教育部「5G行動寬頻人才培育跨校教學聯盟計畫」

5G行動網路協定與核網技術聯盟中心

課程:5G垂直應用網路

單元1
5G垂直應用系統簡介

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Outline

- Syllabus
- Introduction to Vertical Applications (VA)
  - ITU-R IMT-2020 Vision: eMBB, uRLLC and mMTC
  - 3GPP Use Cases and Requirements
- 3GPP Standards for VA
  - Toward 5GS: NR + 5GC
  - Unified Architecture: QoS + CAPIF

教學目標

本課程介紹3GPP R15、R16的5GS行動寬頻網路系統，以及即將開始的R17中，如何支援eMBB(enhanced Mobile BroadBand)、uRLLC(ultra-Reliable Low-Latency Communication)、mMTC(massive Machine-Type Communication)等各種新興垂直應用以及與其相關的行動網路技術與最新標準。5G除了提升對Multimedia Broadcast/Multicast Service (MBMS)、Mission Critical Services、Device-to-Device Communications (D2D)、Vehicular-to-Everything (V2X)、Industrial IoT (IIoT)等的支援，最新的標準也強化對Public Safety Networks (PSN)、Time-Sensitive Networks (TSN)、Non-Public Networks (NPN)、5G Local Area Networks (5GLAN)、5G Satellite (5GSAT)等網路環境的支援，在本課程中也將予以說明並進行介紹。重點包括：

1) 5GS網路系統介紹
2) eMBB 垂直應用網路技術
3) uRLLC 垂直應用網路技術
4) mMTC 垂直應用網路技術

參考教材

- Protocols (Specifications)
  - 3GPP LTE-Advanced Pro, 5G
  - ITU IMT-2020
  - NGMN, ACIA, 5G Americas, 5G PPP
- Programs (Codes)
  - srsLTE: srsUE/srsENB/srsEPC
  - nukxDC/nukxGC
- Platform
  - PC / Raspberry Pi 4 + USRP B210 (LimeSDR, HackRF)
- Papers

課程內容與進度

主題1：5G垂直應用系統簡介 主題2：接取網路：NR及Xn 主題3：核網設計：5GC及NG 主題4：實驗1：開源碼小基站實驗平台之建置與量測
主題5：eMBB垂直應用網路技術 主題6：3GPP eMBB標準現況 主題7：eMBB應用分析 主題8：實驗2：eMBB垂直應用網路實驗
主題9：期中報告
主題10：uRLLC垂直應用網路技術 主題11：3GPP uRLLC標準現況 主題12：uRLLC應用分析 主題13：實驗3：uRLLC垂直應用網路實驗
主題14：mMTC垂直應用網路技術 主題15：3GPP mMTC標準現況 主題16：mMTC應用分析 主題17：實驗4：mMTC垂直應用網路實驗
主題18：期末專題

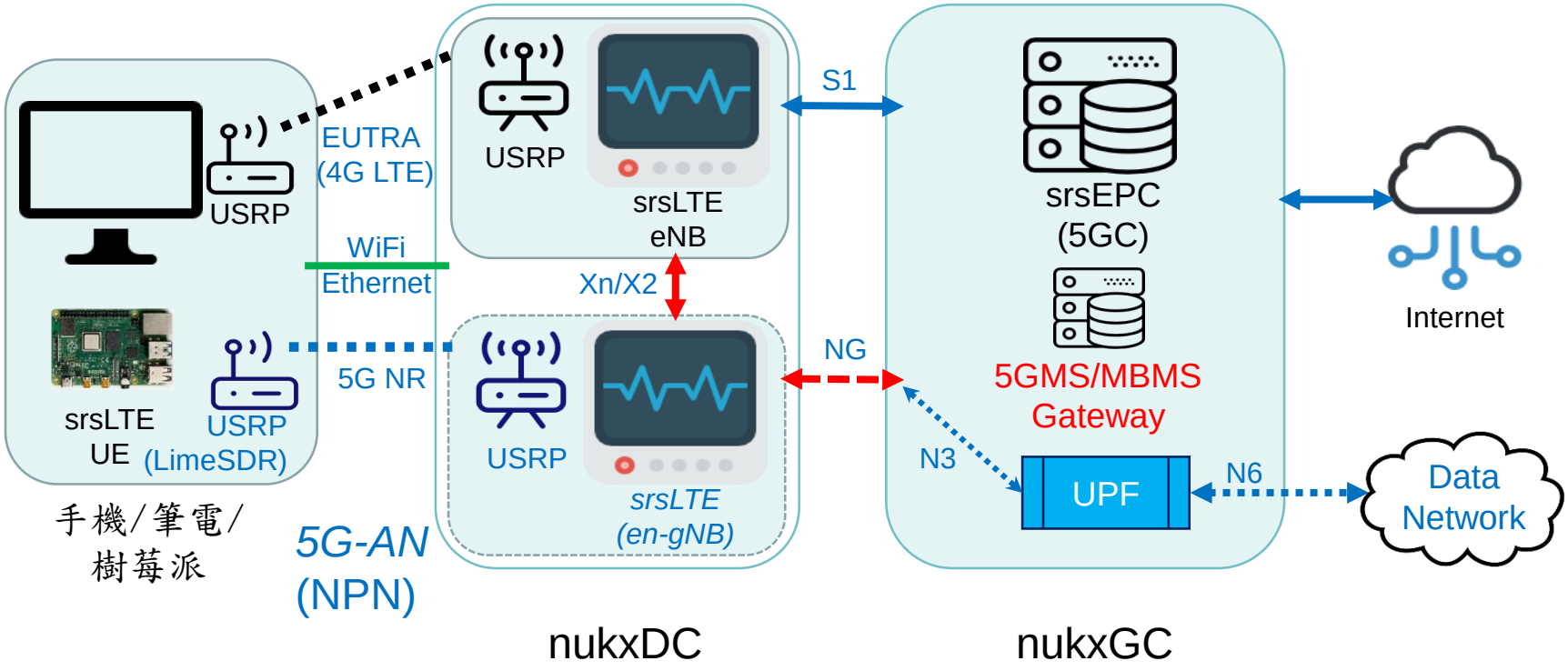
實驗內容

實驗項目	內容說明
實驗一：開源碼小基站實驗平台之建置與量測	1. 建置開源碼小基站及小核網系統 2. 建置UE及設定行動裝置並安裝應用程式以熟悉連線量測工具
實驗二：eMBB垂直應用網路實驗	1. 建置行動寬頻暨MBMS服務應用網路 2. 調整網路架構及參數來分析及量測其對網路傳輸效能的影響
實驗三：uRLLC垂直應用網路實驗	1. 建置以MR-DC支援uRLLC的垂直應用網路 2. 調整應用及網路參數來分析及量測PRP對網路可靠度及時延的影響
實驗四：mMTC垂直應用網路實驗	1. 在單板電腦(如Raspberry Pi 4)上連結SDR建置低耗能的mMTC UE應用系統 2. 調整訊號及網路參數來分析及量測其對系統及網路效能的影響

核心能力

1. 布建及測試5G垂直應用網路系統之能力
2. 在Linux上建置及修改5G暨垂直應用網路開源碼系統的能力
3. 熟稔並能收集分析5G垂直應用系統運作過程中的訊令及封包之能力
4. 了解5G網路系統如何支援垂直應用並能進行整合應用量測之能力

實驗平台



srsLTE / nuk xDC小基站及xGC小核網平台

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什麼是5G？

- 5 GHz?
  - WiFi 6
- 5 GB?
- 5th Generation
  - ITU-R IMT-2020 Requirements
  - 3GPP Release 15/16~ Specifications

Welcome to the Invention Age (Qualcomm, Jan 2019)
https://www.youtube.com/watch?v=TNIg5YeLaQU
Qualcomm presents: A History of 5G
https://www.digitaltrends.com/?page_id=2285944

What is 5G? | CNBC Explains
https://www.youtube.com/watch?v=2DG3pMcNNlw

連結5G以後的世界(日本)
https://www.youtube.com/watch?v=lDJC_yJTXIc

What is the Difference between 4G and 5G?

There are several differences between 4G vs 5G

- User's Views – Human Centric
  - 5G is *faster* than 4G
  - 5G has *lower latency* than 4G
- System's Views - Human + Machine Centric
  - 5G uses spectrum better than 4G
  - 5G has more capacity than 4G
  - 5G is ***a unified platform*** that is more capable than 4G

More Kinds of Applications

Source: https://www.qualcomm.com/invention/5g/what-is-5g

Vertical Applications

- Wikipedia – Vertical Market
  - A vertical market is a market in which vendors offer goods and services *specific to an industry, trade, profession, or other group of customers with specialized needs*
    https://en.wikipedia.org/wiki/Vertical_market
- 5G PPP – 5G Verticals
  - Previous generations of mobile technologies primarily satisfied human communications in the form of voice, data and Internet
  - 5G on the other hand equally aims for industrial communications to help digitize the economy and contribute towards global digital transformation
  - Vertical sectors such as transport, media, and manufacturing will likely be the leading adopter
    https://5g-ppp.eu/verticals/
- 3GPP TS 22.104 – Vertical Domain
  - An industry or group of enterprises in which similar products or services are developed, produced, and provided

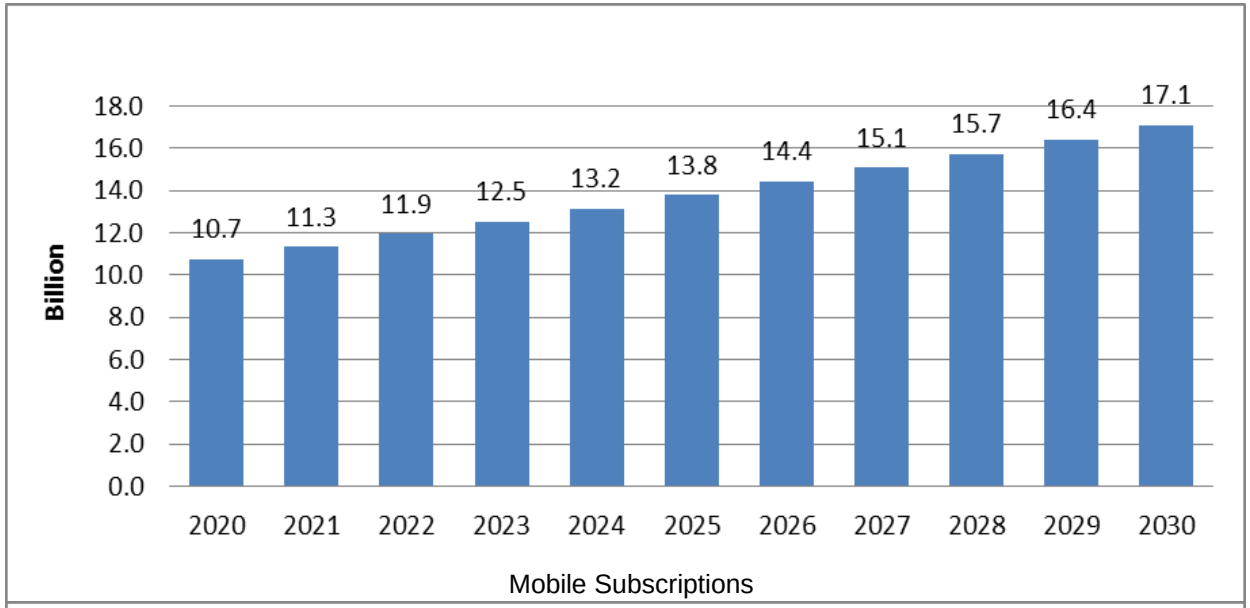
ITU-R IMT-2020 Vision (International Mobile Telecommunications)

User and Application Trends

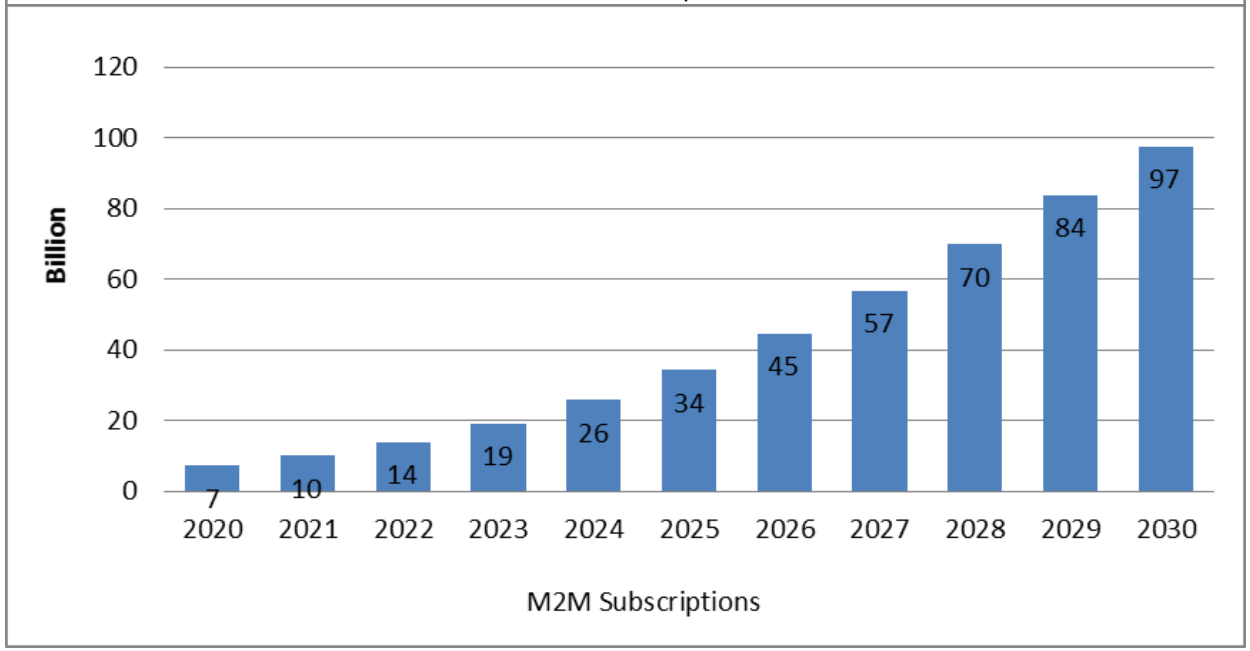
- Supporting very low latency and high reliability human-centric communication
  - Maintaining high quality at high mobility
  - A key factor for the success of cloud services and virtual reality and augmented reality applications
- Supporting very low latency and high reliability machine-centric communication
  - The design of new applications is envisaged based on machine-to-machine (M2M) communication with real-time constraints
- Supporting high user density
  - Exploit the public communication networks in crowded environments and machine-centric devices
- Convergence of applications
  - Enhanced multimedia services
  - Internet of Things
  - Ultra-accurate positioning applications

Growth in IMT Traffic: global IMT traffic will grow in the range of 10-100 times from 2020 to 2030

