5G challenges, requirements and key differentiating characteristics from the perspective of a mobile operator

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Abstract. The present paper studies 5G challenges, requirements and key differentiating characteristics from the perspective of a Romanian mobile operator. The main contribution is that we created a vision about the use cases, physical and logical architecture needed to support these uses cases and other key differentiated factors, that the deployment of a future 5G network will bring in a mobile network. This global vision was made after studying and analyzing the results and publication of the most important research and industry projects on 5G, realized until now. Our main goal is to be prepared in 2020 to develop a commercial 5G network and this analysis was made to observe the main changes and the new requirements that this implementation will bring in our current mobile network.

Keywords: 5G, mobile operator, use case, physical architecture, logical architecture, slice, network functions virtualization (NFV), software-defined networking (SDN), orchestrator

1 Introduction

The fifth generation of mobile networks, 5G, represents one of the key topics in today's research, industry and standardization areas.

5G is the technology which will operate in the 2020-2030 decade. 5G is the future Internet including radio access as well as a convergent core network between fixed access and radio access. It is expected that 5G will deliver more than connectivity. Its innovative design, with a full software approach, will transform networks into one programmable and unified infrastructure integrating networking, computing and storage resources, paving the road to new business models.

5G represents more than an expansion of bandwidth capacity and expects to enable new business models, streamline the service delivery and support different vertical use cases. It is required to support actual and future diverse set of vertical industries and simplify their provisioning process that calls for new architectural frameworks.

A mobile operator will have to deploy orchestrator functions that will allocate appropriate computing and network resources to the services, targeting diverse and dedicated business driven logical networks.

The paper is organized as follows: Subsection 1.1 presents the main challenges, requirements and key differentiating characteristics of a 5G network and Subsection 1.2 presents 5G overall roadmap. In Section 2 we presented the 5G use cases and we summarized in Table 1 the user experience key performance indicators (KPI's) and system performance requirements for each of these use cases. The 5G architecture, who is formed by logical and physical architecture, needed to support these use cases is presented in Section 3. Finally, Section 4 draws the conclusions.

1.1 Challenges, requirements and key differentiating characteristics

5G is the future Internet, accessible from any existing or future access technology and it will be the whole communication system of the 2020-2030 decade, at least, comprising new air interfaces, but also a new core network. The latter will leverage the convergence of telecom and IT in order to offer:

- ➢ an overall system architecture that permits any access technology to be connected to the core network, in particular new air interfaces defined in the future to address new needs;
- ➢ a dynamic configuration as a function of the requested applications to optimize the resource usage on a specific geographic area;
- ➢ a network operating system in charge of managing the global infrastructure;
- ➢ a facilitated fixed-mobile convergence [1].

A 5G network enhances the user experience by providing homogenous services over the coverage area by keeping a high throughput and a low latency communication, from static to high speed trains and from outdoor to deep indoor areas, assuring a seamless handover between any wireless access technology.

From a mobile operator perspective, the main 5G key requirements are: low power consumption and cost efficiency, higher capacity, higher spectrum efficiency and agility, integration of 3rd Generation Partnership Project Radio Access Technology (3GPP RATs) and non 3GPP RATs, ultra low latency, higher number of connected devices, seamless access to different wireless technologies, security and privacy of user`s data, resilience and robustness, flexibility and openness for future integrations, convergence between fixed and mobile verticals and ease of deployment and operation.

1.2 5G overall roadmap

The deployment plans in the following years, based on pre-standard technologies, are led by major mobile operators around the globe, including:

- ➢ Verizon - fixed wireless broadband using frequencies up to 28GHz;

- TeliaSonera – signed a strategic partnership with Ericsson, intending to launch 5G services in Stockholm and Tallinn in 2018, including e-health and connected cars use cases;
- Korea Telecom (KT) and South Korean telecommunications (SKT) – partnership with Samsung and Nokia, respective with Ericsson, are planning to provide 5G services in 2018 at PyeongChang Winter Olympics;
- Orange Group - is leading the worldwide 5G tests and trials initiative, intending to be 5G ready for Euro 2020 in Belgium, Spain and Romania. On January 25th 2017, Orange and Ericsson have demonstrated a wireless 5G communication with peak rates beyond 14 Gbps [2].

As shown in the bellow figure, the first commercial 5G deployments are expected to start in 2020, this term being constrained by standards bodies` readiness and commercial equipment availability [2].

