

Νέες και Παλιές Προκλήσεις στα Δίκτυα Κινητών Επικοινωνιών

ΤΜΗΜΑ ΠΛΗΡΟΦΟΡΙΚΗΣ ΚΑΙ ΤΗΛΕΠΙΚΟΙΝΩΝΙΩΝ, ΕΚΠΑ

ΔΡ. ΔΗΜΗΤΡΗΣ ΤΣΟΛΚΑΣ & ΚΑΘ. ΛΑΖΑΡΟΣ ΜΕΡΑΚΟΣ

Δομή του μαθήματος



Το μάθημα εστιάζει σε ερευνητικές προκλήσεις των παρακάτω θεματικών περιοχών των Δικτύων Κινητών Επικοινωνιών (χρησιμοποιώντας το 5G ως παράδειγμα):

- Αρχιτεκτονική και τεχνολογίες Δικτύων Κινητών Επικοινωνιών
- Ανάλυση επίδοσης Δικτύων Κινητών Επικοινωνιών
- Υπηρεσίες Διαδικτύου των Πραγμάτων (IoT)
- «Ποιότητα Εμπειρίας» σε ασύρματα και κινητά δίκτυα

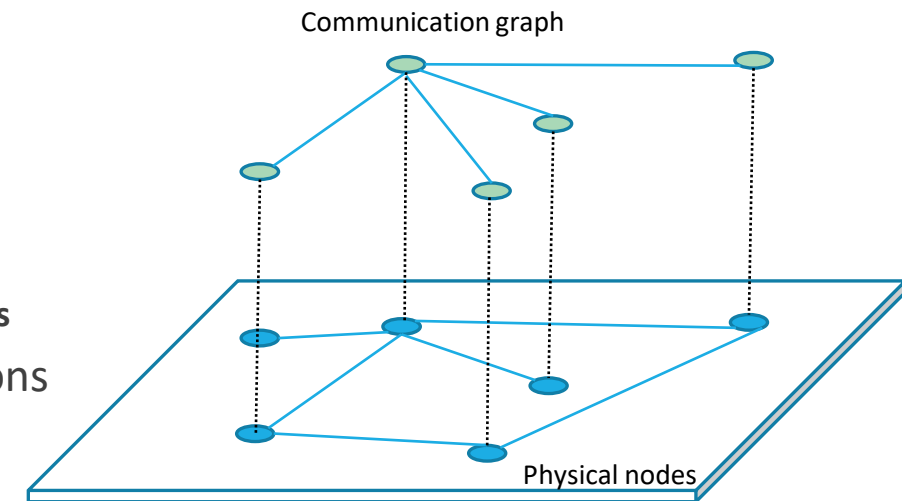
Οι φοιτητές θα κληθούν να επιλέξουν ένα θέμα σχετικό με τις παραπάνω θεματικές περιοχές και να προβούν σε μελέτη και παρουσίασή του (θα δοθεί σχετική βιβλιογραφία)

Clarifying the terminology

Networks (in the ICT sector)

Network: group of (physical and/or virtual) nodes (e.g., switches, eNBs, mobile devices, computers, computer programs, data hosts, servers etc.) that interact through communication interfaces.

- Classification based on how the communication is set
 - **Wireless | wired networks | Satellite networks**
- Classification based on deployment of the nodes
 - **WLAN | WPAN | MANET/VANET | Mobile/Cellular networks**
- Classification based on the characteristics of the services provided
 - **Wireless Sensor Network (WSN) | Multimedia networks | Delay tolerant networks**
- Classification based on the criterion that defines the communications
 - **Data Centric networks | Information Centric Networks**



Clarifying the terminology

Technologies (in the ICT and IT sector)

Technology: a method/technique/approach that fulfills a set of (*standardized*) requirements.

- Technologies for Radio interfaces
 - **5G NR, NB-IoT, LoRA/LoRAWAN** (various OEM provide related products, Ericsson Nokia etc)
- Technologies for virtualization
 - **VMs, Containers, Hypervisors** (e.g., VMware, KVM)
- Technologies for data flow control
 - **SDN** (e.g., Onos SDN controller, OpenDaylight)

Clarifying the terminology

Communication Systems

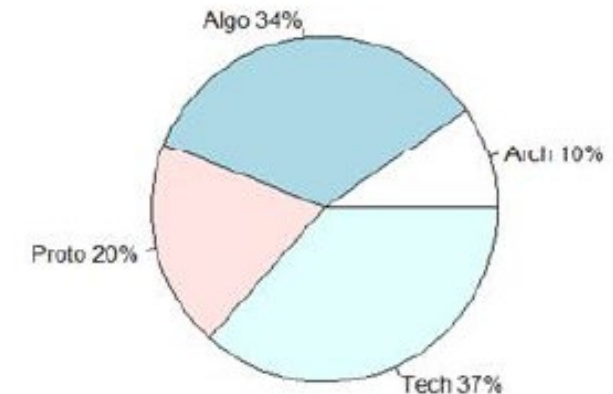
System (or Communication system or telecommunication system): the complete set of functionalities for control/management and data exchange over a network (a system is materialized through a set of protocols, can utilize various technologies and offers a set of services)

- Wireless communication system
 - Communication systems where the underlay network is a wireless network, i.e., radio interfaces are used
 - Mobile Communication systems
 - Key representatives:
 - Public mobile radio systems
 - GSM, UMTS, LTE, LTE-A, 5G (market names: 2G, 3G, 4G, 5G..)
 - Private mobile radio systems
 - TETRA, TETRAPOL

Challenges towards networks 2030

Main factors where gaps are identified

- **Architectural Gaps:** Factors that impact at large scale relating to design, deployment, changes to interface between end hosts and network nodes etc.
- **Protocol Type Gaps:** This factor identifies the aspects where rules for communication need standardization or a common format.
- **Technology Gap:** This factor refers to the advancement or improvements necessary in the hardware or software design or paradigms for a particular gap.
- **Algorithm Type Gap:** This factor refers to requirement for devising new mechanisms and further study of a solution or formal logical procedures.

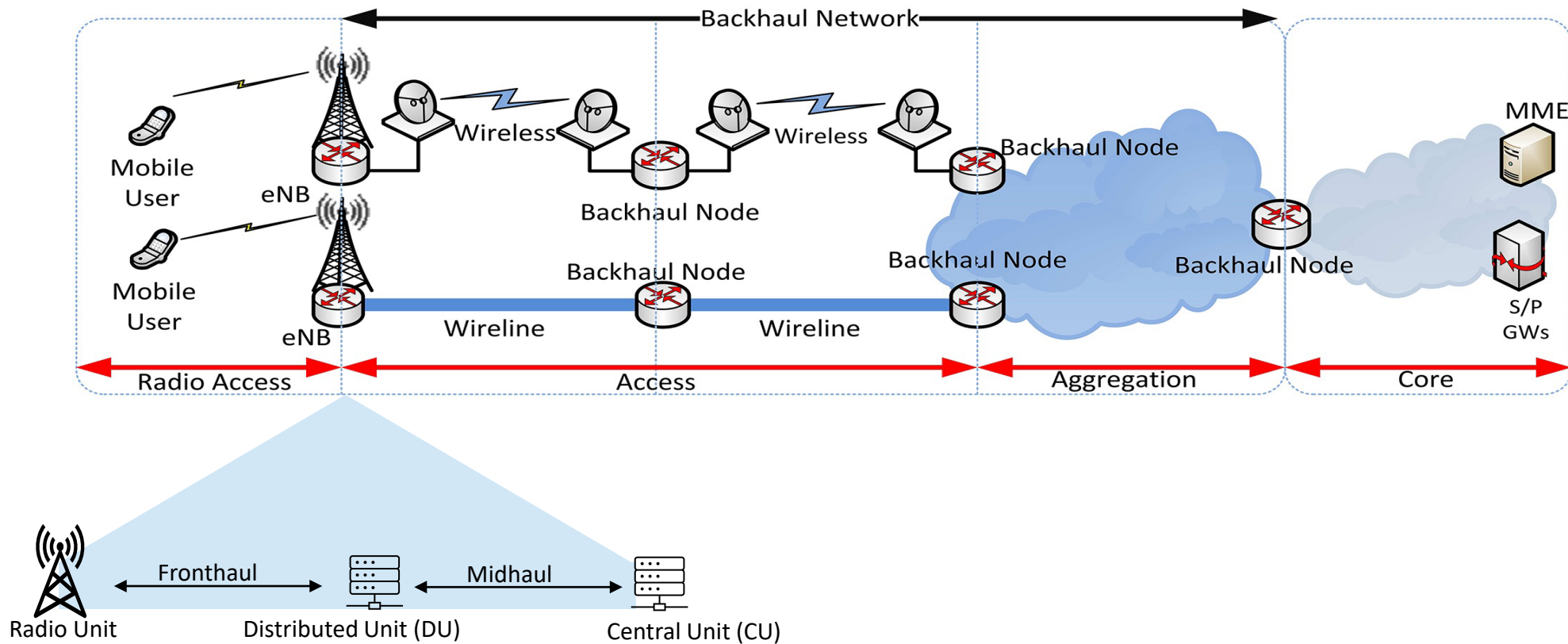


https://www.itu.int/en/ITU-T/focusgroups/net2030/Documents/Gap_analysis_and_use_cases.pdf