Estimation of Global Subscriptions

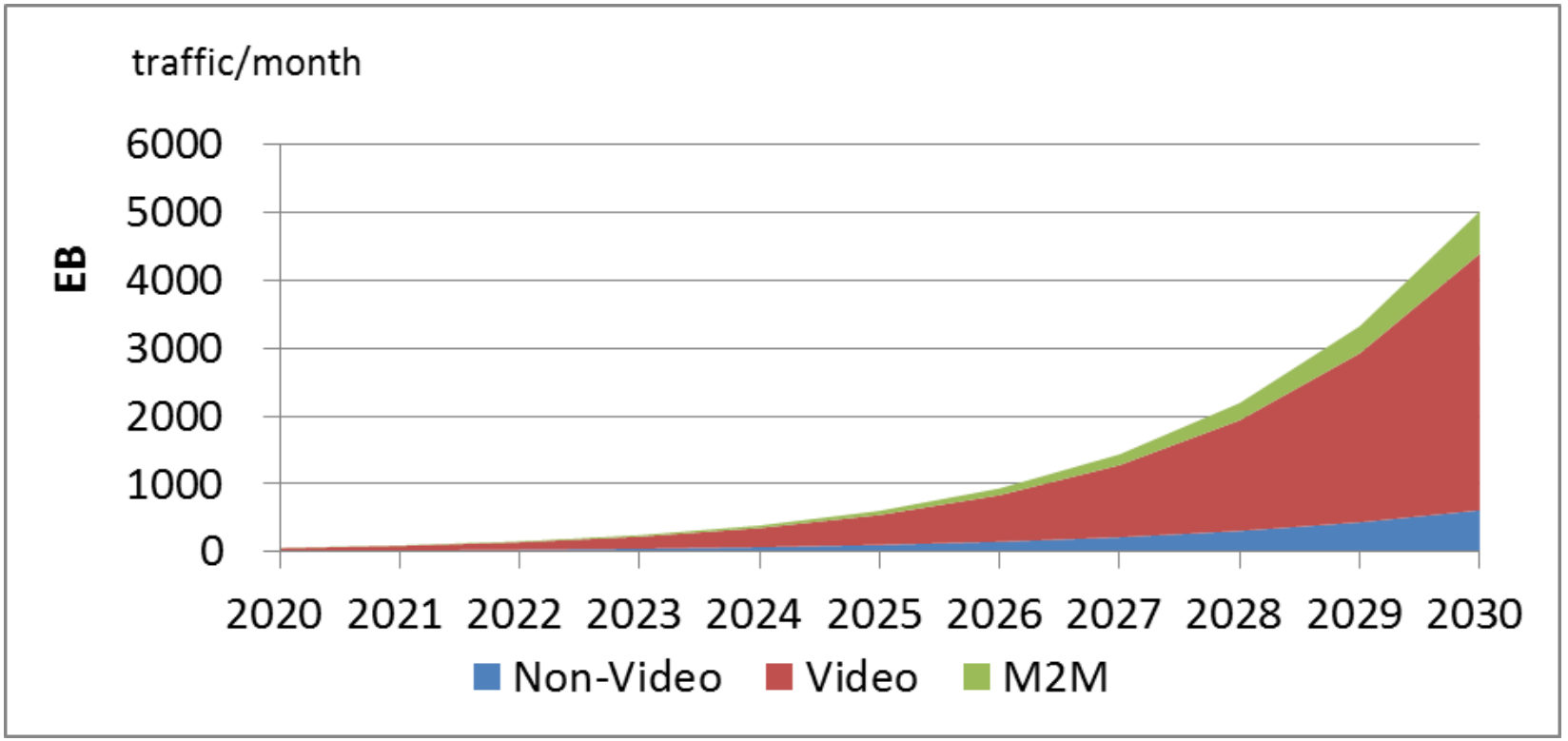


Mobile Subscriptions



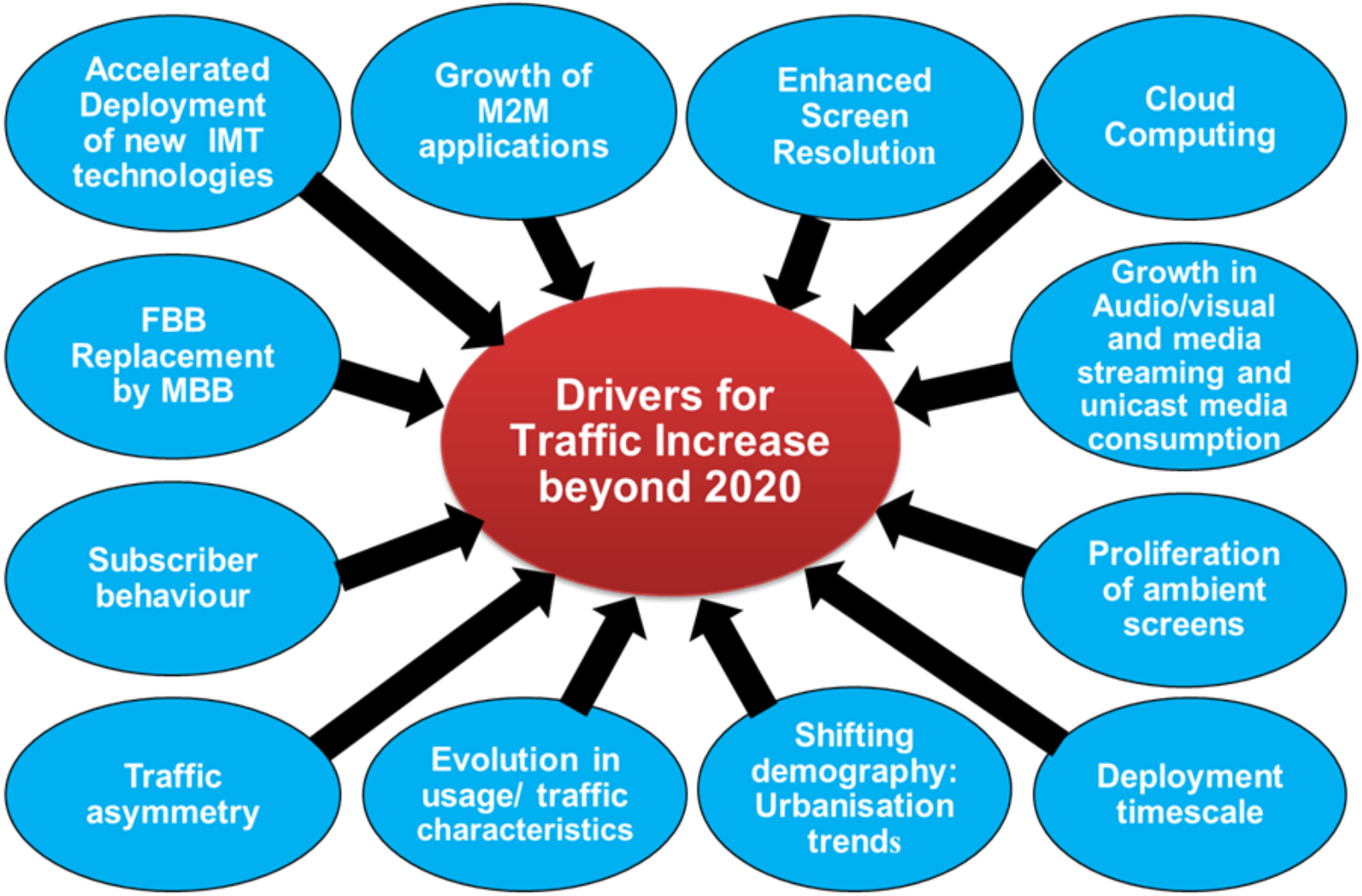
M2M Subscriptions

Estimation of Mobile Traffic by Different Service Types Globally



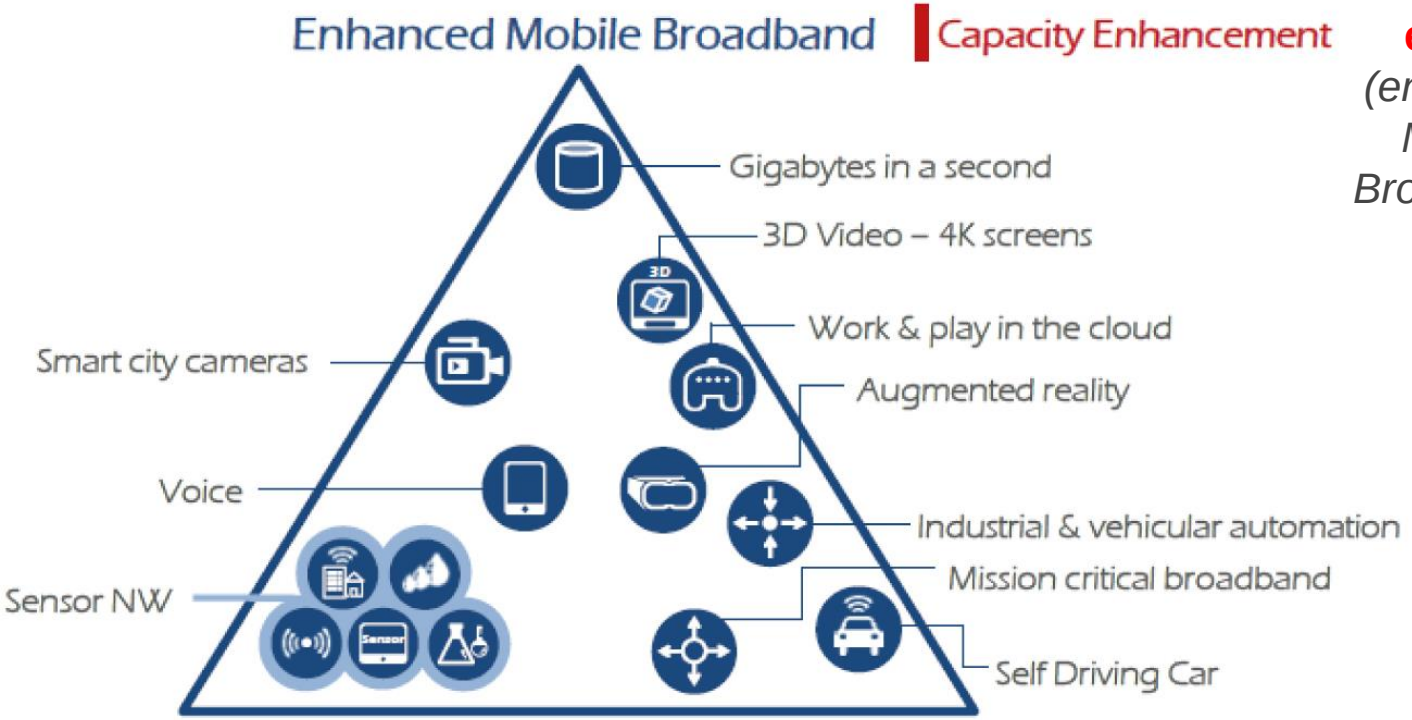
- Mobile internet traffic and M2M traffic will grow dramatically after year 2020
  - Video traffic will be 4.2 times than non-video in 2025 and 6 times in 2030
  - M2M traffic will be 7% of the total in 2020 and 12% of the total in 2030

Drivers for Future Traffic Increase



Source: ITU-R M.2370

Three Dimensions to Performance Improvements with Usage Scenarios for 2020 and Beyond



eMBB
(enhanced Mobile Broadband)

mMTC
(massive Machine Type Communications)

URLLC
(Ultra-Reliable and Low Latency Communications)

https://www.youtube.com/watch?v=lDJC_yJTXIc

Source: ITU-R IMT 2020 Requirements (ITU-R M.2083, 2015)

Usage Scenarios for IMT-2020 and Beyond

- Enhanced Mobile Broadband (eMBB)
  - For the hotspot case, i.e. for an area with high user density
    - Very high traffic capacity is needed
    - The requirement for mobility is low and
    - User data rate is higher than that of wide area coverage
  - For the wide area coverage case
    - Seamless coverage
    - Medium to high mobility are desired
    - Much improved user data rate compared to existing data rates
- Ultra-reliable and low latency communications (URLLC)
  - Stringent requirements for capabilities such as throughput, latency and availability
- Massive machine type communications (mMTC)
  - Characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay-sensitive data
  - Devices are required to be low cost, and have a very long battery life

Better 4G - Enhanced Mobile Broadband

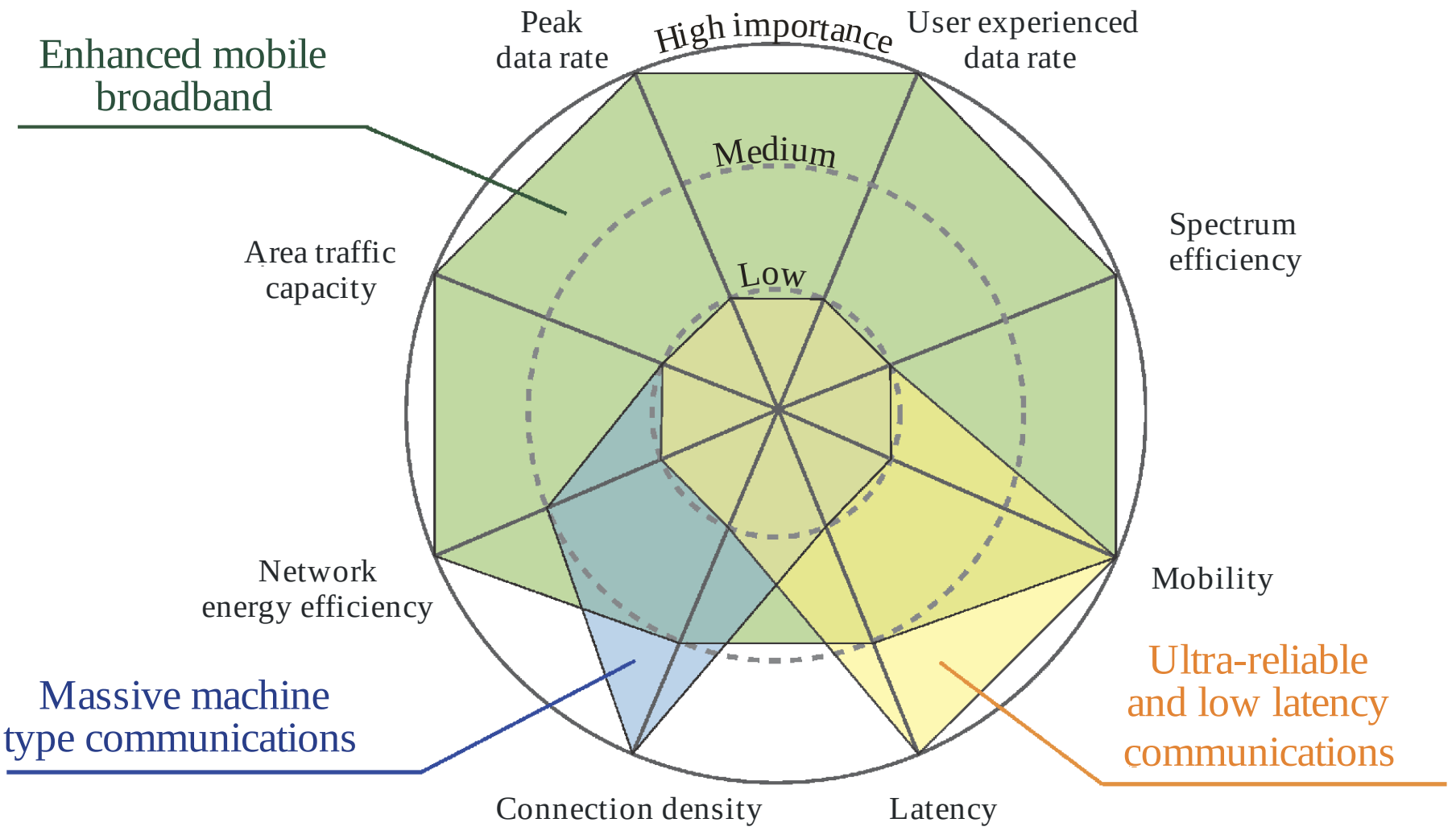
- Mobile Broadband addresses the human-centric use cases for access to multi-media content, services and data
  - The demand for mobile broadband will continue to increase, leading to enhanced Mobile Broadband
  - The enhanced Mobile Broadband usage scenario will come with new application areas and requirements in addition to existing Mobile Broadband applications for improved performance and an increasingly seamless user experience
- This usage scenario covers a range of cases, including wide-area coverage and hotspot, which have different requirements
  - **For the hotspot case**, i.e. for an area with high user density, very high traffic capacity is needed, while the requirement for mobility is low and user data rate is higher than that of wide area coverage
  - **For the wide area coverage case**, seamless coverage and medium to high mobility are desired, with much improved user data rate compared to existing data rates. However the data rate requirement may be relaxed compared to hotspot

Capabilities Maybe Required for IMT-2020

Future IMT becomes more flexible, reliable, and secure

- Spectrum and bandwidth flexibility
  - The flexibility of the system design to handle different scenarios, and
  - The capability to operate at different frequency ranges, including higher frequencies and wider channel bandwidths than today
- Reliability
  - The capability to provide a given service with a very high level of availability
- Resilience
  - The ability of the network to continue operating correctly during and after a natural or man-made disturbance, such as the loss of mains power
- Security and privacy
  - Encryption and integrity protection of user data and signaling
  - End user privacy preventing unauthorized user tracking
  - Protection of network against hacking, fraud, denial of service, man in the middle attacks, etc.
- Operational lifetime
  - Operation time per stored energy capacity
    - This is particularly important for machine-type devices requiring a very long battery life (e.g. more than 10 years) whose regular maintenance is difficult due to physical or economic reasons

