Millimeter-waves, MEC, and network softwarization as enablers of new 5G business opportunities

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***Abstract*—This paper focuses on analyzing some key business aspects that arise during the deployment of key novel enabling technologies for 5G systems. Results are taken out of two EU-funded ongoing research projects, namely 5G-MiEdge and Superfluidity, which largely exploit mmWave communications and softwarization concepts for 5G networks. We initially provide a stakeholder analysis of the 5G ecosystem, as well as a Strengths Weaknesses Opportunities Threats (SWOT) analysis of a couple of key and most promising 5G use cases. For one use case also a preliminary business model is provided. Then we detail an economic 5G cost model, which is able to provide indications on the profitability of 5G networks. Finally, we highlight the planned future works.**

Keywords—mmWave; MEC; Business opportunities; SWOT analysis; stakeholder analysis, softwarization, cost analysis.

I. INTRODUCTION

The forthcoming 5G system paves the way for a whole new plethora of business opportunities, through the introduction of enhanced performance and much higher edge-ification, softwarization and virtualization than prior network generations. The market deployment of new technologies, e.g., millimeter-wave (mmWave) access, Multi-access Edge Computing (MEC), and network softwarization, are going to open new fields of exploitation and spun new revenue sources [1], [2], [3]. Such opportunities can be seized by both existing and new players in the more and more pervasive services, offered by the telecommunication network as well as by the wireless access markets.

In this paper we provide different points of view on a few relevant business and economic aspects of 5G systems, focusing on some of the main results coming out from two ongoing research projects, namely 5G-MiEdge [4] and Superfluidity [5]. The EU-Japan co-funded research project 5G-MiEdge, focusing on MEC, mmWave access and advanced control plane technologies, identified five main use cases for 5G phase 2 systems, as detailed in the project public deliverable D1.1 [6]. This paper analyzes some key business and economic aspects of two of them, as well as performs on them a Strengths Weaknesses Opportunities Threats (SWOT) analysis. For one use case also a preliminary business model design is sketched. The EU-funded research project Superfluidity has focused on the design of a flexible, agile and high performance architecture for 5G networks. The key concept is the decomposition of services and network functions into softwarized components, called Reusable Functional Blocks (RFBs) that can be deployed on the 5G infrastructure [7]. The project has considered an initial evaluation of some economic aspects of the migration from a legacy 4G to a 5G network from the point of view of an operator [3].

The rest of the paper is organized as follows. Section II provides a stakeholder analysis of 5G system, Section III elaborates on two important use cases for 5G system, performs a SWOT analysis on them and sketches a business model design, Section IV discusses an economic cost model for the deployment of 5G networks, finally Section V hints at future works and concludes the paper.

II. STAKEHOLDERS ANALYSIS OF FUTURE 5G NETWORKS

The improved agility and flexibility of the services that will be offered by 5G systems will result in a much more advanced user experience than it is achievable with today's available and deployed technologies. For instance, network slicing and softwarization, which are key concepts in the 5G and beyond network architecture, after years of works in the academia, finally are supposed to allow a successful introduction of a completely new plethora of services. Such services are based on some new promising system architecture paradigms, like the anything as a Service (XaaS) model, which provides IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and NaaS (Network as a Service) capabilities.

Leveraging the XaaS model, a whole range of different and sometimes new vertical industry stakeholders will be able to offer products much more tailored to the specific needs of the targeted end-users. Additionally, the combined capabilities of high bandwidth wireless networks, which exploit mmWave connections and MEC technology, 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, thus providing an appealing possibility to new players to be profitable in the 5G market.

We start the 5G stakeholder analysis from the outcome of [6], which identifies some of them, and we extend here below the obtained results. Following our analysis, the identified main stakeholders of 5G system will be:

1. End customers,
2. Network operators,
3. Network vendors,
4. Service providers,
5. Equipment vendors,
6. Small and Medium Enterprise (SME),
7. Start-ups,
8. Verticals,
9. Public administrations and infrastructure owners,
10. Regulatory and standardization bodies.