A horizontal and vertical view of a mobile network

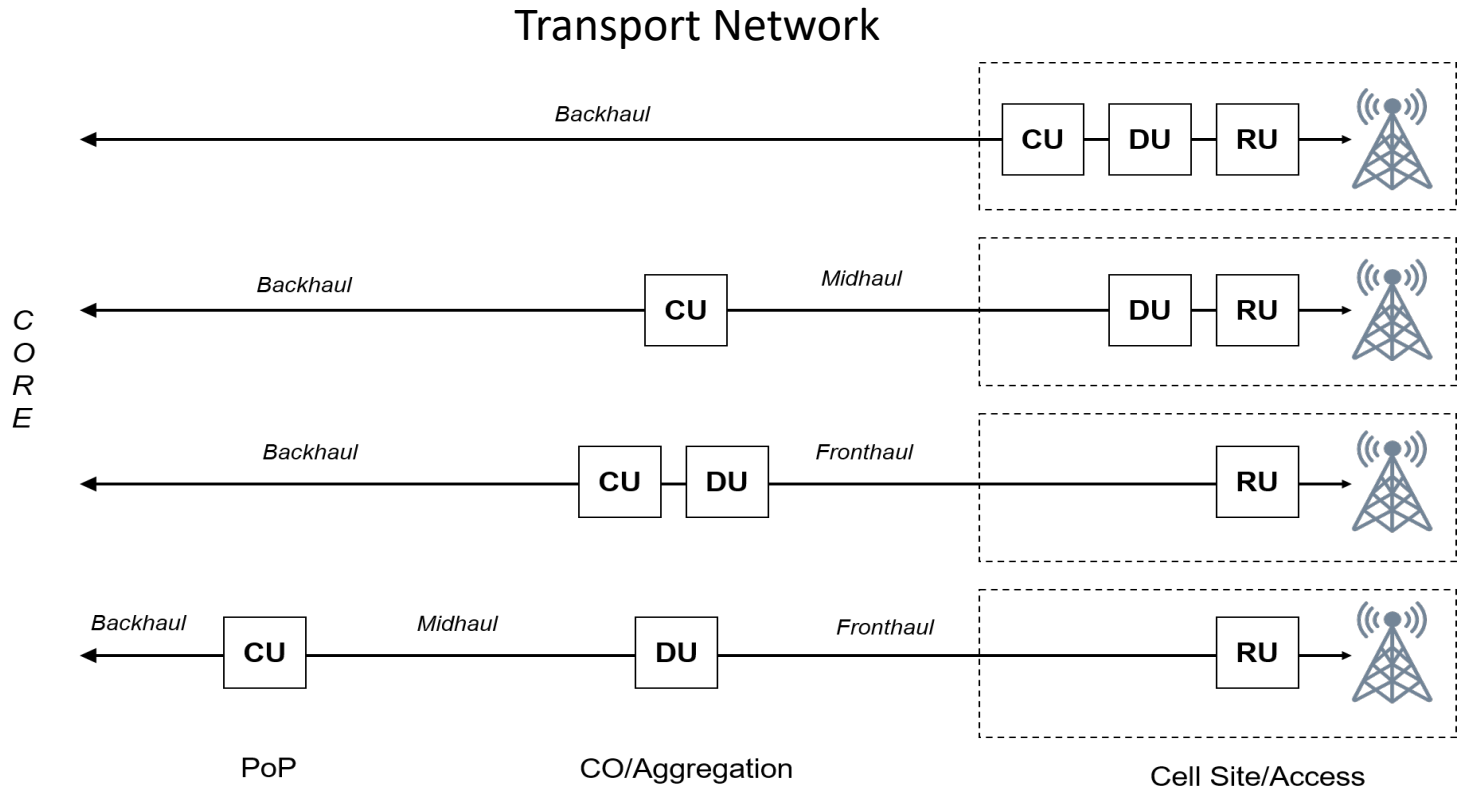
Horizontal view

Understanding the topology of a Mobile network



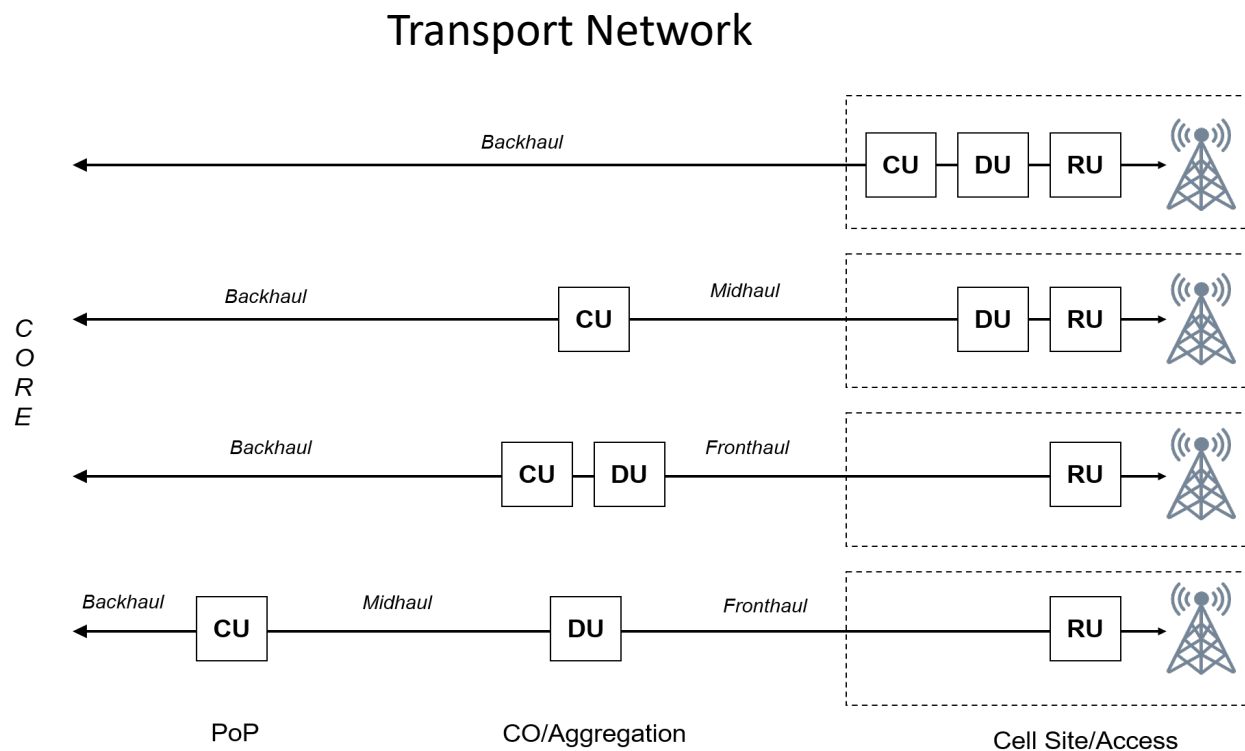
Horizontal view

Understanding the topology of a Mobile network

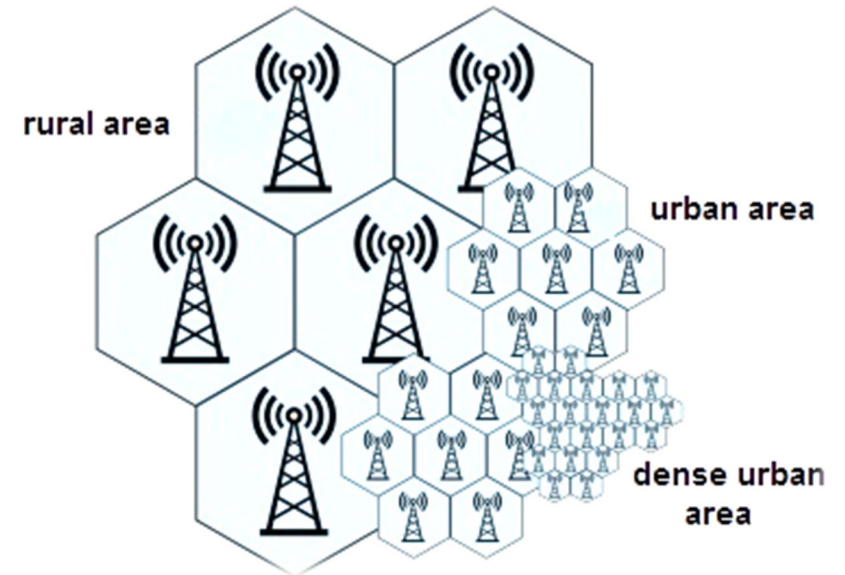


Horizontal view

Understanding the topology of a Mobile network



(Radio) Access Network



4G coverage / antennas

General Details Close

Select Provider

Provider
Cosmote - 2021

Network
4G - LTE

Band
All Bands

Last Updated: Mon, Feb 28, 2022

Advertisement (Remove)

100990 Bands 1,3

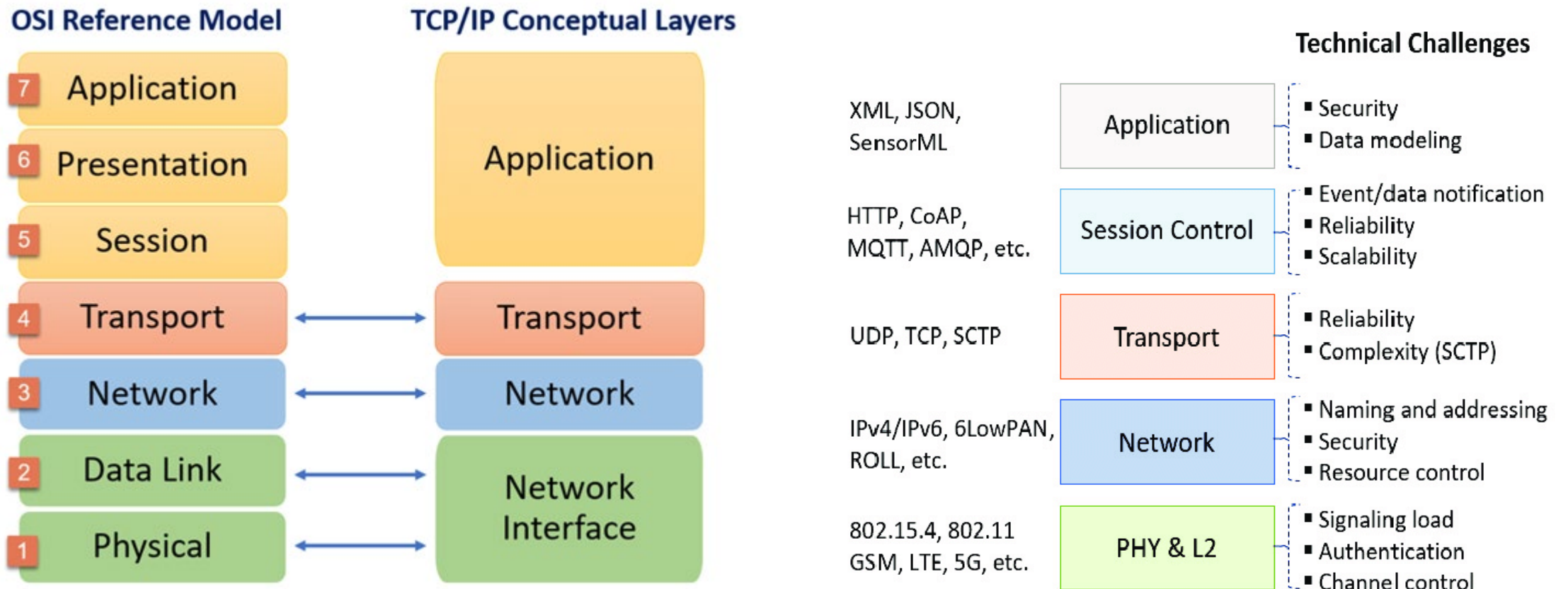
General Details Close

Select Provider

[link](#)

