The 5G-DRIVE project: Cooperation between EU and China for enhanced Mobile Broadband (eMBB) and "Vehicle to Everything" (V2X) applications

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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);*
- ***Intelligence by way of software virtualisation*** *allowing innovative* ***business models across multiple sectors*** *(e.g. transport, health, manufacturing, logistics, energy, media and entertainment).*

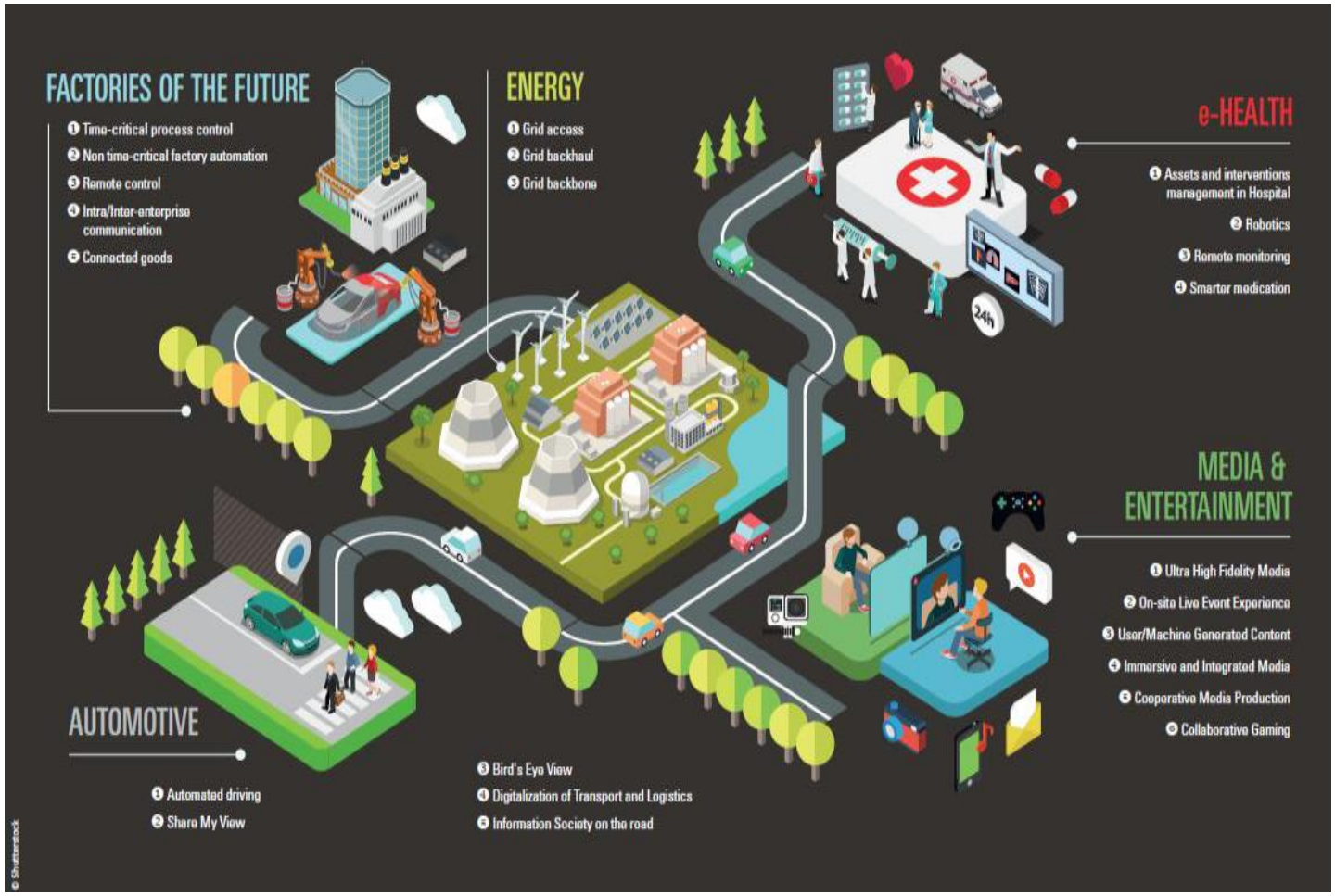
While these transformations have already started on the basis of existing networks, they will further need proper 5G's inclusion if they are to reach their full potential in the coming years…

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 market-led 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)



European Approach within the 5G-PPP Framework

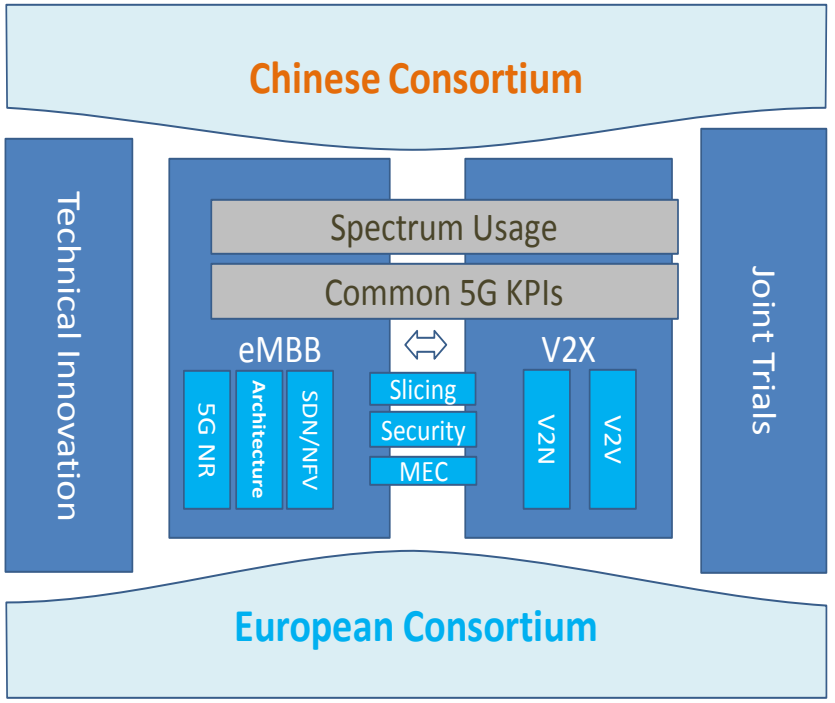
5G-DRIVE: Overall Concept and Key Areas for Innovation

