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5G NETWORK ARCHITECTURE

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Abstract. *The work deals with the main stages in the history of the development of different generations of cellular communication and options for the organization of their architecture. A brief overview of the main features and principles of construction of cellular networks of different generations. The analysis of the features and principles works of modern cellular networks of the fifth generation. Defined possibilities forward directions of modernization of existing cellular communication networks and opportunities to increase their potential.*

Keywords*: cellular network, 5G, MIMO, LTE, WiMAX.*

1 Introduction

Today wireless technology has a fixed position in our everyday life. In order to satisfy rising demand for high-speed wireless connection in near future, the wireless based networks of today will have to advance in various ways. Various current constituent technologies such as high-speed packet access (HSPA) and long-term evolution (LTE) will be used to develop future wireless based technologies. Nevertheless, auxiliary components may also constitute future new wireless based technologies, which may adjunct the evolved technologies. Ultra-dense deployments, direct device-to-device communication, different ways of accessing spectrum and considerably higher frequency ranges and instigation of massive antenna configurations these are all kinds of new technology components [1].

From analog voice calls to current technologies mobile wireless communication has come to high quality mobile broadband services with end-user data rates of several megabits per second over wide areas and tens to hundreds, of megabits per second locally. Evolution of various mobile devices such as smartphones and tablets and extensive improvements in terms of potentiality of mobile communication networks, have resultant exponential growth in network traffic. This paper tries to include a survey from 1G to 5G technologies and general 5G architecture.

We assume that in future there would be network with unbounded access to information and sharing of data which is accessible anytime and everywhere for everyone and everything. To make it true, new technology components need to be examined for the evolution of existing wireless based technologies. Present wireless based technologies, like Wi-Fi, LTE technology, HSPA and 3rd Generation Partnership Project will be incorporating new technology components that will be helping to meet the needs of the future. Nevertheless, there may be certain scenarios that cannot be adequately addressed along with the evolution of ongoing existing technologies. The instigation of completely new wireless based technologies will complement the current technologies which are needed for the long term realization of the future networks.

2 Evolution of wireless technologies

Wireless communications history starts with communicating the letter ‘S’ for 3 km in the form of three dot Morse code with the help of electromagnetic waves by Italian inventor G. Marconi. After this inception, wireless communications have become an important part of present day society. Since satellite communication, television and radio transmission has advanced to pervasive mobile

telephone, wireless communications has transformed the style in which society runs. The evolution of wireless technologies is shown in Fig. 1.

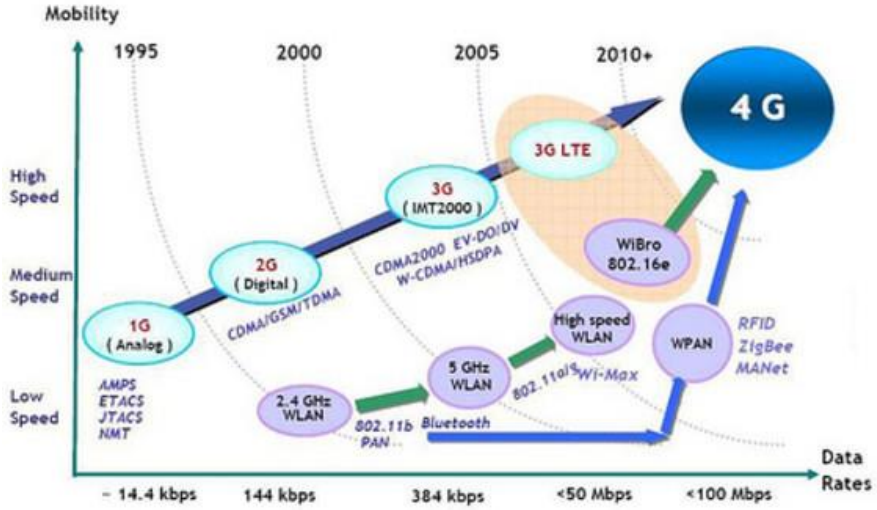

Figure 1 – Evolution of wireless technologies

It shows the evolving generations of wireless technologies in terms of data rate and mobility. With evolution of wireless technologies, the data rate, mobility, coverage and spectral efficiency increases. Technologies of 1G and 2G use circuit switching while 2.5G and 3G uses both circuit and packet switching and the next generations from 3.5G are using packet switching. Along with these factors, it also differentiate between licensed spectrum and unlicensed spectrum. All the evolving generations use the licensed spectrum while the Wi-Fi, Bluetooth and WiMAX are using the unlicensed spectrum. An overview about the evolving wireless technologies is below.