Different stakeholders have different interests and focus on diverse aspects, technologies, applications and services of the 5G system. The biggest opportunity for business is indeed offered to (6) and (7), which have a unique opportunity to enter in a new market and push their ideas, new IP, products and patents in the forthcoming ecosystem. On the other hand, established players, mainly represented by (2), (3), (4), and (5), will have on the one hand the opportunity to enlarge and strengthen their existing market share, on the other hand the need to be able to keep their market share in a fast-changing ecosystem. One of the main expectation on 5G system is its capability to smoothly integrate different market verticals and related technologies [8] that's why (8) will be among the main beneficiaries of a broad deployment of 5G networks. As a matter of fact, (1) and (9) will benefit from a plethora of new services and applications, which will change the daily use of smartphones, and of sensors and wireless devices, thus making a reality the paradigm smart-X (with X= city, grid, network, home, etc.). Finally (10) and partially (9), will focus on establishing agreed-upon procedure, processes and protocols, to guarantee that future systems will be interoperable with legacy ones and that new frequencies will be correctly allocated, thus providing a thrust to the whole worldwide economy.

New services such as MEC 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.

For example the combination of MEC and 5G enables context aware use cases like concierge services in a way that is not feasible in current LTE networks. The drastic reduction of the End-to-End (E2E) latency which can be provided by the combination of MEC and 5G technology will open the stage for new segments, especially in advanced automated and collaborative driving. This will create new categories of uses and will bring new stakeholders into the game, as for example public authorities, which are responsible for road safety, and road infrastructure owners.

Clearly, all those mentioned new opportunities depend upon the ability of 5G technologies to deliver the performance and E2E latency that are expected from them, and meet the demanding requirements that 5G systems will have to fulfill. More in detail, the set of targeted performance levels will convince new vertical stakeholders to invest in 5G networks and to 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, will give more opportunities for new players to be part of the ecosystem and it will thus provide them with a perspective of profitable new businesses. As a consequence of such increase of the number of entities playing in the ecosystem, the overall market value of wireless telecommunication will be greatly enlarged.

MEC computing capability will be added by different stakeholders, and it is not necessarily the service provider who is driving this invest – it will happen that network operators and network vendors will provide the MEC computing power on demand and on a pay-per-use business model. All over all a trend to off-load computing capability from the device (which could also be a car or a manufacturing equipment) to the edge will accelerate indeed.

III. SWOT ANALYSIS OF TWO USE CASES FOR 5G

The economic impact will be a challenge as well as an opportunity for all stakeholders in the forthcoming 5G ecosystem. Therefore it is very important, for those who want to play an active role and be successful, to monitor technological and economic trends and identify business opportunities as early as possible.

Since a few years mmWave technology is considered by the research ecosystem a key pillar for 5G future networks [1]. Building on top of the existing results, the 5G-MiEdge project selected [2] and enhanced, as detailed in [6], five particularly important 5G use cases. For two of them here below it is performed a SWOT analysis, which is a well-known and broadly used planning approach for better understanding the next steps of a complex plan of action. The main aim in our SWOT analysis is to highlight the most relevant hurdles for the adoption of newly proposed technologies, so to lessen the impact of unknown or negative factors in pre-development activities, which are necessarily to be planned before the market launch of any new technology.

For the sake of reducing the length of this paper, one can find in the public document [6] the rationale of why existing cellular networks do not fulfil the requirements of the chosen use cases for the SWOT analysis.

A. 2020 Tokyo Olympics

The 2020 Tokyo Olympic is one of the most challenging use cases of extreme mobile broadband (eMBB), due to the very high bit rate per single connection, the very high user density, and the very low latency constraints required by the foreseen multimedia services, e.g. virtual or augmented reality. The capability of downloading information related to the event at the entrance gates will provide the audience with a much enhanced experience during the Olympic Games.

The deployment geometry of this use case is based on the design of the new National Stadium for Tokyo Olympics 2020 (see Fig. 1).

