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

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Contents:

- Introductory Framework
- 5G-DRIVE: Overall Concept and Key Areas for Innovation
- 5G-DRIVE: Essential Conceptual Approach
- Related Technologies and Challenges
- Views on eMBB and V2X
- Developing V2X Services and Use Cases

Introductory Framework

Introduction_(1)

"5G" can be seen as a 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 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** 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 <u>wider effort is needed</u> 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.***

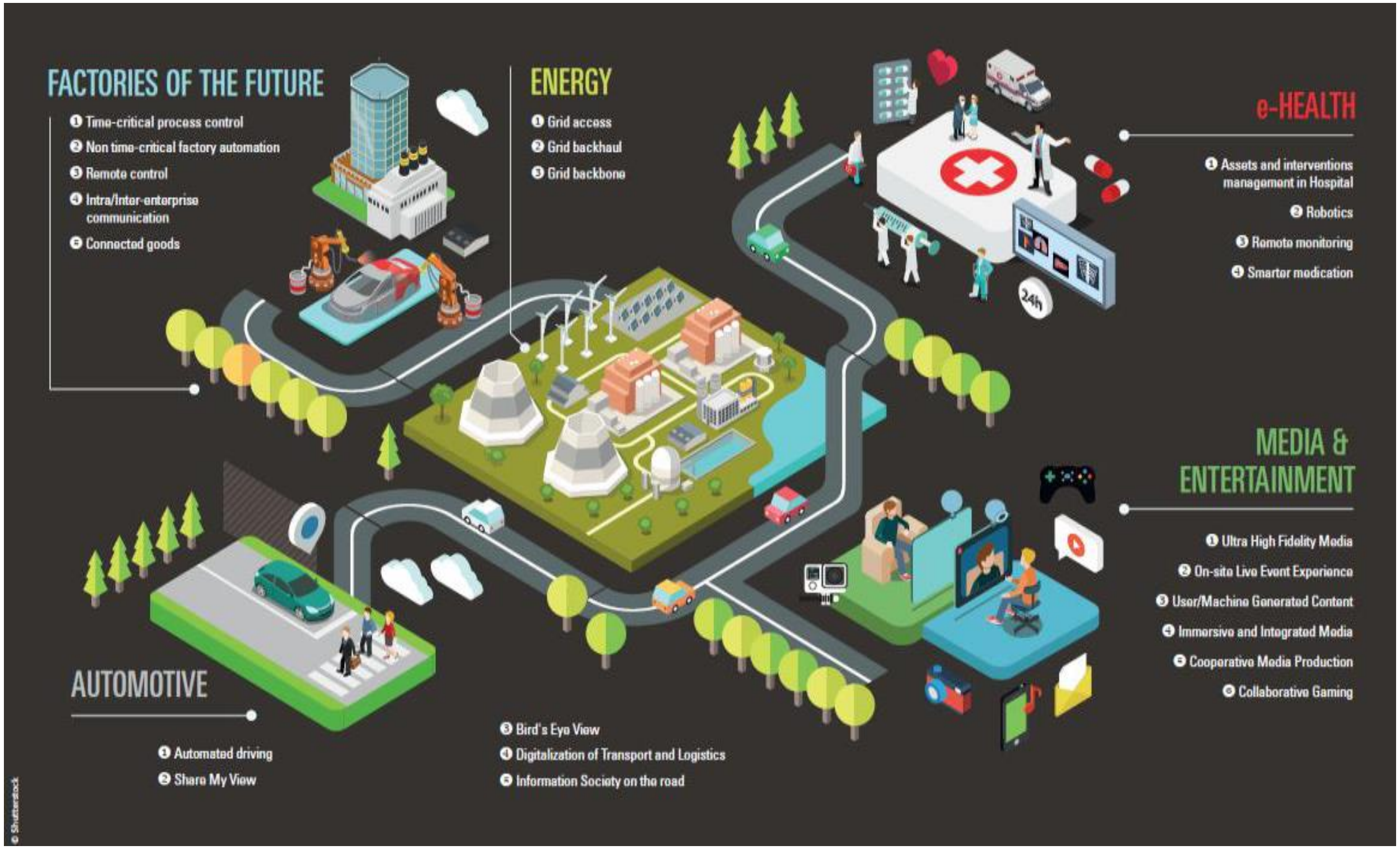
Introduction_(4)

*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 ahead of the 2019 World Radio Communication Conference (WRC-19), 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

Introduction_(6)

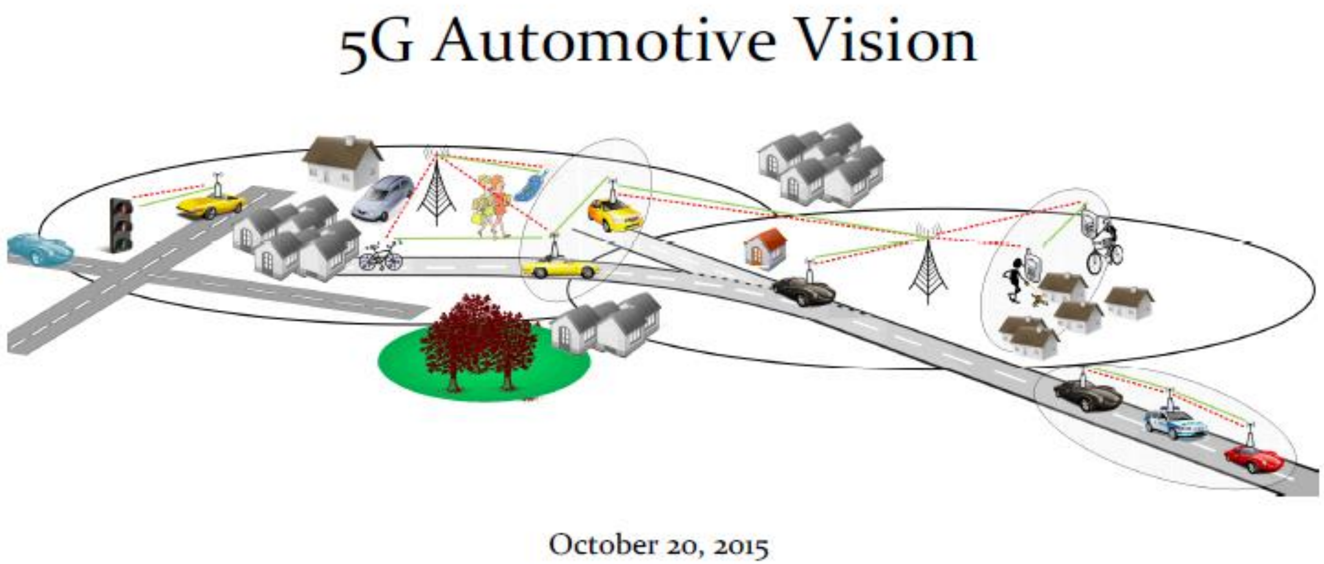
The **vision of advanced driver assistance** systems and, *in an even longer perspective,* **complete autonomous driving cars can promise** not only less fatal accidents, less traffic congestions and less congested cities, but also a **wide range of new business opportunities** for a broad range of industries and **benefits for the environment.**

5G will realise this vision by improving the cooperative automatic driving *in such a way that sensor information will be exchanged in real time between thousands of cars connected in the same area.*

- ***Most foreseen applications cannot be implemented with today's communication technologies. This is why there are high expectations on 5G!***

- *With the introduction of technologies allowing improved performances* ***there can be a myriad of new applications.***
- **The main use cases identified on automotive industry are:** *Automated driving, Share My View, Bird's Eye View, Digitalization of Transport and Logistics, and Information Society on the road.*

Introduction_(7)



***The automotive industry is currently undergoing key technological transformations**, as more and more vehicles are connected to the Internet and to each other, and advance toward higher automation levels.*

*In order to deal with increasingly **complex road situations**, automated vehicles will have to rely not only on their own sensors, but also on those of other vehicles, and will need to cooperate with each other, rather than make decisions on their own.*