Importance of Key Capabilities in Different Usage Scenarios



Source: ITU-R M.2083-0

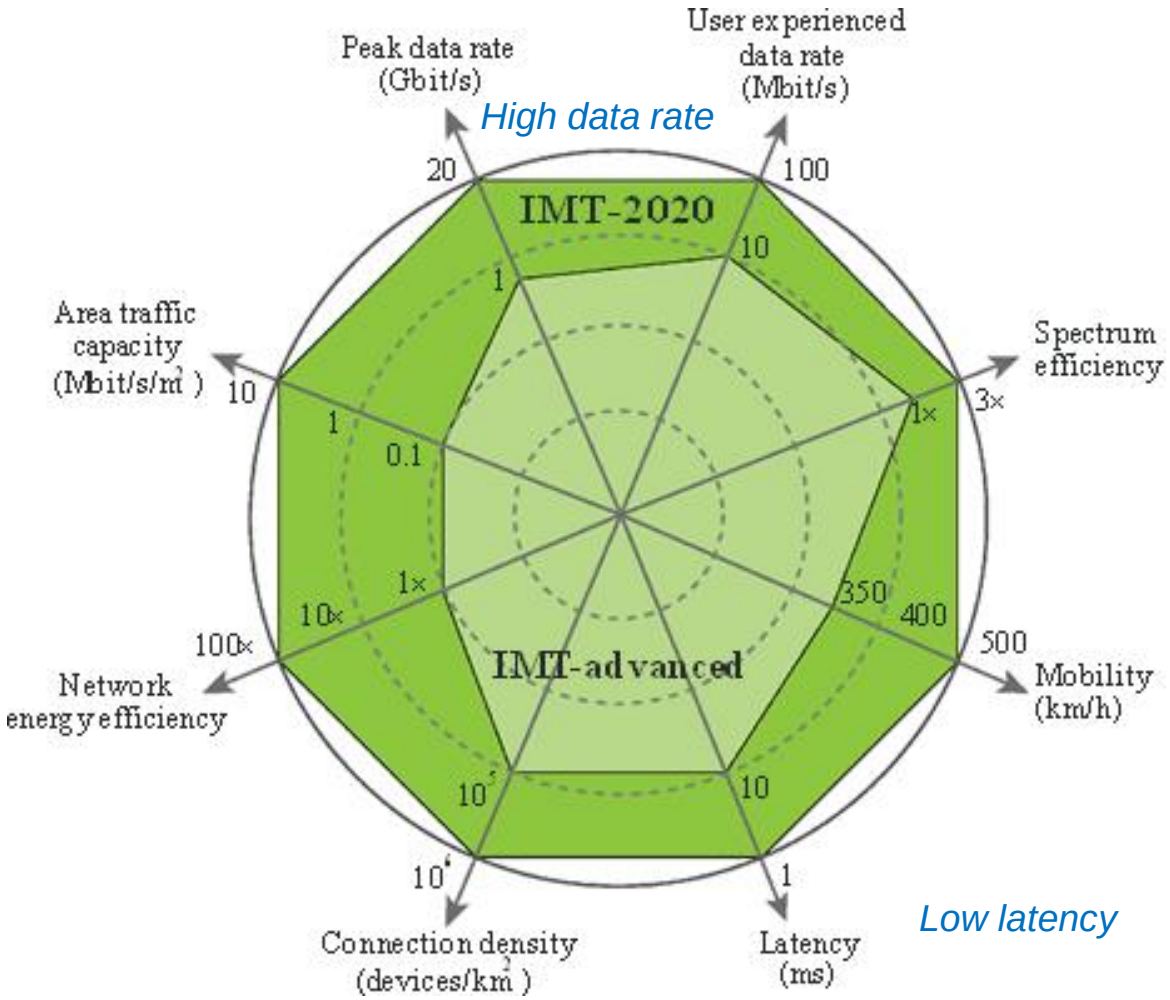
M.2083-04

Capabilities of IMT-2020

Eight parameters as key IMT-2020 capabilities

- Peak data rate
  - Maximum achievable data rate under ideal conditions per user/device (in Gbit/s)
- User experienced data rate
  - Achievable data rate that is available ubiquitously across the coverage area to a mobile user/device (in Mbit/s or Gbit/s)
- Latency
  - Time when a packet sent from the source to the destination (in ms)
- Mobility
  - Maximum speed at which a defined QoS and seamless transfer between radio nodes can be achieved (in km/h)
- Connection density
  - Total number of connected and/or accessible devices per unit area (per km^2)
- Energy efficiency
  - On the network side: quantity of information bits transmitted to/ received from users, per unit of energy consumption of the RAN (in bit/Joule)
  - on the device side: quantity of information bits per unit of energy consumption of the communication module (in bit/Joule)
- Spectrum efficiency
  - Average data throughput per unit of spectrum resource and per cell (bit/s/Hz)
- Area traffic capacity
  - Total traffic throughput served per geographic area (in $Mbit/s/m^2$)

Enhancement of Key Capabilities from IMT-Advanced (4G) to IMT-2020 (5G)



- High data rate
- Low latency
- High reliability
- High density

Source: ITU-R M.2083-0 (Sep 2015)

大頻寬、低延遲、高可靠

International Mobile Telecommunications-2020 (ITU-R IMT-2020 Standard)

- The requirements issued by the ITU-R in 2015 for 5G networks, devices and services

Capability	Description	5G Target	Scenario
Peak data rate	Maximum achievable data rate	20 Gbit/s	eMBB
User experienced data rate	Achievable data rate across the coverage area (hotspot cases)	1 Gbit/s	eMBB
	Achievable data rate across the coverage area	100 Mbit/s	eMBB
Latency	Radio network contribution to packet travel time	1 ms	URLLC
Mobility	Maximum speed for handoff and QoS requirements	500 km/h	eMBB/ URLLC
Connection density	Total number of devices per unit area	10^6 Devices/km^2	MMTC
Energy efficiency	Data sent/received per unit energy consumption (by device or network)	Equal to 4G	eMBB
Area traffic capacity	Total traffic across coverage area	1000 (Mbit/s)/m^2	eMBB
Spectrum efficiency	Throughput per unit wireless bandwidth and per network cell	3–4x 4G	eMBB

Third Generation Partnership Project (3GPP)

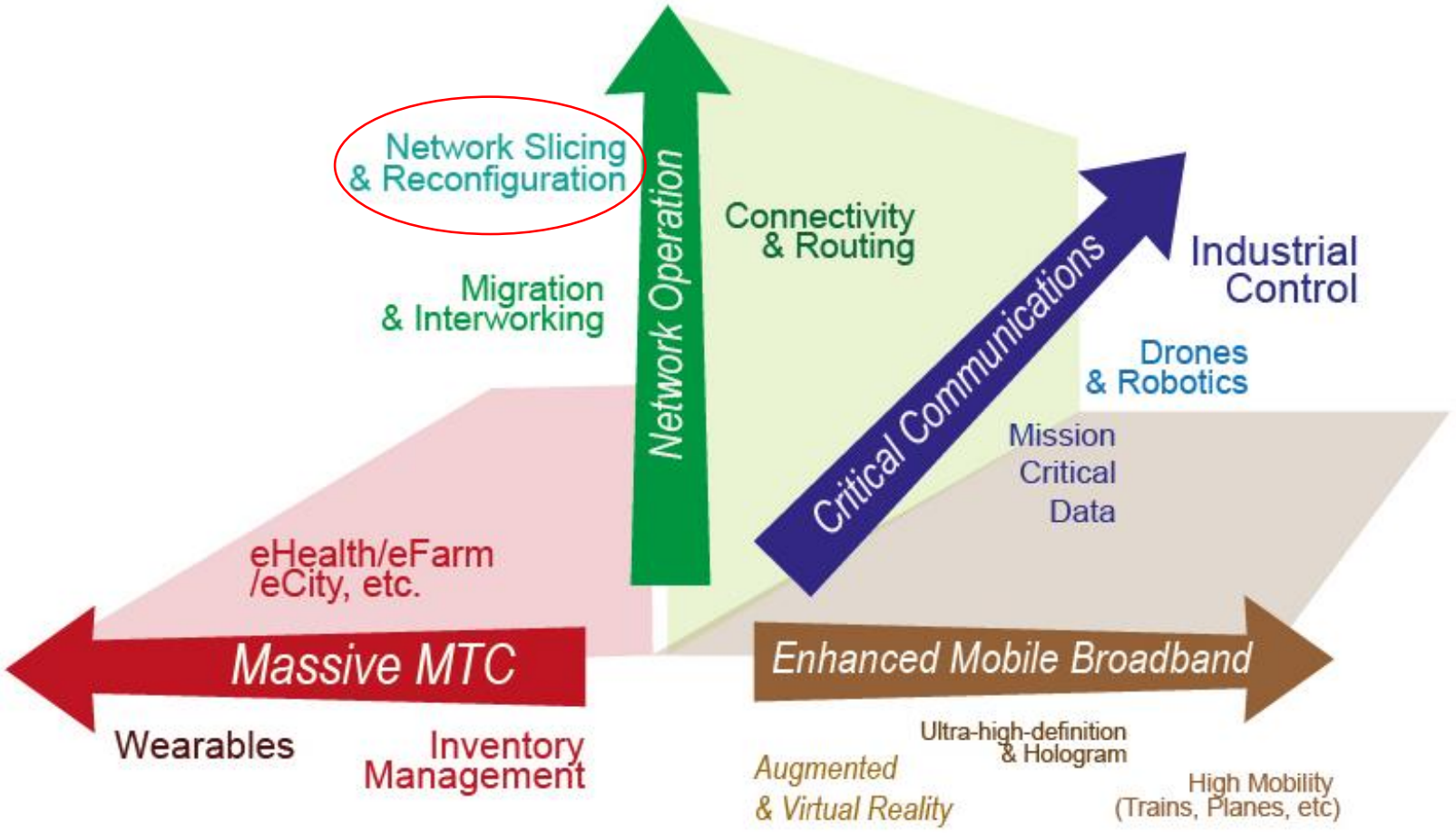
- A global partnership created and managed by regional standards organizations
  - Established in Dec 1998 with the goal of developing a specification for a 3G mobile phone system based on the 2G GSM system
- Members
  - Organizational partners: Seven regional telecommunication associations as primary members
    - ETSI
  - Market representation partners: other organizations as associate members
    - GSMA
- Work in Working Groups (WGs) of three Technical Specification Groups (TSGs)
  - Radio Access Networks (RAN)
  - Services and Systems Aspects (SA)
  - Core Network and Terminals (CT)

3GPP™ A GLOBAL INITIATIVE

5G

https://en.wikipedia.org/wiki/3GPP

3GPP 5G Requirements



TR22.891 with 70s different user cases of four groups (SA1 finalized June 2016)

5G Requirements by 3GPP

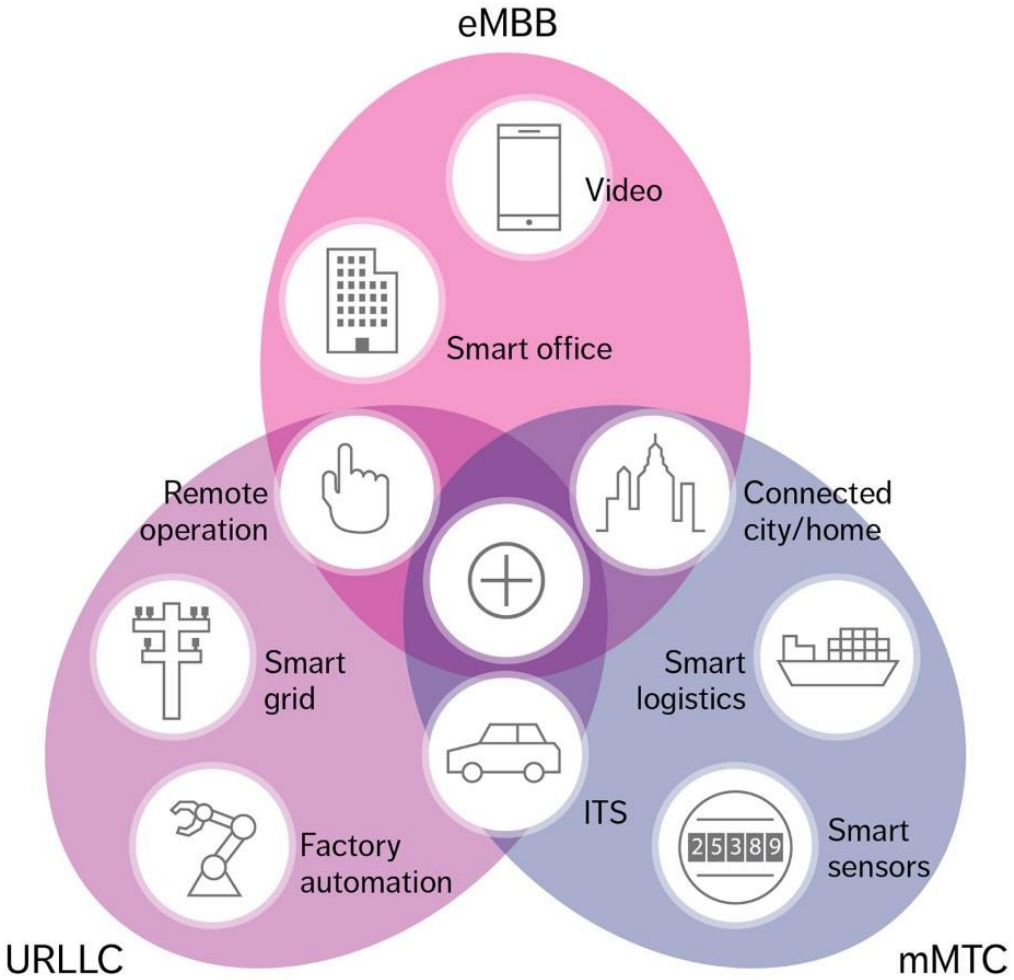
- Looking at potential 5G requirements, 2015
  - More than 70 difference use cases
    - TR 22.891 - Feasibility Study on New Services and Markets Technology Enablers
- Completing its study into 5G requirements, June 2016
  - 3GPP SA#72 approved four new technical reports that outline the New Services and Markets Technology Enablers (SMARTER) for next generation mobile telecommunications (5G)
  - Categorized the use cases into four different groups
    - TR 22.861 - massive Internet of Things
    - TR 22.862 - Critical Communications
    - TR 22.863 - enhanced Mobile Broadband
    - TR 22.864 - Network Operation
- Normative Stage 1 requirements for next generation mobile telecommunications, 2017
  - Consolidating 4 TRs into a single technical specification
    - TS 22.261 - Service Requirements for the 5G System (17.3.0)

https://www.3gpp.org/news-events/1786-5g_reqs_sa1

3GPP Feasibility Study on new Services and MARkets Technology enablERS

TR 22.861: FS_SMARTER – massive Internet of Things	• *Massive Internet of Things* focuses on use cases with massive number of devices (e.g., sensors and wearables) • This group of use cases is particularly relevant to the new *vertical services*, such as smart home and city, smart utilities, e-Health, and smart wearables
TR 22.862: FS_SMARTER – Critical Communications	• The main areas where improvements are needed for *Critical Communications* are latency, reliability, and availability to enable, for example, industrial control applications and tactile Internet • These requirements can be met with an improved radio interface, optimized architecture, and dedicated core and radio resources
TR 22.863: FS_SMARTER – enhanced Mobile Broadband	*Enhanced Mobile Broadband* includes a number of different use case families related to higher data rates, higher density, deployment and coverage, higher user mobility, devices with highly variable user data rates, fixed mobile convergence, and small-cell deployments
TR 22.864: FS_SMARTER – Network Operation	The use case group *Network Operation* addresses the functional system requirements, including aspects such as: flexible functions and capabilities, new value creation, migration and interworking, optimizations and enhancements, and security

Three Main 5G Cases and Examples



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Pre-history of Cellular/Mobile Networks

- Motorola announced DynaTAC 8000x in 1984
  - 4,000 USD, 30-min talk/8hr standby, 30 entries
  - First prototype in 1974
  - SCR-300 in 1941 (16kg/12.9km, FM)

- Advanced Mobile Phone System (AMPS) developed by Bell Labs on October 13, **1983**
  - 1989年台灣交通部電信總局引進，手機俗稱**大哥大**、**黑金剛**

History of Cellular/Mobile Networks – GSM Era

European Conference of Postal and Telecommunications Administrations (CEPT) set up the Groupe Spécial Mobile (GSM) committee in 1983

- Feb 1987 - produced the first GSM technical specification
  - GSM renamed as *Global System for Mobile Communications*
  - 1989 transferred to European Telecommunications Standards Institute (ETSI)
- Dec **1991** - first deployed in Finland
  - 1995 GSM Association (GSMA) formed
    - MoU signed in 1987, Mobile World Congress (MWC) began

- 1996年台灣通過電信三法，開啟電信自由化、民營化
  - 《電信法》修正案、《交通部電信總局組織條例》修正案、《中華電信股份有限公司條例》
  - 1997年開放行動電話、無線電叫人、行動數據與中繼式無線電話等四項行動通信業務
- 1990年7月，台灣第一個網際網路「台灣學術網路(TANet)」成立
  - 1991年12月以64Kbps專線經美國東岸普林斯頓大學連至國際Internet

History of Cellular/Mobile Networks – 3GPP Era

Third Generation Partnership Project (3GPP) started in Dec 1998

- Seven organizations including ETSI and GSMA

- Release 99 standardized UMTS 3G in **2000**
  - 2002年台灣開放3G
- Release 10 (LTE-A) met ITU IMT-Advanced (4G) in **2011**
  - 2013年台灣4G競標並於2014年開台
- Release 15 (5G NR phase 1/NSA) Finalized in Q1 2019
  - Drafted in Q4 2017
  - 台灣2019/12競標、2020/01發照、2020/06開台
- Release 16 (5G NR phase 2/SA) Frozen in July 2020

