5G for Absolute Beginners

Introduction

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APRIL 2020

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Legal Disclaimer

This presentation is intended to stimulate discussion on some of the exciting current and future developments in digital communications technology and networks. It also contains some forward-looking statements, research and speculation that may never become part of standards.

It strives to provide the latest and most correct information. Due to the vastness of standards, constant change and revision, it is possible that the following information may not be entirely up to date or correct. E&OE.

There are references to information in public domain (books, websites, standard documents, etc.) in this material. Attempt has been made to give credit to all such references wherever possible. The original copyright holders retain the copyright to their material.

It would not be prudent to make any financial or investment decisions based on this presentation.

Course Outline: 5G for Absolute Beginners

- Introduction
- Part 1: The Different Generations (‘G’s)
- Part 2: Standardization Organizations
- Part 3: IMT-2020
- Part 4: Why is 5G called 5G
- Part 5: 5G in Simple Words
- Part 6: Standalone and Non-Standalone 5G
- Part 7: 3GPP Roadmap
- Part 8: 5G Spectrum
- Part 9: 5G Launches
- Part 10: 5G Use cases
- Part 11: Course Summary and Conclusion

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Part 1: The Different Generations ('G's)

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Mobile Technology Evolution

1G

Analog

Voice only, Limited coverage and mobility. Example: AMPS

2G

Digital

Improved voice, security, coverage. SMS, data. Example GSM, CDMA

3G

Mobile Data

Higher data rates, smartphones, better voice. Example: HSPA / HSPA+

4G

Mobile Broadband

High speed data, better smartphones. Example: LTE / LTE-A

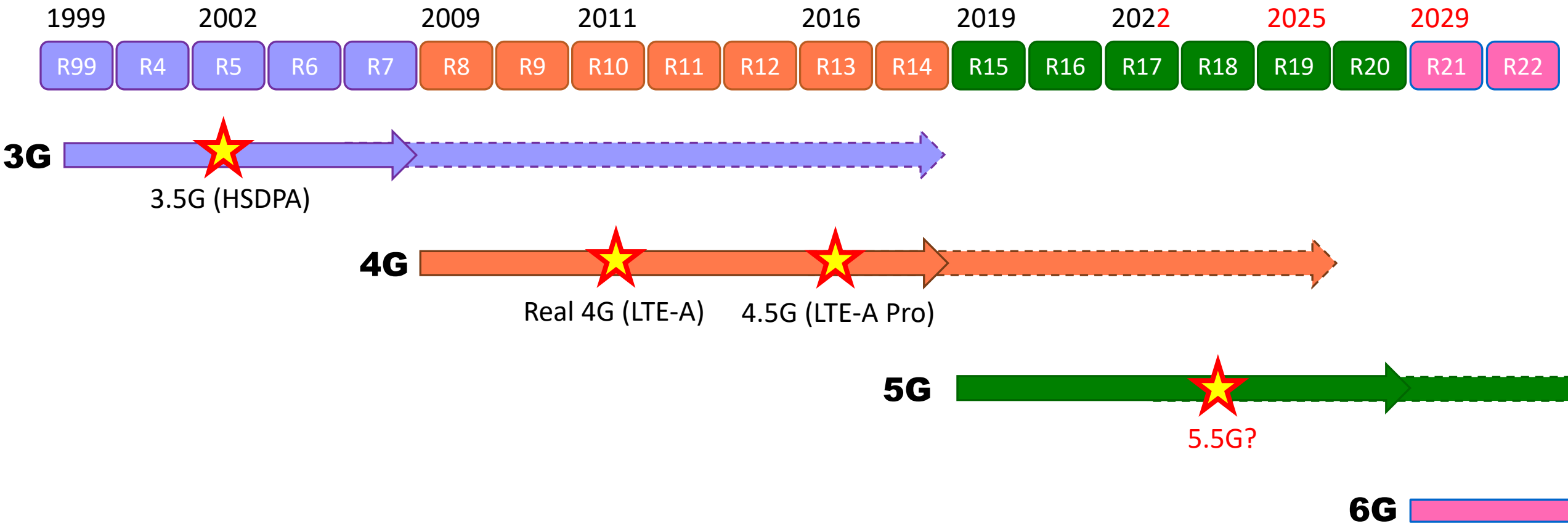
5G

eMBB, mMTC, URLLC

Even higher speeds, ultra-reliable, low latency, high connection density

1980 1990 2000 2010 2020

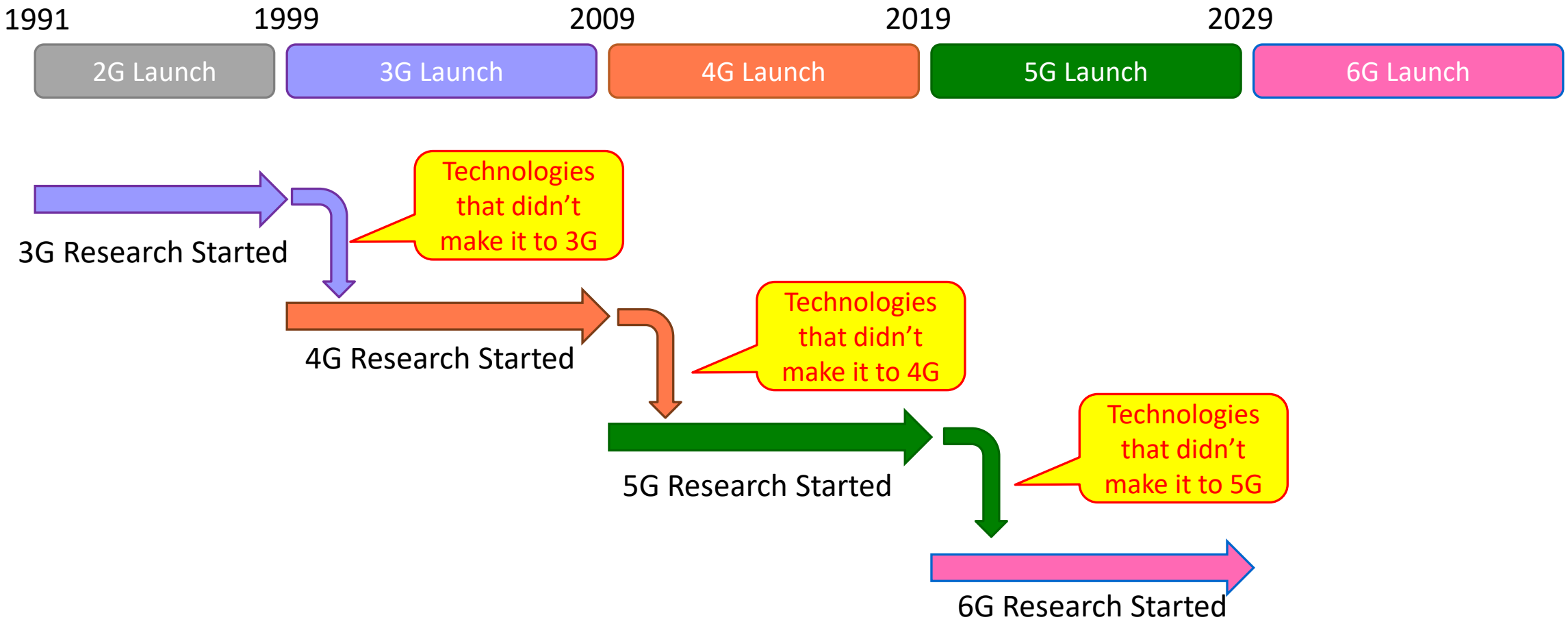
3GPP Releases Timeline



Red indicates dates and features are not confirmed

3GPP Release Dates on 3GPP Portal

Technologies Research Timeline



Further Study on this topic

- How does the mobile technology work? (link)
- Different Generations Of Mobile Technologies (link)
- The Flow of Money in the Mobile Industry (link)
- What is a User Equipment (UE)? (link)
- 30 Years Of Mobile History (link)

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Part 2: Standardization Organizations

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5G Standardisation Process

ITU or International Telecommunication Union is a specialized agency of the United Nations (UN) that is responsible for issues that concern information and communication technologies. It is the oldest among all the 15 specialized agencies of UN.

5G Standardisation Process

ITU-R

IMT-2020

"5G" encompasses a range of features

- Ultra low latency
- High reliability
- Advanced antenna tech
- mmWave
- Massive IoT
- Spectrum flexibility

ITU-R, Radiocommunications part is responsible creating the conditions for harmonized development and efficient operation of existing and new radiocommunication systems, taking due account of all parties concerned.

5G Standardisation Process

ITU-R

IMT-2020

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5G Standardisation Process

ITU-R

IMT-2020

"5G" encompasses a range of features

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SDOs
(Standards Development Organizations)

- 3GPP
- ETSI
- IEEE
- etc.

What is 3GPP?

ARIB
www.arib.or.jp
The Association of Radio Industries and Businesses, Japan

ATIS
www.atis.org
The Alliance for Telecommunications Industry Solutions, USA

CCSA
www.ccsa.org.cn
China Communications Standards Association

ETSI
www.etsi.org
The European Telecommunications Standards Institute

TSDSI
http://tsdsi.org/
Telecommunications Standards Development Society, India

TTA
www.tta.or.kr
Telecommunications Technology Association, Korea

TTC
www.ttc.or.jp
Telecommunication Technology Committee, Japan

Further Study on this topic

- 3GPP Newcomer Orientation (link)

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Part 3: IMT-2020

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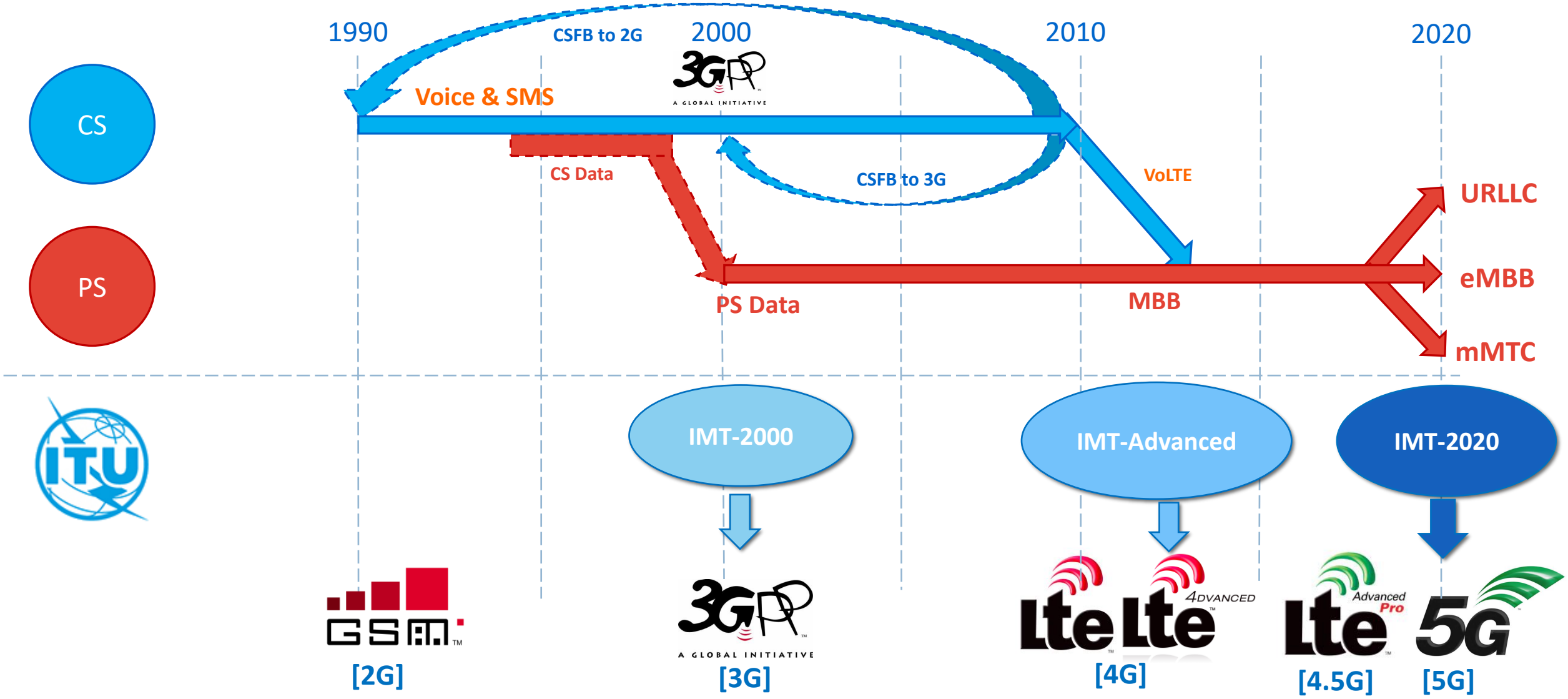
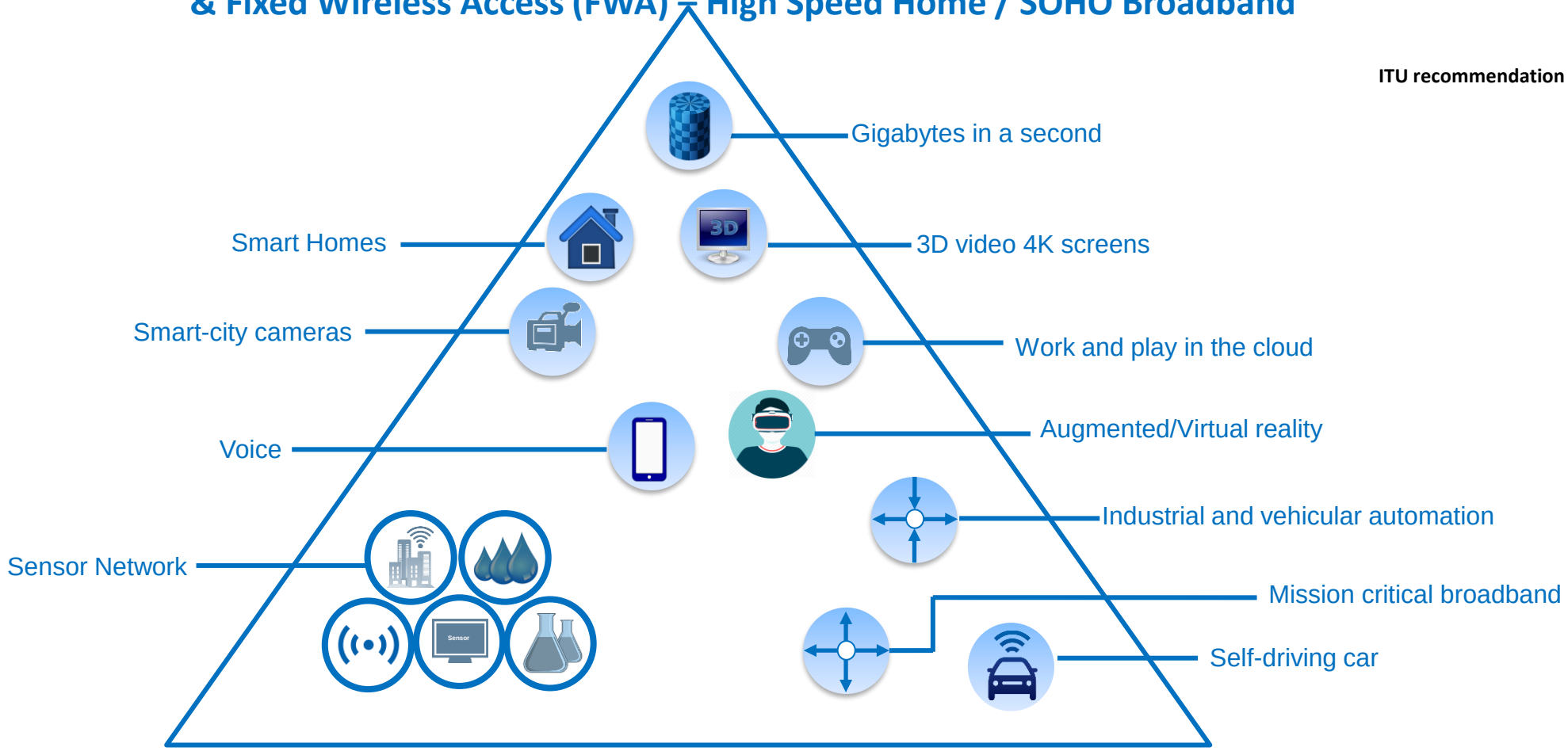
Evolution of Mobile Networks and ITU IMT Vision



IMT-2020 High Level Vision

eMBB (enhanced Mobile Broadband) – Capacity Enhancement
& Fixed Wireless Access (FWA) – High Speed Home / SOHO Broadband

ITU recommendation ITU-R M.2083-0



mMTC (massive Machine Type Communications) – Massive connectivity

URLLC (Ultra-reliable and Low-latency communications) – High reliability, Low latency

IMT-2020 Requirements

ITU-R IMT-2020 requirements

>10 Gbps
Peak data rates

100 Mbps
Whenever needed

100 x
More devices than 4G

10000 x
More traffic than 4G

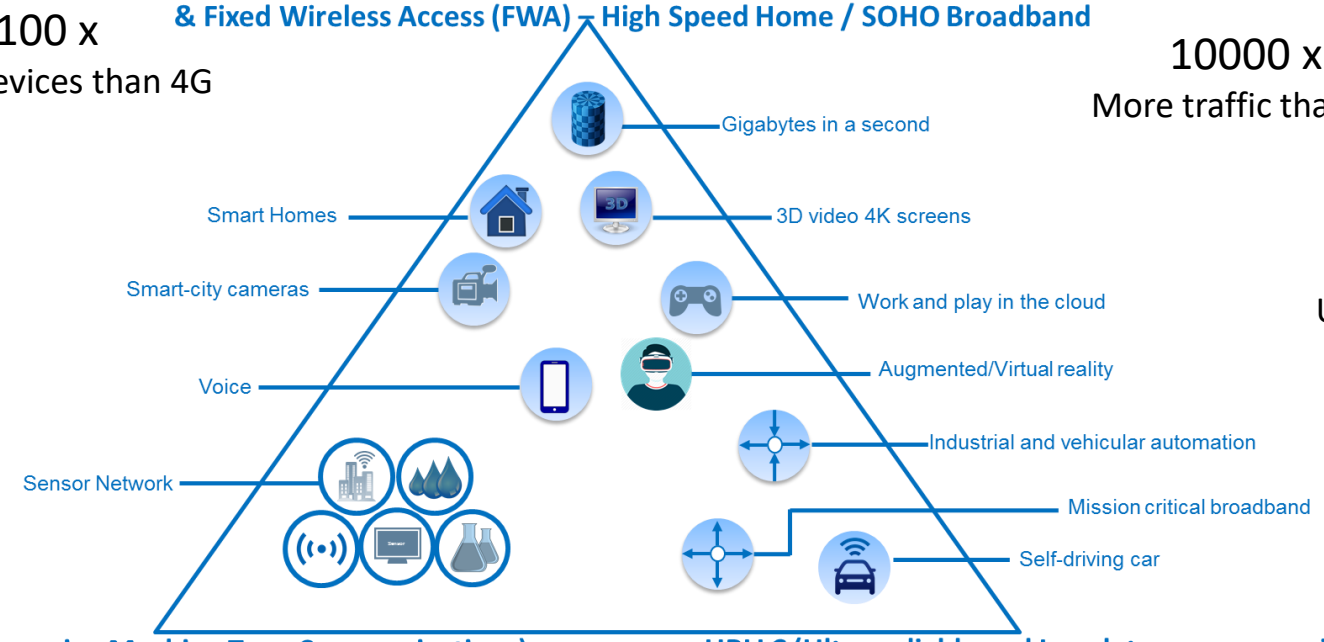
M2M
Ultra low cost

UR
Ultra-Reliable
(99.999%)

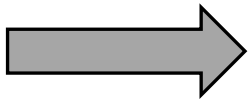
10 years
battery life

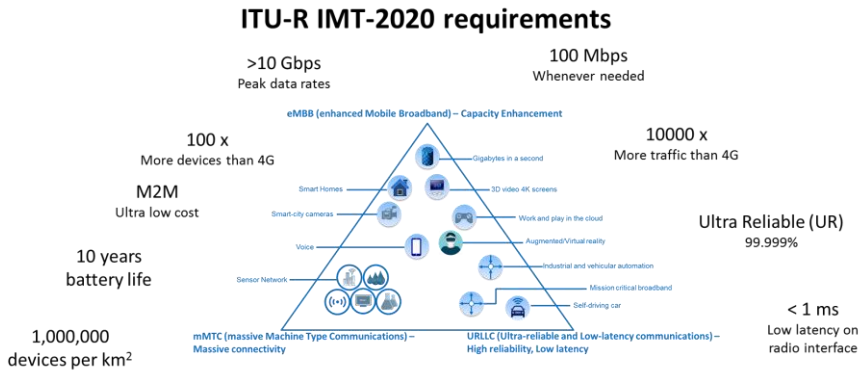
1,000,000
devices per km^2

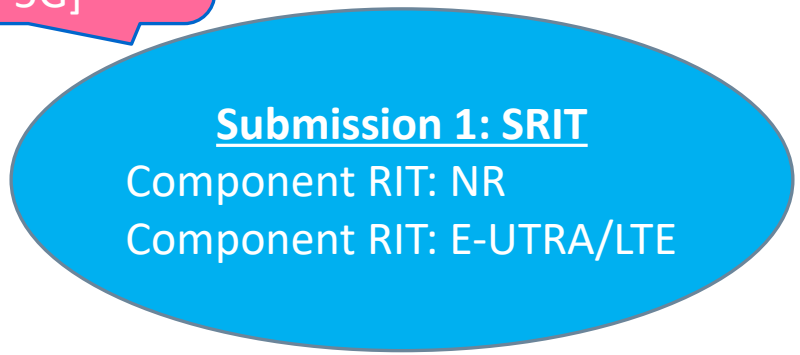
< 1 ms
Low latency on
radio interface

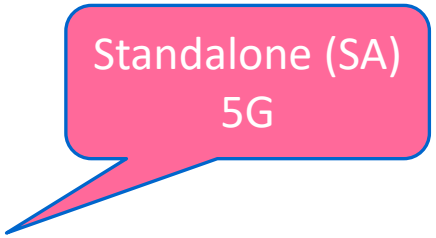


5G and IMT-2020









RIT = Radio Interface Technology
SRIT = Set of Radio Interface Technologies

Further Study on this topic

- Bandwidth, Throughput, Latency & Jitter in mobile networks (link)
- Reliability - 5x9s vs 6x9s (link)
- IMT-2020 (5G) Requirements (link)
- ITU-R FAQ on IMT (link)