Overall Concept & Key Innovative Areas_(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.***
- ***Supports trials for testing and validating "key 5G" functionalities, services and network planning, in eight cities across the EU and China.***



Overall Concept & Key Innovative Areas_(2)

Ambitions:

- **Conduction of trials for selected eMBB and LTE-V2X scenarios,** ***in parallel with a major relevant 5G project in China (coordinated by China Mobile)****.*
- **Promotion of common use case applications, test procedure and KPIs.**
- **Investigation of the applicability 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 & Key Innovative Areas_(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 & Key Innovative Areas_(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.*

Sites for Trials and Cooperative Framework

Trial Sites_(1)

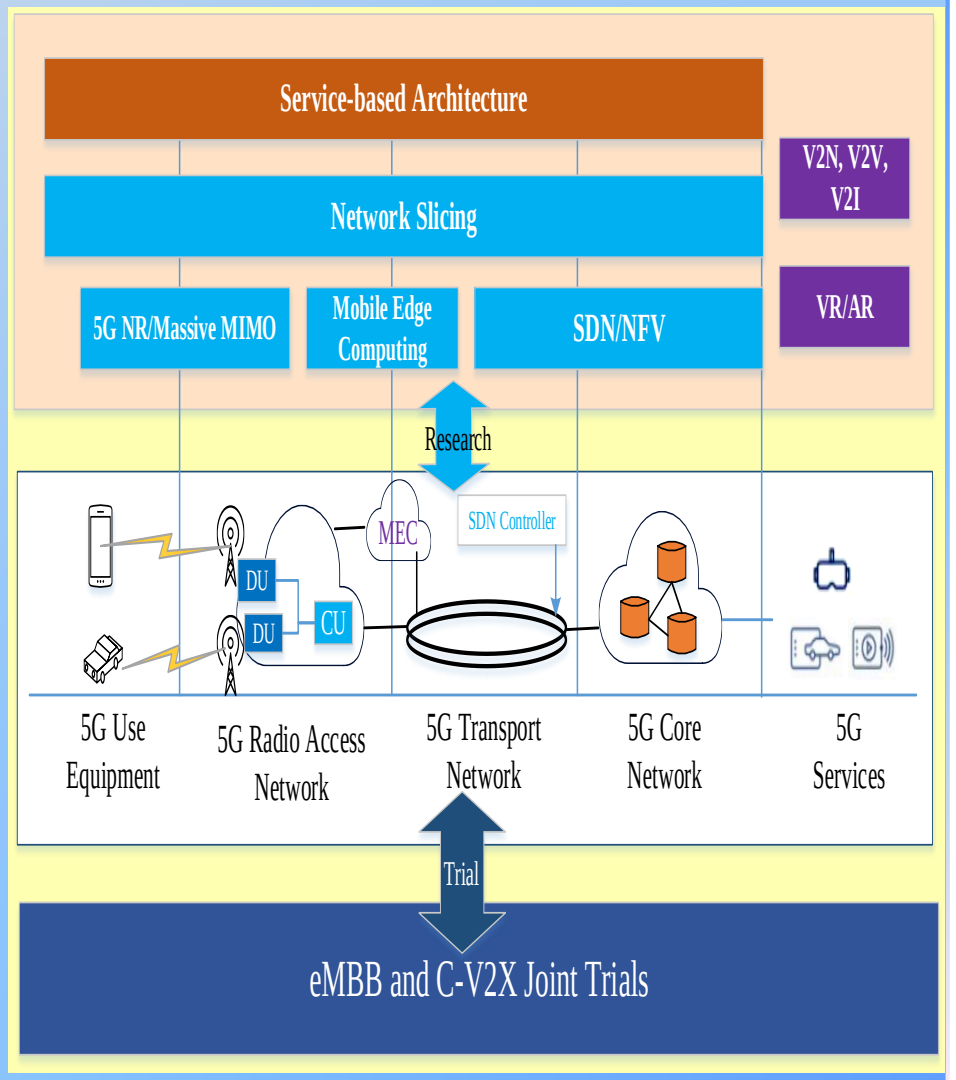
5G-DRIVE will achieve its objectives by defining, organizing and conducting series of trials at three EU locations.

Basic aims of the trials:

- Investigate the **application of new technologies and services (AR/VR, V2X).**
- **Contribution to a common understanding and harmonisation of technical conditions between the EU and China**, *i.e. standards, interoperability requirements, coexistence conditions, and resilience.*
- Flow from research, to **adaptation into existing testbeds** and **pre-commercial testbed deployments,** to the **5G real-world trials.**

✓ ***Significant impact on the validation of standards***

✓ ***Trigger the roll-out of real 5G networks and V2X innovative solutions***

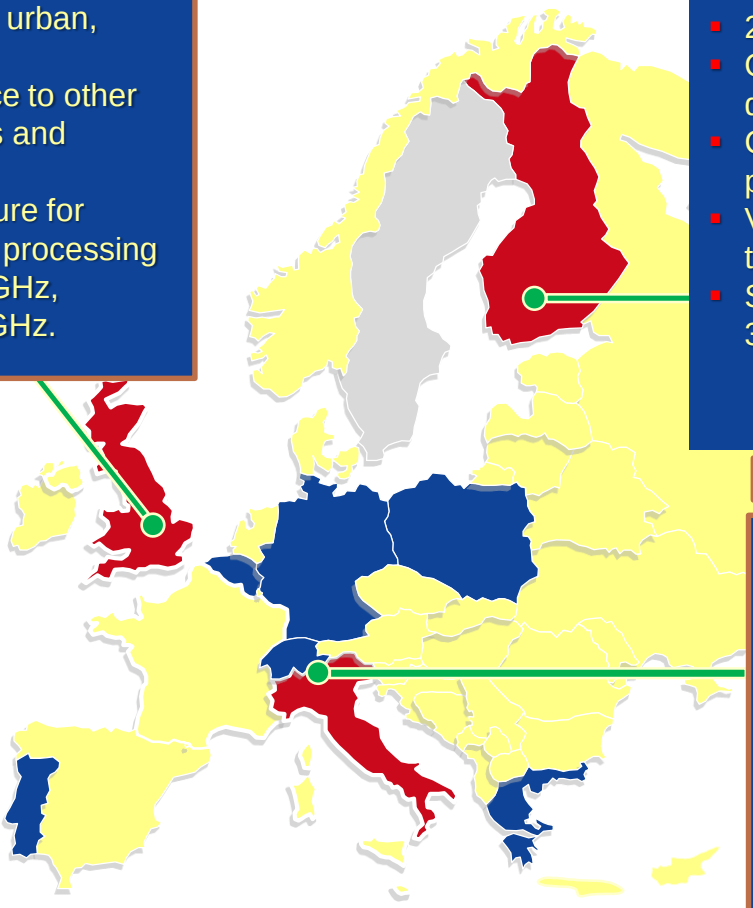


Trial Sites_(2)

5G-DRIVE has defined three testbed installations, for performing 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.

