Abstract

This deliverable provides the vision of the 5G-MiEdge project on how to synergize the work done on innovative 5G solutions in the European and Japanese ecosystems. This deliverable also performs a preliminary analysis of the most interesting use cases related to scenarios where joint deployments of MEC and mmWave technologies will provide most of the benefit to final users. On those use cases a SWOT analysis is performed as the first step of a more thorough business analysis that will follow. Finally the plan of the project of impacting the ecosystem in both Europe and Japan is described.

Keywords

SWOT Analysis, eco-system impact, EU/JP joint collaboration, use cases, business aspects.
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<th>Description</th>
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<tr>
<td>APC</td>
<td>Access Point Controller</td>
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<td>CDN</td>
<td>Content Delivery Network</td>
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<td>CESC</td>
<td>Cloud Enabled Small Cell</td>
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<td>C-Plan</td>
<td>Control-Plan</td>
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<td>CPRI</td>
<td>Common Public Radio Interface</td>
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<td>C-RAN</td>
<td>Cloud-Radio Access Network</td>
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<td>DC</td>
<td>Data Center</td>
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<td>eMBB</td>
<td>enhanced Mobile Broadband</td>
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<td>E2E</td>
<td>End-to-End</td>
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<td>ECC</td>
<td>Edge Cloud Computing</td>
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<td>EU</td>
<td>European Union</td>
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<td>HD</td>
<td>High Definition</td>
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<td>HW</td>
<td>Hardware</td>
</tr>
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<td>JP</td>
<td>Japan</td>
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<td>MEC</td>
<td>Mobile Edge Cloud (computing)</td>
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<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
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<td>mmWave</td>
<td>millimeter-wave</td>
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<td>NFV</td>
<td>Network Functions Virtualization</td>
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<td>NFVO</td>
<td>Network Functions Virtualization Orchestrator</td>
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<td>PA</td>
<td>Power Amplifier</td>
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<td>PNF</td>
<td>Physical Network Function</td>
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<tr>
<td>PoC</td>
<td>Proof of Concept</td>
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<td>OBU</td>
<td>On-Board Units</td>
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<td>QoE</td>
<td>Quality of Experience</td>
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<td>QoS</td>
<td>Quality of Service</td>
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<td>RaaS</td>
<td>RAN as-a-service</td>
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<td>RAN</td>
<td>Radio Access Network</td>
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<td>RM</td>
<td>Resource Management</td>
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<td>Return on Investment</td>
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<td>Road-Side Units</td>
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<td>SW Defined Network</td>
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<td>SW</td>
<td>Software</td>
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<td>SWOT</td>
<td>Strengths-Weaknesses-Opportunities-Threads</td>
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<tr>
<td>UDN</td>
<td>Ultra-Dense Network</td>
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<tr>
<td>uRLLC</td>
<td>ultra-Reliable &amp; Low Latency Communications</td>
</tr>
<tr>
<td>uHSLLC</td>
<td>ultra-High-Speed and Low Latency Communication</td>
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<td>V2V</td>
<td>Vehicle-to-Vehicle</td>
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<td>V2X</td>
<td>Vehicle-to-Everything</td>
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<td>VNF</td>
<td>Virtual Network Function</td>
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<td>WG</td>
<td>Working Group</td>
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<td>WP</td>
<td>Work Package</td>
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Executive Summary

This deliverable provides the vision of the 5G-MiEdge project on how to synergize the work done on innovative 5G solutions in both the European and the Japanese ecosystems.

A detailed analysis of the ecosystem where 5G-MiEdge plays an important role is performed, highlighting the main opportunities of impact and the main research activities and projects with which to synergize in the rest of the project.

This deliverable also performs a preliminary analysis of the most interesting use cases related to scenarios where joint deployments of MEC and mmWave technologies will provide most of the benefit to final users.

On those identified use cases, a SWOT analysis is performed as the first step of a more thorough business analysis that will follow in the forthcoming months of the project.
1 Introduction

The 5G-MiEdge project is a EU-Japan co-founded endeavor, composed of a research team split in two consortia, the European one (CEA, HHI, Intel, Sapienza University, Telecom Italia), and the Japanese one (KDDI Research, Panasonic, Tokyo Tech University).

5G-MiEdge has the ambitious target of providing a framework for research and pre-development activities that is constantly aligned and commonly worked on by two different eco-systems, the European and the Japanese one. For this reason it is key to ensure that a dedicated part of the work in 5G-MiEdge focuses on creating a vision on which are the most promising 5G technology enablers, capable of having a worldwide impact. The project will ensure throughout its duration that such vision is kept aligned and synched among both consortia, as well as among the two related research and development ecosystems. When successful, this approach will allow impacting the wireless global worldwide community in a much more effective way for the academia, the research centers, the operators, and the industry involved in 5G-MiEdge and in the first broad deployment of the 5G system.

Finally a tight co-work of the two consortia will ensure that the technical work done under the 5G-MiEdge project is harmonized, aligned and capable of steering the project towards a successful conclusion and of giving its main outcomes the broadest possible reach and impact to the ecosystem.

Standardization work on 5G topics started properly in 2016, with the definition of the so called Phase I of 5G, i.e. a first set, agreed-upon by the standards community, of features to be defined and described under the activities of the 3GPP Release 15 timeframe (see Figure 1).

![Figure 1: Timeline of 3GPP Releases and 5G Phases](3GPP_Phases)
5G-MiEdge focuses on the set of features that most probably will be part of the forthcoming 5G Phase II, taken care by the planned 3GPP Release 16. 5G-MiEdge is particularly interested to a new class of services called *ultra High Speed Low Latency Communications* (uHSLLC) (see Figure 2), as described in more details in the publicly available project deliverable D1.1 “Use cases and scenario definition” [D1.1].

![Figure 2: 5G-MiEdge main use cases, key system KPIs and 5G Phases [CSCN_Paper]](image)

The key enabling technologies in focus of 5G-MiEdge are briefly summarized in Table 1.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
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<tr>
<td>mmWave Edge Cloud</td>
<td>Pre-fetch and cache user data / applications / computation results and provide them to MiEdge access point and users</td>
</tr>
<tr>
<td>Liquid Radio Access Network (RAN) Control-Plane (C-Plane)</td>
<td>Collect context info (location, habits) to provide traffic forecast to users and application providers</td>
</tr>
<tr>
<td>User / Application Centric Orchestration</td>
<td>Network orchestration fulfilling the applications requirements and specifications</td>
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Ideally the identification of a common business strategy for markets so different such the European and the Japanese one will allow for a much more effective global market penetration, a key feature for successful commercialization of new technologies and a paramount parameter to increase the return on investment (ROI) of the consortium partners, currently heavily investing on the pre-development of new technologies like Mobile Edge Computing (MEC) and mmWave.
1.1 Scope and structure of the deliverable

This deliverable belongs to the WP1 “Scenario/use cases, business model, and 5G architecture and ecosystem” of the 5G-MiEdge project and reflects mainly the year one outcome of Task 1.1 “Joint EU/JP vision for global exploitation of 5G technologies, business models and impact on the eco-system”. Relevant inputs are also taken from the linked activities run in WP5 “Standardization, spectrum regulation, dissemination and exploitation”. All project partners contribute to both WP1 and WP5 work.

Performing an analysis of the existing business models, in the technology domains worked on in the project, provides a key information for future profitable deployments of those technologies. But to be able to perform such an analysis, some tangible figures and first stable simulation results need to be available, which is not yet the case at the end of 5G-MiEdge year 1 activities.

The work done in the deliverable D1.1 [D1.1] is taken as basis with regard to the 5G Phase II use cases and scenarios. A subset of the proposed use cases is chosen and a preliminary analysis of those use cases, based on the Strengths-Weaknesses-Opportunities-Threads (SWOT) approach, is performed.