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Part 4: Why is 5G called 5G

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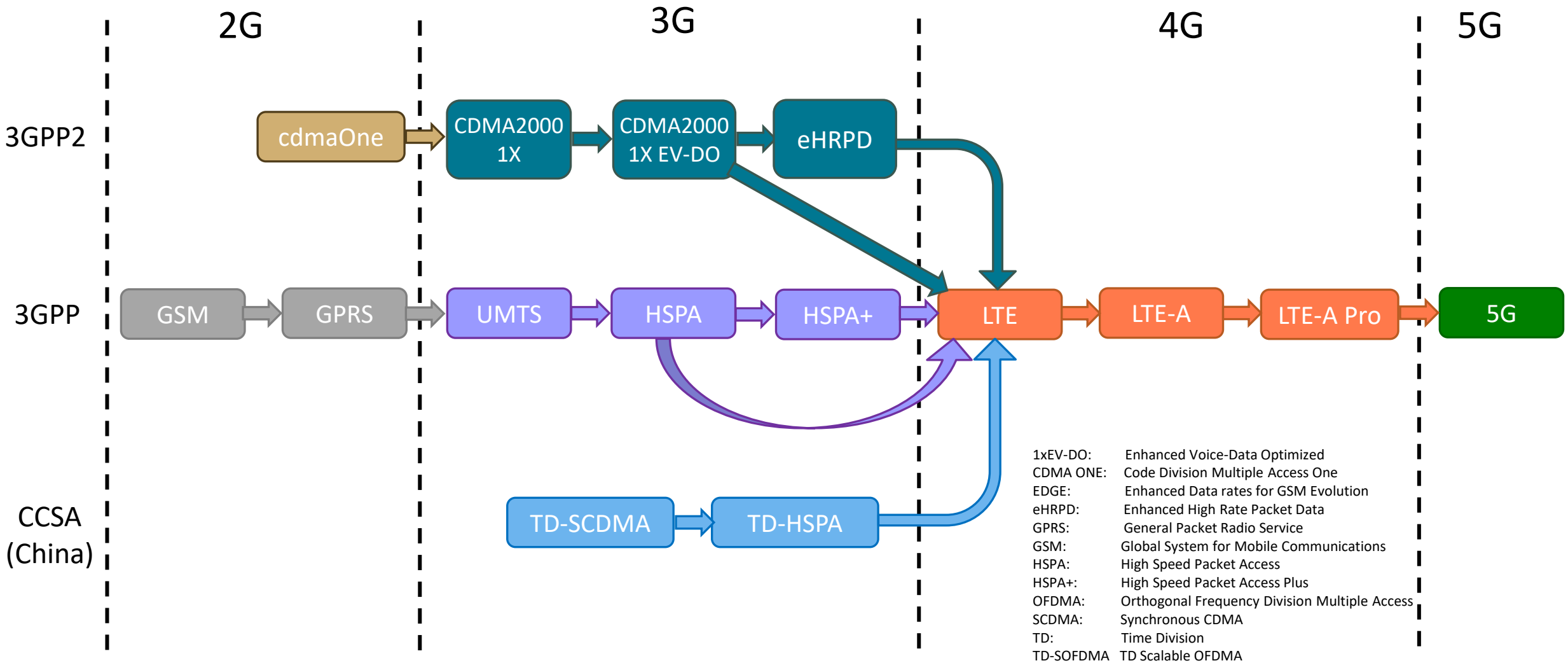
Standards Roadmap: All roads lead to LTE and 5G



1xEV-DO:	Enhanced Voice-Data Optimized
CDMA ONE:	Code Division Multiple Access One
EDGE:	Enhanced Data rates for GSM Evolution
eHRPD:	Enhanced High Rate Packet Data
GPRS:	General Packet Radio Service
GSM:	Global System for Mobile Communications
HSPA:	High Speed Packet Access
HSPA+:	High Speed Packet Access Plus
OFDMA:	Orthogonal Frequency Division Multiple Access
SCDMA:	Synchronous CDMA
TD:	Time Division
TD-SOFDMA	TD Scalable OFDMA
UMTS:	Universal Mobile Telecommunication System

3G, 4G & 5G Naming

Marketing Name	ITU Name	3GPP Name	RAN Name	Core Name	System Name
3G	IMT-2000	UMTS	UTRAN	UMTS Core	UMTS System
4G	IMT-Advanced	LTE-Advanced	E-UTRAN	Evolved Packet Core (EPC)	Evolved Packet System (EPS)
5G	IMT-2020	5G	New Radio (NR)	5G Core (5GC)	5G System (5GS)

Further Study on this topic

- Why is 5G called 5G? (link)
- 5G: A simple explanation (link)
- When will 2G & 3G be switched off now that 5G is here? (link)

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Part 5: 5G in Simple Words

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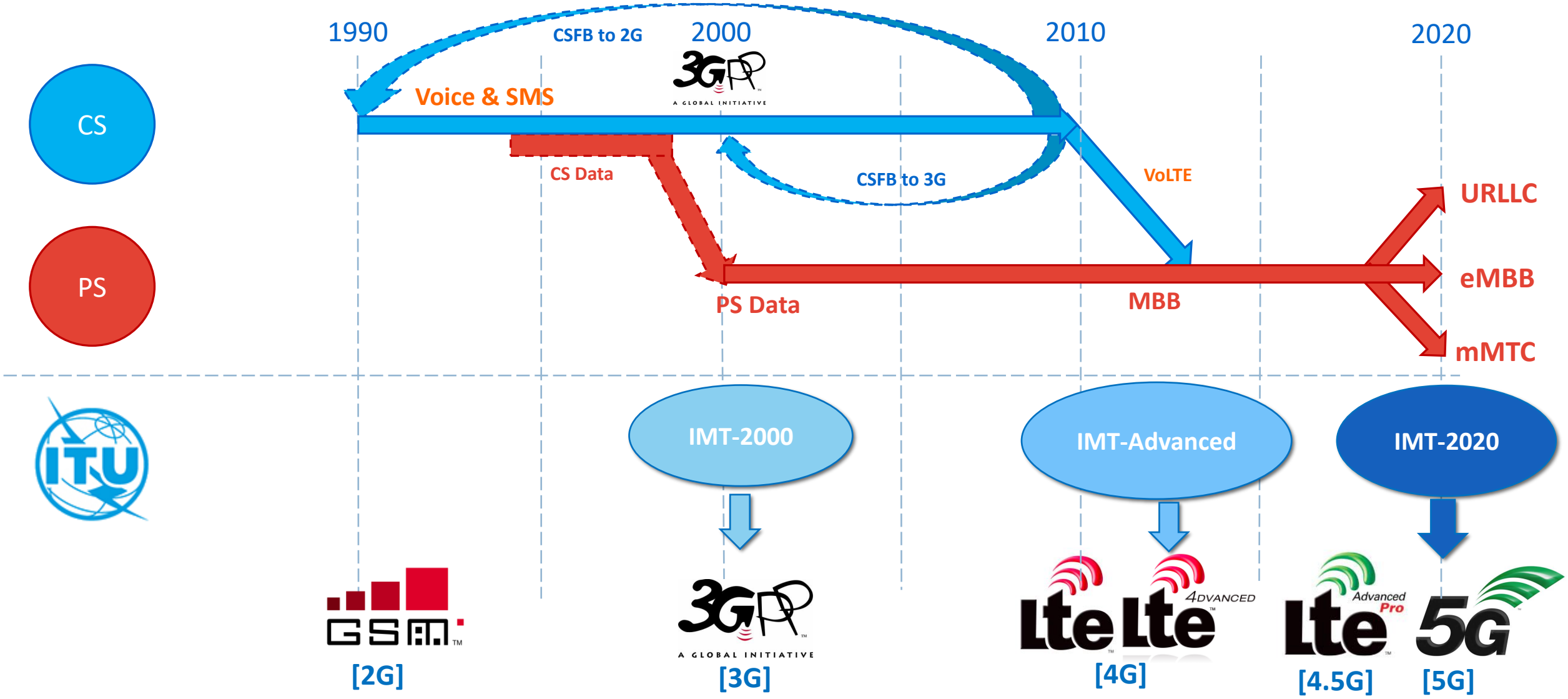
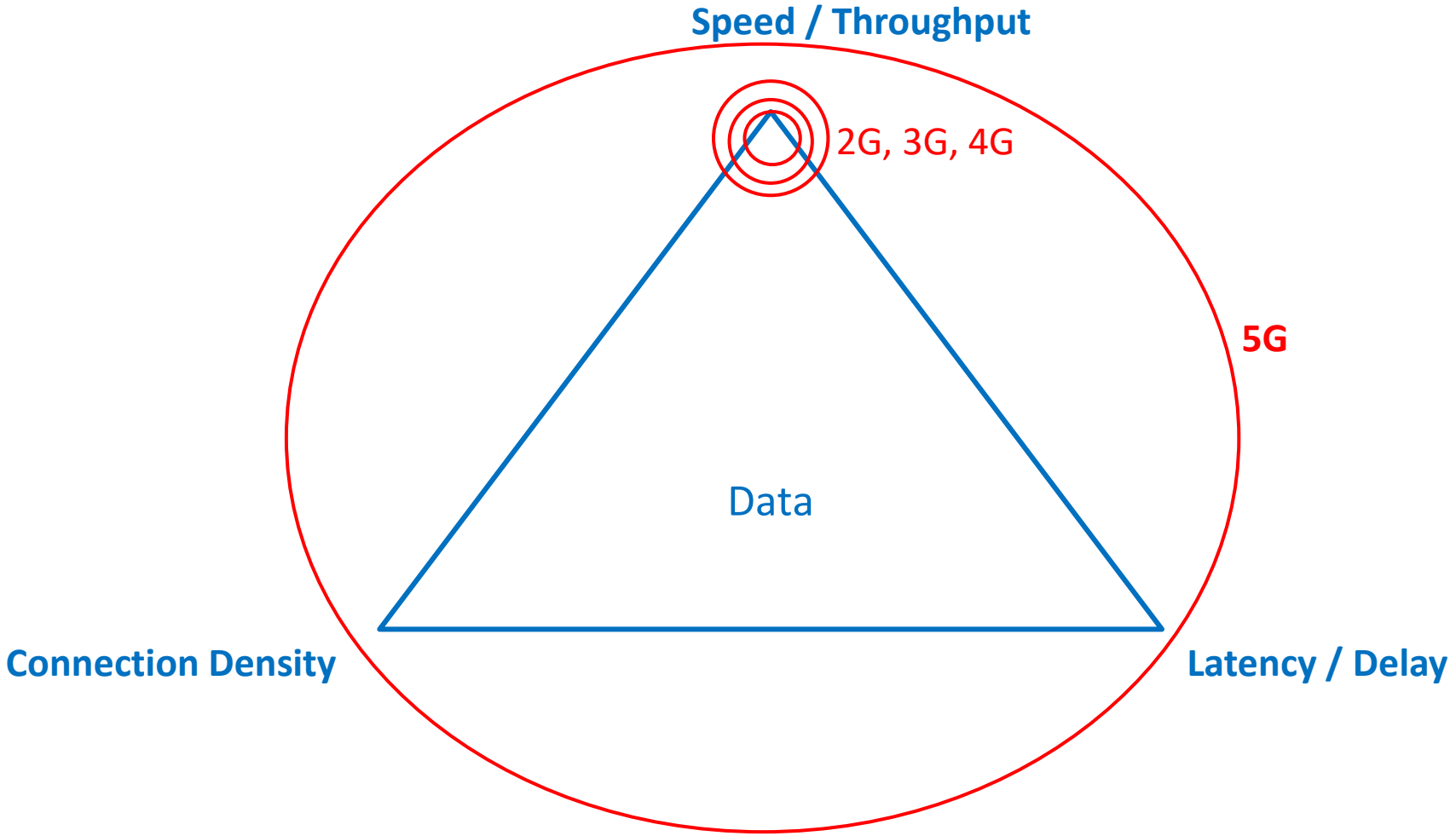
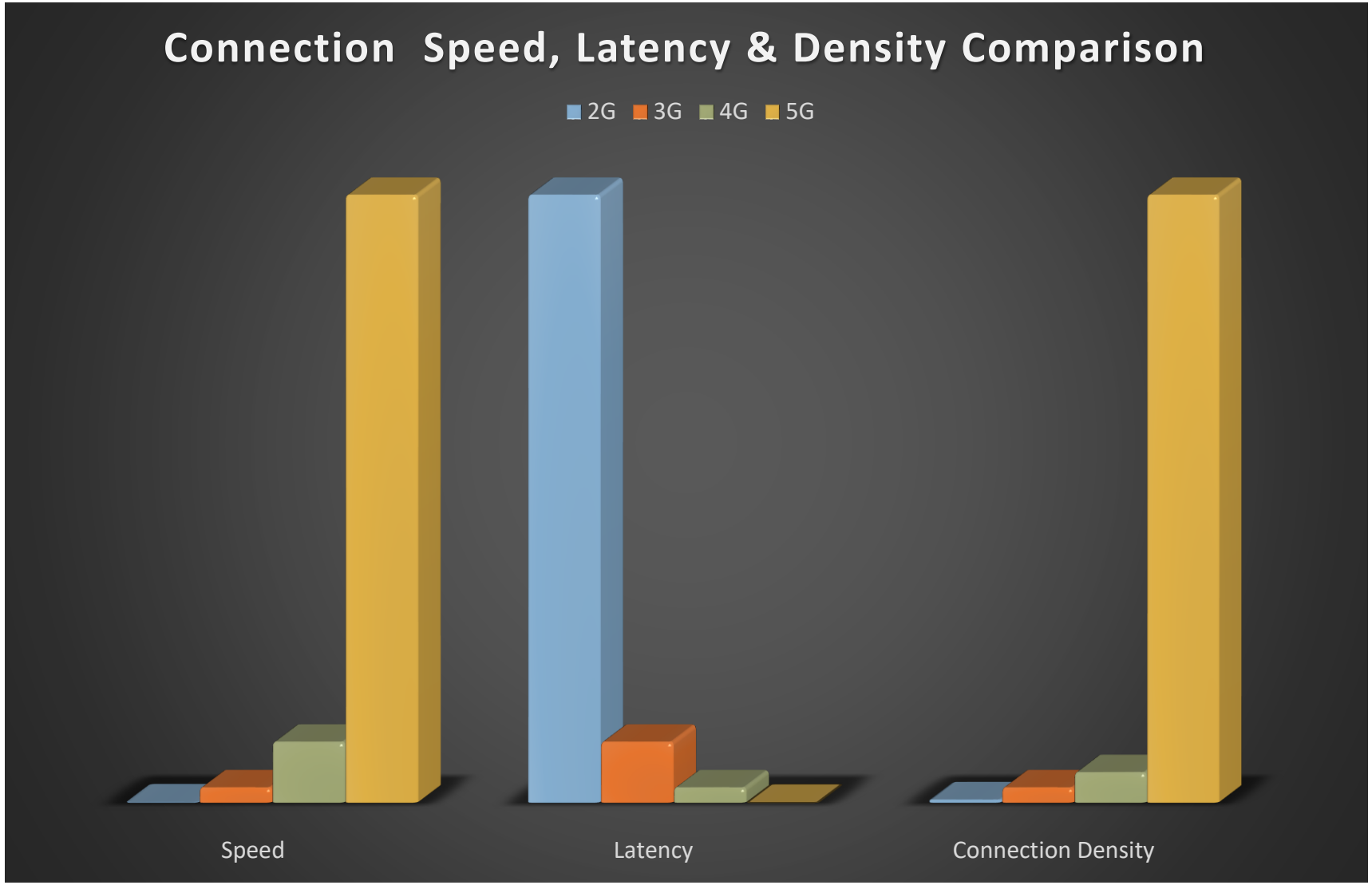
Evolution of Mobile Networks and ITU IMT Vision



Focus area for different technology generations

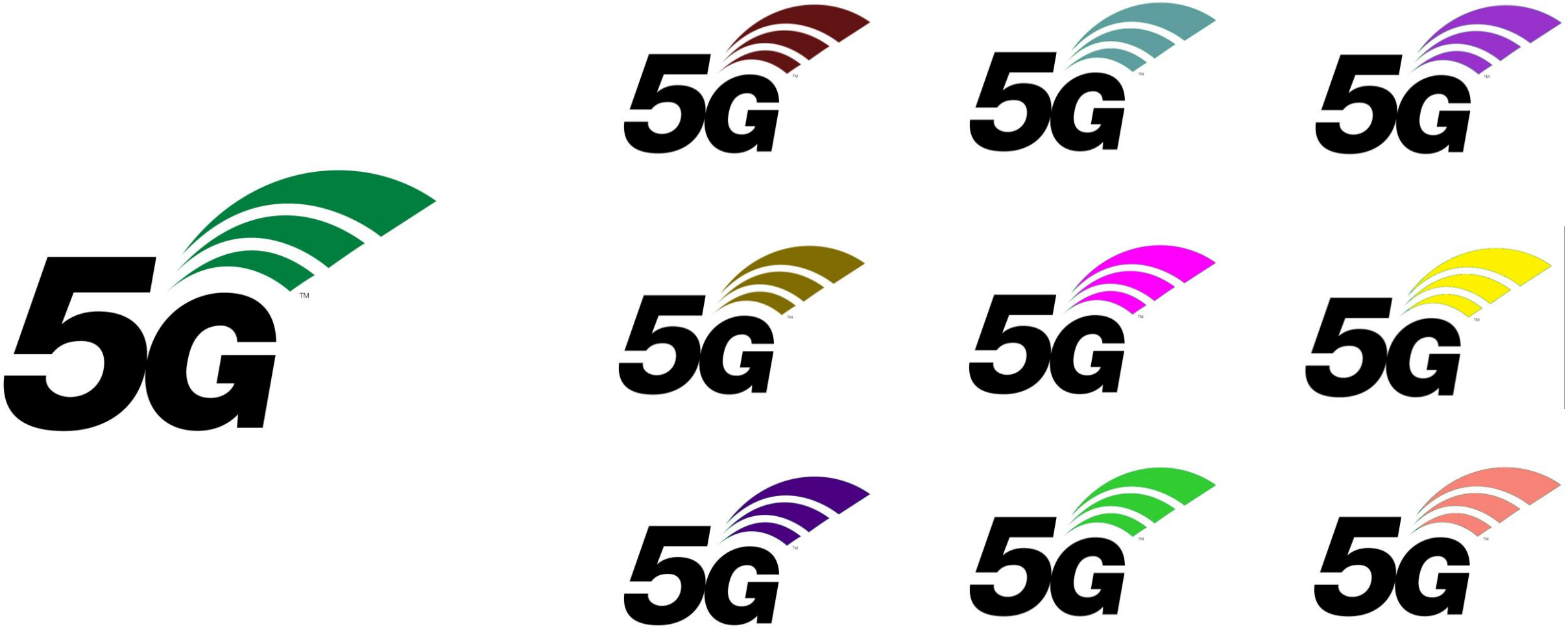


Comparison of 2G, 3G, 4G & 5G technologies



Example only.
Not according to scale

Different Flavours of 5G



Further Study on this topic

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- When will 2G & 3G be switched off now that 5G is here? (link)

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Part 6: Standalone and Non-Standalone 5G

