Use Cases for Developing enhanced Mobile Broadband Services for the Promotion of 5G

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Abstract— **The 5G-DRIVE project promotes a cooperative framework between EU and China by focusing, among others, also upon the evaluation of enhanced Mobile Broadband (eMBB). As the latter is considered as an evolution of current mobile services towards the 5G environment, it is critically important for defining opportunities for further market growth and for the rapid 5G adoption. In the present paper we have briefly discussed the two related use cases that will be about cloud-assisted virtual reality (VR) / augmented reality (AR) and indoor positioning. Both uses vases have been discussed and assessed as for the relevance towards 5G evolution, while corresponding KPIs have been proposed.**

Keywords—5G; 5G New Radio (5GNR), Augnmented Reality (AR); enhanced Mobile Broadband (eMBB); Indoor Positioning System (IPS); Virtual Reality (VR).

I. INTRODUCTION

The 5G-DRIVE project [1] as it is actually funded by the European Commission within the framework of the 5G-PPP Phase 3 [2], aims to perform a "close" collaboration between EU and China to synchronise 5G technologies and spectrum issues before the final roll-out of 5G in order to "address" two most promising 5G deployment scenarios, namely enhanced Mobile Broadband (eMBB) and Vehicle-to-Everything (V2X) communications. The main scope of the 5G-DRIVE's effort is to conduct 5G trials addressing two specific scenarios of prime importance in modern 5G-oriented applications, as follows: (i) 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; *and*; (ii) 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 Research and Innovation (R&I). Both scenarios shall be implemented in both regions through testbeds with interoperability forming the core of the R&I work.

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 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.

The eMBB is one of three primary 5G New Radio (5GNR) use cases [3] defined by the 3GPP as part of its SMARTER ("Study on New Services and Markets Technology Enablers") project ([4], [5]). The 3GPP qualifies ultra-fast mobile broadband as mobile systems capable of delivering speeds of 20 gigabits per second, at least uni-directionally, and without specific latency requirements [6]. The eMBB will initially be an extension to existing 4G services and will be among the first 5G services, which could be commercially available as early as 2019. The objective behind SMARTER [7] was to develop high level use cases and identify what features and functionality 5G would need to deliver to enable them. This specific project began in 2015 and resulted in over 70 use cases, initially grouped into five essential categories which have, *since*, been trimmed to three. They are characterised by the performance attributes the particular use cases will require, although there is some overlap. SMARTER has resulted to three fundamental sets of use cases, including: (i) enhanced Mobile Broadband (eMBB); (ii) Ultra-Reliable Low Latency Communications (URLLC), and; (iii); massive Machine Type Communications (mMTC).

One among the critical objectives of 5G wireless technology is to support the above three generic services with vastly heterogeneous requirements, that is eMBB, mMTC and URLLC. Service heterogeneity can be accommodated by network slicing, through which each service is allocated resources to provide performance guarantees and isolation from the other services [8]. Under a broader concept, the Mobile Broadband (MBB) enhancements aim to fulfil a number of innovative KPIs. These pertain to high data rates, high user density, high user mobility, highly variable data rates, deployment, and coverage. High data rates are driven by the increasing use of data for services such as streaming (e.g., video, music, and user generated content), interactive services (e.g., Augmented Reality (AR)), and internet of Things (IoT).

II. ENHANCED MOBILE BROADBAND'S SCOPE

The enhanced Mobile Broadband (eMBB) "addresses" the human-centric use cases for access to multimedia content, services and data. Based on the original scope of the SMARTER approach, related requirements have been defined on high data rates, higher traffic or connection density, high user mobility, and those relevant to various deployment and coverage scenarios. The scenarios have addressed different service areas (e.g., indoor/outdoor, urban and rural areas, office and home, local and wide areas connectivity), and special deployments (e.g., massive gatherings, broadcast, residential, and high-speed vehicles). Actual technology trends purely "demonstrate" that the demand for mobile broadband will continue to increase, thus leading to enhanced Mobile Broadband. The enhanced Mobile Broadband usage scenario will come with new application areas and requirements in addition to existing Mobile Broadband applications for improved performance and an increasingly seamless user experience. This usage scenario covers a range of cases, including wide-area coverage and hotspot, which have different requirements. We can distinguish the following: (i) For a hotspot case, that is for an area with high user density, very high traffic capacity is needed, while the requirement for mobility is low and user data rate is higher than that of wide area coverage; (ii) For the wide area coverage case, seamless coverage and medium to high mobility are desired, with much improved user data rate compared to existing data rates. However, the data rate requirement may be relaxed compared to hotspot. The eMBB traffic can be considered to be a direct extension of the 4G broadband service. It is characterized by large payloads and by a device activation pattern that remains stable over an extended time interval. This allows the network to schedule wireless resources to the eMBB devices such that no two eMBB devices access the same resource simultaneously. The objective of the eMBB service is to maximize the data rate, while guaranteeing a moderate reliability, with packet error rate (PER) on the order of 10^{-3}.