One additional target of this deliverable is to identify international events, venues, public demonstrations and fora relevant for the technical focus areas of the project. This set of information is overlapping with the work carried on in WP5 and for more details one can look at the WP5 deliverable D5.1 [D5.1] “First report on dissemination, standards, regulation and exploitation plan”. This deliverable D1.2 reports the first outcomes of the work done in WP1 and a plan of activities for the project lifetime, whereas the final project deliverable D1.4 “Final report on joint EU/JP vision, business models and eco-system impact” will contain the summary of all the accomplished activities by the consortium partners and a thorough final business analysis of the technical novelties proposed by the project.

Finally, another important aspect elaborated in this deliverable is to ensure that all the activities undertaken by the 5G-MiEdge consortium are aligned with the parallel and surrounding 5G ecosystem activities, going on in the several research and funding frameworks, international fora and events around the world, e.g. the 5GPPP association in Europe, the NGMN stream of activities, and related research projects in Japan, like 5G-Pagoda and 5G-MiEdge+.

To summarize, the main objectives of this deliverable are:

- Describe the synergies among EU and Japan ecosystems activities,
- Monitor and report activities related to 5G-MiEdge happening in the international broad ecosystem,
- Perform a first step toward a full-fledged analysis of the business models in the technical focus areas of the project,
- Report on the international research projects, events, venues, public demonstrations and fora that are relevant for the project, finally providing a plan of activities for the rest of the project lifetime.
1.2 5G-MiEdge project objectives in focus

This deliverable is mainly linked to the overall project objectives listed below, taken from the text composing the description of work of the 5G-MiEdge project proposal, which was accepted for funding by the European and Japanese funding authorities.

- **Objective 5**: Develop a joint 5G test-bed integrating mmWave edge cloud, liquid RAN C-plane, and user/application centric orchestration to foster an effective impact of 5G-MiEdge in both Europe and Japan, particularly in preparation of 2020 Tokyo Olympic Games. The 5G-MiEdge test-bed will liaise actively with the other EU/JP consortium focusing on the network side as well as to leverage synergies between alternative 5G concepts.

- **Objective 6**: Contribute to the definition of 5G mobile communications standards in 3GPP and IEEE, as well as in open fora such as NGMN, Small Cell Forum, and the International Telecommunication Union (ITU) Industry Specification Group MEC, in terms of mmWave access, liquid RAN C-plane, and protocols for user/application centric orchestration by coordination across European and Japanese partners.
2 Vision of a joint EU / Japan impact

2.1 Ecosystem impact

The 5G-MiEdge project targets to devise and design a new architecture, and implement some of its building blocks, to enhance the currently agreed-upon in standards 5G system structure, building on the synergic role of mmWave access technologies, MEC and liquid RAN C-plane.

The project has a unique potential in providing a significant contribution to the deployment of 5G because of its holistic view of communication, computation and storage resources as parts of a single system, whose goal is to deliver services to mobile users, following within stringent requirements in terms of latency, reliability, and data rate. The consequence of this holistic view is a joint optimization of communication, computation, and caching resources, which represents a significant step ahead with respect to the currently known approaches in literature, from other international research projects and endeavours, and from the ongoing discussions on the main standardization bodies focusing on 5G topics.

This vision builds on top of two main pillars:

- a powerful physical layer, represented by massive Multiple Input Multiple Output (MIMO) mmWave technologies, which provides ultra-broadband services with planned peak user data rate >10 Gbps,
- the separation between the control- and the data-plane.

The opportunities offered by mmWave technologies are exploited without forgetting the new challenges introduced by these technologies, like for example blocking effects. In fact, multi-link communications are thoroughly studied as a possible remedy to blocking. Moreover, in 5G-MiEdge, the C-plane is rooted on macrocell base stations, whereas the data plane exploits mmWave access points. This makes possible to exploit, at the same time, the robustness of macrocell access with the high data rate of mmWave technologies, without sacrificing the overall reliability of the system.

The projects builds on the strong expertise of most of its consortium partners on mmWave technologies, shown also in different FP7 and H2020 research projects, like Miweba, MiWaveS, mmMAGIC, and METIS, to name a few. But the projects aims to move a significant step ahead by considering a cross-layer design that mixes the opportunities of mmWave technologies with the requirements of a truly application-centric design, where what finally matters is actually the perceived user quality of experience (QoE). This vision leads to a joint optimization of communication, computation and caching resources.

A proper dynamic orchestration of MEC servers enables mobile users to be served with very low latency. Our vision is to design a sort of "liquid" structure that follows the moving user along his/her path, in a seamless way. In this proposed framework, the users move around without being aware that applications are running elsewhere,
wherever it is more convenient, either on MEC servers, properly orchestrated, or in the cloud.

The innovations put forward by 5G-MiEdge are mainly meant to properly and effectively address the use cases foreseen and described in D1.1, but their impact is not limited to those use cases, as they have the capability to go further beyond, touching the broader wireless telecommunication ecosystem. This happens because the algorithms designed in 5G-MiEdge to orchestrate radio, computation and storage resources have a wider applicability, and represent a significant step ahead with respect to both current 4G systems and the first set of the first agreed-upon features of 5G system, currently being standardized by 3GPP bodies.

The impact is not only on a more efficient design of the new forthcoming 5G network, but, most important, on the deployment of information technology services with end-to-end guarantees.

We believe that 5G-MiEdge has a unique potential for providing a strong impact in the 5G ecosystem due to its innovative nature, and due to the fact that it can be seen as a technology framework that enables several exploitation and commercialization opportunities, including the possibility to form a completely new value chain within the 5G ecosystem, and to allow for new and or enhanced business models and opportunities.

At the stage of the 5G-MiEdge proposal preparation, we did not identify any major barriers or obstacles that could potentially affect the studies and developments foreseen in 5G-MiEdge, or that might have the potential to significantly modify our expected outcomes. The roadmap of 5G-MiEdge is based upon ideas and technologies (mmWave, MEC, multi connectivity, orchestration and slicing) whose critical role for the future mobile networks is well accepted by the ICT industry, and is starting to be discussed, even though still in general terms, as well in relevant standards bodies, like 3GPP under the ongoing 3GPP Release 15.

One of the unique assets of 5G-MiEde is the collaboration between European and Japanese academies, research centers, manufacturers, and operators, within a joint project. We strongly believe that the diversity resulting from these two worlds has the potentials of providing a significant advancement in terms of research results and business opportunities both for the partners involved in the project, and for the surrounding ecosystems.

Figure 3 shows the relationship between 5G-MiEdge and the standardization bodies, and a selection of relevant research projects. Additionally, the figure also highlights the time plan for the testbeds and proofs of concepts that will be developed by 5G-MiEdge, under the work planned in WP4.
2.2 Analysis of the research ecosystem

Some of the technologies developed in 5G-MiEdge are interconnected to other research projects, just completed, still running or on the way to start. The following list shows, to the best of our knowledge, some key relevant such projects, stressing their goals and the similarities, the shared research topics and the potential common ground with 5G-MiEdge.

2.2.1 MiEdge+

MiEdge+ is the sibling project of 5G-MiEdge, funded by MIC (Japan government), and for that it is expected that a very tight interaction with 5G-MiEdge will take place. NICT, Panasonic and Tokyo Tech are among the members of MiEdge+. As shown in Figure 4, this research project targets to virtually construct a location specific small area access networks operated by a micro operator, especially under the consideration of roaming mobile terminals, which might join this micro operator’s network. In addition to 5G access technology, MiEdge+ plans to introduce edge cloud to simultaneously realize high data rate and low latency communications, so to support...
location specific applications, e.g., (foreign) audiences at event sites such as Olympic stadium.

Differently from 5G-MiEdge, MiEdge+ covers all kinds of 5G access technologies and takes into account the interoperation of different micro operators, which might share the same network infrastructure.

