5G Service Requirements and Operational Use Cases: Analysis and METIS II Vision

Salah Eddine Elayoubi[1], Mikael Fallgren[2], Panagiotis Spapis[3], Gerd Zimmermann[4], David Martín-Sacristán[5], Changqing Yang[6], Sébastien Jeux[1], Patrick Agyapong[7], Luis Campoy[8], Yinan Qi[9], Shubhranshu Singh[10]
[1]Orange Labs, France; [2]Ericsson, Sweden; [3]Huawei Technologies ERC, Germany; [4]Deutsche Telekom, Germany; [5]Universitat Politècnica de València, Spain; [6]Huawei, China; [7]NTT Docomo Eurolabs, Germany; [8]Telefonica, Spain; [9]Samsung Electronics R&D Institute, UK; [10]ITRI, Taiwan

***Abstract*— One of the objectives of METIS-II project is to facilitate discussion on scenarios, use cases, KPIs and requirements for 5G, building upon the comprehensive work conducted in the METIS-I project and taking the work of other European projects as well as other bodies such as ITU-R, NGMN, etc. into account. This paper analyses the landscape of 5G use cases and presents METIS-II 5G use cases that cover the main 5G services, have stringent requirements and whose technical solutions are expected to serve other similar use cases as well. It also links these use cases to the business cases defined by 5G PPP so that requirements of vertical industries can be taken into account when designing the 5G Radio Access Network (RAN).**

Keywords—5G use cases, vertical industries, 5G PPP, METIS-II

I. INTRODUCTION

After several years of research on next generation communications system, there is already a wide consensus on the 5G service landscape, and in particular on the view that 5G will not only be a "business-as-usual" evolution of 4G cellular mobile networks, with new spectrum bands, higher spectral efficiencies and higher peak throughputs, but will also target new services and new business models. These latter are to be developed in close collaboration with vertical industries and imply new requirements and new ways of thinking, building and managing the network. The analysis of the needs and requirements of these verticals has led the METIS-I project [1], and forums such as Next Generation Mobile Network (NGMN) Alliance [2] and ITU-R [3] to consider the following three main 5G service types:

- **Extreme Mobile BroadBand (xMBB)**, often also referred to as enhanced MBB (eMBB), requiring both extremely high data rates and low-latency communication in some areas, and reliable broadband access over large coverage areas.
- **Massive Machine-Type Communications (mMTC)**, requiring wireless connectivity for up to tens of billions of network-enabled devices worldwide. Here, scalable connectivity for an increasing number of devices, wide area coverage and deep indoor penetration are key priorities.
- **Ultra-reliable Machine-Type Communications (uMTC)**, requiring ultra-reliable low-latency and/or resilient communication links for, e.g., vehicle to anything (V2X) communication and industrial control applications.

Having in mind that only a common RAN that accommodates all three service types can be economically and environmentally sustainable, the RAN design is to be performed towards a set of 5G use cases that typically combine multiple service types. We call these as **operational** use cases since they correspond to real situations where the mobile network operators will have to operate and manage the 5G network. The definition of these use cases (UCs) is crucial for the design phase of 5G as these use cases will serve for benchmarking solutions from performance and cost points of views.

The objective of this paper is twofold. First, we analyze in Section II the 5G use cases proposed in the literature, including earlier EU-funded projects and standardization fora, extracting groups of use cases with similar characteristics and requirements. Based on this analysis, we derive in Section III a small set of use cases that METIS-II project considers as representative for the 5G RAN design.

It is worth noting that, in parallel to this work on operational use cases, 5G Infrastructure Public Private Partnership (PPP) was working on the needs of vertical industries and derived the so-called **business** cases. The difference between these vertical oriented business cases and the operational use cases is that a use case of the former focuses on one service of a particular vertical, while the latter have to cover simultaneously several services belonging to several verticals. We show in Section IV how METIS-II use cases can be mapped to these business cases.

