MASSIVE MACHINE-TYPE COMMUNICATIONS: BY MACHINE LEARNING TOWARDS 5G

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Abstract–This paper provides an overview of the development and possible use-case scenarios of the new generation of mobile communication systems known as Next Generation Mobile Network (NGMN). As predicted, current exploitation of the fourth generation mobile communication systems (4G) will reach 50 billion connected devices by 2020. Expectations are that its successor, currently developing fifth generation (5G), is going to be operable by 2020. This new generation of mobile communication systems tends to become a technology platform that will enable the development of new applications, business models, industries, such as massive machine-type communications. This will be possible primarily through the creation of acceptable ecosystem that could provide a massive machine-type communication using a single platform based on the Internet of Things (IoT) concept. NGMN enables the integration of all so far known and used machine-type communications, creating an environment of smart cities and a fully networked society under the new concept of Internet of Everything (IoE). However, such network also poses specific performance requirements reflected through higher transmission speeds, higher data volumes, reduced energy consumption, higher quality of service, and growth in the number of services and users of currently deployed mobile generation.

Keywords-Next Generation Mobile Network, 5G, Machine Type Communication, Internet of Things, Internet of Everything

I. INTRODUCTION

Nowadays, mobile communications have a significant impact on the society and are an important factor in economic development and computerization of society. After a numberof generations and the current commercialization of 4G mobile communication systems (MCS) it is expected that the upcoming 5G is going to be operable by 2020 . Up to this period, 5G is emerging as one of the main fields of research and development . Predictions suggest that 5G will contribute to creating a fully mobile and connected society, which will result with a stronger socio- economic progress of the community.

Over the past decades, the development of information and communication (IC) and computer technology has resulted in universal computerization of society, including the application of various telematics solutions. Telematics solutions have found their purpose primarily in the field of traffic and transport, through the implementation of the Intelligent Transportation Systems (ITS) . However, telematics solutions are experiencing continuous increase of application fields and various users, including the large number of smart phone users, owners of the digital gas meters with the possibility of remote control, owners of smart vehicles, owners of smart homes, telemedicine service users, etc.

More recently, no less important are daily use of technologies such as communication between machines (M2M, Machine to Machine), the devices (D2D, Device to Device) or the vehicles (V2V, Vehicle to Vehicle) and the use of associated services and applications. The goal is

to consolidate all so far known and used machine-type communications (MTC, Machine Type Communication) through a single infrastructure. MTC technology is based on the idea that machines have a growing value proportional to the number of the networked units. This would result in the concept of IoE and the possibility of creating a smart cities environment and a fully networked society by simple increasing the number of networked machines .

Currently, total number of all existing networked machines is hundreds of millions, and the annual growth rate is around 25%. As a result, it is expected that by 2020 the total number of networked machines (equipment, vehicles, goods, etc.) will reach 50 billion . Therefore, network operators will be able to expand their business activities, service portfolios and increase revenues. This technology, combined with the existing ones, has a high potential for the development of future applications. Authors in defined six fields of application which will result with an increase of machine-type communication in a few years from now: (1) automatization and the structural control of buildings, (2) transport and logistics, (3) health, (4) public safety and supervision, (5) monitoring of environmental and utility services, and (6) monitoring of power plants and electric energy distribution.

Until then, complete MTC communication (MMC, Massive Machine Communication / mM2M, massive Machine to Machine communication / mMTC, massive Machine Type Communication) will pave the way for a significant increase of new networked machines, equipment and / or vehicles providing the new innovative services and applications. Consequently, as predicted, in a ten year period from now, this will result with the creation of new ecosystem based on the mentioned IoE concept . The main objective of this paper is to provide an overview of the main focus fields of development and implementation of mMTC communication that will be possible with the advent of 5G networks.

II. MAIN CHARACTERISTICS OF THE FIFTH-GENERATIONOF MOBILE COMMUNICATION SYSTEMS

With every new MCS generation it was possible to experience two times higher speeds of data transfer than it was in the previous generation. In NGMN system, i.e. 5G MCS, one of the main requirements are the increase of data speeds and capacity with the significant reduction of latency level. Figure 1 shows the comparison of latency level between 4G and 5G networks [2].

