5G and its application in the evolution of Smart Cities

Eduardo Moreno, Leonardo Mendes, Paulo Cardieri

***Abstract*— Cellular systems are becoming more important to the society, and this demands more capacity and new features. A new generation of systems, with better characteristics, and the use of advanced technologies are under development: the 5G networks. Smart Cities are evolving and will benefit from this new cellular generation. Several organizations are working on the 5G development, and some of the leading players are mentioned in this article. Smart Cities will demand new resources, new connections, new access methods and the 5G capabilities will give support for some of those needs. This work gives some information about the 5G networks development and their application to the Smart Cities, suggests new applications, and briefly describes Brazilian efforts. The use of 5G networks will enable advances in the Smart Cities and a diversity of new services.**

Keywords— 5G, IMT 2020, Smart Cities, SDN, NFV, mmWave, MIMO, Beam Forming, MBB, Extreme MBB, Massive MTC, Mission Critical MTC, D2D, new RATs.

I. INTRODUCTION

The Cellular Networks have developed and increased their relative importance throughout the economy and in several human activities. This growing demand has required new technological resources and a fifth generation (5G) is being specified and developed, representing a significant development over previous evolutionary stage [1].

Cities that are taking advantage of information and communication technology to their services, to reduce costs, increase efficiencies, enhancing the services and the quality of life of their citizens are known as Smart Cities [2].

Smart cities will make use of a high diversity of telecommunications and computing infrastructure. Cellular network will be an essential part of these resources. Initially, the current networks will be used, and later, when available, services and features of the new 5G networks will be incorporated allowing evolution in the availability and delivery of services in the Smart Cities.

Several organizations are playing an important role in the 5G development, and to follow their work is essential to understand the 5G evolution. Some of these references are:

- ITU- International Telecommunications Union [4,6], that is the specialized agency of the United Nations (UN) that is responsible for issues that concern with information and communication;

Eduardo Moreno, Leonardo Mendes e Paulo Cardieri – DECOM - FEEC-UNICAMP, Campinas – SP, Brasil, Emails: moreno@decom.fee.unicamp.br, lmendes@decom.fee.unicamp.br, cardieri@decom.fee.unicamp.br

- GSMA- The Global System for Mobile Communication Association [1] is the association that represents the mobile operators worldwide;

- GSA- The Global mobile Supplier Association [5], organization represents the telecommunication equipment vendors;

- 5G-PPP- 5G infrastructure Public Private Partnership [7], a group initiated by the EU Commission and industry manufacturers, telecommunications operators, service providers, and researchers that provides specifications to the telecommunication systems;

- METIS- Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society [3, 10], a group of researchers formed by the European Commission;

- Telecommunications Suppliers [2,9];

This article presents the 5G main characteristics, its applications currently considered to the Smart Cities and proposes new applications uses based on the trends of development, which will be made available through the development of the new 5G networks, with the incorporation of new technologies, new services, and applications, and briefly describes the Brazilian efforts on these matters.

This paper is organized as follows; Section II presents the 5G main features, concepts, applications, technical specifications, timelines, and standardization process; Section III presents some application of 5G networks to Smart Cities; Section IV shows development scenarios; Section V presents information about Brazilian efforts towards 5G and Smart Cities; VI concludes this article.

II. 5G DEVELOPMENT

The future new generation of 5G cellular systems will represent a significant development for the telecommunications systems, because it will offer larger capacity, massive connectivity, multiple services, high data rates, low latency, among other requirements. In the ITU context (Fig. 1) it is understood that the 3G (IMT-2000) and 4G (IMT-Advanced) systems will evolve to the new 5G systems (IMT-2020). Besides the availability of Mobile Broadband (MBB) that current systems can provide, it will be demanded much more capacity and connectivity. The IMT 2020 (and Beyond) will respond with the Extreme Mobile Broadband (Extreme MBB), Massive Machine Type Communication (MTC), Mission-Critical Machine Type Communication (Mission-Critical MTC) services, besides new use cases [3,4].