II. 5G USE CASES IN THE LITERATURE

5G research has been quite active in the past years. Thus, several EU funded projects have attempted to create pioneering scenarios for identifying the requirements of 5G. Similarly other initiatives like NGMN, and standardization bodies, like 3GPP and ITU-R, have captured the respective requirements so as to drive the research for handling the future demands. This process resulted in a large number of scenarios and UCs focusing on diverse requirements. Given the large number of UCs, it would be unrealistic to consider all the UCs proposed by the research community and the standardization bodies and fora for evaluation of the 5G RAN design solutions. Thus one of the purposes of METIS-II, which aims to drive 5G research, is to identify the most representative scenarios and use them for the evaluation of the proposed mechanisms. We present here an analysis that identifies similarities and gaps of the already proposed UCs. This section presents a thorough analysis of the UCs of METIS-I, and other EU research projects, as well as those considered by NGMN, 3GPP, and ITU-R. The analysis of the presented scenarios and UCs resulted in the final selection of 5 UCs that are most representative and are presented in the next section.

A. Analysis of METIS-I and European projects use cases

METIS-I, proposed 21 UCs, presented in Table 1, which have been used for evaluating the technology components developed in the project [1].

Table 1: METIS-I Use Cases.

UC name	xMBB	uMTC	mMTC	Key Characteristics
UC1: Virtual reality office	X	-	-	Low user density, and very high data rate, no mobility
UC2: Dense urban information society	X	-	-	High user density, and high data rate, high mobility
UC3: Shopping mall	X	-	-	High user density, and high data rate, low mobility
UC4: Stadium	X	-	-	High user density, and high data rate, with busrty traffic, low mobility
UC5: Tele-protection in smart grid network	-	X	-	Low data rate, no mobility
UC6: Traffic jam	X	-	-	High data rate, in areas with limited infrastructure
UC7: Blind spots	X	-	-	High data rate, in areas with limited infrastructure, and low user density
UC8: Real time remote computing for mobile terminals	X	-	-	High data rate, high mobility
UC9: Open air festival	X	-	-	High data rate, in areas with limited infrastructure, and high user density
UC10: Emergency communications	-	X	-	Low data rate, no infrastructure, high energy efficiency
UC11: Massive deployment of sensors and actuators	-	-	X	Very large number of devices, low data rate, energy efficiency
UC12: Traffic efficiency and safety	-	X	-	Low data rate, very low latency
UC13: Gaming	X	-	-	Low user density, and high data rate, no mobility
UC14: Marathon	X	-	X	High data rate, limited infrastructure, and high user density, diverse traffic
UC15: Media on demand	X	-	-	High data rate, no mobility, several users
UC16: Unmanned aerial vehicles	X	-	-	High data rate, in areas with limited infrastructure
UC17: Remote tactile interaction	-	X	-	Very low latency, no mobility
UC18: eHealth	-	X	-	Low latency, high mobility
UC19: Ultra-low cost 5G network	X	-	-	High data rate, limited infrastructure, low cost
UC20: Remote car sensing and control	-	-	X	Very large number of devices, low data rate,
UC21: Forest industry on remote control	X	X	-	Large number of devices, high data rate, low latency

Based on Table 1, we identify the similarities between UCs and group them in families (bottom up approach):

- Group 1: UCs that mainly address static users in indoor environmentwith high data rate requirements, targeting xMBB service type.
- Group 2: UCs that have moving users in indoor and outdoor environments, with high user density, and whose considered 5G service type is xMBB.
- Group 3: UCs that focus on high reliability and availability, with relatively low user density and whose considered 5G service type is uMTC.
- Group 4: UCs that focus on the user density and the considered 5G service is type mMTC.

Several European FP7 projects have produced their respective UCs, so as to evaluate the developed solutions. The UCs described and used in these projects tend to identify similar requirements compared to the ones of METIS I. Specifically, the UCs of 5GNOW [4], COMBO [5], MiWEBA [6], MAMMOET [7], MOTO [8], TROPIC [9], iJOIN [10] have been analyzed and mapped to the METIS-I UCs. A summary of the findings is given in Table 2.

Table 2: European Projects mapping to Use Case groups.