![Diagram of MiEdge+](image)

**Figure 4: The concept of MiEdge+**

Since MiEdge+ is a sibling project of 5G-MiEdge, both funded by MIC from Japan side, both projects are working together mostly in parallel and tight cooperation is expected, especially on disseminating the research outcomes and in impacting relevant standardization bodies. Further details on the relationship between 5G-MiEdge and MiEdge+ can be found in Figure 5.
2.2.2 5G!PAGODA

5G!PAGODA (Federating Japanese and European 5G Testbeds to Explore Relevant Standards and align Views on 5G Mobile Network Structure Supporting Dynamic Creation and Management of Network Slices for Different Mobile Services) [5G!PAGODA] and 5G-MiEdge are twin projects, selected by the same EU-Japan joint call, under the same topic of “5G: Next Generation Communication Networks (EUJ-01-2016)”, funded by the European Commission (EC) under the Horizon 2020 research and innovation programme and by the Japanese Ministry of Internal Affairs and Communications (MIC) as Strategic Information and Communications R&D Promotion Programme (SCOPE).

The two projects are collaborating tightly with each other to create synergies, with 5G!PAGODA mainly focusing on 5G networks, and 5G-MiEdge on 5G access. The overall objective of 5G!PAGODA is standardization and verification of End-to-End (E2E) network slicing technologies through EU/Japan collaborative R&D efforts. On the other hand, 5G-MiEdge project is developing application centric RANs by combining mmWave access and MEC, to satisfy extreme requirements on high data rate and low latency, needed in specific scenarios such as the 2020 Tokyo Olympic Games and automated driving [D1.1].

The two projects will complement each other, where 5G-MiEdge provides MiEdge enabled RANs to 5G!PAGODA, so to meet with the requirements set by the chosen applications, while 5G!PAGODA provides E2E networks to 5G-MiEdge to realize E2E slice for specific applications. Both 5G-MiEdge and 5G!PAGODA have a plan to

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Figure 5: Cooperation between 5G-MiEge and MiEdge+
show their synergy through joint demonstration of 5G networks and accesses in the last year of their lifetime. Moreover, they will collaborate in standardization of protocols and interfaces for network orchestration that might start to be studied in 3GPP with the planned Release16.

2.2.3 5GPPP community

5GPPP (5G Public-Private Partnership) [5GPPP] is a joint initiative between the European Commission (representing the public side) and the 5G Infrastructure Association (the private side representing the European ICT industry involved on 5G). 5GPPP, promoting and conducting several initiatives in strategic areas like, for example, standardization, frequency spectrum, research and development, aims to deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade.

The 5GPPP activity related to funded actions is organized in different phases:

- Phase 1, focusing on research (2015-2017),
- Phase 2, focusing on optimization (2017-2019),
- Phase 3, focusing on large scale trials (2018-2020).

At the moment the majority of the projects of Phase 1 are in the completion phase and the projects of Phase 2 are just starting.

Looking more in detail to the technical content of those projects, it is possible to identify some of them having a technical content in relationship with 5G-MiEdge, even though, no one is actually focusing on the joint MEC plus mmWave approach. The projects of 5GPPP are more targeted on one only of the two synergic components of 5G-MiEdge and, consequently, can be seen as a good complement to the 5G-MiEdge investigations and Proof of Concepts (PoC). It is worth noting that even in the previous FP7 funding framework of the EC there were projects dealing with aspects related to 5G-MiEdge, like for example Miwaves [MiWaveS], the first initiative studying the application of mmWave for both access and backhauling, and Miweba [Miweba], among the first dealing with pre-development of mmWave building blocks for 5G system.

Special effort was spent by the 5G-MiEdge team in monitoring and analyzing the work of 5GPPP Phase 1 projects, which appear more correlated with the topics in focus in 5G-MiEdge. In the following it is provided the outcome of the survey done on most of them.

2.2.3.1 Phase 1

mmMAGIC

The mmMAGIC (mmWave based mobile radio access network for fifth generation integrated communications) [mmMAGIC] is the main project of the 5GPPP family entirely dedicated to the mmWave technology. Its main objective is to develop
concepts and key components for a new 5G radio access technology, which is expected to operate in the frequency range 6-100 GHz.

The project proposes a new RAT, which will offer self-backhauling and fronthauling capabilities, and will enable the creation of a holistic, scalable and economically viable 5G network solution. With this RAT, mmMAGIC aims “to pave the way for a European head start in 5G standards and to be a focal point for European and global consensus building on the architecture, key components and spectrum for 5G systems operating above 6 GHz” [mmMAGIC].

Additionally work was done on control plane aspects, that are relevant for 5G-MiEdge, for example “As the low frequency bands can offer a more reliable connectivity compared to the high frequencies, it can be beneficial to transmit some of the control signals using the low frequency RATs. For this, it will be necessary to integrate the mm-wave RAT with the low frequency RAT in order to allow a flexible distribution of the control signals. Some of the control signals are directly related to the physical properties of the transmission channel, e.g. synchronization and channel estimation signals, both for initial access and data transmission” [mmMAGIC_White_Paper] as also shown in the following figure.

![Figure 6: Control plane split [mmMAGIC-White_Paper]](image)

During the project duration there will also be a variety of tests and measurement campaigns to verify the capabilities and reliability of the technology. Right now, the mmMAGIC project is in the final phase and final results will be made publicly available (w.r.t. to the public deliverables) after the end of June 2017, when the project finishes.
The mmMAGIC research and technology will be a grand asset in the development of 5G-MiEdge and therefore the research in 5G-MiEdge will certainly benefit from the efforts of the mmMAGIC project, especially focusing on the outcomes achieved in the antenna systems, channel modeling, RF and Physical layer blocks.

FLEX5GWARE

The Flex5Gware (Flexible and efficient hardware/software platforms for 5G network elements and devices) project [Flex5Gware] addresses the improvement of the performance and the reduction of the energy footprint of the HW and SW platforms, on top of which all communication-related functionalities are implemented and executed. Performance improvements require progress not only in quantifiable and quantitative terms (e.g., operated bandwidth or simultaneous computational power enhancement and energy consumption reduction), but also in terms of other important non-functional aspects like scalability, modularity, and high re-configurability, which is also one of the key aspects addressed in Flex5Gware.

The technological progress that is being derived from this project in the development of the 5G mobile networks, especially that one related to improvements on the HW and SW platforms, has a direct benefit to the European society associated to the improvement in the quality of service (QoS), increased number of applications and services and reduced cost of future mobile network. Moreover, the improvements in energy efficiency of 5G platforms pointed out above can reduce carbon dioxide emissions and have a positive impact on climate change. Thanks to the cost efficiency of its HW and SW platforms, the expected ubiquitous coverage of 5G networks will provide similar opportunities for economical and societal progress to diverse areas ranging from densely populated areas to remote rural areas. Finally, the emergence of the 5G mobile networks will contribute to create new job posts and new companies in the communication networks domain and even to a bigger extent in secondary domains related to the application of ICT.

In order to address the problem presented at the beginning and achieve the important societal benefits listed above, the Flex5Gware consortium has defined the following overall high-level objective: to deliver highly reconfigurable HW platforms together with HW-agnostic SW platforms targeting both network elements and user devices, taking into account increased capacity, reduced energy footprint, as well as scalability and modularity, to enable a smooth transition from 4G mobile wireless systems to 5G. Accordingly, Flex5Gware is performing research to pin point specific implementation challenges for key HW and SW building blocks and consider the ability of these functions to co-operate and provide versatile, flexible, reconfigurable, efficient operations for HW and SW platforms.