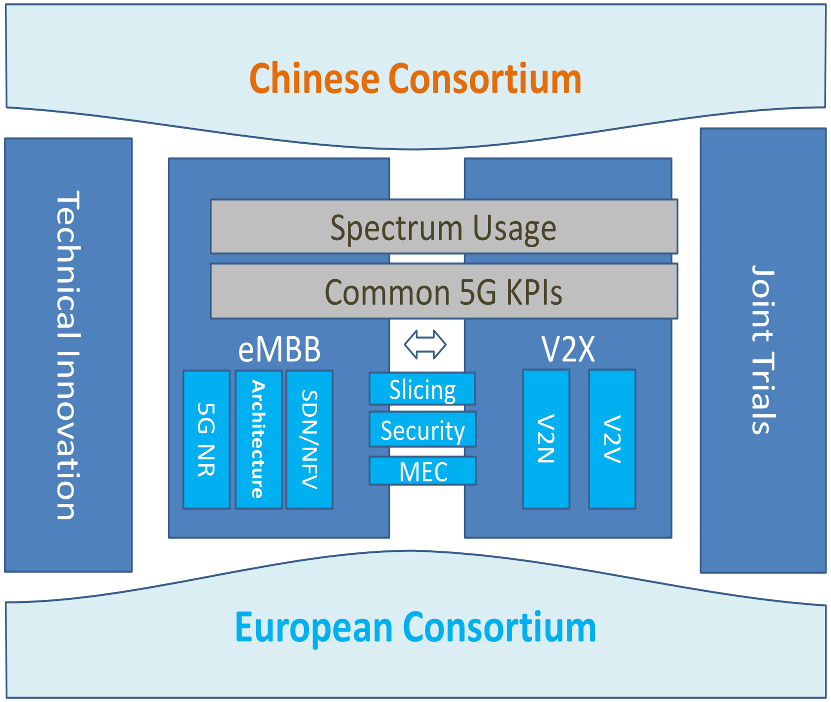
5G-DRIVE: Overall Concept and Key Areas for Innovation

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 will conduct joint trials for eMBB and LTE-V2X scenarios with the major relevant 5G project in China**.
- These joint trials will be based on **common 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 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 will be 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 two regions for 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 to provide joint reports, white papers, and recommendations to address them accordingly.

OBJ6: Submit joint contributions to 3GPP and other 5G standardisation bodies 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 to **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 to 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.*

Relation to the EU Work Program_(1)

Challenges and scope set out in the work programme	How the project addresses the challenges and scope set out in the work programme
1. "The **challenge** is to demonstrate technologies and system interoperability for a number of core applications of interest" …. *within the scenarios identified below* … "in the two regions" *(EU and China)*	5G-DRIVE will meet this challenge by demonstrating the deployment of eMBB in the 3.5GHz band and Long Term Evolution (LTE)-V2X using the 5.9GHz band for V2V and the 3.5GHz band for V2N, in various applications as described below. System interoperability will be demonstrated through the use of network equipment and vehicle components from the EU and China in the trials in both regions, in accordance with international standards. **(OBJ1 - addressed in WP3,WP5)**

Relation to the EU Work Program_(2)

Challenges and scope set out in the work programme	How the project addresses the challenges and scope set out in the work programme
2. "The **scope** is to conduct 5G trials addressing two specific scenarios: • **Scenario n°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; and • **Scenario n°2 - Internet of Vehicles (IoV) based on LTE-V2X using the 5.9GHz band for V2V and the 3.5GHz band for V2N.**	**Scenario n°1: 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).** This will be demonstrated in the Surrey, Espoo and JRC Ispra trial sites. ***(OBJ2, OBJ3, OBJ5-WP2, WP3)*** **Scenario n°2: the application selected to test and validate the use of V2X using the 5.9GHz band for Vehicle-to-Vehicle (V2V) and 3.5GHZ band for V2N is autonomous driving.** This will be shown in the Espoo trial site by VTT, Dynniq and Vedia and in JRC Ispra trial site. **(OBJ4, OBJ5-WP2, WP4)**
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**.	5G-DRIVE builds on the outcomes of previous phases of the following 5G PPP projects: **COHERENT, 5G-ENSURE, SESAME, 5G-ESSENSE, Speed-5G, SELFNET, SLICENET, as well as other EU projects including iCIRRUS, RAPID, 5G!Pagoda**, etc. V2X and IoV scenarios come from the **DRIVE C2X** and **AUTOPILOT** project. MEC implementation build on the **CONCORDA CEF** project. Finally, broadband transmission leverages the Surrey 5G Innovation Centre (5GIC) testbed (4K and 8K TV transmissions) **(OBJ3 -WP3)**
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 5.9GHz bands for these use cases**. Both scenarios shall be implemented in both regions (EU and China) through **testbeds with interoperability** forming the core of the R&I work."	**All of the 5G-DRIVE use cases will be demonstrated in both regions**, thus taking into consideration different geographical conditions (see the test facility descriptions below). In addition, system interoperability will be tested, through the combination of equipment from both the EU and China as part of the trials conducted in both regions. **(OBJ5, OBJ7, OBJ8 - WP3, WP4)**

Relation to the EU Work Program_(3)

Challenges and scope set out in the work programme	How the project addresses the challenges and scope set out in the work programme
3. "The underlying trials' testing facilities shall **implement the latest mature and broadly commonly agreed 5G systems, network architectures and technologies** spanning from the core/transport networks, the radio access, up to the service, orchestration, management and security components." "......The 5G trials' infrastructures shall facilitate the testing and validation of **innovative applications for each of the defined scenarios, including efficiency solutions in the areas of spectrum usage, energy consumption and costs**."	The **Surrey 5GIC testbed** consists of commercial grade communications equipment with all relevant security functionalities built in. It supports various wireless scenarios, from provision to static indoor and outdoor users to eMBB services to mobile users travelling at higher speeds (up to 80km/h, limited due to the set up and coverage of the local road network). Furthermore, the 5GIC holds a trial license for experimental operation in the 3.8GHz band. A license for the 3.5GHz band will be obtained from the regulator (Ofcom) on demand. The **Espoo trial site** provides the latest 5G equipment and network environment for the eMBB and V2X scenarios, in particular for autonomous driving tests with vehicles provided by VTT and Vedia. The **JRC Ispra trial site** comprises circa 186 hectares and 36 km of road infrastructure with real-life conditions under full control of the JRC Ispra Management Department. This trial site is in the process of procuring and deploying the necessary V2X infrastructure to enable on-site IoV tests. ***(OBJ1, OBJ2, OBJ4 - WP3-WP5)***
4. "The trial facility **shall not be restricted to innovative 5G radio access technology, but should include and enable the evolution of 5G networks innovations in network slicing, virtualisation, cross-domain orchestration, in view of supporting resource control from multiple tenants**.	Joint research will be carried out in new innovative areas of 5G, including network virtualisation and end-to-end slicing, multi-domain orchestration, efficient and dynamic resource allocation between multiple tenants, and the definition of service-tailored slices. The results of this work will be incorporated into the trials, to the extent that they are sufficiently developed. **(OBJ2 - WP5)**

Key Areas of the Project Innovation

Key areas of innovation where 5G-DRIVE is expected to contribute:

- **eMBB** ***(enhanced Mobile Broadband)*** **scenario and use case applications trial assessment;**
- **IoV** ***(Internet of Vehicles)*** *including* (**V2V** *(Vehicle-to-Vehicle)*, **V2N** *(Vehicle-to-Network)*, **V2I** *(Vehicle-to-Infrastructure)*, **V2P** *(Vehicle-to-Pedestrian*) **trial assessment** and **security vulnerabilities testing;**
- **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)

Demonstration of 5G capabilities for eMBB and IoV:

- The role of these two scenarios in automotive innovation is increasingly more noticeable and prominent.
- Traditionally, research is focused on IEEE 802.11p (the *de-facto* standard for V2X communication) and other co-existing technologies. However, as the determinants of market differentiation “shift” towards “5G”-*like* features *(such as hyper-connectivity, low latency and higher throughput)* eMBB and LTE-V2X are gaining momentum.
- **Operators and automotive industry increasingly rely on such technologies to build a long-term advantage.**
- **Vehicle manufacturers** will face a growing number of decisions over whether to “push” the development of certain technologies alone or with a partner.

