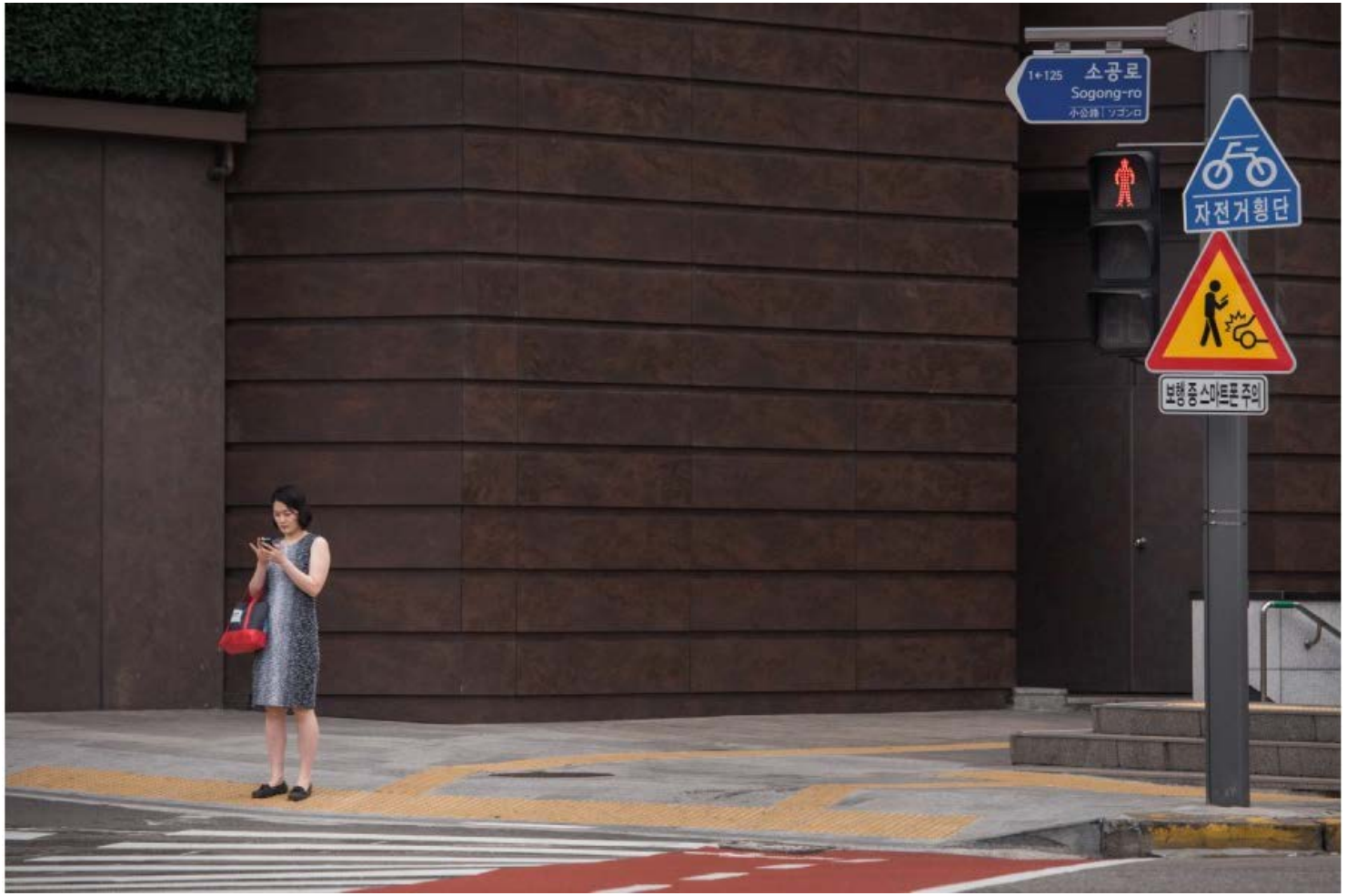
- System update @ German Telekom banned 40 million users from the network
- Simple misconfiguration at Internet routers cut off many autonomous systems

Classical high availability? Emergency calls? Redundancy?

# Questions & Tasks

- Is 5G all about higher data rates? What else do applications in the future need?
- What are the three main application domains of 5G?
- Why is even more than 5G needed? What could be applications?
- Check for LoRaWAN at your place. What else could be used for IoT? Pros and cons?
- This is not a security lecture – but think of vulnerabilities of mobile and wireless systems, think of the many systems depending on these networks…

# Thanks, take care – and have fun with Mobile Communications!




Source: Ed Jones/AFP, Seoul, South Korea,, 22.06.2016