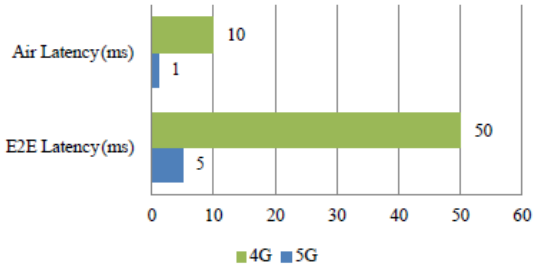

Figure 1 - Latency levels between 4G and 5G systems [30]

The integration of new services and applications is just as important as increasing the speed of data transfer and / or reducing the level of latency. 5G will be the MCS that uses its architecture and functionalities to enable the full implementation of services based on the IoT concept. This will result with a completely new communications between different types of machines (M2M, D2D, V2V, etc.) regardless of whether they're mobile, far apart or interconnected with different IC access technologies. With the advent of new services and the increase of the number of terminal devices, 5G MCS will increase the range of access requests for a mobile connection to the Internet network (MBB, Mobile Broadband) [19] [20].

Required transmission speeds vary based on the volume of the transferable data. The range starts from a very low level for sensor systems to very high level for the transfer of Ultra High Definition (UHD) video files. These requirements are reflected in the expected level of latency that will have to be low, as for security applications (emergency services, e-call about a car accident, alarm systems e-maintenance, etc.). However, there will also be services and applications that will be latency agnostic [21]. In addition, the size of the packets will varyfrom small to large, depending whether it’s a smart phone applications or file transfer application, respectively. Figure 2 provides an overview of the range of data transmission speeds between 4G and 5G MCS.

MCS 5G will enable ubiquitous provisioning of access to a wide array of services and software

solutions. As a result, this will have an impact on daily routines, thus allowing continuous progress of the overall society with a significant reduction in energy consumption . An important feature of 5G networks is also the higher level of security which is reflected in a higher level of privacy for business and private users, and data protection.

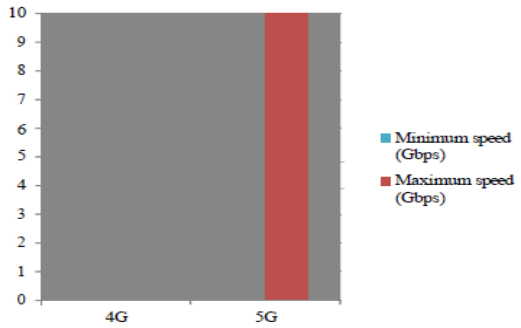

Figure 2 - Comparison of data transfer speeds between 4G and 5G systems [30]

5G systems will bring significant improvements for users and for network operators. Compared with today's networks, the greater efficiency of the use of radio spectrum and the application of mMIMO (massive Multiple Input Multiple Output) will increase the capacity resulting with an average mobile data speeds up to 1 Gbps. By reducing the latency to 1 ms, it will be possible to send a larger amount of multimedia content. Because of these new features, it is expected to connect potentially one trillion of terminal devices that will have smaller dimensions and greater battery autonomy. In order to assure a certain level of quality of service, reliability of service will amount to 99.999% . Figure 3 shows a comparison of the main parameters of the 4G and 5G networks.

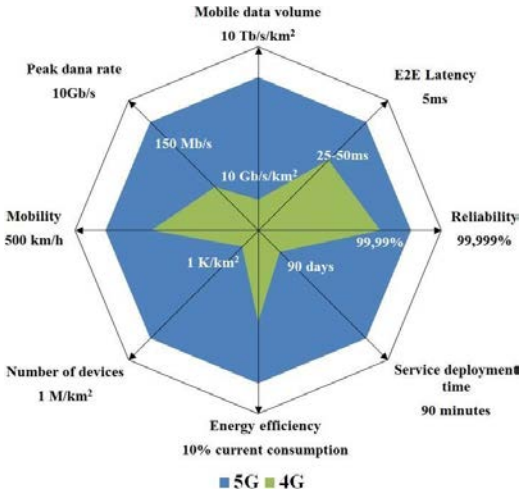

Figure 3 - The range of minimum expected requirements between 4G and 5G systems [4]

The operators' capital expenditure will be lower due to the cost-effectiveness of IC equipment . This is because the future core network of the 5G system will have the ability to dynamically configure the characteristics of communication hardware according to different standards. At the same time, there will be an integration of different technologies such as nanotechnology and Cloud communications .