Hence, the interoperability trial assessment that will be carried out by 5G-DRIVE will become increasingly necessary.

Thus, 5G-DRIVE will “drive” the implementation and deployment of a real-life heterogeneous eMBB/LTE-V2X communications network (with extended capabilities through the realisation of edge services) at the project test sites.

Key Areas of the Project Innovation_(3)

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.*

Trial Sites

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.

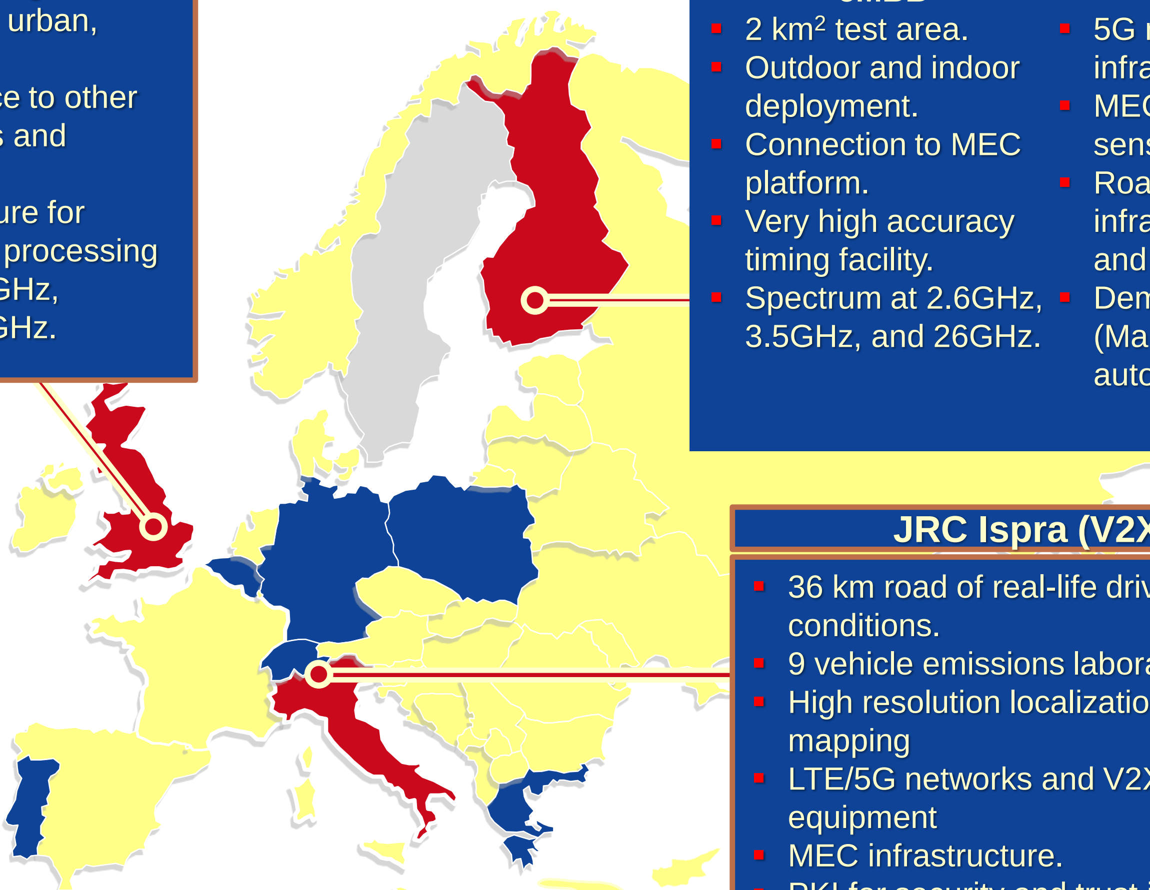
Espoo (eMBB, V2X)

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.

Expected Results and Impact

5G-DRIVE will deliver results related to trials, IPR, specifications and reports.

TRIALS

- **3 trial sites for eMBB:**
  - 5+ gNBs
  - 10+ UEs
  - Cover dense urban and office building
- **2 V2X trial network.**

SPECIFICATIONS

- **Joint (with China) test specifications.**
- **Cover field equipment, performance, interoperability, V2X specifications**

IPR

- 3**+ patents.**
- **Covering of 5G key technologies , including massive MIMO, network slicing, V2X, MEC, etc.**

REPORTS

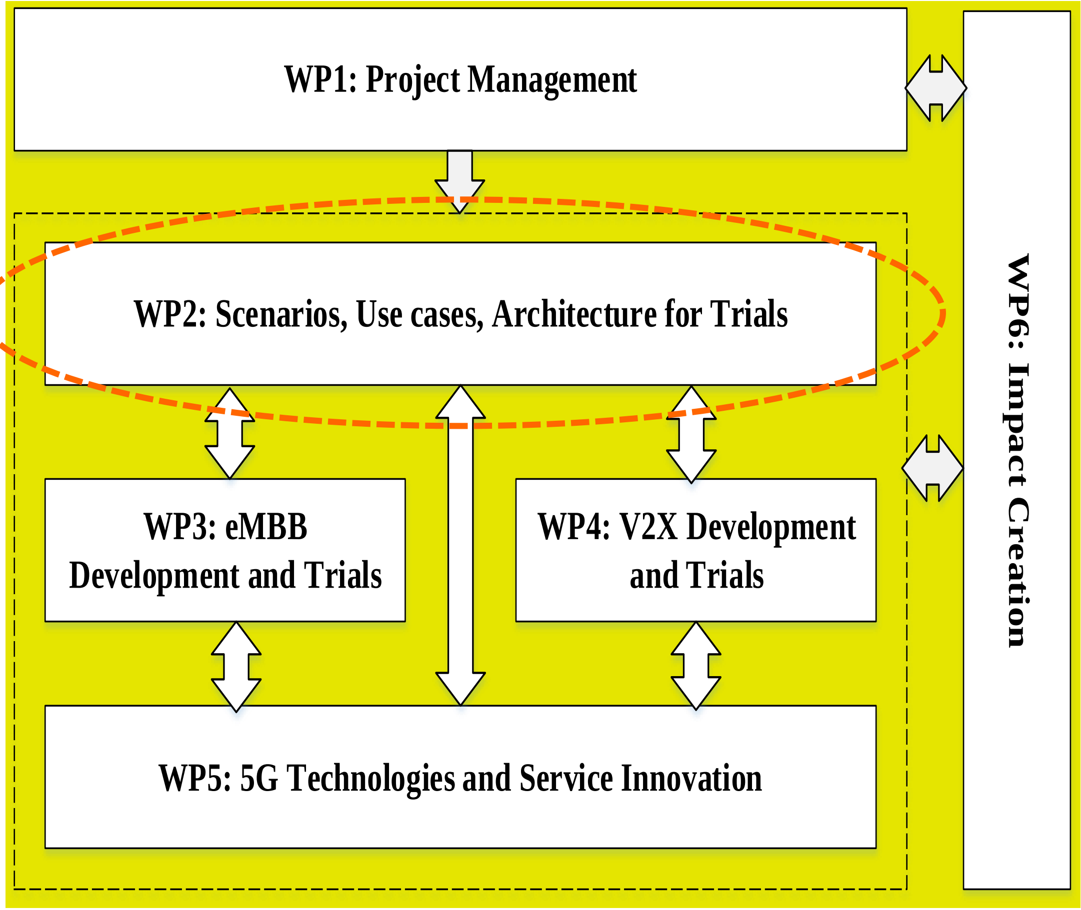
- **Over 10 Deliverables**
- **More than 4 joint reports (with China).**
- **Cover key technology evaluation report, system interoperability, service platform.**