The 1st generation was announced in initial 1980's and has a data rate up to 2.4kbps. Major subscribers were Advanced Mobile Phone System, Nordic Mobile Telephone, and Total Access Communication System. It has a lot of disadvantages like below par capacity, reckless handoff, inferior voice associations, and with no security, since voice calls were stored and played in radio towers due to which vulnerability of these calls from unwanted eavesdropping by third party increases [4].

The 2nd generation was introduced in late 1990's. Digital technology is used in 2nd generation mobile telephones. Global Systems for Mobile communications (GSM) was the first 2nd generation system used for voice communication and having a data rate up to 64kbps. 2G mobile handset battery lasts longer because of the radio signals having low power. It also provides services like Short Message Service and e-mail. Vital eminent technologies were GSM, Code Division Multiple Access (CDMA), and IS-95 [4].

The 2.5G generation generally subscribes a 2nd generation cellular system merged with General Packet Radio Services (GPRS) and other amenities doesn't commonly endow in 2G or 1G networks. A 2.5G system generally uses 2G system frameworks, but it applies packet switching along with circuit switching and has a data rate up to 144kbps. The main 2.5G technologies were GPRS, Enhanced Data Rate for GSM Evolution (EDGE), and CDMA 2000 [4].

The 3G generation was established in late 2000 and imparts transmission rate up to 2Mbps. Third generation systems merge high speed mobile access to services based on Internet Protocol (IP). Aside from transmission rate, unconventional improvement was made for maintaining quality of service. Additional amenities like global roaming and improved voice quality made 3G as a remarkable generation. The major disadvantage for 3G handsets is that, they require more power than most 2G models. Along with this 3G network plans are more expensive than 2G [4]. Since 3G involves the introduction and utilization of Wideband CDMA, Universal Mobile Telecommunications Systems and CDMA 2000 technologies, the evolving technologies like High Speed Uplink/Downlink Packet Access and Evolution-Data Optimized has made an intermediate wireless generation between 3G and 4G named as 3.5G with improved data rate of 5-30 Mbps.

LTE technology and Fixed Worldwide Interoperability for Microwave Access (WiMAX) is the future of mobile data services. LTE and Fixed WiMAX has the potential to supplement the capacity of the network and provides a substantial number of users the facility to access a broad range of high speed services like on demand video, peer to peer file sharing and composite Web services. Along with this, a supplementary spectrum is accessible which accredit operators manage their network very compliantly and offers better coverage with improved performance for less cost [3-4].

4G is generally referred as the descendant of the 3G and 2G standards. 3rd Generation Partnership Project is presently standardizing LTE Advanced as forthcoming 4G standard along with WiMAX. A 4G system improves the prevailing communication networks by imparting a complete and reliable solution based on IP. Features like voice, data and multimedia will be imparted to subscribers on anytime and everywhere basis and at quite higher data rates as related to earlier generations. Applications that are being made to use a 4G network are Multimedia Messaging Service, Digital Video Broadcasting, and video chat, High Definition TV content and mobile TV [2-3].

With an exponential increasing users demand, 4G will be replaced with 5G with an advanced access technology named Non- and quasi-orthogonal or filter bank multi carrier multiple access and Beam Division Multiple Access (BDMA). BDMA technique concept is explained by considering the case of the base station communicating with the mobile stations. In this communication, an orthogonal beam is allocated to each mobile station and BDMA technique will divide that antenna beam according to locations of the mobile stations for giving multiple accesses to the mobile stations, which correspondingly increase the capacity of the system [5]. Incentives to move towards 5G is based on current drifts, it is commonly assumed that 5G cellular networks must eliminate six weaknesses of 4G i.e. higher capacity, higher data rate, lower End-to-End latency, massive device connectivity, reduced cost and consistent quality of experience provisioning. These challenges are concisely shown in Fig. 2 along with some potential facilitators to address them. An overview of the challenges, facilitators, and corresponding design fundamentals for 5G is shown in Fig. 2 [8].