Furthermore, it is expected that the IoT concept and 5G network will penetrate into various industries where they can contribute to interconnection and integration of different industrial facilities, medical equipment, vehicles, etc. In this way, this upcoming trend will meet required demands (which are impossible on 4G technologies to such an extent) for diverse services, including production services, medical services, transportation and other industries, thus resulting with a completely new concept and ecosystem based on the IoE paradigm.

III. PERSPECTIVES TOWARDS MASSIVE MACHINE -TYPE COMMUNICATIONS AND 5G

5G MCS will enable a complete implementation of the IoT concept, along with the advance of all machine-type communications through a single infrastructure (a prerequisite for MMC communications). Although most of the applications (such as M2M) transmit a small volume of data between end- devices (sensors, smart meters, etc.), it is predicted that a number of these new end-devices in the next few years will reach up to 50 billion. As a result, this will make maintenance and planning of today's telecommunications networks expensive and complicated. During the same period, an increase in the number of terminal devices will increase the volume of generated data traffic up to ten times .

A. Internet of Things concept

IoT is the concept of the information and communication network, where objects ("things") from diverse environments are mutual connected into a single large-scale network based on the Internet Protocol (IP) . As a result, all these connected objects are part of a single converged ecosystem. The IoT is the basis for the development of smart environments such as smart homes, roads, factories, cities, etc. The term IoT was first used in 1999. However, IoT is very popular during

the past several years. The formal introduction of the IoT concept was in 2005 with the release of the IUT-T (International Telecommunication Union - Telecommunication Standardization Sector) report . The development of IoT will allow each device around us to communicate with other devices. IoT consists of smart machines interacting with other machines, objects, things, environment and infrastructure . Therefore, M2M communication it's often associated with MTC IoT concept, which is the integral part of today's IoT concept. The common characteristic of IoT and M2M concepts is the remote device access . IoT connects the computer with the things (machines, devices, sensors, products, etc.), systems (business applications, support systems, analytical systems, data warehouses, control systems, etc.), and people (customers, employees, partners and customers).

IoT usually integrates the sensor data with analytics and business applications to improve productivity, service, and increase production and market share . Some of the main challenges that accompany the implementation of the IoT concept include security, privacy and trust, managing heterogeneity, limited network capacity, managing large amounts of information and processing large amounts of data in order to provide useful information / services and enable the efficient regulatory policy in the field of IoT.

B. Internet of Everything Concept

In contrast to IoT, IoE includes interconnection of people, objects, things, data and processes. IoT will reach its full potential during the next five years. In fact, IoT concept is a transitional technology. On the other hand, IoE concept encompasses a number of technologies including the IoT as a transitional technology.

The usefulness of IoE will result from the impact obtained by interconnecting people, processes, and data over IPnetwork, (Figure 5). Figure 6 shows the evolution of Internet-of-X concept starting with Internet of People (IoP, connecting people), followed by IoT concept, which will finally result with interconnection of everything as a part of IoE concept. IoE concept will create new opportunities for providing services to various individuals, organizations, communities and countries.

There is extraordinary potential of the IoE concept. According to the research conducted by Cisco Systems Inc. Corporation, 99.4% of physical objects that will one day be a part of the IoE concept aren't currently interconnected . Not only that these objects (things) do not make the connection, but they aren't even a part of the IoT world. This is primarily because there are no such services that would result with the interconnection of these devices.

