The context of the 5G-DRIVE EU-Funded project in the scope of cooperation between the EU and China – Cooperation for enhanced Mobile Broadband (eMBB) and "Vehicle to Everything" (V2X) applications

–

Scenarios, Use Cases and Essential Technological Background for Trials

Dr. Ioannis Chochliouros

Head of Fixed Network R&D Programs Section

Hellenic Telecommunications Organisation S.A.

Mr. Athanassios Dardamanis - *SMNET S.A.*

Dr. Michail-Alexandros Kourtis – *ORION Innovations P.C.*

Contents:

- Introductory Framework
- 5G-DRIVE: Overall Concept and Key Areas for Innovation
- Cooperative Framework: Inclusion within the EU context for trials
- Selected Sites for Trials and Cooperation with China
- Views on selected Use Cases (eMBB and V2X-based communications)
- Architectural Approach
- Radio Frequency spectrum Issues

Introductory Framework

Introduction_(1)

"5G" can be seen as a basic game changer, enabling:

- ***Industrial transformations** through **wireless broadband services provided at gigabit speeds**;*
- ***Support of new types of applications connecting devices and objects** (the Internet of Things-IoT);*
- ***Versatility by way of software virtualisation** allowing innovative **business models across multiple sectors** (e.g. transport, health, manufacturing, logistics, energy, media and entertainment).*

While these transformations have already started on the basis of existing networks, they will further need 5G if they are to reach their full potential in the coming years…

Introduction_(2)

The Commission strategy** for the Digital Single Market (DSM strategy) **and the Communication** about Connectivity for a Competitive Digital Single Market: "Towards a European Gigabit Society", **both underline** the **importance of very high capacity networks** as a **"key asset" for Europe to compete in the global market.

The Commission has launched a Public-Private-Partnership (5G-PPP) backed by 700 million euro of public funding with the aim of making sure that 5G technology is available in Europe by 2020.
However, research efforts alone will not be sufficient to ensure Europe's leadership in 5G.
A wider effort is needed to make a reality the 5G and the services that will flow from it, in particular for the emergence of a European "home market" for 5G.

Introduction_(3)

Since major research efforts are underway worldwide, ***it is essential to avoid incompatible 5G standards emerging in different regions.***

If Europe is to "help shape a global consensus as regards the choice of technologies, spectrum bands and leading 5G applications effective", ***EU coordination and planning on a cross-border basis will be needed****.*

The launch of commercial 5G services will also require substantial investments*, the* ***availability of a suitable amount of spectrum****, and* ***close collaboration between telecom players and "key" user industries.***

- ***Network operators will not invest in new infrastructures if they do not see clear prospects for a solid demand and regulatory conditions that make the investment worthwhile.***
- ***Equally, industrial sectors interested in 5G for their digitisation process may want to wait until the relevant 5G infrastructure is tested and ready.***

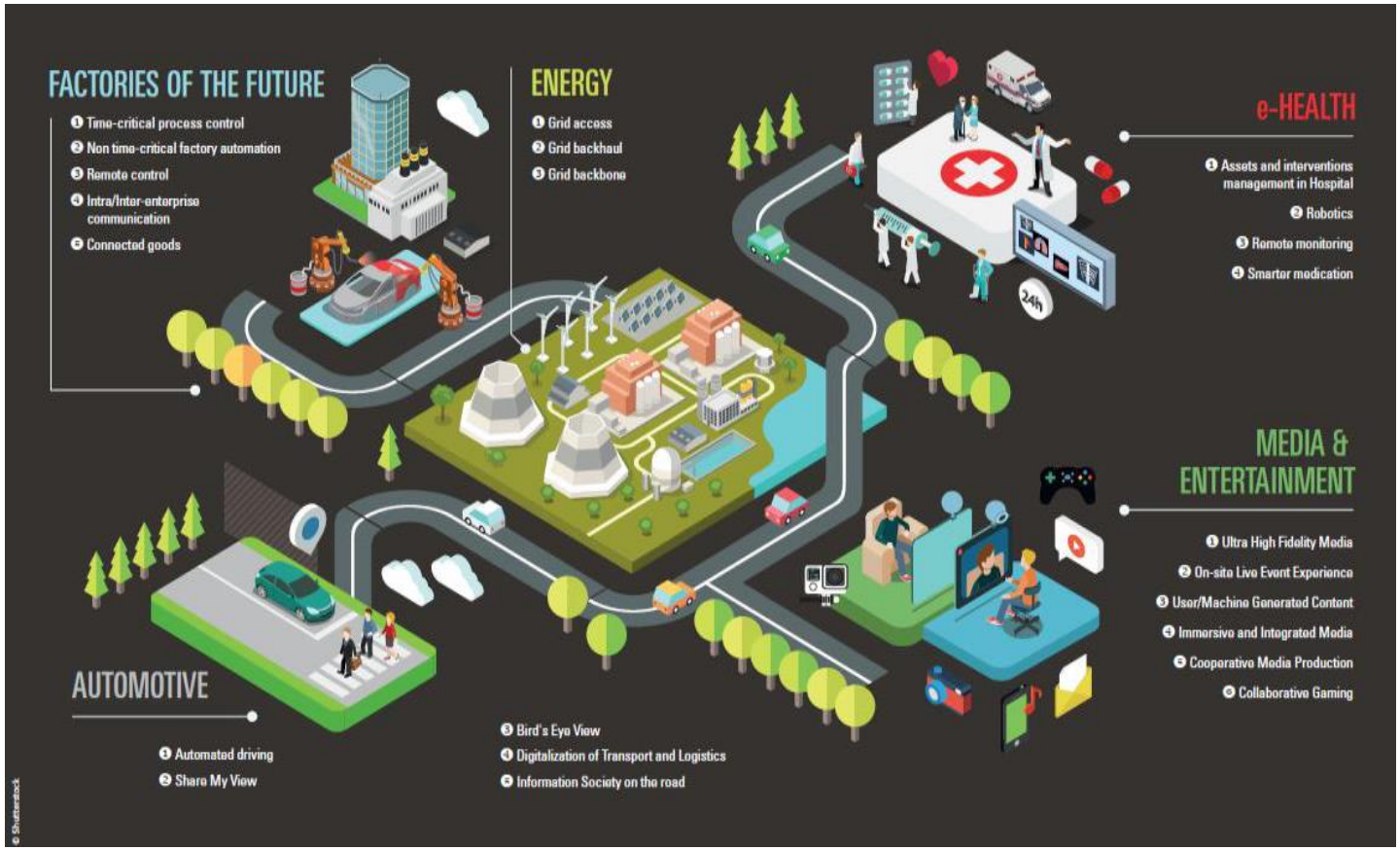
Introduction_(4)

Potential lack of coordination** between European approaches concerning the roll-out of 5G networks **could create a significant risk of fragmentation** in terms of **spectrum availability, service continuity across borders (e.g. connected vehicles)** and **implementation of standards.

Several EU proposed policy actions:

- ***Align** roadmaps and priorities for a coordinated 5G deployment across EU Member States.*
- ***Make provisional** spectrum bands available for 5G, to be complemented by additional bands as quickly as possible.*
- ***Promote** early deployment in major urban areas and along major transport paths.*
- ***Encourage** (pan-European and multi-stakeholder) trials as "catalysts" to turn technological innovation into full business solutions.*
- ***Facilitate** industrial involvement also coming from "vertical sectors", in support of 5G-based innovation.*
- ***Unite** leading actors in working towards the promotion of global standards.*
- ***Support** international cooperation towards supporting common technical standards and approaches.*

Introduction_(5)



European Approach within the 5G-PPP Framework

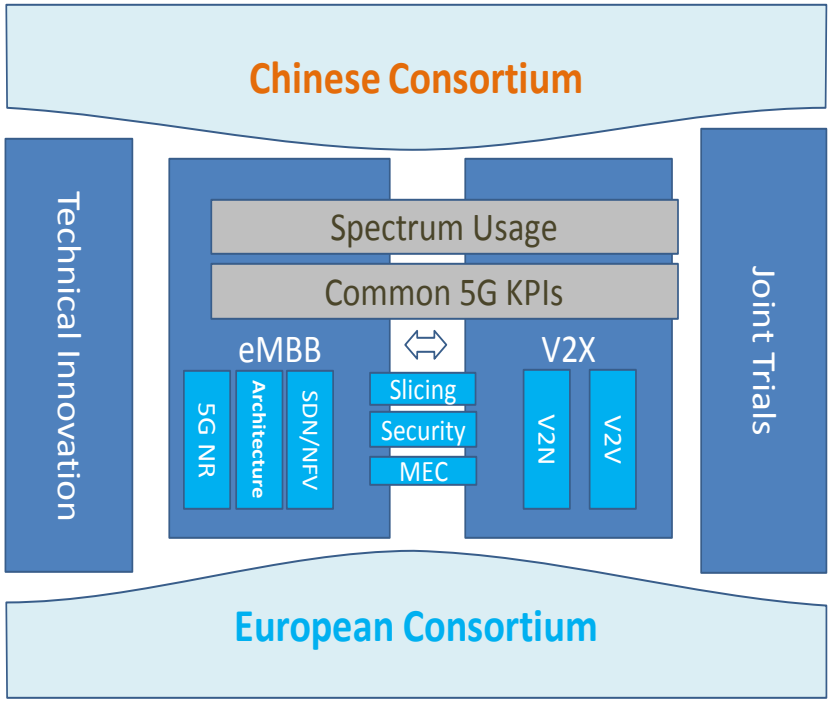
5G-DRIVE: Overall Concept and Key Areas for Innovation

Overall Concept_(1)

- *The European Commission and the Peoples' Republic of China have agreed to fund a **joint project on 5G trials** in order **to address two most promising 5G deployment scenarios**, namely enhanced Mobile Broadband (eMBB) and Vehicle-to-Everything (V2X) communications.*
- ***The 5G-DRIVE project**, established by major 5G players in both regions, **takes the ambition to fulfil this goal**.*

The 5G-DRIVE project:

- ***Predicts for joint trials and research activities** to facilitate technology convergence, spectrum harmonisation and business innovation before large scale commercial deployments of 5G networks take place.*
- ***Aims to develop key 5G technologies and pre-commercial testbeds for eMBB and V2X services** in collaboration with the "twinned" Chinese project led by China Mobile.*
- ***Trials for testing and validating key 5G functionalities, services and network planning** will be conducted in eight cities across the EU and China.*



Overall Concept_(2)

Ambitions:

- **5G-DRIVE conducts joint trials for eMBB and LTE-V2X scenarios with a major relevant 5G project in China (*coordinated by China Mobile*)**.
- These joint trials will be based on **parallel and "analogous" test end-to-end-architectures, use case applications, test procedure and KPIs**.
- 5G-DRIVE will investigate the **application of new technologies and services** *such as network slicing, MEC, and privacy-friendly communications* **for eMMB and connected and automated vehicles.**
- **Contribution to a common understanding and harmonisation of technical conditions between the EU and China**, *i.e. standards, interoperability requirements, coexistence conditions, and resilience.*

Overall Concept_(3)

Technical objectives:

OBJ1: Build pre-commercial end-to-end testbeds in two cities with sufficient coverage to perform extensive eMBB and Internet of Vehicles (IoV) trials. *(Joint test specifications have been defined through the Collaborative Agreement with the Chinese project).*

OBJ2: Develop and trial "key" 5G technologies and services, *including (but not limited to) massive multi-input multi-output (MIMO) at 3.5GHz, end-to-end network slicing, mobile edge computing for low latency services and V2X, Software-defined networking (SDN) for transport and core network, and network and terminal security.*

OBJ3: Develop and trial cross-domain network slicing techniques across the two regions, for promoting new services.

OBJ4: Demonstrate IoV services using Vehicle-to-Network (V2N) and Vehicle-to-Vehicle (V2V) communications operating at 3.5GHz and 5.9GHz, *respectively*.

OBJ5: Analyse potential system interoperability issues *identified during the trials in both regions* and **provide** *joint reports, white papers, and recommendations to address them accordingly.*

OBJ6: Submit contributions to 3GPP and other 5G standardisation bodies, *where relevant*, regarding the key 5G technologies developed and evaluated in the project.

Overall Concept_(4)

Regulatory objectives:

OBJ7: Evaluate spectrum usage at 3.5GHz for indoor and outdoor environments in selected trial sites and **provide joint evaluation reports and recommendations on 5G "key" spectrum bands in Europe and China.**

OBJ8: Investigate regulatory issues regarding the deployment of V2X technologies, *i.e. coexistence in the 5.9GHz band,* **and provide joint reports**.

Business objectives:

OBJ9: Investigate and promote 5G business potential *through joint development of 5G use cases and applications.*

OBJ10: Strengthen industrial 5G cooperation between the EU and China.