Vertical view

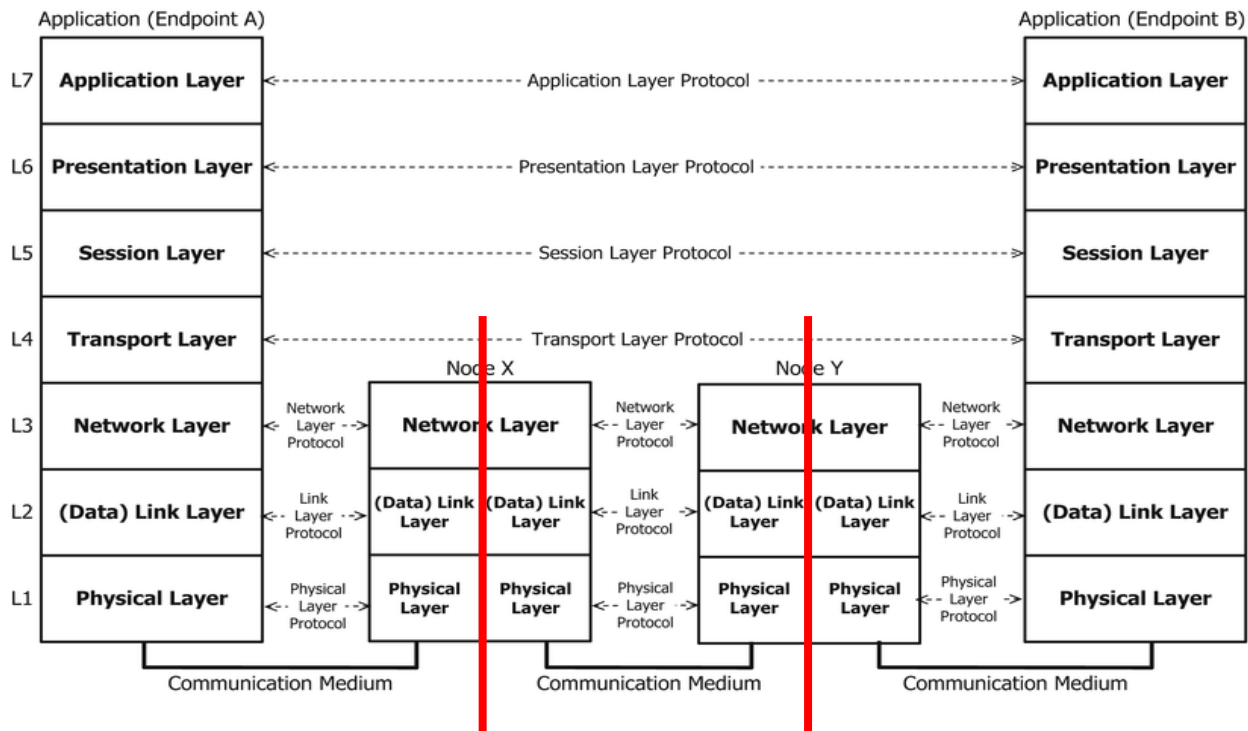
Understanding the Protocol stack



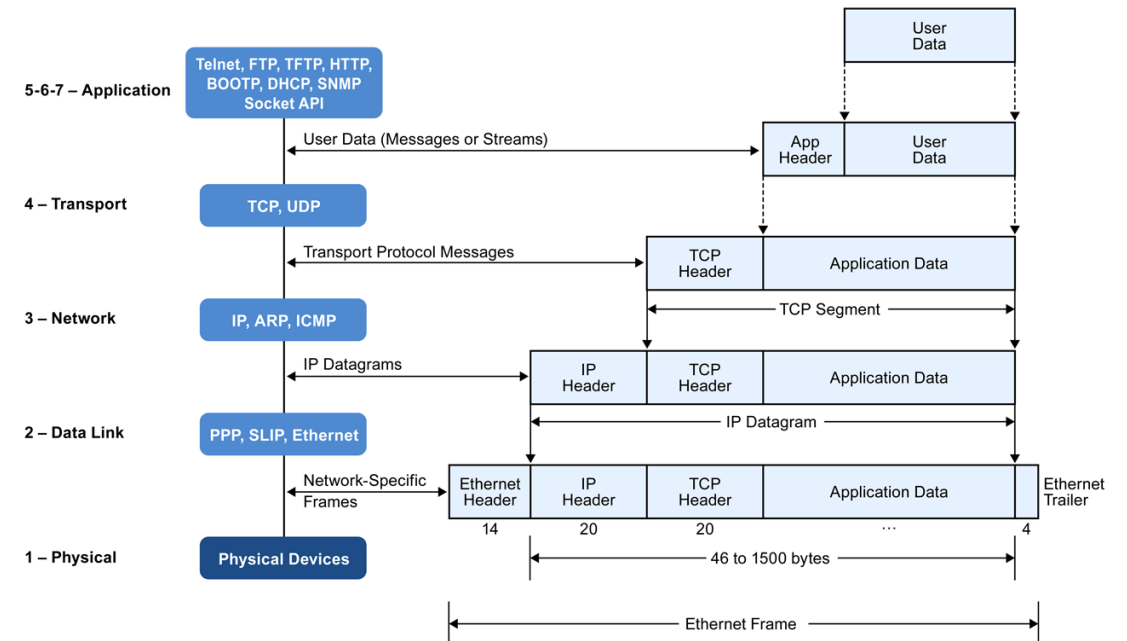
Vertical view

Understanding the Protocol stack

Protocol stack support Reception and Send process



Main action per layer: add/removal of headers

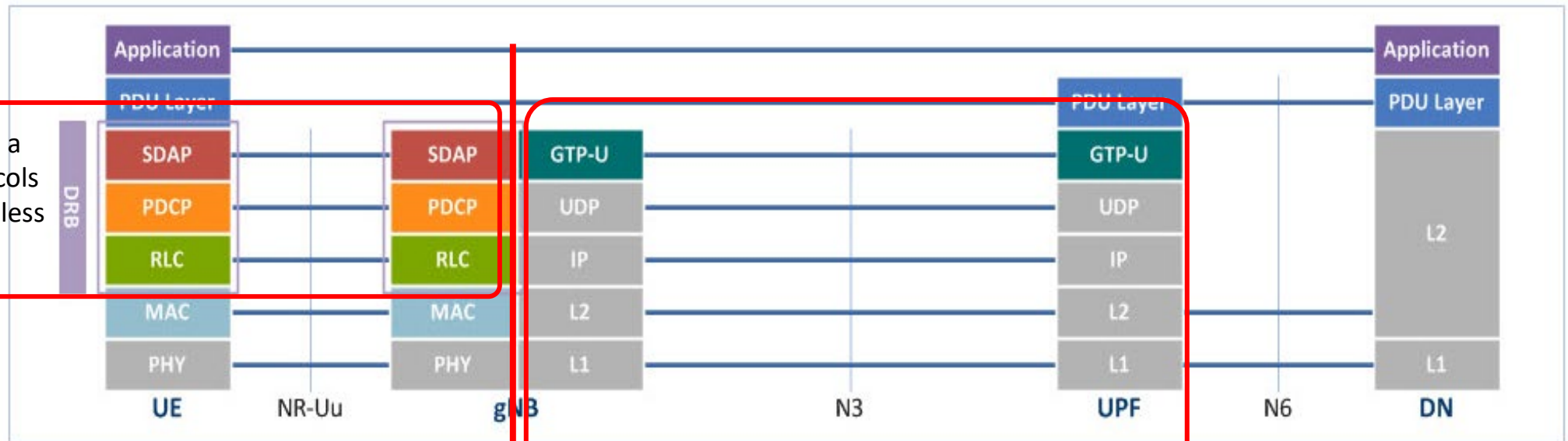


Vertical view

Understanding the Protocol stack

Protocol stacks support Reception and Send process

- Different protocols can be used (gNB case) **depending on the source / destination**



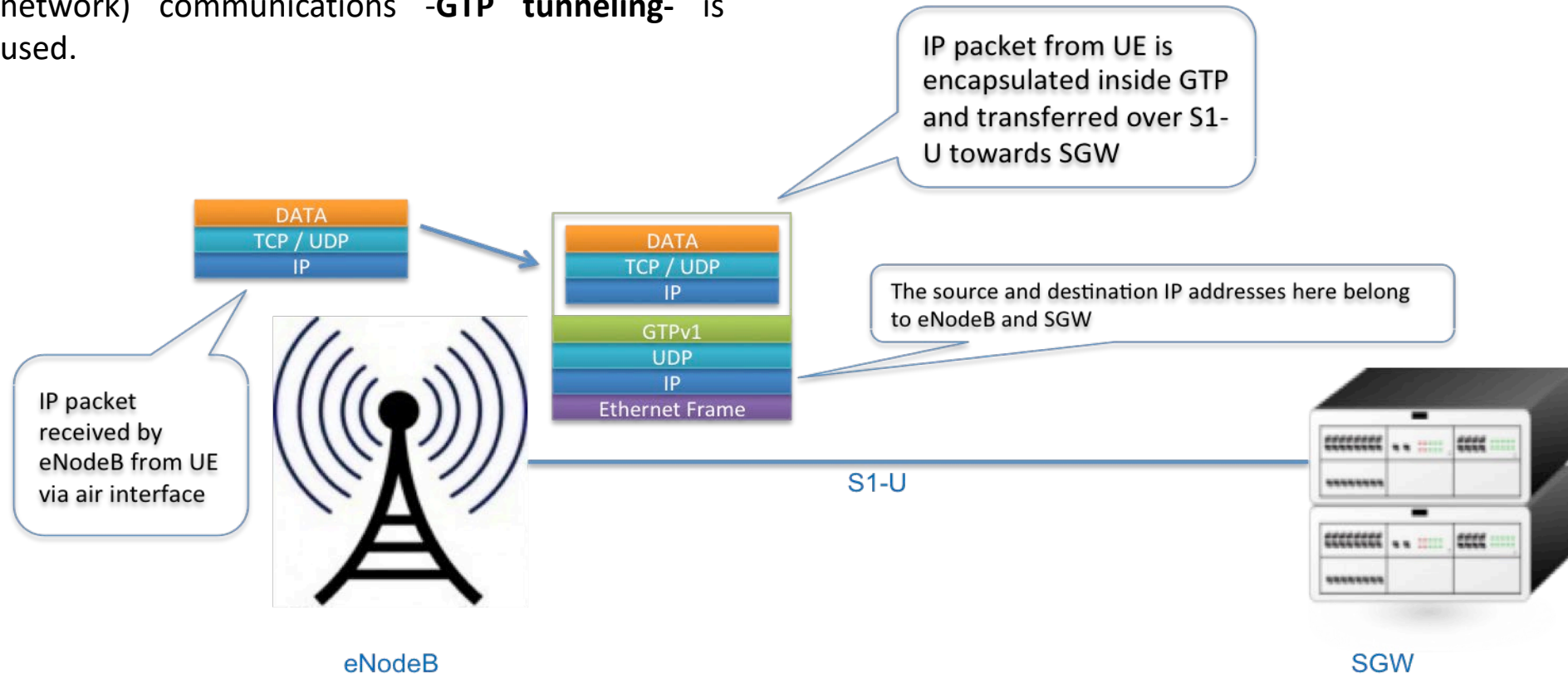
The radio part includes a set of additional protocols for controlling the wireless link (SDAP/PDCP/RLC).

Tunneling for the internal (inside the operator's network) communications
-GTP tunneling-

Vertical view

Understanding the Protocol stack

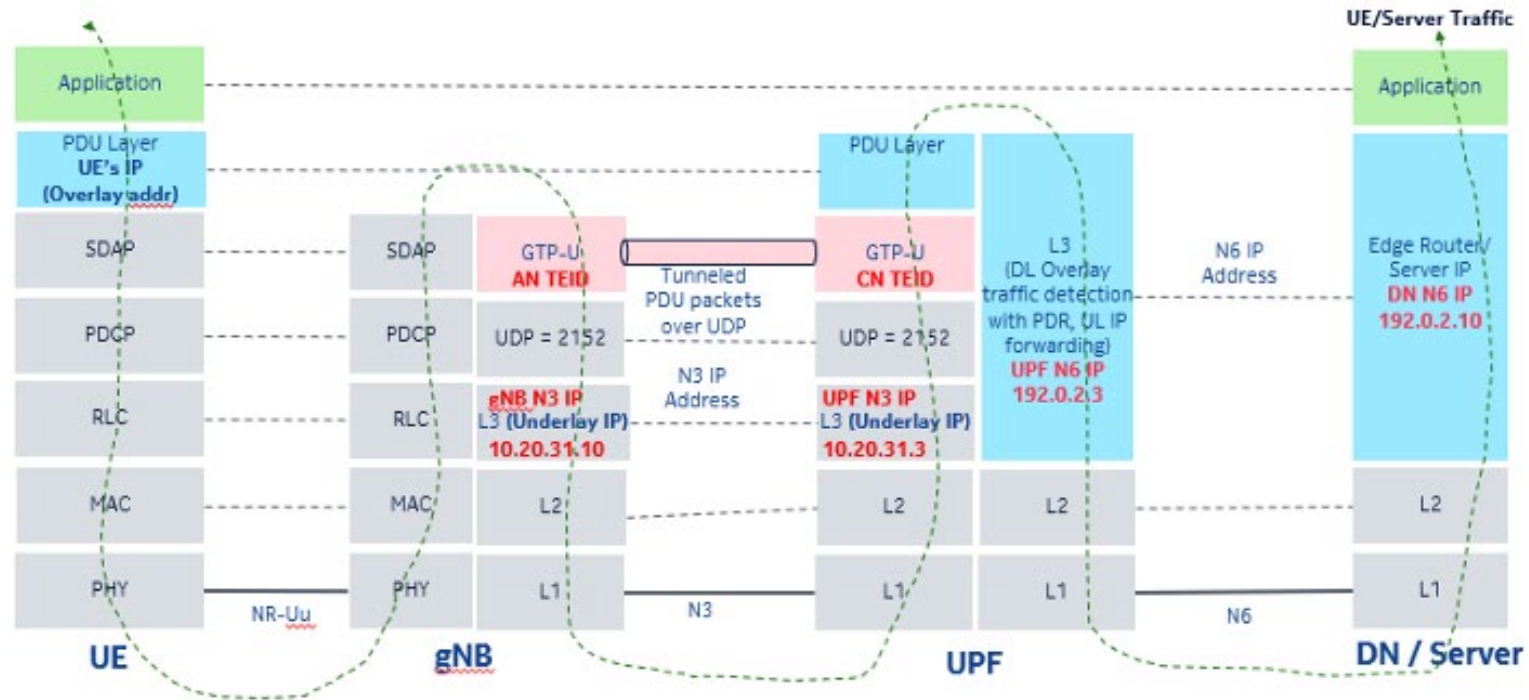
- Tunneling for the internal (inside the operator's network) communications -**GTP tunneling**- is used.



Vertical view

Understanding the Protocol stack

- Tunneling for the internal (inside the operator's network) communications -**GTP tunneling**- is used.

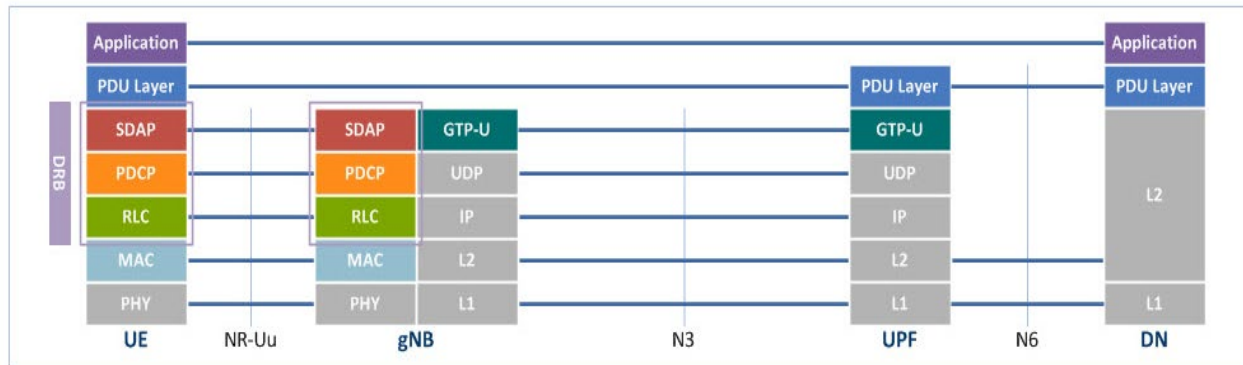


Vertical view

Understanding the Protocol stack

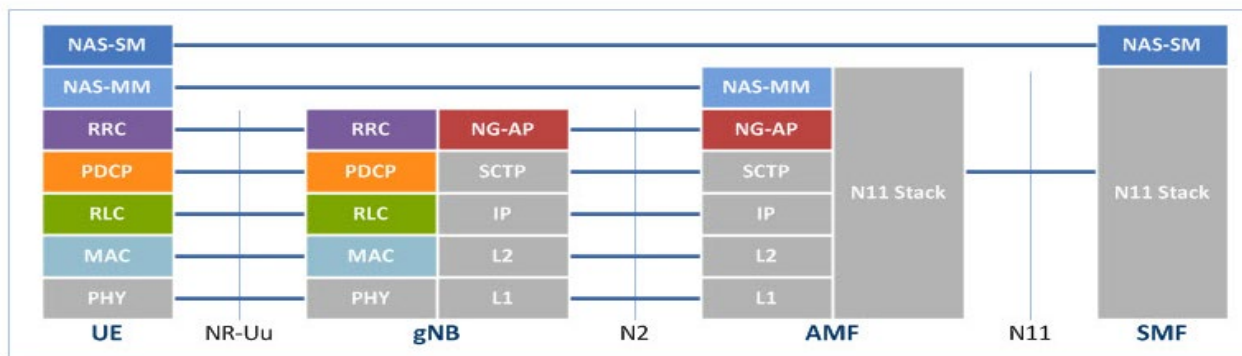
Protocol stacks support Reception and Send process