Figure 7 shows the HW and SW implementation of the final PoC developed within the project.
As it has already been described above, Flex5Gware innovations target both user devices and network elements. A very important aspect related to 5G devices is that they are expected to integrate and interact with a multiplicity of sensors (e.g., those related to location and positioning, environmental conditions, image processing etc.).

In the HW domain of network elements, Flex5Gware research focuses on incorporating solutions for increased operating bandwidth, multiband functionalities and key component implementation for mmWave transceivers, which will enable the efficient utilization of spectral resources at frequencies below 6 GHz and also at mmWave ranges. In particular, Flex5Gware researchers have proposed an architecture design for the transceiver of medium range base stations that supports three radio bands, together with a design of a multiband high power amplifier (PA). The presented three-band transceiver solution considers radio bands defined for mobile communications and one band which is in discussion to become available during the next years (2.7 - 2.9 GHz).

Other relevant hardware improvements for network elements that are being researched in Flex5Gware are active envelope tracking and PA pre-distortion for wideband PAs, and the addition of new features and capabilities that are not yet in operational use, such as implementations of massive MIMO technologies.

The part related to mmWave investigated within the Flex5GWare project could represent a good complement of 5G-MiEdge activities and could potentially provide good hints for the setup of the planned final project demonstrator.

Figure 7: Flex5Gware Proof-of-Concept Hardware/Software Implementation
CHARISMA

The CHARISMA (converged heterogeneous advanced 5G cloud-RAN Architecture for Intelligent and secure Media Access) project [CHARISMA] targets the development of an open access, converged 5G network, which can enable multi-tenancy and that is supported by a hierarchical architecture, with intelligence distributed out towards end-users. More specifically, CHARISMA studies functionalities to enable low-latency network, security, and multi-tenancy.

The overall CHARISMA concept is depicted in Figure 8. The main relation of CHARISMA with 5G-MiEdge is represented by the common objective of design a low-latency 5G network by exploiting smart content caching. To achieve this goal, CHARISMA proposes a cooperative hierarchical caching, where caching decisions are made both locally and globally. Beyond this, CHARISMA uses a hierarchical in-network caching where cache functionalities reside at network devices like routers and switches. This system is steered through a centralized SW Defined Network (SDN) controller used to manage and control content replicas, by keeping track of the location and availability of content in distributed locations, in order to realize an efficient load balancing and limit redundant content stored in the network.

Figure 8: The concept of CHARISMA [Charisma]

SESAME

The fundamental component of the SESAME (small cell coordination for multitenancy and edge services) project [SESAME] is the virtualization of small cells and their utilization and partitioning into logically isolated slices, so to support multi-tenancy. In this context, the placements of network intelligence and applications in the network edge through Network Function Virtualization (NFV) and Edge Cloud Computing (ECC) represents a central element of the project. SESAME proposes a Cloud Enabled Small Cells (CESCs), able to support ECC in a multi-tenant, multi-service ecosystem, where Physical Network Function (PNF) and Virtual Network
Function (VNF) are logically separated. Two types of VNFs are identified: Service Chain (SC) VNFs that are associated to the virtualized execution of different functionalities of the SC, and Service VNFs that target to improve the 5G KPIs through dedicated functionalities, such as e.g., virtual firewall and virtual caching.

Moreover, to efficiently deploy VNFs, a micro server whose architecture and characteristics are optimized for the MEC environment is co-located with the CESC. In addition, the CESC's clustering enables the achievement of a micro scale virtualized execution infrastructure in the form of a distributed data center, denominated Light Data Centre (Light DC), enhancing the virtualization capabilities and process power at the network edge. The block architecture proposed by SESAME is described in Figure 9. The results obtained w.r.t. the ECC part could be of interest also for 5G-MiEdge.

![Block diagram of the overall SESAME architecture](image)

**Figure 9: Block diagram of the overall SESAME architecture [SESAME]**

**METIS-II**

The METIS-II (Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society) project [METIS-2] has been one of the beaconing projects of 5GPP Phase 1, having as key objectives: (i) to develop the overall 5G radio access network design, and (ii) to provide the technical enablers needed for an efficient integration and use of the various 5G technologies and components currently developed.

The innovation pillars (also shown in Figure 10) that allow METIS-II to achieve its goals are listed in the following:
- Holistic spectrum management architecture addressing the spectrum crunch,
- Air interface harmonization framework enabling an efficient integration of new and legacy air interfaces,
- Agile Resource Management (RM) framework providing the dynamics required to efficiently adapt the integrated 5G air interfaces and radio concepts to the varying traffic demand and service requirements,
- Cross-layer and cross-air-interface system access and mobility framework ensuring a ubiquitous access continuum,
- Common control and user plane framework providing the means for an efficient support of the broad versatility of services expected for 5G as well as a future-proof and cost-efficient implementation of the 5G integration.

![Overall 5G RAN Design](image)

**Figure 10: METIS-II Key Innovation Pillars**

METIS-II targets the overall RAN design, air interface variants harmonization and resource management, but its activities have not been focusing on the details of the different air interface variants, which have been dealt with by other projects (e.g., FANTASTIC-5G [Fantastic5G] for frequencies below 6 GHz and mmMAGIC [mmMAGIC] for frequencies above 6 GHz). Within the several topics investigated by METIS-II, some effort has also been dedicated to some specific aspects of mmWave communications. More in details, the following topics have been touched:

- Aspects related to the cell discovery and initial access in mmWave cellular components [Barati2015],
- Architecture for access to mmWave segment with the assistance of 5G low band component exploiting multi-connectivity [Azizz2016],
- Harmonization/aggregation of the various Air Interface variants (including those operating at mmWave) into a single 5G Air Interface framework [Kilinc2016].
The results obtained by METIS-II in these specific areas can be considered as very useful to complement the more specifically focused investigations planned within 5G-MiEdge, which is more specialized in the synergic use of mmWave access and MEC technology, so to target simultaneously low latency and high QoE in several use cases characterized by very dense scenarios.

2.2.3.2 Phase 2

It has to be remarked that the short descriptions of the Phase 2 projects contained in this paragraph are still quite at high level, due to the fact that very limited public material is available, besides what is available on the 5GPPP website [5GPPP]. In fact most of the project start in June or July 2017, and the respective projects websites are not yet available.

5G-CORAL

The 5G-CORAL (a 5G convergent virtualized radio access network living at the edge) project [5GCoral] aims at delivering a convergent 5G multi-RAT access through an integrated virtualized edge and fog solution that is flexible, scalable, and interoperable with other domains including transport (fronthaul, backhaul), core and clouds. Among the several KPI that can be achieved through the 5G-CORAL solution, it has to be highlighted the ultra-low end-to-end latency in the order of milliseconds.

This ambitious target of the 5G-CORAL project is in line with the targets pursued by 5G-MiEdge.

ONE5G

The ONE5G (E2E-aware Optimizations and advancements for the Network edge of 5G New radio) project [One5G] has the overall goal to design the evolution of the 5G system and build consensus in 3GPP on the proposed promising extensions beyond Release 15, in order to meet the demands of megacities and underserved areas in a performance and cost efficient manner. In order to meet the requirements of such scenarios, the project will propose advanced link technologies and enhancements beyond Release 15 to enable multi-service operation and practical implementation of '5G advanced (pro)', with future-proof access schemes, advanced massive MIMO enablers and link management. Highly performance optimization schemes will be investigated also with respect to the E2E user experienced performance.

Both the high E2E user experience and the massive MIMO are topics touched by 5G-MiEdge.

MATILDA

The MATILDA (A holistic, innovative framework for the design, development and orchestration of 5G-ready applications and network services over sliced programmable
infrastructure) project [MATILDA] aims to devise and realize a radical shift in the development of software for 5G-ready applications, as well as virtual and physical network functions and network services, through the adoption of a unified programmability model, the definition of proper abstractions and the creation of an open development environment that may be used by application as well as network functions developers.