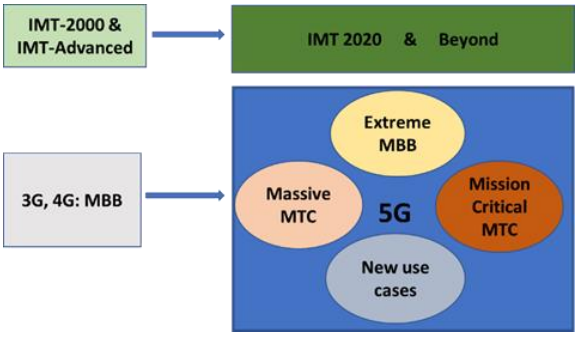

Fig. 1 - IMT for 2020 & Beyond development [3, 4, 6]

Within the set of applications that will use the Massive Type Communication are the applications in Smart Cities (see Section III), Smart Homes and Smart Buildings. In applications that will use ultra-reliable and low latency communications services stand out more application in Smart Cities, like Transport Control, Safety Management, and other critical applications like Automation. Advanced broadband services will allow the fast data transfers via modems and terminals (E-MBB), several services like 3D and very high definition videos, Amplified Reality, among others will be available.

Fig. 2 shows schematically the 3 groups of services that will be demanded from the 5G networks: Extreme Mobile Broadband, Massive machine type Communications, and Ultra-reliable and low latency communications.

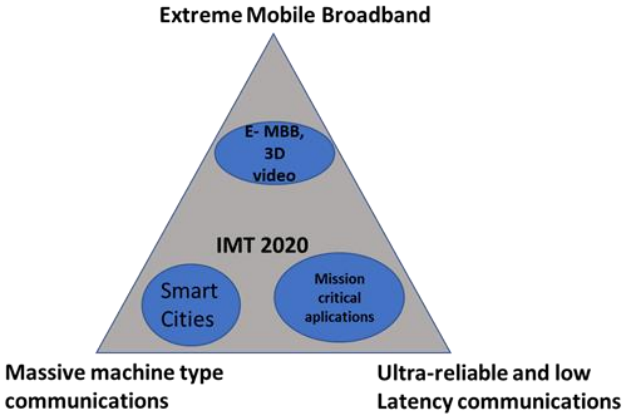

Fig. 2 - IMT 2020 usage scenarios [based on 4]

The new 5G networks will have challenging specifications such as high connectivity, high data rate, low latency, high reliability, and low power consumption. The technical answers to these requirements should come with heterogeneous networks that will use many different technologies, operating in several bands, with new and flexible architectures and advanced devices.

New features such as SDN (Software Defined Network) and NFV (Network Function Virtualization), SON (Self-Organized Network), self-backhauling, dynamic refarming, massive MIMO (Multiple In Multiple Out), new RATs (Radio Access Technologies), D2D (Device to Device) new architectures among others resources will be part of 5G solutions [5].

Tab. 1 shows some parameters considered for the future 5G networks. Some of the technological solutions that will allow their achievement are still in the process of research and development and represent a challenge for the industry, achieving some of those parameters (for example the Latency) will demand a complete change in the network architecture to be used.

Tab. 1 – Parameters for 5G networks [based on 5]

Parameter	Value
Peak throughput per connection	10Gbit/s
System spectral efficiency	10bit/s/Hz/Cell
Area capacity density	1Tbit/s/km$_2$
Connection density	100 X LTE Connection density
Latency (device to core)	<10ms
Latency (air link)	<1ms
Energy efficiency	>90% over LTE

Fig.3 shows an overview of the timeline for the development of the standardization of 5G systems, defined by 3GPP (3G Partnership Program), by ITU, set in the framework of the ITU-IMT-2020 project, and the corresponding development of networks by the industry. This standardization process includes workshops, technical evaluations, trials, definitions, seeking consensus among the parties. Further associated recommendations and systems will be delivered as well.