5G-DRIVE: Essential Conceptual Approach

5G-DRIVE: Work Plan

***WP2* defines the scenarios, use cases and reference architecture for research and trials.**

- **WP2 will collaborate with the Chinese project to define the common use cases, architecture and KPIs for trials.**
- **The technical alignment across trial sites between two twin projects is maintained through WP2.**



WP2 – Objectives_(1)

- **WP2 will examine** **project-related scenarios**, corresponding **use cases** as well as the **reference architecture** necessary for the intended trials.
- **WP2 shall primarily focus upon** the definition and the evaluation of selected use cases *that will be **assessed** for further solution development as well as for the intended trials within the course of the project, and will be **examined in detail** in WP3-WP5.*
- **The approach shall be based on the two core and more generalised scenarios, covering eMBB** *(in particular by using the 3.5GHz band)* **and V2X** *(at both 3.5GHz and 5.9 GHz bands),* intending to **promote** a sort of converged network design and approach for both the above scenarios, *to the extent possible so that to **endorse** market appliance.*
- **The effort will define** **detailed specification of the corresponding requirements** for the selected uses cases, **together with the appropriately defined KPIs,** *per case.*
- **WP2 will then define** the detailed scope of architecture to **serve** the intended trials that are to be realized in the project.

WP2 – Objectives_(2)

Specific WP2 objectives are listed as follows:

- Identification of the joint use cases and measured KPIs in the fundamental scenarios (eMBB, V2X);
- Identification of new business cases under the two fundamental scenarios and to analysis of how these can affect the related system's architecture and intended deployment;
- Analysis of the spectrum usage by both sides and identification of the spectrum harmonisation issues between the EU and China on 3.5GHz and 5.9GHz;
- Definition of common tasks in trials and identification of the topics in joint trial specifications and reports for WP3 and WP4;
- Provision of guidelines and/or recommendations for joint trials and result analysis in WP3 and WP4;
- Identification of the architecture to be used in the project in the two fundamental scenarios and assessment of the related major architectural components in view of 5G;
- Identification of "gaps" between the standards and the implementation and provision of guidelines for research in WP5.

Unlocking Bottlenecks_(1)

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, ***to enable 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.*

Related Technologies and Challenges

Related Technologies & Challenges_(1)

***For what concerns future radio access**, after several years of research driven by academia and industry, and the delivery of mature technology enablers for 5G, **3GPP is now drafting the standard for 5G V2X, starting with Rel.16**.*

***In order to accelerate the deployment of 5G, a first version of the standard will be released, with a focus on eMBB services, operating at frequencies below 6 GHz and probably co-existing with legacy LTE systems**.*

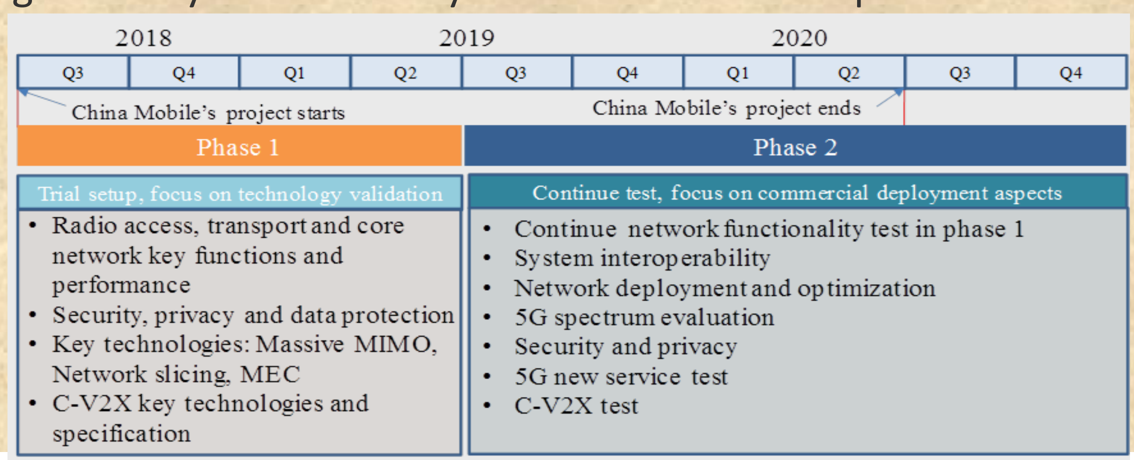
It is expected that this first release of 5G will enable a significant set of advanced ITS services and provide the basis for the second wave of even more challenging services.

The roadmap to 5G V2X, *which is currently assumed to begin with 3GPP Rel.16, **also includes standards and V2X technologies which are (almost) available, as e.g. LTE V2X and IEEE 802.11p.***

Their main role is seen in providing enhanced data rates and basic ITS services and are, therefore, considered as part of the future landscape of vehicular telecommunication.

Related Technologies & Challenges_(2)

- In the **first phase of the project**, **the joint tests will focus 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. Depending on the availability of 5G UE (which is expected by the end of 2018) the ***initial trial will start in 2019.*** *The eMBB trial will be mainly performed in the Surrey trial site, while the availability of the eMBB trial in Espoo and Ispra trial site will depend on the agreement with the ICT-17-2018 project. 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.



Related Technologies & Challenges_(3)

5G-DRIVE has ambitions to investigate 5G eMBB services and new technologies for connected and automated vehicles.

5G-DRIVE will mainly cover the following 5G key technologies:

- *5G NR*
- *Network slicing*
- *NFV*
- *SDN*
- *MEC*
- *C-V2X and*
- *Transport network.*

Related Technologies & Challenges_(4)

5G NR / Massive MIMO:

- Recent research indicates that ***massive MIMO significantly improves the sum spectral efficiency (SE) of cellular networks*** *by spatial multiplexing of a large number of UEs per cell.*

- The ***main difference between massive MIMO and classical multi-user MIMO*** *is the large number of antennas, at each base station whose signals are processed by individual radio-frequency chains.*
- ***The massive MIMO technology has been proposed as a key NR technology for the next generation of cellular networks.***

- ***There are several key technical challenges for applying mmWave for mobile networks***, including severe path-loss, high power consumption in RF power amplifiers and data converters, narrow beamwidth and side-lobes leading to higher sensitivity to misalignment between the transmitter and the receiver.
  To "address" these challenges, the extensive research and deployment for the future mobile networks has already been carried out around the world.

Related Technologies & Challenges_(5)

Network slicing:

- ***The network slicing concept enables creation of many virtual networks over a common infrastructure.***
- *In opposite to Virtual Private Network (VPN) concept, **the network slicing enables creation of fully-fledged networks** that can be combined with applications, while maintaining the isolation and privacy.*
- ***The concept is linked with ETSI NFV technology**. It is worth mentioning that the ETSI NFV framework has no inherent support for network slicing, however it is possible to provide logical isolation of virtual networks (i.e. grouped and interconnected virtual network functions (VNF)).*
- ***There are three main benefits of network slicing:***
  - *dynamic deployment of networking solutions with short time to market and low capital expenditure (CAPEX);*
  - *ability to create the networks that are tightly coupled with their service(s);*
  - *delegation of almost complete network slice management to a slice “tenant” (e.g., a vertical).*

Related Technologies & Challenges_(6)

Network Function Virtualisation (NFV)* offers the prospect of implementing specific network functions** *(e.g. Content Delivery Network, Customer Premises Equipment management, etc.)* ***in software running on generic hardware, without the need for costly hardware-specific machines.