Multi-site management of the cloud and edge computing and IoT resources are supported by a multi-site virtualized infrastructure manager, while the lifecycle management of the supported VNF Forwarding Graphs (VNF-FGs), as well as a set of network management activities, are provided by a multi-site NFV Orchestrator (NFVO).

The MATILDA project touches some technical aspects that are complementary to those investigated in 5G-MiEdge, like for instance the multi-site management of the cloud-edge computing resources.

NRG5

The NRG5 (Enabling Smart Energy as a service via 5G Mobile Network advances) [NRG5] project aims to contribute to the 5G-PPP/5G Initiative research and development activities and participate at the relevant 5G Working Groups, by delivering a novel 5G-PPP compliant, decentralized, secure and resilient framework, with highly availability, able to homogeneously model and virtualize multi-homed, static or moving, HW constrained (smart energy) devices, edge computing resources and elastic virtualized services over communications’ and energy utilities’ infrastructures.

The NRG5 project investigates the edge computing resources in the scenario of energy utilities infrastructures. It can then considered as having relations with 5G-MiEdge for the edge computing topic.

5G-PHOS

The 5G-PHOS (5G integrated Fiber-Wireless networks exploiting existing photonic technologies for high-density SDN-programmable network architectures) project [5GPHOS] aims to develop novel 5G broadband fronthaul architectures and evaluate them for Ultra-Dense and Hot-Spot areas; exploiting the recent advances in optical technologies towards producing a powerful photonic integrated circuit technology toolkit. It aims to capitalize on novelties in indium phosphide transceivers, triplex optical beamformers and multi-bitrate optical communications into next generation fronthaul in order to migrate from Common Public Radio Interface (CPRI) -based to integrated Fiber-Wireless packetized C-RAN fronthaul supporting mmWave massive MIMO communications.

The topics worked on by the 5G-PHOS project are different with respect to 5G-MiEdge, but its outcomes can be relevant for 5G-MiEdge since it is targeting a fronthaul’s solution suitable for mmWave massive MIMO communications, which is one of the two key subject of 5G-MiEdge.
5G CAR

The 5G CAR (Fifth Generation Communication Automotive Research and innovation) project [5GCAR] develops an overall 5G system architecture providing optimized E2E Vehicle-to-X (V2X) network connectivity for highly reliable and low-latency V2X services, which supports security and privacy, manages QoS and provides traffic flow management in a multi-RAT and multi-link V2X communication system. Also the demonstration and validations of the developed concepts and evaluation of the quantitative benefits of 5G V2X solutions using automated driving scenarios in test sites are foreseen.

5G CAR is focused on automotive and, as a consequence, is investigating low latency solutions for V2X communications. Since also one of the use cases considered in D1.1 by 5G-MiEdge is the “Automated driving”, the results of 5G CAR could be of interest for 5G-MiEdge.

5G ESSENCE

The 5G ESSENCE (Embedded Network service for 5G Experiences) project [5GEssence] addresses the paradigms of ECC and Small Cell-as-a-Service (SCaaS).

This is another project addressing the edge computing paradigm, and therefore potentially interesting with respect to 5G-MiEdge.

On the base of what reported above, it is clear that it is really worth to monitor the publications and the main outcomes of those 5G-PPP projects, due to some presumed overlaps in key technical aspects. In fact 5G-MiEdge could exploit some of those results and, when possible and reciprocally advantageous, try to set up more direct relationships or, at least, have interactions through the Steering Board, the Technical Board or the specific Working Groups (WG) of 5GPPP (different WGs focusing on the following topics: Spectrum, Trials, Vision, Pre-standardization, Architecture).

2.2.3.3 Trials and 5GPPP Phase 3

The 5GPPP Phase 3 is currently under definition and will span over the 2018-2020 time frame, is targeted to the validation (through large scale trials) of the system concepts and architectures investigated in the Phase 1 and Phase 2 projects, also in line with the 5G Action Plan. During the recent EuCNC’2017 conference, the EU Commission (Pearse O’Donohue and Bernard Barani) provided some more details on 5GPPP Phase 3. Phase 3 will be split in two parts: Phase 3A and Phase 3B. Projects of Phase 3A are expected to start around June 2018 and have to focus on the trial platforms to be used during Phase 3B to carry on the actual trials. Projects of phase 3B should start around 2019. 5GPP Phase 3 projects are also expected to start investigations on “Beyond 5G” around the year 2020.
These Phase 3 projects represent a part of the most general 5G Pan-European Trials Roadmap defined by the 5G Infrastructure Association [5G-IA]. The association defined a solid and comprehensive strategy to develop Pan-European coordinated trials, and foster as well the creation of international trials with non-EU partner countries, addressing several key elements of the 5G Action Plan. According to the roadmap version 1.0, four main pillars are addressed: 5G private trials, 5G vertical pilots, 5G for UEFA Euro 2020 and 5G trials cities.

In particular, the 5G pan European trials tied to Euro 2020 appear of particular interest for 5G-MiEdge. This is due to the timing of the Euro 2020 football championship planned in the summer of 2020, just before the 2020 Olympics in Japan. This will give to 5G-MiEdge the opportunity to align in due time with those planned activities and exchange some potentially useful information for the final 5G-MiEdge trials.

Among the so called “triple A trial services”, the most interesting with respect to 5G-MiEdge are those related to the stadium (5G augmented and virtual reality applications related to Euro 2020 or football in general). Also the services related to public safety (e.g., augmented reality used to mark persons based on facial recognitions) are of interest for the topics investigated in 5G-MiEdge. For these trials sufficient spectrum (at least 100 MHz per operator across the 3.4 - 3.8 GHz band, several hundreds of MHz in the 26 GHz band) is targeted for availability from the related member states.

### 2.2.4 Cooperation and synergy with other research projects during year 1

A detailed description of the impact that the 5G-MiEdge project managed to obtain in the ecosystem in the first year of its lifetime is fully described in D5.1, in the following (Error! Reference source not found. below) a short list of the main achieved collaborations with other running research projects is reported.

<table>
<thead>
<tr>
<th>Conference</th>
<th>Date</th>
<th>Location</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICC 2017</td>
<td>May 2017</td>
<td>Paris, France</td>
<td>Invited talk “mmWave use cases: the visions of the 5G-MiEdge and 5GCHAMPION projects (Olympic Games are coming …)” to the industrial panel “Practical Issues on mmWave Communications: Current Status and Future Technologies”. Together with the project 5G CHAMPION</td>
</tr>
<tr>
<td>COCORA 2017</td>
<td>May 2017</td>
<td>Venice, Italy</td>
<td>Special Track “Mobile Edge Computing and Millimeter Waves as Key Technology Enablers for 5G Systems”. Together with the project 5G CHAMPION</td>
</tr>
<tr>
<td>Event</td>
<td>Date</td>
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<tr>
<td>COCORA 2017</td>
<td>May 2017</td>
<td>Venice, Italy</td>
<td>Invited talk on “From concept to deployment: the visions of the 5GCHAMPION and 5G-MiEdge projects (Olympic Games are coming …)” Together with the project 5GCHAMPION</td>
</tr>
<tr>
<td>COCORA 2017</td>
<td>May 2017</td>
<td>Venice, Italy</td>
<td>Invited talk on “Resource and spectrum management - an European research projects survey” to the Special Track “5GSPECTRUM: Advanced Spectrum Management in 5G and Beyond Systems”. Together with the project SPEED-5G.</td>
</tr>
<tr>
<td>Industrial Workshop</td>
<td>Jun 2017</td>
<td>Brasilia, Brazil</td>
<td>Invited talk on “5G use cases for Olympic Games: The visions of the projects 5GCHAMPION and 5G-MiEdge”. Together with the project FUTEBOL, during the organized industrial panel.</td>
</tr>
<tr>
<td>EUCNC 2017</td>
<td>Jun 2017</td>
<td>Oulu, Finland</td>
<td>Co-organization of the Special Session “Toward 300 GHz wireless networks, challenges and opportunities”. Together with the research project TWEETHER.</td>
</tr>
<tr>
<td>EUCNC 2017</td>
<td>Jun 2017</td>
<td>Oulu, Finland</td>
<td>Co-organization of the Workshop “Millimetre-wave technology for 5G access, fronthaul and backhaul”. Together with the research projects mmMAGIC and RAPID-5G.</td>
</tr>
<tr>
<td>EUCNC 2017</td>
<td>Jun 2017</td>
<td>Oulu, Finland</td>
<td>Co-organization of the Workshop “Prototyping 5th Generation Cellular Wireless Technology”. Together with the research projects 5GCHAMPION, MiWaveS and Flex5GWare.</td>
</tr>
</tbody>
</table>