More specifically, to support the initial rollout of eMBB services, since March 2017 the 3GPP's RAN (Radio Access Network) Group committed to finalise the Non-Standalone (NSA) 5G NR variant by March 2018. In fact, the standard was approved in December 2017 [9]. 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. This is the configuration that will be the target of early 2019 deployments (in 3GPP terminology, this is NSA 5G NR deployment scenario Option 3). 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", which will be encompassed in the 3GPP Release 15 standard [9]. The 5G Phase 2 will go beyond the 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. By considering the case of connected cars as a characteristic example, the first phase of eMBB services will include enhanced in-vehicle infotainment, like real-time traffic alerts, high-speed internet access, streaming real-time video or playing games involving 3D 4K video. The second phase would involve autonomous vehicles on a mass scale capable of connecting to and interacting with other vehicles and/or with the nearby road infrastructure [10].

Following to the above context, the eMBB can be seen as a natural development of current 4G networks that will deliver faster data rates and, *consequently*, a better user experience than present mobile broadband services [11]. Nevertheless, it is expected that eMBB will evolve further and assure faster downloads to offer a progressively more seamless user experience that will conceal the quality of service we now experience from fixed broadband technologies. In the long run, it will also allow the provision of 360° video streaming, rightly immersive Virtual Reality (VR) and Augmented Reality applications and a variety of modern solutions.

An overview of the 5G-DRIVE's eMBB-based use cases that will be realised in the trial site of the University of Surrey (UoS) and its 5GIC [12] are described in the following section. The related site provides unique state-of-the-art 5G test and demonstration platforms.

III. USE CASES FOR eMBB

A. *Cloud-assisted AR/VR*

Virtual Reality (VR) is the term used to describe a three-dimensional, computer-generated environment that can be explored and interacted with by a person. That person becomes part of this virtual world or is immersed within this environment and whilst there, is able to manipulate objects or perform a series of actions. One of the major developments in virtual reality is CAVE (CAVE Automatic Virtual Environment), in which the person is fully immersed within it. CAVE takes the form of a cube-like space in which images are displayed by a series of projectors. Some systems enable the person to experience additional sensory input, such as sound or video, which contributes to the overall experience. A main feature of the CAVE system is interaction. The combination of interaction and total immersion is known as "telepresence", in which a person can literally lose themselves within the virtual environment. Interaction takes place using a variety of input devices, such as a joystick, a wand or, more commonly, a haptics device (e.g., data glove). This enables the person to interact with objects, for example, by pulling, twisting, or gripping by means of touch. The ability to do this is known as haptics. VR engineering includes the use of 3D modeling tools and visualization techniques as part of the design process. This technology enables engineers to view their project in 3D and gain a greater understanding of how it works. Plus they can spot flaws or potential risks before implementation. This also allows the design team to observe their project within a safe environment and make changes as necessary. What is important is the ability of virtual reality to depict fine-grained details of an engineering product to maintain the illusion. This means high-end graphics, video with a fast refresh rate, and realistic sound and movement.

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, haptic, somatosensory and olfactory [13]. The overlaid sensory information can be constructive (i.e. additive to the natural environment) or destructive (i.e. masking of the natural environment) and is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment. In this way, augmented reality alters one's ongoing perception of a real-world environment, whereas virtual reality completely replaces the user's real-world environment with a simulated one. Augmented reality is related to two largely synonymous terms: mixed reality and computer-mediated reality. The primary value of augmented reality is that it brings components of the digital world into a person's perception of the real world, and does so not as a simple display of data, but through the integration of immersive sensations that are perceived as natural parts of an environment. The first commercial augmented reality experiences were used largely in the entertainment and gaming businesses, but now other industries are also getting interested about AR's possibilities (for example in knowledge sharing, educating, managing the information flood and organizing distant meetings). Augmented reality is also transforming the world of education, where content may be accessed by scanning or viewing an image with a mobile device or by bringing immersive, markerless AR experiences to the classroom. Augmented reality is used to enhance natural environments or situations and offer perceptually enriched experiences. With the help of advanced AR technologies (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable. Information about the environment and its objects is overlaid on the real world. This information can be virtual or real, e.g. seeing other real sensed or measured information such as electromagnetic radio waves overlaid in exact alignment with where they actually are in space. Augmented reality also has a lot of potential in the gathering and sharing of tacit knowledge. Augmentation techniques are typically performed in real time and in semantic context with environmental elements. Immersive perceptual information is sometimes combined with supplemental information like scores over a live video feed of a sporting event. This combines the benefits of both augmented reality technology and heads-up display technology (HUD).