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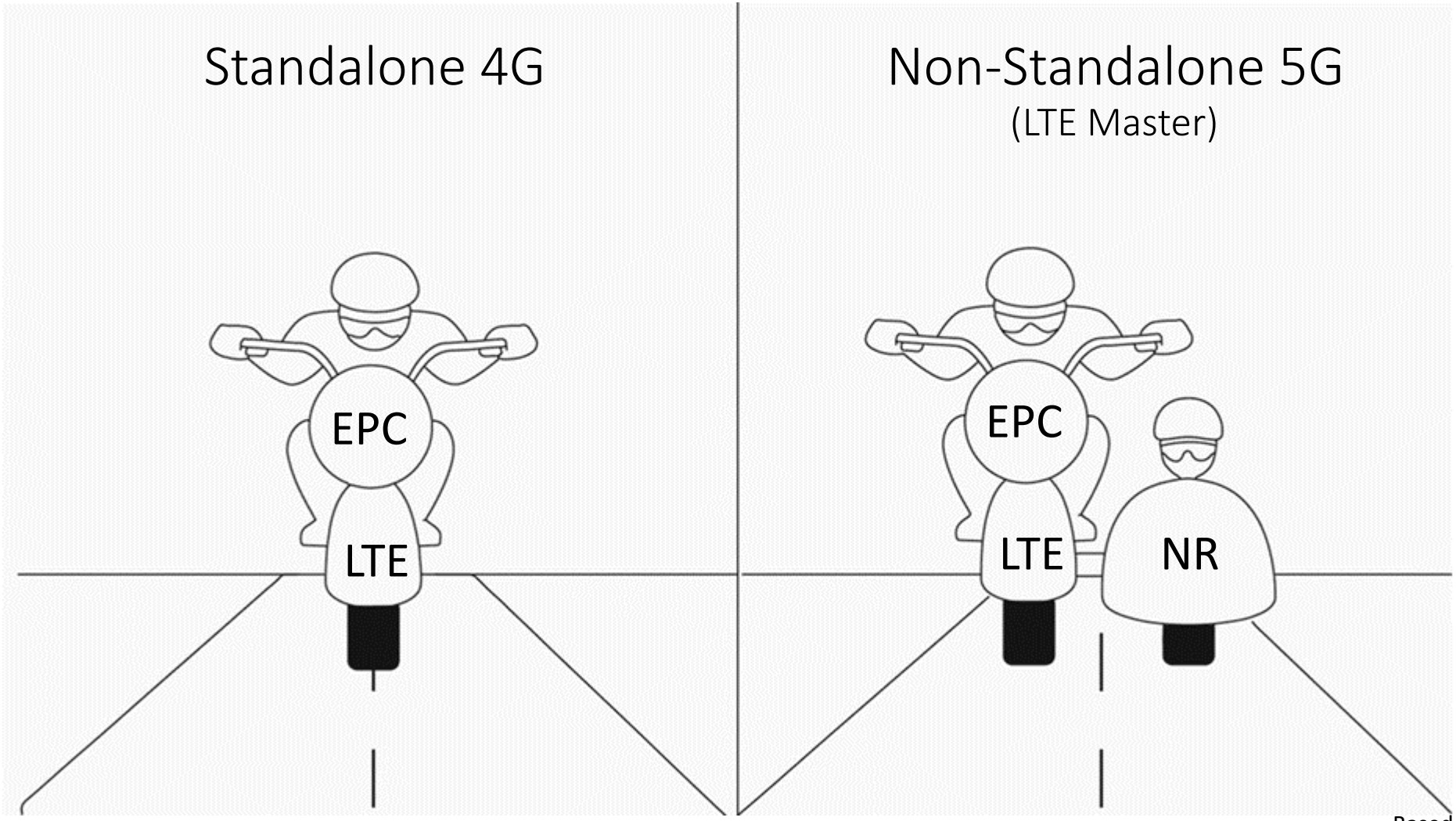
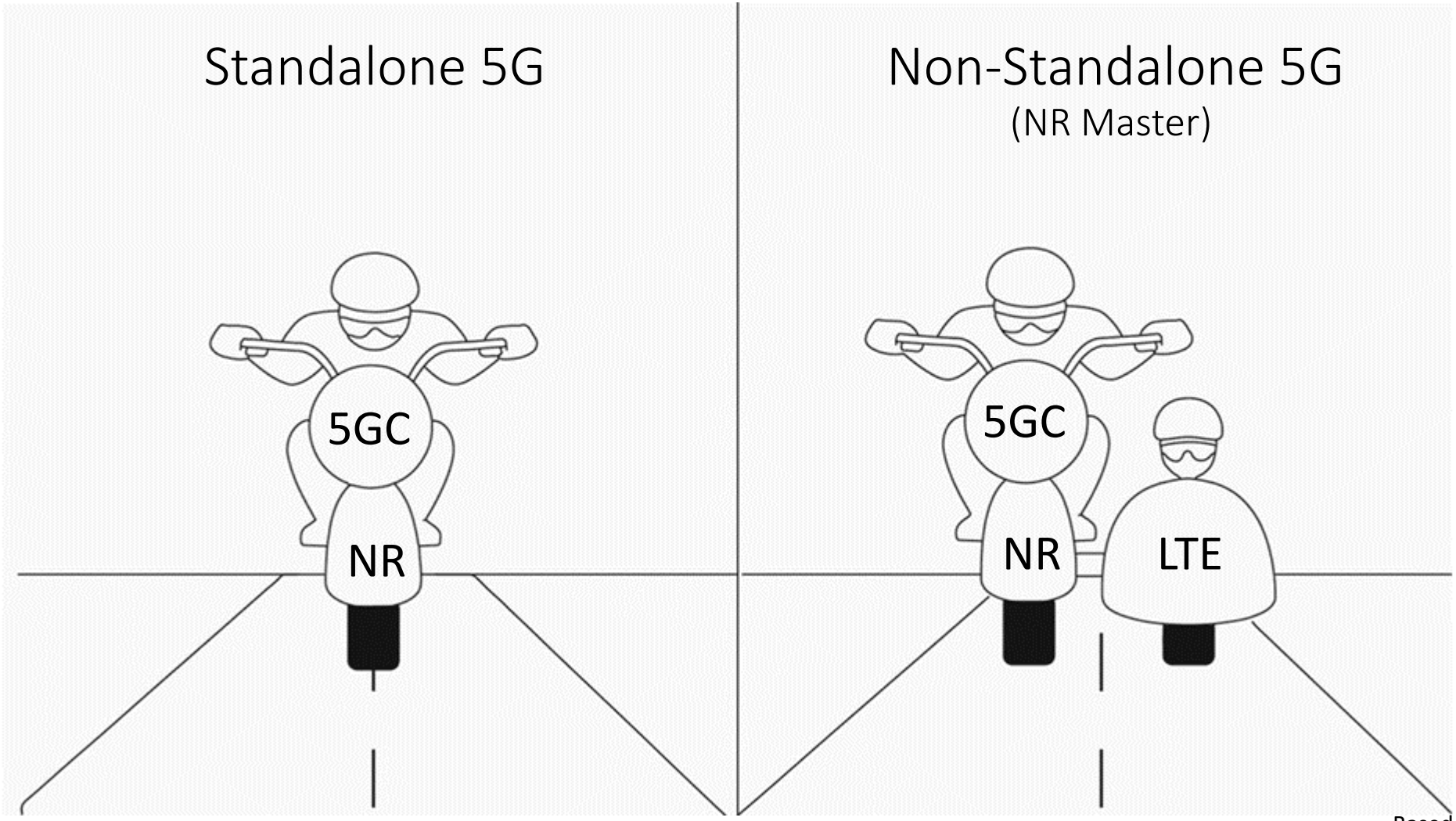
Standalone vs Non-Standalone



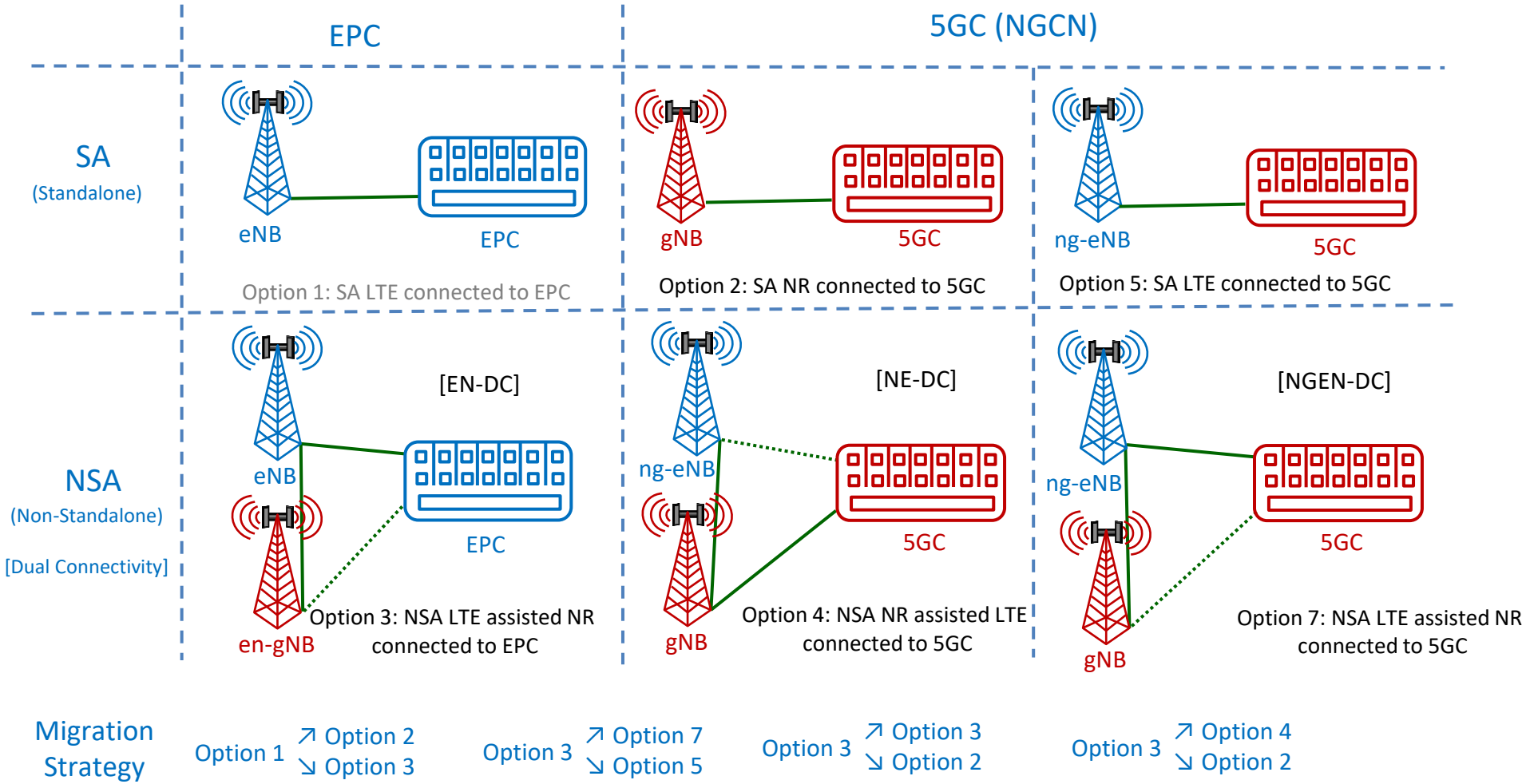
Based on original by Ericsson

Standalone vs Non-Standalone

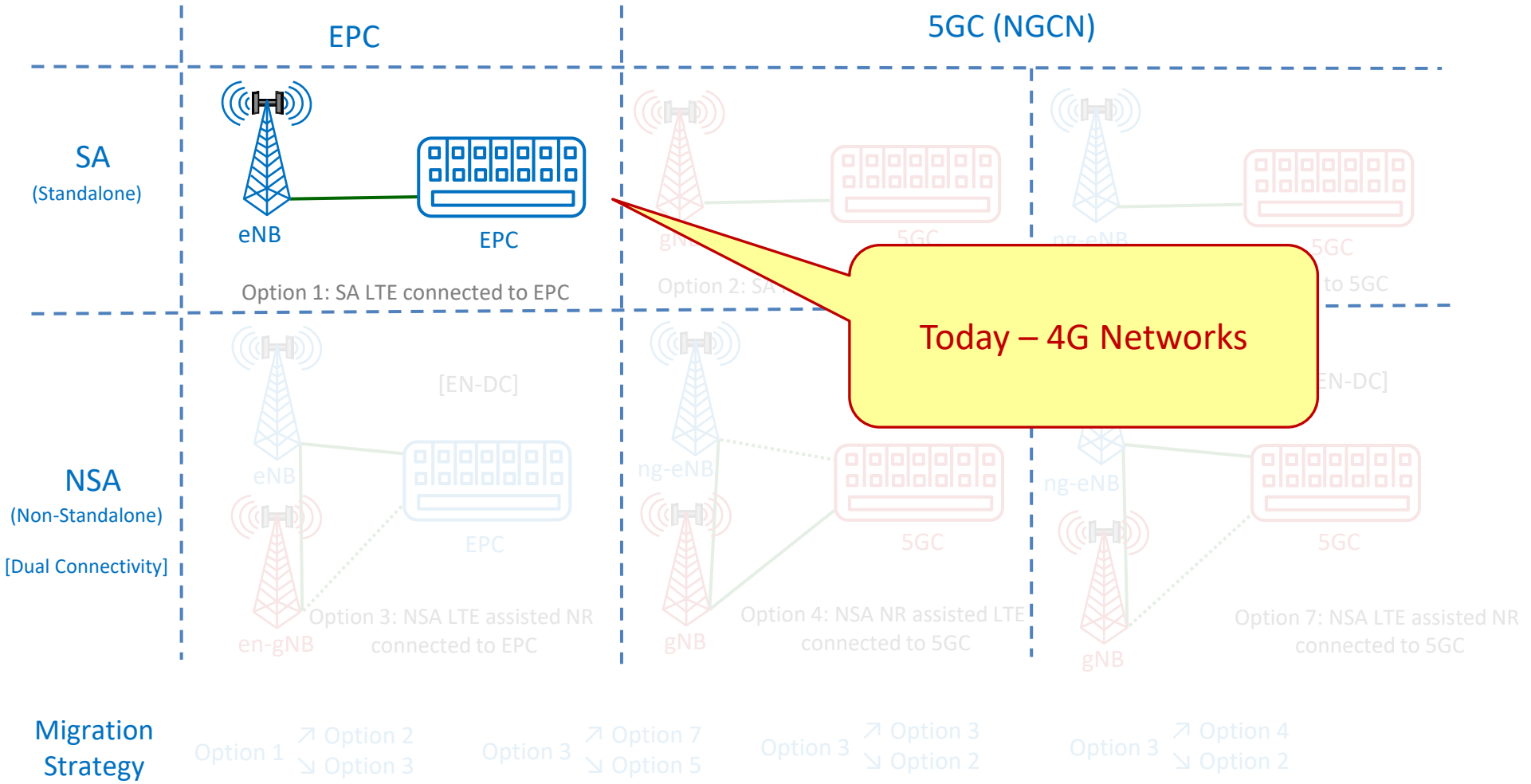


Based on original by Ericsson

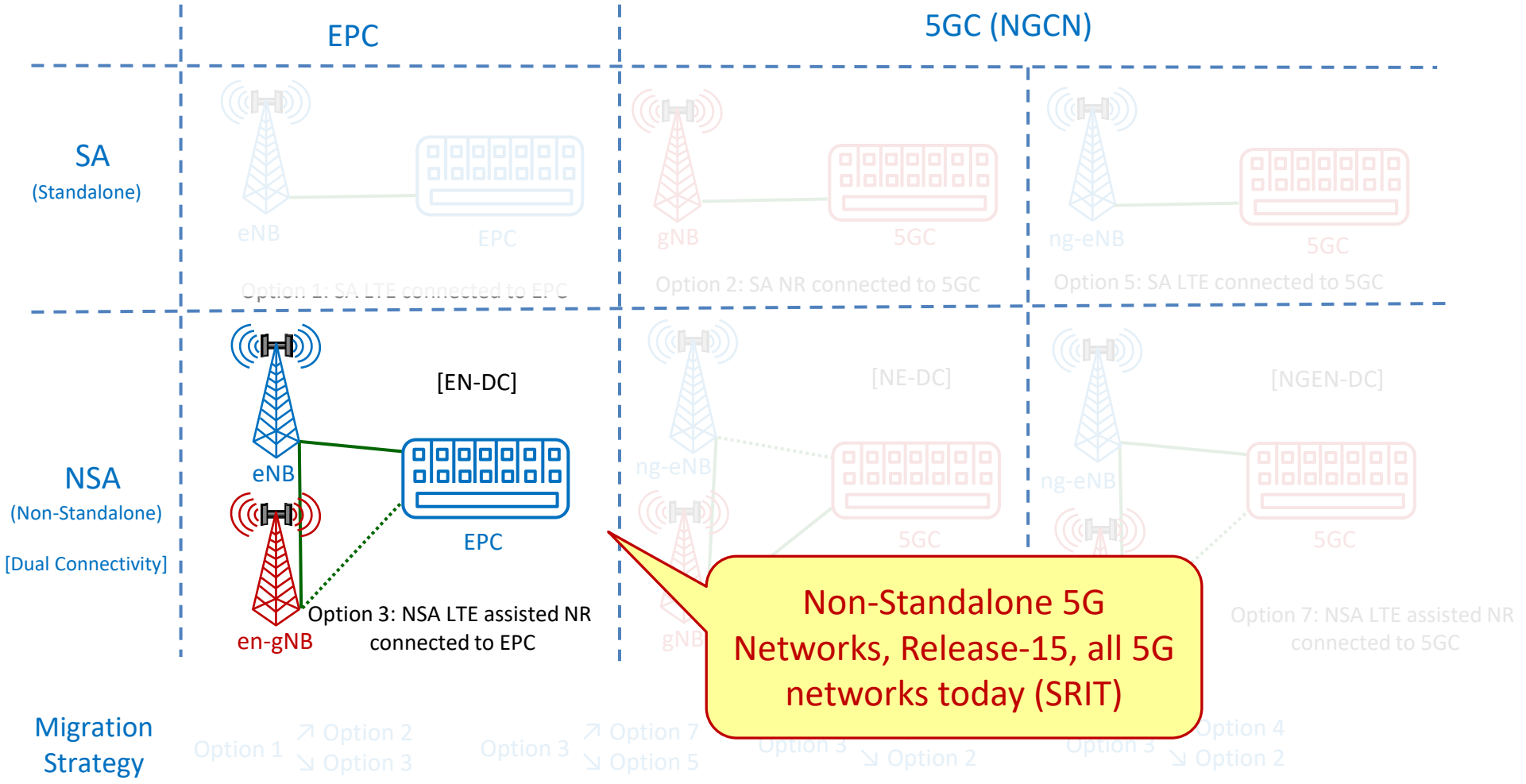
5G Deployment Options and Migration Strategy



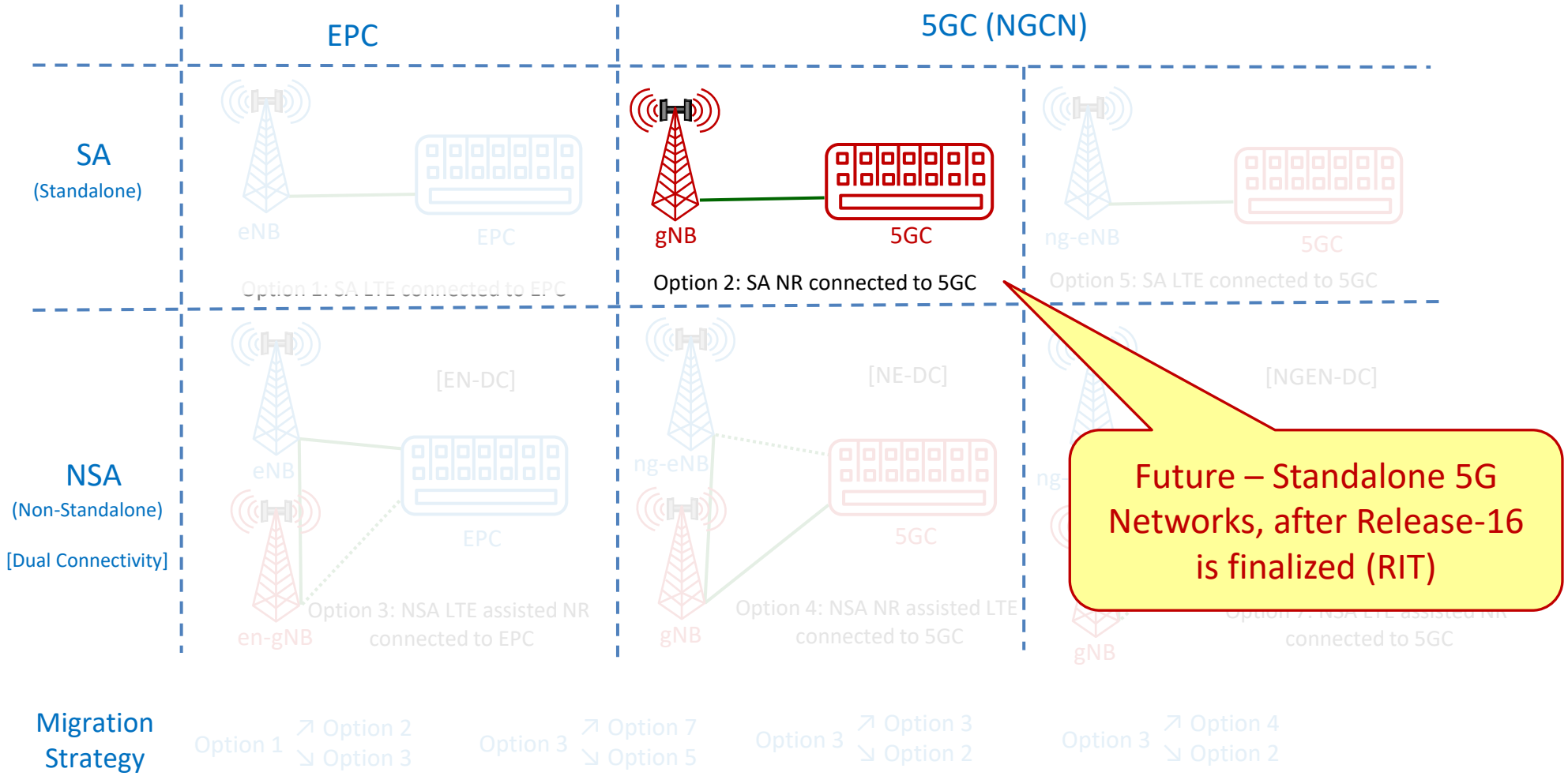
5G Deployment Options and Migration Strategy



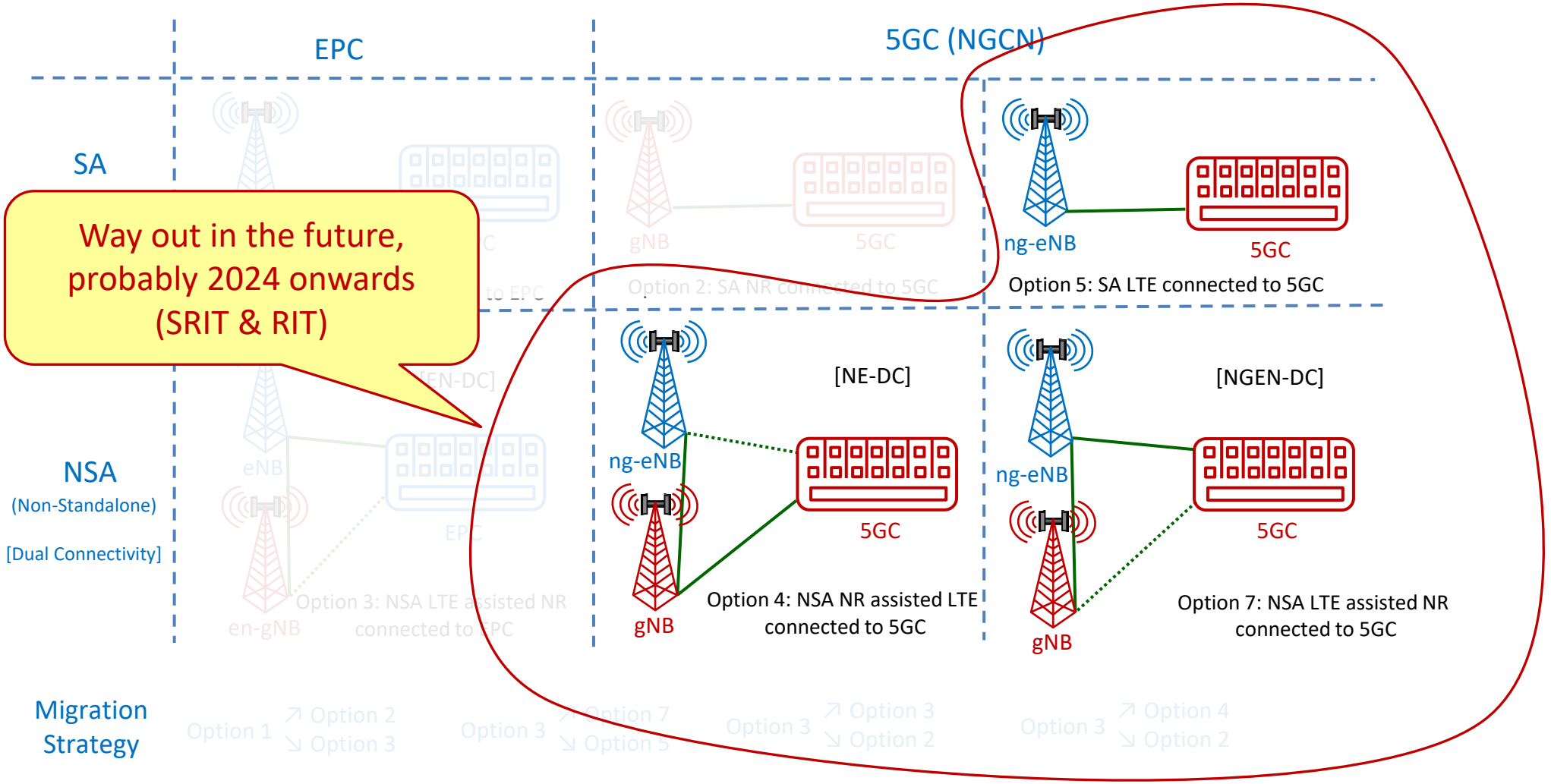
5G Deployment Options and Migration Strategy