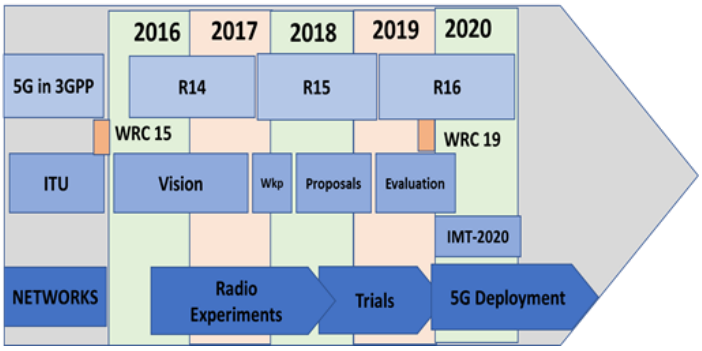

Fig. 3 - 5G Systems Timeline [based on 4,6,7]

III. Application of 5G Networks to Smart Cities

The development of Smart Cities will use available telecommunication and computing resources, initially its development will have resources of the current cellular networks, specifically 3G and 4G networks, but later with the availability of 5G networks, these new systems will form an important part of the infrastructure of several areas of a Smart City, such as Smart Education, Smart Government, Smart Mobility, Smart Grids, Public Safety, Smart Traffic Control, Autonomous Cars, among others (Fig. 4). The future Smart Cities will need 5G resources to be able to handle several innovative Smart City challenges [8].

There are several possibilities of applications of 5G networks to Smart Cities, in different groups of services. Some of these possibilities are MTC, Mission-Critical MTC systems, in Extreme MBB systems and in new use cases.

The application of the 5G network resources using MTC in Smart Cities considers the use of large-scale communication devices with low-cost, supporting services such as Smart Grids (for electricity distribution systems), surveillance camera systems for public safety, traffic management, and public transport management services [9].

Mission-Critical MTC systems will deliver high reliability, small delay communications and will be important for applications such as Autonomous Cars, Smart Traffic Control,

Work Safety Management, and Safety Management. They will also allow the support for several private activities such as industrial automation [9,10].

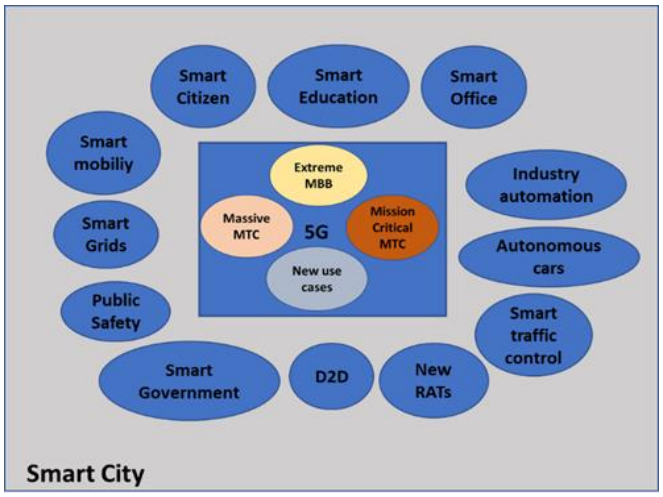

Fig. 4 - Application of 5G Networks to Smart Cities

Extreme MBB systems will bring applications in several areas of public administration that demand greater data volume, such as Finance, Construction, Health, and Education. Several applications like Augmented Reality can be used for public services, such as Tourist and Cultural Information, allowing progress in the efficiency and provisioning of those services [9,10].

The development of 5G networks will provide a support of infrastructure for the development of Smart Cities and making them able to take advantage of information and communication technologies, in several areas, to provide better and more efficient public services [1,2].

Another suggestion is the application of the feature D2D (Device to Device), which will allow a user terminal transmit information directly to another user, without passing through the access network or the operator's core. For example, in Brazil, there is an important challenge to provide communication to rural and remote areas, where radio signal propagation is difficult, in these scenarios, users can benefit from the use of this feature. Thus, there is the potential to extend data and voice services to those regions, as well as various public services such as information, education, health, transportation, among others (fig.5).