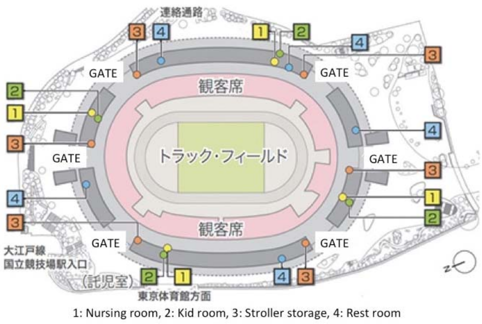

Fig. 1. New national stadium for Tokyo Olympics 2020 [9]

As shown in Fig. 2, the six entrance gates are subdivided in a number of multiple access ports, through which visitors will pass with a very high frequency, i.e. every five seconds while entering and less than one second while leaving the stadium. To accelerate the flow rate, the spectators' 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, videos of related past events, player's profiles etc.

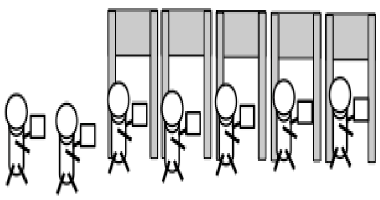

Fig. 2. The stadium entrance gate will be composed of several ports

According to the 5G-MiEdge analysis [6], the network shall 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 such high data rate, the deployment of a so called 'mmWave edge shower', one per each entrance port, is proposed. Fig. 3. shows in a simplified way (only one port per gate is shown) the design of each port, which consists of an antenna array, capable of a very high data rate using mmWave access, that acts as an enhanced access point to the stadium communication system.

The 'mmWave edge shower' refers to the concept that when people walk through a port of a gate, they will be able to download a massive amounts of content. In order to achieve ultra-high-speed throughput, such shower will combine mmWave access with MEC technology. In fact, on the one hand MEC enables to pre-fetch the most popular contents, or user-specific content based on registered profiles, to the local edge server, in order to prevent backhaul congestion. On the other hand mmWave access will enable to transfer the dedicated data with a very short latency and, thanks to directive beams, to limit the interference between neighboring showers.

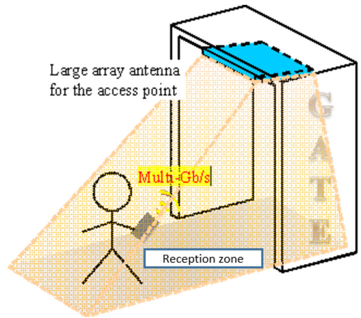

Fig. 3. mmWave edge showers

We think that the envisioned mmWave edge shower can be a very attractive solution for the 2020 stadium use case needs. To underline this fact, we carried out a SWOT analysis, which is summarized in the following Table.

TABLE I. SWOT ANALYSIS FOR THE OLYMPIC STADIUM USE CASE

Strengths	Weaknesses
- Can reach the target data rate - Enables focusing the data transmission to a single user - Enables highly customized content delivery in a short time - Data transmission transparent to the user	- Optimal deployment is still challenging - Sensitive to blockage due to obstacles, e.g., human bodies
Opportunities	**Threats**
- Reduce the transport network load - Customized content may also include advertising, promotions, or security-related messages - Data analysis in a larger use community may enable new use cases and services	- mmWave access needs to be adopted and broadly integrated in future user equipment - Business models have to be established across several stakeholders

B. Omotenashi Services and related business model

The Japanese concept of 'Omotenashi' refers to make visitors who come to Japan have fun and feel satisfied, by providing a service adjusted to their needs. In [6], three typical scenarios (airport, train station and food court) were selected where many people need to wait in dedicated areas. In such scenarios, the main applications of Omotenashi 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.