- Different protocols can be used (UE, gNB, AMF etc case) **depending on the type of data exchanged**



User Plane

- Type of data is the user's actual data
- The communicating nodes include nodes outside the operator's network e.g., the internet / data network



Control Plane

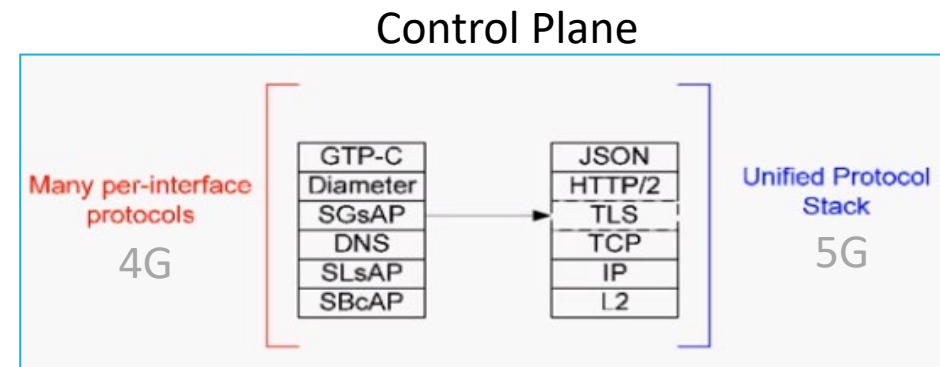
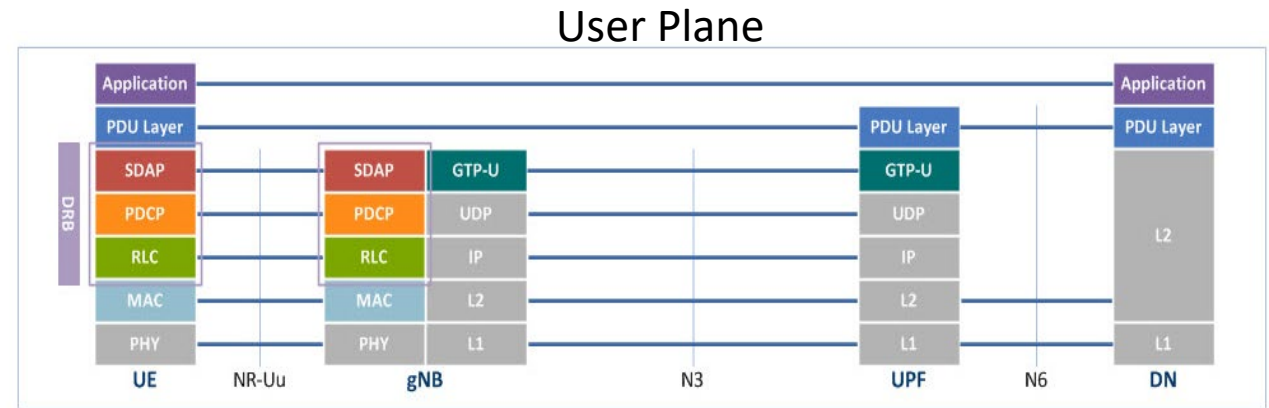
- Type of data is signaling or controlling message
- All the communicating nodes are internal to the operator's network

Vertical view

Understanding the Protocol stack

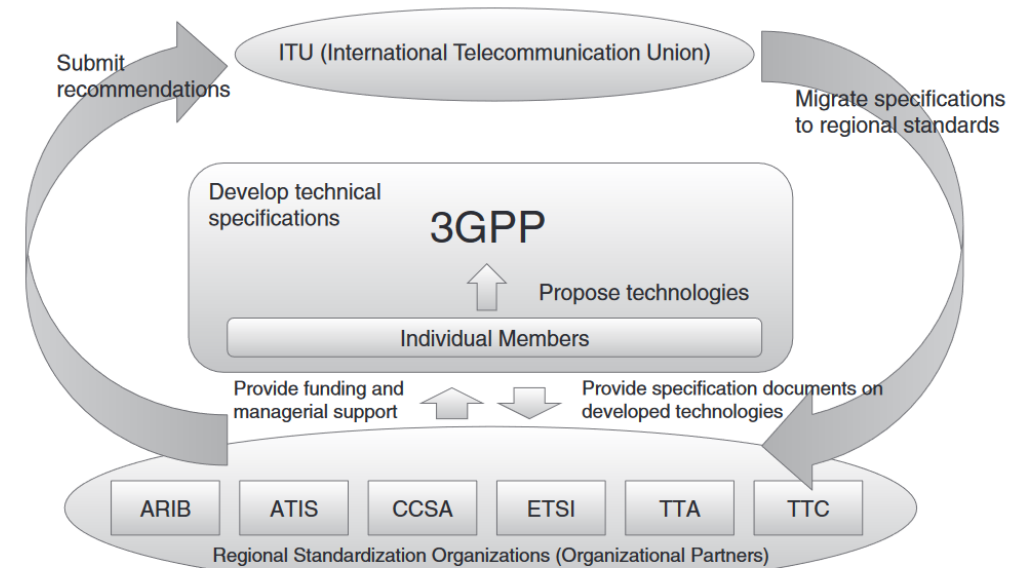
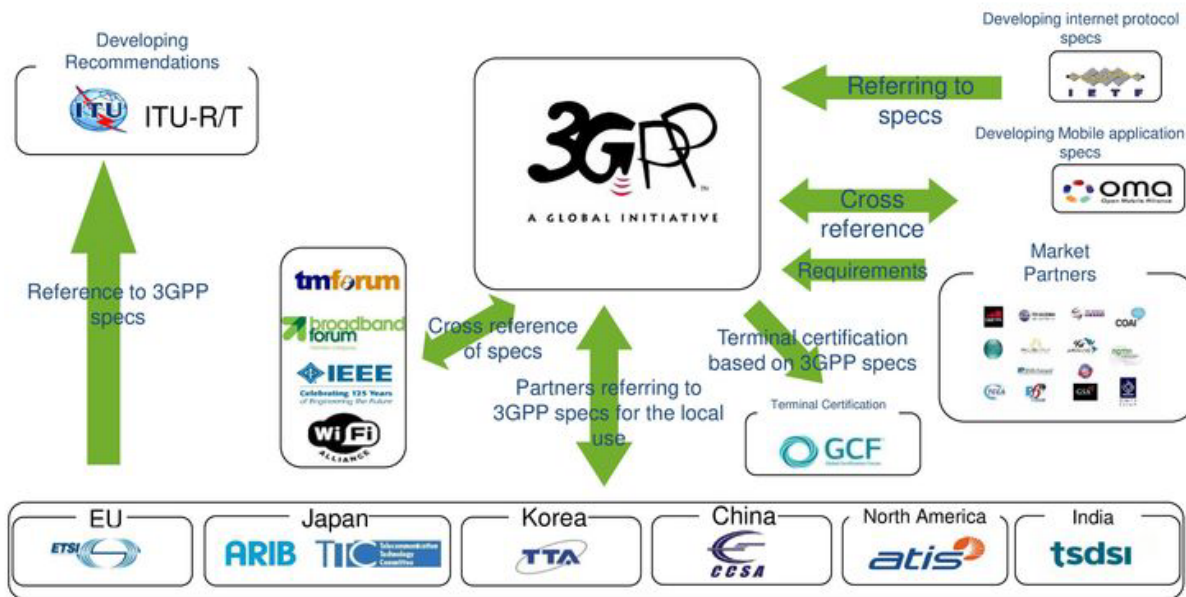
4G vs 5G

- User Plane: compared to 4G, the SDAP (Service Data Adaptation Protocol) is a new protocol added in 5G systems
- All the 4G signaling protocols SBcAP, SLsAP, DNS, SCsAP, Diameter, GTP-C that existed in the evolved packet core; they are all replaced in 5G with a single stack IP, TCP, TLS, HTTP2 and JSON.



Requirements and Performance Targets for mobile networks - ITU – 3GPP -

SDOs ecosystem



ARIB: Association of Radio Industries and Businesses
 ATIS: Alliance for Telecommunications Industry Solutions
 CCSA: China Communications Standards Association
 ETSI: European Telecommunications Standards Institute
 TTA: Telecommunications Technology Association of Korea
 TTC: Telecommunication Technology Committee

ITU

About the ITU

- The ITU –International Telecommunications Union
- Specialized UN agency responsible for issues that concern ICTs
- Coordinates global use of the radio spectrum
- Assists in the development of worldwide ICT technical standards

Target technologies: broadband internet, latest generation wireless technology, internet access, data, voice, TV broadcasting, next-Generation networks, ...

ITU IMT-2020 =>5G

About the IMT

IMT = International Mobile Telecommunications

IMT 2000 technologies (Marketed as 3G)

- 3GPP Family: UMTS WCDMA (GSM Evolution)
- 3GPP2 Family: CDMA2000 (1xEV DO Rev A, EV DO Rev B)

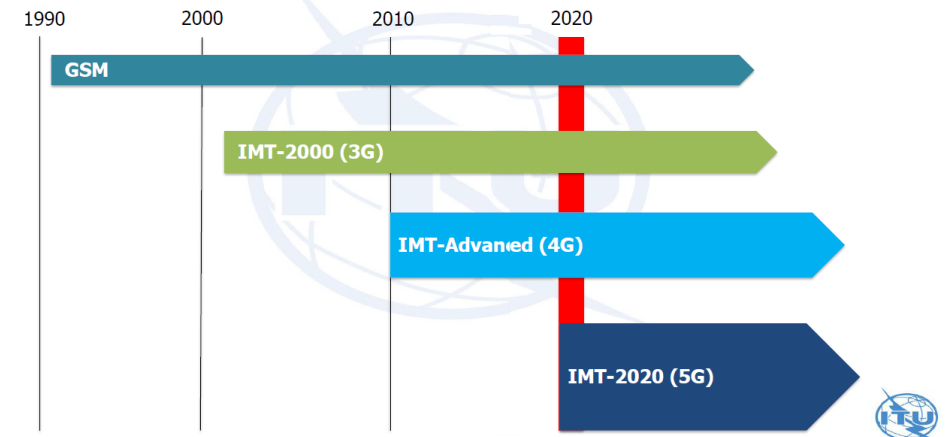
IMT Advanced technologies (Marketed as 4G)

- 3GPP Family: LTE Advanced (E UTRA)
- IEEE Family: WiMAX (802.16m)

IMT 2020 => 5G

- 3GPP Family: 5G
- IEEE Family: wifi 6 (802.11ax)