UC group	METIS-I UCs in the group	Other EU projects
Group 1	UC1, UC13, UC15	Generic Use case for small cells cloud services: Bottom up scenario – processing/workload distribution (TROPIC), Corporate Virtual Desktop (TROPIC)
Group 2	UC2, UC3, UC4, UC6, UC7, UC8, UC9, UC14, UC16, UC19	All iJoin UCs, All COMBO UCs, All MiWEBA UCs,All MAMMOET UCs, All MOTO UCs
Group 3	UC5, UC10, UC12, UC17, UC18, UC21	Real time (5GNOW)
Group 4	UC11, UC20	M2M: sensing, collecting (5GNOW)

The description of the UCs of the analyzed projects is mainly based on the 5G service type, the number of users, their mobility, the latency requirements and the infrastructure availability. The analysis of these UCs leads to the outcome that mainly xMBB UCs are being considered, whereas a limited number of UCs targets mMTC and uMTC, lacking the level of details that they have in METIS-I.

B. Standardization fora and bodies use cases

Standardization bodies and fora have been active in defining their UCs, so as to extract in a proper manner the respective 5G requirements. In this section we analyze NGMN UCs, as well as approaches of the ITU-R and 3GPP for defining their scenarios.

1) NGMN

According to NGMN [2], the business context beyond 2020 will be notably different from today since it will have to handle the new UCs and business models driven by the customers' and operators' needs. Apart from the support of the evolution of mobile broadband, 5G will have to handle new UCs ranging from ultra-low latency applications to high speed entertainment applications in a vehicle, and from best effort applications to reliable and ultra-reliable ones such as health and safety. Thus, NGNM has proceeded in a thorough analysis for capturing all the customers' and operators' needs. The analysis is based on 25 UCs for 5G grouped into 8 UC families. The UCs and UC families serve as an input for stipulating requirements and defining the building blocks of the 5G architecture [2]. Following the same procedure as in previous subsection for the European projects UCs, we map the NGMN UCs to the identified UC groups.

Table 3: NGMN UCs mapping to Use Case groups.

UC group	NGMN UCs in the respective group
Group 1	UC2: Smart Office
	UC4: HD Video/Photo Sharing in Stadium/Open-Air Gathering
Group 2	UC1: Pervasive Video
	UC3: Operator Cloud Services
	UC6: Ultra-low Cost Networks
	UC7: High Speed Train
	UC8: Remote Computing
	UC9: Moving Hot Spots
	UC10: 3D Connectivity - Aircraft
	UC22: News and Information
	UC23: Local Broadcast-like Services
	UC24: Regional Broadcast-like Services
	UC25: National Broadcast-like Services
Group 3	UC14: Tactile Internet
	UC15: Natural Disaster
	UC16: Automated Traffic Control and Driving
	UC17: Collaborative Robots: A Control Network for Robots
	UC18: eHealth: Extreme Life Critical
	UC19: Remote Object Manipulation: Remote Surgery
	UC20: 3D connectivity: Drones
	UC21: Public Safety
Group 4	UC11: Smart Wearables
	UC12: Sensor Networks
	UC13: Mobile Video Surveillance

Table 3 maps the NGMN UCs to the UC groups, as they came up in Section II-A. As shown in Table 3, most of the NGMN UCs can be grouped in the considered categories. The two UCs that couldn't be mapped to the groups are UC5 "50+ Mbps everywhere", which considers mobility combined with xMBB service, with lack of infrastructure and UC16 "Automated Traffic Control and Driving", which considers heavy moving users (i.e., cars) which have to exchange (a) information transfer with high reliability and with very low latency, and, (b) xMBB service among the cars. This use case may be seen as a mixture of METIS-I UCs 8 (Real-time remote computing for mobile terminals) and 12 (Traffic efficiency and safety). However, it focuses on the ultra-reliability nature, since it refers to automated driving, whereas METIS-I UC8 is related to remote computing, focusing on the xMBB nature.

2) ITU-R

ITU-R defined in [3] the overall objectives of the future development of International Mobile Telecommunications (IMT) for 2020 and beyond. Similarly to METIS-I, ITU-R has identified three directions of services, namely "Enhanced mobile broadband", "Ultra-reliable and low latency communications", and "Massive machine type communications". The three scenarios have certain key capabilities related to data rates, latency, energy efficiency, etc. Specifically, as shown in Figure 1, "Enhanced mobile broadband" focuses on data rate, network energy efficiency, spectrum efficiency and mobility. On the other hand, the "Ultra reliable and low latency communication" focuses on high mobility use cases where the key requirement is the low latency. Finally, the "Massive machine type communications", targets network energy efficiency coupled with high connection density.