Mobile Phone Generations

1G (1979)	AMPS
2G (1991)	GSM, PHS
2G transitional (2.5G, 2.75G)	GSM/3GPP - GPRS, EDGE, CDMA2000
3G (2001)	3GPP R99 - UMTS, W-CDMA
3G transitional (3.5G, 3.75G, 3.9G)	3GPP - HSPA, LTE (E-UTRA); IEEE WiMAX 802.16e
4G (2013) (IMT-Advanced)	3GPP R10 - LTE-A, LTE-A Pro (4.5G-4.9G); IEEE WiMAX 802.16m
Under development (IMT-2020)	3GPP R15/R16 - 5G (2020)

Source: https://en.wikipedia.org/wiki/Template:Cellular_network_standards

Features of 3GPP 5G System (5GS) Architecture

- Service Based Architecture
  - The architecture elements are defined as *network functions*
  - Adopts principles like modularity, reusability and self-containment of network functions
- Common Core Network
  - Enables to operate with different access networks
- Network Slicing
  - Allows for controlled composition of a PLMN from the specified network functions with their specifics and provided services that are required for a specific usage scenario
- Application Support
  - **A new QoS model enables differentiated data services to support diverse application requirements**

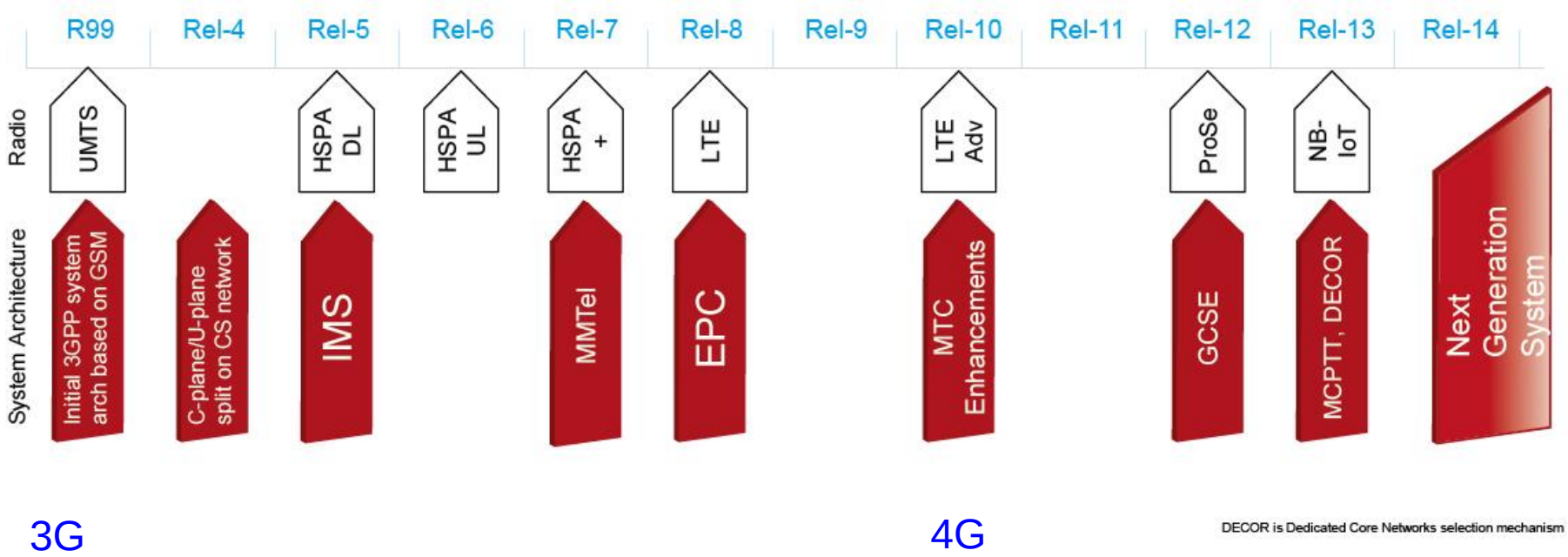
3GPP TSGs and WGs

Project Co-ordination Group (PCG)		
TSG RAN Radio Access Network	TSG SA Service & Systems Aspects	TSG CT Core Network & Terminals
RAN WG1 Radio Layer 1 spec	SA WG1 Services	CT WG1 MM/CC/SM (lu)
RAN WG2 Radio Layer 2 spec Radio Layer 3 RR spec	SA WG2 Architecture	CT WG3 Interworking with external networks
RAN WG3 lub spec, lur spec, lu spec UTRAN O&M requirements	SA WG3 Security	CT WG4 MAP/GTP/BCH/SS
RAN WG4 Radio Performance Protocol aspects	SA WG4 Codec	CT WG6 Smart Card Application Aspects
RAN WG5 Mobile Terminal Conformance Testing	SA WG5 Telecom Management	
~~RAN WG6~~ (closed June 2020) GSM EDGE RAN	SA WG6 Mission-critical applications	

TSG: Technical Specification Group

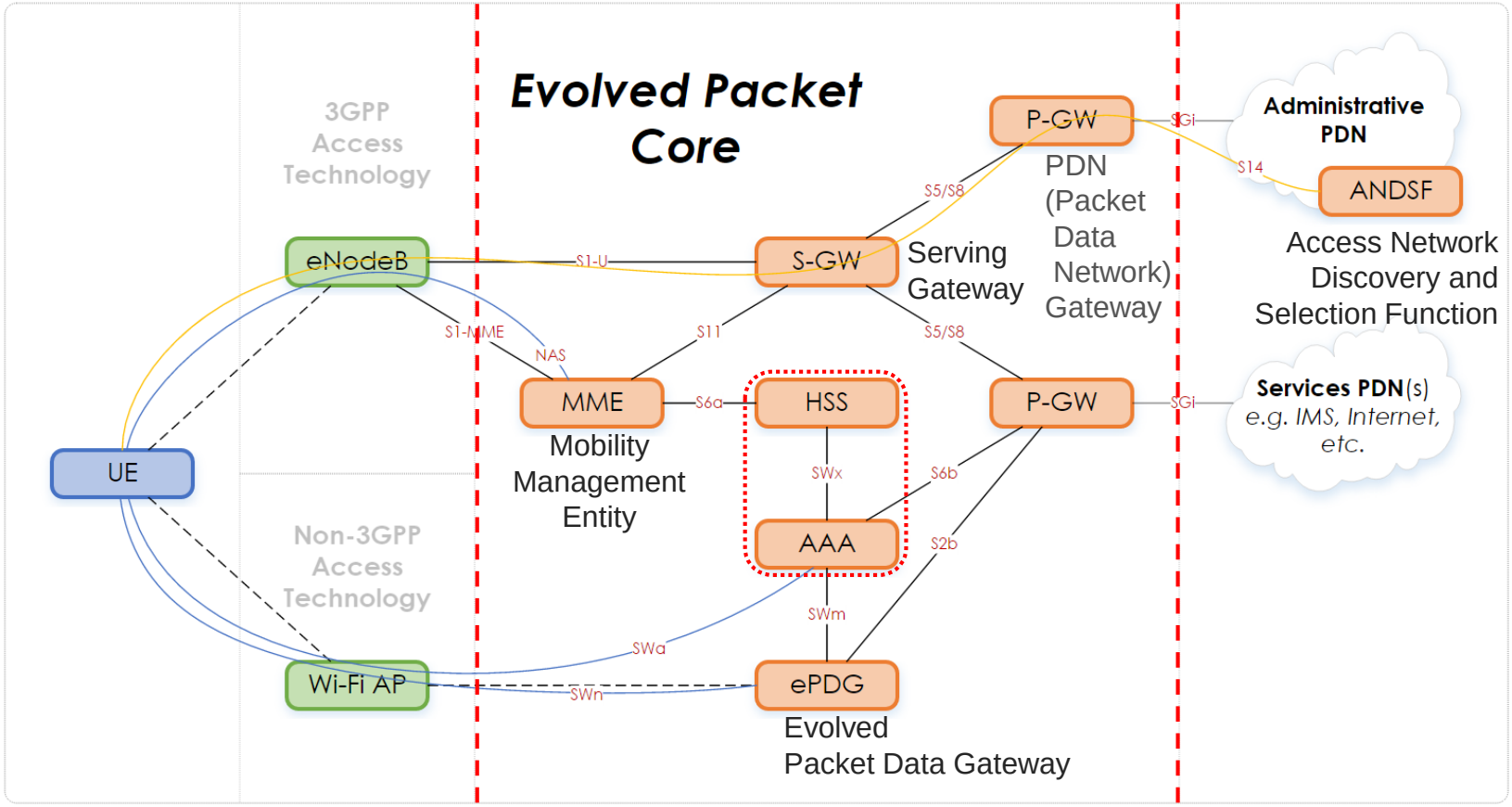
https://www.3gpp.org/specifications-groups

Core Network Evolution



Source: https://www.3gpp.org/about-3gpp/about-3gpp

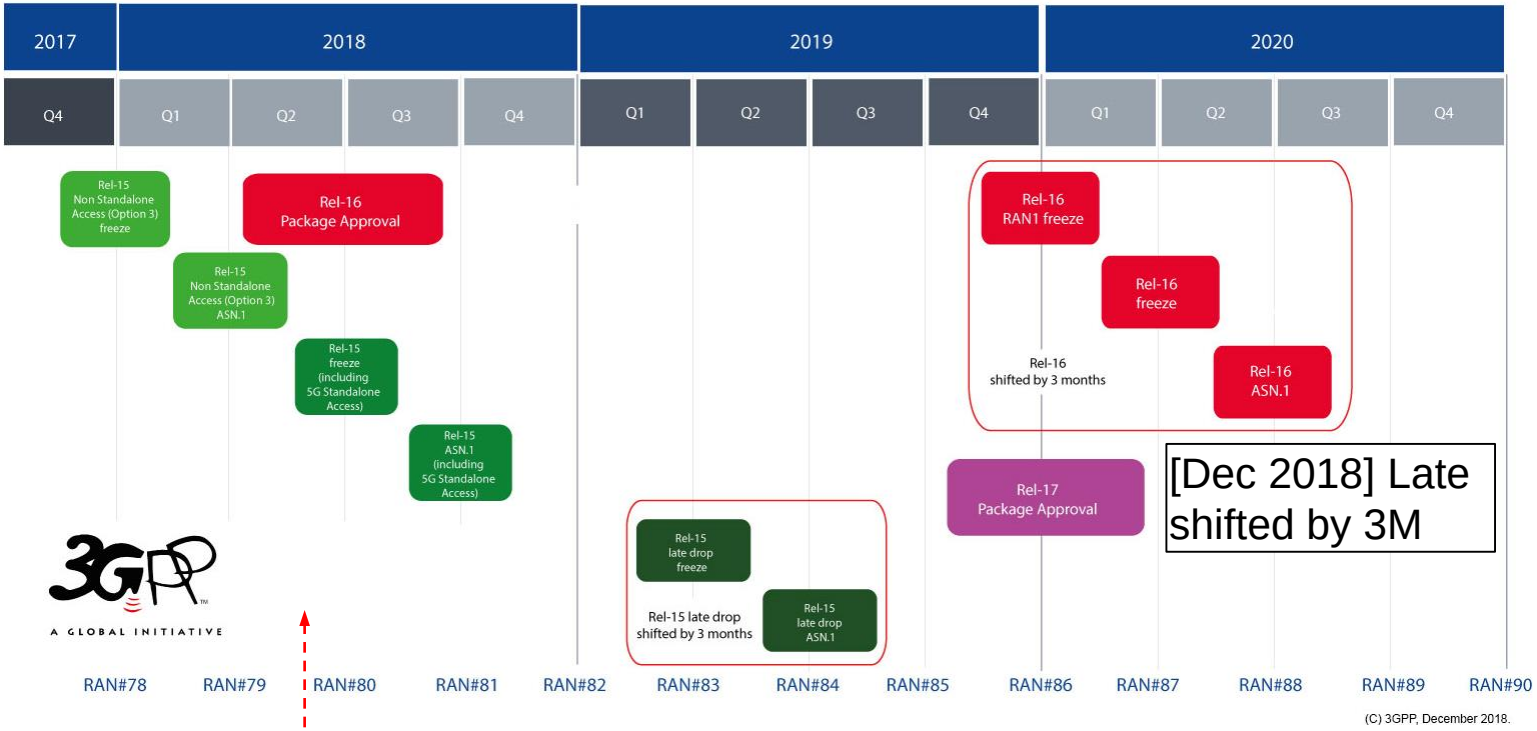
3GPP 4G - EPS (Evolved Packet System) / SAE



- EPC (Evolved Packet Core): main component of EPS, includes
  - MME: key control-node for LTE – UE paging; chooses S-GW for UE during attach and handover
    - Authenticating the user (by interacting with HSS - Home Subscriber Server)
  - S-GW: manages and stores UE contexts; routes and forwards user data packets
  - P-GW: provides connectivity from the UE to external packet data networks
  - ePDG: secures data transmission with UE connected to EPC over untrusted non-3GPP access
  - ANDSF: provides information to UE to discover available access networks (either 3GPP or not)

3GPP 5GS - R15 and R16 NR Milestones

[Dec 2017] Non-standalone (NSA) 5G NR mode for eMBB (Option 3)

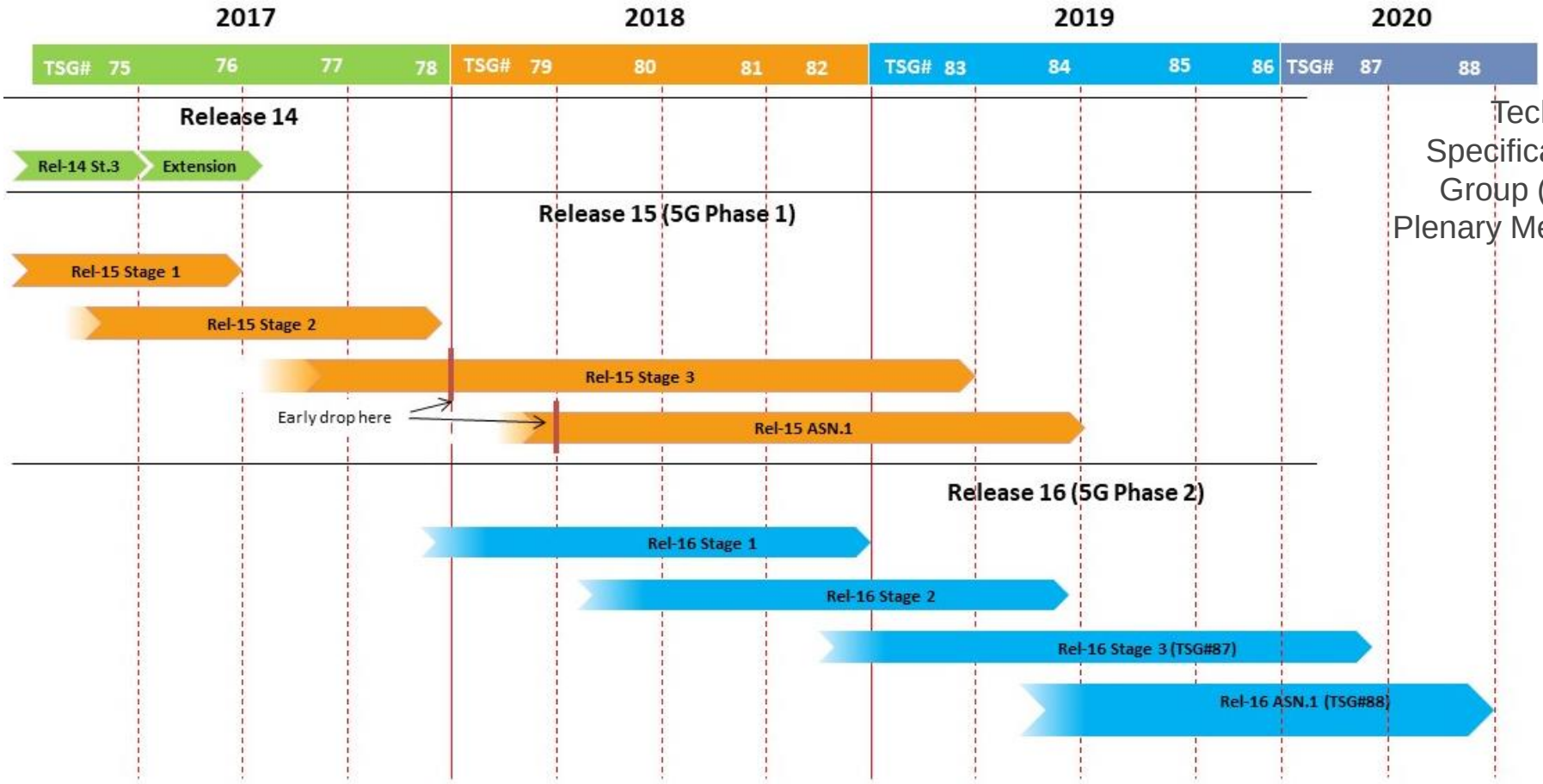


[Dec 2018] Late shifted by 3M

[June 2018] Standalone (SA) 5G NR (Option 2) approved by TSG #80 Plenary Meeting

- **5G Non-Standalone (NSA)**: The existing LTE radio access and core network (EPC) is used as an anchor for mobility management and coverage to add the 5G carrier
- **5G Standalone (SA)**: A new 5G Packet Core comprising of 5G New Radio (5G NR) and 5G Core Network (5GC/~~NGC~~) is introduced with several new capabilities built inherently