OBJ11: Promote early 5G market adoption through joint demonstrations in large showcasing events, *developed and evaluated in the project.*

Key Areas of the Project Innovation_(1)

Key areas of innovation where 5G-DRIVE contributes:

- **eMBB** ***(enhanced Mobile Broadband)*** **scenario and use case applications trial assessment;**
- **IoV** ***(Internet of Vehicles)*** **(mainly V2V** ***(Vehicle-to-Vehicle)*****, V2N** ***(Vehicle-to-Network)*****,** *and potentially* ***V2I*** *(Vehicle-to-Infrastructure),* ***V2P*** *(Vehicle-to-Pedestrian)* ***including*** **trial assessment** *&* **security vulnerabilities testing;**
- **Technological innovation** *in radio access, transport networks, slicing, security and privacy-friendly communications for future 5G vehicular networks, built on Car Connectivity;*
- *The* ***most important contribution*** *of 5G-DRIVE will be the* ***demonstration of capabilities of current 5G technologies for two main scenarios: eMBB and IoV.***

Key Areas of the Project Innovation_(2)

Other essential concerns:

Another significant area of innovation in 5G-DRIVE is the research study that will be carried out.

The aim of this research is threefold:

- **Investigation** of the **radio access and transport protocols**.
- **Study** of the **innovation in virtualisation and networks slicing.**
- **"Addressing" precisely a greater concern for connected vehicles in 5G future vehicular networks: Secure & privacy-friendly communications.**

*To secure a vehicle adequately, the **security must be considered from the design and at all levels**, especially at the networking and the MEC level.*

***5G-DRIVE is committed to study security and privacy technologies** for the new transportation ecosystem.*

Making 5G radio spectrum available

The deployment of 5G networks requires the timely availability of a sufficient amount of harmonised spectrum. *A major new requirement specific for 5G is the need for large contiguous bandwidths of spectrum (up to 100 MHz) in appropriate frequency ranges to provide higher wireless broadband speeds.*

Spectrum availability between 1 GHz and 6 GHz, where EU-wide harmonised bands are already available and licensed in a technology neutral way across Europe.

In particular, the 3.5 GHz band can offer high potential to become a strategic band for 5G launch and deployment in Europe.

This approach is supported by industry, *and it is considered as an "adequate response" to the developing spectrum plans in competing economies*

Unlocking Bottlenecks_(2)

Preserving 5G Global Interoperability with suitable standards

From an EU strategy perspective, the main challenges identified are as follows:

- ***Timely availability of 5G standards***, that shall be globally accepted.
- ***Compatibility with further development*** of standards ***for innovative use cases*** related to massive deployment of connected objects and the IoT.
- ***Avoidance of*** *the emergence of parallel -potentially conflicting-* ***specifications, developed outside global standardisation bodies.***
- *Development of standards on the basis of experimental evidence*, ***taking advantage of international cooperation*** and a multi-stakeholder approach.
- ***Addressing the future evolution of the overall network architecture and fulfilling the need for "flexibility",*** in particular in response to new use cases arising in key industrial sectors.

These aspects require due consideration for open innovation and opportunities for start-ups. It is so essential to promote and apply a comprehensive and inclusive approach, for enabling a suitable commercial launch on 5G.

Unlocking Bottlenecks_(3)

Stimulating new connectivity-based ecosystems through experiments and demonstrations

From an EU strategy perspective, the main challenges identified are as follows:

- ***Running pilot trials*** *to increase predictability, reduce investment risks and validate both the technologies and the business models.*
- ***Experiments*** *are also needed to provide input for the standardisation organisations.*
- ***Put greater emphasis on pilots and experiments in the run-up to 5G*** *and* ***support the deployment of selected 5G trials*** *(with a clear EU dimension), including the testing of new terminals and applications.*
- *Where possible,* ***5G experiments should make use of facilities already developed*** *in the context of activities conducted in Member States.*

Cooperative Framework:

Inclusion within the well-defined 5G Pan-EU Trials Roadmap

Cooperative Framework_(1)

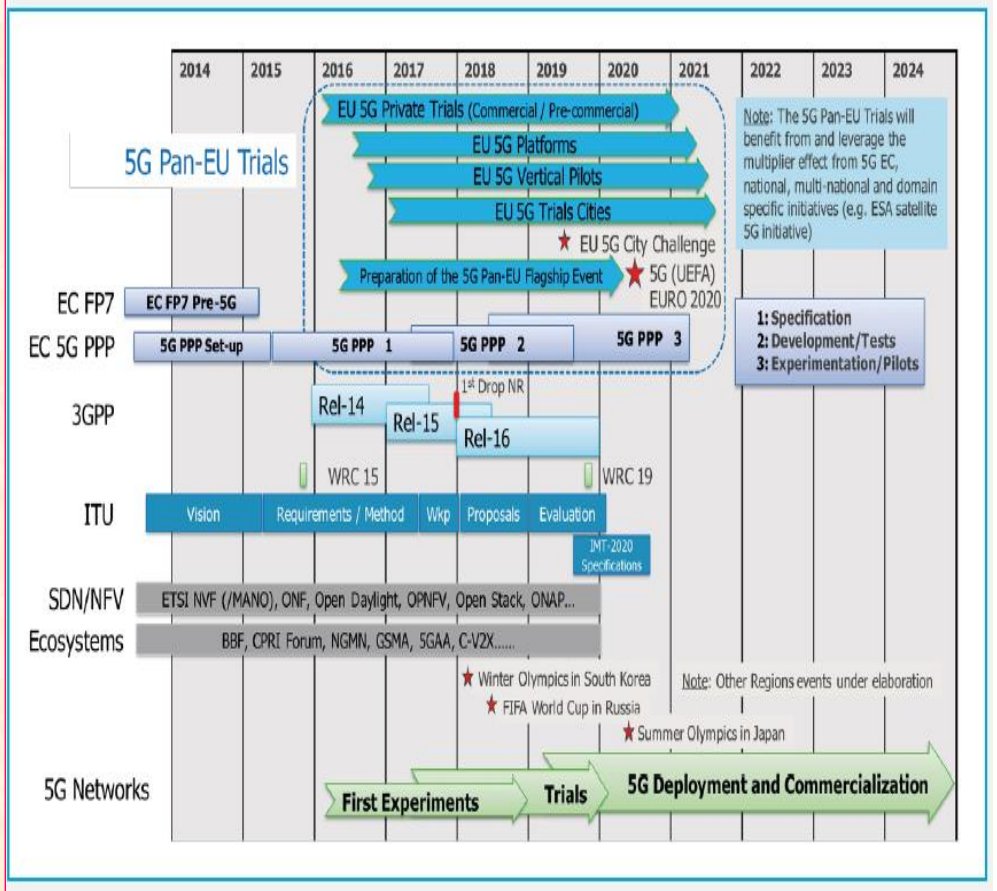
Among the actual priorities of the European Commission *(interactively with Member States (MSs) and industrial stakeholders/market actors)* ***is the voluntary establishment of a common timetable for the launch of early 5G networks*** *(initially scheduled to be operational by the end of 2018) and followed by the launch of fully commercial 5G services in Europe by the end of 2020 and beyond.*

According to the 5G Action Plan (5GAP), the relevant EU timetable is actually driven by the following key objectives:

(i) ***Promoting*** *preliminary trials, under the 5G-PPP arrangement to take place from 2017 onwards, and pre-commercial trials with a clear EU cross-border dimension from 2018;*

(ii) ***supporting*** *of commercial launch of 5G services in at least one major city in all MSs in 2020, and;*

(iii) ***encouraging*** *MSs to develop national 5G deployment roadmaps as part of the national broadband plans, with uninterrupted coverage in all urban areas and along main transport paths in 2025.*



Cooperative Framework_(2)

The EC supports pilots and experiments in the course of the 5G growth, though the coordination of the 5G-PPP, via selected 5G trials.

The EC counts on the trial results, *to be able to identify and address specific sectorial policy issues and seek the active support of MSs to resolve them whenever they constitute a major obstacle to high value applications relying on 5G.*

Experimental platforms for 4G/5G in Europe are results-"outcome" of private and public efforts at national and/or European level.

Via enhancing trial capabilities and suitable pilots' development, ***research and experimental platforms can support future 5G evolution...***

From a high-level perspective, one way to "view" the 5G ecosystem can be in terms of platforms (i.e.: hardware (HW) and software (SW), services and use cases).

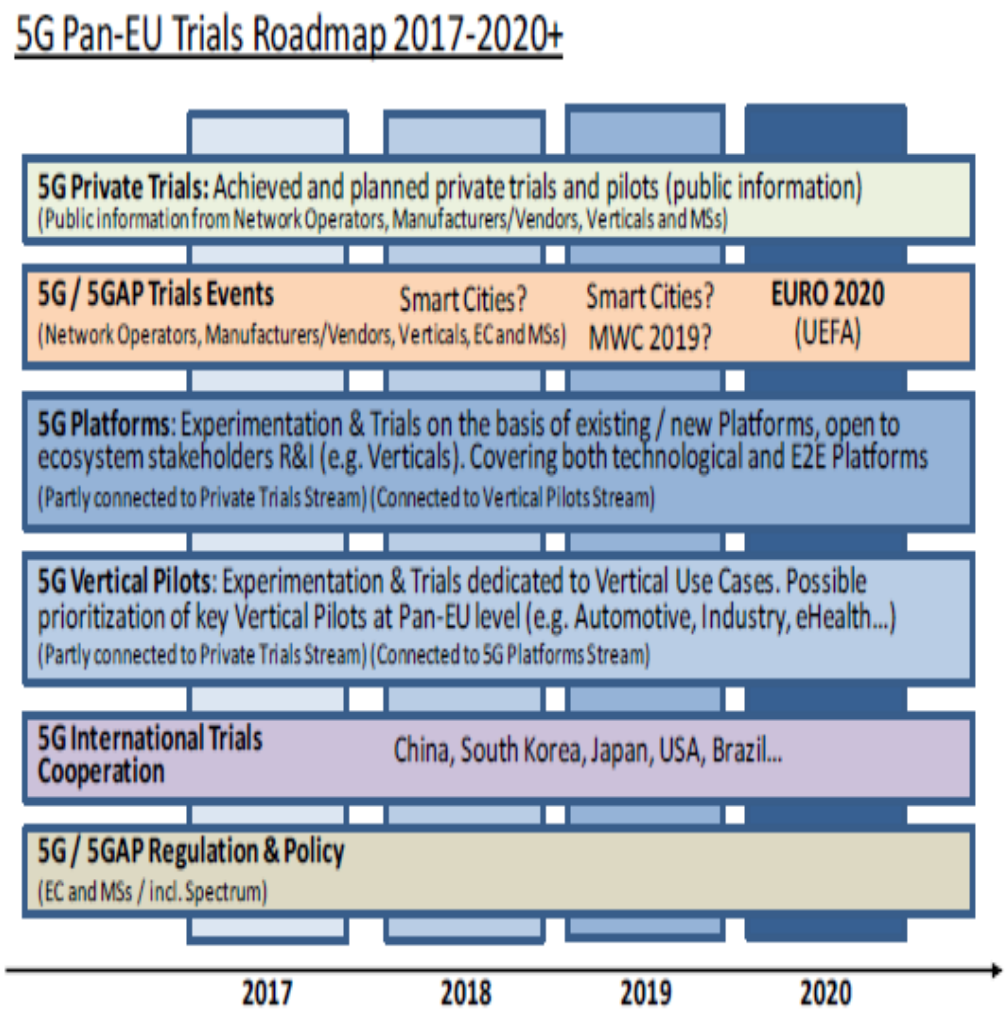
- *For new platforms and services to be created,* ***key decisions need to be taken****, both business-wise and technically.*
- ***Business cases have to be developed****, while tests, trials and evaluations to satisfy the involved stakeholders have to be achieved.*
- *Considering* ***vertical sectors****, these* ***will make use of relevant innovations and generate use cases*** *for their own benefit.*

Cooperative Framework_(3)

Within the 5G-PPP context, **the Trials Working Group (WG) is elaborating a solid and comprehensive strategy** *to develop pan-EU coordinated trials as well as international trials with the participation of non-EU countries*.