The expected impacts are:

- *A drastic reduction in capital expenditure (capex) and network management costs – operational expenditure (opex);*
- *reuse and sharing of the same functionality between several customers;*
- *higher innovation capability through easy introduction of new software functionalities and creation of a "network app" market place.*

Related Technologies & Challenges_(7)

***Software Defined Networking (SDN)* is a complimentary trend to NFV that allows the control of network resources to be opened to third parties, with the possibility for these third parties to manage their own physical or virtual resources individually, as needed, with the required level of performance tailored to actual needs.**

This possibility goes much beyond the management capabilities offered to today's MVNO's.

In the context of 5G developments, and in view of supporting ad-hoc digital business models of industrial users, SDN and NFV are seen as key components *to enable these specific categories of professional users to control their network capabilities dynamically according to their needs.*

Mobile Edge Computing (MEC):

- ***MEC enables innovative service scenarios that can ensure enhanced personal experience and optimized network operation, as well as opening up new business opportunities*** *(introduced and specified by ETSI ISG MEC).*
- ***MEC has been seen as a remedy to provide time-critical operations at the network edge.*** *Furthermore, providing services near to end-users easily offloads the core nodes, in order to have full utilisation of the network.*
- *ETSI specifies a rich set of functionalities to ensure that MEC concept can be a solution to problems coming out with the demands of future mobile networks and open for vendor implementation approaches.*
- *With the release of ETSI MEC specifications,* ***massive research has been conducted*** *and since the noticeable success made by SDN,* ***several MEC use cases have been proven to benefit from the integration of SDN.***

Related Technologies & Challenges_(10)

Transport Network:

The traditional transport network has consisted of a backhaul between the base station and the evolved Packet Core functions *(Mobility Management Entity (MME), serving gateway (S-GW), packet data network gateway (P-GW) etc., in a 4G network)* ***and a fronthaul***, in some deployments, ***which allowed the separation*** ***of centralized base station baseband functions and remote radio functions.***

In small cell deployments, a "midhaul" segment was defined for the connection of micro-base stations to a controlling macro-base station. **For 5G, it is recognized that the transport network will need to evolve radically.**

There are several significant factors that have led to this requirement, such as, for example:

- Huge increases in data rates and numbers of users, and the densification of access networks;
- Recognition that the sampled waveform transport used in fronthaul up to now, cannot be used for 5G.
- A common transport infrastructure may simultaneously carry traffic from different RAN functional splits, as well as traditional midhaul and backhaul, together with fixed access network traffic, enabling fixed-mobile convergence.
- Affecting change in the transport network arises from the increased softwarisation of network functions - NFV and SDN; this requires the transport network to be similarly softwarized and software-defined, such that it can be orchestrated and centrally managed.

Related Technologies & Challenges_(9)

The core capabilities outlined in previous slides go "much beyond" the current and future 4G/LTE capabilities in the following ways:

- **Speed**
- **Flexibility** to accommodate demanding professional-grade applications
- **Instant response time**: *Core 5G application requirements such as low **latency of 1ms** (10 to 20 ms for 4G), serving 1 million devices/km² (about 1000 device/km² for 4G) or fast deployment of new services in the order of 1 hour deployment time (measured in days with current technology) **are not part of today's 4G technology.***

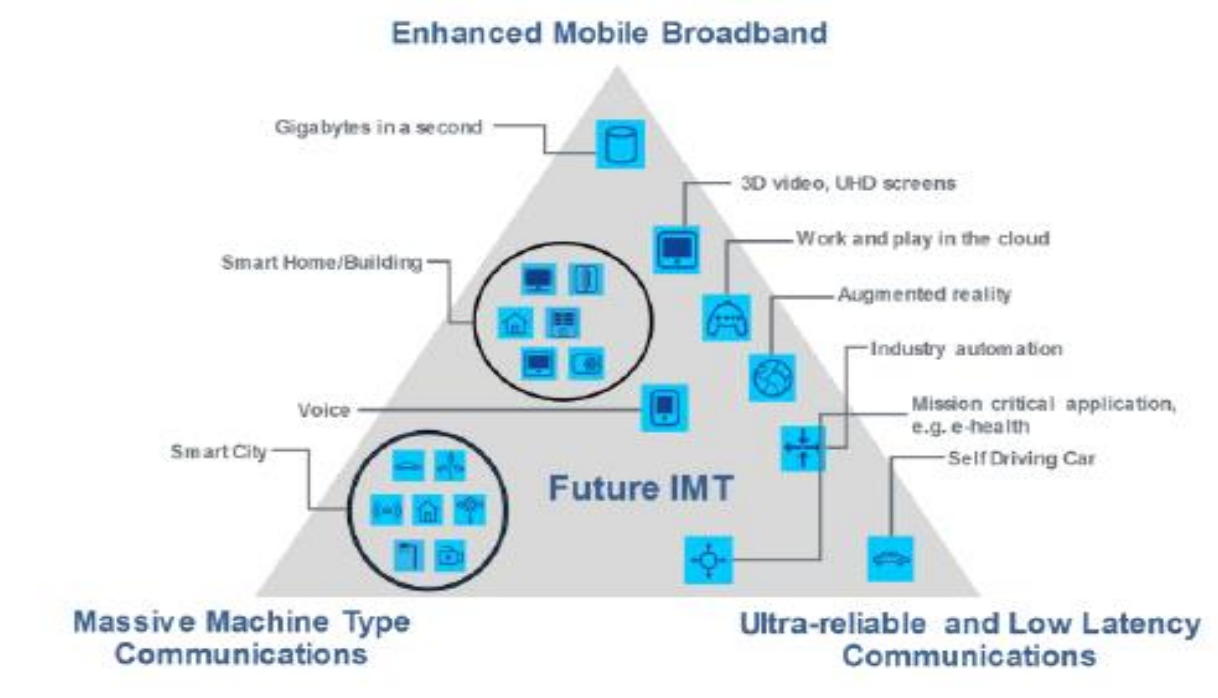
Views on eMBB and V2X

Views on eMBB and V2X_(1)

The ITU recommendation ITU-R M.2083-0 (approved in September 2015), defines the overall objectives of the future development of IMT for 2020 and beyond.

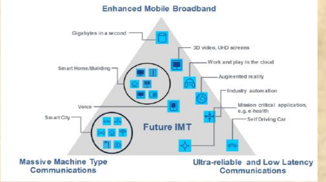
It calls for 5G system improvements that cover three generic classes of services, based on anticipated market developments.

These are outlined in the "ITU triangle" :



Views on eMBB and V2X_(2)

***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.*



<u>The three fundamental sets of use cases are as follows:</u>

- ***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.*

Views on eMBB and V2X_(3)

- *It is expected that eMBB will primarily be an extension to existing 4G services and will be amongst the first 5G services, which could be commercially offered as early as 2019.*

- *The eMBB can be seen as the first phase of 5G, which will be incorporated in the 3GPP Release 15 standards update due for completion within 2018.*

- *5G Phase 2 will go beyond eMBB services to more transformational URLLC and mMTC applications and will be included in Release 16, which is due to be completed at the end of 2019.*

Views on eMBB and V2X_(4)

In case of connected cars:

- ***The first phase of eMBB services will involve** enhanced in-vehicle infotainment, like real-time traffic alerts, high-speed internet access, streaming real-time video or playing games involving 3D 4K resolution video.*

- ***The second phase would be 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 360° video streaming as well as the provision of VR and AR applications.*

Views on eMBB and V2X_(5)

Within the context of EMBB and for the proper offering of the related use cases in the market sector,
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 indoors and outdoors (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).*

Views on eMBB and V2X_(6)

- *The eMBB will support an extended set of (cloud-based) applications and of related facilities,*
  affecting our digital experiences via a great diversity of devices and/or equipment wirelessly and seamlessly connected.

- *Moreover, it will also support applications from fully immersive VR and AR to real-time video monitoring and virtual meetings*
  with 360^o video, real-time interaction and even real-time translation for participants speaking different languages.