It is worth stressing the fact that 5G-MiEdge has managed, already within the first year of the project, to demonstrate an impact on the global ecosystem, collaborating and successfully participating and co-organizing internationally recognized and top-notch events (COCORA, ICC, EUCNC), disseminating its results to most of the global geographical areas (Europe, Asia, North America, Industrial panel in South America), all done in synergy and collaboration with several other research projects with global reach (FUTEBOL, mmMAGIC, Flex5GWare, TWEETHER, MiWaveS, 5GCHAMPION, RAPID-5G).
2.2.5 First tangible exploitation results obtained in year 1

In June 2017 5G-MiEdge participated with an invited talk at an industrial panel with the Brazilian ecosystem (operators, regulators, research community and industry) organized by the FUTEBOL H2020 research project, more info are available in the project webpage [FUTEBOL]. Following the presentation, the biggest and most important industry in the world for iron extractions, Vale, posed lots of questions on the 5G-MiEdge identified use cases and asked for a follow up with the project team.

A conference call is organized and will be held at the end of July, to deeply analyse the assumption and value of the 5G-MiEdge project use cases, scenarios and identified KPIs, and potential synergies with real-life industrial need in an important industrial sector not directly related to wireless technologies will be investigated, mainly focusing on joint activities in the area of MEC and mmWave access.

2.3 Plan for the next two years of the project

The plan for improving the synergies between EU and Japan in the remaining two years of the project is partially overlapping with the charter and the work planned in WP5, especially w.r.t. the exploitation and dissemination activities, described in full detail in D5.1.

In this section it is briefly commented on the potential impact of the 5G-MiEdge project on the global ecosystem in the next two years of the project, and the identified plan for further actions in further tightening the EU-JP interwork and expanding the reach of 5G-MiEdge to the global ecosystem.

2.3.1 Further impact of 5G-MiEdge on EU/JP ecosystems

The unique potential of the 5G-MiEdge project is its ability of providing a strong impact in the global 5G ecosystem, due to its innovative nature and the fact that it can be seen as a technology framework that enables several exploitation and commercialization opportunities, including the possibility to form a completely new value chain for the 5G ecosystem. In fact 5G-MiEdge focuses on providing a unique approach to solve some concrete identified issues in current 5G systems, when dealing with a strongly societal impacting event, i.e. the 2020 Olympic Games. The planned deployment and pre-development oriented expected results are supposed to be very useful for all the players in the wireless domain, who plan to broadly leverage on key pillars of future 5G system, like mmWave and MEC technologies.

Finally, another strong points of 5G-MiEdge lays on the diverse expertise, affiliation and geographical composition of its partners, which includes operators, vendors, research institutes and universities, belonging to different areas of the world. This aspect facilitates not only the broadest possible reach of 5G-MiEdge results, but also gives the consortium partners the capability of understanding what is needed for
a real global impact for the still under definition 5G and beyond key technology enablers, under work in the project.

2.3.2 Plan for further cooperation and synergy with other research projects

Throughout its lifetime, 5G-MiEdge aims to tightly collaborate with other research projects so to find all possible synergies, leverage on and benefit from each other’s results, and finally obtain the broadest possible impact on the research and industrial ecosystems.

In addition to the mentioned sibling project MiEdge+, also close collaborations and synergies with relevant running projects will be pursued, e.g. with 5G!PAGODA, and follow-ups with recently finished ones will be looked for, e.g., with mmMAGIC, the results of which will be used as basis for some of the 5G-MiEdge work, especially with regard to integrate fronthaul/backhaul in small cell mesh networks, as well as radio access technology in the mmWave spectrum.

Further alignments, synergies and collaboration will be continuously pursued in the final two year of 5G-MiEdge, e.g. most likely with the just starting H2020 5G-PPP Phase 2 projects. The focus of this part of the project activities will be on finding common interests and similarities and proposing potential synergies of the topics in focus in those projects. A continuous monitoring task will be run by the consortium partners, and those ones involved in the new running projects will periodically report on the advancements of those projects, provided that the confidentiality framework will not be broken (i.e. project-specific info not publicly available and bound by project-NDAs of course will not be discussed).

2.3.3 Strategies to meet the set goals

Each involved partner in the project has a specific role in the holistic strategy defined by 5G-MiEdge, in order to achieve the broadest possible impact in the global ecosystem. Operators will lead the further identification of advanced requirements and scenarios in the identified use cases and will contribute by providing their specific business interests towards the first deployment of the project-specific newly proposed technologies. Industrial partners will assess as much as possible such technologies and will try to create new market windows for them, at the same time providing key contributions to realize in practice the technical goals of the project. Research institutes will be fundamental in linking the more theoretical work with real-life the proof-of-concepts and will provide a key contribution to their implementations. Universities will be the key responsible entities to advance the state of the art of the research topics, through the investigation and the proposition of innovative and breakthrough concepts arising from the merging mmWave and MEC.

In order to strengthen the bond between European and Japanese partners, several actions have already been taken to ensure a full success to the aforementioned strategies and so to make in a way that the expected impacts are realized in practice. Several demos and booths have been jointly organized by the European and Japanese partners, as detailed in the deliverable D5.1 [D5.1].
The Japanese project coordinator from Tokyo Tech University has spent one and half years at the premises of European project coordinator, Fraunhofer-Heinrich-Hertz-Institut. This cooperation between project coordinators, orchestrated by the technical project manager is of paramount importance in order to harmonize the activities of the two different Japanese and European realities. Additionally, a PhD student from Tokyo Tech University is planned to spend some time at Sapienza University of Rome, and a student from Sapienza is planned to visit the CEA-LETI institute. Further synergies are planned to start in year two and will be exploited, e.g., by an even tighter collaboration between the research activities of Intel (PhD student) and Sapienza University of Rome.
3 Business analysis

3.1 Business Opportunities and Stakeholders in 5G

The 5G system paves the way for a whole new plethora of business opportunities, through enhanced performance as well as improved softwarization and virtualization compared to prior generations of mobile networks.

The improved agility and flexibility of the services that can be offered with 5G permit far more than what is possible today. For instance, Network Slicing, a key concept in the 5G network architecture, makes it possible to offer a completely new plethora of services using the Anything as a Service (XaaS) model, which includes the services IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and NaaS (Network as a Service).

Leveraging the XaaS model, a whole range of different, and sometimes also new, vertical industry stakeholders are given the possibility of offering products, which are much more tailored to the specific needs of their targeted end users. Additionally, the combined capabilities of high bandwidth wireless networks, which use mmWave connections and MEC, may open up completely new business opportunities. In fact, the introduction of edge and cloud computing into the telecom and wireless industry enables and facilitates even more the entry of potentially new IT service providers in the telecom market.

The main stakeholders around 5G that were identified by 5GPPP are summarized in Error! Reference source not found..