IMT Standards Evolution towards 5G



ITU IMT-2020

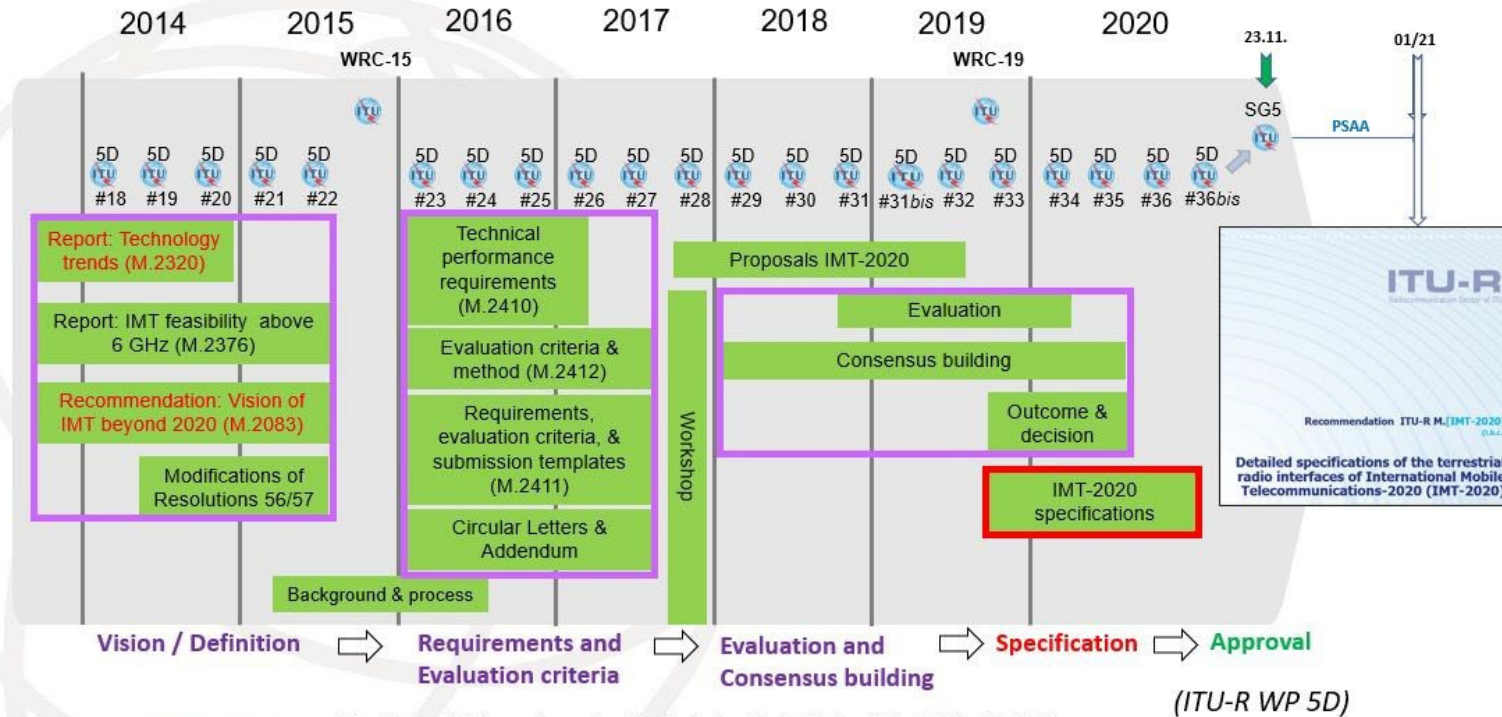
IMT-2020 Overview

- IMT-2020 [ITU-R M-2083-0]: systems, system components, and related aspects that support to provide far more enhanced capabilities than those described in Recommendation ITU-R M.1645.
- IMT-2020 Radio:= IMT evolution + new RAT revolution
- IMT-2020 Network:= flat architecture + white-box-hardware + Virtualization + LINP/ Slices + Softwarization+ MEC + DAN (ICN/ CCN) + e-2-e VoLTEenabling + ...

ITU IMT-2020 time plan

Timeline for IMT-2020

Committed to Connecting the World



ITU-R M.2150

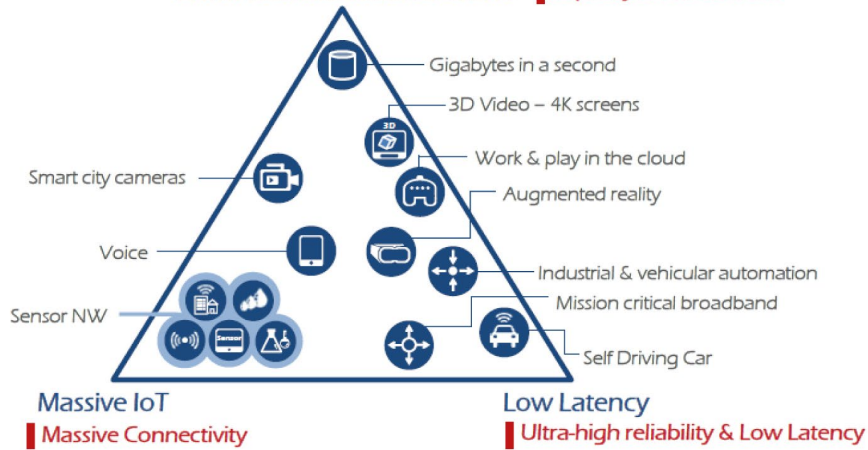
18th January 2021

Note: Meeting #36bis was a focused meeting (technology) for finalization of Step 8 of the IMT-2020 process and completing draft new Recommendation ITU-R M.[IMT-2020.SPECS]

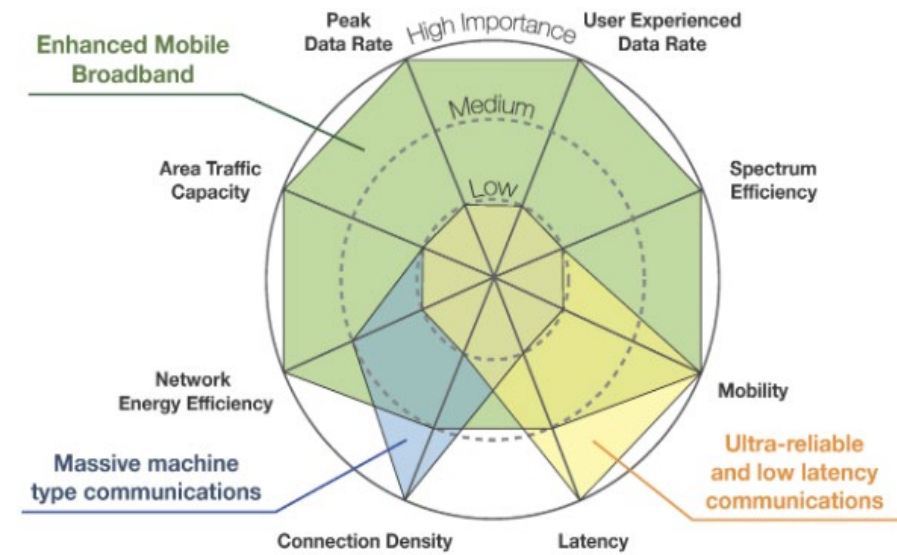
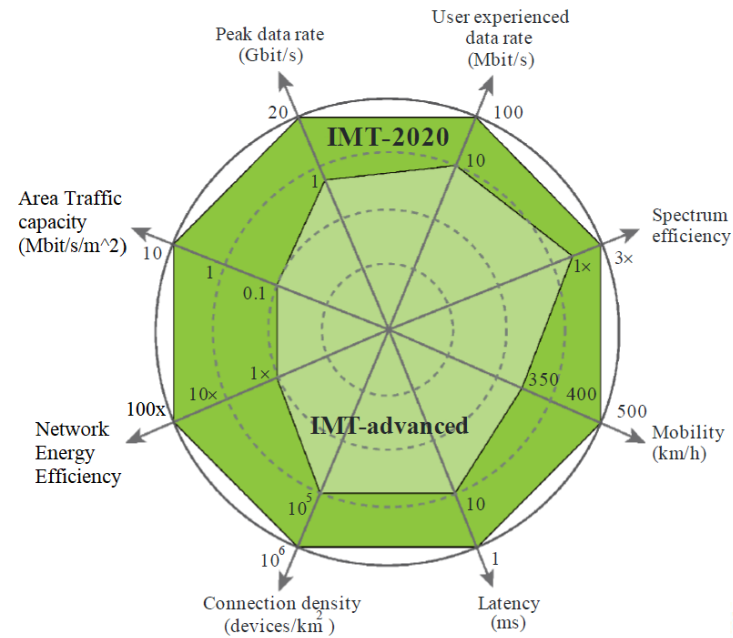
(ITU-R WP 5D)

5G Performance

Enhanced Mobile Broadband | Capacity Enhancement

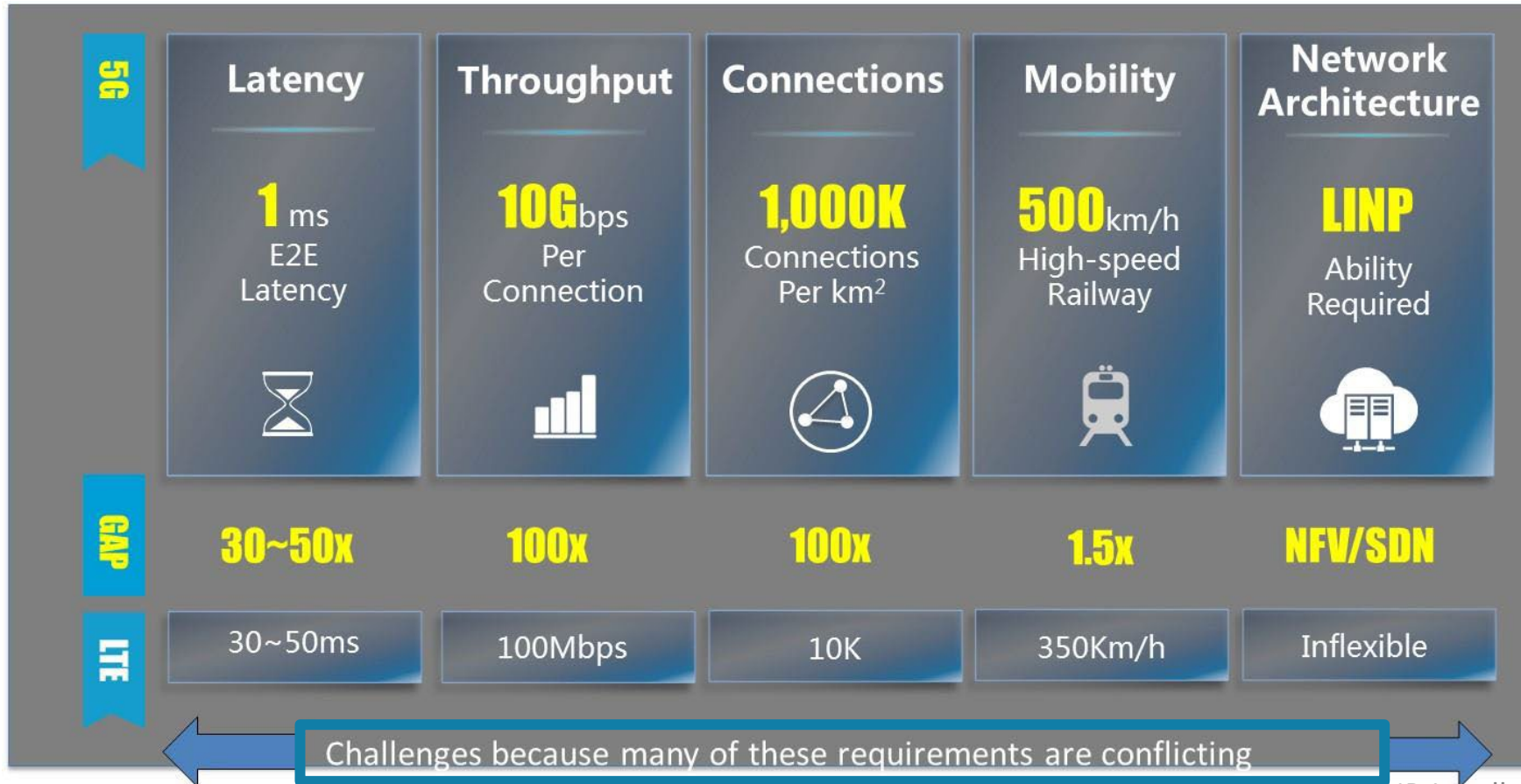


(Source: ETRI graphic, from ITU-R IMT 2020 requirements)



[Reference link](#)

5G Performance (compared to 4G/LTE)



*LINP-Locally Isolated Network Partitions

5G Specifications

3GPP for 5G Standardization (meeting the ITU IMT2020 req.)



IMT-2000

IMT-Advanced

IMT-2020



UMTS (FDD & TDD),
HSPA (Rel-99 onwards)

LTE (Rel-8 onwards)

LTE (Rel-10 onwards)

5G NR & LTE (Rel-15 onwards)

3GPP Specifications: structure

Target Specification Groups

The TSG Core Network and Terminals (TSG CT) is responsible for specifying terminal interfaces (logical and physical), terminal capabilities (such as execution environments) and the Core network part of 3GPP systems.

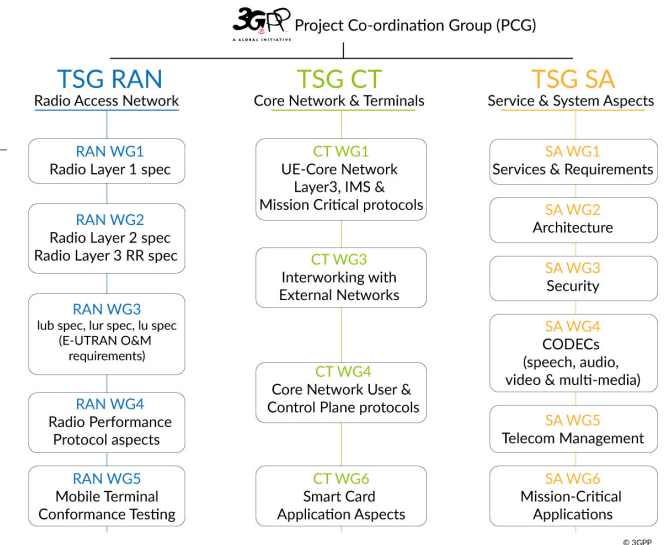
The TSG Radio Access Network (TSG RAN) is responsible for the definition of the functions, requirements and interfaces of the UTRA/E-UTRA network in its two modes, FDD & TDD.