As one of the most typical application examples, Fig. 4 shows a prototype of the high-speed content delivery system based on WiGig/IEEE 802.11ad [10], where authentication, connection management as well as content browsing are executed via Wi-Fi to achieve wide coverage. While the UE is connected to Wi-Fi, the access point controller (APC) periodically collects expected WiGig link quality via Wi-Fi [Fig. 4 (1)]. When the UE requests WiGig connection, the APC connects the UE to one of the WiGig modules that provides the best link quality [Fig. 4 (2)]. When the user requests the content via an application, the UE starts downloading from the local storage via WiGig [Fig. 4 (3)]. The prototype achieves 1.8 Gbps throughput, which enables to download 2 GB content (2 hours of HD video) in 10 seconds.

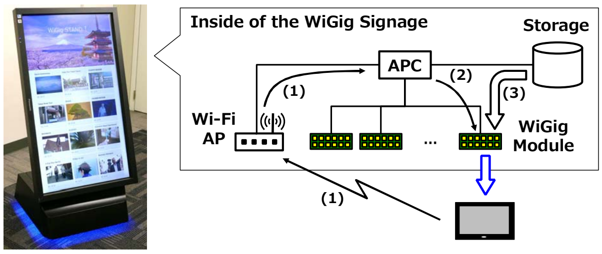

Fig. 4. WiGig signage prototype

Fig. 5 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' needs using the context information (such as location, habits) based on an enhanced control-plane [11] provided by the mobile network operator.

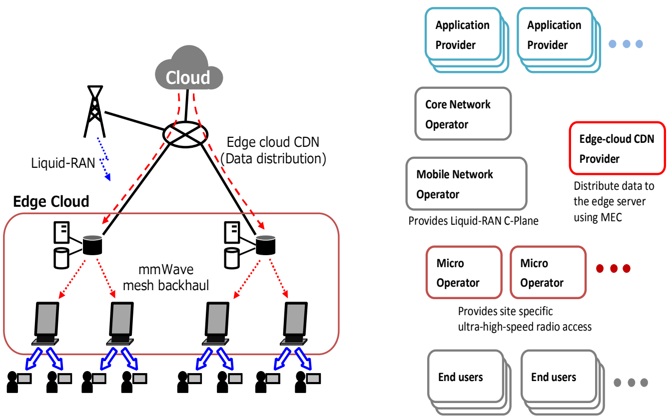

Fig. 5. Architecture of contents delivery service (left) and key players (right)

Even though there are many different potentially fitting business model designs for this use case, Fig. 6 shows an example of a 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 can be considered as additional sources of revenue.

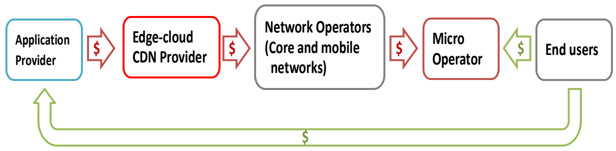

Fig. 6. Example of business model diagram

The following table summarizes the SWOT analysis for the Omotenashi use case. 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, e.g., mmWave and microwave cooperative heterogeneous network, an interesting research topic which is left as future work.

TABLE II. SWOT ANALYSIS FOR THE OMOTENASHI USE CASE

Strengths	Weaknesses
- Less than 1/10 download time - Low cost deployment by mmWave mesh backhaul - Capability of site-specific marketing and advertising	- Narrow area coverage of mmWave access - Sensitive to blockage due to obstacles, e.g. human body
Opportunities	**Threats**
- Continuous increase of data size (such as 4K/8K videos) - Limit throughput of the access part (Wi-Fi, LTE etc.) especially in high user density area	Emergence of new wireless standards, e.g. IEEE 802.11ax, which may achieve significant throughput improvement even in high user density area

IV. ECONOMIC COST MODEL FOR THE 5G DEPLOYMENT

The cost of the migration from a 3G/4G network to a 5G one will play a fundamental role in the transition phase. The operators needs to plan the deployment of 5G networks by taking into account the business opportunities (as described in the previous section) and by considering the profitability with analysis of costs and revenues. Focusing on this last aspect, in the following we identify a methodology to assess the profitability of the deployment of a 5G architecture based on the softwarization principles [7].