Connected V2X (C-V2X)

C-V2X as initially defined as LTE-V2X in 3GPP Release 14 is designed to operate in several modes:

- ***D2D*** *(to link vehicles, roadside and pedestrian to each other),*
- ***Device to cell tower*** *(mainly to share resources with a MEC), and*
- ***device-to-network*** *(mainly to link to the cloud via an IoT platform).*

Ad-hoc communications are based on 3GPP D2D communications defined as ***part of proximity services in Release 12 and Release 13*** *of the specification.*

A new D2D interface was introduced as PC5 *(Proximity Communication 5: name of interface), also known as side link at the physical layer.*

It has been enhanced for vehicular use cases*, specifically addressing* ***high speed*** *(up to 250Km/h) and* ***high density*** *(thousands of nodes).*

Views on eMBB and V2X_(8)

The V2X technology is based on 5.9 GHz dedicated short-range communications (DSRC), *a Wi-Fi derivative specifically defined for fast-moving objects and enabling the establishment of a reliable radio link, even in non-line-of-sight conditions.*

The core motivations for V2X are:

- *Road safety;*
- *traffic efficiency, and;*
- *energy savings.*

By sharing data (*such as their position and speed),* ***to surrounding vehicles and infrastructures, V2X systems improve:***

- *driver awareness of upcoming potential dangers;*
- *collision avoidance, resulting in heavily reduced fatalities and injury severity;*
- *warnings for traffic congestion.*

***There are two types of V2X communication technology** depending on the underlying technology being used:*

***(i) WLAN-based**, and;*

(ii) cellular-based

Views on eMBB and V2X_(10)

- *The 3GPP started standardization work of cellular V2X (C-V2X) in **Release 14** in 2014.*
- ***It is based on LTE as the underlying technology.***
- *Specifications were published in 2016.*
- ***Because this C-V2X functionalities are based on LTE, it is often referred to as "cellular V2X" (C-V2X) to “differentiate” itself from the 802.11p based V2X technology.***
- ***The scope of functionalities supported by C-V2X includes both direct communication (V2V, V2I) as well as wide area cellular network communication (V2N).***

Views on eMBB and V2X_(11)

- ***In Release 15, 3GPP continued its C-V2X standardization, based on 5G.***
  To indicate the underlying technology, the term 5G-V2X is often used in contrast to LTE-based V2X (LTE-V2X).
  Either case, C-V2X is the generic terminology that refers to the V2X technology using the cellular technology irrespective of the specific generation of technology.

- ***In Release 16, 3GPP further enhances the C-V2X functionality.***
  The work is currently in progress.
  In this way, C-V2X is inherently future proof by supporting migration path to 5G.

Developing V2X Services and Use Cases

Developing V2X Services and Use Cases_(1)

Vehicles can exchange information with other vehicles (V2V), with the roadside infrastructure (V2I), with a backend server (e.g., from a vehicle manufacturer or other mobility service providers) or with the Internet (V2N), with a pedestrian (V2P), etc. To refer to all these types of vehicular communication, **the term** Vehicle-to-Everything (V2X) **has been proposed**.

Connected vehicle services have existed in the market for more than 10 years with the provision of automated crash notifications, vehicle breakdown notifications, traffic information and infotainment services, *among others.*

Future vehicles will be connected, as **connectivity is a key enabler** for the provision of value added services relating to the different types of vehicles.

In the global context of road transport, **connectivity will be a critical enabler to support the takeoff of new business opportunities** relating to vehicles and the EU and Member states' policies in the context of transport.

The Internet of Things will contribute to collect additional data, complementing the data already collected by vehicles and traffic management centers

Developing V2X Services and Use Cases_(2)

***The** **automobile industry** **sees two main trends** with relevance for the 5G automotive vision:*

- ***automated driving** (e.g.: automated overtake; cooperative collision avoidance; high-density platooning)*

  and

- ***road safety** and **traffic efficiency services**.*

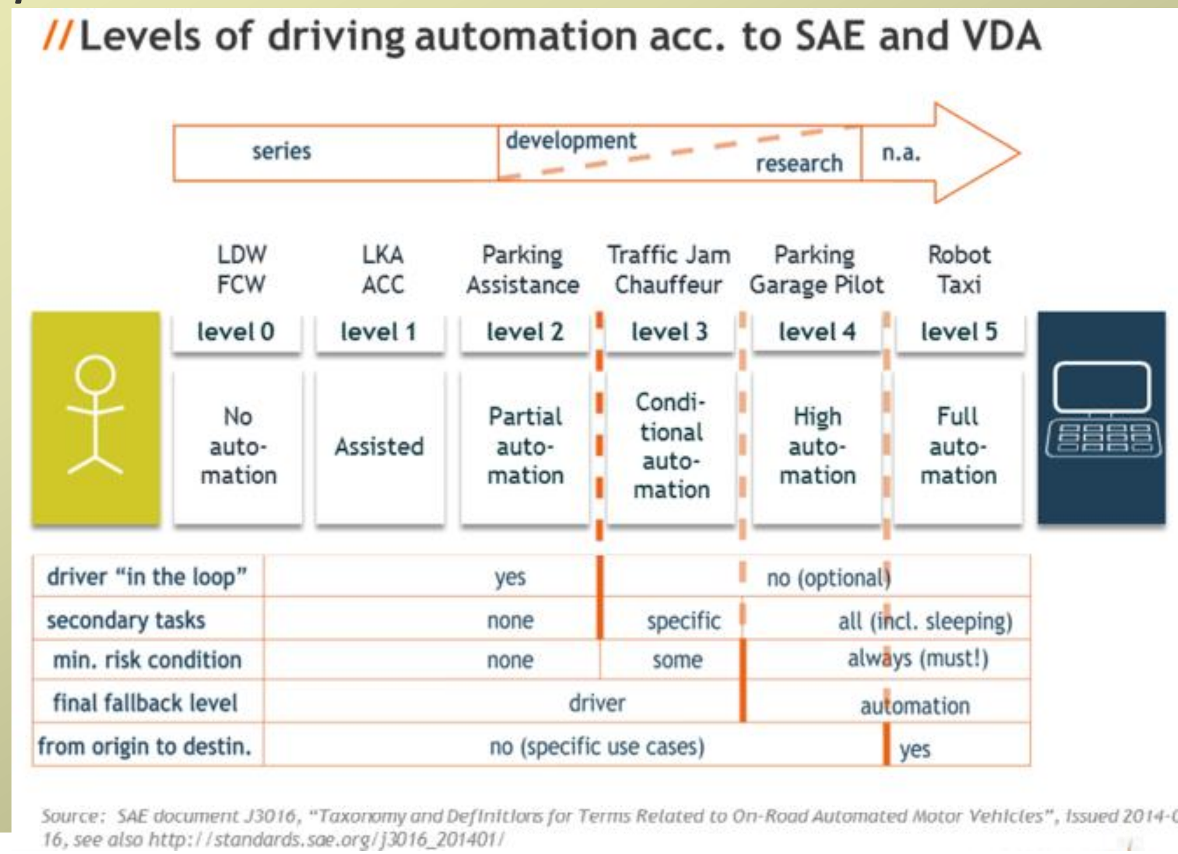
Activities from various stakeholders, including governments, in Europe and the US, are supporting -or even advocating- vehicle communication.

Developing V2X Services and Use Cases_(3)

According to the **US Society of Automotive Engineers (SAE)** and the **German Association of the Automotive Industry (VDA), six levels with increasing degree of automation are defined for automated driving** (*SAE Standard J3016, January 2014*).

An introductory scenario for automated driving with examples of possible functionalities with a time horizon until 2025 is presented below:

In principle, automated driving is possible without V2X communication, even for high and full automation.



Developing V2X Services and Use Cases_(4)

Automated Overtake: **A fully autonomous self-driving car will need to perform overtake maneuvers not only on highways** (unidirectional travel) **but also on two-way roads**, where oncoming vehicles may be well beyond the range of its sensors, but approaching very quickly. **Performing such maneuvers safely will require cooperation among vehicles on multiple lanes**, to create the necessary gap to allow the overtaking vehicle to quickly merge onto the lane corresponding to its direction of travel.