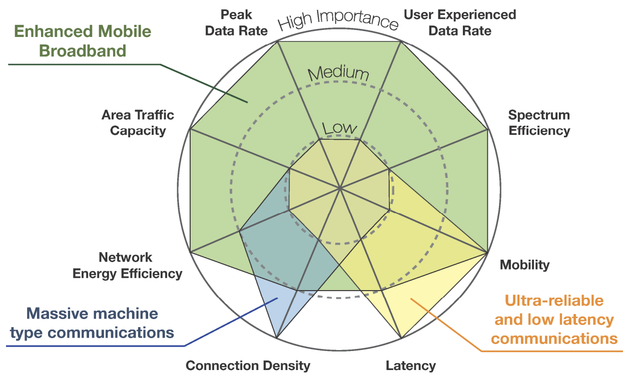

Figure 1: Importance of the key capabilities for different usage scenarios of IMT beyond 2020 [3]

3) 3GPP

3GPP SA1 in March 2015 started working on a new Study Item called "Study on New Services and Markets Technology Enablers" (FS_SMARTER) [11]. The work focuses on UCs and requirements that cannot be met with today's LTE system. In first phase, SA1 developed 74 use cases for various scenarios and identified related high-level requirements. In the ongoing second phase, SA1 grouped together UCs with common characteristics and agreed on four building blocks or categories: massive Internet of Things, Critical Communications, enhanced Mobile Broadband, and Network Operation (TR 22.891 [12]). The latter category covers UCs which are more related to future network set-up and operation such as Network slicing, Coexistence with legacy systems, Flexible application traffic routing, Network enhancements to support flexibility, scalability, and automation, and Wireless backhauling. These are out of scope of METIS-I UCs since METIS-I UCs are user and service-centric.

The service-related UCs of the first 3 categories cover different xMBB usage scenarios, e.g. for indoor and hotspot scenarios (incl. "virtual presence") as well as seamless wide-area coverage. In addition, use cases for low mobility as well as high mobility including connectivity to cars are listed. Also broadcasting is highlighted by use cases. Typical mMTC service is reflected by several use cases such as "Wide area sensor monitoring and event driven alarms", "Low mobility devices", as well as by use cases addressing configuration of such "low-cost devices". Several use cases listed are related to uMTC scenarios, such as "Tactile internet", "Industrial control and factory/process automation", "Robotics", "Localized as well as wide-area remote control" (e.g., connectivity for drones), etc. Further examples are on emergency and lifeline communications as well as on highly accurate user/device positioning and tracking. These service-related use cases in TR 22.891 are already considered to a large extent by the corresponding descriptions of METIS-I scenarios and test/use cases [1], at least w.r.t. their challenging requirements.

3GPP SA1 is also working on 3 other Study Items which have some relevance for 5G. These are related to V2X (TR 22.885 [13]) and mission critical communications (TR 22.879 [14] and TR 22.880 [15]). In most cases, the UCs do not provide dedicated values for Key Performance Indicators (KPIs) which can be transferred to 5G, but only functional requirements that wireless systems are expected to fulfill.

III. THE FIVE USE CASES OF THE METIS-II PROJECT

The large number of METIS-I UCs made their analysis and use for evaluation hard, thus indicating that in METIS-II a more concise approach should be followed, without losing the details of each UC. Thus, based on the analysis presented in the previous section the identified METIS-I UC groups combined with the identified required extensions, so as to cover the other proposals from European projects and standardization bodies and fora. Five UCs were selected to be used as a basis of METIS-II evaluations. In this section the five METIS-II UCs and their main KPIs and requirements are presented. More details are provided in [16].

A. *Use case descriptions*

1) UC1: Dense urban information society

In the future of a dense urban society the exchange of information will be more vital than today. The traffic between humans together with machine and cloud interactions therefore needs to be handled in an even more efficient way in order to enable the success of new 5G services, such as immersive Ultra-High Definition (UHD) video streaming, cloud gaming, and ubiquitous mobile video surveillance. This UC is directly linked with METIS-I UC2.

2) UC2: Virtual reality office

The interactive video communication will increase in the future for both personal and professional use. Today's tele-presence services will evolve into high-resolution 3D versions, allowing friends and relatives to have an amazing "as if you were there" experience. On the professional side, the technology developed will support this kind of complex interactive work, by means of e.g. virtual reality imaging. This UC comes from the METIS-I UC1.