Core objectives are to:

i. *Affirm global European leadership on 5G technology, 5G networks deployment and profitable 5G business models;*
ii. *demonstrate benefits of 5G to vertical sectors, public sector, businesses and consumers;*
iii. *show a clear path to successful and timely 5G deployment;*
iv. *provide robust response to the EC 5GAP, and;*
v. *complement commercial trials and demonstrations as well as national initiatives.*



Sites for Trials and Cooperative Framework with China

Trial Sites_(1)

5G-DRIVE will achieve its objectives
by defining, organizing and conducting a series of trials at three EU locations, *with key characteristics*:

Guildford, Surrey (eMBB trials)

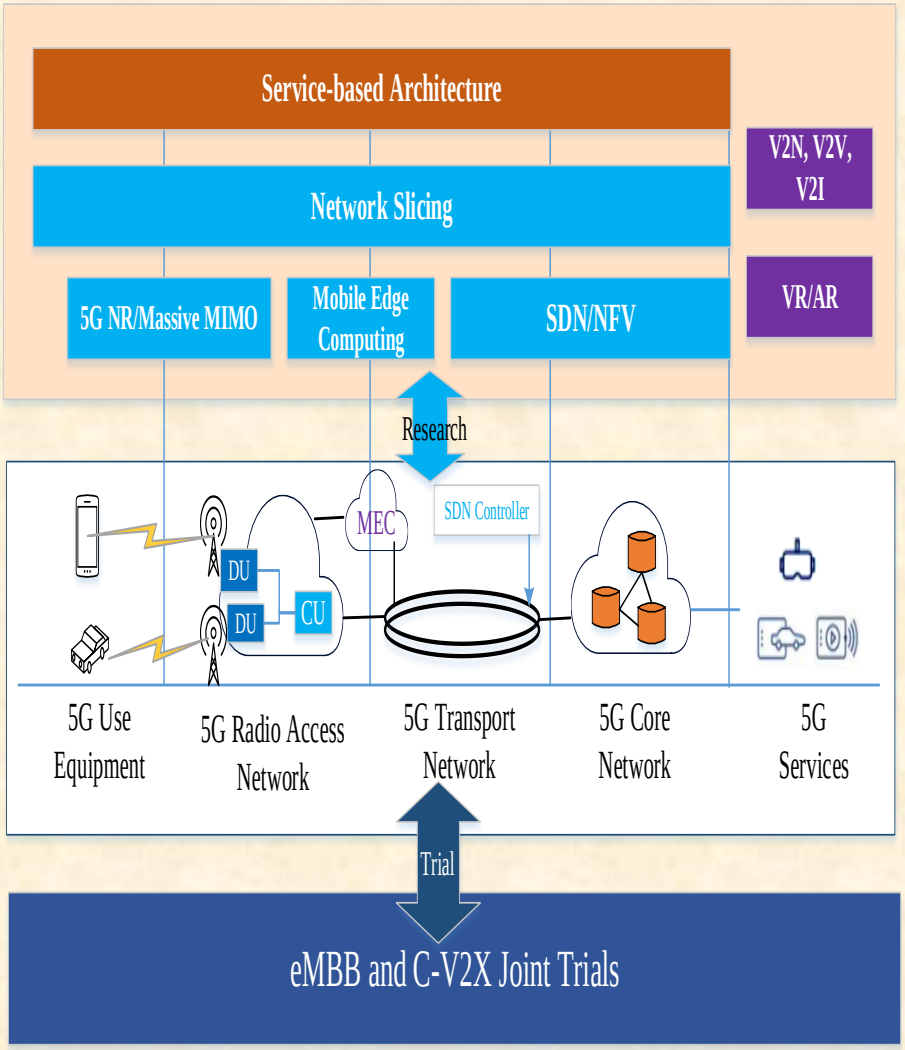
- *4 km² for 5G testing (motorway, rural, urban, dense areas).*
- *Supports interface to other testbeds, servers and databases.*
- *C-RAN architecture for coordinated joint processing.*

JRC Ispra (V2X trials)

- *36 km of real-life driving conditions roads.*
- *ITS-G5 equipment, large-scale shielded anechoic chamber and 9 vehicle emission laboratories.*
- *PKI for security and trust in road transportation.*

Espoo (eMBB and V2X trials)

eMBB	V2X
• 2 km² test area. • Outdoor and indoor deployment. • Connection to MEC platform.	• 5G network infrastructure for V2X. • MEC for vehicle data sensing. • Road-side unit and infrastructure for V2I and V2N • Demo vehicle (Marilyn) for autonomous driving.

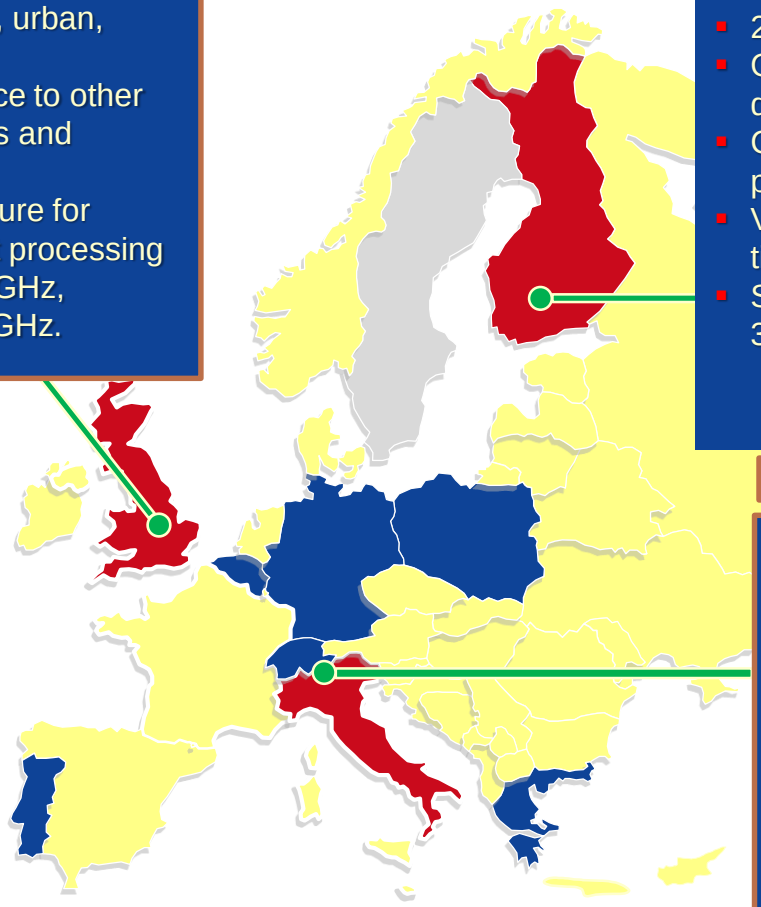


Trial Sites_(2)

5G-DRIVE has defined three testbed installations where it will run various trials:

Surrey (eMBB)

- 4 km^2 for 5G testing (motorway, rural, urban, dense areas).
- Supports interface to other testbeds, servers and databases.
- C-RAN architecture for coordinated joint processing
- Spectrum at 3.5GHz, 28GHz, and 60 GHz.



Espoo (eMBB, V2X)

eMBB

- 2 km^2 test area.
- Outdoor and indoor deployment.
- Connection to MEC platform.
- Very high accuracy timing facility.
- Spectrum at 2.6GHz, 3.5GHz, and 26GHz.

V2X

- 5G network infrastructure for V2X.
- MEC for vehicle data sensing.
- Road-side unit and infrastructure for V2I and V2N
- Demo vehicle (Marilyn) available for autonomous driving.

JRC Ispra (V2X)

- 36 km road of real-life driving conditions.
- 9 vehicle emissions laboratories.
- High resolution localization and mapping
- LTE/5G networks and V2X equipment
- MEC infrastructure.
- PKI for security and trust in road transportation.

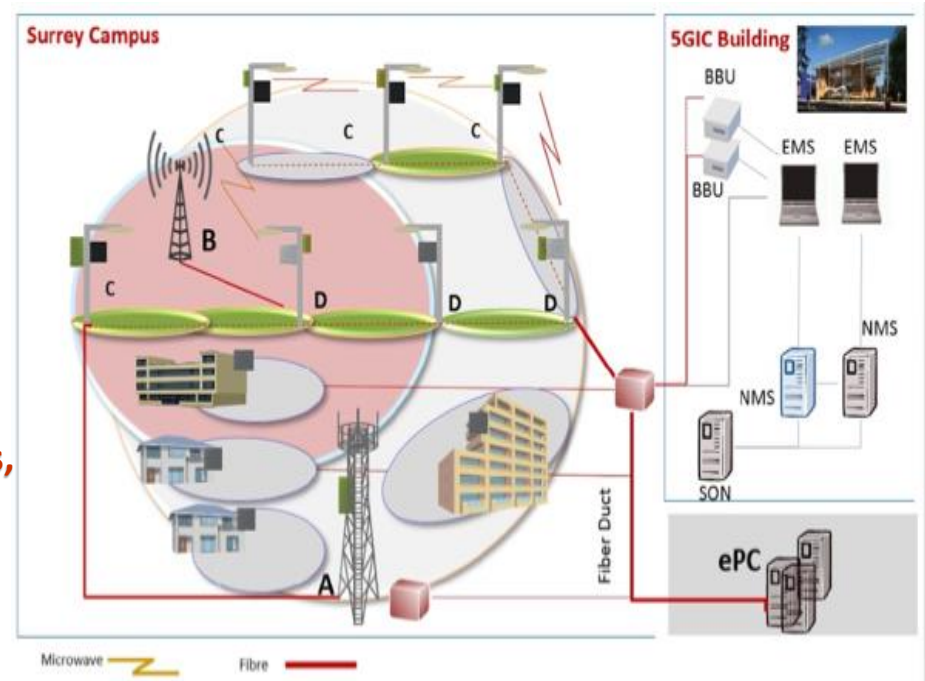
Trial Sites_(3)

- The **UniS trial site and the 5G Innovation Centre** **includes a Cloud-RAN (C-RAN) test platform which supports clusters of remote radio heads (RRH), supported by high performance core processing facilities for experimental research on advanced techniques** *(such as joint transmission coordinated multi-point transmission and reception (CoMP) schemes).*

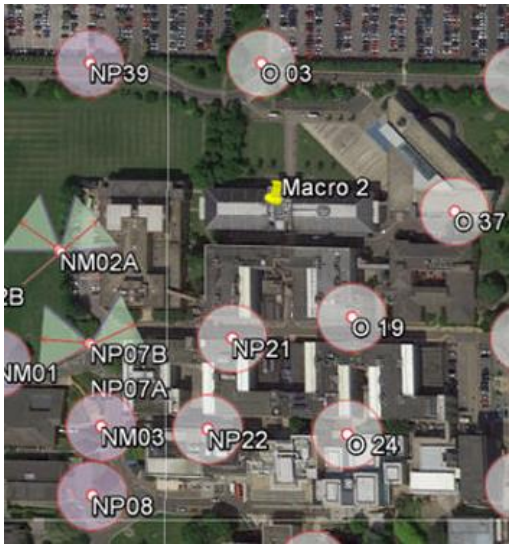
- The test network provides a unique environment to test operation of **heterogeneous access networks in a real life environment.**
- **The testbed is connected to *Cloud Computing* facilities and covers a 4 km² area for the testing of 5G technologies.**
- **The coverage area encompasses a stretch of motorway, rural, urban and dense urban radio environments.**

- **The outdoor deployment consists of 44 sites and 65 cells (of which 3 are macro cells, the remainder are small and ultra-dense cells).**
  This end-to-end testbed incorporates a different range of frequency bands (3.5 GHz, 28 GHz and 60 GHz) and allows the **testing and trialling of new air-interface solutions**. Supported by a mix of wireless and fibre optic backhaul connectivity, trials can be matched to meet industry requirements.

- **The platform can support interfacing to other testbeds, servers and databases** for integration of different components provided by other consortium members and external experiments.



UniS/5GIC Trial Site



Trial Sites_(5)

The **Espoo trial site** provides 5G testing facilities built in several national projects under the 5GTNF (5G Test Network of Finland) framework.

The site will focus on the development and evaluation of both eMBB and V2X scenarios.