We focus on a so called 'superfluid network' architecture, which exploits the decomposition of functional components into RFBs. Each RFB performs a specific task, such as Remoted Radio Head (RRH), Base Band Unit (BBU) or MEC. The main idea of the superfluid network is deploy nodes hosting RFBs, which are softwarized components, based on the users (and the network) requirements. In particular, the RFBs can be shared, moved and deployed run-time across the nodes, thus realizing the high level of flexibility and dynamicity required by the 5G network.

The first step of the proposed methodology is to introduce a cost model for installing the 5G HardWare (HW) required by the Superfluid network. Apart from dedicated HW, which is used to host low-level RFBs mostly interacting with the physical antennas, the network requires to install commodity HW, which is used to run the high level RFBs, such as the MEC ones. In this scenario, we model the cost of each node by considering a fixed term, which depends on the type of HW installed on the node, plus an additional term, which depends on the type and the number of RFBs installed. In general, the costs of commodity HW are affected not only by the type of CPU installed, but also by the amount of Random Access Memory that is installed in each node. The sum of these installation costs defines the Capital Expenditures (CAPEX) for each single node.

Apart from the fixed costs, that are paid when the nodes is installed, there are also Operating Expenditures (OPEX) that need to be faced in each year of the architecture lifetime. In particular, we have defined a cost model to take into account also the yearly cost for the energy consumption of each node, as well as the costs of scheduled maintenance operations.

Given the aforementioned costs, which are defined for a single node, a natural question is then: What is the total cost that need to be paid by an operator to deploy a 5G network? A possible answer is that the operator will likely start upgrading sites currently hosting 3G/4G technologies to 5G sites. Clearly, the transition between the old and the new technology has to take into account a set of issues, like ensuring the limits on the exposure to electromagnetic fields, or the need to guarantee legacy accesses and services. Nevertheless, we can consider a “what-if” scenario, in which the operator faces the issue of providing the 5G services by directly upgrading the current 3G/4G sites. As a result, we have extended the aforementioned CAPEX and OPEX model by considering the actual number of nodes to be deployed in the network.

Apart from the aforementioned costs, the network operator will gain a profit from the subscription of the users, which will pay a monthly subscription fee to exploit the 5G connectivity. In this scenario, given the CAPEX, the yearly OPEX, and different values of possible monthly subscription fees, we have computed the Net Present Value (NPV), which is a metric used to assess the benefit for an investment in economic fields. In particular, if the NPV is larger than 0, the 5G deployment is able to generate a net profit for the network operator. On the other hand, if the NPV is lower than 0, the 5G deployment will generate a monetary loss for the operator. In our analysis, we have considered the impact of the NPV by varying the monthly subscription fee. In particular, considering that the resulting NPV is a monotonically increasing function, it is possible to compute in a fast and reliable way the minimum monthly subscription in order to generate a profit for the operator. We refer the reader to [3] for a detailed description of the obtained results. In brief, our analysis confirms that, in scenarios in which the number of 4G cells is already pretty dense, the transition to 5G services will be smooth: in this case, in fact, it will be possible to install the 5G nodes directly in the same sites currently hosting 4G equipment. On the other hand, in scenarios that include a limited number of cells, it is mandatory to install new sites, in order to fulfill the requirements in terms of bandwidth and latency.

V. Conclusions

In this paper we analyzed several aspects of the business opportunities that the forthcoming 5G deployment will open up to the telecommunication ecosystem. A 5G system stakeholder analysis, a SWOT analysis of two interesting 5G use cases, one sketched business model for one use case and finally an economic cost model have been proposed. Results are based on the work of two ongoing international research projects.

Future works will concentrate on analyzing the impact of the synergy of different technologies, e.g. mmWave and microwave accesses in heterogeneous architectures, on refining the sketched business model and extending it to other relevant 5G use cases. On the cost analysis side, more parameters will be taken into account, e.g. the site acquisition costs.

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