Cooperative Collision Avoidance: **This use case highlights the communication challenges faced by self-driving vehicles when trying to prevent collisions** *(e.g., at intersections in an urban environment)* **after all other traffic control mechanisms have failed.**
Collisions between two or more vehicles are prevented by controlling the longitudinal velocity and displacement of each vehicle along its path without creating hazardous driving conditions for other vehicles that are not directly involved. In such a complex and dynamic environment, upon identification of a collision risk, vehicles cannot decide individually in time to avoid a collision with an oncoming vehicle. and apply the appropriate action without prior coordination. Different individual actions might lead to additional collisions or uncontrolled situations.

High Density Plattoning **implicates for the creation of closely spaced multiple-vehicle chains on a highway, and has multiple benefits, such as fuel saving, accident prevention, etc.**
However, this requires cooperation among participating vehicles in order to form and maintain the platoon in the face of dynamic road situations. High Density Platooning will further reduce the current distance between vehicles down to 1 meter.

Developing V2X Services and Use Cases_(5)

Emergency Braking: **Being able to safely handle all the aspects of the Dynamic Driving Tasks (DDT) is a requirement for SAE (Society of Automotive Engineers) level 4 and level 5 automated vehicles.**

This includes the ability to provide safe and timely responses to unpredictable road events.

Moreover, **in more adverse situations** (e.g. sensor failing, adverse weather or road conditions), **the automated systems should be able to safely provide an automated emergency strategy (fallback).** Emergency braking systems are of paramount importance in the development of a successful collision-avoidance and automated fallback. In order to operate efficiently, these systems require precise and timely identification of road obstacles, Vulnerable Road User (VRUs), and faulty vehicle system conditions.

Lane Merging: **Autonomously merging a new lane has several of the same technological requirements of automated overtake.**

This is also an eminently cooperative task, since communication between vehicles is needed to decide on safe margins to merge. Time-to-contact, based on the vehicle's trajectories in the merging lane, needs to be accurately calculated and communicated to the vehicle making a merge manoeuvre.

Precise position estimations and low-latency communications between different vehicles will be required in order to implement safe lane merging strategies.

Developing V2X Services and Use Cases_(6)

Vehicle automation is being developed very quickly, fostered by competition.

*The information collected for vehicle automation through V2X connectivity also **enables the provision of warning applications to the driver**.*

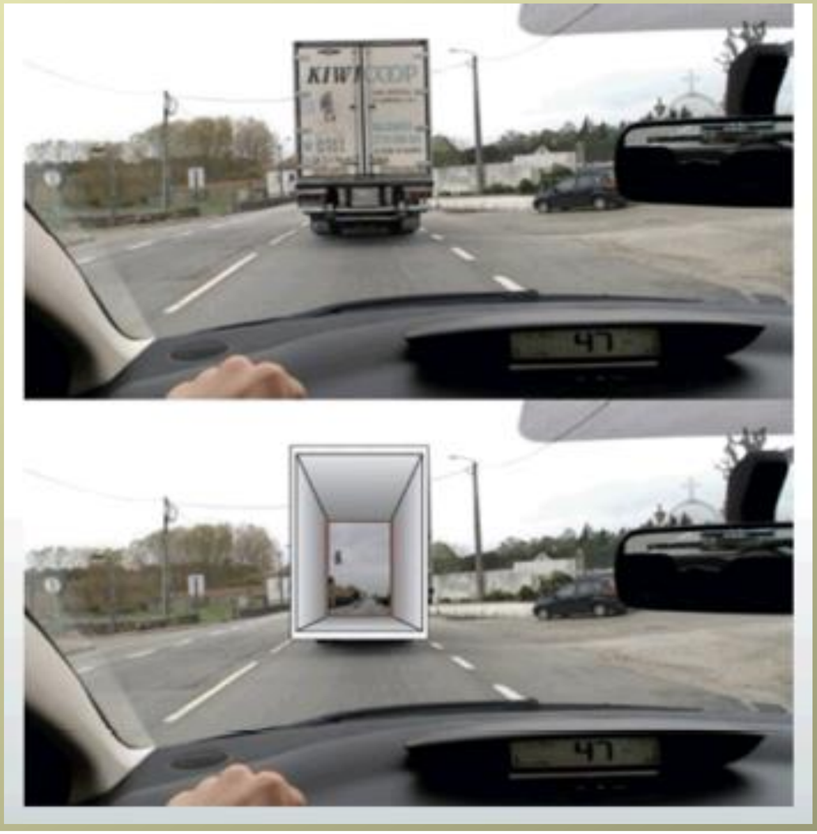
*Both EC and national funded projects have successfully demonstrated various V2X applications **supporting vehicle users towards driving more safely and efficiently,** such as:*

- *Intersection Collision Risk Warning*
- *Road hazard warnings (road works, car breakdown, weather conditions, etc.)*
- *Approaching emergency vehicle warning*
- *Pre-/Post-Crash*
- *Electronic Emergency Brake Warning*
- *GLOSA – Green Light Optimal Speed Advisory*
- *Energy-efficient intersection*
- *Motorcycle approaching information*
- *In-vehicle signage*
- *Red light violation warning*
- *Traffic jam ahead warning*

Developing V2X Services and Use Cases_(7)

- ***See-Through:*** **See-through refers to the sharing of sensory information between two vehicles (one following the other) to allow the following vehicle (and driver) to "see" what is ahead of the leading vehicle.**

- *A car can be behind a truck, when suddenly, a pedestrian is crossing the road in front of the truck.*
- *Fortunately, the truck camera detects the situation and shares the image of the pedestrian with the car, which sends an alert and shows the pedestrian in virtual reality on the windshield board.*



Developing V2X Services and Use Cases_(8)

***Vulnerable Road User (VRU) Discovery:* Vehicles periodically announce their presence and position.**

VRUs *(pedestrians, cyclists, etc., carrying a mobile device)* ***discover vehicles in proximity and begin announcing themselves.***

VRU discovery systems have the potential to improve both driver and VRU awareness of a crossing event.

The VRU mobile device may trigger a loud warning sound, vibration, flashing light, etc., in case of imminent danger.

Vehicles in proximity of an announcing VRU incorporate the received information into their Local Dynamic Map (LDM) and potentially notify both the driver and the VRU if a vulnerability situation is detected.

Developing V2X Services and Use Cases_(9)

Bird's Eye View: **An intersection** *-either in a city or on a highway at a merge-in location-* **equipped with sensors such as cameras or radar can provide this streaming information to approaching vehicles.**

The vehicles use this data stream *(maybe in conjunction with other similar data streams provided by vehicles equipped also with camera and radar sensors)* and identify eventual pedestrians or free places, which they could not detect with their on-board sensors, *so that they can better plan their future trajectories – to merge in on a highway or navigate through an intersection.*

The data streams have to be provided with very low latencies in order to allow vehicles to use the data streams similarly to the data streams provided by on-board sensors.

Developing V2X Services & Use Cases_(10)

Enhance 3D Surround View including HD Maps: **Continuous surround awareness is a vital safety concern in automated vehicles *as limited and directional vision inhibits their ability to perceive and efficiently react to dynamic events in the surrounding environment.***

- *Enhance 3D surround view combines the vision of 4 cameras mounted in vehicle.*
- *Four (-4-) cameras are jointly calibrated based on a spherical camera model to yield a bird's-eye view.*
- *The view of vicinity vehicles received by 5G will be combined to generate a HD Map of the vehicle surroundings.*
- *While the potential benefits of such solution are substantial and **to be effective it will require reliable, low-latency and high data-rate V2V communication.***

Developing V2X Services & Use Cases_(11)

Information Society on the Road

- ***Vehicle passengers can have the same demand*** *concerning connectivity performance in the vehicles* ***as at home or at work****.*

- *Furthermore,* ***partial or high automation allows the driver to use this connectivity while the car is driving autonomously****.*

- *These key transformations can "trigger" the* ***evolution of vehicle dashboards providing appropriate Human Machine Interfaces (HMIs) for using leisure and entertainment services in the vehicles***
or
allowing the drivers to use the car as a second office.