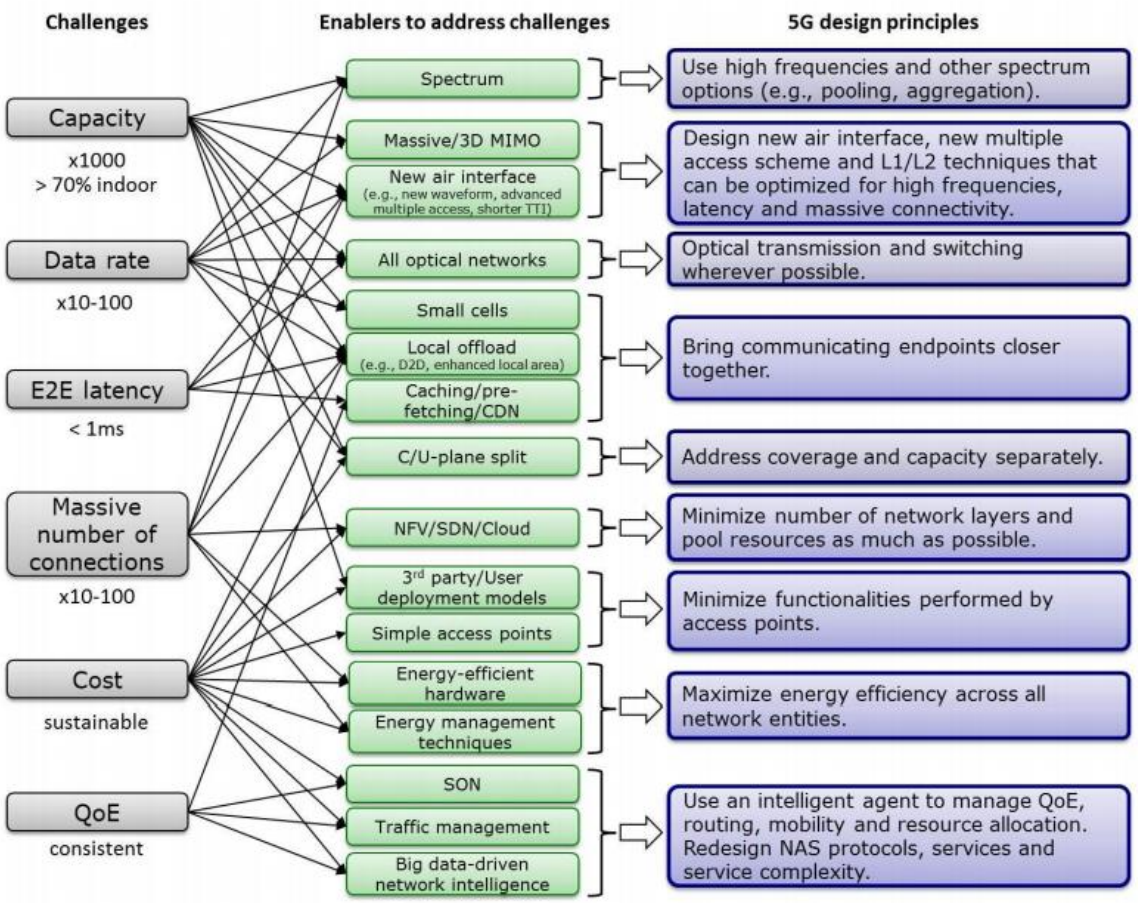

Figure 2 – 5G challenges, potential enablers and design principles

3 5G cellular network architecture

Before the demonstration 5G technology to end user it is necessary to modernize the existing basis. Current technologies like OFDMA will work at least for next 50 years, so there is no need to change wireless setup which had come about from 1G to 4G. In order to please user requirements, we could only complement existing fundamental network. This will provoke the package providers to drift for a 5G network as early as 4G is commercially set up [5]. We have to make drastic changes in the strategy of designing the 5G wireless cellular architecture, to meet the users demands and to overcome challenges that has been put forward in the 5G system. A general researchers' observation has shown that most of the wireless users stay inside for 80 % and outside 20 % of time [6]. In present wireless cellular architecture we have an outside base station in the middle of a cell, that allows a mobile user to communicate. While users inside, the signals from outside base station will have to travel through the walls, and this will result in high penetration loss, which correspondingly costs with reduced spectral efficiency, data rate and energy efficiency of wireless communications. To overcome this challenge there was proposed a new designing technique for scheming the 5G cellular architecture [5]. With this designing technique, the penetration loss through the walls of the building will be slightly reduced. This idea will be supported with the help of massive MIMO technology, in which geographically dispersed array of antenna's are deployed which have tens or hundreds of antenna units.