Cooperative Framework_(1)

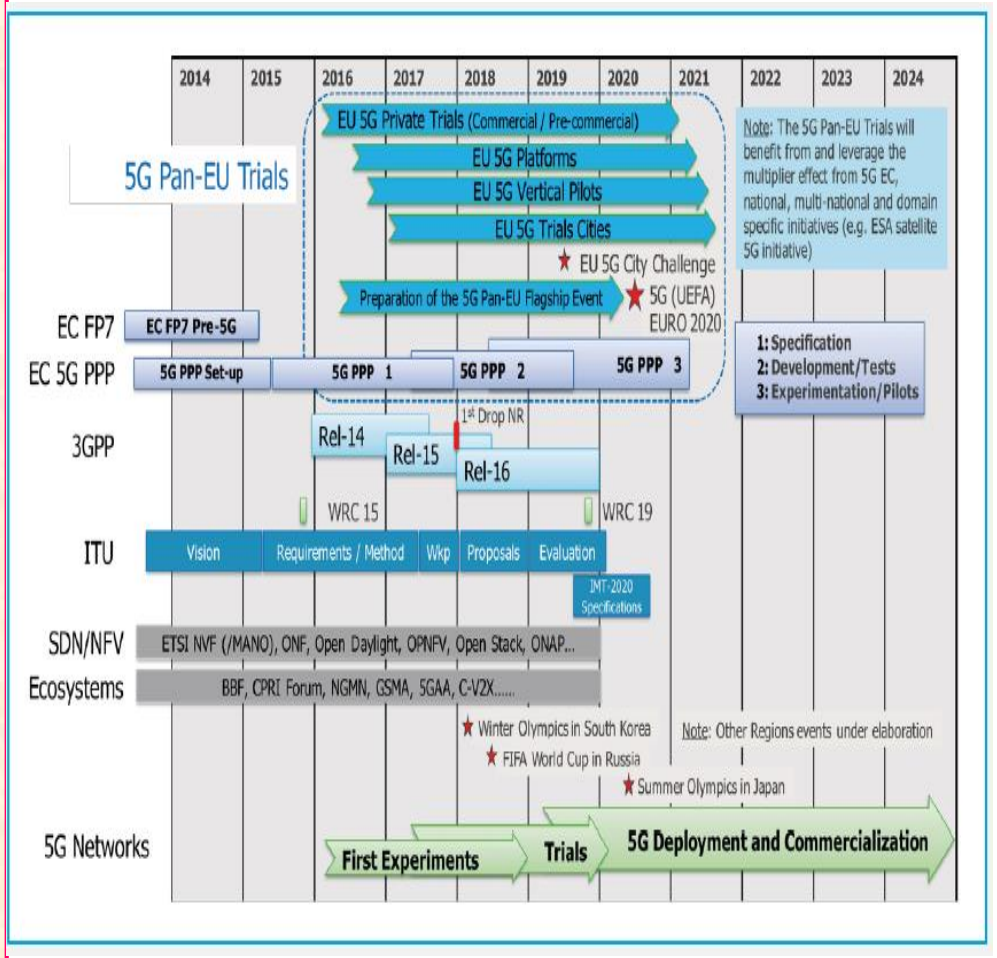
Among the actual priorities of the European Commission *(interactively with Member States (MSs) and industrial stakeholders/market actors)* ***is the voluntary establishment of a common timetable for the launch of early 5G networks*** *(initially scheduled to be operational by the end of 2018) and followed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

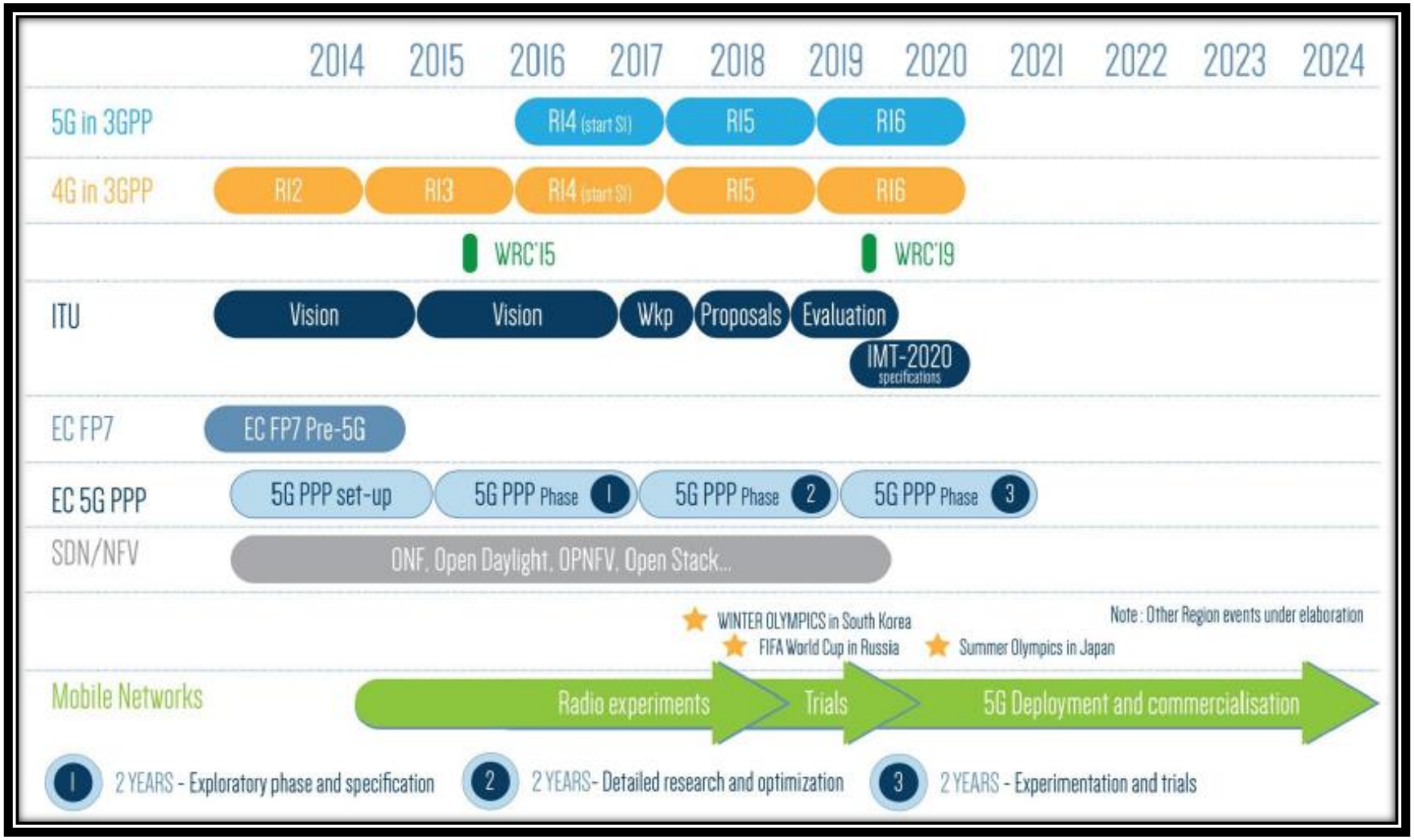
(i) ***Promoting*** *preliminary trials, under the 5G-PPP arrangement to take place from 2017 onwards, and pre-commercial trials with a clear EU cross-border dimension from 2018;*