Developing V2X Services & Use Cases_(12)

In the case of connected vehicles, **5G will supersede earlier investments in ITS-G5** *(Intelligent Transport System / "G5" is a standard for car-to-car communications)* **technology**, *as currently deployed in Europe and in other regions of the world.*

This technology is based on an evolution of the WiFi standard (802.11.P) and is recognised as a technology of choice for early ITS deployment in Europe, ***targeting primarily road safety services in the first instance.***

A scenario for the consideration of 5G functionalities can be for the **provision of additional services compared to the earlier rolled out technologies**.

This could include both hazardous location notifications as well as signage applications :

- **Hazardous location notifications:**
  - *Slow or stationary vehicle(s) & Traffic ahead warning*
  - *Road works warning*
  - *Weather conditions*
  - *Emergency brake light*
  - *Emergency vehicle approaching*
  - *Other hazardous notifications*

Developing V2X Services & Use Cases_(13)

- **Signage applications:**
  - *In-vehicle signage*
  - *In-vehicle speed limits*
  - *Signal violation / Intersection Safety*
  - *Traffic signal priority request by designated vehicles*
  - *Green Light Optimal Speed Advisory ("GLOSA")*
  - *Probe vehicle data*
  - *Shockwave Damping (under the ETSI Category "local hazard warning")*

Technical Requirements and KPIs for V2X use cases:

- *End-to-end latency (ms):* **Maximum tolerable elapsed time from the instant a data packet is generated at the source application to the instant it is received by the destination application.**
- *Reliability (10-x):* **Maximum tolerable packet loss rate at the application layer** (i.e., after HARQ, ARQ, etc.). A packet is considered "lost" if it is not received by the destination application within the maximum tolerable end-to-end latency for that application. *For example, 10^{-5} means the application tolerates at most 1 in 100,000 packets not being successfully received within the maximum tolerable latency. This is sometimes expressed as a percentage (e.g., 99.999%) elsewhere.*
- *Data rate (Mbit/s):* **Minimum required bit rate for the application to function correctly**.
- *Communication range (m):* **Maximum distance between source and destination(s) of a radio transmission within which the application should achieve the specified reliability.**
- *Node mobility (km/h):* **Maximum relative speed under which the specified reliability should be achieved.**
- *Network density (vehicles/km2):* **Maximum number of vehicles per unit area under which the specified reliability should be achieved.**
- *Positioning accuracy (cm):* **Maximum positioning error tolerated by the application**.
- *Security:* **Specific security features required by the application**. These include user authentication, authenticity of data, integrity of data, confidentiality, and user privacy.

Benefits of connected and automated driving:

Vehicle manufacturers

- Optimal navigation through optimal information
  - → A very exact prognosis of the traffic
- Enable automatic driving over large parts of individual trips
  - → Very exact positioning (absolute and relative)
  - → Increased availability (also on snowy roads, less perfect markings)

Infrastructure operators

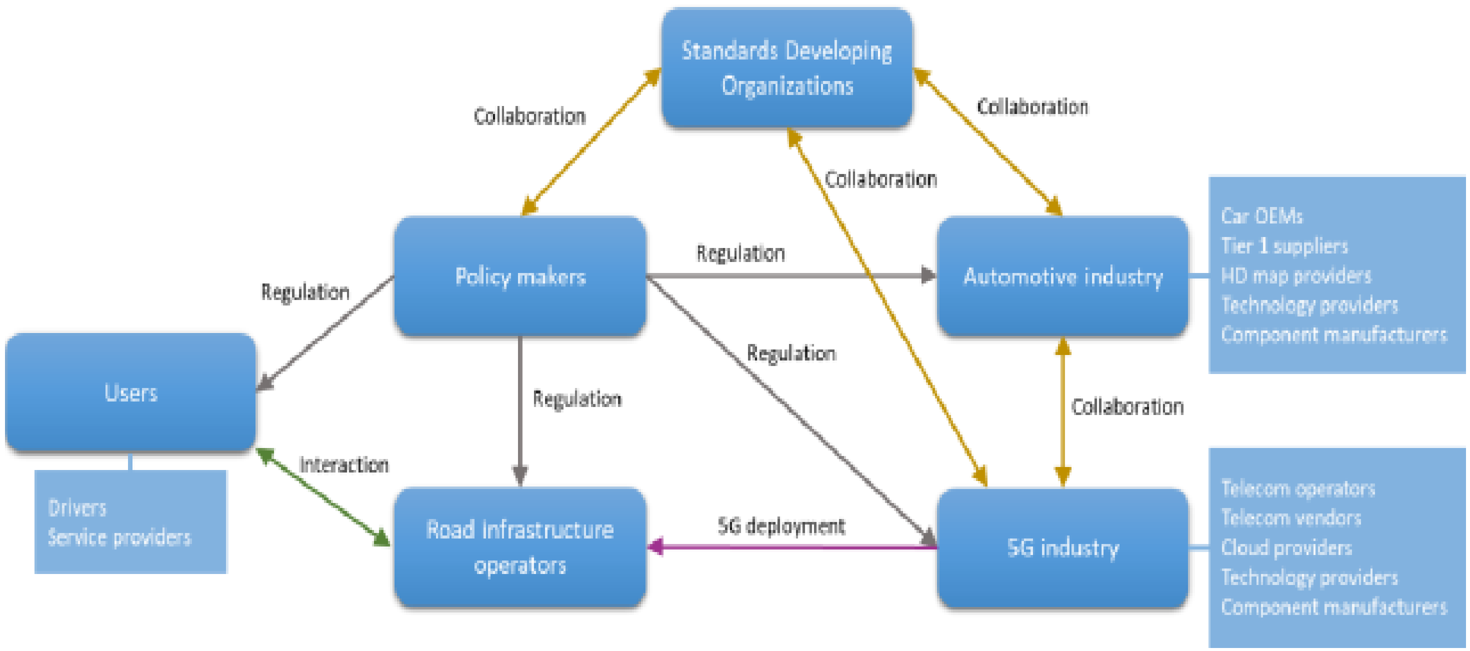
- Reduce maintenance costs
- Optimize the capacity and usage of their network
  - → Digital traffic signs / Digital data collection
  - → IRSs could complement less-perfect markings
  - → Increased availability (also on snowy roads, less perfect markings)

Developing V2X Services & Use Cases_(16)

Some main stakeholder categories involved in 5G V2X include:

5G industry, automotive industry, Standards Developing Organisations (SDOs), road infrastructure operators, policy makers, and users.

The end users can be either the drivers, or the passenger or the service providers.



European Electronic Communications Code

*The Code promotes investment and timely deployment of 5G networks and services**

- **Harmonised principles and criteria** for authorisation regimes and sharing conditions
- A **reference framework** on conditions and fees for tights of use and design of assignment processes
- A **peer review** to achieve internal market **consistency** on spectrum authorisation by building best practice
- Promotion of spectrum **trading and leasing**
- **Coordinated timing** of 5G spectrum assignment
- **Common** assignment **deadline** for **5G Pioneer Bands**: **December 2020**
- **Sufficiently long duration of rights** for 5G harmonised spectrum: **20 years** of regulatory predictability
- Facilitation of **small cells deployment** and **RLAN access**: removal of administrative obstacles and undue restrictions

* The information provided is based on the provisional agreement between the European Parliament and the Council as of 1 March 2018

Summarizing aspects:

- 5G opportunities for digital transformation
- Consistent EU framework conditions unlocking 5G investment (spectrum, small cells, investment incentives)
- Need for industry commitment
- Trials and partnerships are key to develop 5G ecosystems at early stage

For more details…

For More Details:

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5G-DRIVE Consortium

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