New services such as cybersecurity of data analytics and machine-learning-based network management can therefore be offered in a much more proficient way to the
5G ecosystem, allowing even more profitable services and thus enlarging the overall revenues of entire industries.

Clearly, all those mentioned new opportunities depend upon the ability of 5G technologies to deliver the performance that are expected from them, and meet the demanding requirements that were defined for 5G systems. Precisely the set targeted performance levels will convince new vertical stakeholders to invest in 5G networks and join the dynamic and thriving ecosystem around mobile networks. Moreover, it is worth mentioning that the forthcoming 5G system, thanks to its capability of seamlessly merging together different technologies in the same network architecture, will give more opportunities for new players to be part of the ecosystem and thus provide them with a perspective of a profitable new business. As a consequence of such increase of the number of entities in the ecosystem and in their related business, the overall market value of wireless telecommunication will be greatly enlarged.

Finally it is very important to mention that another key parameter to be taken care of when dealing with the introduction of a new technology, is the final cost of implementing and deploying the envisaged new enhancements in the forthcoming 5G system. The 5G-MiEdge project, with its strong focus on demos and trials-based scope, can play a key role in assessing and identify, well ahead of commercial deployments, which are the most promising technologies for the market, not only from the point of view of technical feasibility, but also from the not least important aspect of could be the potential ROI of the investigated and proposed new technologies.

### 3.2 Economic impact

The economic impact will be a challenge as well as an opportunity for all project partners and stakeholders in the ecosystem.

The evolution towards the 5th generation of cellular communication is expected to enable new business models in vertical markets with new industries and stakeholders. Therefore it is very important for the ecosystem players to monitor technological and economic trends and identify business opportunities as early as possible. In particular European and Japanese project partners are leading players in technology fields relevant for 5G and the 5G-MiEdge project is meant to be instrumental for maintaining and extending such leadership.

The 5G-MiEdge project will support key KPIs relevant for 5G and address the forthcoming trends in the most appropriate way. Furthermore, new use cases and derived disruptive business models are to be identified in order to provide new stakeholders with more opportunities to enter the enhanced Mobile BroadBand (eMBB) market, thus being capable of delivering new integrated solutions and innovative services already in an early phase of the 5G role out.

The 5G-MiEdge project will mainly focus on three technologies, as described in Table 1, to enable a part of those use cases and scenarios. As mentioned, the goal of mmWave Edge Cloud is to bring cloud-computing capabilities, including computing and caching, at the edge of the mobile network, within the RAN, in close proximity to mobile subscribers.
The future 5G system, which will take advantage of the mmWave Edge Cloud technology, is therefore expected to provide final users with the following service aspects:

- Higher peak data rate or higher area capacity,
- Low latency to deliver services and contents to mobile subscribers,
- Local (venue specific) services and contents delivery,
- Network slicing optimized for a specific application/service.

mmWave Edge Cloud also brings new business related opportunities allowing mobile operators to monetize combined cloud and network resources, as well as particular services to third parties. Resource brokering solutions are one approach that requires further investigation in such types of networking environments [MEC_Survey].

3.3 Selection of the most interesting 5G-MiEdge use cases

The 5G-MiEdge project, among the plethora of use cases for 5G discussed and still under discussion in several gremiums and bodies, selected, as detailed in the deliverable D1.1 [D1.1] and briefly described in the following, a few most promising ones, which can show best the benefit of merging mmWave with MEC technology, the core of the project contribution to the telecommunication ecosystem.

For the chosen use cases, a SWOT analysis is performed, which is a broadly appreciated and a well-known planning approach for better understanding the next steps of a complex plan of action. The main aim for the 5G-MiEdge project in performing the SWOT analysis is to highlight the most relevant hurdles for the adoption of the newly proposed technologies, so to best focus on them during the remaining part of the project lifetime, and to lessen the impact of negative factors in the first pre-development and deployment activities, planned towards the end of the project.

3.3.1 2020 Tokyo Olympics

The 2020 Tokyo Olympic represents one of the most challenging use cases of extreme mobile broadband due to both the very high bit rate requirements per single connection and the very high user density. In addition to the requirements affecting the total system capacity, very low latency constraints required by some of the foreseen multimedia services (e.g., virtual/augmented reality) make even more difficult to design an adequate communication system. Downloading information about the entertainment events in advance at the entrance gates might facilitate the enjoyment of audiences during the Olympic Games. These applications will require a combination of ultra-high connection density, high data rate and low latency.

3.3.1.1 Stadium Description

The typical geometry of this use case is based on the plan of the new National Stadium for Tokyo Olympics 2020 (see Figure 12), which is planned to be completed in November 2019 [Japan Sp. Council]. The stadium will be built above an area of
about $113\times10^3 \, m^2$, with a building coverage area of approx. $72.4\times10^3 \, m^2$, and a total floor area of approx. $194\times10^3 \, m^2$. It will have a height of about 47.4 m with two underground floors and 5 floors above the ground. It will have a seating capacity for 60,000 people, which may be extended to 80,000 people in the future. This stadium has six gates each might be supported by multiple entrance ports to accommodate all the audiences attending the events.

![Diagram of the stadium](image)

1: Nursing room, 2: Kid room, 3: Stroller storage, 4: Rest room

**Figure 12: New National Stadium for Tokyo Olympics 2020 [JPSPC]**

### 3.3.1.2 5G MiEdge Information Shower

In the 2020 Tokyo Olympic stadium, a visitor may be expected to pass under the 6 entrance gates (see Figure 13) with a very high frequency (each 5 second at the entrance and less than 1 second while leaving the stadium) [D1.1]. The 6 entrance gates are subdivided in a large number of multiple access ports (typically equipped with turnstiles), to enable an efficient filling of the stadium. To accelerate the flow rate, spectator electronic tickets may be read from fixed access points. Whenever a visitor passes the gate, one can download event-specific applications together with the associated large volume of data e.g. event schedule, related videos in the past events, player’s profile etc. to enjoy the unique applications e.g. AR/VR while watching the game. Regarding the hot spot antenna used, two possible solutions can be considered: a single hot spot antenna that serves all the access ports of a gate, or multiple antennas (one information shower per each entrance port).

According to the analysis detailed in D1.1 [D1.1], it is expected that the network should be able to provide, per each person, 1.718 Gbit/s at the entrance gate and 4.2 Gbit/s at the exit gate. To deal with this peak high data rate, one information shower
per each entrance port is planned to be deployed, based on mmWave and MEC technologies (see Figure 14).

![Figure 13: Entrance ports equipped with mmWave showers](image1)

The “information shower” refers to the concept that when people walk from room to room, it is possible to download or exchange with devices on an as-needed basis a massive amounts of content. In order to achieve ultra-high-speed throughput, the 5G-MiEdge shower will combine mmWave access with MEC. In particular, MEC enables to pre-fetch the most popular or requested contents to the local edge server, in order to prevent backhaul congestion. This content can be customized on the person’s profile, one’s supporting team, age, etc. Also mmWave technology will enable to transfer the dedicated data with a short latency, and thanks to the directive beams, to limit the interference between neighboring showers.

![Figure 14: mmWave showers](image2)

At this stage of the project, we think that the envisioned information shower can be a very attractive solution for the H2020 stadium. To underline this, we carried out a SWOT analysis, which is summarized in Table 3.