(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.*



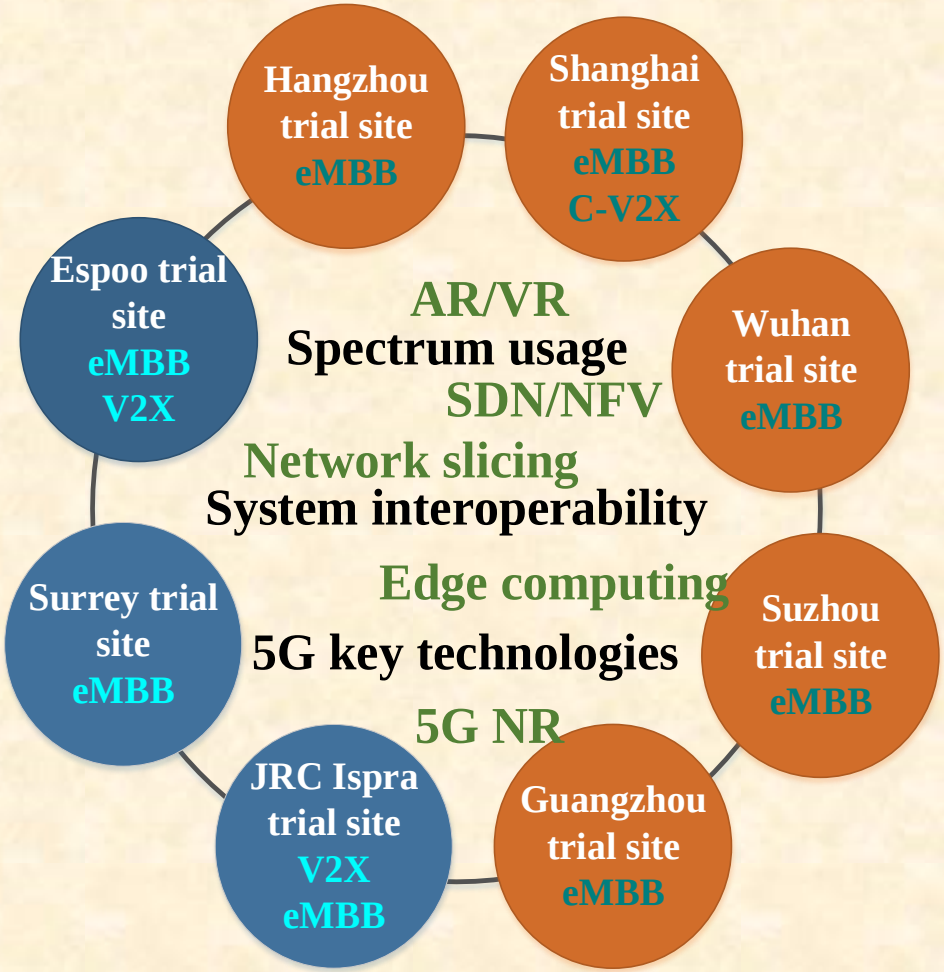
Cooperative Framework_(2)



Cooperative Framework with China

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

- ***Joint experimental activities with the major trial project in China*** *("5G Large-scale Trial" coordinated by China Mobile)*
- ***8 Chinese partners,*** *including vendors and research institutes*
- ***Verification of 5G network deployments*** *for eMBB C-V2X tests in real-life scenarios*
- ***Inclusion of indoor and outdoor scenarios in complex urban areas***



Scenarios and Selected Use Cases

Scenarios of Use

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 **Cloud-assisted Augmented Reality (AR).**