The TSG Service and System Aspects (TSG-SA) is responsible for the overall architecture and service capabilities of systems based on 3GPP specifications and, as such, has a responsibility for cross TSG co-ordination.

Releases

3GPP uses a system of parallel "Releases" which provide developers with a stable platform for the implementation of features at a given point and then allow for the addition of new functionality in subsequent Releases.

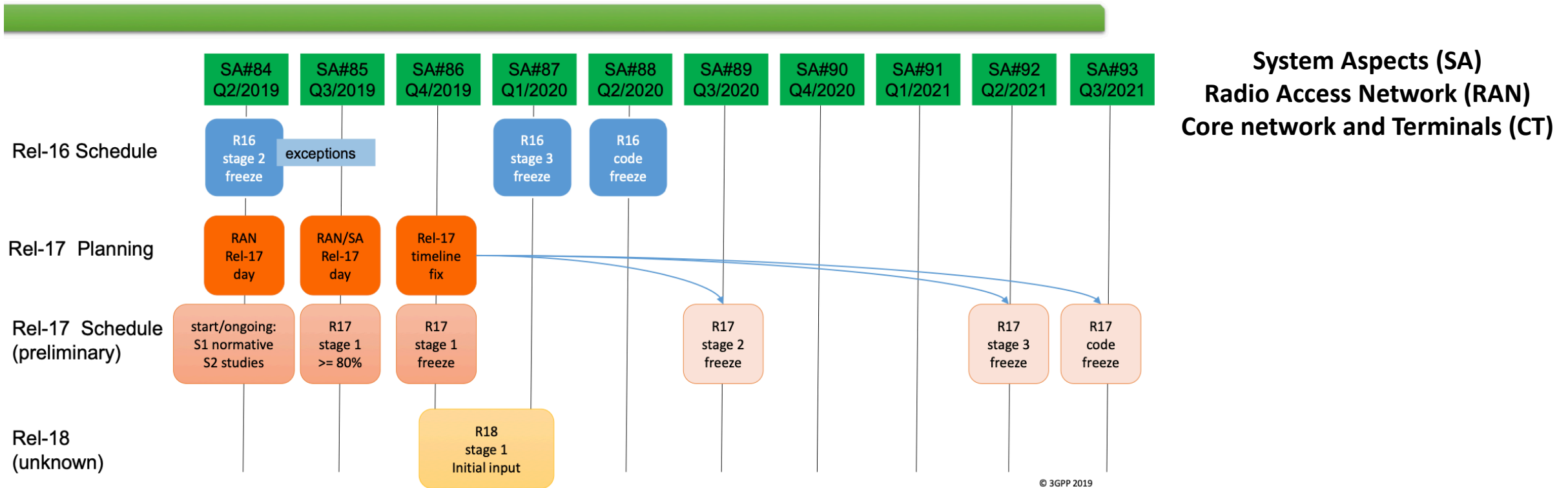
[Reference link](#)



Reports produced

Radio aspects	36 series (LTE, LTE-Advanced) 37 series (Multiple radio access technologies) 38 series (NR)
Requirements	21 series
Security aspects	33 series
Security algorithms	35 series , 55 series (GERAN specific)
Service aspects	22 series
Network signaling protocols (24 & 29 series)	24 series , 29 series
Technical realization ("stage 2")	23 series

3GPP Specifications: Releasing



Stage 1 Service requirement level -> Stage 2 Functions to be supported by the system -> Stage 3 Implementation aspects

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-to-end networks
- API Exposure – 3rd party access to 5G services
- Service Based Architecture (SBA)
- Further LTE improvements
- Mobile Communication System for Railways (FRMCS)

Release 16

- The 5G System – Phase 2
- V2x Phase 3: Platooning, extended sensors, autonomous 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

Release 17

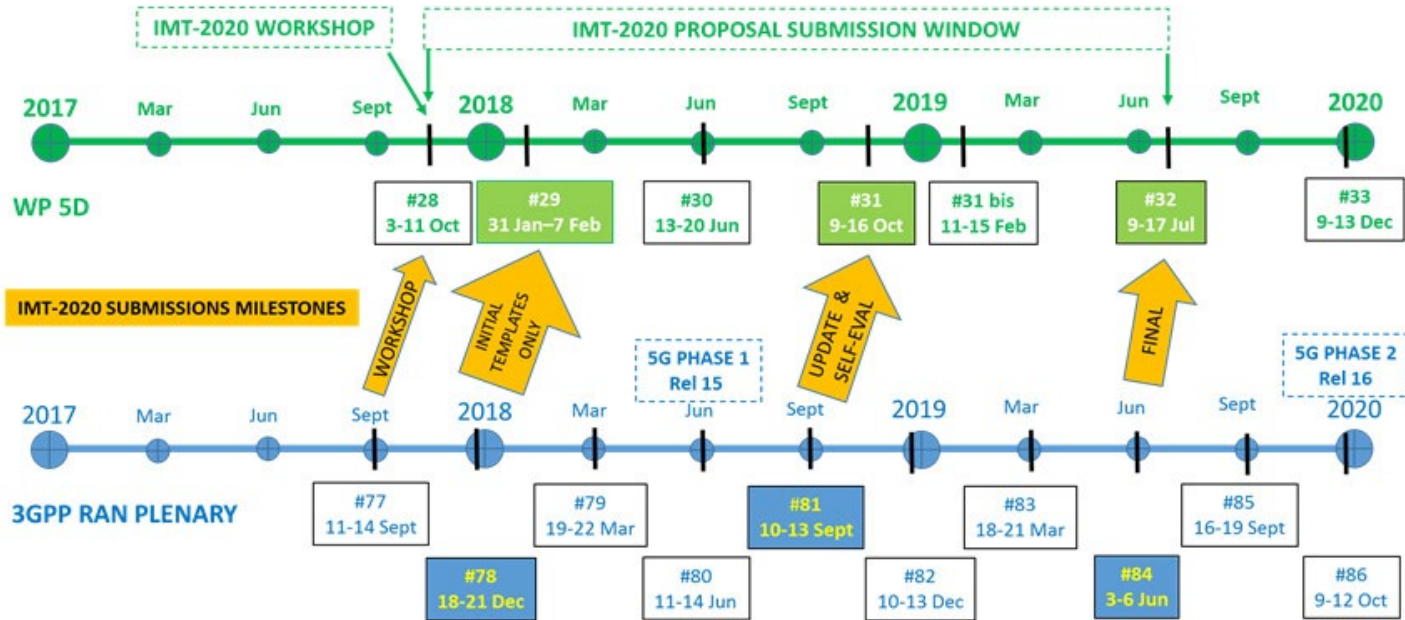
- NR MIMO
- NR Sidelink enh.
- 52.6 - 71 GHz with existing waveform
- Dynamic Spectrum Sharing (DSS) enh.
- Industrial IoT / URLLC enh.
- Study - IoT over Non Terrestrial Networks (NTN)
- NR over Non Terrestrial Networks (NTN)
- NR Positioning enh.
- Low complexity NR devices
- Power saving
- NR Coverage 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

5G Standardization: 3GPP Rel.15/16/17

What about the IMT-2020 requirements?



3GPP meets IMT-2020

November 28, 2020

Earlier this week the ITU issued a press release to publicise the move to the approval process - by the 193 member states of the Union - of their ITU-R Recommendation: 'Detailed specifications of the radio interfaces of IMT-2020.' (ITU-R M.[IMT-2020.SPECS]).

The document - due for publication in February 2021 - will be the end product of a long process, initiated in 2012, under the banner 'IMT for 2020 and beyond' where the ITU set out its agenda for a steady progression of 5G research activities that would nourish the 3GPP efforts on the new radio and 5G core specification work.

The ITU press release formally announces the radio interfaces that conform with the International Mobile Telecommunications 2020 (IMT-2020) performance requirements:

"The technologies are: 3GPP 5G-SRIT and 3GPP 5G-RIT submitted by the Third Generation Partnership Project (3GPP), and 5Gi submitted by Telecommunications Standards Development Society India (TSDSI). During the multi-year development and evaluation process by the ITU Radiocommunication Sector (ITU-R), these technologies were deemed to be sufficiently detailed to enable worldwide compatibility of operation and equipment, including roaming."



Release 18



TSG SA priorities*

SA2 led - System Architecture and Services

- XR (Extended Reality) & media services
- Edge Computing Phase 2
- System Support for AI/ML-based Services
- Enablers for Network Automation for 5G Phase 3
- Enh. support of Non-Public Networks Phase 2
- Network Slicing Phase 3
- 5GC LoCation Services Phase 3
- 5G multicast-broadcast services Phase 2
- Satellite access Phase 2
- 5G System with Satellite Backhaul
- 5G Timing Resiliency and TSC & URLLC enh.
- Evolution of IMS multimedia telephony service
- Personal IoT Networks
- Vehicle Mounted Relays

SA3 led - Security and Privacy

- Privacy of identifiers over radio access
- SECAM and SCAS for 3GPP virtualized network products and Management Function (MnF)
- Mission critical security enhancements Phase 3
- Security and privacy aspects of RAN & SA features

SA4 led - Multimedia Codecs, Systems and Services

Systems & Media Architecture:

- 5G Media, Service Enablers
- Split-Rendering
- 5G AR Experiences Architecture

Media:

- Video codec for 5G
- Media Capabilities for Augmented Reality Glasses
- AI / ML Study

Real-Time Communications:

- XR conversational services
- WebRTC-based services and collaboration models

Immersive Voice & Audio:

- EVS Codec Extension for Immersive Voice and Audio Services (IVAS_Codec)
- Terminal Audio quality performance and Test methods for Immersive Audio Services (ATIAS)

Streaming & Broadcast services:

- 5GMS Enh. (Network slicing, Low latency, Background traffic, 5GMS Uplink)
- Further MBS Enh. (Free to air, Hybrid unicast/broadcast)

*These are preliminary lists (As at SA#94-e)

- Access Traffic Steering, Switching & Splitting support in the 5G system architecture Phase 3
- Proximity-based Services in 5GS Phase 2
- UPF enh. for Exposure & SBA
- Ranging based services & sidelink positioning
- Generic group management, exposure & communication enh.
- 5G UE Policy Phase 2
- UAS, UAV & UAM Phase 2
- 5G AM Policy Phase 2
- RedCap Phase 2
- Support for 5WWC Phase 2
- System Enabler for Service Function Chaining
- Extensions to TSC Framework to support 5G-Net
- Seamless UE context recovery
- MPS when access to EPC/5GC is WLAN

SA5 led - Management, Orchestration and Charging

Operations, Administration, Maintenance and Provisioning (OAM&P):

- Intelligence and Automation: Self-Configuration of RAN NEs, Enh. autonomous network levels, Evaluation of autonomous network levels, Enh. intent driven management services for mobile networks, AI/ ML management, Enh. of the management aspects related to NWDAF

- Management Architecture and Mechanisms: Network slicing provisioning rules, Enh. service based management architecture

- Support of New Services: Enh. Energy Efficiency for 5G Phase 2, New aspects of Energy Efficiency for 5G networks Phase 2, Enh. management of Non-Public Networks, Network and Service Operations for Energy Utilities, Key Quality Indicators(KQIs)for 5G service experience, Deterministic Communication Service Assurance

- Charging:
- Charging Aspects for Enh. Support of Non-Public Networks

SA6 led - Application Enablement & Critical Communication Applications

Critical Communications:

- MCX Enhancements – MC over 5GS (5MBS, ProSe) Adhoc group comm., MCPTT Enh.
- Railways - Gateway UE, Interworking

Service Frameworks:

- Edge App Architecture Enh., SEAL Enh., Subscriber-Aware API (CAPIF Enh.)

- Fused location, Application Data Analytics, App Layer NW Slicing

Enablers for Vertical Applications:

- Enhancements to V2X, UAS application-enablement
- Future Factories, Personal IoT networks, Capability exposure for IoT platforms

See the 3GPP Work Plan for full details, as Release 18 develops: www.3gpp.org/specifications/work-plan

TSG RAN priorities*

RAN1 led - Radio Layer 1 (Physical layer)

- NR-MIMO Evolution
- AI/ML - Air Interface
- Evolution of duplex operation
- NR Sidelink Evolution
- Positioning Evolution
- RedCap Evolution
- Network energy savings
- Further UL coverage enhancement
- Smart Repeater
- DSS
- Low power WUS
- CA enhancements

RAN2 led - Radio layer 2 & layer 3 Radio Resource Control

- Mobility Enhancements
- Enhancements for XR
- Sidelink Relay Enhancements
- NTN (Non-Terrestrial Networks) evolution - NR
- NTN (Non-Terrestrial Networks) evolution - IoT
- UAV (Uncrewed Aerial Vehicle)
- Multiple SIM (MUSIM) Enhancements
- In-Device Co-existence (IDC) Enhancements
- Small data
- MBS

RAN3 led - UTRAN/E-UTRAN/NG-RAN architecture & related network interfaces

- Additional topological improvements – IAB/VMR
- AI/ML for NG-RAN WI
- AI/ML for NG-RAN SI
- SON/MDT Enhancements
- QoE Enhancements
- Resiliency of gNB-CU-CP

RAN4 led - Radio Performance and Protocol Aspects

- RAN4-led spectrum items
- <5MHz in dedicated spectrum

Rel-18 Workplan for TSG CT

CT will work on stage 3 completion and ASN.1 code and OpenAPI freeze of Rel-17 until June 2022 (TSG#96).