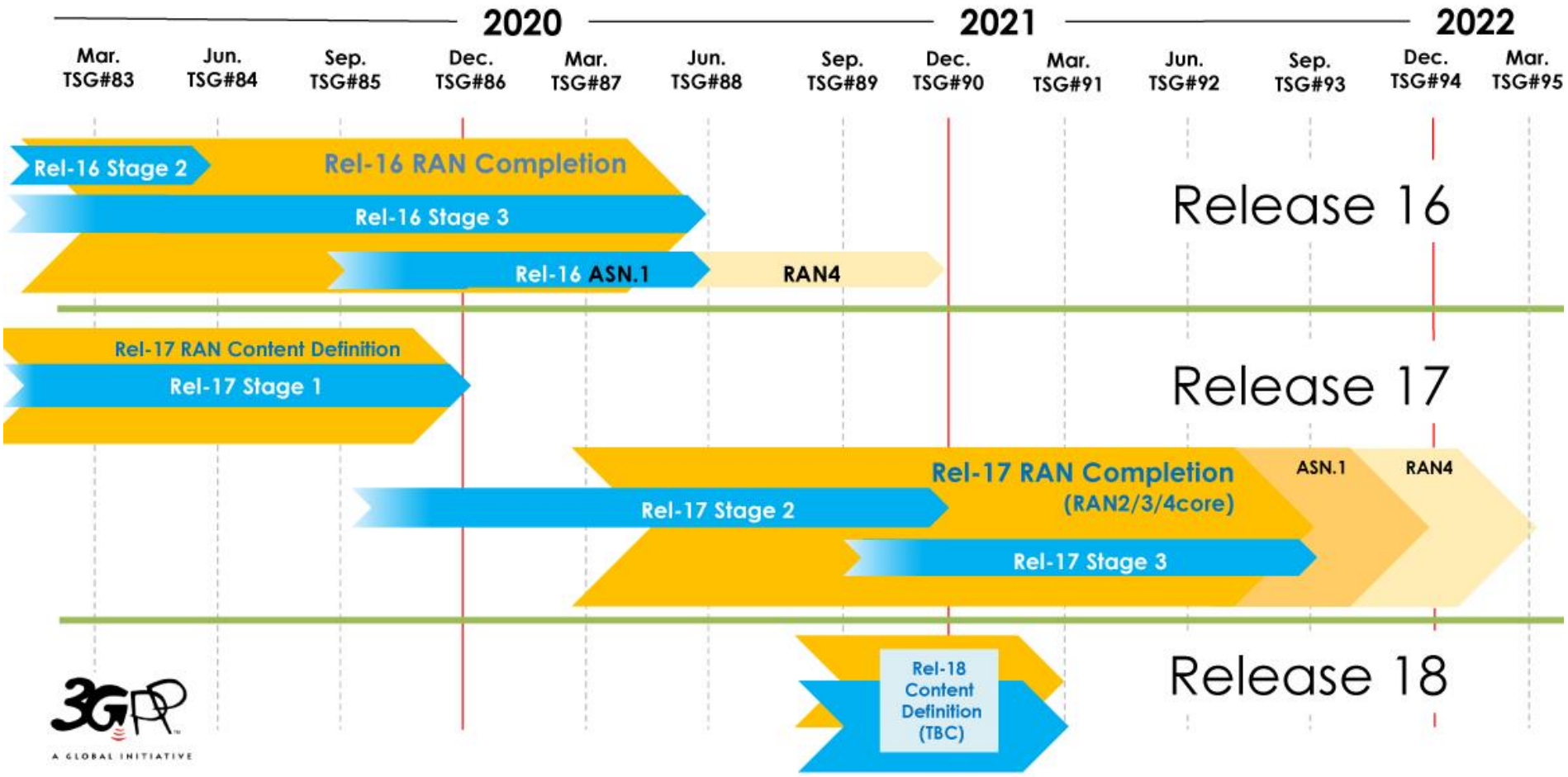
3GPP 5G Releases



Stage 1: an overall service description *from the user's standpoint*
Stage 2: an overall description of the *organization of the network functions* to map service requirements into network capabilities
Stage 3: the definition of *switching and signalling capabilities* needed to support services defined in stage 1
ASN.1: Standard interface description for defining data structures

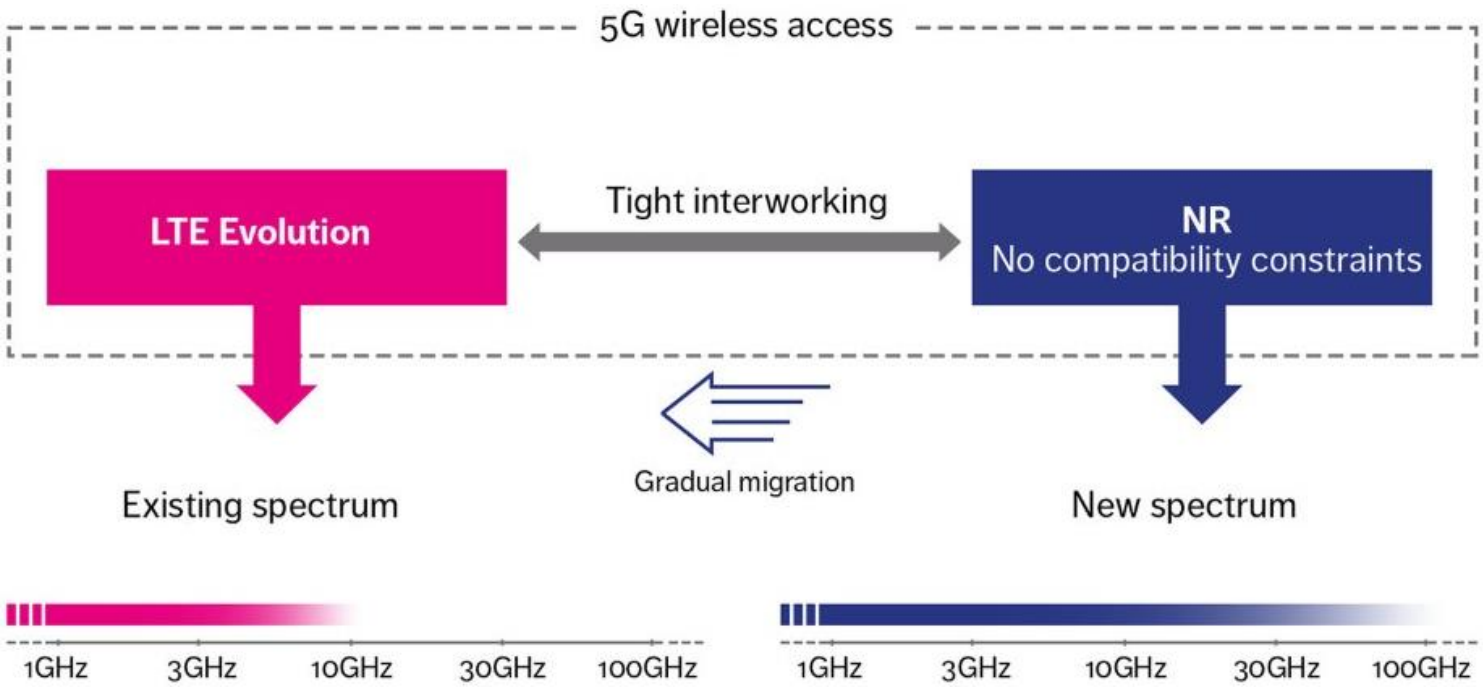
https://www.3gpp.org/specifications/67-releases

3GPP Ongoing Releases



Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

5G Radio Access Roadmap



- Two tracks
  - Evolution of LTE (Non Standalone)
  - New Radio (NR, LTE-5G)
    - Free from backward compatibility requirements / network slicing
    - Targeting spectrum at high (mm-wave) frequencies
- Two main features
  - FD-MIMO (Full-Dimension)
  - Unlicensed operations

5G NR

- Frequencies
  - FR1: Lower frequencies (below 6 GHz)
  - FR2: Higher Frequencies (above 24 GHz)
- Enabling Technologies

Scalable Numerology	Flexible Frame Structure	Advanced Channel Coding	Enhanced MIMO	Beam Forming
Single framework for f_c = sub 1-GHz – 50+ GHz Low latency* * One way latency ~ 1ms	Forward compatible design Flexible TDD	**LDPC** for high through-put low latency data channels. **Polar** codes for control channels.	Higher spectral efficiency MU-MIMO support	mmWave support Enhanced coverage

- R17 work areas under consideration

NR Light	Multi-SIM	IIoT/URLLC enhancements	NR-U Enhancements
Small data Enhancements	NR Multicast/ Broadcast	MIMO Enhancements	Power saving Enhancements
Sidelink Enhancements	Coverage Enhancements	NTN Enhancements	Data collection Enhancements
Above 52.6 GHz	NB-IoT Enhancements	IAB Enhancements	Positioning Enhancements

https://www.3gpp.org/news-events/partners-news/2061-atis-webinar-%E2%80%93-5g-standards-development

Rel-17 Prioritized Headline Features

- NR MIMO
- NR Sidelink enh.
- 52.6 - 71 GHz with existing waveform
- Dynamic Spectrum Sharing (DSS) enh.
- Industrial IoT / URLLC enh.
- Study - IoT over Non Terrestrial Networks (NTN)
- NR over Non Terrestrial Networks (NTN)
- NR Positioning enh.
- Low complexity NR devices
- Power saving
- NR Coverage enh.
- Study - NR eXtended Reality (XR)
- NB-IoT and LTE-MTC enh.
- 5G Multicast broadcast
- Multi-Radio DCCA enh.
- Multi SIM
- Integrated Access and Backhaul (IAB) enh.
- NR Sidelink relay
- RAN Slicing
- Enh. for small data
- SON / Minimization of drive tests (MDT) enh.
- NR Quality of Experience
- eNB architecture evolution, LTE C-plane / U-plane split
- Satellite components in the 5G architecture
- Non-Public Networks enh.
- Network Automation for 5G - phase 2
- Edge Computing in 5GC
- Proximity based Services in 5GS
- Network Slicing Phase 2
- Enh. V2x Services
- Advanced Interactive Services
- Access Traffic Steering, Switch and Splitting support in the 5G system architecture
- Unmanned Aerial Systems
- 5GC LoCation Services
- Multimedia Priority Service (MPS)
- 5G Wireless and Wireline Convergence
- 5G LAN-type services
- User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)

These are some of the Rel-17 headline features, prioritized during the December 2019 Plenaries (TSG#86)

Start of work: January 2020

- Start of work: January 2020
- Details: https://www.3gpp.org/specifications/work-plan

Some Release 17 Feature or Study Items

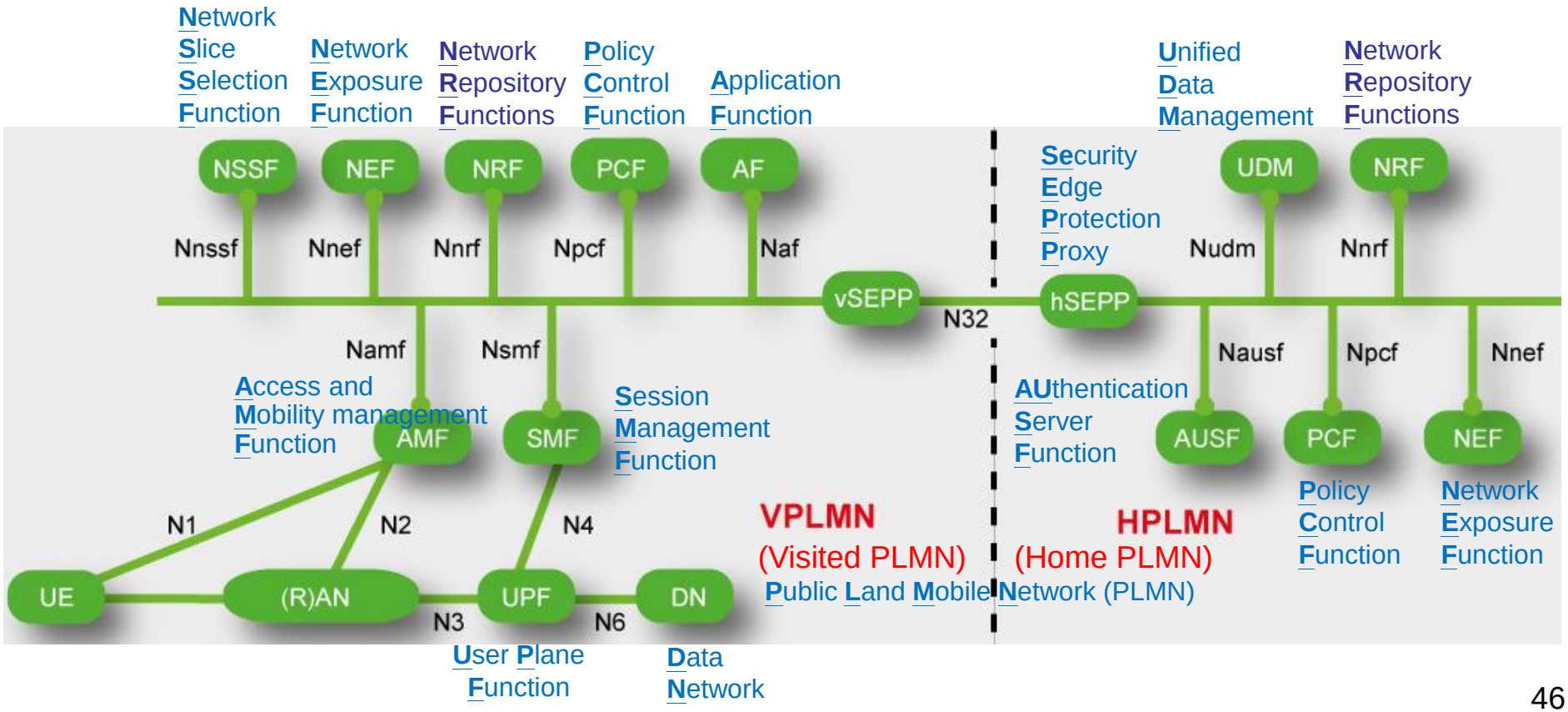
- Enhancements for cyber-physical control applications in vertical domains (eCAV)
- 5G Enhancement for UAVs
- Complete Gap Analysis for Railways Mobile Communication System (MONASTERYEND)
- Audio-Visual Service Production (AVPROD)
  - Requirements for using 5GS for the production and contribution of audio-visual content and
- Network Controlled Interactive Service (NCIS)
  - Specify KPIs for interactive service
- Support for Multi-USIM Devices (MUSIM)
- Multimedia Priority Service (MPS) Phase 2 (MPS2)