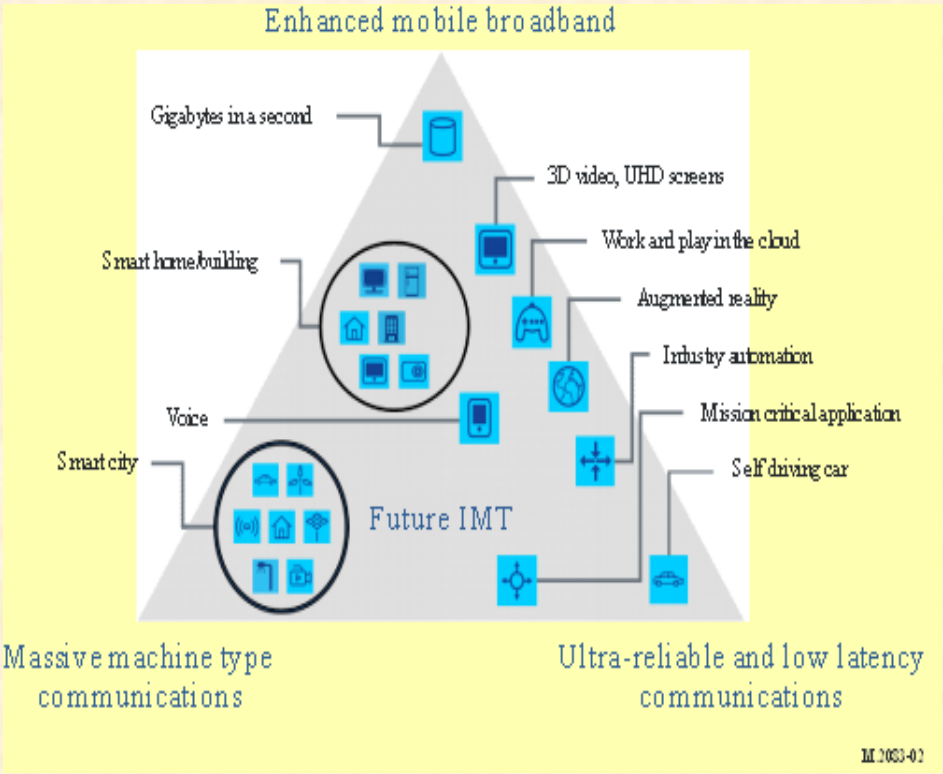
- ***Scenario no.2*** - ***Internet of Vehicles (IoV) based on LTE-V2X using the 5.9 GHz band for Vehicle-to-Vehicle (V2V) and the 3.5 GHz band for Vehicle-to-Network (V2N)***.

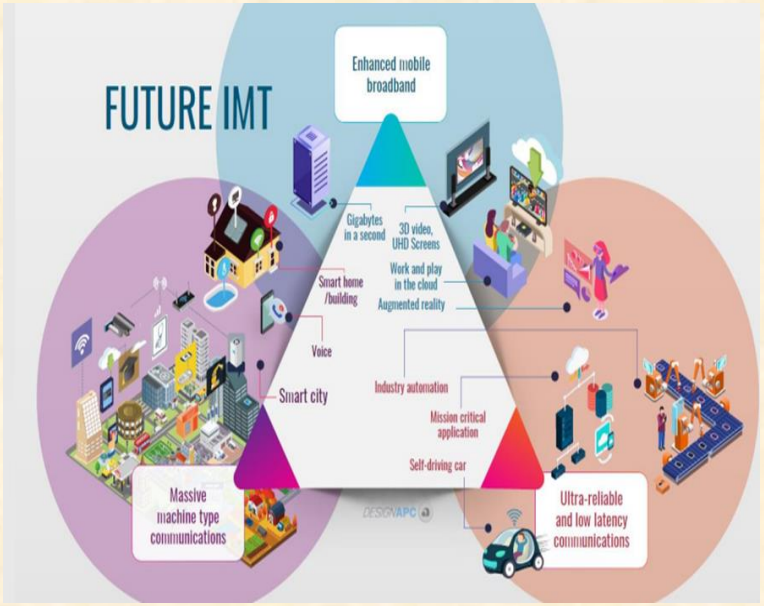
  The **overall goal is to evaluate in real setup innovative end-to-end 5G systems,** *built on the outcomes of the previous phases of the 5G R&I.*

  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 3.5 and 5.9 GHz bands for these use cases.*

eMBB Use Cases_(1)

eMBB 5G-DRIVE Use Cases



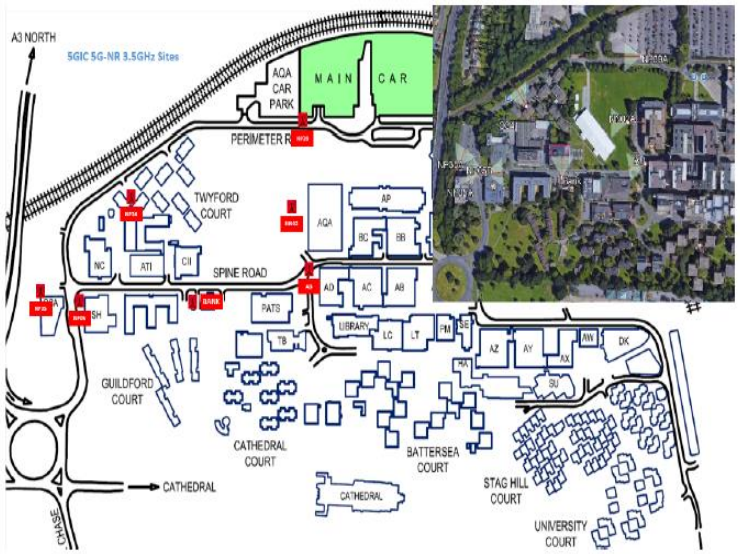


Consideration of the scope proposed by IMT 2020 and beyond

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

eMBB Use Cases_(2)

Surrey Trial Site



- 4 km² test area
- 7 sites and 9 gNB outdoor development
- Contributed to eMBB trial measurements in 5G- DRIVE over 3.5 GHz

Espoo Trial Site

- 2 km² test area
- Connect to MEC platform
- Support eMBB and URLLC
- Contributed to eMBB trial measurements in 5G- DRIVE over 3.5 GHz

eMBB Use Cases_(3)

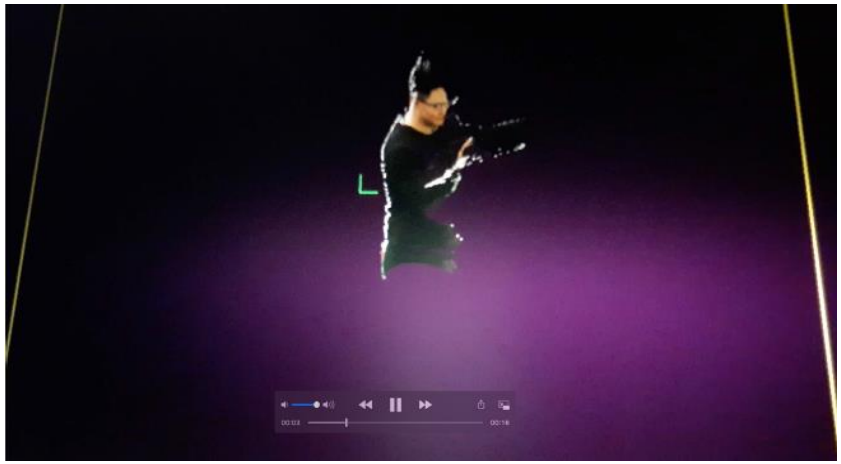
Cloud-assisted AR

- **Augmented Reality (AR)** is an ***interactive experience*** *of a real-world environment where the objects that reside in the real-world are "augmented" by computer-generated perceptual information*, sometimes across multiple sensory modalities (including visual, auditory, etc.). **In AR, the real-world view is augmented or assisted, by computer generated views.**