Work item discussion on Rel-18 Stage 2 / Stage 3 (under CT) from June 2022.

*Source: RP-213697 (RAN#94-e)

5G-Advanced Standardization: 3GPP Rel.18 ...

Is 5G NR the only Radio Interface that meets the IMT 2020 requirements?

WiFi 6 is an air Interface (not a system) that refers to the IEEE efforts– in parallel to those of 3GPP for 5G NR – towards ITU-IMT 2020 targets

Advancements:

- 8x8 MiMo
- More Bandwidth (from 80 MHz to 160 MHz)
- Interference avoidance
- ...

IEEE 802.11ax MAC/PHY (i.e., WiFi 6) meet or exceed 5G requirements for the 5G Indoor Hotspot use case defined by IMT-2020

5G-related ETSI standards

While NR is the major feature for high performance in 5G systems.. many architectural and management advancements, that are part of 5G, borrow/consider/take advantage of ETSI standards.

- ETSI Industry Specification Group (ISG) on Network Functions Virtualization [[ref](#)]
- ETSI Management and Orchestration Architecture (MANO) [[ref](#)]
- ETSI Multi-Access Edge Computing (MEC) [[ref](#)]
- ETSI Industry Specification Group on Zero touch network and Service Management (ZSM ISG) [[ref](#)]
- ETSI Industry Specification Group Experiential Networked Intelligence (ENI ISG) [[ref](#)]

5G Research in EU

5G-PPP partnerships for 5G



EU funding

FUNDING PROGRAMMS

- ..

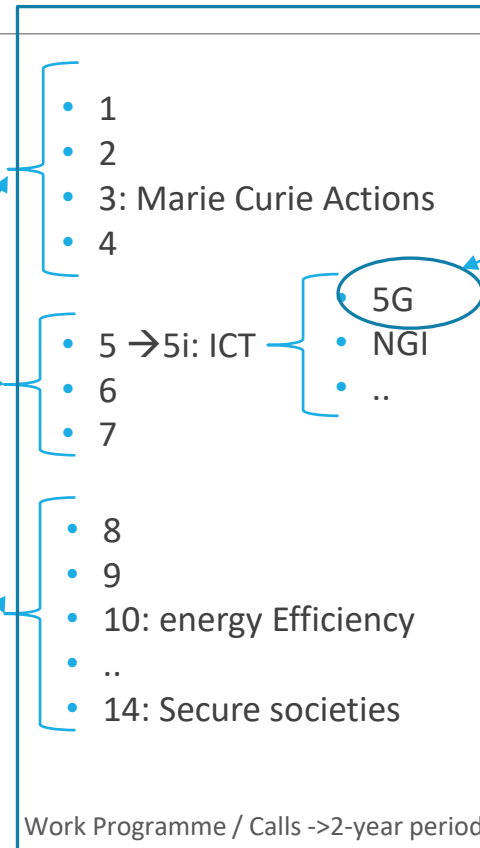
- FP7

2014-2020

Horizon 2020 → sections

- Horizon EUROPE

- ..Excellence Science
- ..Industrial Leadership
- ..Societal Challenges
- ..
- ..
- ..



Under 5G PPP umbrella

5G-PPP working groups

5G-PPP = European Commission + 5G Infrastructure Association (IA)

5G-PPP Working Groups (WGs)

- Originated by 5G IA (6):
 - Pre-Standardization -> Alignment with ETSI, 3GPP, IEEE, ITU-R
 - Security
 - Vision & societal challenges
 - Spectrum
 - IMT-2020 Evaluation Group -> one of the 11 independent 5G Evaluation Groups from ITU-R
 - Trials -> [European Trial Roadmap v0.4](#)
- Originated by 5G-PPP projects (4):
 - Automotive
 - Software
 - Architecture -> [white paper](#)
 - Network Management & QoS
 - Test, measurements and KPIs validation (TMV)
- Originated by Networld2020 (1):
 - SME

5G-PPP Technology Board

(Technical representatives from 5GPPP research projects)

5G-PPP Steering Board

(Coordinators from 5GPPP research projects)

EU funding

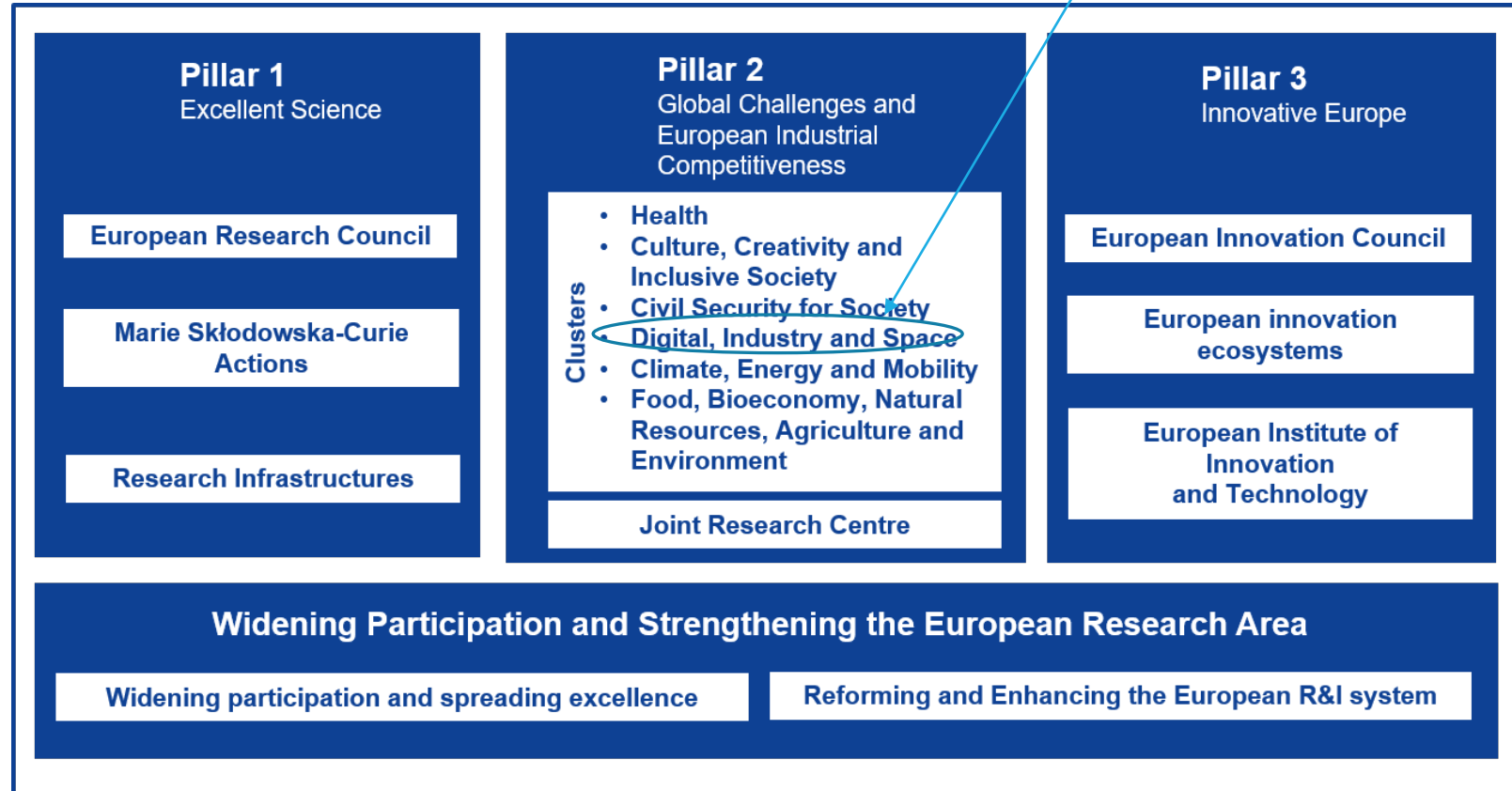
FUNDING PROGRAMMS

- ..
- FP7
- Horizon 2020

2021-2027

Horizon EUROPE →

Under SNS umbrella

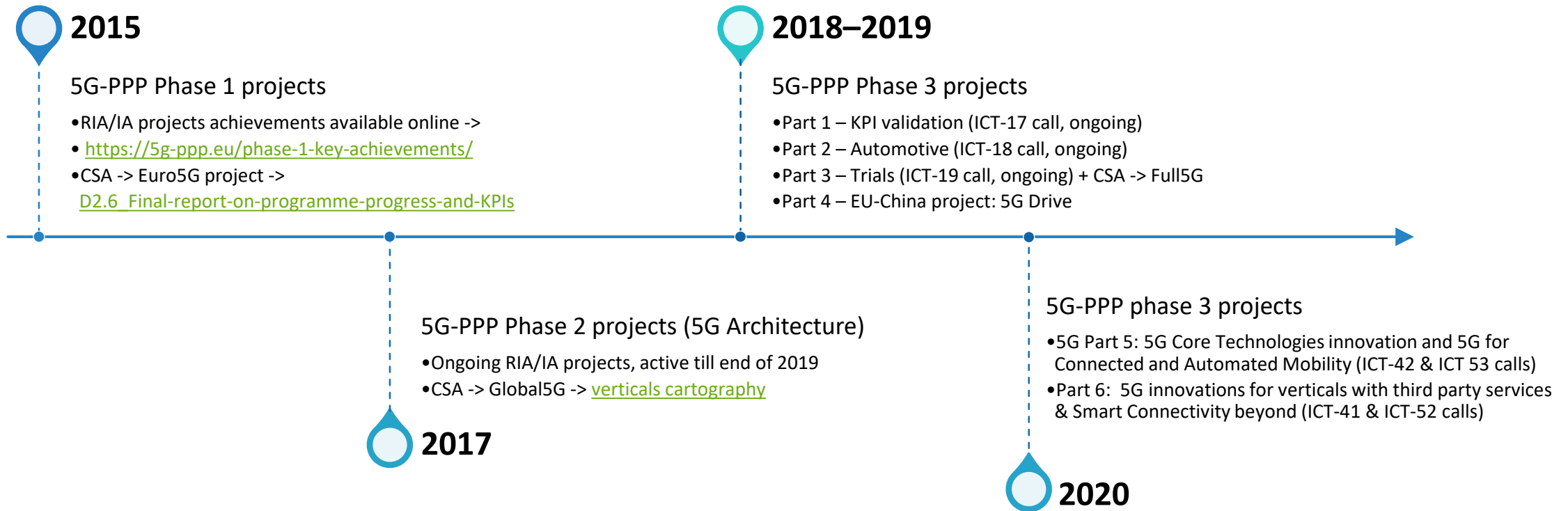


Institutionalised European Partnerships

The proposed partnerships cover the following topics:

- EU-Africa research partnership on health security to tackle infectious diseases
- Innovative Health Initiative
- Key Digital Technologies
- Smart Networks and Services
- European Metrology
- Transforming Europe's rail system
- Integrated Air Traffic Management
- Clean Aviation
- Circular bio-based Europe
- Clean Hydrogen
- Safe and Automated Road Transport
- Innovative SMEs