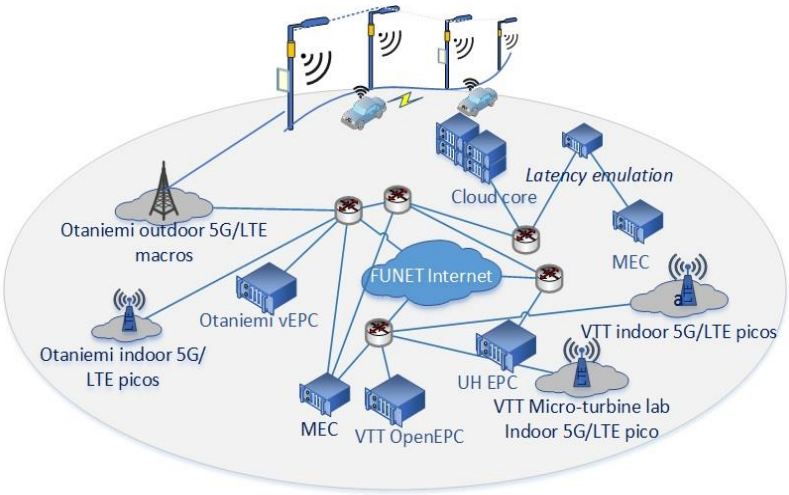
The current network infrastructure is built on top of Nokia's NetLeap LTE test network. ***It will be gradually upgraded to 5G networks when 5G NR and 5G core network components are available.***

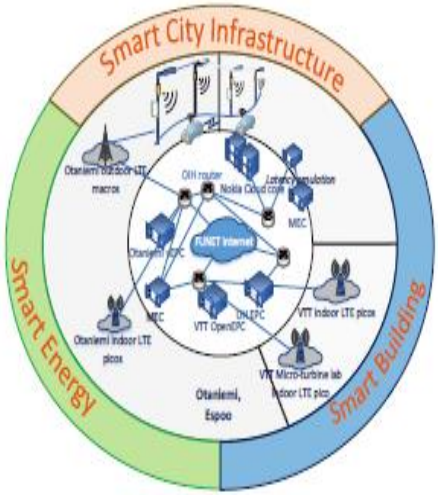
The network contains:

- *both **indoor and outdoor eNodeBs** operating at 2.6 GHz,*
- ***lamppost integrated small cell networks** operating at 3.5 GHz;*
- ***mm-wave bands** at 26 GHz, and;*
- ***Wi-Fi networks** operating at unlicensed 2.4 GHz and 5 GHz.*

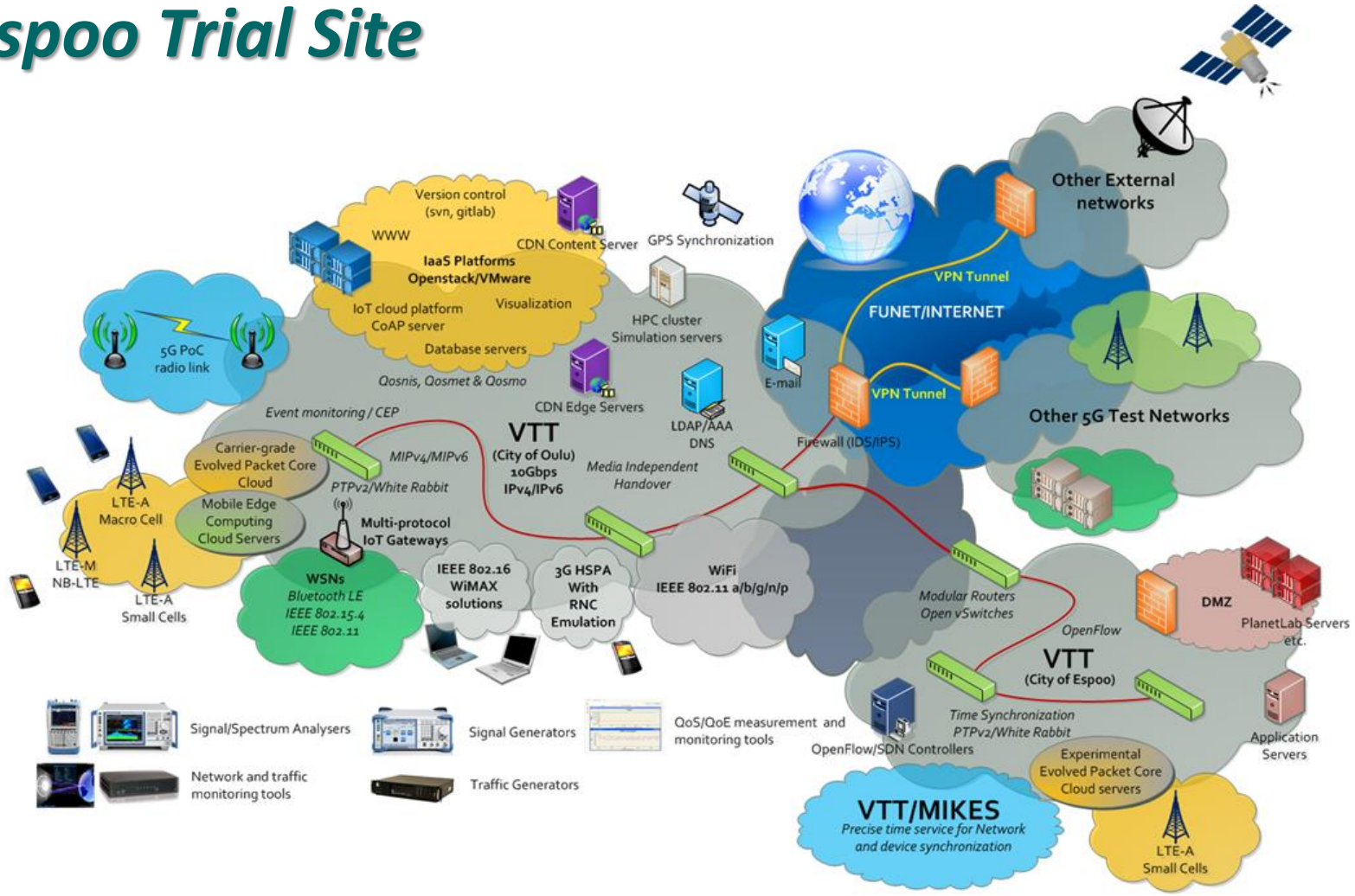
This site enables creating a virtual mobile network with its own evolved packet core (EPC) and can utilize the edge computing platform for developing localized services.
The test network is open for experimental EPCs.

It enables multi-operator scenarios and testing of network slicing
The testbed in Espoo provides facilities and test environments for SDN/MEC, indoor positioning, latency reduction, reliability and other topics.



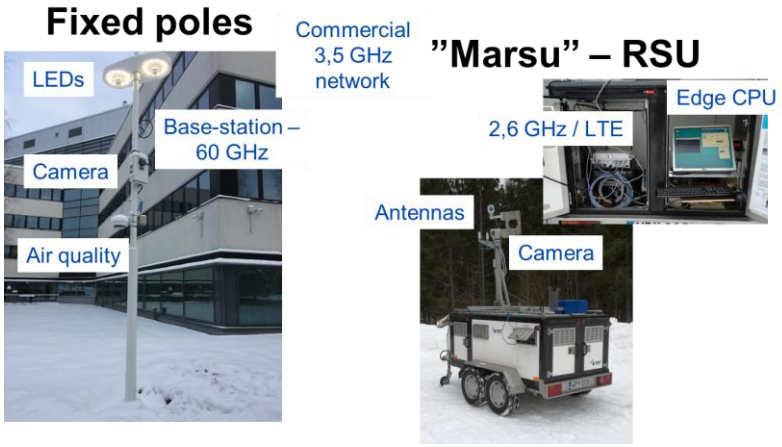


Espoo Trial Site



Equipment used in Espoo trial site

- Many communication technologies
- MEC available on-site
  - Connected to RSU
  - Connected to IoT



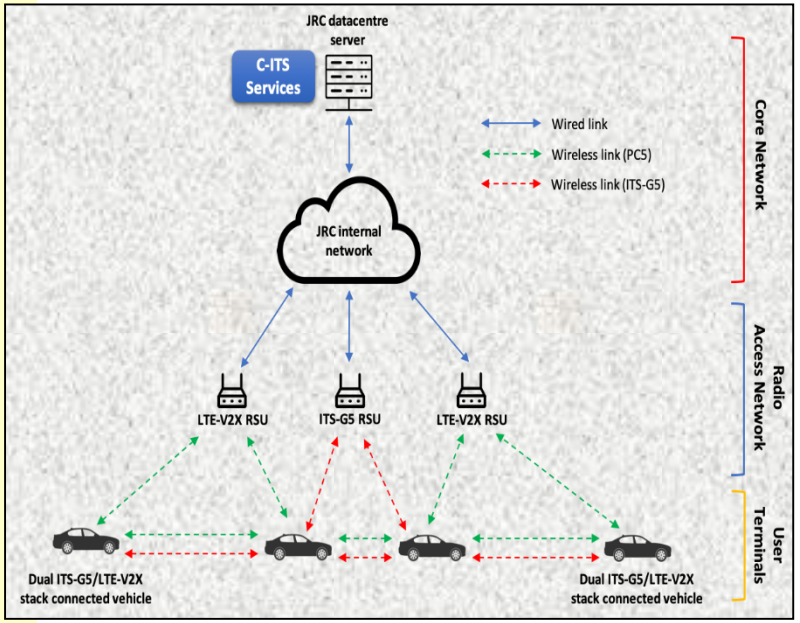
Trial Sites_(8)

The **JRC Ispra trial site** is a fully fenced research campus equipped with high-level safety and security features – *a 167-hectare controlled environment for hands-on experimentation, testing and demonstration purposes.*

It features 36 km of roads under real-life driving conditions, as well as 9 Vehicle Emissions Laboratories (VELA 1-9) that can be used for calibration, electromagnetic compatibility/interference testing and other experimental activities.

The JRC Ispra site focuses upon the development and evaluation of V2X scenarios, with a particular focus on laboratory and field ITS-G5/LTE-V2X coexistence testing.

- ***The site has been mapped at very-high resolution using drones and Laser Imaging Detection and Ranging (LiDAR), with digital maps available in various formats.*** *This information will be used for network planning as well as vehicle localisation and intelligent routing.*
- ***The site owns various LTE eNodeBs*** *of both commercial and experimental grade,* ***as well as a software-defined LTE core network,*** *to provide mobility, session management and user authentication services to internal test users.*
- ***MEC infrastructure can be connected to the core network****, by using either radio links or low latency fibre.*
- ***The site is also equipped with a production-level Public Key Infrastructure (PKI), used as the European Root Certification Authority for the EU Digital Tachograph project.***



Equipment used in JRC Ispra trial site

- LTE FDD/TDD MIMO equipment

- ITS-G5 equipment

Cooperative Framework with China_(1)

Proposed Concept and Methodology

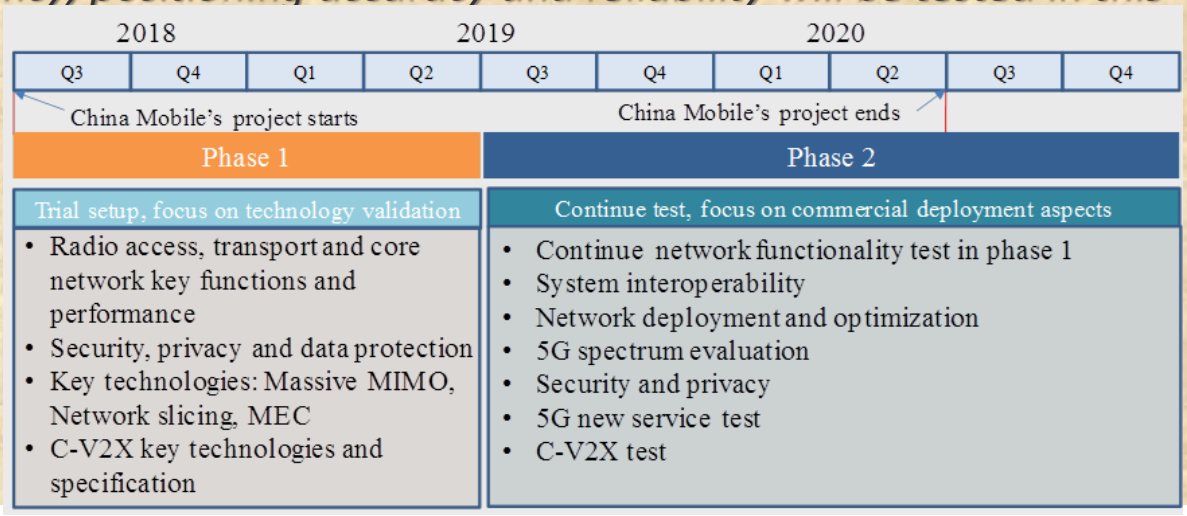
	Trials	IPR	Specifications	Reports

5G-DRIVE	• 3 trial sites for eMBB
	  • 5+ gNBs
	  • 10+ UEs
	  • Cover dense urban and office building
	• 2 V2X trial network
		• 3+ patents
		• Cover 5G key technologies , including massive MIMO, network slicing, V2X, MEC, etc.
			• Joint test specifications 2+
			• Cover field equipment, performance, interoperability, 2X specifications
				• Deliverables 10+
				• Joint test report 4+
				• Cover key technology evaluation report, system interoperability, service platform

China Mobile's Project	• 5 large scale trial networks
	  • 50+ gNBs
	  • 100+ UEs
	  • Cover dense urban and office building
	• 1 C-V2X trial network
	  • >20km^2
	  • 5+ intersections
	  • 15+ intersection units
		• 10+ patents
		• Cover 5G key technologies , including massive MIMO, network slicing, V2X, network planning, etc.
			• Test specifications 10+
			• Cover field equipment, terminal functions, performance, interoperability, C-V2X specifications
				• Research report 10+
				• Test report 15+
				• Cover key technology evaluation report, network planning methods, system interoperability, terminal functionality test, IoT, vendor equipment interoperability

Cooperative Framework with China_(2)

- In the **first phase** **of the project**, **the joint tests focused on the verification of 5G key technologies, including 5G NR, network slicing, MEC, and SDN for transport networks**.
  - *The **joint work on V2X** in this phase includes the requirement analysis and technique specification for C-V2X.* ***The initial trial started in Q4/2019, approx.***
  - *The **eMBB trial** is mainly performed in the Surrey trial site.* ***The initial trial started in Q3/2019.***
  - *The Espoo and Ispra trial site will focus more on the V2X trials, based on the ongoing V2X activities in each site.*
- In the **second phase** **of the project**, **the joint tests will focus on system interoperability, network coverage and support for 5G services**. *The joint verification of V2X key technologies will be conducted in this phase. The network performance for V2N, including the network coverage, latency, positioning accuracy and reliability will be tested in this phase.*