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), 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.

While some new technologies, such as eye tracking and foveated rendering are essential ingredients for high-resolution head-mounted displays (HMDs), bandwidth and latency requirements have pushed the expectations for 5G networks. As it is known, display resolutions and high immersive content play a key role to push users to seek out more robust data service and plans. FOV (Field of View) could range from 1080x1200 per eye to retina AR display (6600x600) per sys and require data rates at the low end (30 fps) between 100 Mbps to 9.4 Gbps at the high end (120 fps). 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. Fig.1 depicts an overview of the corresponding setup for validating the related use case.

Fig. 1. 5GIC Kinect sensors setup for providing cloud-assisted AR experiment

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

- 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.

B. *Indoor Positioning*

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 [14]. There are several commercial systems on the market, but there is no specific standard for an IPS system. IPS can be used to locate people or objects inside buildings, typically via a mobile device such as a smart phone or tablet. Although the technology is newer than GPS, services that leverage IPS are quickly gaining traction in places like shopping malls, hospitals, airports and other indoor venues where navigation and other location-based services (LBS) can prove to be indispensable.

Indoor positioning systems use different technologies, including distance measurement to nearby anchor nodes (nodes with known fixed positions, e.g. WiFi/LiFi access points or

Bluetooth beacons), magnetic positioning and dead reckoning [15]. They either actively locate mobile devices and tags or provide ambient location or environmental context for devices to get sensed. The localized nature of an IPS has resulted in design fragmentation, with systems making use of various optical, radio or even acoustic technologies. For smoothing to compensate for stochastic (unpredictable) errors there must be a sound method for reducing the error budget significantly. The system might include information from other systems to cope for physical ambiguity and to enable error compensation. Detecting the device's orientation (often referred to as the compass direction in order to disambiguate it from smartphone vertical orientation) can be achieved either by detecting landmarks inside images taken in real time, or by using trilateration with beacons. There also exist technologies for detecting magnetometric information inside buildings or locations with steel structures or in iron ore mines.

Due to the signal attenuation caused by construction materials, the satellite based Global Positioning System (GPS) loses significant power indoors affecting the required coverage for receivers by at least four satellites. In addition, the multiple reflections at surfaces cause multi-path propagation serving for uncontrollable errors. These very same effects are degrading all known solutions for indoor locating which uses electromagnetic waves from indoor transmitters to indoor receivers. A bundle of physical and mathematical methods are applied to compensate for these problems. Promising direction radiofrequency positioning error correction opened by the use of alternative sources of navigational information, such as inertial measurement unit (IMU), monocular camera Simultaneous Localization and Mapping (SLAM) and WiFi SLAM. Integration of data from various navigation systems with different physical principles can increase the accuracy and robustness of the overall solution.

Indoor position information obviously 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.

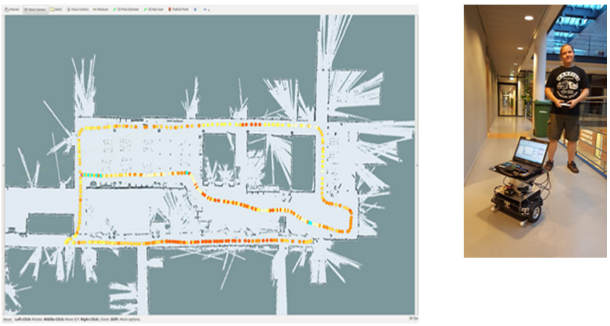

Fig. 2. Measurement route and mobile robot for providing reference location and indoor maps

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. Due to the nature of network control and monitoring, additional signalling overhead gets created from sending infrequently small packets. From the mobile network side, this requires re-allocation and scheduling of radio resources with increased latency. Location information can be used by the network and devices to optimise communication and to save energy by reducing signalling. 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 are listed as follows:

- Peak data rate: already defined in the previous part B of the per cent section.
- 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.

IV. CONCLUSIONS

5G-DRIVE is a modern innovative cooperative framework between the EU and China, aiming to promote innovative solutions for two essential scenarios, one of which is about the enhanced Mobile Broadband promotion. In fact, eMBB can be assessed as an important evolutionary development of current 4G networks aiming to deliver faster data rates as well as improved user experience if compared to current mobile broadband services. The 5G-DRIVE has proposed two fundamental use cases for further trials, including cloud-assisted AR/VR and indoor positioning. Both use cases that are of market importance have been discussed and initially assessed under a conceptual framework, together with the definition of several corresponding KPIs. Further work in the project will provide more concrete results

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