5G-PPP Research Projects

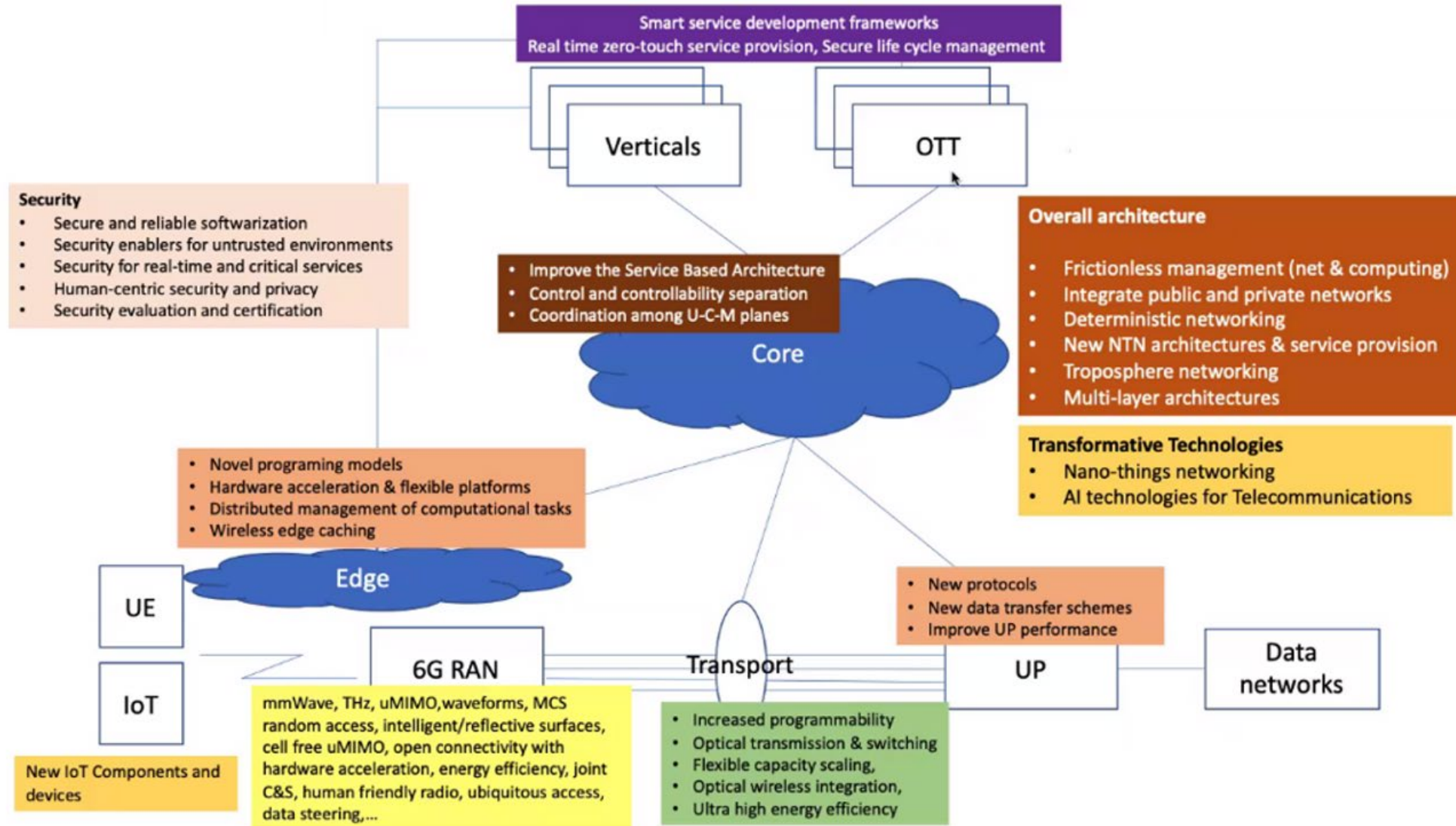


5G (research) platforms around Europe

- On the EU map: [link](#)
- The roadmap for 5GTrials: [link](#)
- Spectrum 3400 – 3800 MHz (awarding trial licenses)



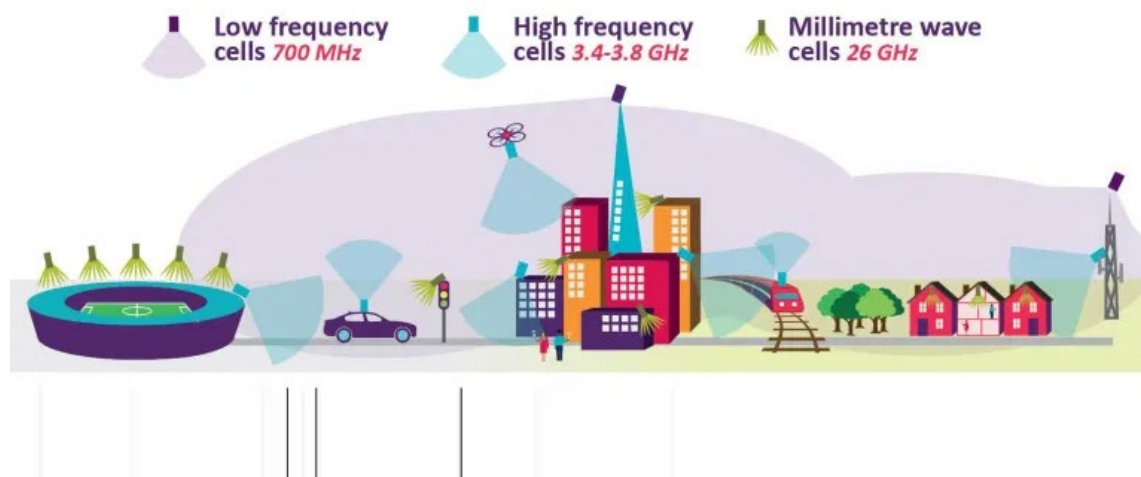
Research topics toward 6G



5G Market and business aspects

5G in market

New Spectrum - - -> New Infrastructure



Η ανακοίνωση της ΕΕΤΤ

Συνολικά κατακυρώθηκαν στις τρεις συμμετέχουσες εταιρίες τα εξής τμήματα ραδιοσυχνότητων:

• COSMOTE:

- δεκαπέντε (15) τμήματα στη ζώνη των 3400-3800 MHz με τίμημα 30.705.000 ευρώ
- δύο (2) τμήματα στη ζώνη των 700 MHz με τίμημα 50.578.000 ευρώ
- τέσσερα (4) τμήματα στη ζώνη των 2 GHz με τίμημα 35.270.000 ευρώ
- δύο (2) τμήματα στη ζώνη των 26 GHz με τίμημα 6.481.000 ευρώ

και συνολικό τίμημα 123.034.000 ευρώ.

• VODAFONE-ΠΑΝΑΦΟΝ:

- δεκατέσσερα (14) τμήματα στη ζώνη των 3400-3800 MHz με τίμημα 37.516.000 ευρώ,
- δύο (2) τμήματα στη ζώνη των 700 MHz με τίμημα 51.060.000 ευρώ
- τέσσερα (4) τμήματα στη ζώνη των 2 GHz με τίμημα 35.120.000 ευρώ
- δύο (2) τμήματα στη ζώνη των 26 GHz με τίμημα 6.480.000 ευρώ

και συνολικό τίμημα 130.176.000 ευρώ.

• WIND:

- δέκα (10) τμήματα στη ζώνη των 3400-3800 MHz με τίμημα 30.306.051 ευρώ
- δύο (2) τμήματα στη ζώνη των 700 MHz με τίμημα 50.080.051 ευρώ
- τέσσερα (4) τμήματα στη ζώνη των 2 GHz με τίμημα 35.420.000 ευρώ
- ένα (1) τμήμα στη ζώνη των 26 GHz με τίμημα 3.245.051 ευρώ

και συνολικό τίμημα 119.051.153 ευρώ.

5G in market


5G Routers

Model	Speed	Wi-Fi 6	CPU	Support 5G Bands	4G LTE
Huawei 5G CPE Pro H112-372	5G: 1.65Gbps/ 250Mbps 4G : 1.6Gbps/ 150Mbps	N	Balong 5000	5G: n41/ n77/ n78/ n79	LTE: B1/3/5/7/8/18/19/20/28/32/34/38/39/40/41/42/43
Huawei 5G CPE Pro H112-370	5G: 1.65Gbps/ 250Mbps 4G: 1.6Gbps/ 150Mbps	Y	Balong 5000	5G: n78	LTE: B1/3/5/7/8/18/19/20/28/32/34/38/39/40/41/42/43
Huawei 5G CPE Pro 2 H122-373	5G: 3.6Gbps/ 250Mbps 4G: 1.6Gbps/ 150Mbps	Y	Balong 5000	5G: n1/ 3/ 5/ 7/ 28/ 38/ 40(2300–2390 MHz)/ 41/ 77/ 78/ 79/ 80/ 84	LTE: B1/3/5/7/8/20/28/32/34/38/39/40(2300–2390 MHz)/41/4
Huawei 5G CPE Win H312-371	5G: 1.65Gbps/ 250Mbps 4G: 1.6Gbps/ 150Mbps	N	Balong 5000	5G: n41/ n77/ n78/ n79	LTE: B1/3/5/7/8/18/19/20/28/32/34/38/39/40/41/42/43
Huawei 5G Mobile WiFi E6878-870	5G: 1.65Gbps/ 250Mbps 4G: 300Mbps/ 75Mbps	N	Balong 5000	5G: n41/ n77/ n78/ n79	LTE FDD: B1, B3, B5, B7, B8, B20, B28, B32 LTE TDD: B34, B38, B39, B40, B41, B42
Huawei 5G Mobile WiFi Pro E6878-370	5G: 1.65Gbps/ 250Mbps 4G: 300Mbps/ 75Mbps	N	Balong 5000	5G: n41/ n77/ n78/ n79	LTE FDD: B1, B3, B5, B7, B8, B20, B28, B32 LTE TDD: B34, B38, B39, B40, B41, B42
ZTE 5G CPE Indoor WiFi MC801	5G: 2.8Gbps	Y	Qualcomm Snapdragon X50	5G: n41/ n77/ n78/ n79	4G LTE™: Global FDD and TDD, 600MHz~3.8GHz, CAT20

5G Devices


Xiaomi 5G Phones

>



Samsung 5G Phones

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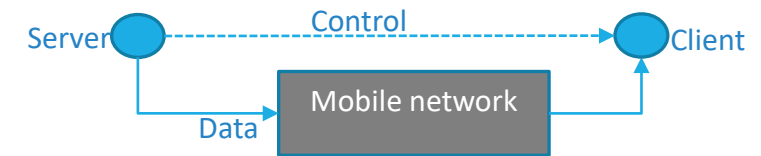


Vertical industries

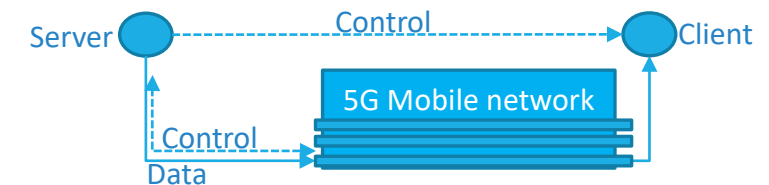
Vertical Industries -> https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf



Before 5G
Over the top Service Providers



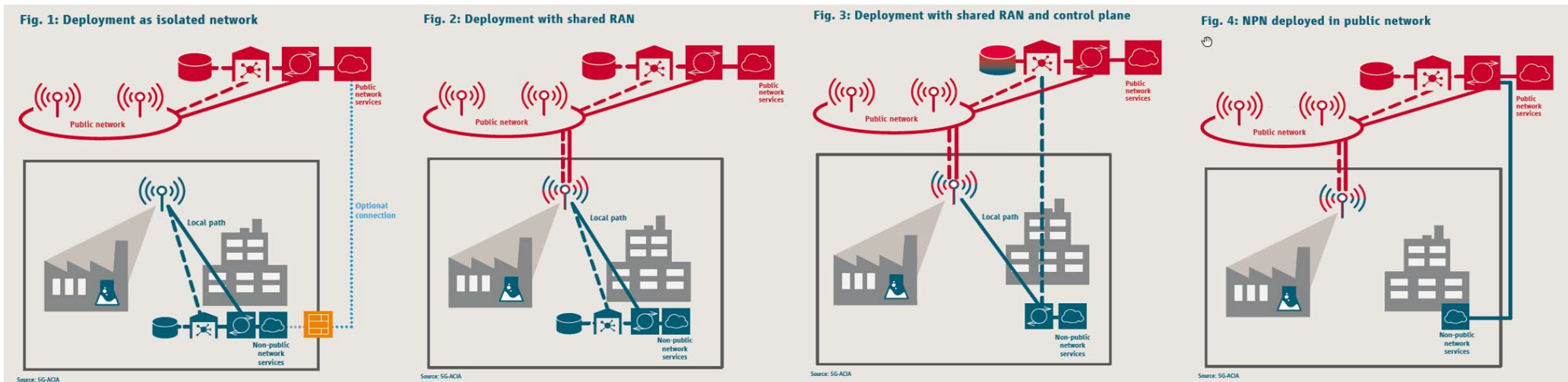
In 5G
Vertical Service providers



5G: serving the vertical industries

Two key (interlinked) features

- 5G Openness
 - Verticals interact with 5G network components
- NPN deployments (Non-Public Networks) [\[ref\]](#)
 - A 5G network deployment can be totally isolated or well-separated from a public 5G mobile network;
 - 5G as the total solution for communication and management in vertical industries



Take-aways and specific topics to dig into

- 5G mobile system is not only about better performance for the end user.. is also a flexible management platform that creates business opportunities for verticals
- From the standardization point of view 3GPP Rel15 and Rel16 define the 5G architecture and the related technologies
- There are key advancements from IT sector that are consider in the Telco sector for the realization of 5G features (e.g., ETSI MANO for network slicing)
- The 5G research in EU has recognized the need for 5G (and B5G) experimentation platforms (dedicated spectrum for experimentation, development of 5G testbeds around EU)

Target topics

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)