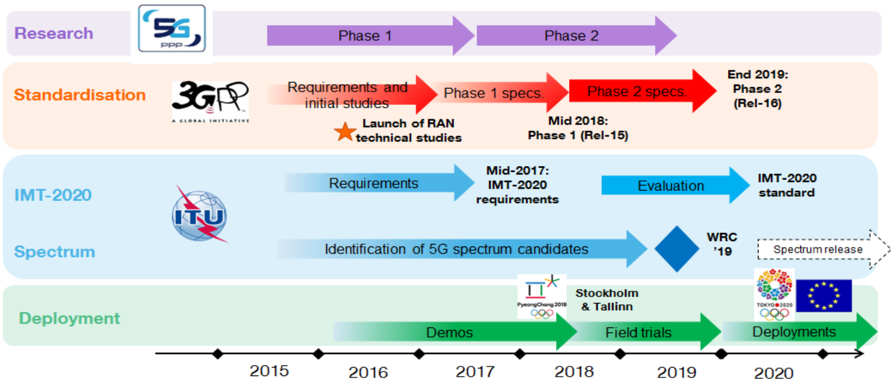

Fig. 1. 5G overall roadmap

2 Use cases and their requirements

After analysis of most important research and industry projects (5GPPP, METIS I, METIS II, NGMN, ETSI, etc), we found there are three main categories of use cases:

- massive broadband (xMBB) that delivers gigabytes of bandwidth on demand;
- massive machine-type communication (mMTC) that connects billions of sensors and machines;
- critical machine-type communication (uMTC) that allows immediate feedback with high reliability and enables for example remote control over robots and autonomous driving.

These three main categories could be further divided in eight families, each of them including some of use cases. This approach is very well presented in Next Generation Mobile Networks (NGMN) white paper [3]. We analyzed the main results of the 5G research projects and we decided that the NGMN presents and covers all the use cases. In the Table I, we presented each family, its use cases and key requirements for each of these use case.

Table 1. User Experience KPI's and System performance requirements

	Use case category	User Experience Data Rate	E2E Latency	Mobility	Connection Density	Traffic Density
Broadband access in dense area	Broadband access in dense areas	DL: 300 Mbps UL: 50 Mbps	10 ms	0-100 km/h	200-2500 /km2	DL: 750 Gbps / km2 UL: 125 Gbps / km2
	Indoor ultra-high broadband access	DL: 1 Gbps UL: 500 Mbps	10 ms	Pedestrian	75,000 / km2	DL: 15 Tbps/ km2 UL: 2 Tbps / km2
	Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian	150,000 / km2	DL: 3.75 Tbps/ km2 UL: 7.5 Tbps / km2
Broadband access everywhere	50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	0-120 km/h	400 /km2 in suburban 100 / km2 in rural	DL: 20 Gbps / km2 in suburban UL: 10 Gbps / km2 in suburban DL: 5 Gbps / km2 in rural UL: 2.5 Gbps / km2 in rural
	Ultra-low cost broadband access	DL: 10 Mbps UL: 10 Mbps	50 ms	0-50 km/h	16 / km2	16 Mbps / km2
High user mobility	Mobile broadband in vehicles (cars, trains)	DL: 50 Mbps UL: 25 Mbps	10 ms	up to 500 km/h	2000 / km2 (500 active users per train x 4 trains, or 1 active user per car x 2000 cars)	DL: 100 Gbps / km2 (25 Gbps per train, 50 Mbps per car) UL: 50 Gbps / km2 (12.5 Gbps per train, 25 Mbps per car)
	Airplanes connectivity	DL: 15 Mbps/ user UL: 7.5 Mbps/ user	10 ms	up to 1000 km/h	60 airplanes per 18,000 km2	DL: 1.2 Gbps / plane UL: 600 Mbps / plane
Massive Internet of Things	Massive low-cost/long-range/low-power MTC	Low: 1-100 kbps	seconds to hours	0-500 km/h	Up to 200,000 / km2	Non critical
	Broadband MTC	See the requirements for the Broadband access in dense areas and 50+Mbps everywhere categories				
Extreme real time communication	Ultra-low latency	DL: 50 Mbps UL: 25 Mbps	<1 ms	Pedestrian	Not critical	Potentially high
Lifeline communication	Resilience and traffic surge	DL: 0.1-1 Mbps UL: 0.1-1 Mbps	not critical	0-120 km/h	10,000 / km2	Potentially high
Ultra-reliable communication	Ultra-high reliability & Ultra-low latency	DL: 50 kbps - 10 Mbps UL: few bps - 10 Mbps	1 ms	0-500 km/h	Not critical	Potentially high
	Ultra-high availability & reliability	DL: 10 Mbps UL: 10 Mbps	10 ms	0-500 km/h	Not critical	Potentially high
Broadcast like services	Broadcast like services	DL: Up to 200 Mbps UL: 500 kbps	<100 ms	0-500 km/h	Not relevant	Not relevant

3. 5G Architecture

5G infrastructure will consist in a collection of functions (the network slicing principle) that compose various logical architecture on top of a single physical architecture like in Fig. 2 [4].