Cooperative Framework with China_(3)

Trial sites in the 5G-DRIVE and the China Mobile's project

Cooperative Framework with China_(4)

Concept for Data Management and Knowledge Sharing

- *Knowledge Management*
- *Management of IPRs and Ethics*
- *Privacy and Personal Data*

- *Open Access and Data Management (within the H2020 scope)*

- *Data Share Mechanism with the 5G-DRIVE consortium (Consortium Agreement)*
- *Data Share Mechanism with the Chinese Consortium (Collaboration Agreement)*
- *Data Share Mechanism with Third Parties (Website, social networks, videos, press releases, eNewsletters, events)*

Views on MBB and V2X - Approach for Definition and Assessment of selected Use Cases

WP1: Project Management

WP2: Scenarios, Use Cases, Architecture for Trials

- D2.1: Joint trial plan and data share mechanism
- D2.2: Joint architecture, use cases and spectrum plan
- *Work on use case implementation and cross-project technical alignment*

WP3: eMBB Development and Trials

- D3.1: eMBB development and test plan
- D3.2: Joint specification for eMBB trials
- *eMBB phase-I joint trial started*
- *Cross region trial on AR/VR use case under discussion*
- *Joint trials at Chinese trial site under discussion*

WP4: V2X Development and Trials

- D4.1: V2X development and test plan
- D4.2: Joint specification for V2X trials
- D4.3: Report on potential vulnerabilities of V2X Communications
- *Espoo and Ispra site prepared for phase-I V2X trials -Espoo V2X trial started*

WP5: 5G Technology and Service

- D5.1: first Year Report on 5G technology and Service Innovations

WP6: Impact Creation

- D6.1: 5G-DRIVE dissemination and communication plan
- Active dissemination done through project website, news, press release, social media and project driven events
- D6.2: Plan for Standardisation
- D6.3: Plan for exploitation and business modelling

Use Cases Definition and Assessment_(1)

Proposed Main Scenarios

- ***Scenario no.1.*** ***- enhanced Mobile Broadband (eMBB) on the 3.5GHz band,*** *which is a* ***priority band*** *in the two regions for early introduction of very high rate services*.

  The applications used to test and validate the use of eMBB in the ***3.5GHz band*** are **typical mobile broadband services** as well as **Virtual and Augmented Reality (VR, AR).**

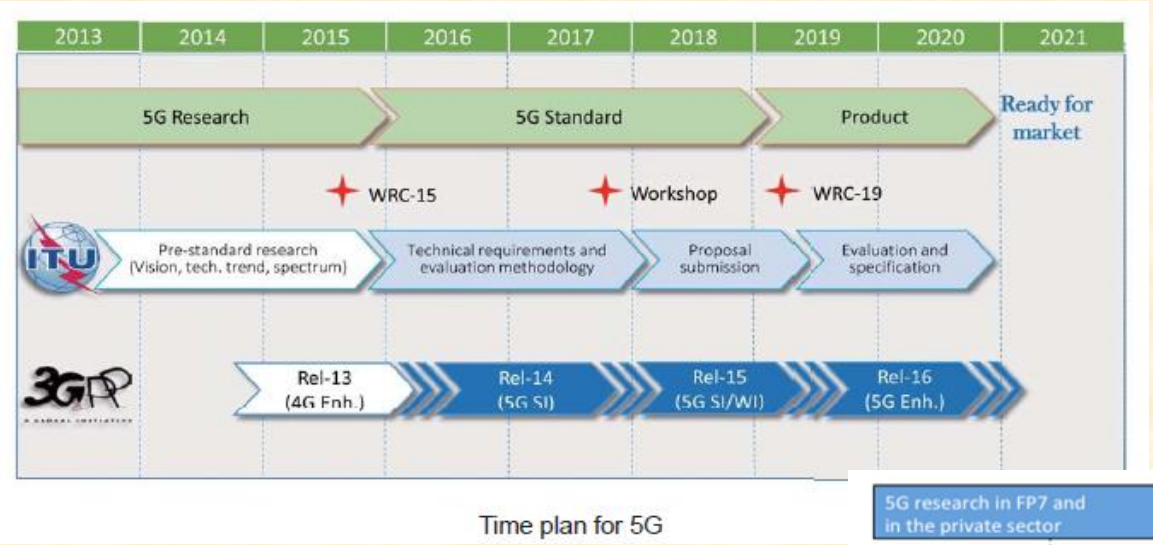
- ***Scenario no.2*** - ***Internet of Vehicles (IoV) based on LTE-V2X using the 5.9 GHz band for Vehicle-to-Vehicle (V2V) and the 3.5 GHz band for Vehicle-to-Network (V2N)***.

  The **overall goal** is to evaluate in real setup innovative end-to-end 5G systems built on the outcomes of the previous phases of the 5G R&I.

  More specifically, the optimisation of the band usage in multiple scenarios with different coverage is a **key target**, *so as the validation of the geographic interoperability of the* ***3.5GHz and 5.9 GHz bands****, for these use cases.*

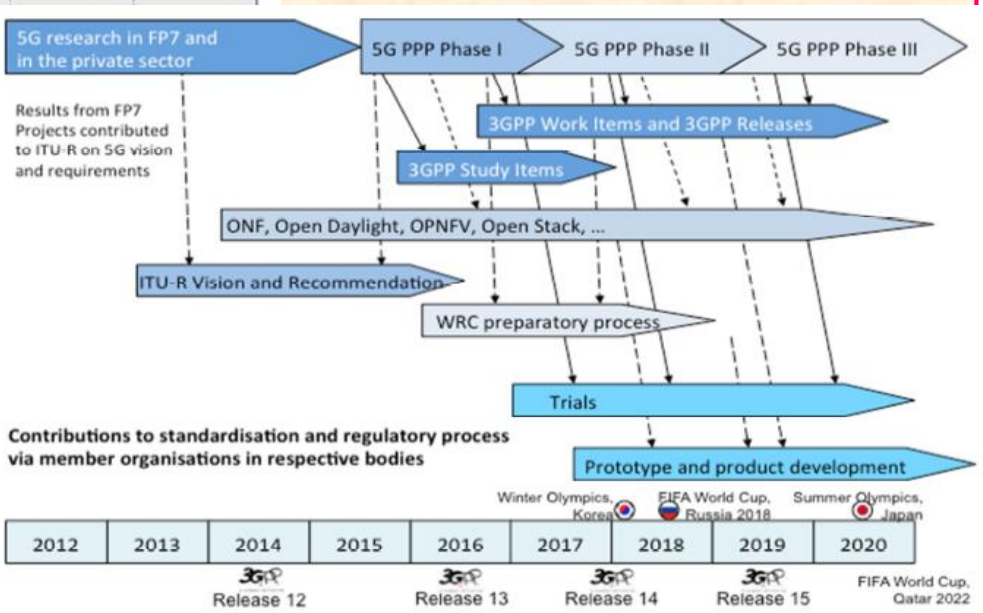
Use Cases Definition and Assessment_(2)

Full alignment with the 5G-PPP context and EU policy



Time plan for 5G

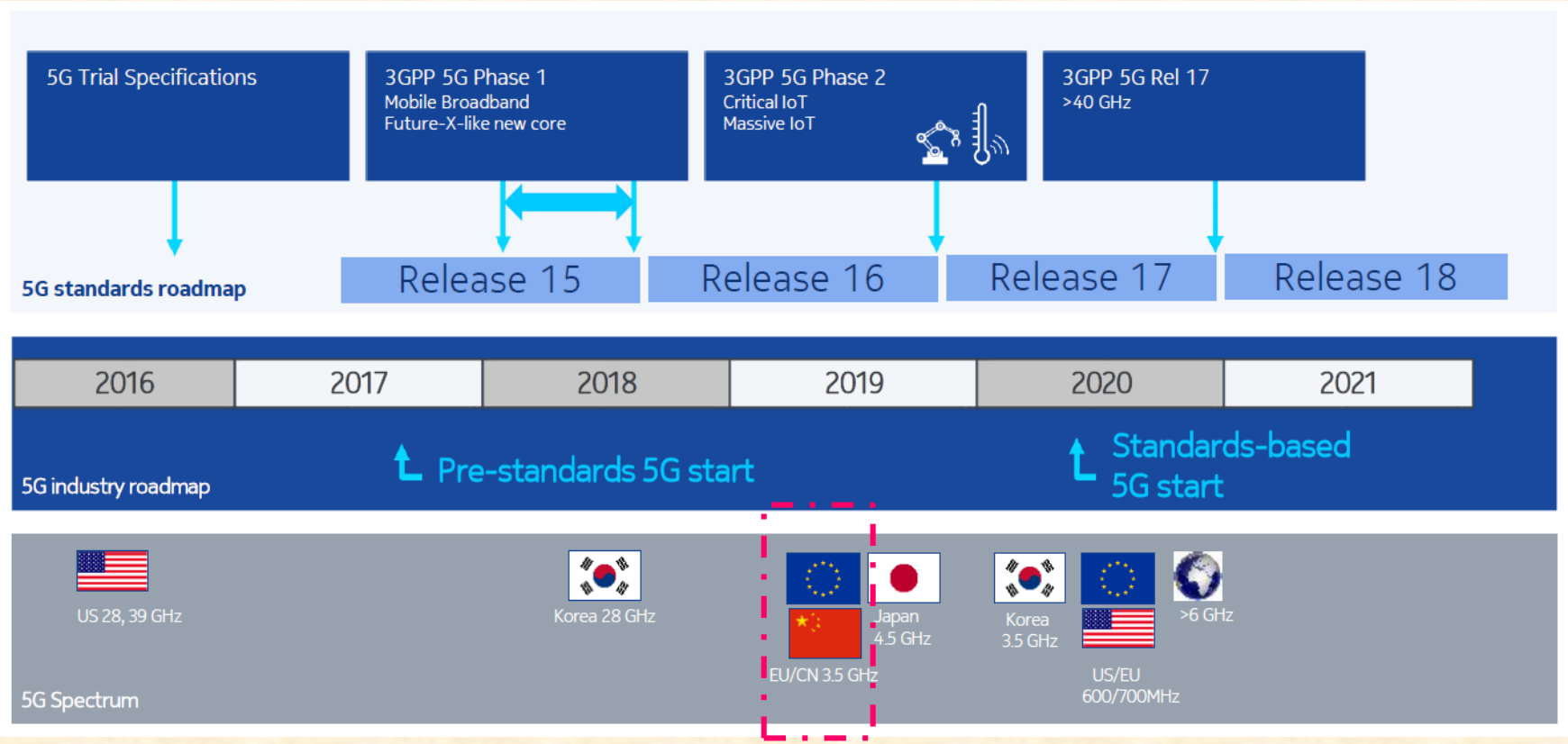
*Source: "***The 5G Infrastructure Public-Private Partnership" – NET Features 2015 – 5G PPP Vision** – 25.03.2015. [Presentation by Jean-Sebastien Bedo]. Available at: *https://5g-ppp.eu/wp-content/uploads/2015/07/BEDO-25Mar2015.pdf*



*Source: "*The 5G Infrastructure Public-Private Partnership": **Joint 3GPP and 5G-PPP Approach on Standardization**

Use Cases Definition and Assessment_(3)

Alignment to present international standardization trends



Source: 5G for people and things. Spectrum and standardization towards 5G - Nokia [https://www.eett.gr/conference2017/pdf/Rehfuess.pdf]

Use Cases Definition and Assessment_(4)

Consideration of fundamental standards and enabling technologies

3GPP Technical Specifications for 5G Mobile Communications

eMBB and V2X Standards

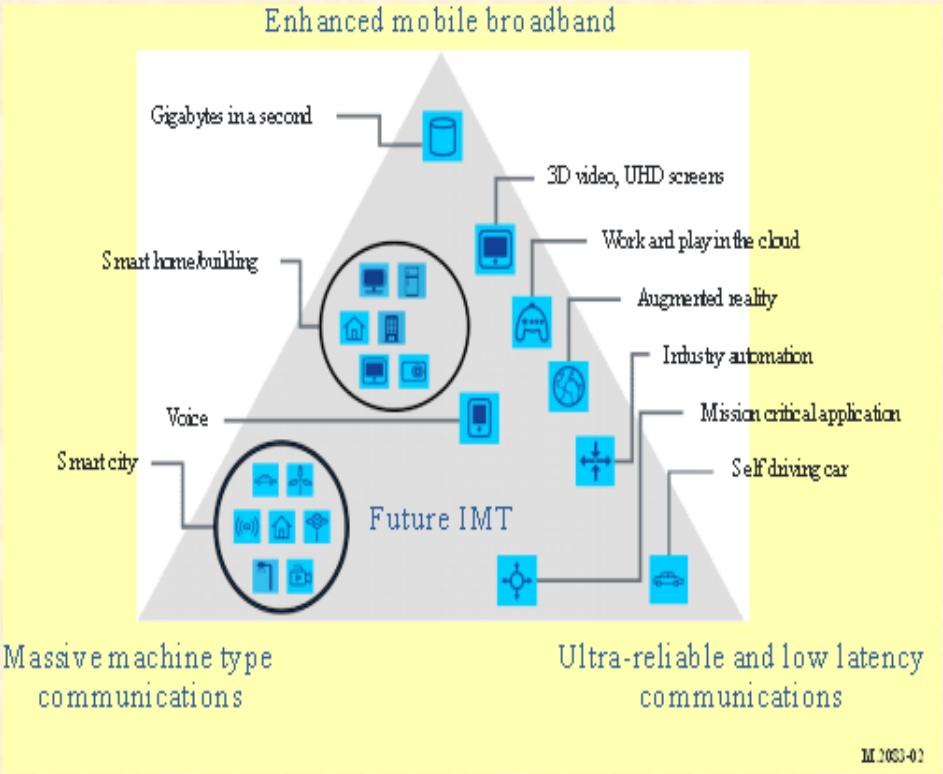
- Release 14 (LTE-V2X)
- Release 15 (5G Phase I)
- Release 16 and beyond (5G Phase II)
- 3GPP Submissions to IMT-2020