Full list: https://www.3gpp.org/dynareport/TSG-WG--S1--wis.htm?Itemid=438

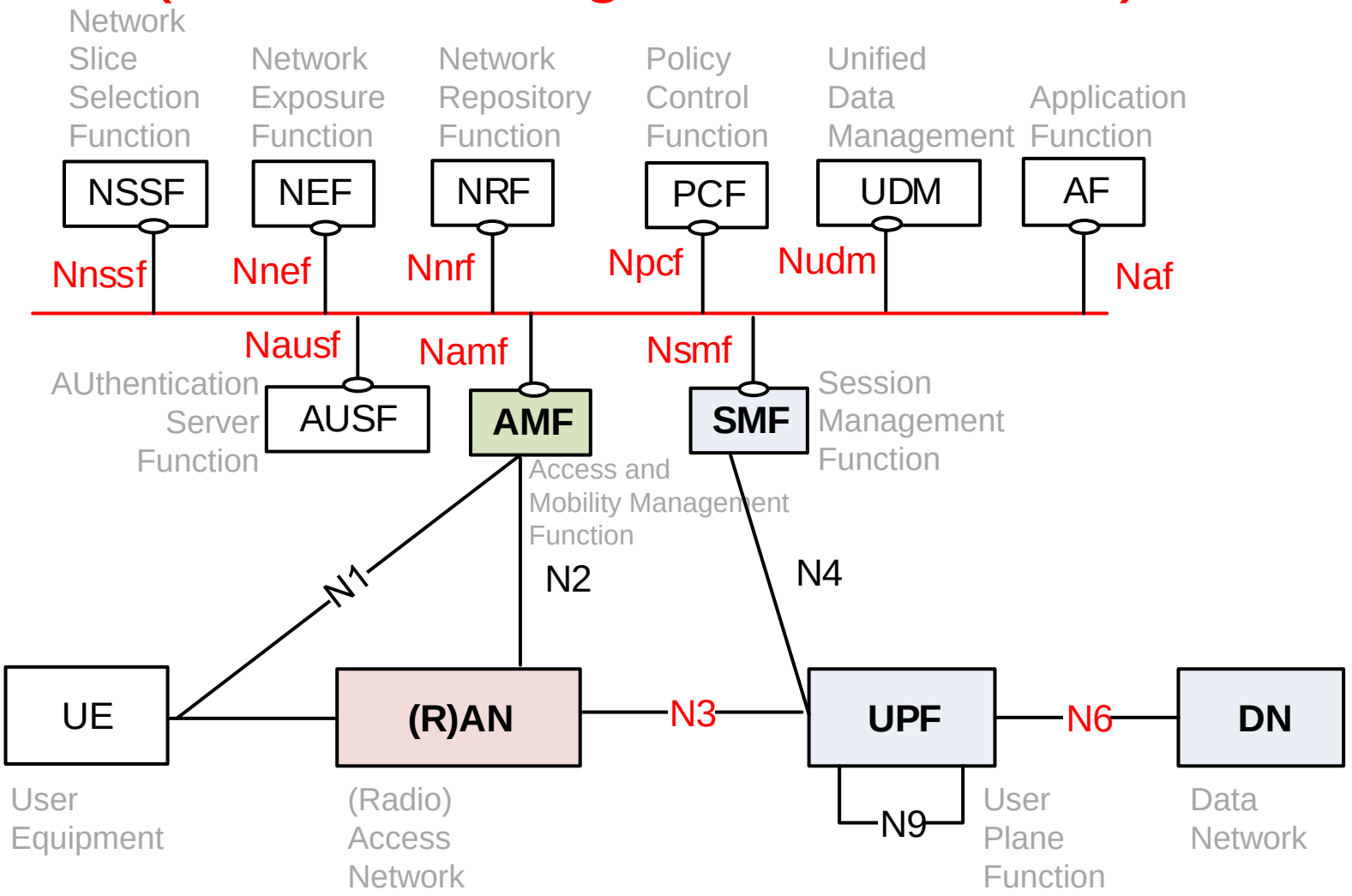
Source: https://www.atis.org/01_news_events/webinar-pptslides/5g-slides7312019.pdf

5G Service-Based Architecture

- Service Based Architecture: the architecture elements are defined as network functions
  - That offer their services via *interfaces of a common framework* to any network functions that are permitted to make use of these provided services
  - ***Network Repository Functions (NRF)*** allow every network function to discover the services offered by other network functions
  - Network functions may store their contexts in ***Data Storage Functions (DSF)***

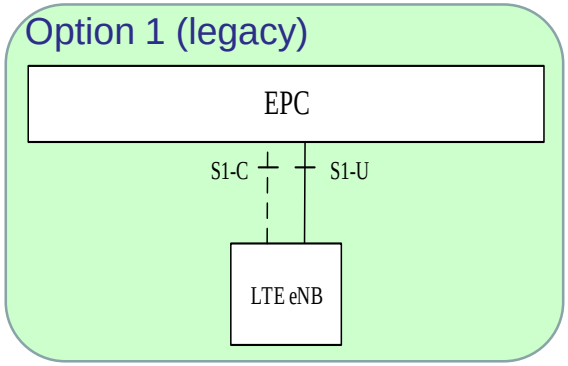


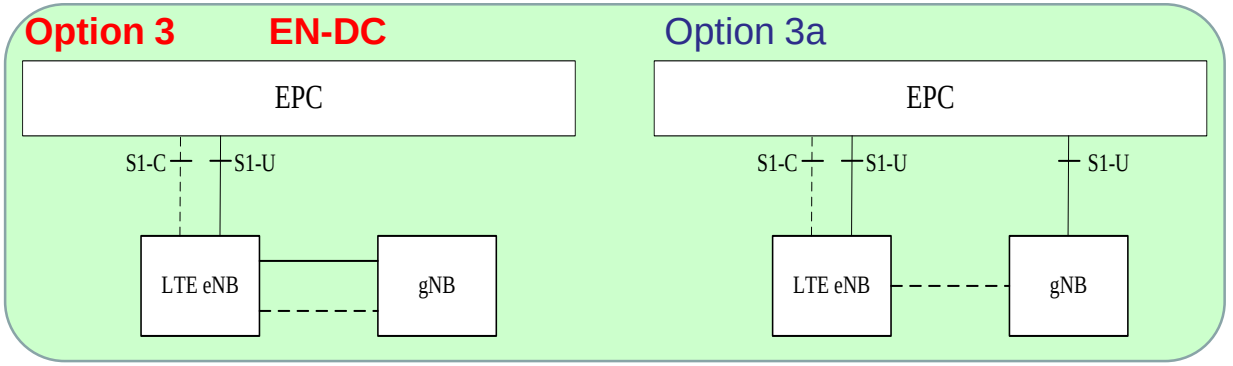
5G System Architecture (Non-Roaming Service-Based)

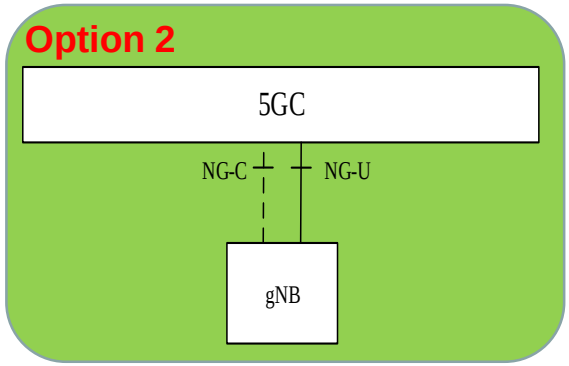


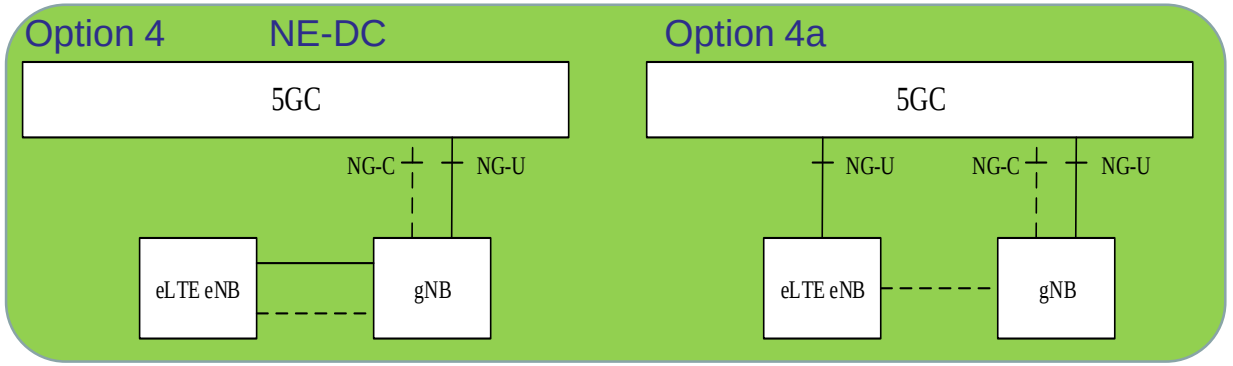
The non-roaming reference architecture with service-based interfaces used within the Control Plane (TS23.501)

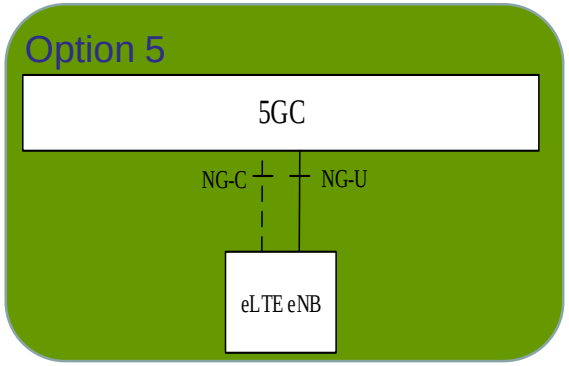
5G Architecture Options (TR38.801)

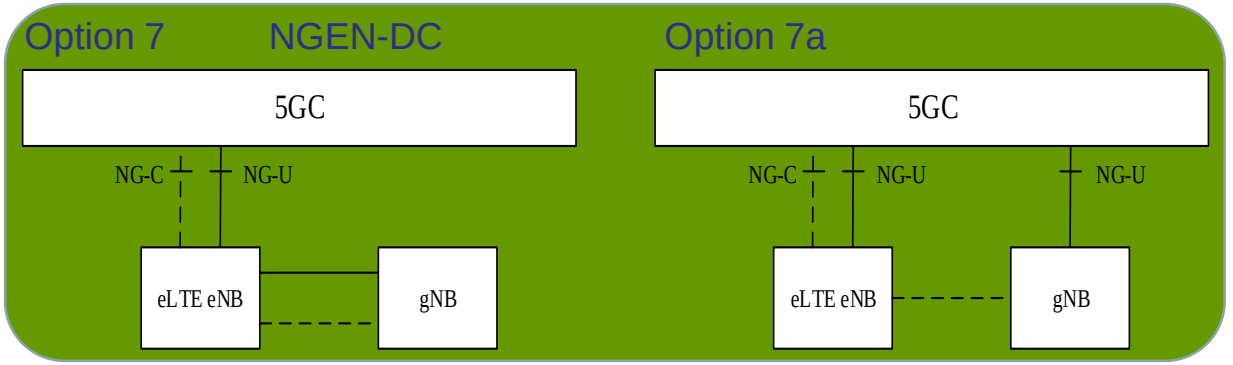




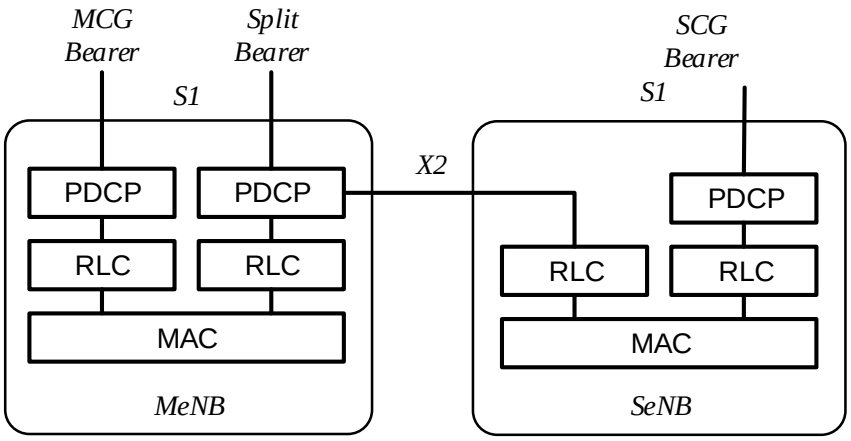




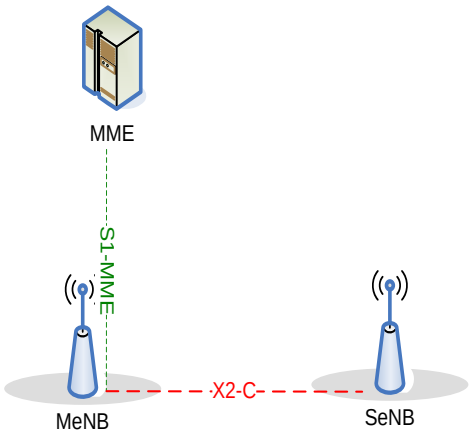




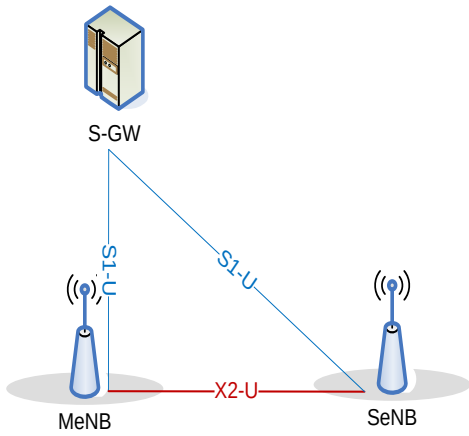
E-UTRAN for Dual Connectivity (DC) (TS36.300)



Radio Protocol Architecture



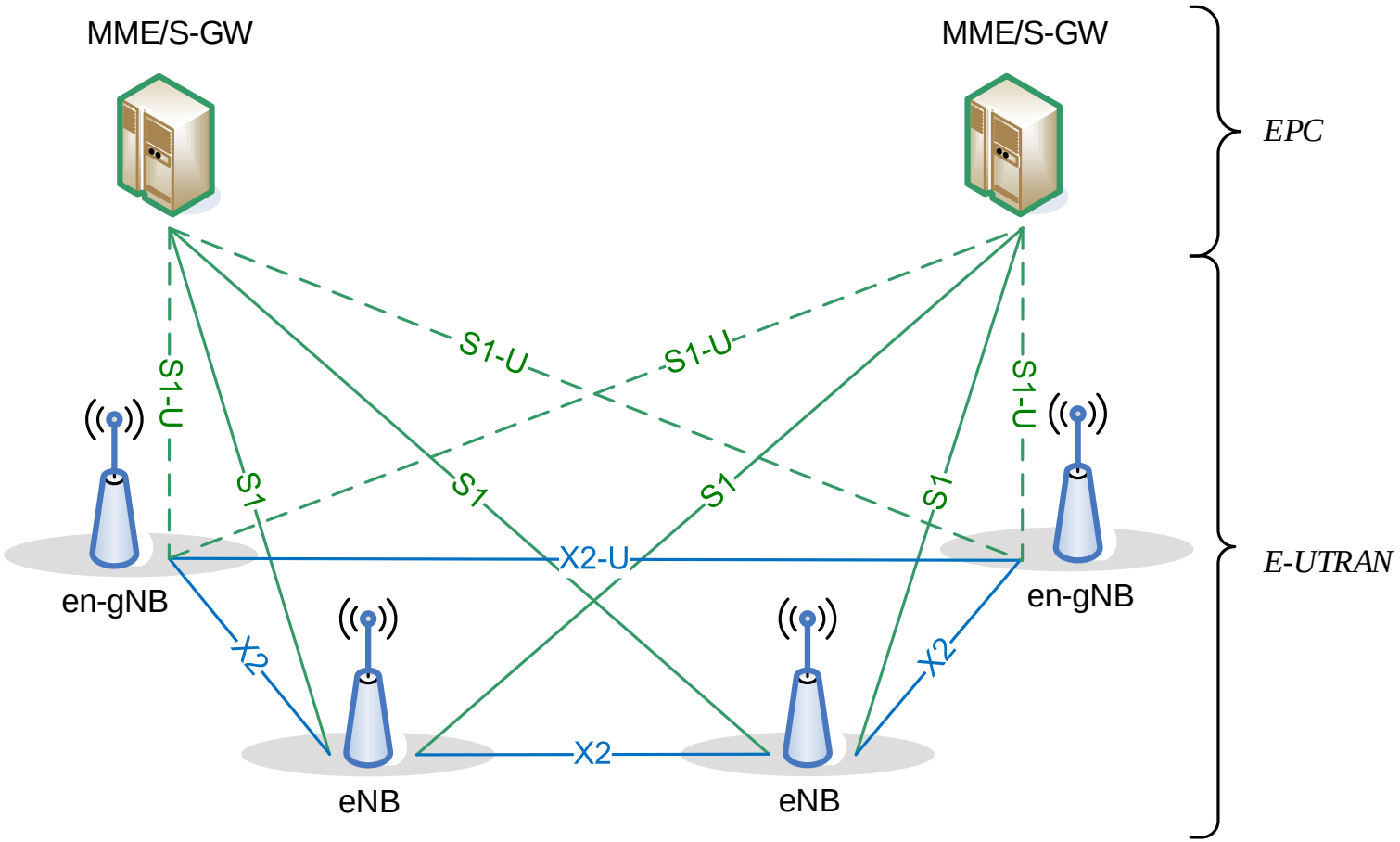
C-Plane



U-Plane

- Three bearer types exist
  - MCG bearer (Master Cell Group)
  - SCG bearer (Secondary Cell Group) and
  - Split bearer
- Network Interfaces
  - C-Plane: by means of X2 interface signalling
    - There is only one S1-MME connection per DC UE between the MeNB and the MME
  - U-Plane: two different user plane architectures are allowed
    - One in which the S1-U only terminates in the MeNB and the user plane data is transferred from MeNB to SeNB using the X2-U, and
    - A second architecture where the S1-U can terminate in the SeNB