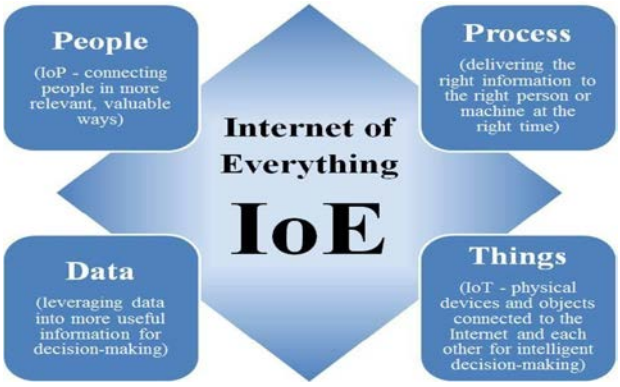

Figure 5 - Entities forming Internet of Everything concept

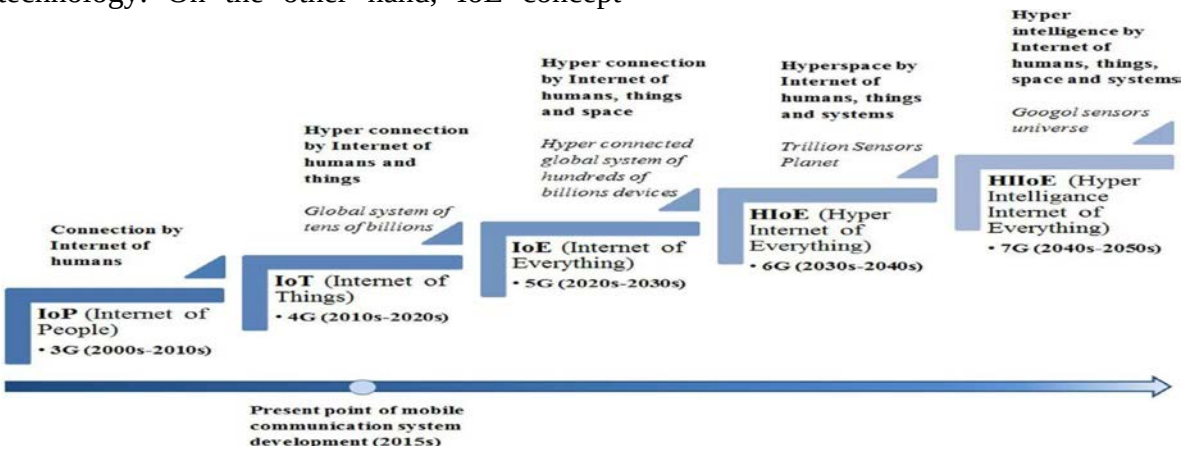

Figure 6 - The evolution of mobile communication systems and supporting services in the period from 2000 to 2040

Development of the 5G MCS will have an impact on economics, especially on the private sector. This is because of the simultaneous development of 5G objects, services and

applications. Predictions claim that the interconnection of the currently unconnected objects may result with a total profit of
$19 trillion; only private sector will make a profit of $14.4 trillion . Connection of the objects will most commonly be performed through 5G MCS with the use of full communication functionality of machines such as the MMC, People to Machine communications (P2M), V2V, V2I, direct D2D (dD2D), etc.

C. Massive Machine-Type Communication
Through the IoE concept, MMC communication will enable the connection of tens of billions of IP-based devices through 5G MCS. For example, as shown on Figure 7, 5G will be a systematic part of the Smart Cities in which 5G services and applications will have an impact on smart networked households(Domotics), smart/intelligent vehicles, tele surgery, fun, and time-critical applications that require an immediate reaction .
MMC concept includes a set of radio ICT and techniques, thus enabling the expected growth rate in the number of terminal devices and related services and applications. These access technologies are divided into three types :

- Direct access, terminal devices connect and communicate via direct access node
- Aggregation point access
- MTC communication between devices

The development of ICT and related services is gradually changing complete society in the last 20 years as well as the habits of each individual. However these are only the foundations for social changes which will follow after the implementation of future IC networks. For example, more than a third of the world population is nowadays constantly connected to the Internet; smartphones are becoming more and more popular and the development of mobile sector is expecting 4 billion users by 2017. NGMN will be the first complete system to fully implement converged IC network in which wired and/or wireless communications technologies will be using a single infrastructure . Described 5G IC infrastructure will be the base for the development of fully interconnected society.

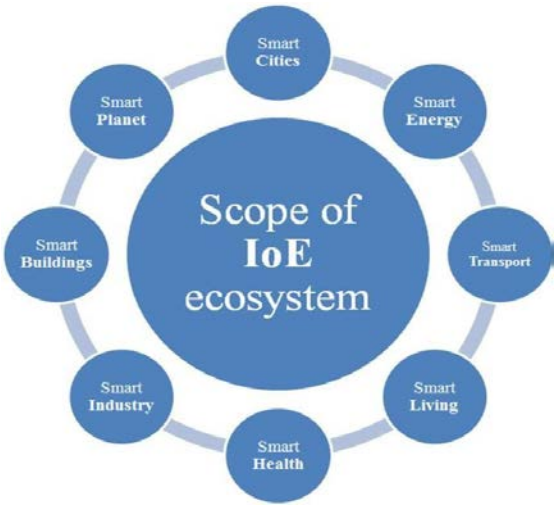

Figure 7 - Examples of application of Internet of Everything concept based on 5G

The adoption of these services and applications is part of the IoT / IoE ecosystem. In particular, the 5G era will be characterized with a fully interconnection of all things . Mobile network services, which were until recently limited only to smartphones, are gradually introduced to devices such as smart watches and sunglasses. In near future, each person will have several such devices.