5G Deployment Options and Migration Strategy



5G Deployment Options and Migration Strategy



Further Study on this topic

- 5G Terminology (link)
- 5G Network Architecture Options (link)

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Part 7: 3GPP Roadmap

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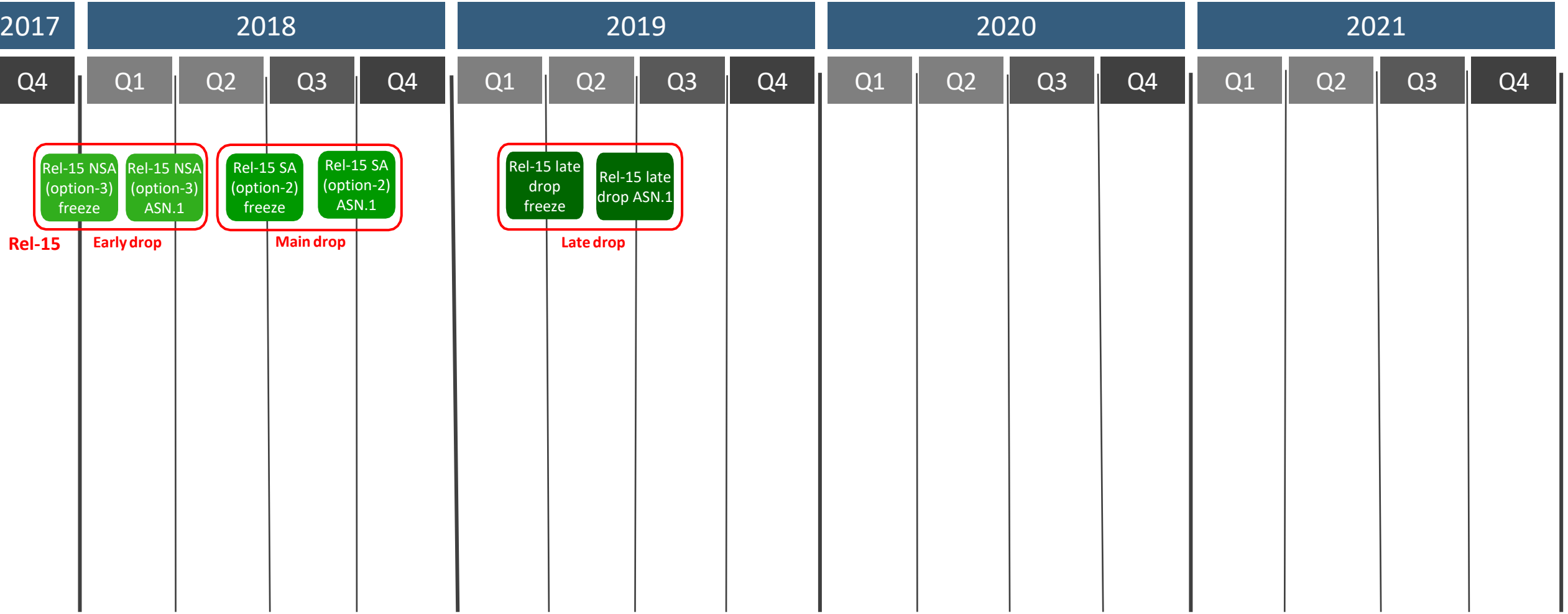
3GPP Standards Timeline – Revised Dec. 2019

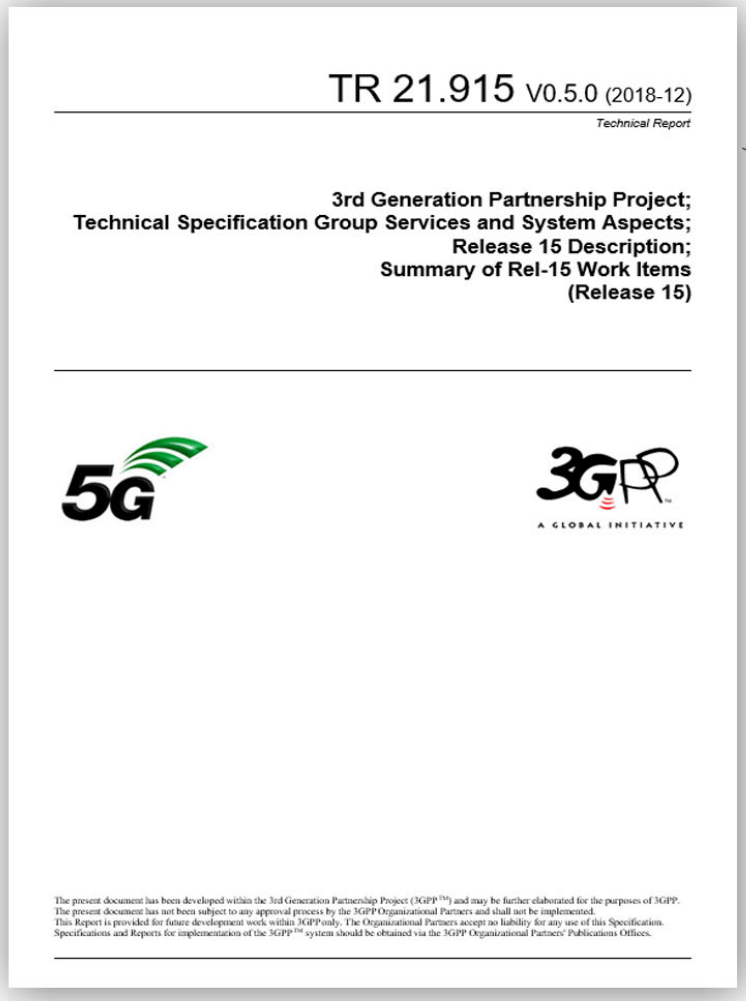


Designed by 3G4G, based on roadmap from 3GPP, Dec 2019

3GPP Release-15

Release 15

- NR
- The 5G System – Phase 1
- Massive MTC and Internet of Things (IoT)
- Vehicle-to-Everything Communications (V2x) Phase 2
- Mission Critical (MC) interworking with legacy systems
- WLAN and unlicensed spectrum use
- Slicing – logical end-2-end networks
- API Exposure – 3rd party access to 5G services
- Service Based Architecture (SBA)
- Further LTE improvements
- Mobile Communication System for Railways (FRMCS)



TR 21.915 V0.5.0 (2018-12)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Services and System Aspects;
Release 15 Description;
Summary of Rel-15 Work Items
(Release 15)

The present document has been developed within the 3rd Generation Partnership Project (3GPP™) and may be further elaborated for the purposes of 3GPP.
The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Report is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and Reports for implementation of the 3GPP™ system should be obtained via the 3GPP Organizational Partners' Publications Offices.

Source: 3GPP

See 3GPP Release Features and Study Items here

Rel-15

Includes work on:

- The 5G System - Phase 1
- Machine-Type of Communications (MTC) and Internet of Things (IoT)
- Vehicle-to-Everything Communications (V2X) Improvements
- Mission Critical (MC) improvements
- WLAN and unlicensed spectrum
- System enhancements
  - Control plane – user plane separation
  - Quality of Experience (QoE)
  - Security-related improvements
  - Virtual Reality (VR), TV, Codec and multimedia-related improvements
  - Codec and multimedia-related improvements
  - Active Antenna System (AAS)
  - OAM improvements

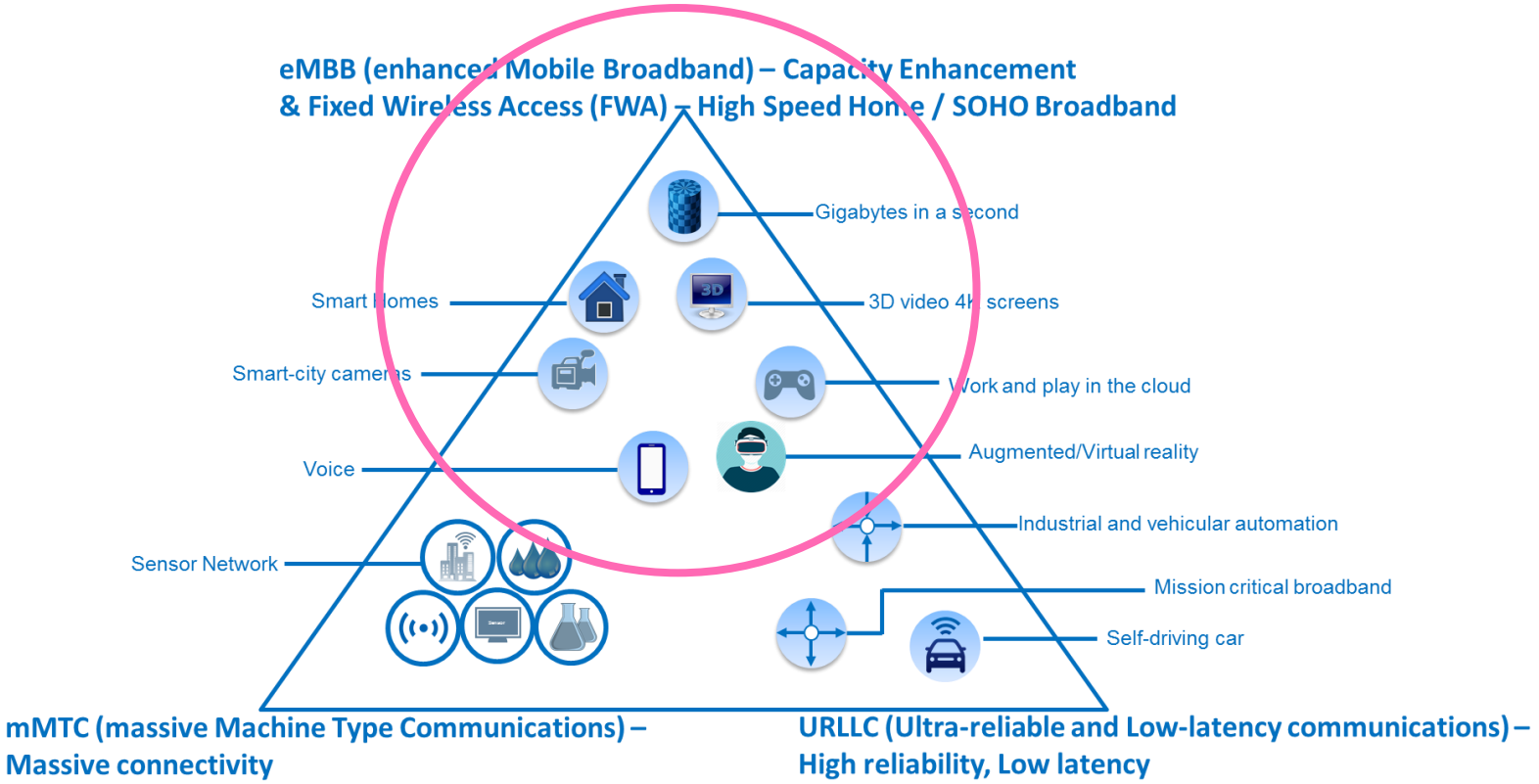
LTE improvements

- Further enhancements to Coordinated Multi-Point (CoMP) Operation for LTE
- Enhancements for high capacity stationary wireless link and introduction of 1024 QAM for LTE DL
- UE requirements for network-based CRS interference mitigation for LTE
- Bluetooth/WLAN measurement collection in LTE Minimization of Drive Tests (MDT)
- UL data compression in LTE
- UE Positioning Accuracy Enhancements for LTE
- UE requirements for LTE DL 8Rx antenna ports
- Shortened TTI and processing time for LTE
- Enhanced LTE Support for Aerial Vehicles

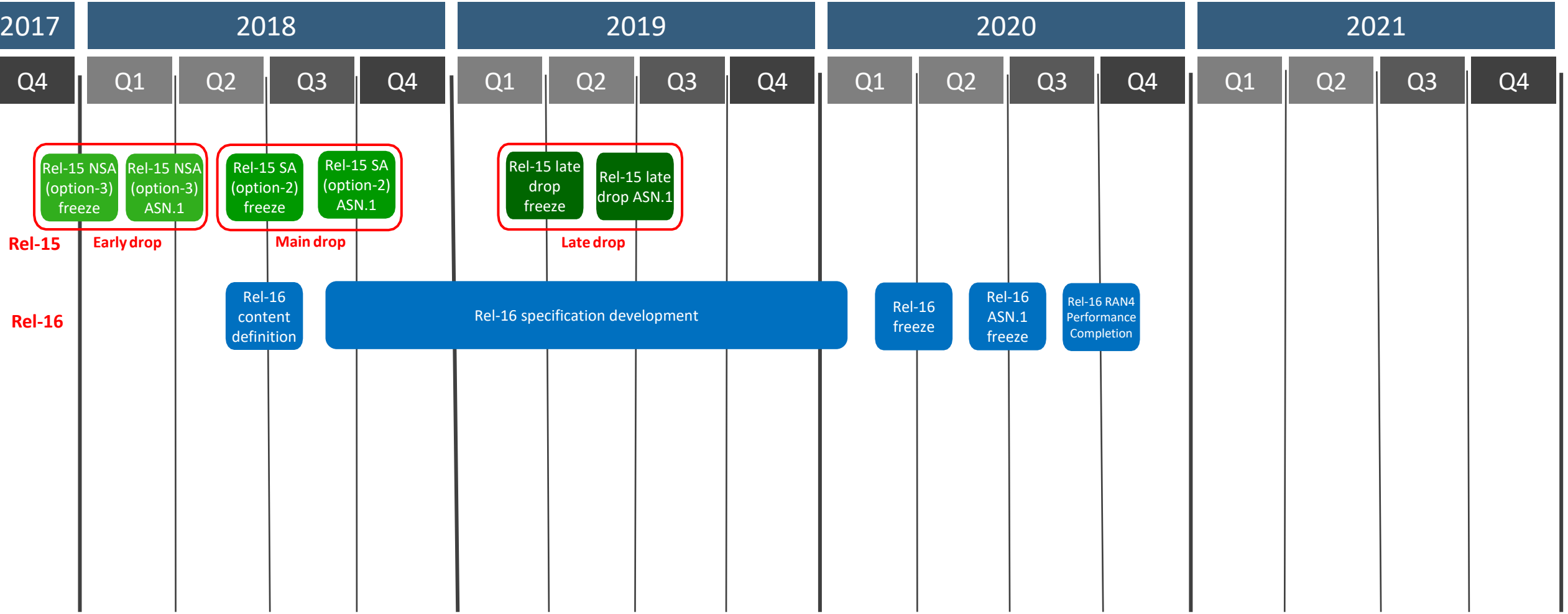
Other new features:

- Mobile Communication System for Railways
- Northbound APIs
- Remote UE access via relay UE

Release-15 Output: Focussed on eMBB & FWA support



3GPP Standards Timeline – Revised Dec. 2019

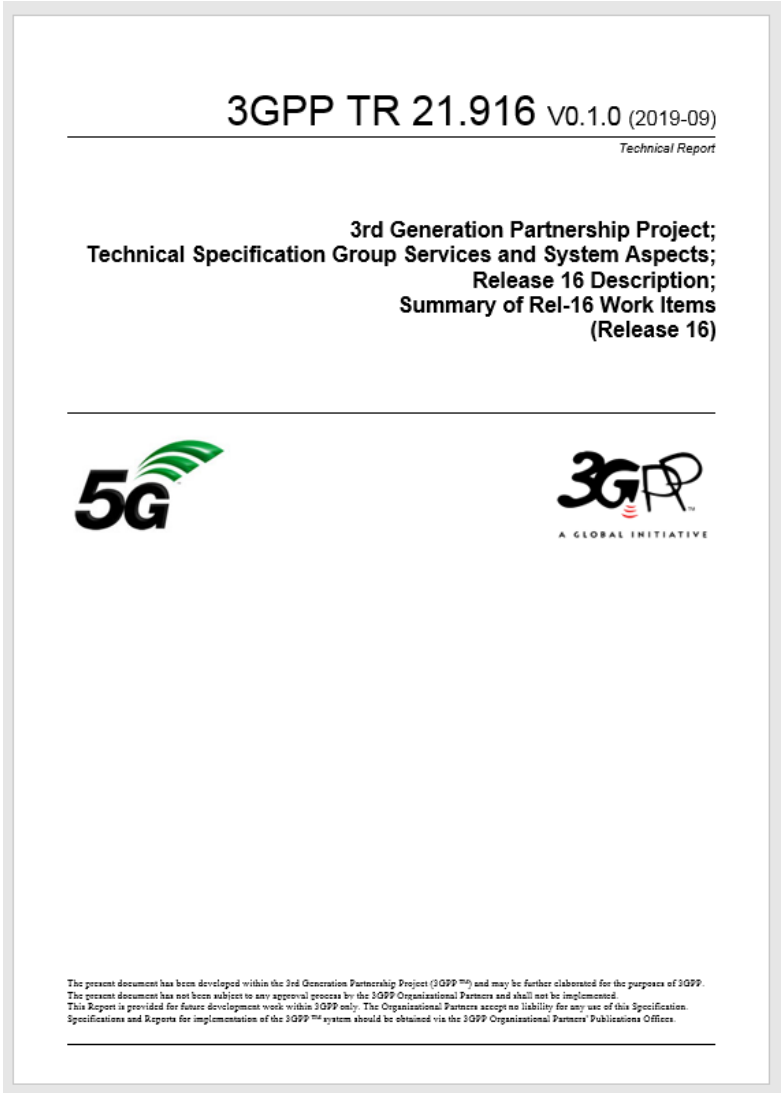


Designed by 3G4G, based on roadmap from 3GPP, Dec 2019

3GPP Release-16

Release 16

- **The 5G System – Phase 2**
- **V2x Phase 3:** Platooning, extended sensors, automated driving, remote driving
- **Industrial IoT**
- **Ultra-Reliable and Low Latency Communication (URLLC) enhancements**
- **NR-based access to unlicensed spectrum**
- **5G Efficiency:** Interference Mitigation, SON, eMIMO, Location and positioning, Power Consumption, eDual Connectivity, Device capabilities exchange, Mobility enhancements
- **Enhancements for Common API Framework for 3GPP Northbound APIs (eCAPIF)**
- **FRMCS Phase 2**



3GPP TR 21.916 V0.1.0 (2019-09)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Services and System Aspects;
Release 16 Description;
Summary of Rel-16 Work Items
(Release 16)

5G

3GPP
A GLOBAL INITIATIVE

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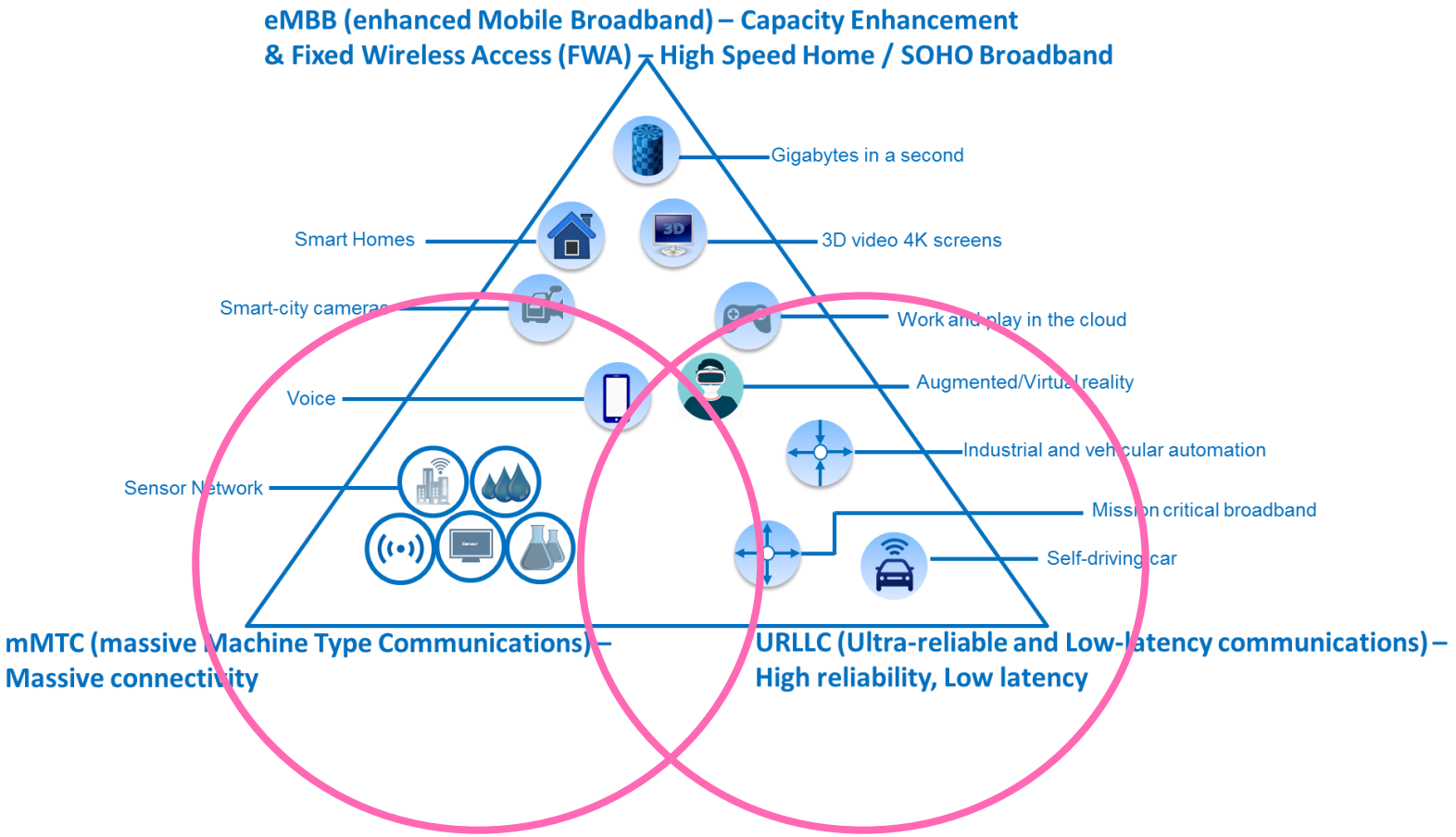
Work in Progress