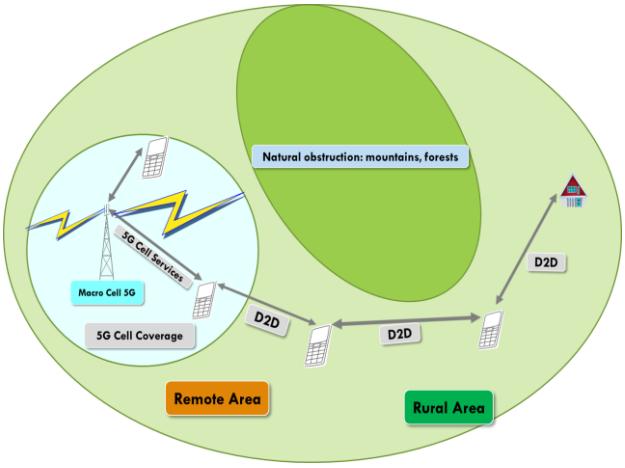

Fig. 5 – 5G Application to Remote and Rural Areas

The possibility of using new radios (New RATs) and new frequency bands, with higher capacity systems will allow the availability of wireless communication networks with more capabilities and more flexibility. These new technologies will support the citizen (Smart Citizen), the business sector (Smart offices), and will allow the improvement of public services which demand telecommunications resources, to improve the competitiveness of those cities.

IV. DEVELOPMENT SCENARIOS

The initial development of the new 5G Networks should take place from the existing 4G networks, with the implantation of new 5G cells (Small / Femto Cells). The macro 4G cells will perform the associated control in the legacy 4G spectrum. The new 5G cells are expected to use the legacy frequencies, licensed for 3G and 4G systems, as well as new, licensed, and unlicensed bands that will be available.

MTC (Machine Type Communication), massive and ultra-reliable systems should also have control processes associated with the 4G (LTE) overlay network (Fig.6).

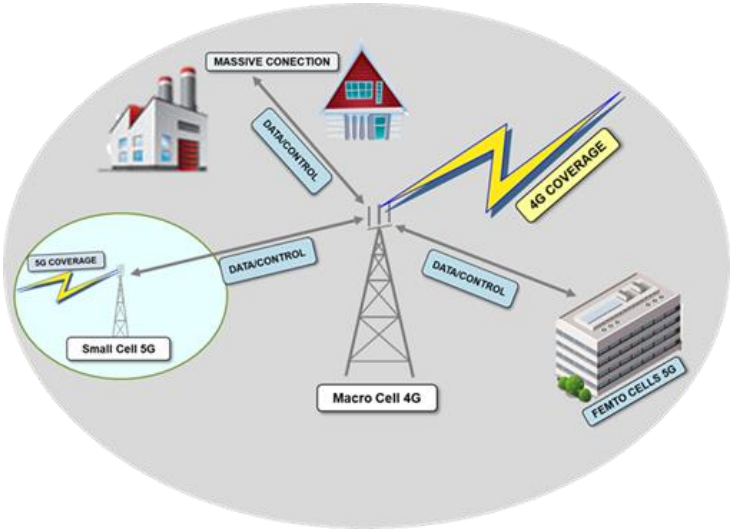

Fig. 6 - Macro Cell 4G integrating 5G systems

The structuring of the new 5G networks will require several technological advances, some of which are still at an early stage of research and development, for further development of equipment and systems. However, it is possible to foresee some of the development trends to contemplate the various dimensions of the specifications demanded.

Among the evolutionary need for the 5G Networks is the network densification, with a large number of elements such as Small and Femto Cells composing the system's topology. Carrier Aggregation will allow the use of discontinuous portions of the spectrum to provide higher capacity, dual connection to enable the increase of the transmission capacity with the terminal device being served by more than one network element. MIMO will increase the efficiency of the radiating systems, advanced receivers, more efficient and with more significant interference immunity, leading to the so-called convergence of multiple radio access devices (Multi-RAT).

Those facilities will provide more flexibility and efficiency in the provision of services, assisted access to optimize spectral occupancy, optimization of traffic distribution, and unloading of the system through auxiliary systems such as Wi-Fi

networks and terminals themselves communicating directly with others (D2D), new network architectures, network layering, cloud utilization, and more.

In the field of network operation, there is a trend to implement the Self Organized Network (SON) functionality to optimize the use of network resources. Reconfigurable NFV and SDN resources, the use of features to make the system more fault tolerant, Fixed-Mobile convergence (FMC), which will bring more efficiency in the use of legacy networks will also be used.