3.1 5G Physical Architecture

We consider that in order to have an efficient 5G network on the radio network, it is necessary to integrate an additional layer of small cells into the existing macro-cellular radio access network (RAN). The new small cells layer can be implemented using the classic RAN distribution or the innovative cloud-RANs (C-RAN) solution in which small cells are deployed as remote radio heads (RRHs) connected to a centralized macro-cell via a front haul interface. Firstly, it is expected that new types of frequency bands such as micro and millimeter waves to be used. This will make the

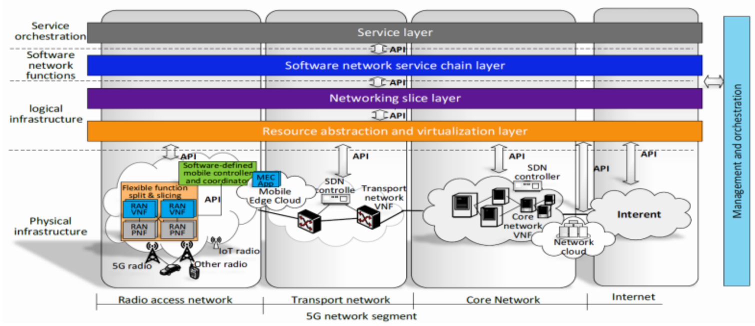

Fig. 2. 5G overall architecture

smaller cells even smaller and denser than in the current settings. As well, adopting massive MIMO (multiple input, multiple output) schemes will require more efficient interference management systems. This coordination of interferences must occur between systems (between macro and small cells e.g.) [4].

The transmission network will be deployed on fiber optic that can transport a large capacity (up to 100 Gb). There will be new segments of fiber and the existing ones will be adapted to support new requirements.

Core Network segment will be represented in majority of cases by VNF as we can observe from Fig. 2, thus running in virtual machines over standard x86 servers on cloud computing infrastructures orchestrated by a Virtual Infrastructure Manager. These VNFs have to be flexibly deployed by a VNF Manager in different data centers, with respect to the requirements regarding to latency, processing and storage capacity or available transport.

3.2 5G Logical Architecture

The 5G logical architecture will leverage the separation of hardware and software based on the programmability offered by SDN and NFV. In opposition to traditional network architecture where network functions are organized into logical entities, the 5G architecture will provide the flexibility to allow a per-slice basis grouping of network functions to logical entities and further the logical to physical architecture in accordance with ETSI (Telecommunication Standards Institute) NFV framework. When we talk about "network functions" in 5G, we will relate to computation and storage in all 5G network segments and the connectivity. With the ability to program the infrastructure, the control and data plane functions will be tailored according to the real-time network conditions and service needs, enabling scalability of both planes. In order to decoupling logical functionality from its physical realization, dedicated security mechanisms has always been required. One example can be access control mechanisms and encryption that are required to allow sensitive data to be stored or communicated on physically shared media such as radio links. In agreement with the decomposition of mobile network elements, the evolution towards 'cloudified' networks is envisioned that it will dramatically change the way mobile network functionality is deployed and geographically distributed. Insensitive to service- and slice-specific tailoring and chaining of network functions, and their flexible mapping to physical architecture, interoperability between vendors will require that some logical interfaces between network functions being standardized [4].

A network slice, namely "5G slice", supports the communication service of a particular connection type with a specific way of handling the control and user plane for this service. To this scope, a 5G slice is a collection of 5G network functions and specific radio access technology settings that are combined together for the specific use case. The slices don't contain the same functions, some functions that now seem essential for a mobile network might even be missing in some of the slices. The aim of a 5G slice is to provide just the traffic treatment required for the case and to avoid any other unnecessary functionality [3]. It will be enabled an end-to-end slice management across different planes, FCAPS (Fault, Configuration, Accounting, Performance and Security), that is missing in actual systems.

4 Conclusions

This paper presented, in a mobile operator vision, a brief description and the main challenges, requirements and key differentiating characteristics of a 5G network. We also analyzed the main future use cases, their requirements and the architecture that a mobile operator must to deploy to support these use cases. We consider that starting from different requirements of vertical use cases, 5G networks will rely on a larger spectrum portfolio compared with the previous generations. We think that besides re-farming the actual bands used in 2G, 3G and 4G networks, 5G will use low frequency bands to provide extended coverage and also high frequency bands to assure capacity and high user throughput.

Taking into account the aspects presented in this paper, we conclude that the spectrum characteristics, as well as the diverse use cases particularities, will require the ability to concurrently support multiple instances of differently parameterized network functions. The parameterization and the placement of these functions will depend on the deployment of the available hardware, the nature of the communication links and the required topology.

Acknowledgments. The authors are grateful to Alexandru Vulpe for the fruitful discussions that lead to this paper. This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 761913; project SLICENET.

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