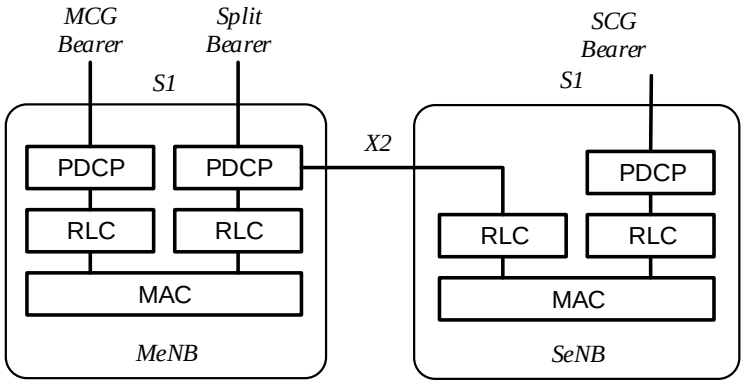
EN-DC Overall Architecture

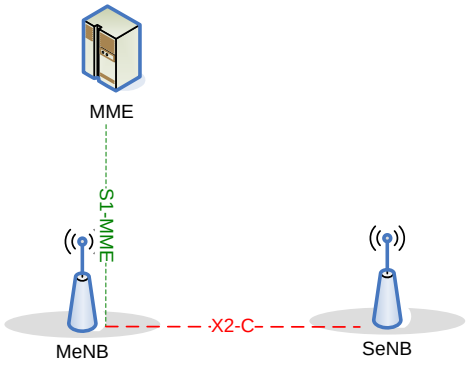


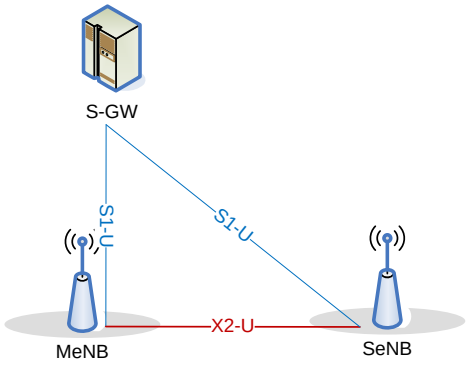
en-gNB: node providing NR user plane and control plane protocol terminations towards the UE, and acting as *Secondary Node* in EN-DC (TS 37.340 Clause 4)

DC and EN-DC

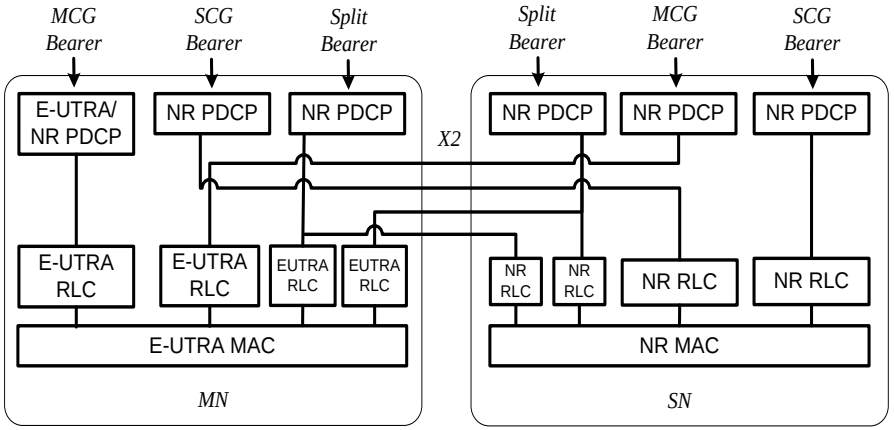
DC

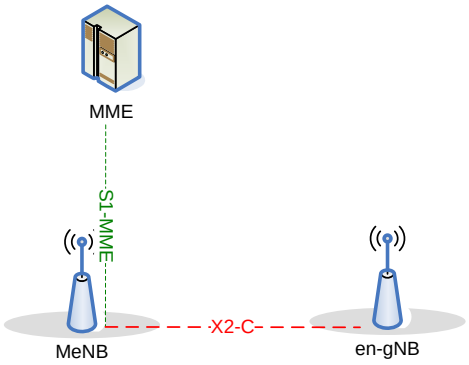


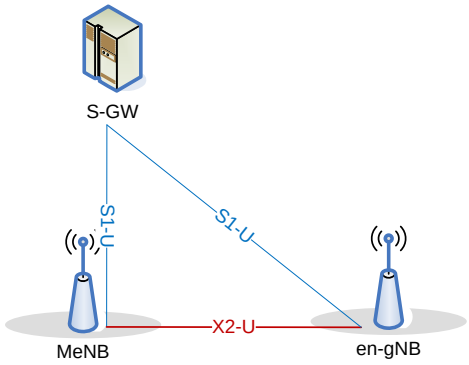




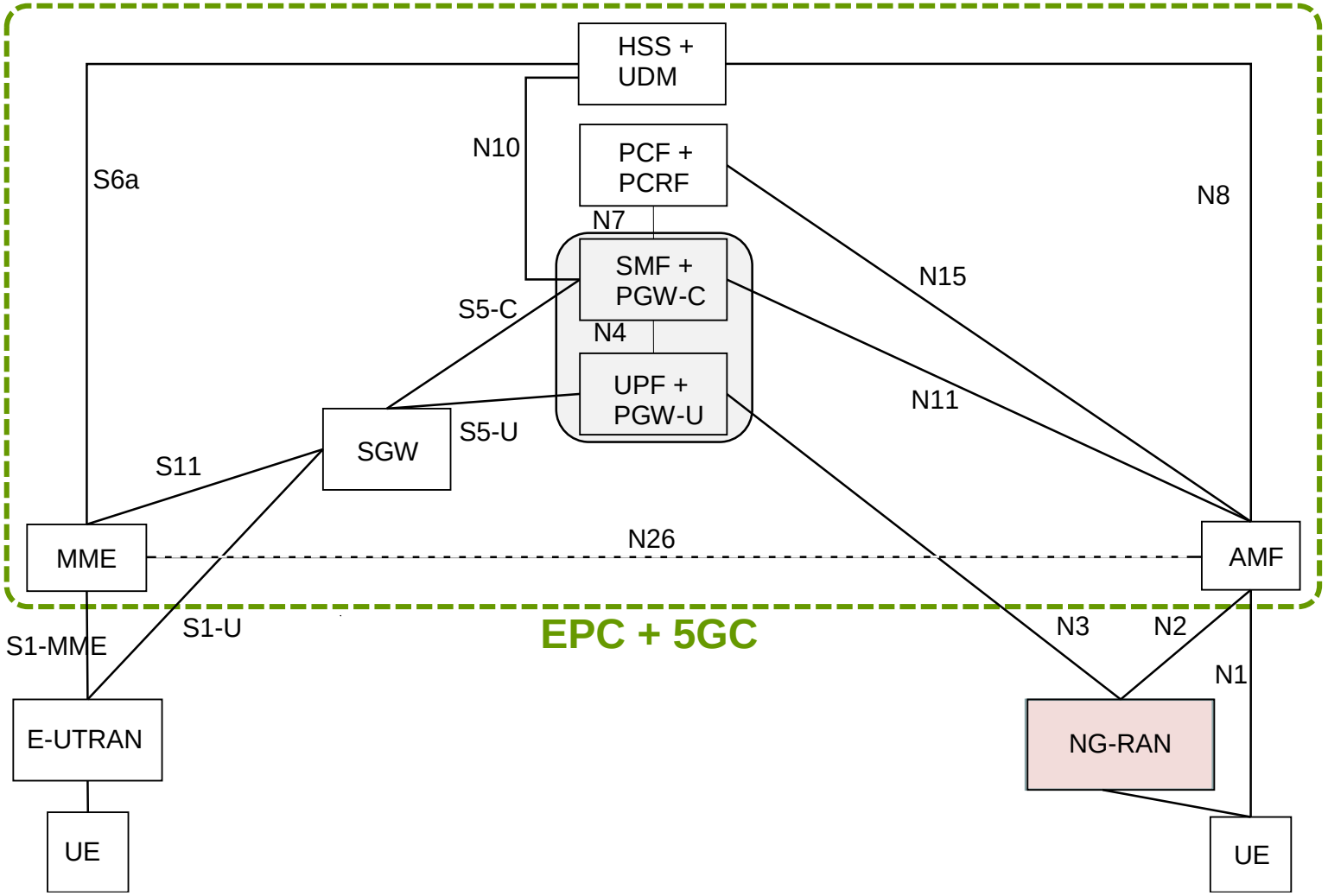
EN-DC





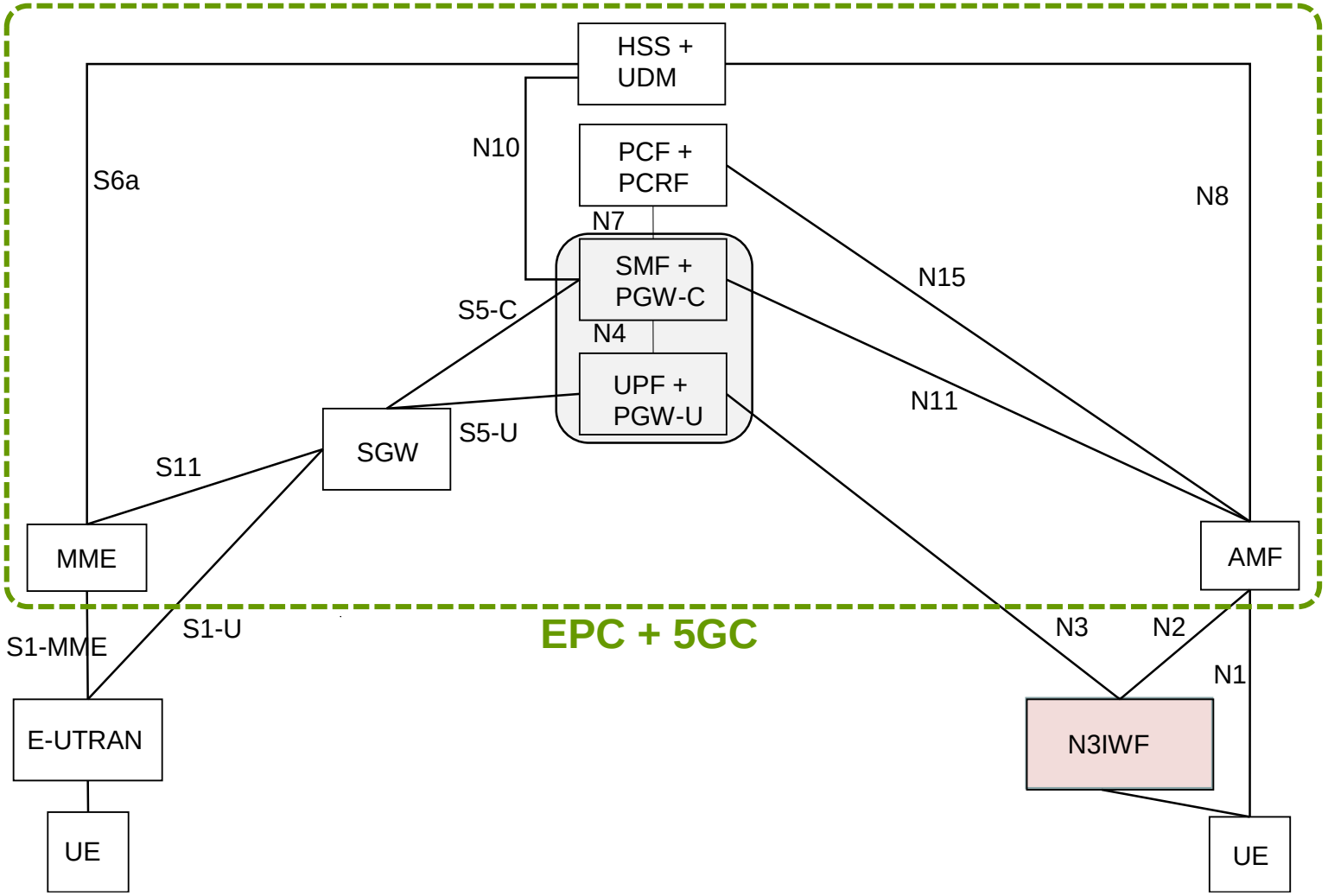


Non-roaming Architecture for Interworking between 5GS and EPC/E-UTRAN



TS 23.501 (Clause 4.3 - Interworking with EPC)

Non-roaming Architecture for Interworking between 5GC via Non-3GPP Access and EPC/E-UTRAN

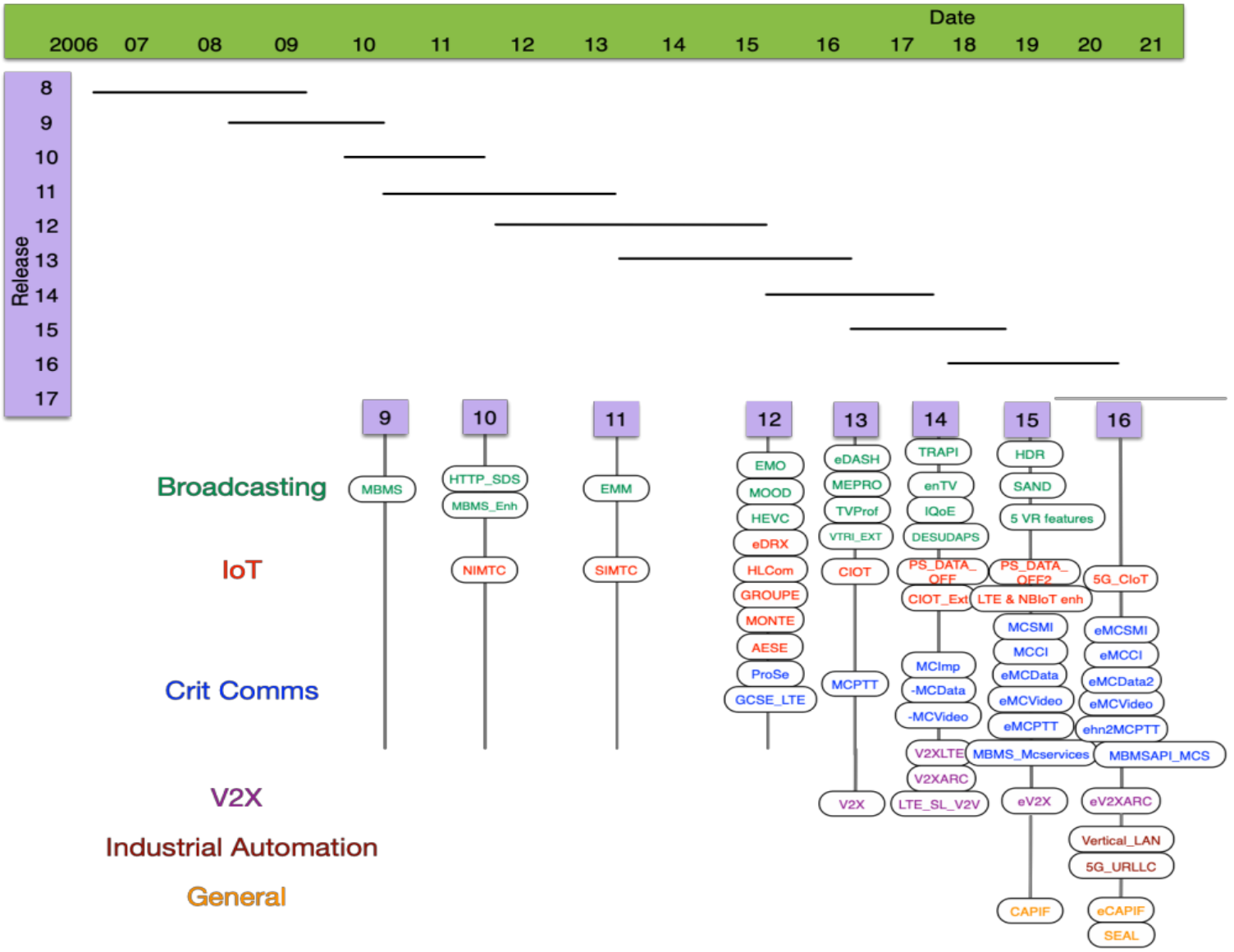


TS 23.501 (Clause 4.3 - Interworking with EPC)