- **The cloud-assisted AR enables users to stream video games or virtual contents from cloud servers, like other streaming media.**
- **The eMBB is required to reach tens of Gbps to support the speed requirement of AR application, providing a more uniform experience for users.**

Setting up of a joint AR demo between Surrey and Espoo (trial in December 2019)

VR essential features	AR essential features
▪ Computer-generated simulation of a 3D environment; ▪ Lack of real elements; ▪ Totally immersive environment; ▪ Visual senses are under control of system (sometimes aural and proprioceptive sense too).	▪ An AR system adds virtual computer-generated objects, audio and other sense enhancements to a real-world environment in real time; ▪ System augments the real world scene; ▪ User maintains a sense of presence in real world; ▪ Needs a mechanism to a combine virtual and real worlds.



Real-time 3D video as shown at VTT site transmitted from Surrey site

KPIs	Tests with CMRI in November	Demo with VTT in December
Peak data rate	18-22 Mbps	45-50 Mbps
fps	20 fps	30 fps

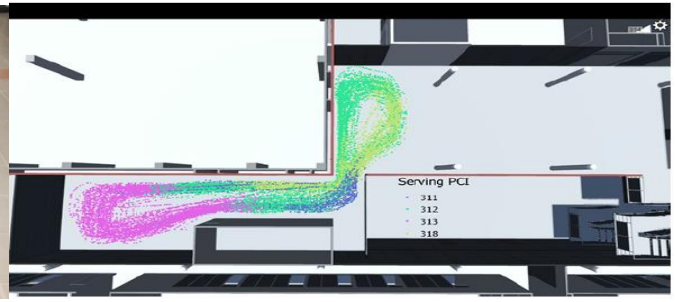
eMBB Use Cases_(4)

Indoor Positioning System (IPS)

- ***An Indoor Positioning System (IPS) is a system used to locate objects or people inside a building using lights, radio waves, magnetic fields, acoustic signal, or other sensory information***. *This can be done typically via a mobile device such as a smart phone or tablet.*
- ***Performance criteria*** *associated with localization systems can be classified in: (i) Accuracy (or location error); (ii) responsiveness; (iii) coverage; (iv) adaptiveness; (v) scalability; (vi) cost and complexity.*
- ***The combination of location information with other functionalities, supports dynamic adjustment of data loads and routing and also the control of the latency and its deviation;*** *the shared location information is a valuable asset for both mobile end-users and eMBB service providers to maintain and operate their devices.*

Positioning offers means to utilize location information to improve network communication reliability, to reduce latency, and to balance data loads.

Mobile robot used for the indoor positioning platform at Espoo site



(Coloured route of the indoor positioning platform on the VTT premises floorplan

Measurement devices used for indoor and outdoor measurements

Relevant KPIs:

- **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.*

eMBB Use Cases_(5)

The scope of the trials for eMBB on the European and Chinese sides covers:

- **Basic performance of the 5G NR in SA and NSA modes**, *that is with the 5G RAN equipment attached to a 5G CN or a 4G (LTE) CN, respectively.*
- **Indoor coverage performance tests**, *for example, using small/pico-cells and/or distributed antenna systems, and examining localization techniques.*
- **Multi-antenna or mMIMO array antenna subsystem tests**, *which will examine the enhanced performance possible from such beamforming systems, and different beamforming operational methodologies.*

- ***The EU side will not have the SA mode, at least during 5G-DRIVE project period, due to the delayed progress from vendors.***
- ***On the contrary, the China side will have both SA and NSA modes.***

eMBB Use Cases_(6)

Trial activities

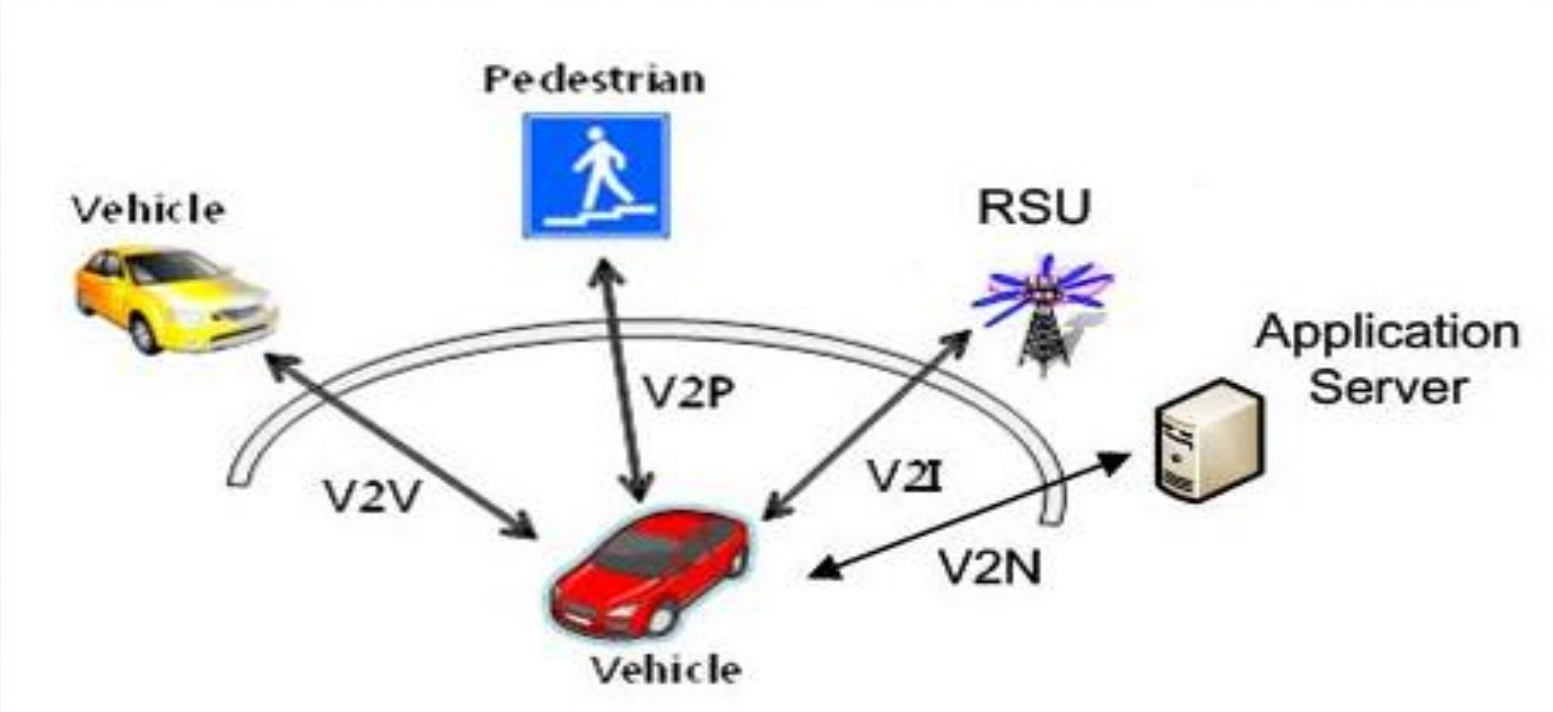
- 5G NSA basic performance trial measurements at eMBB trial sites in EU at 3.5GHz
- 5G NSA and SA basic performance joint trial measurement at Hangzhou eMBB trial sites in China at 2.6 GHz and 4.9GHz
- 3D beamforming performance joint trial measurement at Hangzhou eMBB trial site in China