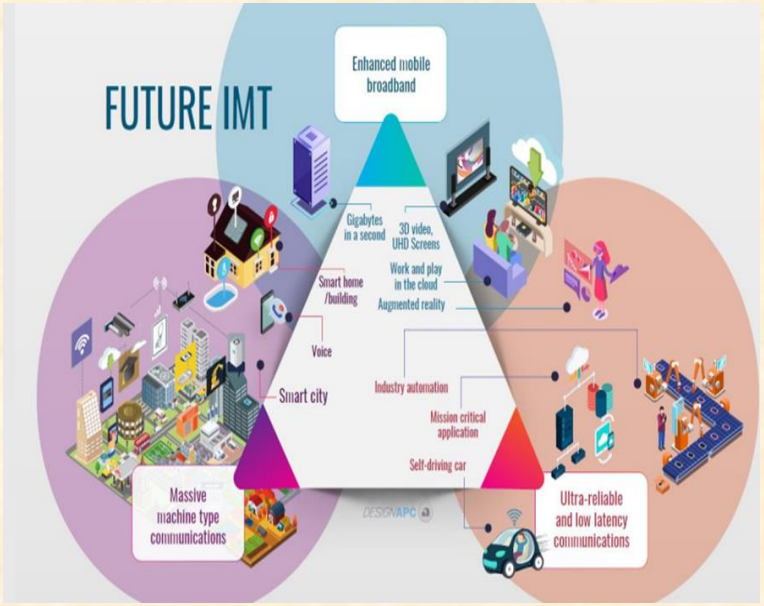
5G Enabling Technologies

- Advanced MIMO Techniques (Multi-User MIMO, Massive MIMO, Beamforming)
- Millimetre Wave (mmWave)
- Network Function Virtualisation (NFV) / Software-Defined Networking (SDN)
- Network Slicing
- Mobile Edge Computing (MEC)
- Cellular V2X (C-V2X)

Use Cases Definition and Assessment_(5)

eMBB 5G-DRIVE Use Cases



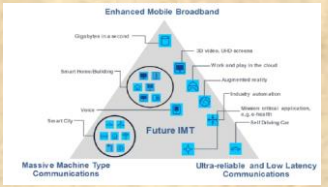


Consideration of the scope proposed by IMT 2020 and beyond

Recommendation ITU-R M.2083-0 (09-2015): "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond".

Use Cases Definition and Assessment_(6)

Enhanced Mobile Broadband (eMBB) is one of three primary 5G New Radio (NR) use cases defined by the 3GPP as part of its SMARTER (Study on New Services and Markets Technology Enablers) project.



The three fundamental sets of use cases are as follows:

- ***Enhanced Mobile Broadband (eMBB):*** ***Data-driven use cases, requiring high data rates across a wide coverage area.***
- ***Ultra Reliable Low Latency Communications (URLLC):*** ***Strict requirements on latency and reliability for mission critical communications, such as remote surgery, autonomous vehicles or the Tactile Internet.***
- ***Massive Machine Type Communications (mMTC):*** ***Need to support a very large number of devices in a small area, which may only send data sporadically, such as Internet of Things (IoT) use cases.***

Use Cases Definition and Assessment_(7)

- In order to support the initial rollout of eMBB services, **the 3GPP's RAN** (Radio Access Network) **Group committed to finalise the Non-Standalone (NSA) 5G NR variant** by *March 2018*.
  In fact, this standard **was approved in December 2017.**
  The NSA mode considers the current 4G network, as supplemented by 5G NR carriers to boost data rates and decrease latency. The NSA 5G NR will utilize the existing LTE (Long Term Evolution) radio and core network as an anchor for mobility management and coverage, while adding a new 5G carrier.

- **The Standalone (SA) variant** was to be completed by September 2018 but was also **finished early, in June 2018.** ***The SA 5G NR implies full user and control plane capability for 5G NR, utilizing the 5G next-generation core network architecture (5G NGC)*** also being done in 3GPP.
  SA 5G NR technical specifications have been completed in June 2018 as part of 3GPP Release 15.

- ***Thus, eMBB can be assessed as the first phase of 5G, as encompassed in the 3GPP Release 15 standard.***
- ***It offers faster data rates and, consequently, a more enhanced and improved user experience*** *than existing mobile broadband services.*
- ***5G Phase 2 will go beyond the eMBB services to more transformational URLLC and mMTC applications and will be included in Release 16*** *(by end of 2019 and/or further).*

Use Cases Definition and Assessment_(8)

		Advantages	Disadvantages
Radio access network	**SA**	• Simple to manage • Inter-generation handover between 4G-5G	• Not able to leverage existing LTE deployments if NR is used in SA
	NSA	• Leverage existing LTE deployments	• Tight interworking between LTE and NR required • May impact end user experience
Core network	**EPC**	• Leverage existing EPC deployment	• Cloud support is optional
	5GC	• Cloud native • Easier to support multiple access	• New deployment required

Comparison of 5G Radio Access and Core Networks

Use Cases Definition and Assessment_(9)

- *The first phase of eMBB services involves, inter-alia, enhanced infotainment, high-speed internet access, streaming real-time video or playing games involving 3D 4K resolution video.*
- *The second phase would be extended to autonomous vehicles on a mass scale, able to connect to and interact with other vehicles and the surrounding road infrastructure.*

The eMBB will offer faster data rates and more enhanced and improved user experience.
The eMBB will support the provision of 360º video streaming as well as the provision of VR and AR applications.

Use Cases Definition and Assessment_(10)

Within the context of EMBB
and for the proper offering of the related use cases in the market, there are three distinct attributes/features that 5G has to assure:

- ***Higher capacity:*** *this implicates that the intended broadband access has to be adequately available in densely populated areas, both indoor and outdoor (such as the cases of city centres, office buildings or public venues like stadiums or conference centres).*
- ***Enhanced connectivity:*** *this implicates that broadband access has to be offered "everywhere", on order to deliver a reliable user experience.*
- ***Higher user mobility*****:** *this implicates that it will also predict to enable mobile broadband services in moving vehicles (including cars, buses, trains and/or planes).*

Use Cases Definition and Assessment_(11)

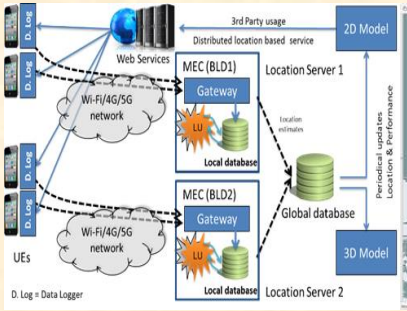
5G-DRIVE Use Cases (with relevance to WP3)

eMMB use case #1: Cloud-assisted AR/VR

- Description
- Rationale
- KPIs

eMMB use case #2: Indoor Positioning

- Description
- Rationale
- KPIs



Use Cases Definition and Assessment_(12)

Cloud-assisted AR/VR

- ***Cloud-assisted 3D Augmented Reality (AR) is a 5G-DRIVE use case in the eMBB scenario.*** *As opposed to conventional gaming consoles or personal computers (which are highly dependent on the signal processing capabilities of the GPU (Graphics Processing Unit)),* ***the cloud-assisted AR enables users to stream video games or virtual contents from cloud servers, like other streaming media. This new type of services offers an opportunity for more varied and interactive contents and makes user devices lighter and cheaper.***
- ***The eMBB is required to reach tens of Gbps to support the speed requirement of AR application, providing a more uniform experience for users of AR, given the ultra-high data volume requirements that can be handled more effectively.***

To maintain the QoE levels required in real-time, high-definition cloud-assisted 3D AR, the following KPIs are of special interest:

- ***Peak data rate:*** *This metric denotes the maximum physical-layer throughput achievable between the 5G gNB and the UE, in Gbps.*
- ***Offloading time cost:*** *This KPI denotes the time cost difference (in seconds) between the tasks running on the UE (i.e., mobile, Hololens, etc.) and the cloud.*

5GIC Kinect sensors setup for providing cloud-assisted AR experiment

Use Cases Definition and Assessment_(13)

Indoor Positioning

- **Indoor position information supports navigating within building premises**. However, this location information is also a **valuable asset** ***for providing and maintaining high quality eMBB services to end-user devices***.
- ***Positioning offers means to utilize location information to improve network communication reliability, to reduce latency, and to balance data loads.***
- *Since most of the network control components are fixed at specific locations,* ***eMBB services to mobile end-user devices require also support for mobility****. (First the mobile terminal receives the eMBB service signal from one base station and then gradually moves to the coverage area of another base station, so a handover in the indoor network is executed).*
- ***Mobility comes at a cost in terms of extra signalling messages, processing resources and delay in setup and data message transactions.***
- ***By combining location information with other forthcoming functionalities, it may be possible to dynamically adjust data loads and routing and to control the latency and its deviation.*** *The shared location information is therefore a valuable asset for both mobile end users and eMBB service providers to maintain and operate their devices.*

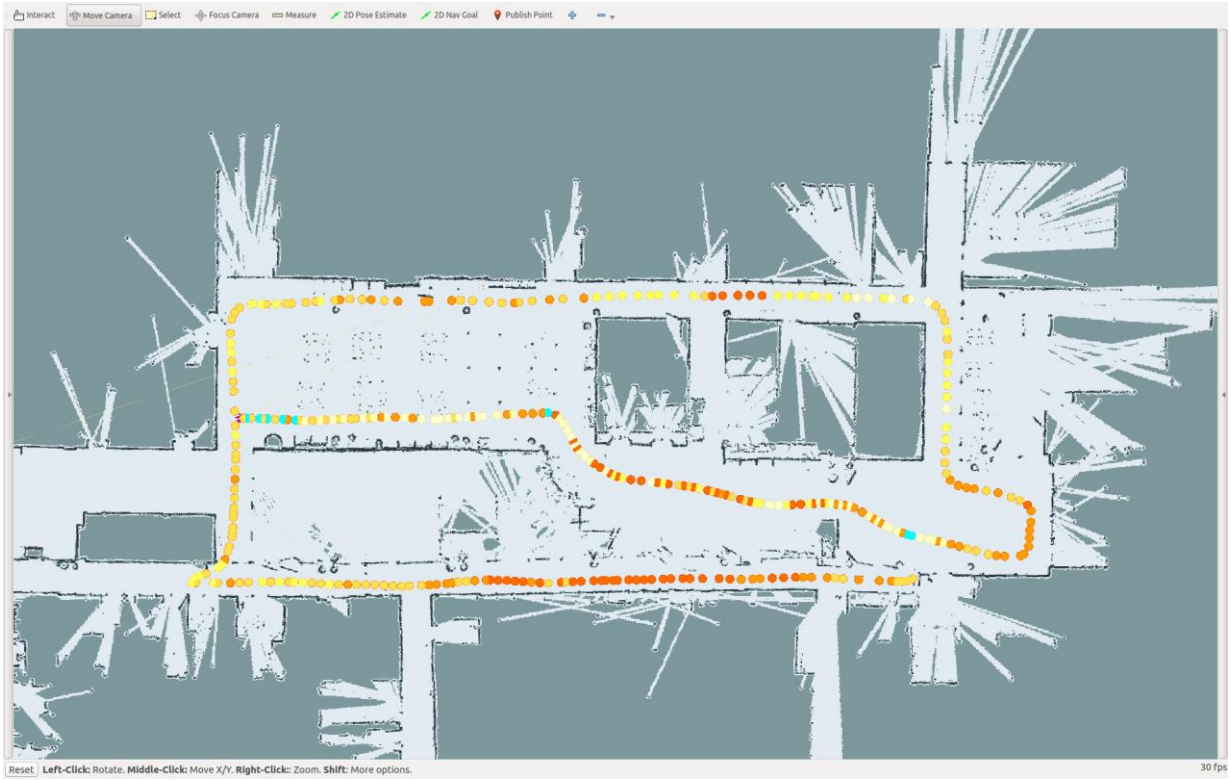
Relevant KPIs for this use case:

- ***Peak data rate:*** *This metric denotes the maximum physical-layer throughput achievable between the 5G gNB and the UE, in Gbps.*
- ***Jitter:*** *This KPI denotes the variation in the delay experienced by received packets (in ms).*
- ***Latency:*** *Radio latency is the radio access network contribution to the total delay between the transmitter and the receiver, expressed in ms.*

Measurement route and mobile robot for providing reference location and indoor maps

Use Cases Definition and Assessment_(14)

- ***Indoor coverage measurements are conducting in multiple floors***

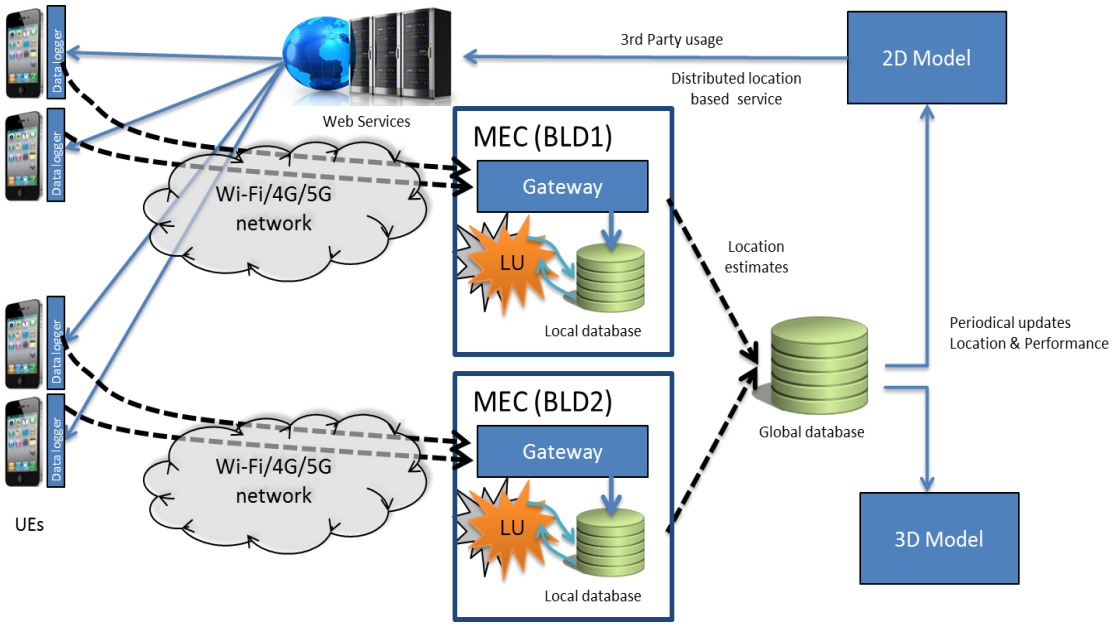


Measurement route and mobile robot for providing reference location and indoor maps

Use Cases Definition and Assessment_(15)

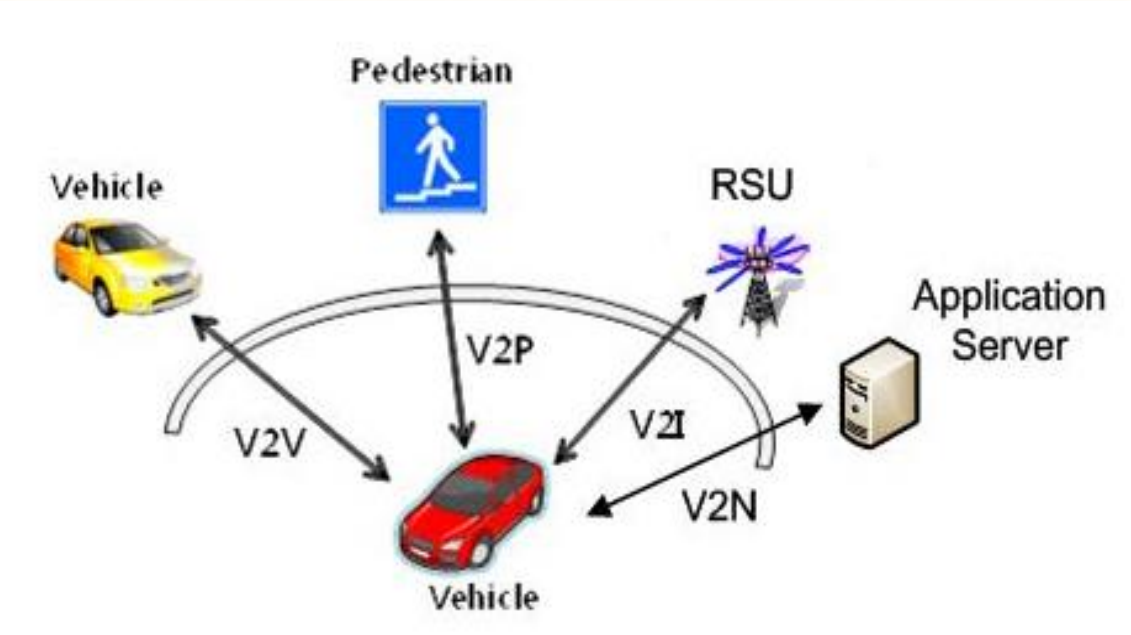
Positioning platform

- Provides a platform for testing different positioning technologies and methods.
- Exploits test network infrastructure including Nokia's MEC platform, indoor LTE-Wi-Fi pico cells, Wi-Fi FTM APs, mesh Wi-Fi 2.4/5.0 APs.
- Combines positioning and network performance measurement and is supported with mobile robots providing reference location.



Use Cases Definition and Assessment_(16)

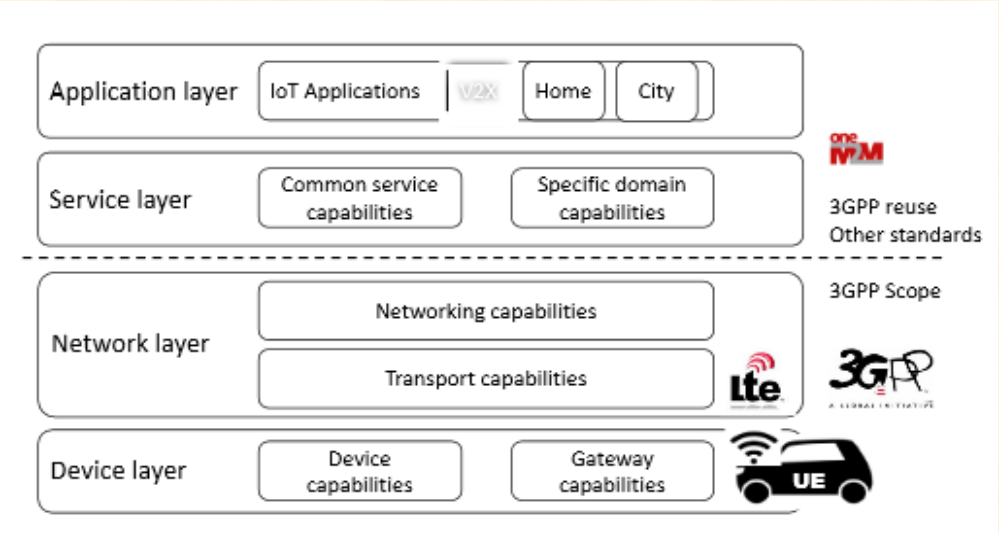
V2X 5G-DRIVE Use Cases (with relevance to WP4)



Consideration of the scope proposed by ETSI

[Source: ETSI TS 122 185]

Use Cases Definition and Assessment_(17)



Proposed architecture overview for V2X according to IEEE 1609 *– Family of Standards for Wireless Access in Vehicular Environments (WAVE) - (https://www.standards.its.dot.gov/Factsheets/Factsheet/80)*

- *The **fundamental motivations for V2X applications are road safety, traffic efficiency** and **energy savings**.*
- *There are two types of V2X communication technology depending on the underlying technology being used, that is, **WLAN-based (ITS-G5)** and **cellular-based (C-V2X).***

Use Cases Definition and Assessment_(18)

Consideration of prior EU/international standardization works

- **IEEE 802.11p** standard aimed at adding **wireless access in vehicular environments** (WAVE), a vehicular communication system. **It is the basis of a European standard for vehicular communication known as ETSI ITS-G5** (described by the ***ETSI EN 302 663***).

- **3GPP started standardization work of cellular V2X (C-V2X) in Release 14, in 2014**.
  It is based on LTE as the underlying technology and specifications were published in 2016.
  It is often referred to as LTE-V2X.

- **In Release 15, 3GPP continued its C-V2X standardization to be based on 5G.** Specifications have been published in 2018.
  To emphasise the underlying technology, the term 5G-V2X is often used in contrast to LTE-based V2X (LTE-V2X).

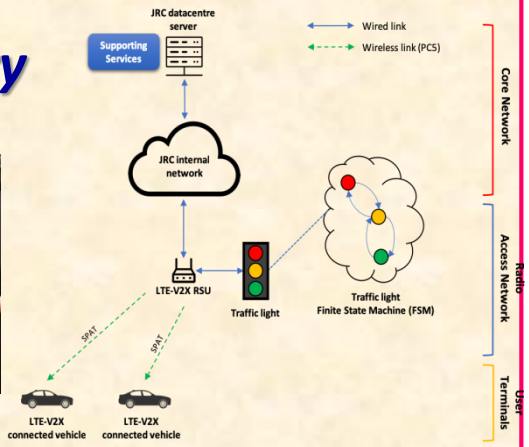
- **Release 16 of the 3GPP Technical Specifications further enhances the C-V2X functionality**.
  Standardisation work is currently in progress.

Use Cases Definition and Assessment_(19)

V2X 5G-DRIVE Use Cases (with relevance to WP4)

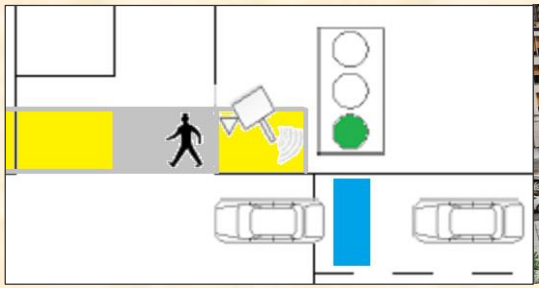
V2X case #1: Green Light Optimised Speed Advisory (GLOSA) system

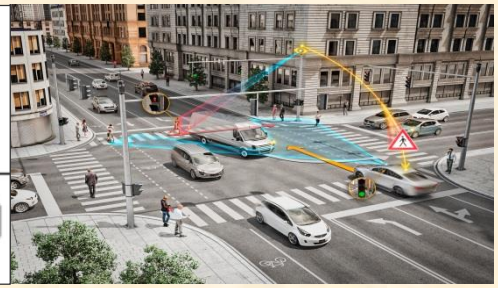
- Description
- Rationale
- KPIs



V2X use case #2: Intelligent Intersection

- Description
- Rationale
- KPIs



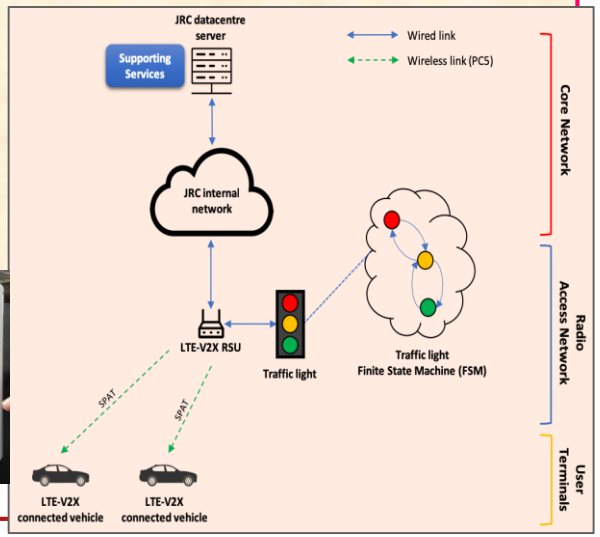


V2X case #1: Green Light Optimised Speed Advisory (GLOSA) system

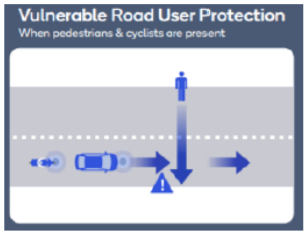
- ***GLOSA is a signage C-ITS (Cooperative Intelligent Transport Service) aimed at informing end-users about the speed that needs to be sustained (within legal limits) to reach an upcoming traffic light in green status.*** *Although specific UI features are manufacturer-specific, end-user GLOSA notifications usually follow a common structure.*
- **GLOSA provides end-users with short-term information on upcoming traffic light status *to optimise traffic flows, help prevent speed limits violations, improve fuel efficiency and reduce pollution.***
- *In a GLOSA use case, an RSU (Road-Side Unit) co-located with a traffic light (and having access to its internal finite state machine), broadcasts timing information about the traffic light's "red", "amber" and "green" status via Signal Phase and Timing messages (SPAT). Neighbouring vehicles can receive these messages and process them locally along with their own positioning, speed and direction data (amongst others). By doing so, on-board V2X modules can notify drivers about the optimal speed to reach an upcoming traffic light in green status or, alternatively, to be aware that the traffic light will nevertheless transition to red imminently.*