Outline

- Syllabus
- Introduction to Vertical Applications (VA)
  - ITU-R IMT-2020 Vision: eMBB, uRLLC and mMTC
  - 3GPP Use Cases and Requirements
- 3GPP Standards for VA
  - Toward 5GS: NR + 5GC
  - Unified Architecture: QoS + CAPIF

Verticals in 3GPP



https://www.3gpp.org/ftp/Information/presentations/presentations_2019/2019_06_erik_EUTC-5G-Workshop-Standards-Overview-01.Erik-Guttman.pdf

Support Verticals with QoS

- The 5G QoS model is based on QoS flows
  - A QoS Flow is associated with QoS requirements as specified by QoS parameters and QoS characteristics
- The 5G QoS model supports the following QoS flows
  - **GBR QoS** flows: require *Guaranteed* flow *Bit Rate*
  - **Non-GBR QoS** flows: do not require guaranteed flow bit rate
  - **Reflective QoS** (TS 23.501 clause 5.7.5)
    - Enables the UE to map UL User Plane traffic to QoS flows without SMF provided QoS rules and
    - It applies for IP PDU session and Ethernet PDU session

QoS Flow

- The QoS flow is the finest granularity of QoS differentiation in the PDU Session
- Within the 5GS, a QoS flow is controlled by the SMF and may be preconfigured, or established via
  - the PDU Session Establishment procedure (TS 23.502 clause 4.3.2), or
  - the PDU Session Modification procedure (TS 23.502 clause 4.3.3)

QoS Flow ID (QFI)

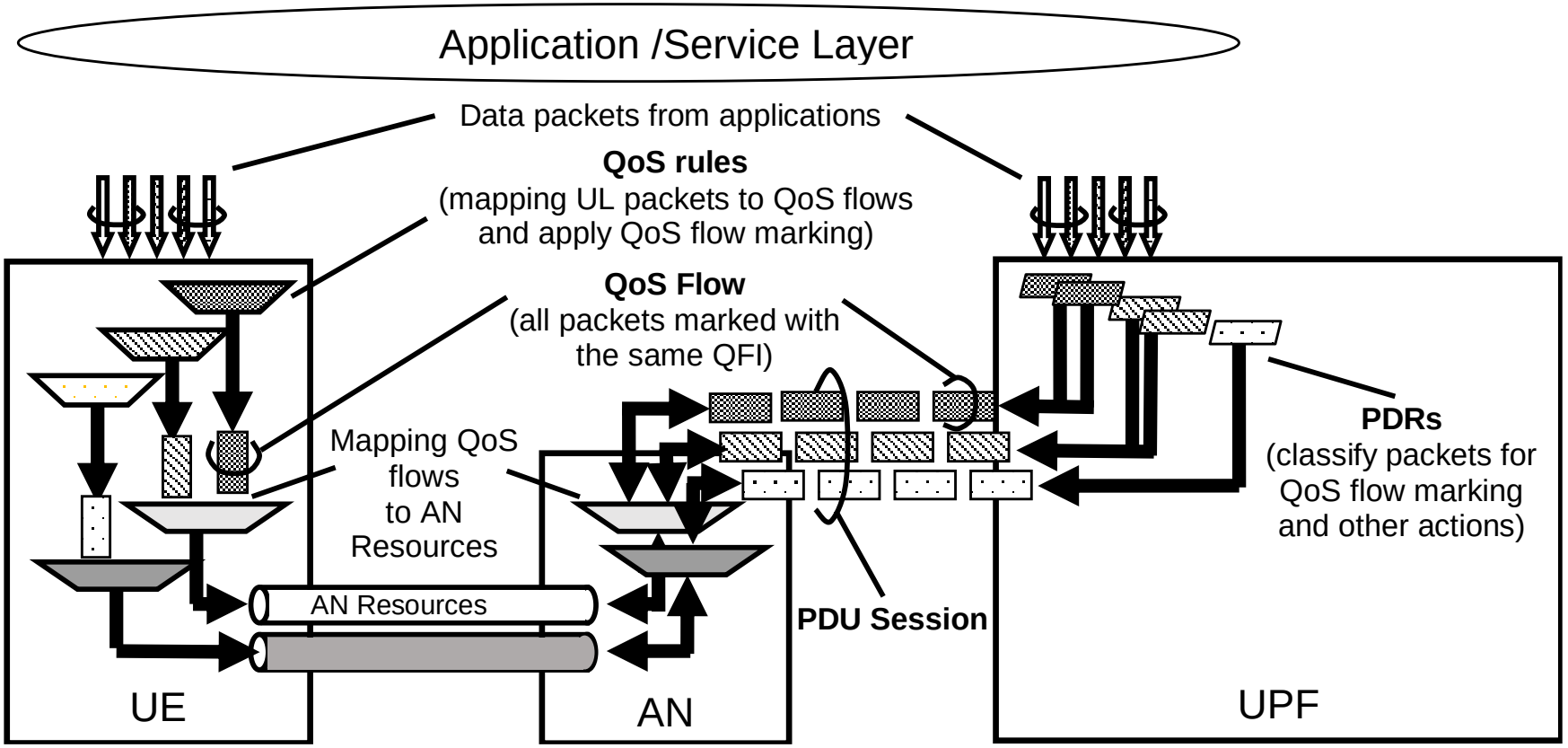
- A QoS Flow ID (QFI) is used to identify a QoS Flow in the 5G System
  - User Plane traffic with the same QFI within a PDU Session receives the same traffic forwarding treatment (e.g. scheduling, admission threshold)
  - The QFI is carried in an encapsulation header on N3 (and N9) i.e. without any changes to the e2e packet header
  - QFI shall be used for all PDU Session Types
  - The QFI shall be unique within a PDU Session
  - The QFI may be dynamically assigned or may be equal to the 5QI (clause 5.7.2.1)

QoS Flow Characteristics

Any QoS Flow is characterized by

- A QoS profile provided by the SMF to the AN
  - via the AMF over the N2 reference point or preconfigured in the AN
- One or more QoS rule(s) and optionally QoS Flow level QoS parameters (TS 24.501) associated with these QoS rule(s)
  - Provided by the SMF to the UE via the AMF over the N1 reference point and/or
  - Derived by the UE by applying Reflective QoS control
- One or more UL and DL Packet Detection Rules (PDRs) provided by the SMF to the UPF

Classification and User Plane Marking for QoS Flows and Mapping to AN Resources



5G QoS Parameters

- 5QI – 5G QoS Indicator
  - A specific QoS forwarding behaviour for a 5G QoS Flow (similar to the QCI value used for LTE)
- ARP - Allocation and Retention Priority
- RQA - Reflective QoS Attribute
- TS23.203 Policy and Charging Control Architecture (PCC)

5QI to QoS Characteristics Mapping – **GBR** Resource Types

TS23.501 Table 5.7.4-1

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Averaging Window	Example Services
1	20	100 ms	10^{-2}	2000 ms	Conversational Voice
2	40	150 ms	10^{-3}	2000 ms	Conversational Video (Live Streaming)
3	30	50 ms	10^{-3}	2000 ms	Real Time Gaming, V2X messages (TS 23.287). Electricity distribution – medium voltage, Process automation monitoring
4	50	300 ms	10^{-6}	2000 ms	Non-Conversational Video (Buffered Streaming)
65	7	75 ms	10^{-2}	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66	20	100 ms	10^{-2}	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67	15	100 ms	10^{-3}	2000 ms	Mission Critical Video user plane
71	56	150 ms	10^{-6}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
72	56	300 ms	10^{-4}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
73	56	300 ms	10^{-8}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
74	56	500 ms	10^{-8}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
76	56	500 ms	10^{-4}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)

5QI to QoS Characteristics Mapping – **Delay Critical GBR** Resource Types

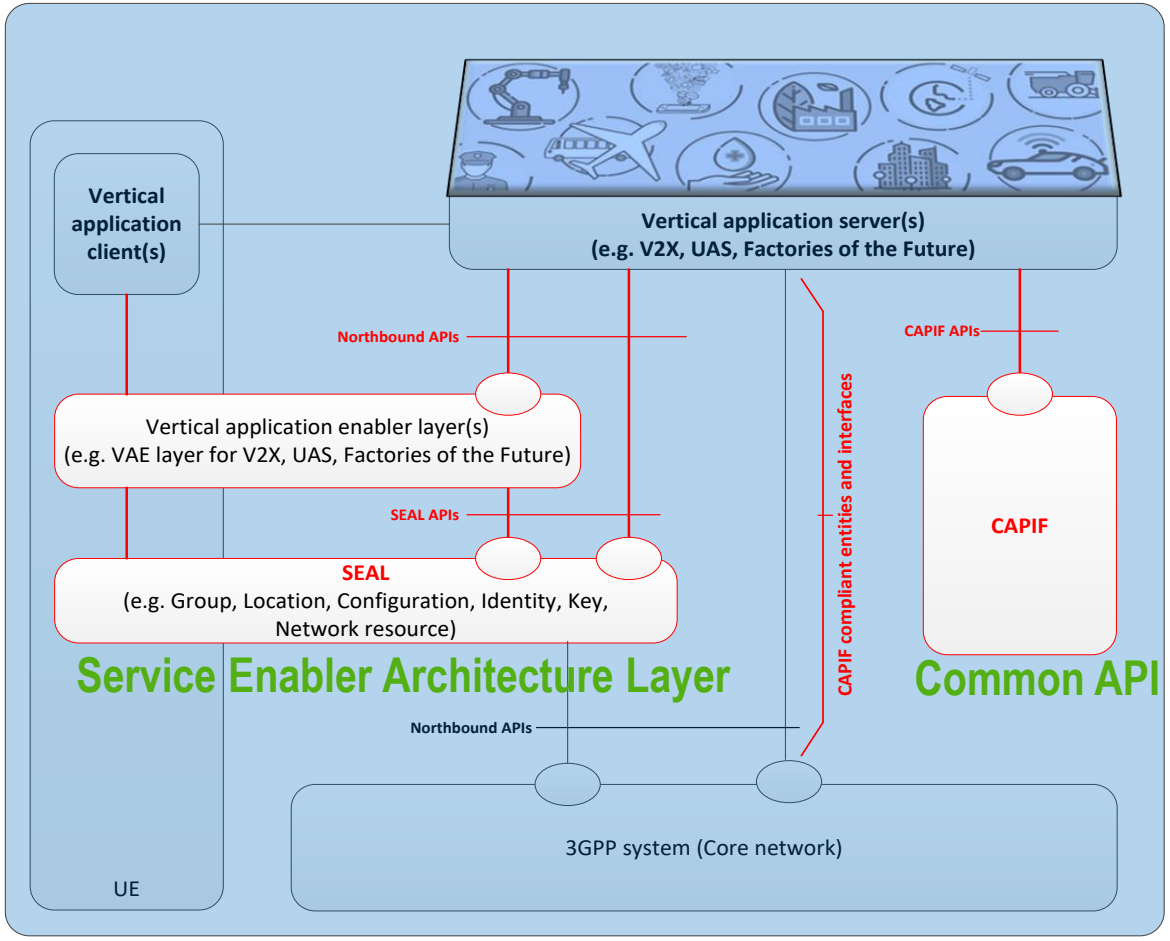
5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Max Data Burst Volume	Default Averaging Window	Example Services
82	19	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation (TS 22.261)
83	22	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation (TS 22.261); V2X messages (UE - RSU Platooning, Advanced Driving: Cooperative Lane Change with low LoA. TS 22.186, TS 23.287)
84	24	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent transport systems (TS 22.261)
85	21	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution- high voltage (TS 22.261) V2X messages (Remote Driving. TS 22.186, TS 23.287)
86	18	5 ms	10^{-4}	1354 bytes	2000 ms	V2X messages (Advanced Driving: Collision Avoidance, Platooning with high LoA. TS 22.186, TS 23.287)

5QI to QoS Characteristics Mapping – **Non-GBR** Resource Types

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Example Services
5	10	100 ms	10^{-6}	IMS Signalling
6	60	300 ms	10^{-6}	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7	70	100 ms	10^{-3}	Voice, Video (Live Streaming), Interactive Gaming
8 9	80 90	300 ms	10^{-6}	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
69	5	60 ms	10^{-6}	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling)
70	55	200 ms	10^{-6}	Mission Critical Data (e.g. example services are the same as 5QI 6/8/9)
79	65	50 ms	10^{-2}	V2X messages (TS 23.287)
80	68	10 ms	10^{-6}	Low Latency eMBB applications Augmented Reality

3GPP SA6 Working Group - VA via CAPIF and SEAL

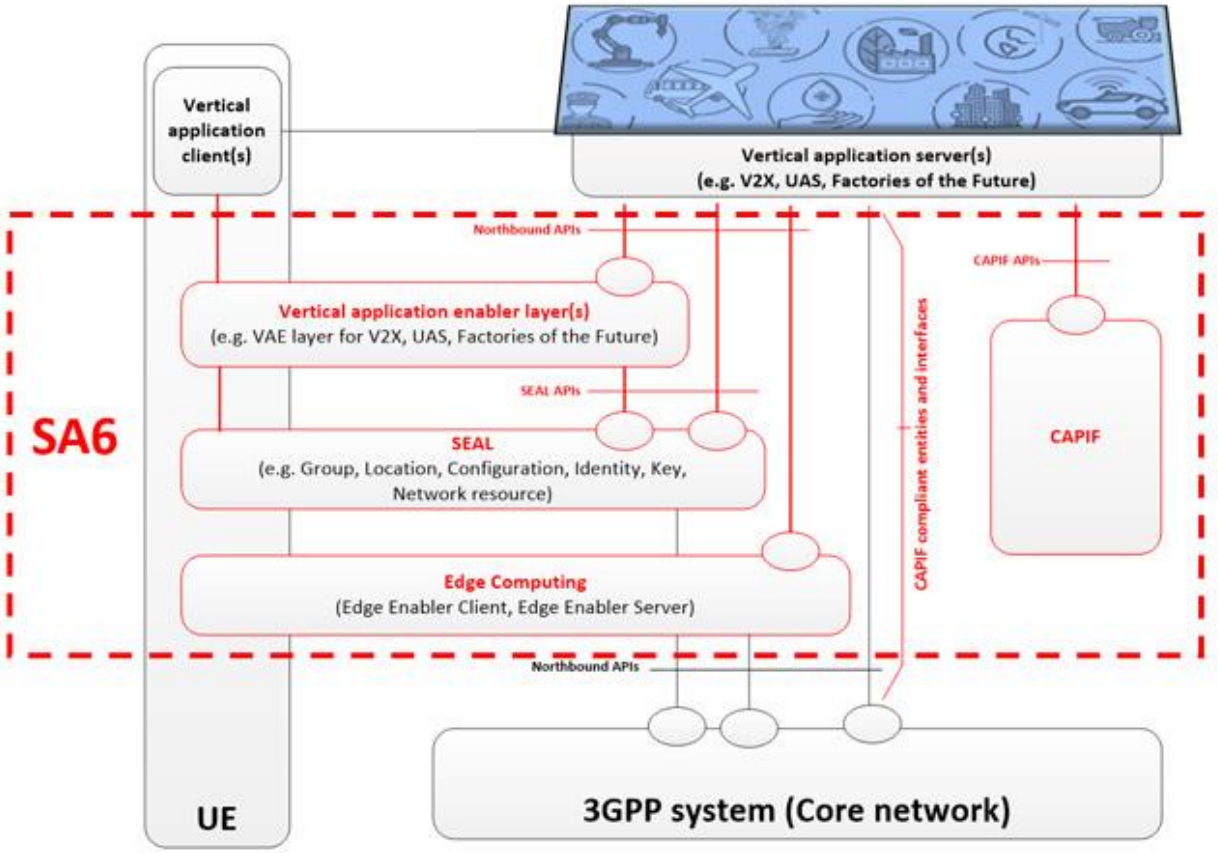
- Enables rapid deployment of new vertical applications, with access to the common SEAL services provided by MNOs
  - **SEAL** services (e.g. location, group, etc.) exposed as Northbound APIs
  - **CAPIF** used for publishing and discovery of SEAL services by the Vertical applications



Operator-Centric Solution

- Benefits
  - Vertical Service Provider
    - Reduced time to market
  - Mobile Network Operator
    - Maximize reuse of their existing deployments

Leveraging SA6 for 5G Verticals with EdgeAPP



- CAPIF to expose the API to 3GPP functions
- SEAL to allow quick on-boarding for verticals
- Vertical Application Enablers for support for the creation of actual applications (work and studies ongoing for V2X, UAS and Future Factories)
- EdgeAPP Enablers for support 5G verticals

Summary

- Introduction to Vertical Applications (VA)
  - IMT-2020 key capability parameters
  - Three main usage scenarios: eMBB, URLLC, mMTC
- 3GPP for Vertical Applications
  - Use cases and requirements
  - 5GS: NR+5GC by Rel-15 and above
  - QoS networks supporting CAPIF