**Table 3: SWOT analysis of 5G-MiEdge information shower.**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatible with the target data rate</td>
<td>Optimal deployment is still challenging</td>
</tr>
<tr>
<td></td>
<td>Sensitive to blockage due to obstacles such as human body</td>
</tr>
</tbody>
</table>
mmWave technology enables to focus the data transmission to a single user passing the gate

- MEC enable customized content delivery
- Data transmission transparent to the user

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reducing the stress for the transport network</td>
<td>• mmWave technology needs to be adopted and broadly integrated in future terminals</td>
</tr>
<tr>
<td>• Customized content may include advertising, promotions, security messages</td>
<td></td>
</tr>
</tbody>
</table>

### 3.3.2 Automated driving

Automated driving is considered as one of the three most important use cases of future 5G systems [5GPPPWP_AV]. The 1\textsuperscript{st} phase of 5G Vehicle-to-Vehicle (V2V) and Vehicle-to-Everything (V2X) communications feature, under definition by the 3GPP standards body, aims at driver assistance systems and exchanges messages, either directly between vehicles or via appropriate infrastructure [3GPP22885]. These messages are transmitted in case of an emergency or as so-called awareness messages, which contain information such as location, speed and heading direction. However, the planned 2\textsuperscript{nd} phase of the 5G V2X feature aims at automated driving applications, where automated control SW become primarily responsible for monitoring the environment and the driving vehicles, referred to as Levels of Automation (LoA) in the range 3 to 5 [SAE].

Automated driving systems require highly resolved and dynamic maps in order to maneuver safely. Since the resolution of current maps used for car navigation is definitely not sufficient, high resolution and real-time maps, also called dynamic High Definition (HD) maps, become indispensable [SH16].

Figure 15 shows an example of automotive traffic in a dense urban city environment. To exchange such amounts of vital information, the estimated traffic between the vehicles is 1Gbps. Considering an average density of around 0.2 vehicles/m/\textsuperscript{lane}, the Road-Side Units (RSU) need to be placed with a distance of 40m to each other and support an average data rate of 24Gbps. Another crucial part of the system is the latency value, which for automated driving needs to stay below 10ms [5GPPPWP_AV]. The range of RSUs and On-Board Units (OBUs) needs to be at least 150m.
With current technologies, such as [3GPP22885], it is not possible to create a system that can meet all the requirements summarized in Table 4. This opens up a range of new opportunities for new products based on mmWave transmission.

Table 4: V2X communication requirements

<table>
<thead>
<tr>
<th>Scenario conditions</th>
<th>Resulting requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle density</td>
<td>Vehicle speed</td>
</tr>
<tr>
<td>0.2 m per Lane</td>
<td>≤ 250kmh</td>
</tr>
</tbody>
</table>

Figure 16 shows an example of a system architecture for mmWave based V2V/V2X in order to realize a real-time exchange of HD maps between OBUs mounted in vehicles and RSUs.

![Figure 15: Automotive traffic scenarios in urban city environments](image)

![Figure 16: RSU and OBU composed of mmWave and MEC](image)
Finally, Table 5 summarizes the SWOT analysis for the automated driving use case.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Compatible with the target data rate</td>
<td>● Optimal deployment is still challenging</td>
</tr>
<tr>
<td>● mmWave technology enables a dense deployment</td>
<td>● Sensitive to blockage due to obstacles such as human body</td>
</tr>
<tr>
<td>● MEC can improve the quality and reliability of collected sensor data</td>
<td></td>
</tr>
<tr>
<td>● Low latency times enable a real-time collection of sensor data coming from all vehicles in the area</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Huge market opportunities in the automotive market</td>
<td>● Being able to develop a reliable technology for the automotive market</td>
</tr>
<tr>
<td></td>
<td>● Adoption of vehicle manufacturers of the V2X technology</td>
</tr>
</tbody>
</table>

3.3.3 Omotenashi services

The goal of Omotenashi services is to make the customers who come to Japan have fun and feel satisfied by providing a service adjusted to customers’ needs. In [D1.1], three locations (airport, train station and food court) were selected as typical scenarios where many people need to wait in a dedicated areas, as shown in Figure 17. For example, main applications of these services are (a) Ultra-high-speed content download in a dense area and (b) Massive video streaming, both of which are very challenging to be fulfilled due to the very high user density.

![airport](image1.png) ![train station](image2.png) ![food court](image3.png)

(a) Airport                          (b) Train station                   (c) Food court

Figure 17: Scenario examples of Omotenashi services

As one of the most typical application examples, Figure 18 shows a high-speed content delivery system based on WiGig/IEEE 802.11ad [WiGig] which was showcased at the Wireless Technology Park (WTP) 2017 event. As illustrated in Figure 18 (a), in this prototype the users’ status (link quality etc.) is collected to the access point controller (APC) via legacy Wi-Fi, which can cover wider area as compared to WiGig. When the user moves to the WiGig area, the APC establishes a WiGig link...
based on the users’ status. The prototype achieves 1.7 Gbps throughput, which enables to download 2 GB content (2 hour HD video) from the storage within 10 seconds.

(a) WiGig signage prototype

(b) Demonstration at WTP 2017

Figure 18: Example of high-speed content delivery system

Figure 19 shows an example of the overall system architecture and its key players. The edge cloud consists of a MEC server, a local storage and a WiGig signage. In order to prevent network congestion from the central cloud, the contents are pre-fetched to the local storages by the edge cloud contents delivery network (CDN). The contents in the local storage can be delivered to each WiGig signage through mmWave backhaul, which can lower installation cost.

Since the edge cloud needs to be optimized for each location, the micro operators may provide a site specific wireless access for the end users. The edge cloud CDN provider plays a significant role to efficiently distribute contents to the local storages. This is done by the MEC server which estimates users’ need using the context information (such as location, habits) based on the liquid RAN C-plane provided by the mobile network operator.
Even though there are many possibilities in business model design, Figure 20 shows an example of the business model diagram where the end users are the main source of revenue. The revenue can be maximized by running analytics on the MEC servers to predict the most popular contents across time for optimizing the pre-fetching step. The MEC analytics can also be utilized for target marketing and advertising, which may be additional sources of revenue.

Table 6 summarizes the SWOT analysis for the content delivery scenario. In addition to high speed contents download, the site specific service can create new business opportunities such as effective target marketing, selling video clips for a specific event, shopping promotions etc. On the other hand, the mmWave access may suffer from narrow area coverage and high sensitivity to signal blockage. These weaknesses can be alleviated by adopting mmWave and microwave cooperated heterogeneous network.
Table 6: SWOT analysis of contents delivery with mmWave and MEC

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Less than 1/10 download time</td>
<td>• Narrow area coverage of mmWave access</td>
</tr>
<tr>
<td>• Low cost deployment by mmWave mesh backhaul</td>
<td>• Sensitive to blockage due to obstacles such as human body</td>
</tr>
<tr>
<td>• Capability of site specific target marketing and advertising</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunities</td>
<td>Threats</td>
</tr>
<tr>
<td>• Continuous increase of data size (such as 4K/8K videos)</td>
<td>• Emergence of new wireless standards (such as IEEE 802.11ax), which may achieve significant throughput improvement even in high user density area</td>
</tr>
<tr>
<td>• Limited throughput in existing wireless solutions (Wi-Fi, LTE etc.) especially in high user density area</td>
<td></td>
</tr>
</tbody>
</table>

3.4 Techno-economic evaluation

After careful consideration, the 5G-MiEdge team has decided that it is advisable to wait for more concrete results and for a more detailed performance evaluation of the technologies addressed in the project, in order to perform a sound business analysis of the considered use cases. At the end of year 1 of the project not enough simulation results and performance analysis are available to provide a sound study.

Therefore it is more convenient, and more professional at the same time, to provide the planned business model analysis in the next planned deliverable D1.4 “Final report on joint EU/JP vision, business models and eco-system impact”, the starting point of which will be the SWOT analysis of each use case, performed in this deliverable. For each use case, based on the achieved simulations and obtained result, a more detailed and sound business analysis will be performed, together with a more detailed CAPEX/OPEX discussion.
4 Conclusions

The deliverable has presented the joint vision of the European and Japanese consortium and introduced a preliminary analysis for a selection of the use cases identified within the project. This will form the starting point for a more detailed business analysis that will follow in future project deliverables.
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