To build or construct a large massive MIMO network, firstly the outside base stations will be fitted with large antenna arrays and among them some are dispersed around the hexagonal cell and linked to the base station through optical fiber cables, aided with massive MIMO technologies. The mobile users present outside are usually fitted with a certain number of antenna units but with cooperation a large virtual antenna array can be constructed, which together with antenna arrays of base station form virtual massive MIMO links. Secondly, every building will be installed with large antenna arrays from outside, to communicate with outdoor base stations with the help of line of sight components. The wireless access points inside the building are connected with the large antenna arrays through cables for communicating with indoor users. This will significantly improves the energy efficiency, cell average throughput, data rate, and spectral efficiency of the cellular system but at the expense of increased infrastructure cost. With the introduction of such an architecture, the inside users will only have to connect or communicate with inside wireless access points while larger antenna arrays remained installed outside the buildings [5]. For indoor communication, certain technologies like Wi-Fi, Small cell, ultra wideband, millimeter wave communications, and visible light communications are useful for small range communications having large data rates [6]. But technologies like millimeter wave and visible light communication are utilizing higher frequencies which are not conventionally used for cellular communications. But it is not an efficient idea to use these high frequency waves for outside and long distance applications because these waves. Technical comparison between recent 802.11 standards. will not infiltrate from dense materials efficiently and can easily be dispersed by rain droplets, gases, and flora. Though, millimeter waves and visible light communications technologies can enhance the transmission data rate for indoor setups because they have come up with large bandwidth. Along with the introduction of new spectrum, which is not being conventionally used for wireless communication, there is one more method to solve the spectrum shortage problem by improving the spectrum utilization of current radio spectra through cognitive radio (CR) networks [6].

Since the 5G cellular architecture is heterogeneous, so it must include relays, macro-, micro- and small cells. A mobile small cell concept is an integral part of 5G wireless cellular network and partially comprises of mobile relay and small cell concepts [7]. It is being introduced to put up high mobility users, which are inside the automobiles and high speed trains. Mobile small cells are positioned inside the moving automobiles to communicate with the users inside the automobile, while the massive MIMO unit consisting of large antenna arrays is placed outside the automobile to communicate with the outside base station. According to user's opinion, a mobile small cell is realized as a regular base station and its allied users are all observed as a single unit to the base station which proves the above idea of splitting indoor and outdoor setups. Mobile small cell users [7] have

a high data rate for data rate services with considerably reduced signaling overhead, as shown in [5]. As the 5G wireless cellular network architecture consists of only two logical layers: a radio network and a network cloud. Different types of components performing different functions are constituting the radio network. The network function virtualization cloud consists of User and Control plane entities that perform higher layer functionalities related to the User and Control plane, respectively. Special network functionality as a service (XaaS) will provide service as per need, resource pooling is one of the examples. XaaS is the connection between a radio network and a network cloud [8].

The 5G cellular network architecture is explained in [5,8]. It has equal importance in terms of front end and backhaul network respectively. In this paper, a general 5G cellular network architecture has been proposed as shown in Fig. 3. It describes the interconnectivity among the different emerging technologies like Massive MIMO network, Cognitive Radio network, mobile and static small-cell networks. This proposed architecture also explains the role of network function virtualization cloud in the 5G cellular network architecture. The concept of Device-to-Device communication, small cell access points and Internet of things has also been incorporated in this proposed 5G cellular network architecture. In general, this proposed 5G cellular network architecture may provide a good platform for future 5G standardization network.

Figure 3 illustrates a 5G mobile network architecture that utilizes the enablers discussed previously [8]. The key elements in the architecture are summarized below.

- Two logical network layers, namely a radio network (RN) that provides only a minimum set of L1/L2 functionalities and a network cloud that provides all higher layer functionalities.
- Dynamic deployment and scaling of functions in the network cloud through SDN and NFV.
- Lean protocol stack achieved through elimination of redundant functionalities and integration of AS and NAS.
- Separate provisioning of coverage and capacity in the RN by use of C/U-plane split architecture and different frequency bands for coverage and capacity.
- Relaying and nesting (connecting devices with limited resources non-transparently to the network through one or more devices that have more resources) to support multiple devices, group mobility and nomadic hotspots.
- Connectionless and contention-based access with new waveforms for asynchronous access of massive number of MTC devices.
- Data-driven network intelligence to optimize network resource usage and planning.