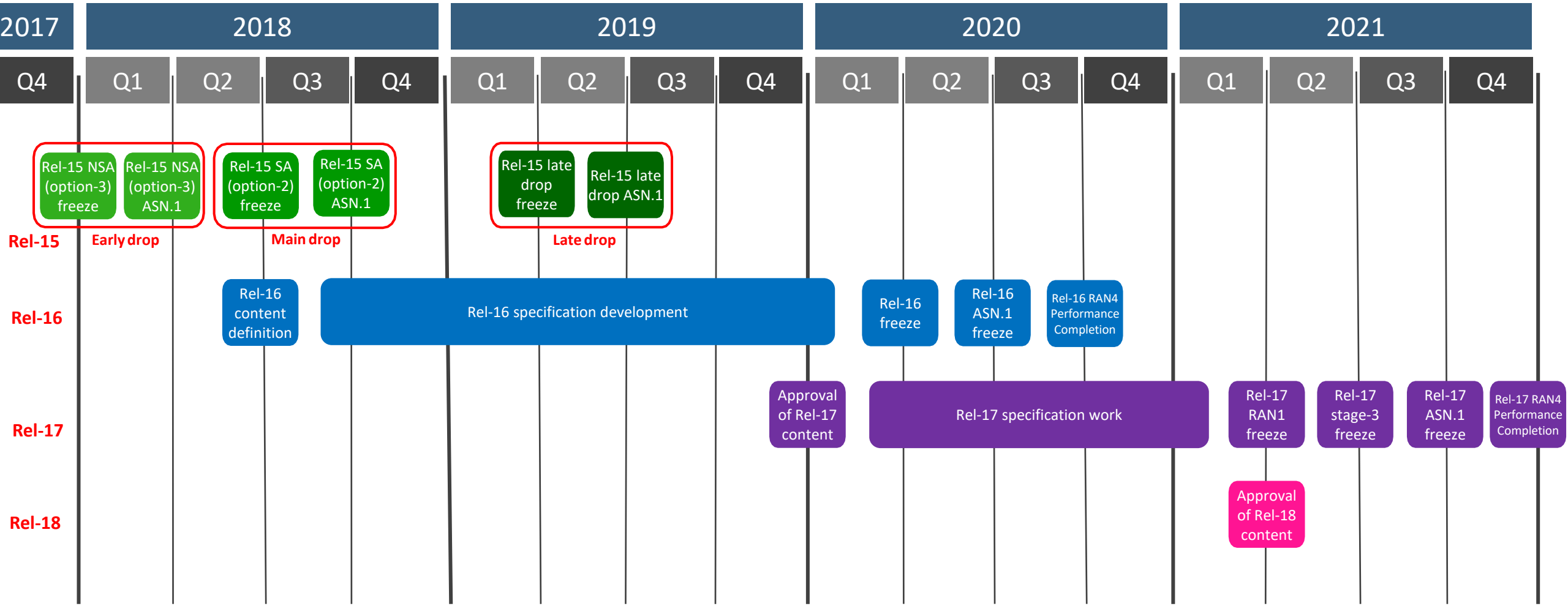
Source: 3GPP

See 3GPP Release Features and Study Items here

Release-16 Output: URLLC + mMTC (rebraded LTE-M/NB-IoT)



3GPP Standards Timeline – Revised Dec. 2019



Designed by 3G4G, based on roadmap from 3GPP, Dec 2019

3GPP Release-17

Release 17 Content Approval*

TSG SA Work Areas under discussion at SA#85 (September 2019):

- 5G System Enhancement for Advanced Interactive Services (5G_AIS)
- Cellular IoT enhancement for the 5G System (5G_MCIoT)
- System enhancement for Proximity based Services in 5GS (5G_ProSe)
- Enhancement of support for 5G LAN-type service (5GLAN_enh)
- Integration of Satellite in 5G Systems (5GSAT_ARCH)
- Architectural enhancements for 5G multicast-broadcast services (5MBS)
- Study on enhancement of support for 5G Wireless and Wireline Convergence (5WWC_enh)
- Application Awareness Interworking between LTE and NR (AAI_LTE_NR)
- Extended Access Traffic Steering, Switch and Splitting support in the 5G system architecture (eATSSS)
- 5G Enhancement for unmanned aerial vehicles - UAVs (EAV)
- Enhanced IMS to 5GC Integration (eIMS5G)
- Enhancement to the 5GC LoCation Services-Phase 2 (eLCS_ph2)
- Enablers for Network Automation for 5G - phase 2 (eNA_Ph2)
- Enhancement of support for Edge Computing in 5GC (enh_EC)
- Enhanced support of Non-Public Networks (eNPN)
- Enhancement of Network Slicing Phase 2 (eNS_Ph2)
- Enhancement of 5G UE Policy (eUEPO)
- Architecture enhancements for 3GPP support of advanced V2X services - Phase 2 (eV2XARC_Ph2)
- Supporting Flexible Local Area Data Network (FLADN)
- Supporting Unmanned Aerial Systems Connectivity, Identification and Tracking (ID-UAS)
- Enhanced support of Industrial IoT - TSC/URLLC enhancements (IIoT)
- Support for Minimization of service Interruption (MINT)
- Multimedia Priority Service Phase 2 (MPS2)
- Support for Multi-USIM Devices (MUSIM)
- System architecture for next generation real time communication services (NG_RTC)
- Service-based support for SMS in 5GC (SB_SMS)
- Smarter User Plane (SUP)
- UPF enhancement for control and Service Based Architecture (UPCAS)
- Usage of User Identifiers in the 5G System (UUI5)

TSG RAN Work Areas under discussion For final decision at RAN#86 (December 2019):

- NR Light
- Small data transfer optimization
- Sidelink enhancements
- NR above 52.6 GHz (inlc 60GHz unlicensed)
- Multi SIM operation
- NR multicast broadcast
- Coverage enhancements
- NB-IoT and eMTC enhancements
- Industrial IoT & URLLC enhancements
- MIMO enhancements
- NR for Non Terrestrial Networks
- Integrated Access and Backhaul enhancements
- Generic enhancements to NR-U
- Power saving enhancements
- RAN data collection enhancements
- Positioning enhancements

* *Mainstream Rel-17 specification work will start at the beginning of 2020, with the functional freeze of physical layer aspects scheduled for the second quarter of 2021.*

The ASN.1 freeze should follow in September 2021.

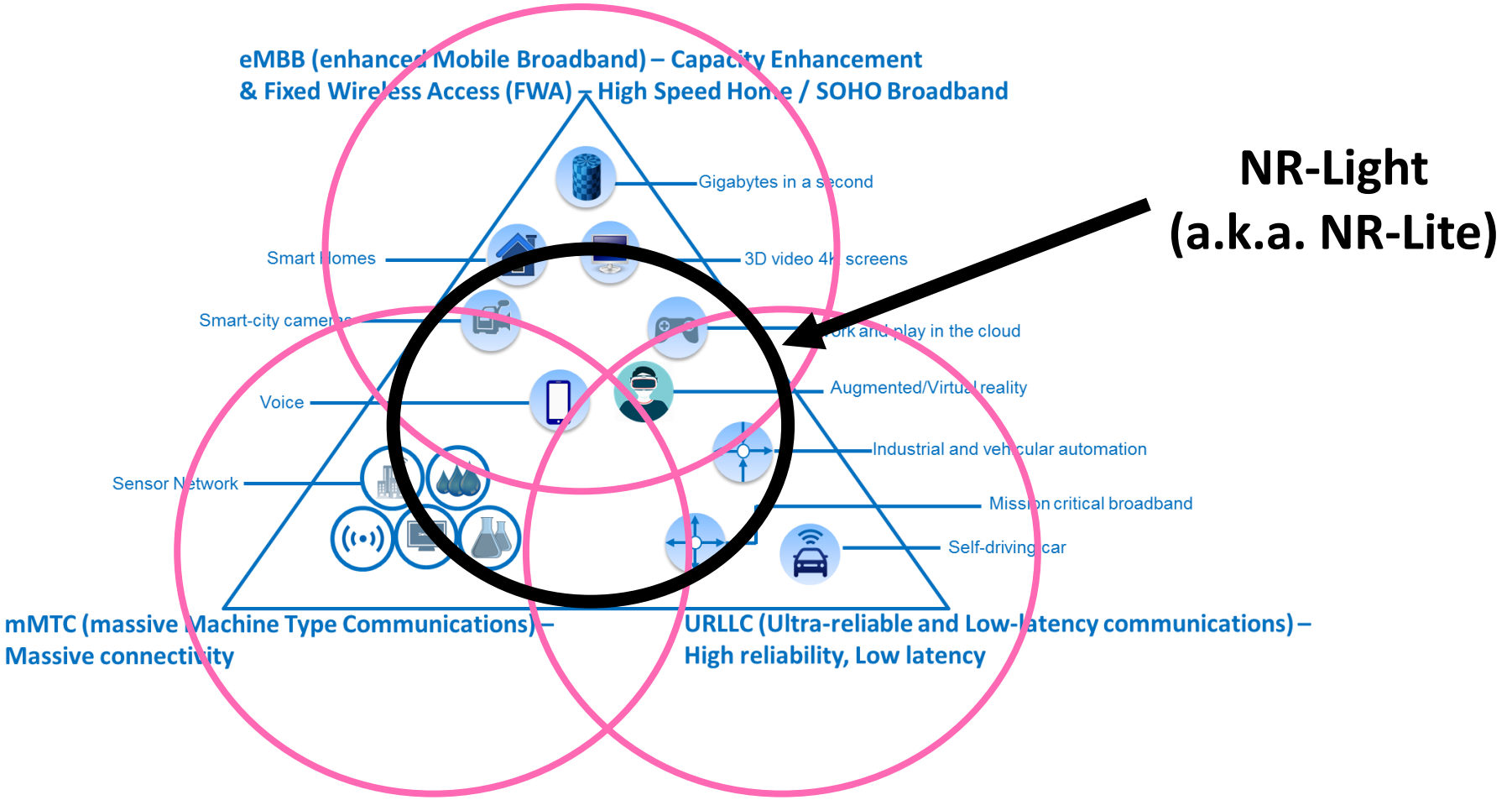
There are a large number of work areas to be discussed. Realistically, we will only be able to take on board a sub-set of them within Rel-17.

Approved Sep. 2019

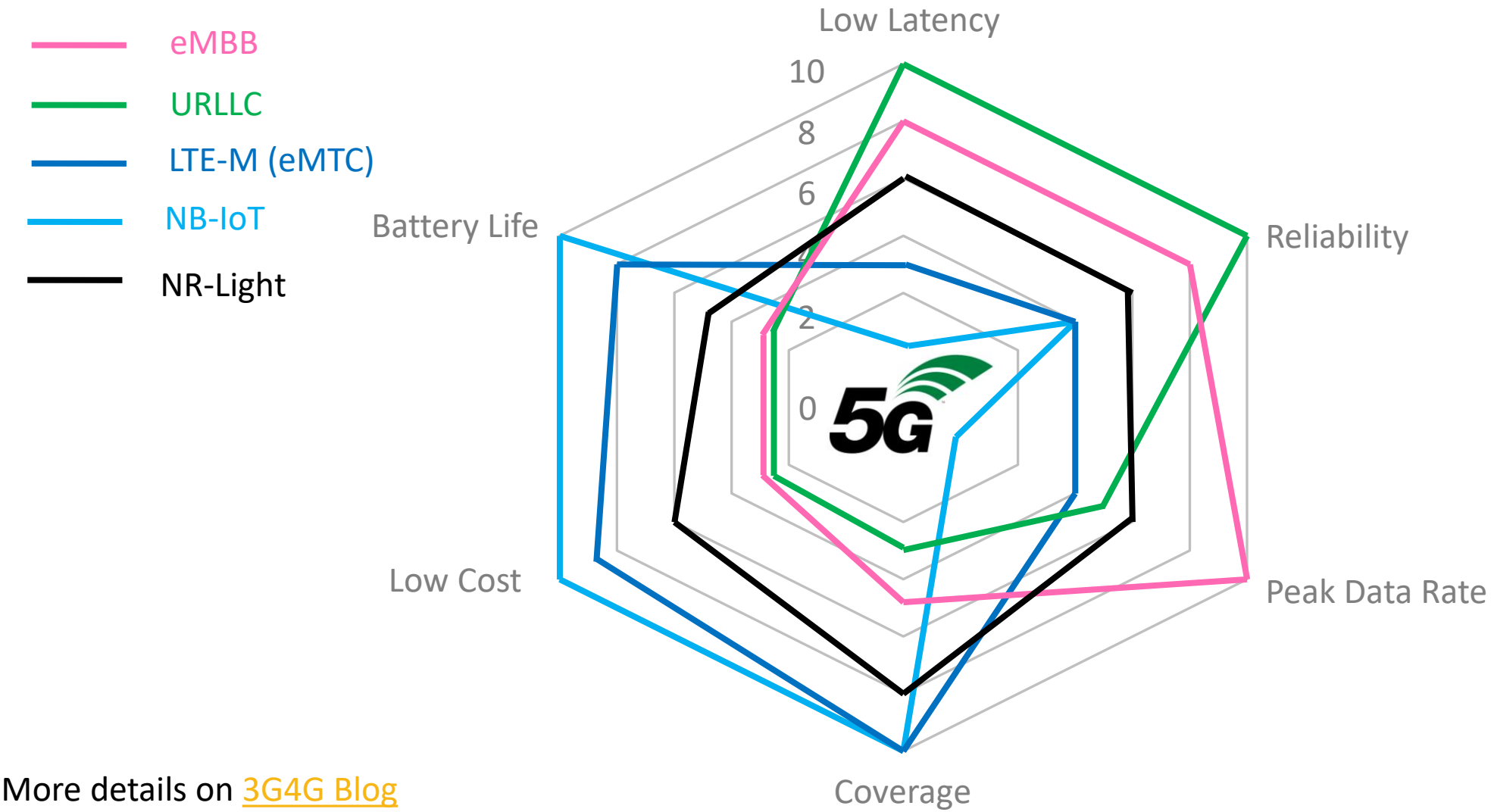
Source: 3GPP

See 3GPP Release Features and Study Items here

Release-17: Motivation for NR-Light

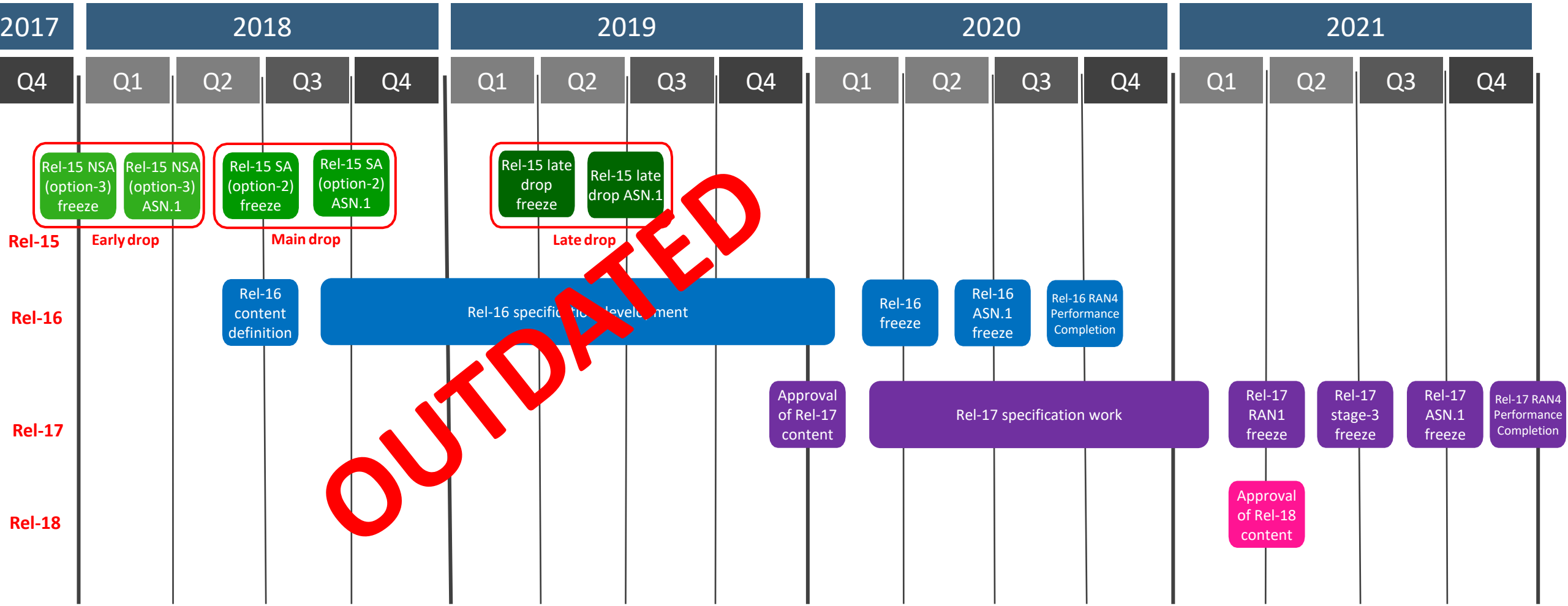


5G Spider Diagram Combined with NR-Light



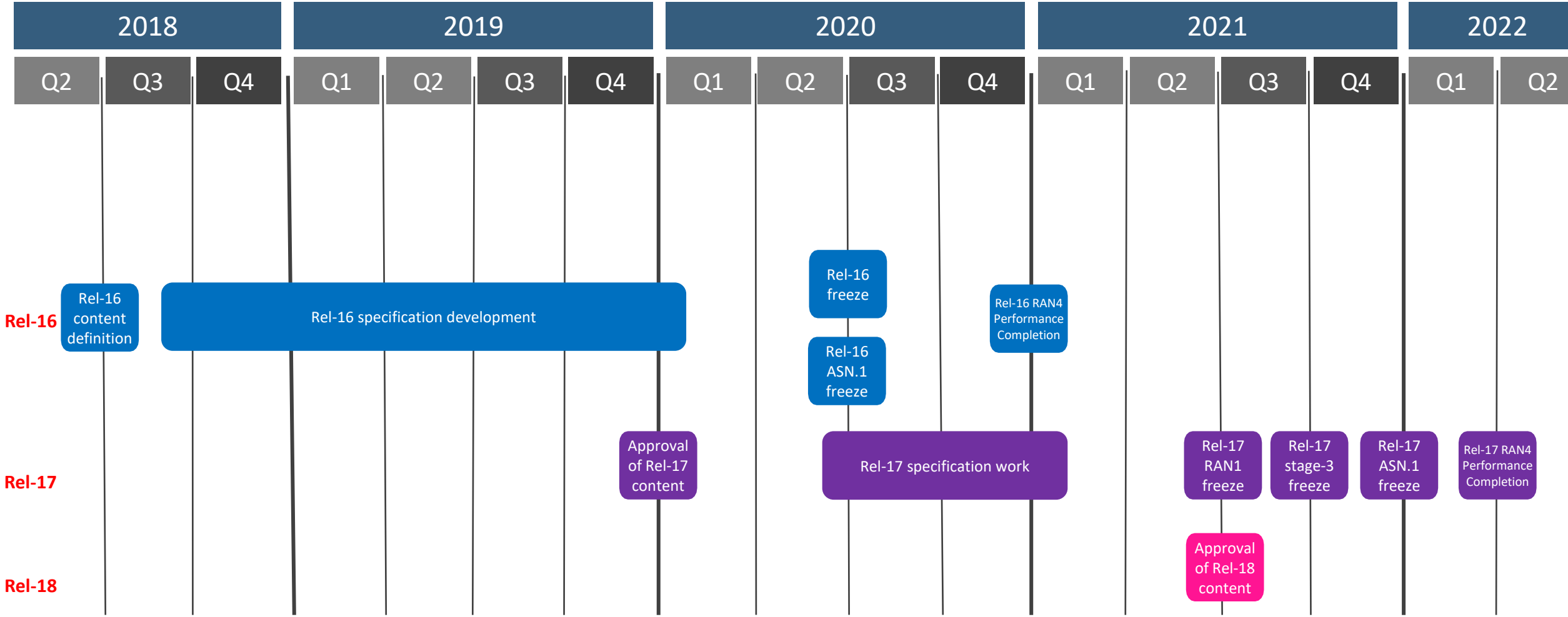
More details on [3G4G Blog]

3GPP Standards Timeline – Revised Dec. 2019



Designed by 3G4G, based on roadmap from 3GPP, Dec 2019

3GPP Standards Timeline – Revised Mar. 2020



Designed by 3G4G, based on roadmap from 3GPP, Mar 2020

Further Study on this topic

- 3GPP Release 15 (link)
- 3GPP Release 16 (link)
- 3GPP Release 17 (link)
- 3GPP 5G Specifications (link)
- Introduction to NR-Light a.k.a. NR-Lite (link)