3) UC3: Broadband access everywhere

High quality broadband access is needed everywhere. The ubiquitous capacity demands of future users will be challenging to satisfy in sparse network infrastructure areas, such as scarcely populated areas, rural and even suburban areas. The wide coverage and flexible solutions need to be energy and cost efficient in order to provide ubiquitous coverage in those remote rural and suburban areas. This UC is based on NGMN UC5 since it could not be covered by the identified METIS-I UC groups as analyzed in Section II.B.1.

4) UC4: Massive distribution of sensors and actuators

The importance of this use case will grow together with the massive deployment of low cost and of low energy consumption devices. In order to get the maximum of information from these devices, to increase environmental awareness and better user experience, there is a need for these devices to be able to communicate with other devices, the network, or with other mobile phones. This UC covers the mMTC service and is linked with METIS-I UC11.

5) UC5: Connected cars

With higher user mobility enabled services on-the-way both workers and leisured peoples can enjoy the benefits of real-time remote computing. At the same time, the connected car provides a safe and efficient journey by communicating with its surrounding. This communication enables the car to avoid accidents, perform traffic planning to avoid traffic jam and to minimize fuel consumption. This UC is a combination of the METIS-I UC8, METIS-I UC12 and NGMN UC16.

B. *KPIs and requirements*

The main KPIs and requirements of the five use cases in METIS-II are given in Figure 2. On a higher level the three main 5G service: xMBB; mMTC; uMTC; are used to depict and span the foreseen future trends.

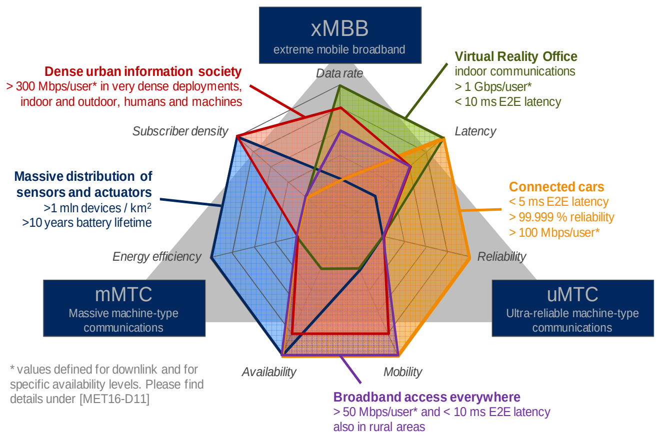

Figure 2: The METIS-II 5G use cases and their mapping to the 5G services.

The extreme mobile broadband related use cases focus on the ability to provide certain amount of data rates to the end-users while also fulfilling additional requirements. The massive machine-type communications use case focuses on the foreseen massive number of devices that wants to communicate and their individual need for long battery life. The ultra-reliable machine-type communications use case addresses high reliability combined with low latency.

An overall design goal for the 5G system is to be highly energy efficient. The amount of energy consumed by the infrastructure and the battery consumption of the devices are to be at low levels while providing the 5G services.

IV. 5G USE CASES MAPPED TO VERTICAL INDUSTRY NEEDS

While METIS-II use cases have been intentionally mixing services with different requirements for the purpose of challenging the 5G RAN design, 5G PPP adopted a vertical industry driven approach. Each of its **business** cases addresses a specific vertical service, as described in the 5G PPP white papers on verticals requirements[1]. We introduce these business cases and show how the METIS-II UCs can map into them.

A. 5G PPP business cases

Table 4 illustrates the ambition of 5G PPP for a 5G network federating the needs of vertical industries. Several business cases are defined for each vertical industry, as detailed in [17].

Table 4: vertical industries business cases.