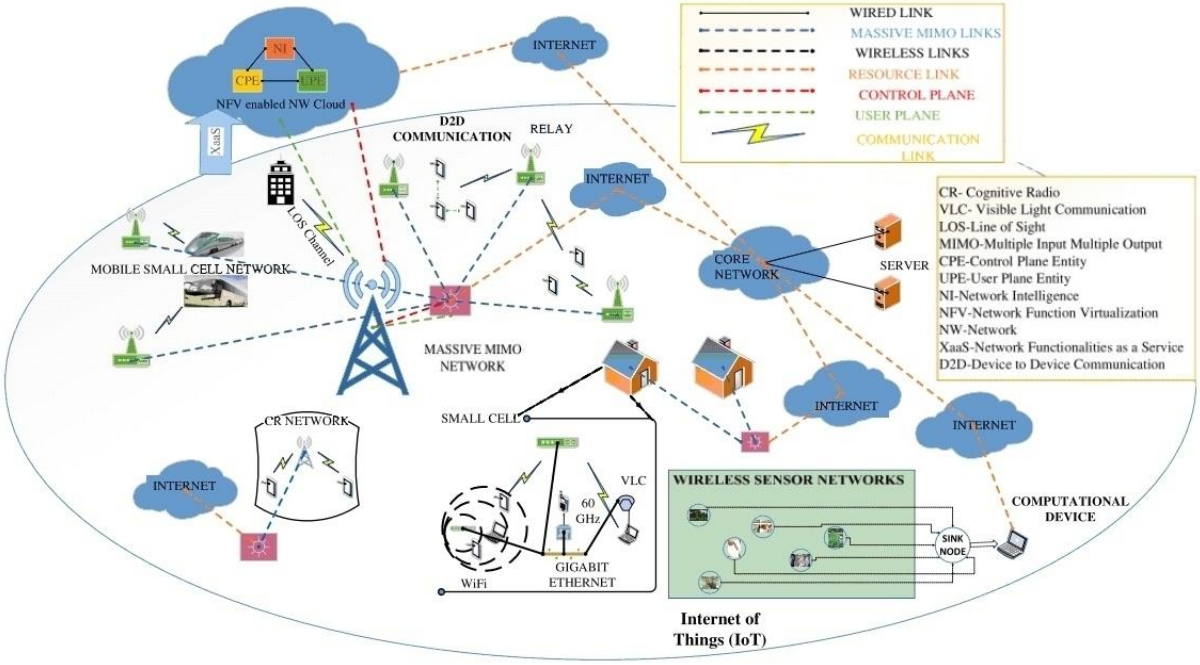

Figure 3 – A general 5G cellular network architecture

4 Conclusions

The modern world needs everything recently developed especially in terms of technologies also. First generation starts in the year of 1980s but now it seems to be older than a century because of its speed. From there onwards a new step or ladder is leaned as proportional to speed and year. In this paper, a detailed survey has been done on the generations history of cellular networks, network architecture and performance requirements for 5G wireless cellular communication systems that have been defined in terms of capacity, data rate, spectral efficiency, latency, energy efficiency, and quality of service. A 5G wireless has been explained in this paper with massive MIMO technology, network function virtualization cloud and device to device communication. This paper may be giving a good platform to motivate the researchers for better outcome of different types of problems in next generation networks.

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Мережева архітектура п'ятого покоління

Анотація. Робота присвячена розгляду основних етапів в історії розвитку різних поколінь стільникового зв'язку та варіантів організації їх архітектури. Виконано короткий огляд основних особливостей функціонування і принципів організації мереж стільникового зв'язку різного покоління. Проведено аналіз можливостей та принципів побудови сучасних стільникових мереж п'ятого покоління. Окреслено перспективні напрями модернізації існуючих мереж стільникового зв'язку та визначено можливості нарощування їх потенційних можливостей.

Ключові слова: стільниковий зв'язок, 5G, MIMO, LTE, WiMAX.

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Сетевая архитектура пятого поколения

Аннотация. Работа посвящена рассмотрению основных этапов в истории развития различных поколений сотовой связи и вариантов организации их архитектуры. Выполнен краткий обзор основных особенностей функционирования и принципов организации сетей сотовой связи различного поколения. Проведен анализ возможностей и принципов построения современных сотовых сетей пятого поколения. Обозначены перспективные направления модернизации существующих сетей сотовой связи и определены возможности наращивания их потенциальных возможностей.

Ключевые слова: сотовая связь, 5G, MIMO, LTE, WiMAX.