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Part 8: 5G Spectrum

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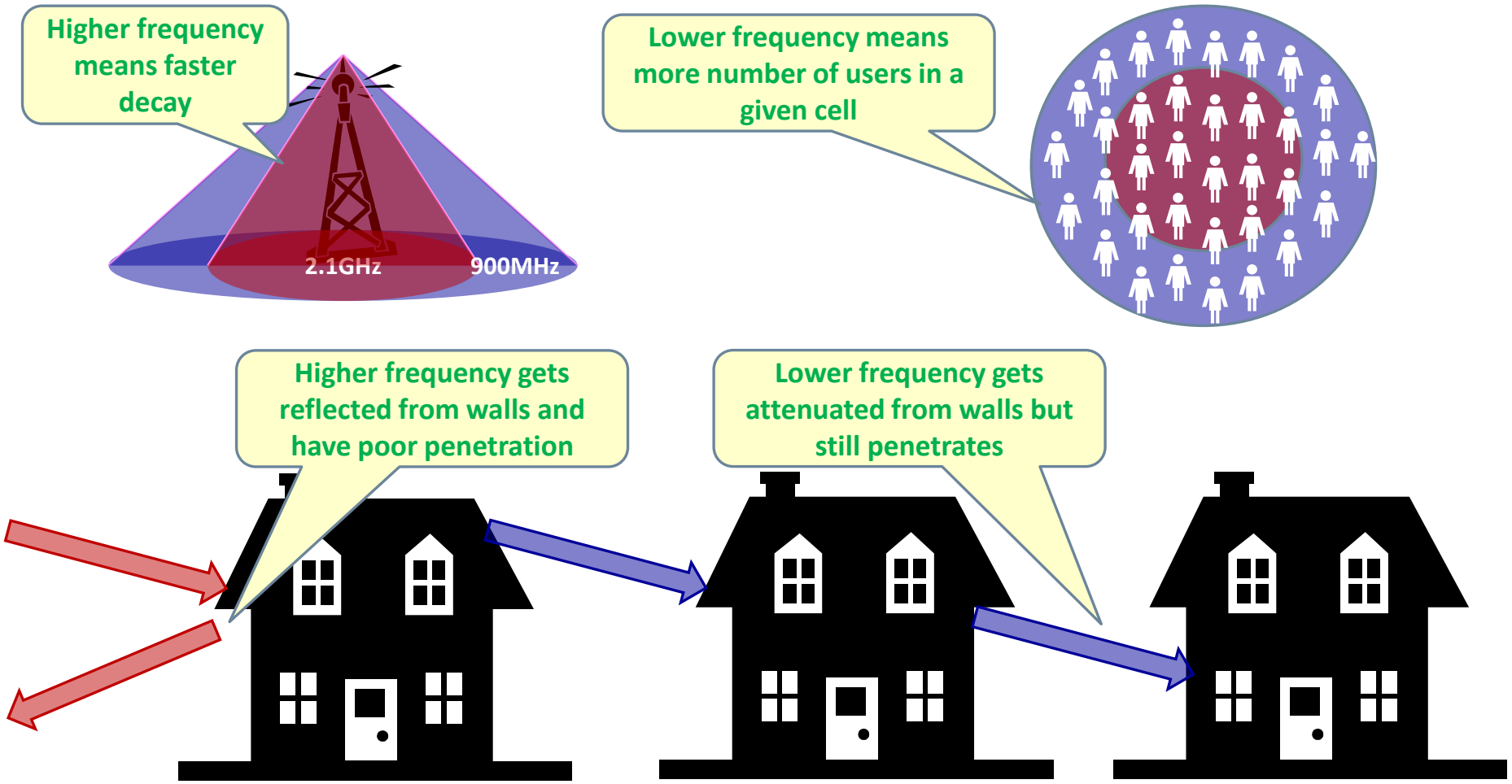
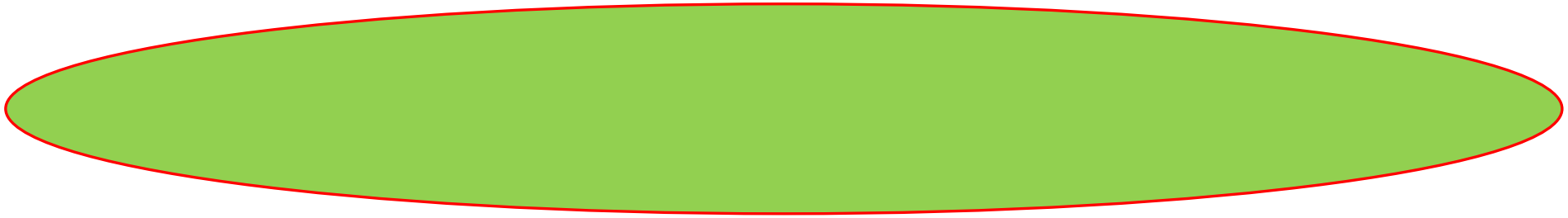
Importance of Frequency selection

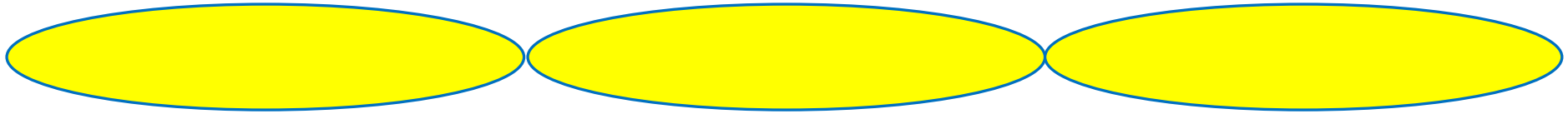


5G: Multiple Layers for multiple needs

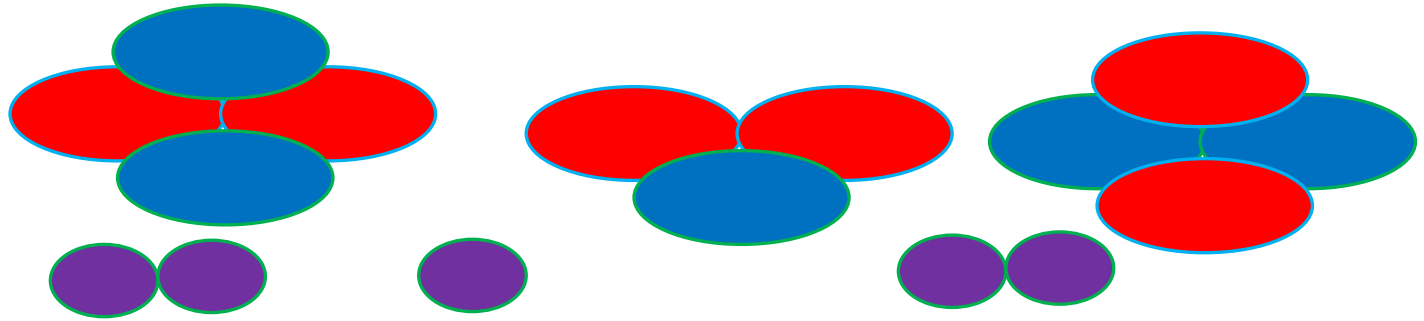
Coverage Layer
Sub-1GHz



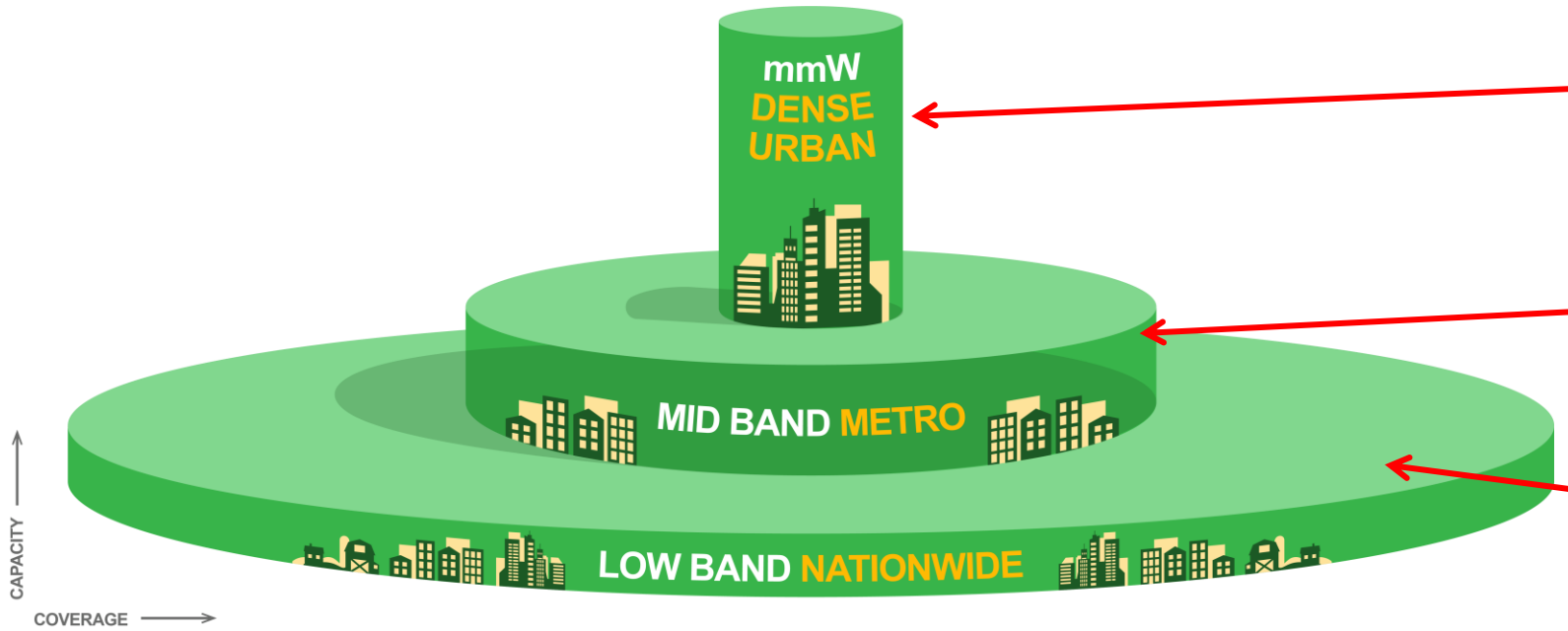
Capacity Layer
1GHz – 7.125GHz



High Throughput Layers
24.25GHz – 52.6GHz



Most Popular 5G Frequency Bands



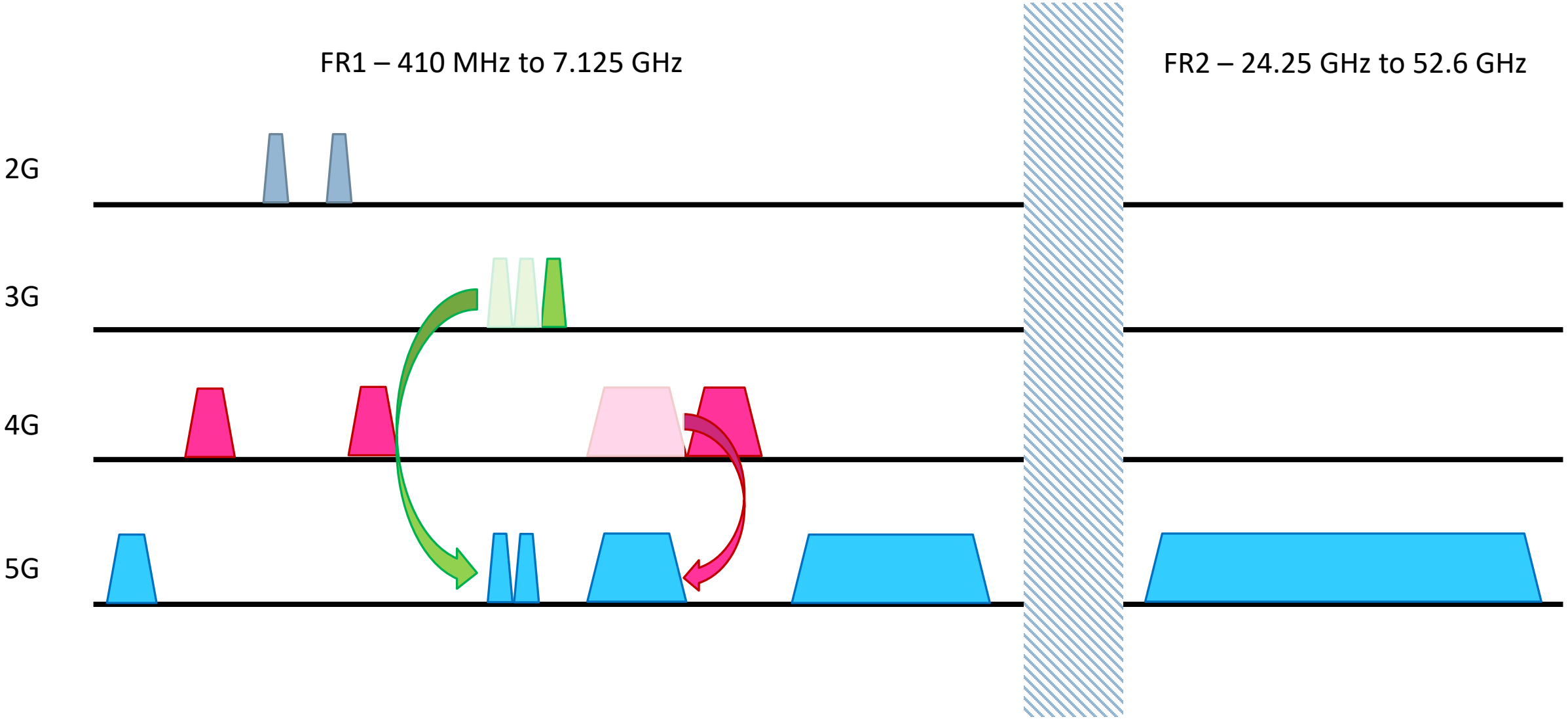
26/28 GHz – most popular band

3.5 GHz – most popular band

700 MHz – most popular band

5G Layer Diagram

Typical Operator Spectrum – 2G, 3G, 4G, 5G



Further Study on this topic

- Radio Frequency, Band and Spectrum (link)
- 5G Spectrum (link)
- Bandwidth, Throughput, Latency & Jitter in mobile networks (link)
- 5G Technologies: Millimeter Waves Explained (link)
- Non millimeter Wave (mmWave) 5G (link)

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Part 9: 5G Launches

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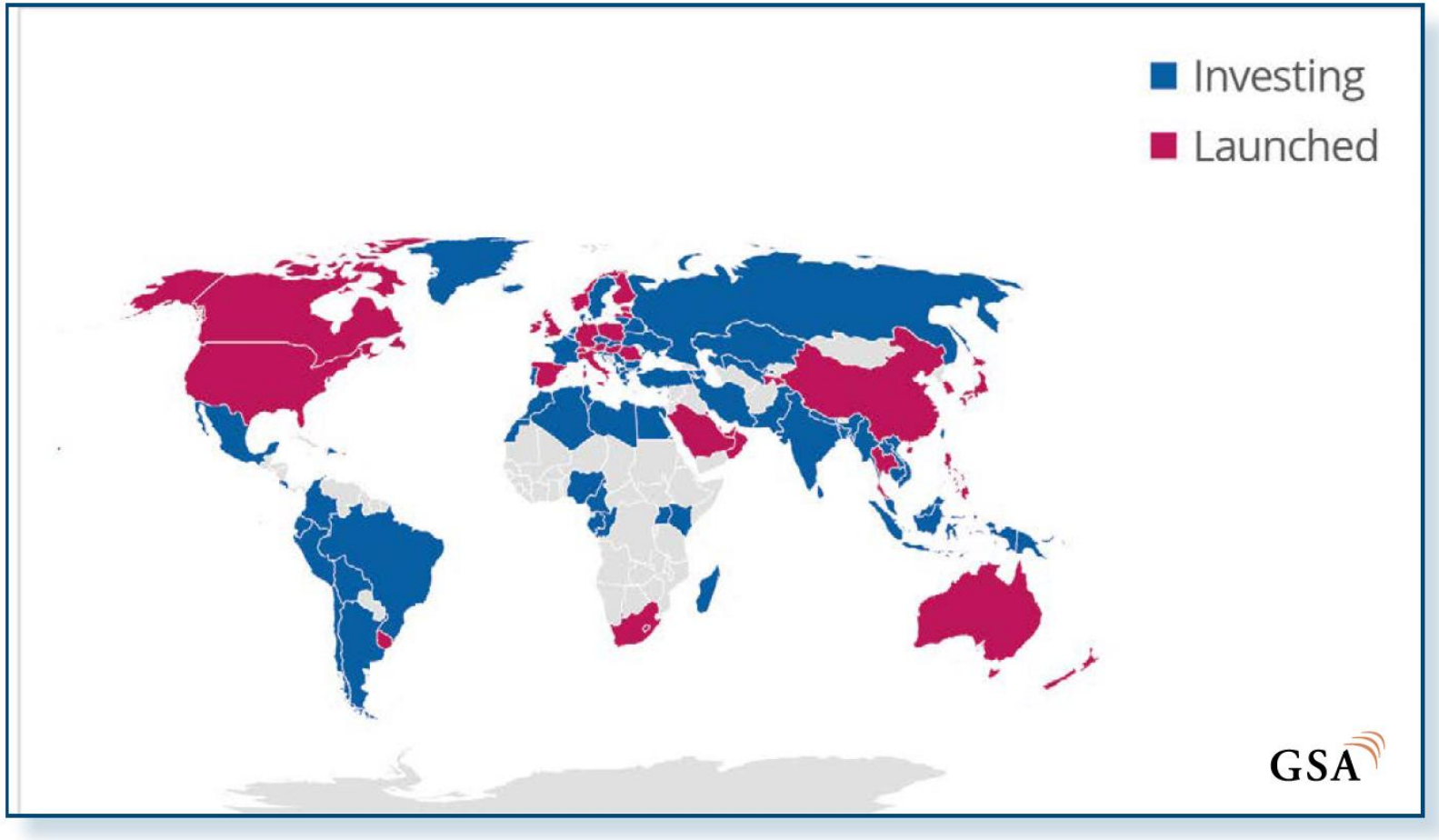
5G March 2020 Status: 70 operators in 40 countries

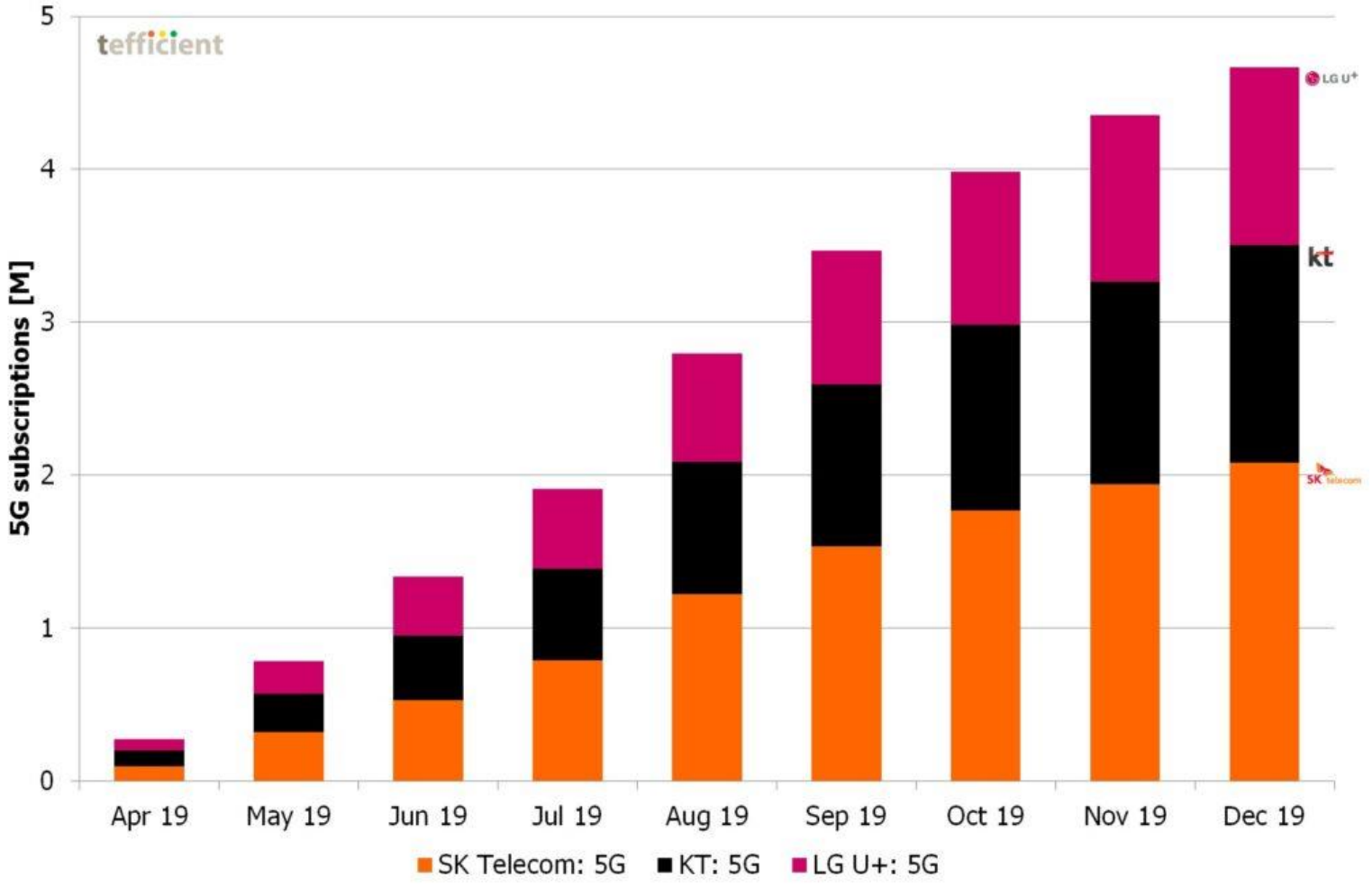
Figure 3: Map of global operator investments in 5G: mobile and fixed access



South Korea Launches 5G on Dec 1, 2018

- The South Korean Government had forced the 3 operators; SK Telecom, KT & LG Uplus to launch 5G at the same time, with the announcement coming back in July.
- Instead, the date was preponed and all of them launched their 5G networks on 1st Dec.
- The South Korean government had mandated the operators collaborate on 5G deployments by sharing core fiber infrastructure, rather than RANs, in a bid to reduce the cost of rolling out the technology and so enable operators to pass on the savings to customers.