Vertical	Associated business cases
Automotive	Al-Automated driving. A2- Road safety and traffic efficiency services. A3- Digitalization of transport and logistics. A4- Intelligent navigation. A5- Information society on the road. A6- Nomadic nodes.
eHealth	H1- Assets and interventions management in Hospitals H2- Robotics H3- Remote monitoring of health or wellness data H4- Smarter medication
Energy	El-Grid access E2- Grid backhaul E3- Grid backbone
Media & Entertainment	ME1- Ultra High Fidelity Media: ME2- On-site Live Event Experience ME3- User Generated Content & Machine Generated Content ME4- Immersive and Integrated Media: ME5- Cooperative Media Production: ME6-Collaborative Gaming
Factories of the Future	Fl- Time-critical process optimization inside factory to support zero-defect manufacturing; F2- Non time-critical optimizations inside factory to realize increased flexibility and ecosustainability; F3- Remote maintenance and control optimizing the cost of operation while increasing uptime. F4- Seamless intra-/inter-enterprise communication, allowing the monitoring of assets distributed in larger areas and the efficient coordination of cross value chain activities F5- Connected goods

B. How METIS-II use cases map to the business cases

Having a closer look of the business cases of Table 4, we can see that METIS-II operational use cases cover the requirements of most of them as follows:

- UC1 "Dense urban information society", covers requirements of H3, H4, ME1, ME3, ME4, ME6, F2 to F5.
- UC2 "Virtual reality office" focusing on xMBB service for indoor environments and static users, covers requirements of H2, ME5.
- UC3 "Broadband access everywhere" with focus on high availability for xMBB in areas with limited infrastructure, covers requirements of H3, F3, F4, E1.

[1] https://5g-ppp.eu/5g-for-vertical-sectors/

- UC4 "Massive distribution of sensors and actuators" with focus on massive connectivity of objects, covers requirements of F5, H3, ME2, ME3.
- UC5 "Connected cars" with focus on highly reliable communications, combined with xMBB, covers the requirements of the automotive cases, A1 to A5.

A 5G network that fulfills the requirements of the METIS-II operational use cases would thus be able to address the needs of verticals industries as defined in the business cases.

V. Conclusion

This paper presents a comprehensive analysis of 5G use cases of EU-funded projects, such as METIS-I, and of standardization bodies and fora (NGMN, ITU-R and 3GPP). Based on this analysis, we developed five representative use cases for the METIS-II project. We then show how these use cases map to the vertical-driven business cases. These five use cases will be used as the basis for the evaluation of 5G RAN design solutions developed in METIS-II.

Acknowledgment

The work in METIS-II is performed under the H2020 framework in the H2020-ICT-2014-2 call.

References

[1] ICT-317669 METIS, Deliverable 1.5 Version 1, "Updated scenarios, requirements and KPIs for 5G mobile and wireless system with recommendations for future investigations", April 2015.

[2] NGMN Alliance, "NGMN 5G White paper", February 2015.

[3] ITU-R Working Party WP 5D: Draft New Recommendation "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond", Doc. R12-SG05-C-0199, June 2015.

[4] ICT– GA 318555 "5G Cellular Communications Scenarios and System Requirements", March 2013.

[5] S. Gosselin et al., "Fixed and Mobile Convergence: Needs and Solutions", European Wireless 2014, 14-16 May 2014.

[6] ICT-608637, "Definition of Scenarios and Use Cases", December 2013

[7] ICT- 619086, "System scenarios and requirements specifications", January 2015.

[8] ICT- 317959, "Use Cases and Requirements", February 2013.

[9] ICT-318784, "Scenarios and Requirements", July 2013.

[10] ICT-317941 iJOIN, "Final Definition of iJOIN Requirements and Scenarios", November 2014.

[11] 3GPP SA, "Study on New Services and Markets Technology Enablers (FS_SMARTER)", Doc. SP-150142, March 2015.

[12] 3GPP TR 22.891, "Feasibility Study on New Services and Markets Technology Enablers; Stage 1", v1.1, Doc. S1-152336, Nov. 2015.

[13] 3GPP TR 22.885, "Study on LTE support for V2X services (Release 14)", v0.3.0, Doc. S1-152760, August 2015.

[14] 3GPP TR 22.879, "Feasibility Study on Mission Critical Video Services over LTE (Release 14)", v0.2.0, Doc. S1-152339, August 2015.

[15] 3GPP TR 22.880, "Feasibility Study on Mission Critical Data Communications (Release 14)", v0.2.0, Doc. S1-152340, August 2015.

[16] ICT-671680 METIS-II, Deliverable 1.1 Version 1, "Refined scenarios and requirements, consolidated use cases, and qualitative techno-economic feasibility assessment", January 2016.

[17] European commission, RP-15166, 3GPP Liaison statement on 5G use cases from verticals, December 2015.