D. Direct Device to Device Communication
As previously described, the MMC communication and the supporting IoT / IoE services provided via 5G platform will tend toward the creation of a fully networked and connected society. In a fully connected ecosystem enabled by 5G, the important role will play the ability to connect objects via D2D, i.e. dD2D technology . D2D communication is implemented within the 4G MCS but it's not widely operable, mainly because of its still limiting performance (level of latency, capacity, data rate, the level of confidence, etc.). Consequently, D2D will not become a part of everyday operable technologies primarily because due to these limitations when compared with its direct competitor - V2V solutions based on VANET (Vehicular Ad-Hoc Networks) technology.
Although the VANET solutions have their disadvantages, they are developed for the specific environment and their usability in V2V communication is currently more prominent. However, the concept of NGMN and earlier NGN (Next Generation Network) system are designed for all-IP communication via single infrastructure. This will result with the convergence between different access and

transmission technologies. Therefore, it was decided that one part of MTC communication will be enabled by dD2D technology over 5G [39]. Unlike the original D2D concept, dD2D will allow the planning and implementation of V2V communication within the IoE ecosystem. As mentioned earlier, with the development and implementation of 5G, several V2V requirements will be met, such as low latency of 1ms, default 99.999% reliability of communications, high availability and dependability and low failure rates .

CONCLUSION

The main objective of this paper was to present an insight into future developments, possible implementation and key features of the massive machine-type communication by introducing 5G. It is expected that in the next five years, mobile networks are going to experience a significant change compared to the current state. Transmission rate will be higher, the number of users and associated machines will increase by 10-100 times, and the traffic volume will increase up to 1000 times. It is necessary to consider the entire field as it opens new opportunities for network operators, service providers, and users within the value chain.

IC development and computer technologies have evolved simultaneously with the telematics systems and their field of application. Although the application of telematics solutions has its wider exploitation within the application segment of ITS, in the past decade their application is found in other fields as well. This is mainly due to the development of MTC Communications and later to the development of modern MCS and wider use of the accompanying smart phones.

Virtual connection of all types of devices such as, home appliances, vehicles, industrial machinery, vending machines, computers, etc. is becoming easier. The development of the IC networks and their environments, such as the MCS and WLAN with reduced size, high performance, and low-cost communication hardware has enabled easier way of connecting almost everything from the everyday living environment.

Today, MTC communication is possible even for devices that until a few years ago were not designed with the purpose of network communication, such as, air conditioners, gas meters, vehicles, televisions, and the list is still growing. MTC technologies such as M2M, D2D and V2V are becoming a reality and an everyday need through the concept of IoT. Communication of all these things through the IoT concept allows them to communicate directly with and without human intervention (automatic process control, monitoring and collection of data between devices, providing services through devices, etc.). A significant number of things/objects will find their application in IoT segment through various fields of activity (expectations are that by 2020, 50 billion things are going to be globally connected into one ecosystem).

In order to globally realize a trend and a plan for development of ICT and related services, it is necessary to fully develop 5G MCS as a single platform for the successful provision of cutting edge IC and telematics services. Estimated completion of the development and start of the implementation is beyond 2020. To realize all the predictions of the technological development, 5G networks in relation to the current MCS will have to assure significant improvements, particularly the increase of capacity, multiple increases of data speeds, and a high level of reliability, availability and dependability with low levels of latency in the network. As a result, this will allow a massive MTC communication that will contribute to IoT concept which will become a part of everyday life and enable transition to IoE concept.

IoE concept will bring a significant change for the society. It will change the way people live and contribute to the higher quality of life. With such development of ICT, implementation of new 5G MCS, and provision of various IoE services, it’s possible to make MMC homes, roads, vehicles, cities, countries, etc. an integral part of an instrumented world of widely distributed artificial intelligence in which almost everything becomes a communication unit (objects, things). Those machines in the common ecosystem interact with each other and solve complex tasks, often independently without any human intervention. Maintenance of buildings, bridges, roads, etc. will be raised to a higher level with the possibility of remote e-maintenance assisted with sensors and software as part of MMC and IoE world. Options for the application of modern

telematics solutions are almost limitless and the development and the implementation of 5G MCS will create a platform for their exploitation.

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