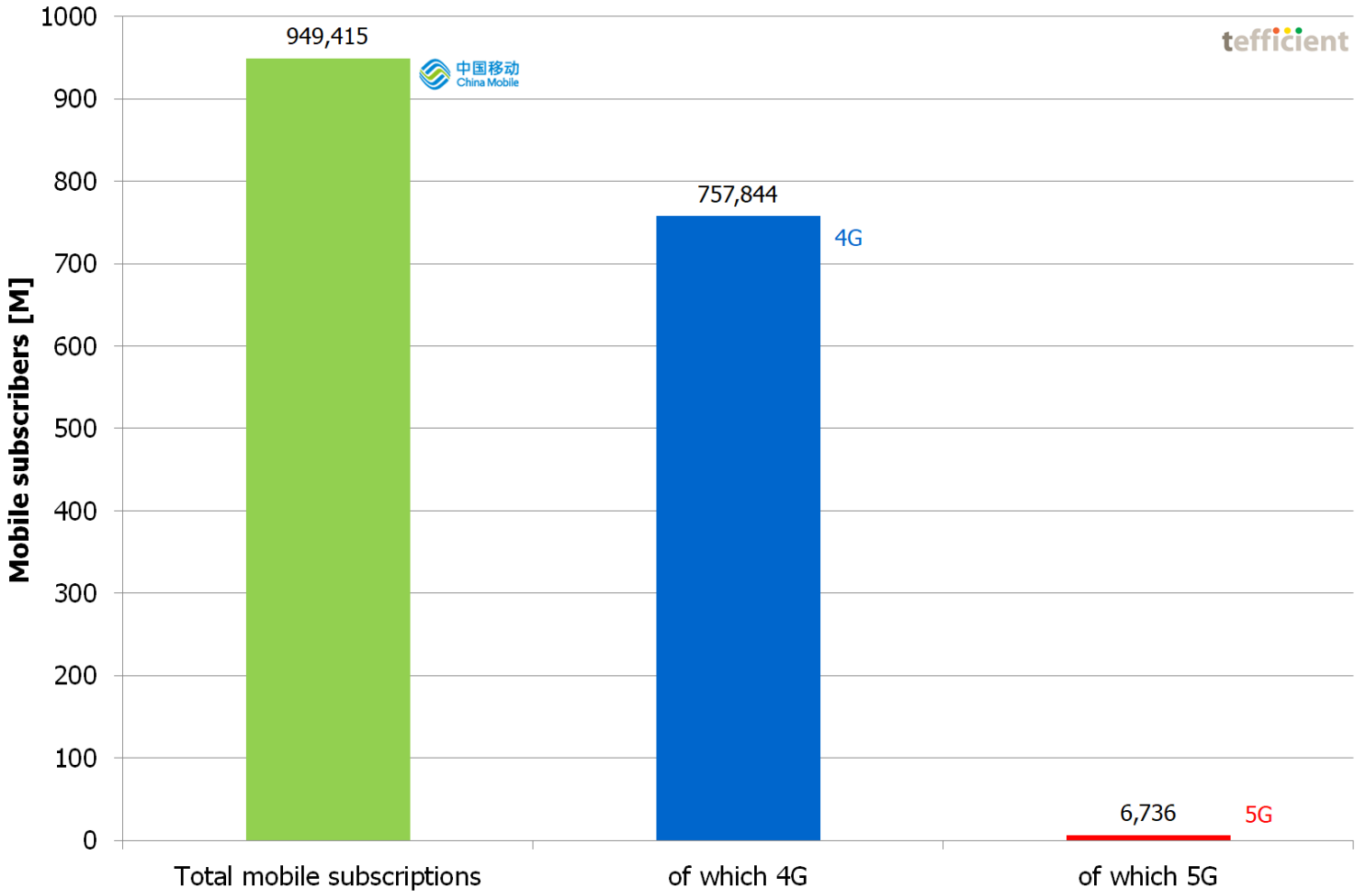
South Korea: 4.7 mil 5G subs on 31 Dec 2019



- 7% of Korea's mobile subscribers used 5G just nine months after launch.
- Average data use is 27 GB per month.

Source: Tefficient

China Mobile has 6.7m 5G subscribers by end of January



Further Study on this topic

- Global mobile Suppliers Association (GSA) 5G Reports (link)
- Operator Watch Blog: 5G (link)

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Part 10: 5G Use cases

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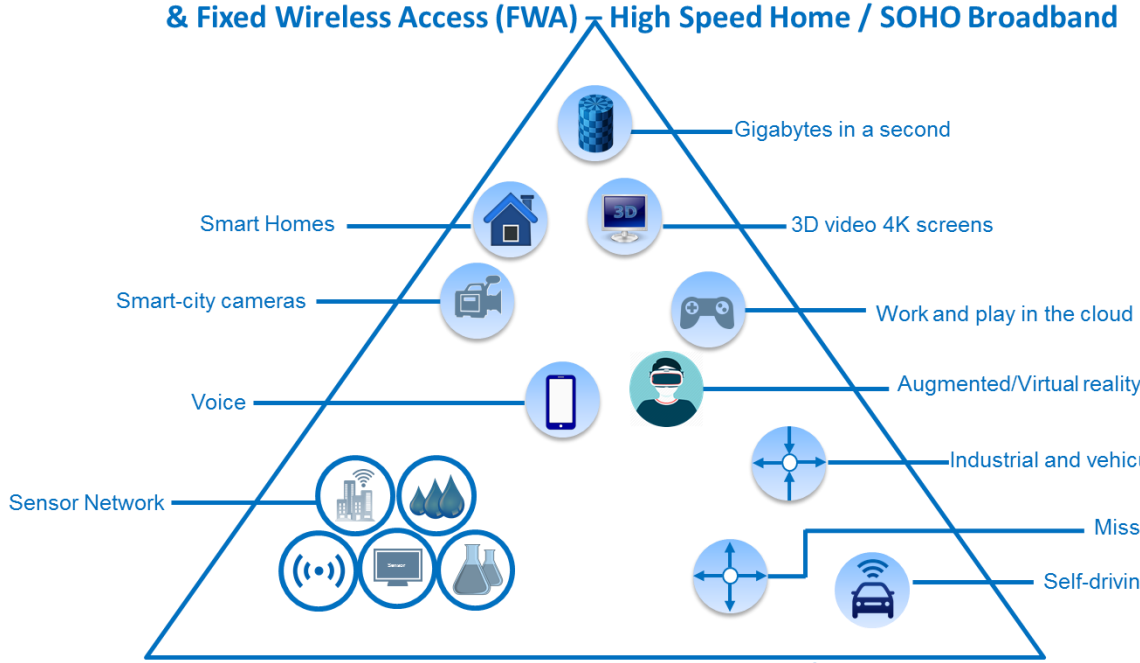
5G Use Cases

High Data Rates



High Density

Ultra-Reliability & Low Latency

Augmented reality (AR)

In Augmented Reality (AR), virtual information and objects are overlaid on the real world. This experience enhances the real world with digital images, text, and animation.

LG U+ AR Dance-Off

Virtual Reality (VR)

In a Virtual Reality (VR) experience, users are fully immersed in a simulated digital environment. Users must put on a VR headset or head-mounted display (HMD) to get a 360 -degree view of an artificial world

NTT Docomo VR Example

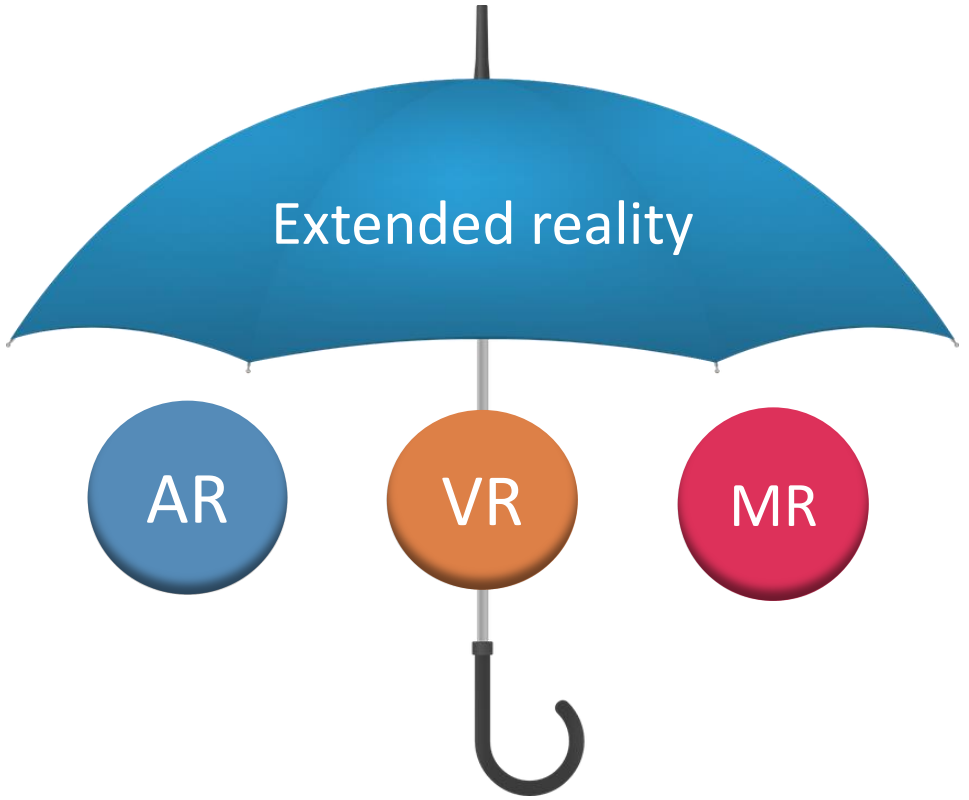
Mixed Reality (MR)

In Mixed Reality (MR), digital and real-world objects co-exist and can interact with one another in real-time. This is the latest immersive technology and is sometimes referred to as hybrid reality.

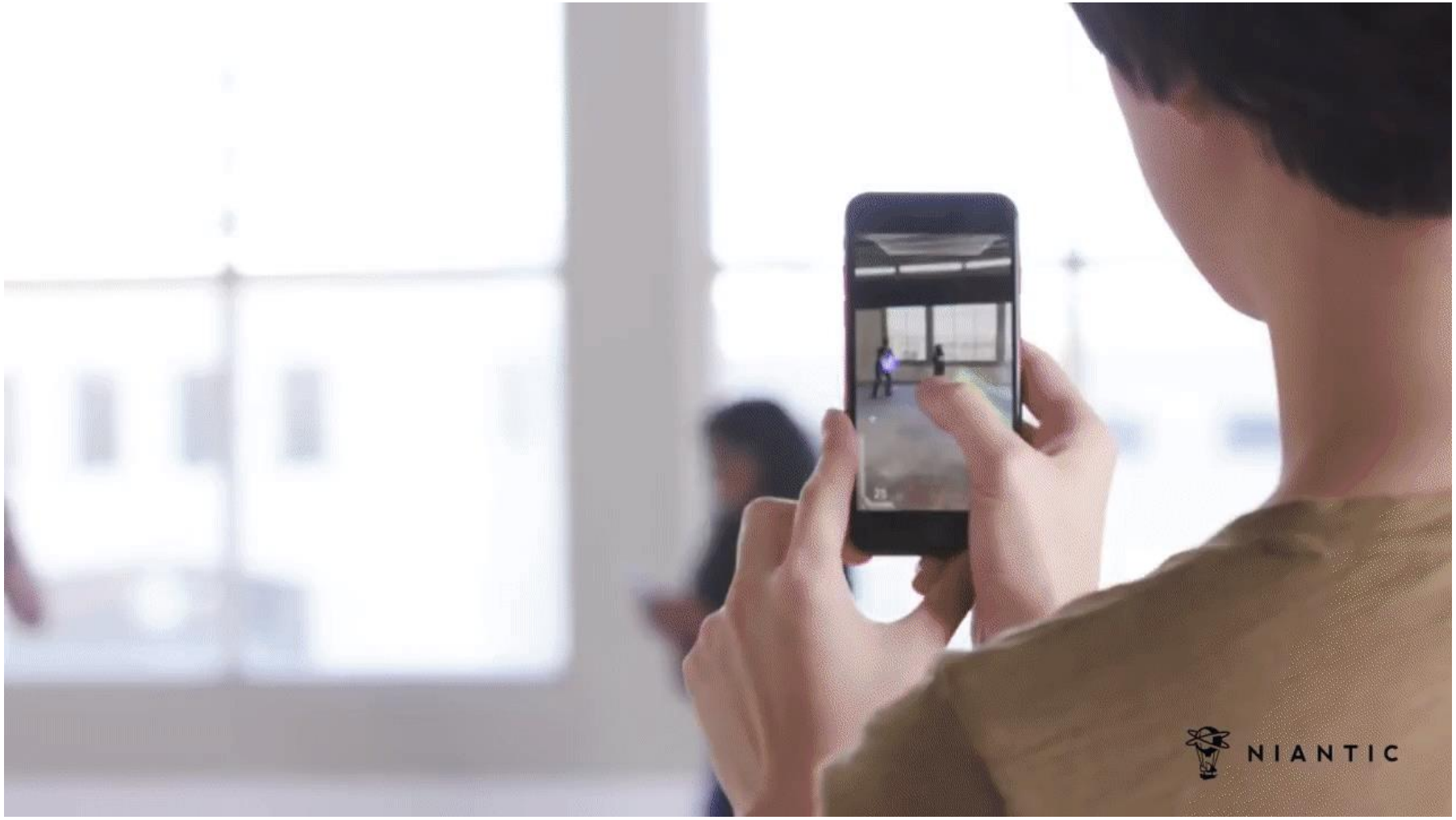
Microsoft HoloLens MR Example

Extended Reality (XR)?

Extended Reality (XR) is an umbrella term for all the immersive technologies.