5G NSA single user basic performance measured at University of Surrey at 3.5 GHz

2.6 GHz and 4.9 GHz base station on the roof of the opposite building and the location of the selected measurement points

V2X Use Cases_(1)

V2X 5G-DRIVE Use Cases



Consideration of the scope proposed by ETSI

[Source: ETSI TS 122 185]

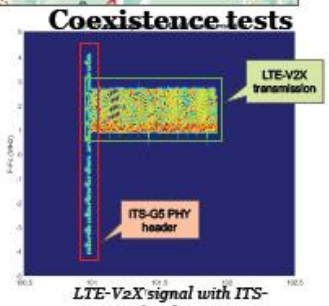
V2X Use Cases_(2)

Espoo site conducts trials on *automated driving, hybrid positioning, GLOSA and intelligent intersection with V2N and V2I.*

Ispra site conducted *LTE-V2X and ITS-G5 coexistence tests in lab environment.*
Field test of GLOSA are under preparation.

Espoo site

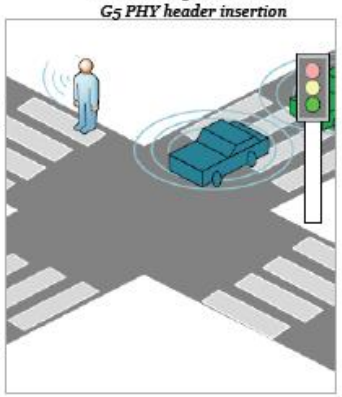
JRC Ispra site



LTE-V2X signal with ITS-G5 PHY header insertion

V2X field trials

- Green Light Optimal Speed Advisory (GLOSA) use case
- Intelligent intersection use case



V2X Use Cases_(3)

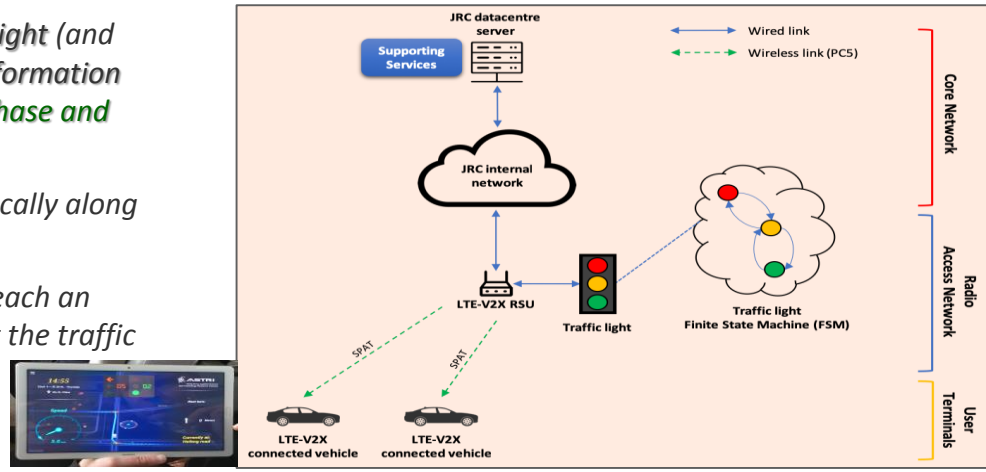
Green Light Optimised Speed Advisory (GLOSA)

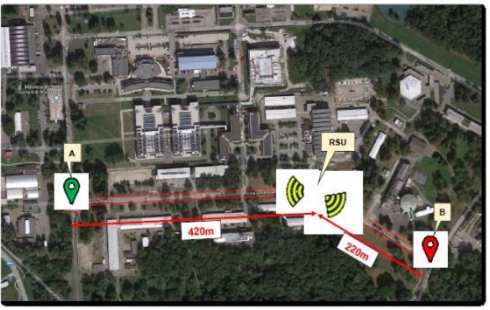
- ***GLOSA is a signage C-ITS (Cooperative Intelligent Transport Service) aimed at informing end-users about the speed that needs to be sustained (within legal limits) to reach an upcoming traffic light in green status.***
- **GLOSA provides end-users with short-term information on upcoming traffic light 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).

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.