From a business point of view, the NFV and SDN resources will be important to allow the rapid and efficient launch of new services. The evolution of existing services, using fixed-mobile convergence (FMC) is also a clear trend and several value-added services (e.g., big data, AAA, billing, etc.) that will support all business with agility and efficiency.

V. BRAZILIAN EFFORTS TOWARDS 5G AND SMART CITIES

In Brazil, on February 15, 2017, representatives of the Federal Government, through the MCTIC (Ministry of Science, Technology, Innovation, and Communications), ANATEL (National Telecommunications Agency), representatives of the telecommunication industry, telecommunications service providers, and academy launched the 5G Brazil Project. This project aims to foster the creation of an ecosystem of fifth generation mobile telephony systems in the country and its participation in the international standardization and forums [11, 12].

ANATEL intends to hold a public consultation on the allocation of high frequencies to 5G (mmWave) in 2018. This process will subsidize the Brazilian position in the WRC-19 (World Radiocommunication Conference -2019), on the frequency bands to be used in the fifth generation, anticipating the global schedule in band definition, such as 26 and 40 GHz. This proceeding can advance the procedures of cleaning, allocation, dynamic allocation, sharing and transfer of these bands, which would allow its use. In those frequencies it would be possible to provide 200 MHz bands for each Telecom operator, which could boost a substantial capacity increase. In the ITU technical meeting, held in Abu Dhabi in September 2017, the Brazilian administration, represented by ANATEL, presented a study demonstrating the technical feasibility of using the 26 GHz band. As Brazil uses intensive satellite communications solutions, the concern was the interference of these services in the Ka-band occupying the spectrum between 27 and 30 GHz, with the use of the 26 GHz band for cellular services. This study reinforces the use of the 26 GHz band as a candidate for the extension band for 5G services. The challenge will be to harmonize this and other tracks in the rest of the world. Ofcom, British regulatory agency, has already shown support to this proposal. Also, ANATEL intends to allocate 100 MHz in the range of 2.3 and 2.4 GHz for 5G services [13, 14].

MCTIC and BNDES (National Development Bank) are developing a plan for IoT in Brazil. This program presented 43 measures to be taken, 39 structuring actions and 25 enablers. Issues such as the use of sectoral funds, exemptions, technological and regulatory issues, strategies for the diffusion of IoTs for small and medium-sized companies, as well as IoT for Intelligent Cities are addressed.

ANATEL believes that one of the most significant regulatory challenges soon will be the regulation of the Internet of Things (IoT), and it should initiate the process of associated public consultations in 2018. Several issues will be addressed such as spectrum, connectivity, classes of service, granting, numbering, quality, certification, roaming, coexistence, security, privacy, delivery models, and taxation [13, 14].

Those new technologies will be important for structuring the Smart Cities in the country, especially because there is a significant gap in the country's fixed broadband infrastructure.

Several Brazilian cities have made efforts to improve the use of their Telecommunications, and IT resources for the benefit of their citizens, with applications and solutions efforts in important areas such as mobility, energy, urban planning, environment, technology, education, health, safety, entrepreneurship, economics, governance, among others, have been carried out in several cities. We can mention cases of efforts for the development of intelligent cities like Búzios-RJ [15], examples are the development of alternative energy systems [16] and lighting [17], Natal-RN consists of another Smart City development initiative [18]. The improvement of the telecommunications infrastructure, the new technologies and the resources that will be available with the new 5G networks will potentiate the use of these solutions and their evolution.

VI. CONCLUSION

The 5G networks will represent a technical evolution to the telecommunication area, and this will support Smart Cities in their development. In this article we briefly presented the 5G characteristics, technical specifications, their application to Smart Cities, some applications suggestions, development scenarios, and information about the Brazilian development in those areas. Several groups of 5G services like MTC, Mission-Critical MTC systems, Extreme MBB and New uses categories will allow new services for Smart Cities. Further work will be required, to find new applications from 5G networks to Smart Cities following the 5G standardization and the system's development.

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