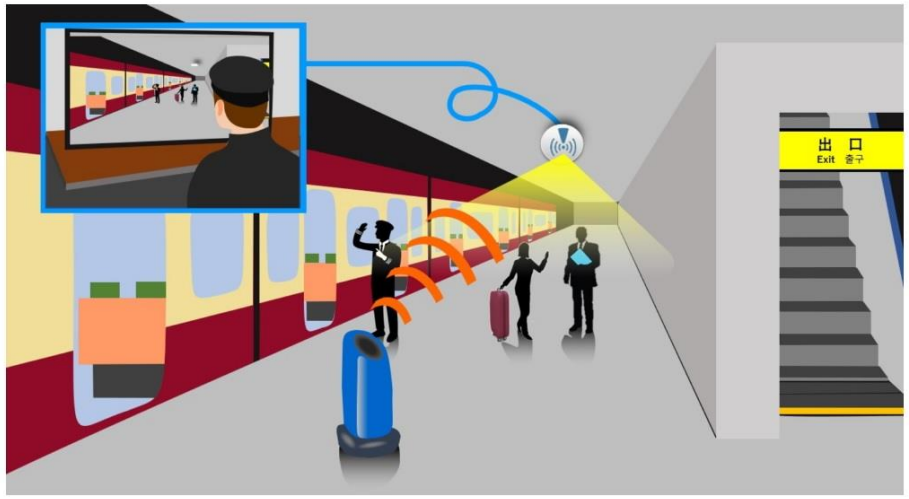


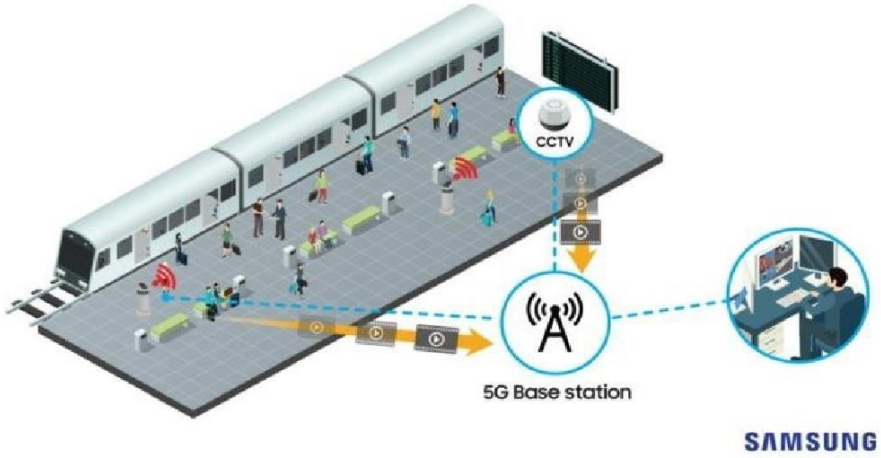
AR Games



Read more on this topic

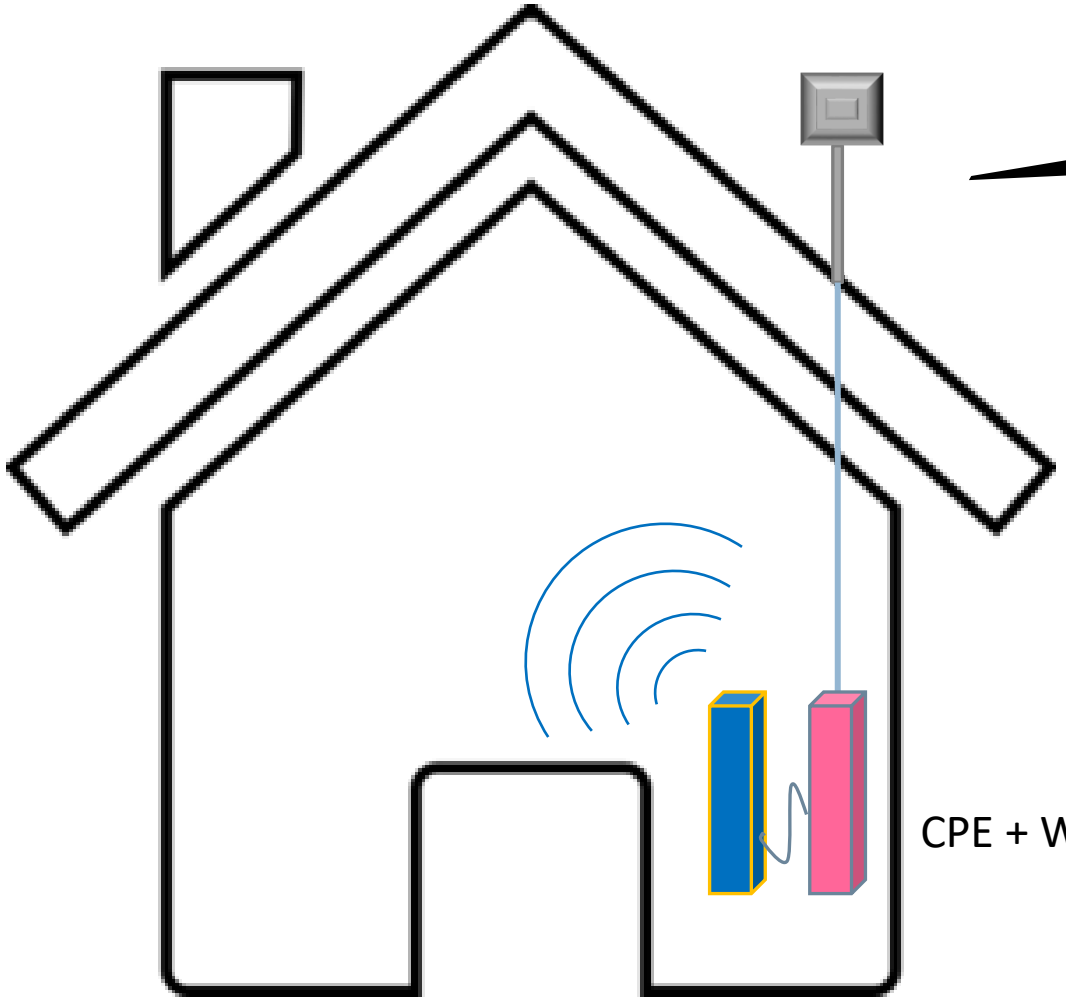
Monitoring & Surveillance



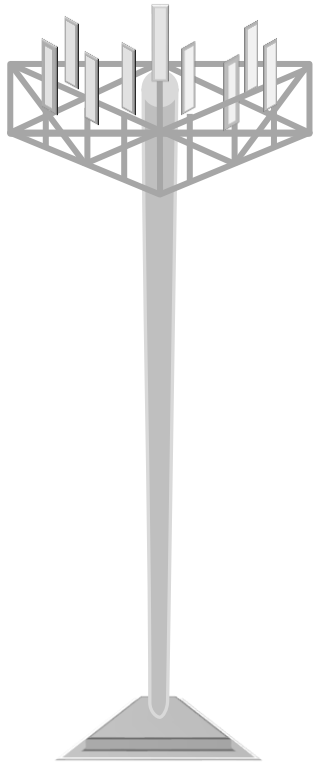


Read more about Samsung & KDDI trials

Fixed Wireless Access (FWA): Indoor



CPE + Wi-Fi router

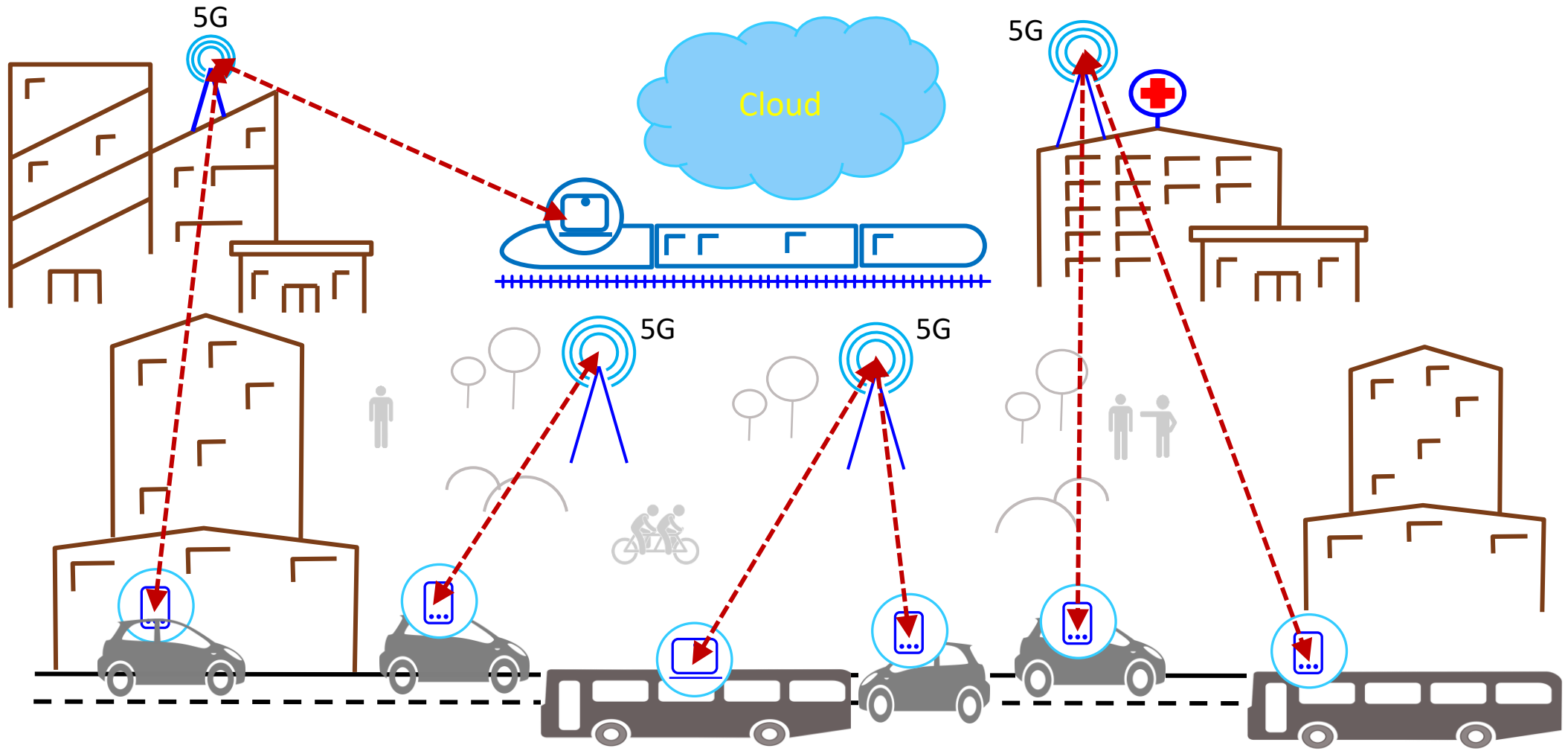


CPE: Customer Premises Equipment

Fixed Wireless Access (FWA) Example

Orange Romania FWA Test

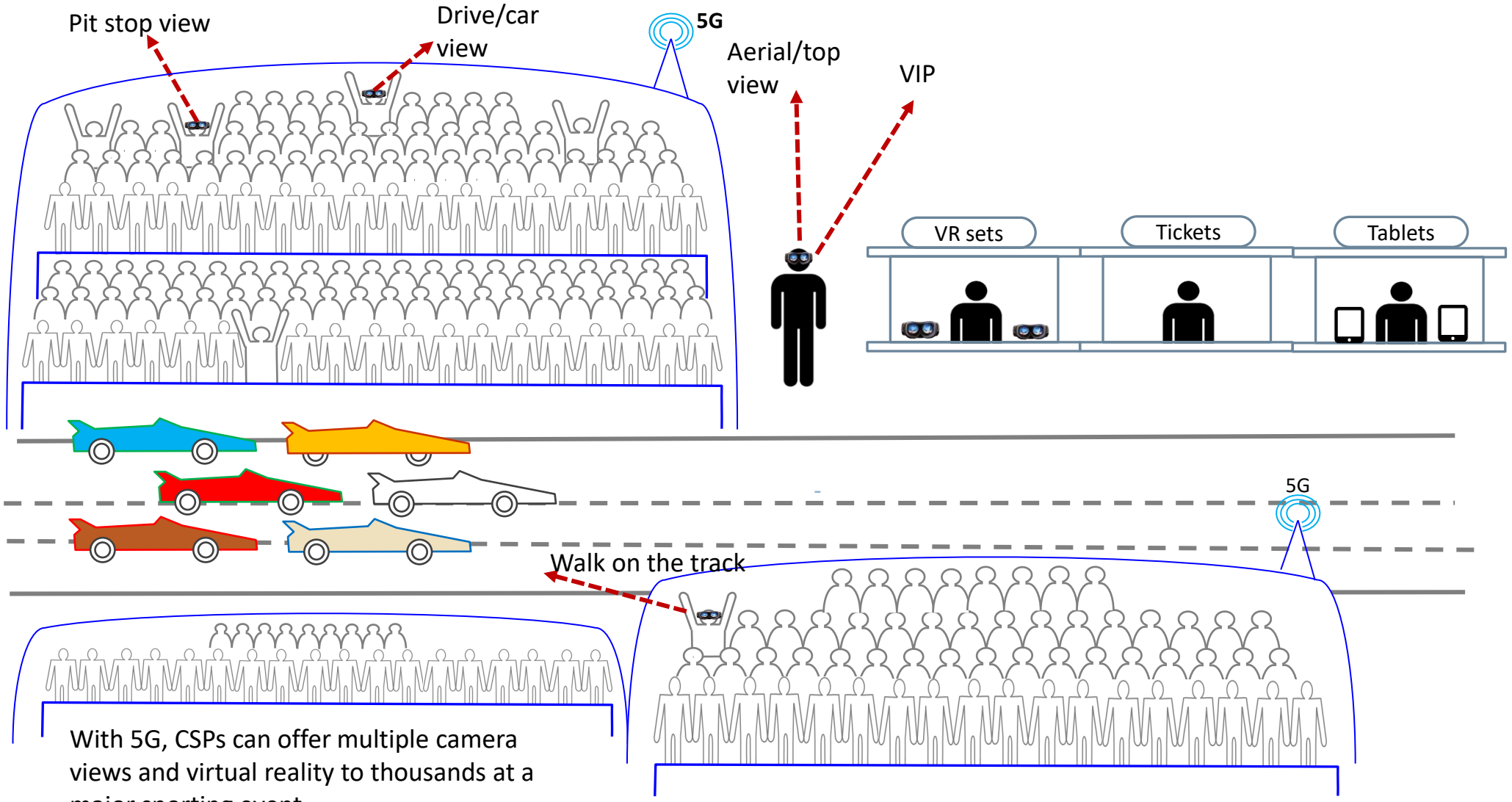
5G Connected Car: In-vehicle infotainment



A dense city center deployment of 5G deliver mobile broadband and infotainment services to customers using public transport

Based on a picture by Nokia

5G Connected Stadiums

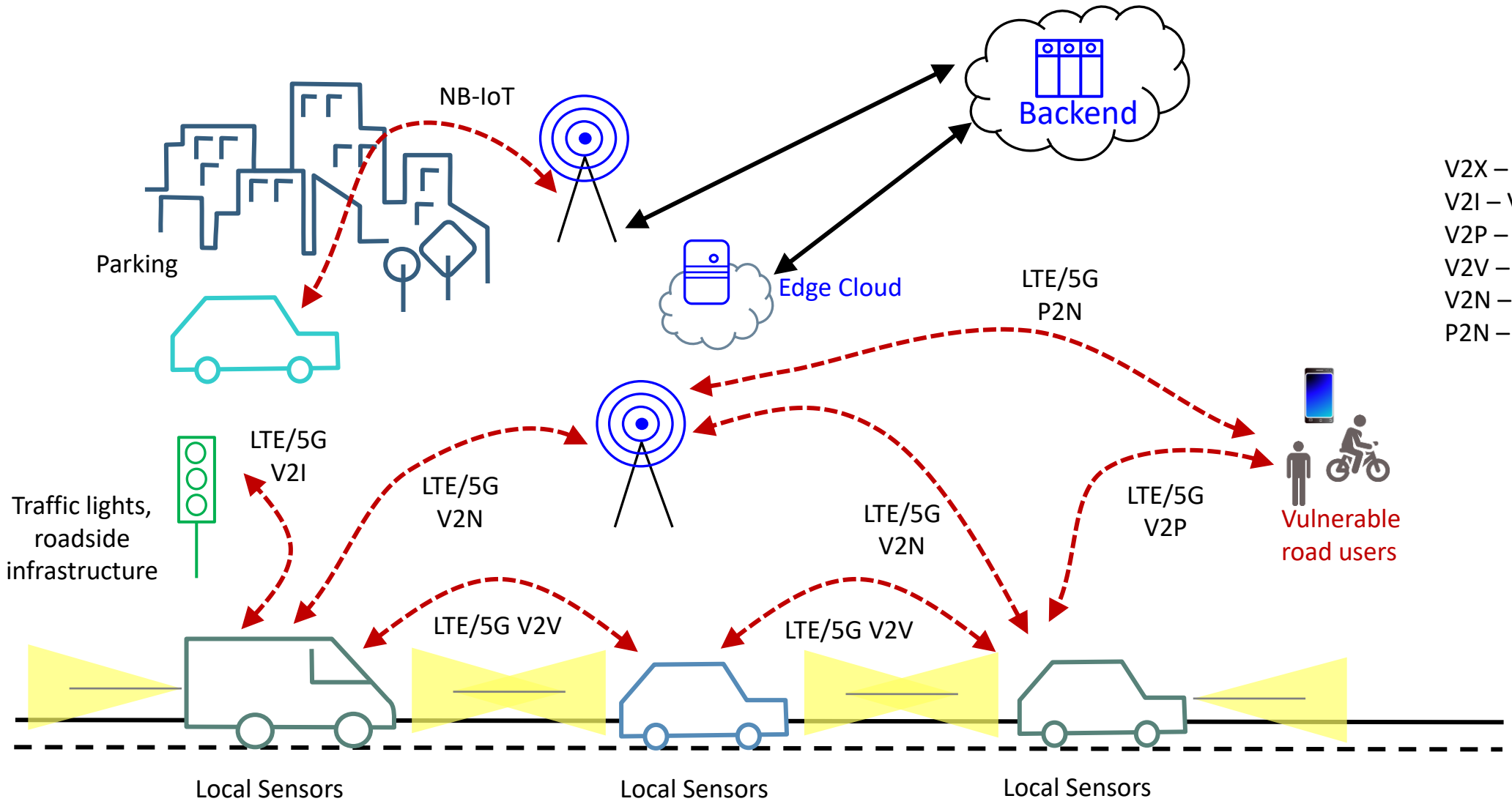


With 5G, CSPs can offer multiple camera views and virtual reality to thousands at a major sporting event

Based on a picture by Nokia

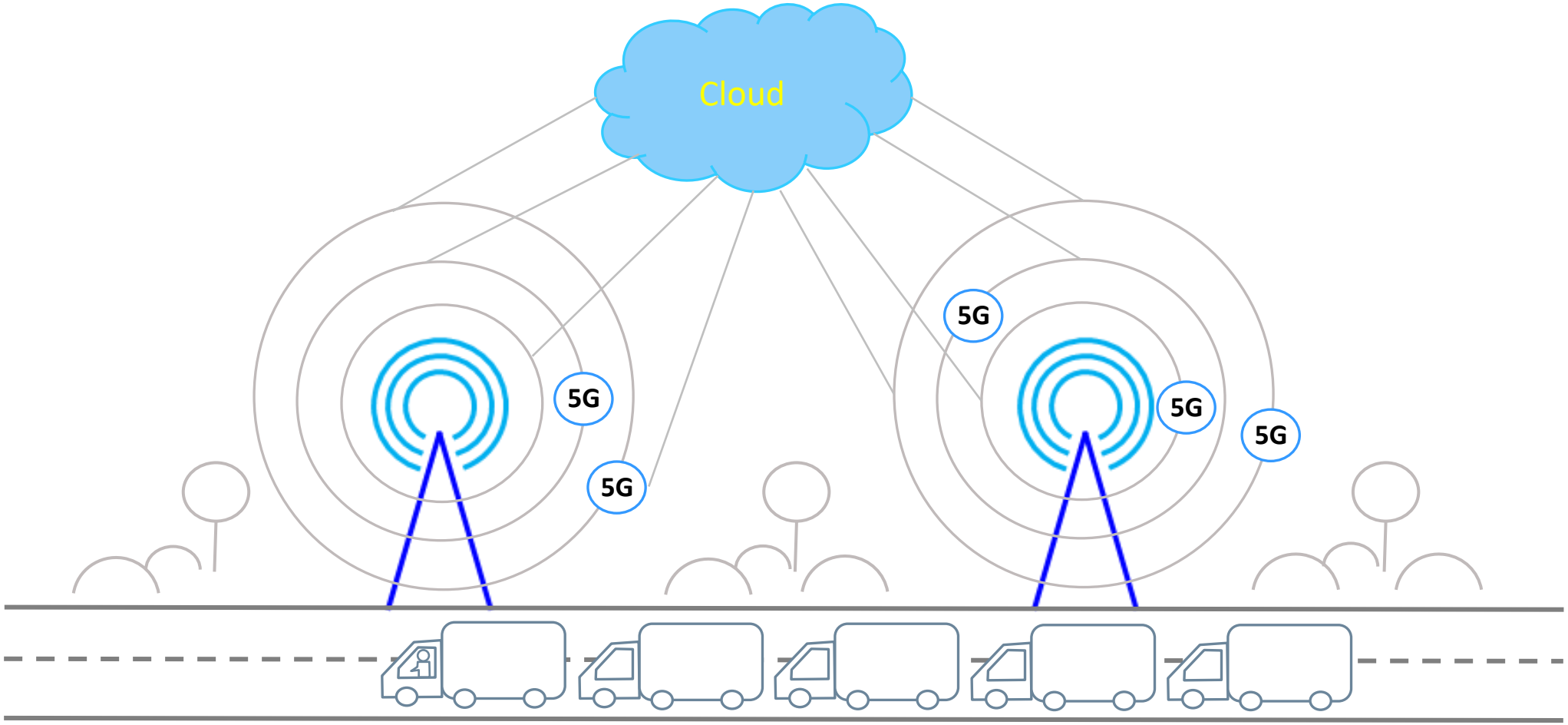
Private & Industrial Networks

Cellular V2X Concept



V2X – Vehicle to Everything
V2I – Vehicle to Infrastructure
V2P – Vehicle to Pedestrian
V2V – Vehicle to Vehicle
V2N – Vehicle to Network
P2N – Pedestrian to Network

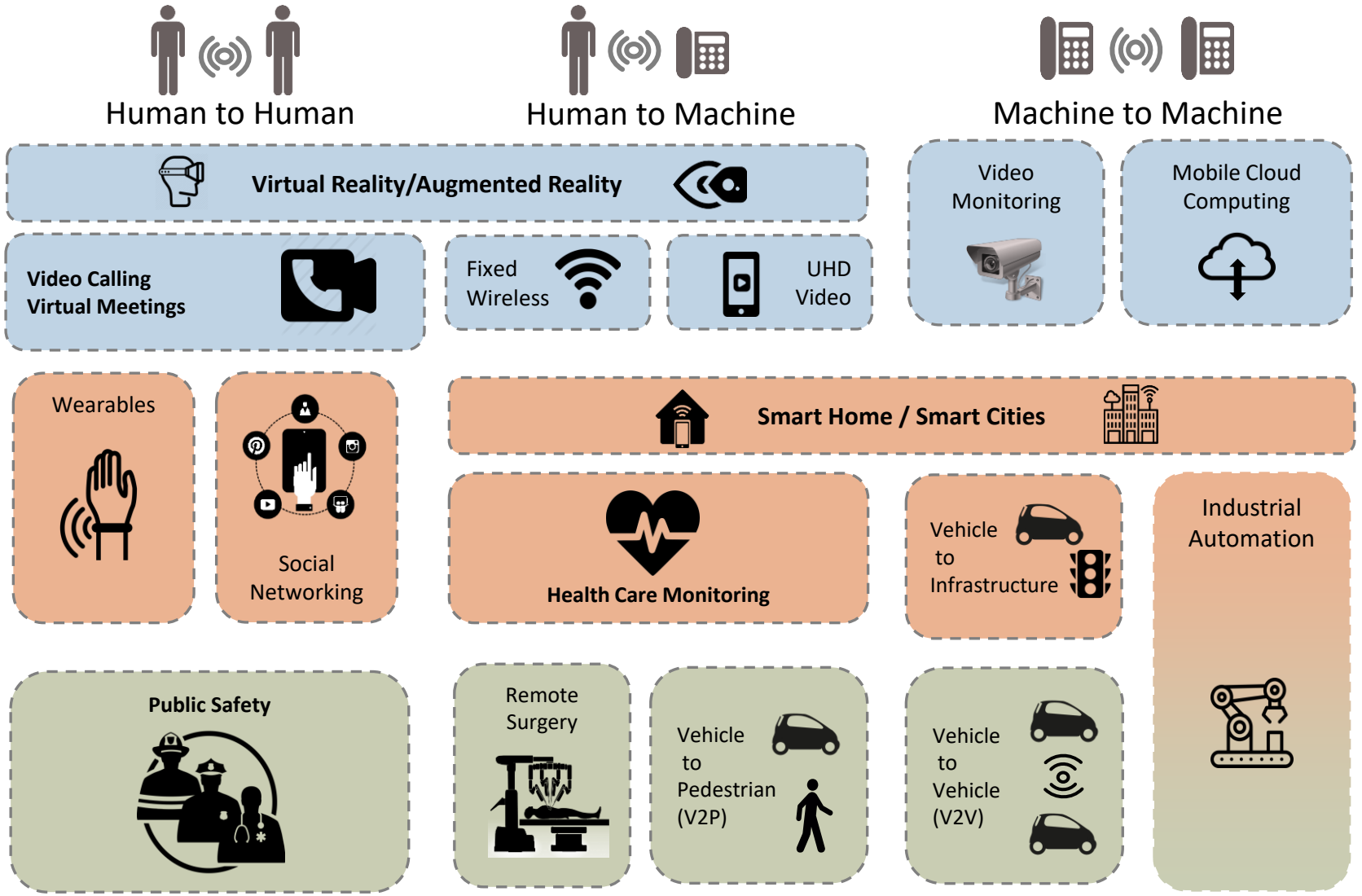
5G Autonomous Driving: Platooning



5G is the most promising enabler of truck platooning in which long convoys of trucks are automatically governed and require only a single driver in the lead vehicle

Based on a picture by Nokia

Summary of 5G Use Cases



Enhanced MBB
- 20/10 Gbps DL/UL*
- 4 ms user plane latency
- 500 km/h mobility

Massive MTC
- 1 million devices / km^2
- 10+ years battery life
- 20 dB coverage enhancement

URLLC
- 1 ms user plane latency
- Highly secure / resilient
- 99.99999% availability

* Peak theoretical rate

Source: 5G Americas

Further Study on this topic

- Examples of 5G Use Cases & Applications (link)
- 5G Use Cases YouTube Playlist (link)
- 5G Americas whitepaper: 5G Services & Use cases (link)
- Fixed Wireless Access (FWA) (link)
- 5G eXtended Reality (5G-XR) in 5G System (5GS) (link)
- Real-life 5G Use Cases for Verticals from China (link)
- 5G Private and Non-Public Network (NPN) (link)
- 5G and Industry 4.0 (link)
- What is Industrial IoT (IIoT) and how is it different from IoT? (link)

5G for Absolute Beginners

Part 11: Course Summary and Conclusion

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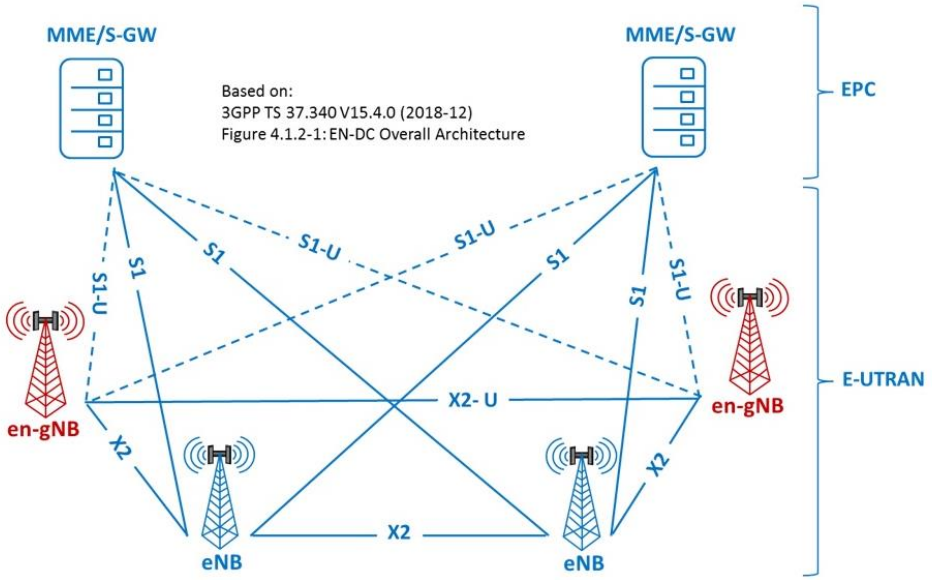
Course Outline: 5G for Absolute Beginners

- Introduction
- Part 1: The Different Generations (‘G’s)
- Part 2: Standardization Organizations
- Part 3: IMT-2020
- Part 4: Why is 5G called 5G
- Part 5: 5G in Simple Words
- Part 6: Standalone and Non-Standalone 5G
- Part 7: 3GPP Roadmap
- Part 8: 5G Spectrum
- Part 9: 5G Launches
- Part 10: 5G Use cases
- Part 11: Course Summary and Conclusion

Where to go next

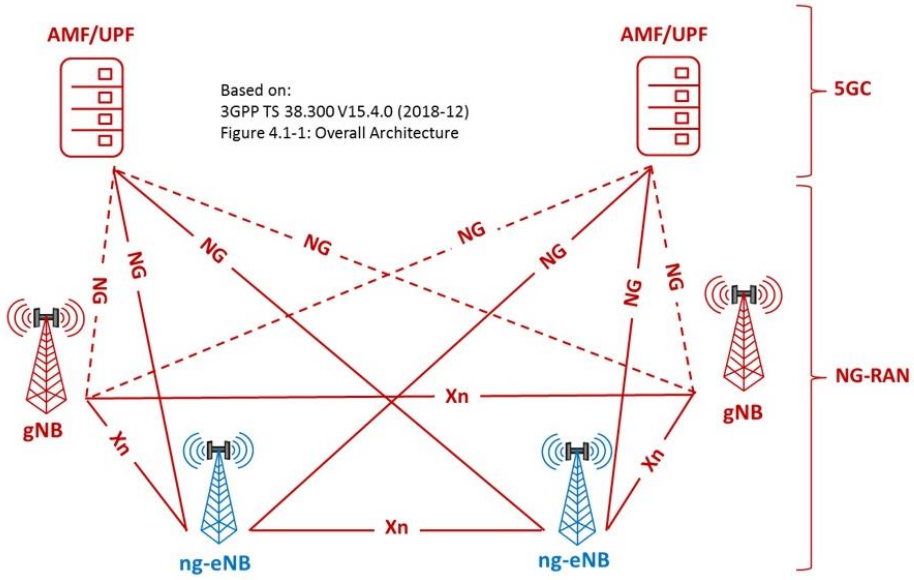
- 3GPP 5G Specifications (link)

EN-DC Overall Architecture



- **en-gNB**: node providing NR user plane and control plane protocol terminations towards the UE and acting as Secondary Node in EN-DC.
- In simple English, it's a gNB that supports legacy E-UTRAN interface

5GS Overall Architecture



An NG-RAN node is either:

- a **gNB**, providing NR user plane and control plane protocol terminations towards the UE; or
- an **ng-eNB**, providing E-UTRA user plane and control plane protocol terminations towards the UE.

Resources for further study

- 5G (IMT-2020) Wireless Resources (link)
- 5G on The 3G4G Blog (link)
- 3G4G YouTube channel (link)
- The 3G4G Blog (link)
- Telecoms Infrastructure Blog (link)
- Operator Watch Blog (link)
- Connectivity Technology Blog (link)

Free Online 5G eBooks/Magazines

- Sprint: 5G For Dummies, Sprint Business Special Edition
- Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency by Emil Björnson, Jakob Hoydis and Luca Sanguinetti
- 5G New Radio: Fundamentals, Procedures, testing aspects – Rohde & Schwarz
- 5G Technical Training Notes – Rohde & Schwarz

Thank You

To learn more, visit:

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3G4G Blog – https://blog.3g4g.co.uk/

Telecoms Infrastructure Blog – https://www.telecomsinfrastructure.com/

Operator Watch Blog – https://www.operatorwatch.com/

Connectivity Technology Blog – https://www.connectivity.technology/

Free 5G Training – https://www.free5gtraining.com/

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