Location of the RSU providing the ***GLOSA service*** *at the JRC Ispra campus*

ITS-G5 RSU deployed in the JRC Ispra campus

Relevant KPIs:

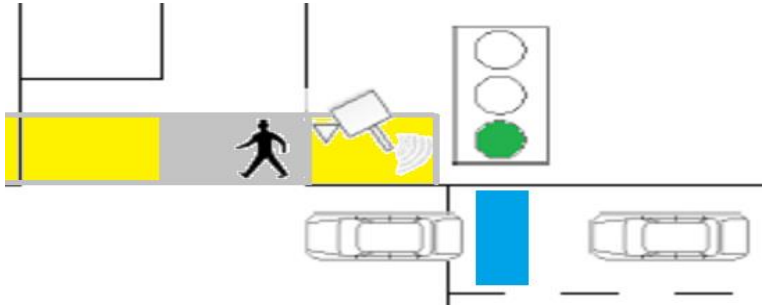
Packet Error Rate (PER): ratio of unsuccessfully received packets in the OBU *vs.* total number of packets sent by the RSU (in percentage).

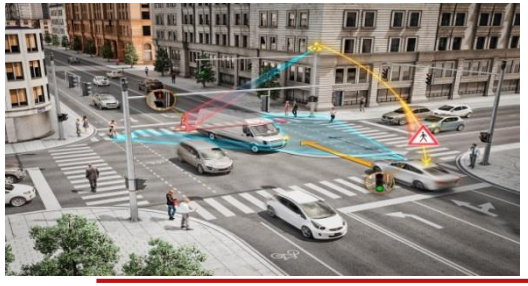
Latency: the radio access network contribution to the total elapsed time, measured from the instant the RSU sends a packet to the moment when the OBU receives it (in ms).

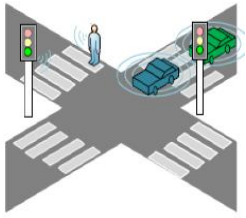
V2X Use Cases_(4)

Intelligent Intersection

- ***This use case deals with safety on intersections, focusing on infrastructure detection of situations that are difficult to perceive by vehicles themselves.***
- ***An example is the case 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 back-office 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), to warn vehicles** further upstream that a potential conflict may occur in the future and to prevent future hard braking.*





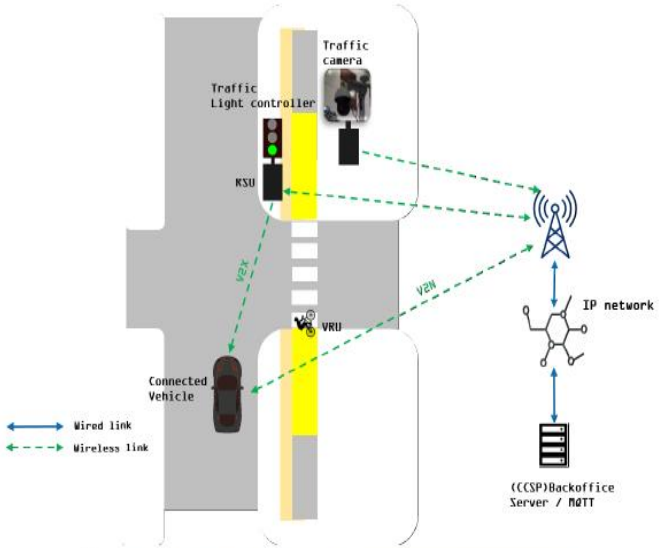


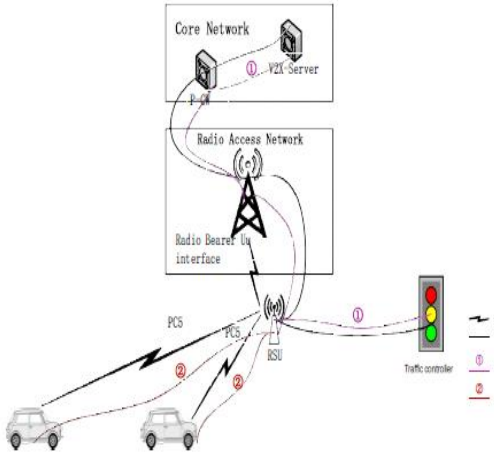
Relevant KPIs:

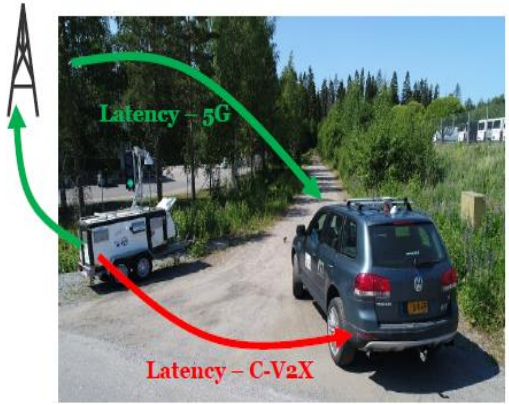
- **Packet Error Rate (PER):** *ratio of unsuccessfully received packets in the OBU vs. total number of packets sent by the RSU (in percentage).*
- **Latency:** *the radio access network contribution to the total elapsed time, measured from the instant the RSU sends a packet to the moment when the OBU receives it (in ms).*
- **Total active stations:** *This KPI tracks how many other stations were active at the same time while in communication range of the test subject.*
- **Total channel load in Mbps:** *The total load of the channel is an important contextual variable to determine how much interference can be expected.*
- **Total messages per seconds on channel:** *One other client using a load of 1 Mbps has much less chance of packet collisions than a hundred clients transmitting at 10 kbps.*

V2X Use Cases_(5)

Tampere test architecture + Shanghai test architecture







Application scenarios/use cases

EU	China
GLOSA: Green Light Optional Speed Advisory	GLOSA: Green Light Optional Speed Advisory
Intelligent Intersection (VRU)	FCW: Forward Collision Warning
	BSW/LCW: Blind Spot Warning /Lane Change Warning
	AVW: Abnormal Vehicle Warning
	EVW: Emergency Vehicle Warning
	SLW: Speed Limit Warning
	RLVW: Red Light Violation Warning
	TJW: Traffic Jam Warning

5G-DRIVE Consortium

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

EURESCOM
VTT
BMW GROUP
MINI
European Commission
ERTICO ITS EUROPE
MARTEL innovate
OTE
MANDAT INTERNATIONAL
orange
ORION INNOVATIONS
Smartenet
spi Sociedade Portuguesa de Inovação
vedia
dynniq energising mobility
University of Kent
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