Relevant KPIs for this use case:

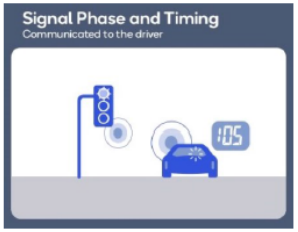
- ***Packet error rate (PER):*** *Ratio of unsuccessfully received packets in the OBU (On-board Unit) vs. total number of packets sent by the RSU (in percentage).*
- ***Latency:*** *The radio access network contribution to the total elapsed time, measured from the instant the RSU sends a packet to the moment when the OBU receives it (in ms).*



Joint V2X use cases: GLOSA and vulnerable road user warning (V-Alert)



@Qualcomm/5GAA

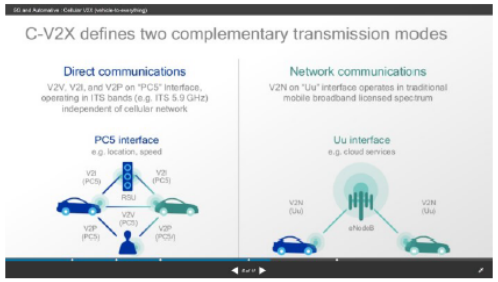


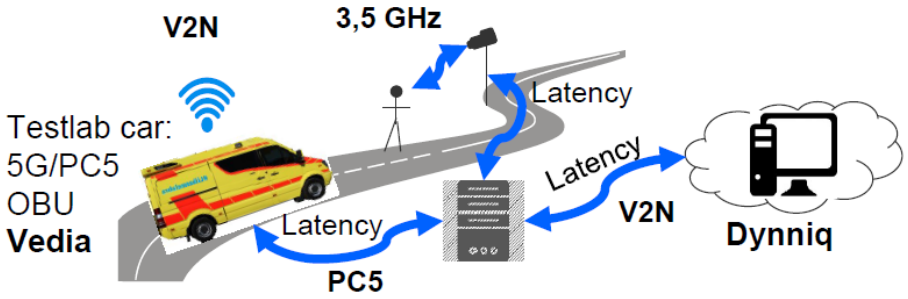
@Qualcomm/5GAA

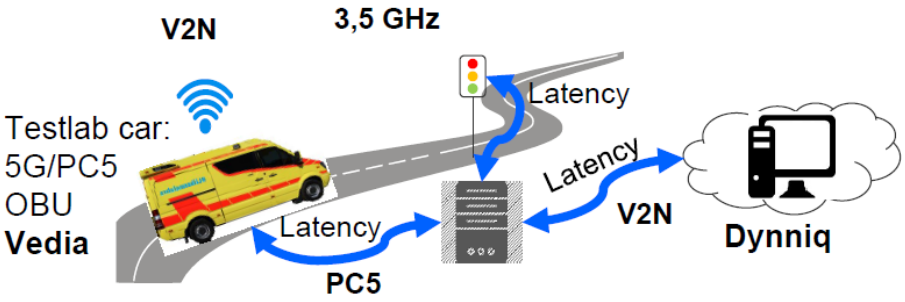
Joint V2X use cases: Glosa and vulnerable road user warning (V-Alert)

5G/3.5 GHz UU-testing with RTK-Inertia positioning

Automated car:
5G/PC5
OBU
VTT



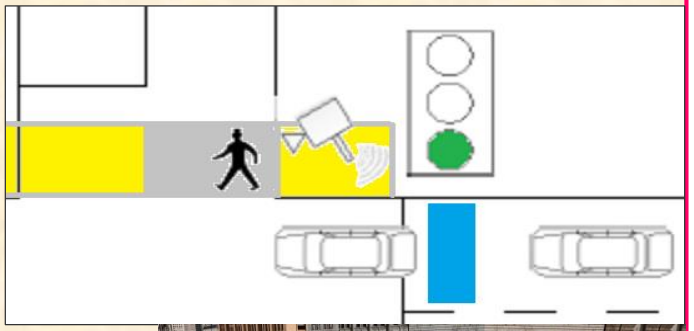




Use Cases Definition and Assessment_(22)

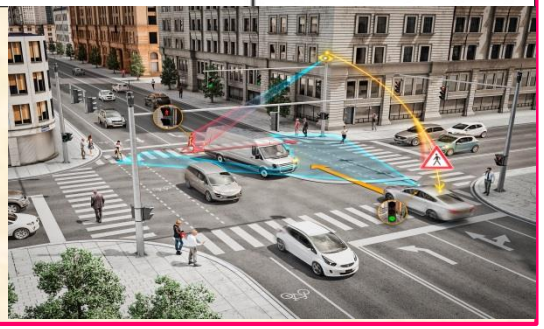
V2X case #2: Intelligent Intersection

- ***This deals with safety on intersections, focusing on infrastructure detection of situations that are difficult to perceive by vehicles themselves.***
- *A **good example** is the situation where a vehicle wants to make a right turn while parallel VRUs (Vulnerable Road Users) also have a green phase and right of way (permissive green for motorized traffic).*
- ***When a pedestrian is detected in the grey area, a Decentralized Environmental Notification Message (DENM) should be broadcasted by the RSU, while the backoffice should geocast this to all vehicles in the vicinity.***
  *In the yellow areas, given a movement direction of the pedestrian towards the intersection, the infrastructure should send out Collaborative Perception Messages (CPM). This is to **warn vehicles** further upstream that a potential conflict may occur in the future and to prevent future hard braking.*

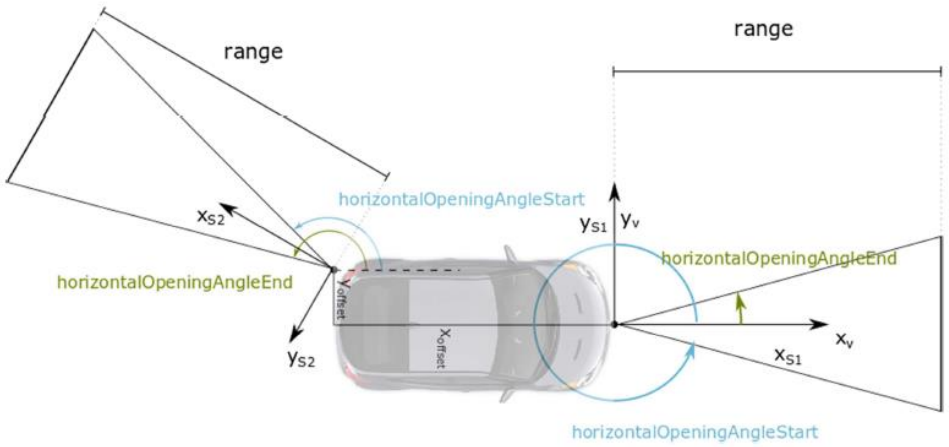


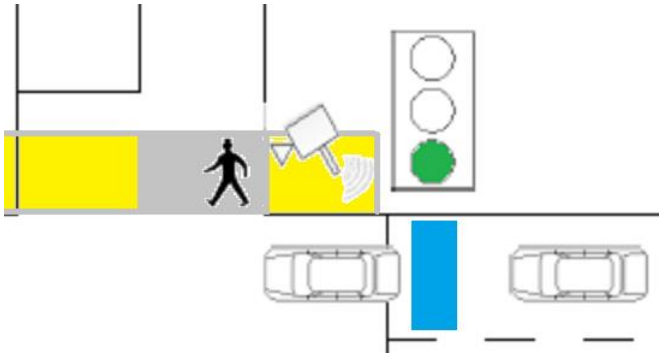
Relevant KPIs for this use case:

- ***Packet error rate (PER):*** *Ratio of unsuccessfully received packets in the OBU vs. total number of packets sent by the RSU (in percentage).*
- ***Latency:*** *The radio access network contribution to the total elapsed time, measured from the instant the RSU sends a packet to the moment when the OBU receives it (in ms).*
- ***Total active stations:*** *This "tracks" how many other stations were active at the same time while in communication range of the test subject.*
- ***Total channel load in Mbps:*** *This determines how much interference can be expected.*
- ***Total messages/sec on channel:*** *One other client using a load of 1Mbps has much less chance of packet collisions than a hundred clients transmitting at 10 Kbps.*



Use Cases Definition and Assessment_(23)





- *Collaborative Perception Message*
- *Manoeuvre Coordination Message (V2V conflicts, I2V advice)*
- *Significant increase of channel load*
- *To be included in safety use cases*
- *Liaison with H2020 automated driving projects*

Architectural Approach for eMBB-based proposed Use Cases

Architectural Approach_(1)

"Joint architecture" is not an easy concept to define. *Our current understanding of "joint architecture" is as follows:*

- **Each trial site has defined its own architecture based on existing SW/HW components, network infrastructure and services needed to implement the corresponding trial.** ***These per-site architectures are the starting point of the 5G-DRIVE joint architecture.***
- As already accepted by the 5G-DRIVE consortium, **"joint" means "jointly-defined"** — ***that is, an architectural design to be put together by both the EU and the Chinese consortia.*** *(By the term "joint" we do not mean a single architecture that encompasses both eMBB and V2X scenarios).*
- **The aim of a "jointly-defined" architecture is to collaboratively (and iteratively) converge to a specific network design that enables comparability of results** ***between the EU and China trials.***
- **We should also compare and contrast the Chinese and EU architectures to point out commonalities and differences**. *This will, nevertheless, happen in a natural way, as the Chinese and EU trials are different (and, therefore, their architectural designs are also different).*

Architectural Approach_(2)

- The concept of joint architecture in 5G-DRIVE is the output of an iterative process aimed at comparing and contrasting the architectural proposals for the different trials in the EU and Chinese consortia.

- The "goal" is to converge to an overall architectural design, reflecting the key characteristics of each eMBB and V2X trials in both consortia.

Architectural Approach_(3)

Large Scale Trial Architecture in China

- **China Mobile wants to test different 5G network features, services and also gain some experience related to 5G network management.** ***The list of the verified network features is long and submitted to all vendors in the form of requirements. For instance, some of them use KPIs specified by 3GPP.***
- **In the current stage, China Mobile is focusing on verifying eMBB and voice services (VoNR + EPS fallback), and will later on consider verifying 4K/8K HD video, AR/VR and other use cases.**

The essential enabling technologies to be used for the selected use cases, which are to be validated through trials include:

- ***Wireless network technologies:***
  - *Massive MIMO (Multiple-Input, Multiple-Output)*
  - *CU (Central Unit) / DU (Distribution Unit) separation technology*
  - *DAS (Distributed Antenna Systems) and Pico-RRU (Remote Radio Unit)*
  - *MEC (Mobile Edge Computing)*
- ***Core network technologies:***
  - *Service-based architecture*
  - *NFV (Network Functions Virtualisation)*
  - *Slicing*
  - *Edge computing*
- ***Transport network technologies:*** SPN (Slicing Packet Network)
- ***5G end-to-end voice, short message and data service interoperability:***
  - *Voice over 5G New Radio (VoNR)*
  - *EPS (Evolved Packet System) Fallback*
  - *SMS (Short Message Service) over NAS (Non-Access Stratum) - (SMSoNAS)*

5G-DRIVE Consortium

5G-DRIVE has 17 partners from ten European countries
(Germany, Finland, Belgium, Italy, Switzerland, Poland, Greece, Portugal, United Kingdom and Luxembourg).

Contact Information:

Dr. Ioannis P. Chochliouros
Telecoms Engineer, M.Sc., Ph.D.,
Head of Fixed Network R&D Programs Section

Hellenic Telecommunications Organization S.A. (OTE)
(Member of the DT Group of Companies)
Division of Core Network DevOps & Technology Strategy, Fixed & Mobile
Research and Development Department, Fixed & Mobile
Fixed Network R&D Programs Section

1, Pelika & Spartis Street
15122 Maroussi-Athens
Greece

Tel.: +30-210-6114651
Fax: +30-210-6114650
E-Mail: *ichochliouros@oteresearch.gr; ic152369@ote.gr;*

Acknowledgment:

The research conducted by 5G-DRIVE receives funding from the European Commission H2020 programme under Grant Agreement Nº 814956. The European Commission has no responsibility for the content of this presentation.

Thank you for your attention!

Find us at: www.5g-drive.eu

Twitter: 5gDrive

Acknowledgment:

The research conducted by 5G-DRIVE receives funding from the European Commission H2020 programme under Grant Agreement Nº 814956. The European Commission has no responsibility for the content of this presentation.