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4G AND 5G STANDARDIZATION AND ARCHITECTURE: A COMPARATIVE STUDY

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Abstract— Development in human society can be easily observed after every innovation. Due to never ending needs, human beings always try for something new faster and smarter technologies. In the field of communication there is a huge development from first generation to fifth generation mobile communication We are now in the era of 5G technology. Here 5G Technology stands for Fifth Generation of Mobile technology. The network of Fifth generation offers inexpensive and faster broadband wireless connectivity. This paper presents a comparison between the different network architecture of fourth and fifth generation technology. The standards of 4G provide extensive with accessible voice, data and streamed multimedia at "Anytime and Anywhere". Support for Global mobility is also provided by the Global mobility protocols like IPv6.

In the fifth generation, focus has been given on voice over IP (VOIP) enables devices, in which a high level of call volume and faster data transmission can be observed by the users. In a 5G network users have been offered simultaneous connection to multiple users and switching between them. This latest technology supports IPv6 and flat IP. The purpose of this paper is to provide a detailed study of 4G and 5G technologies, in terms of their characteristics, their contributions and behavior in terms of QoS. The difference and similarities have also been studied to present the requirement to merge the LTE and WiMAX.

Keywords—5G, 4G, QoS, LTE, WiMAX, OFDM, CDMA, LTE, HSPA, UMTS.

I. INTRODUCTION

The main aim of every new generation is to provide communication familiar. With the rapid increase in the number of users and their needs, the wireless communication becomes fast growing field. From 1997 to 2002 the users have increased from 214 million to 116y 2 million and continuously increasing day by day. Therefore, it is required to expand wireless communication technology. Currently many things have been accepted by 4th generation to give users many applications to perform different tasks. This requirement results new technology, the 5th generation [1]

The era of wireless communication has begun in prior 1970s. During next four decades the technology had reached from 1G to 5G. During the formation of third generation of mobile communication systems, the interest of some researches have been developed beyond 3G, which is called 4G. Research started with the objectives like, it should be fully IP based integrated system, data rate must be between 100Mbps with good quality and security. In the fourth generation system, a combination of WiMAX and Wi-Fi technology was used. [7] Foe

fifth generation mobile technology, large bandwidth is used along with some new and advanced features. These new features make it more popular. At present, all wireless and mobile technologies are available, like 3G mobile networks called UMTS (universal mobile telecommunication system, cdma 2000), LTE (long term evolution), WiFi (IEEE 802.11wireless networks), WiMAX (IEEE 802.16 wireless and mobile networks) along with sensor networks (Bluetooth, ZigBee). Interfaces like GSM, which is based on circuit switching are also available. [2].

During last fifteen years there is a huge development in the field of mobile communication made by remote systems and wireless networks. The use of the technology is increasing day by day, due to which the demand of number of devices is also increasing. Therefore, in order to be in the footstep with the growing world, the wireless technology has introduced the fifth generation (5G). The benefits of 5G are high connectivity speed and huge bandwidth. [3]

One of the major difference between 5G and all the other earlier network is that in 1G to 4G the system architecture was hardware based which was replaced by the functionality based software. A centralized unit is also used whose function is to relate all the cell transmitters. A problem of weak signal wavelength occurs which is overcome by reducing the size of cells as now the concept of cloud radio access network is used, hence no major hardware is required.[5]

At present mobile system is working with 5G technology, in which heterogeneous wireless devices are connected with the architecture of 4G IP. 5G supports and combine all the 4G technology like unlicensed spectrum, device to device discovery and LTE broadcast. [6].

The remaining sections of this paper are organized as follows: Section II introduces 4G Architecture, Section III presents 4G standards, Section IV presents 5G standards, Section V outlines 5G regulations, Section VI gives the comparison between the architecture and regulations of 4G and 5G technology and finally Section VII outlines the conclusion and future scope of this work.

I. 4G Architecture

4G stands for fourth generation mobile system. 4G is the advanced form of 3G in terms of offered administrations and higher transfer speed. 4G has the capability to interface with the wireline backbone network, which can transmit multimedia and data across all over the world. The frequency range used in 4G is 2 to 8 GHz. Bandwidth used is same as used in 3G, which is 5-20 MHz. Data rate is more than 20 Mbps. It also uses multicarrier CDMA or OFDM system along with packet switching and message switching techniques. 4G offers some advantages over 3G like, downloading of files over a wireless network is much faster, improved voice quality, internet access has become more easy and much higher bandwidth. 4.G is ten times faster than 3G. WiMAX, LTE and HSPA+ are all the versions used in 4G. There are some disadvantages of 4G like new components in cell towers are required if new frequencies are used. Customers are facing higher data prices and they have to purchase a new device to support the 4G. It is not possible to make our current equipment compatible with the 4G network.

4G mobile telecommunication offers packetized data communication along with fast and high data rate. The main task forces used in 4G are ITU and IEEE, which work on the possible completion for the 4G mobile standards.

4G mobile systems are mainly characterized by a model called horizontal communication model. In this model all the access technologies like cellular, cordless, wireless LAN systems, short range wireless connectivity and wired systems are combined on a common platform to complement each other in the best possible way for radio environments and different service requirements.

The modulation scheme used in 4G is OFDM (orthogonal frequency division multiplexing). In OFDM the bandwidth usage is more efficient and is immune to multipath fading. The values of ICI and ISI are also very small. Its spectral and power proficiency is also excellent The effect of high speed communication is inter symbol interference or ISI. ISI occurs whenever the transmitted signal interferes with itself and the received signal is not properly decoded by the receiver. The transmission capacity of OFDM is much higher and the modulation technique used is also adjustable. Because of its adjustable quality of modulation scheme, it is used in digital sound recording broadcasting (DAB), terrestrial electronic digital video broadcasting TELEVISION SET (DVB-T), asymmetric digital prospective subscriber lines (ADSL), Ultra wideband technique.
In 1966, Chang PATANG researched OFDM. It also has low complexity execution as compared to that in traditional single carrier systems. [9]

OFDM suffers from a large value of PAPR. In order to reduce the PAPR, the operating point of the nonlinear power amplifiers is to be shifted. The change in the operating point again reduces the efficiency of the amplifiers. Hence some techniques are employed to overcome the effect of PAPR. Like- clipping and filtering, selected mapping (SLM), partial transmit sequence(PTS) etc. A clipper can directly be used which is a nonlinear processing. Such a nonlinear processing causes in-band distortion and out of band radiation. Out of band interference, which is filtered out by the clipping, again grows and appears in the signal. Repeated clipping and filtering are capable of reducing the values of PAPR and out of band radiation, but they are unable to remove in band distortion. [11]

Bandwidth utilization of OFDM is better as compared to that in conventional modulation schemes. All.the subcarriers used in OFDM are mutually orthogonal to each other. This orthogonality reduces the cross talk between the subcarriers and offers high spectral efficiency. [12]

In single carrier modulation techniques, the channel suffers from the frequency selective fading and to overcome this effect some complex equalization techniques are required. In case of OFDM, the available bandwidth is split between a large number of narrow spaced orthogonal sub carriers. Hence the single channel bandwidth is now become many narrow flat fading sub channels. As the channel gain and the phase associated with the sub carriers are varying, hence all the subcarriers suffers only flat fading. At the receiver, all the subcarriers are weighted according to their channel gain and phase associated with them. [13]

II. 4G standards

LTE-A is the main standard used in 4G technology. It is the tenth version of LTE. Hence its characteristics are almost similar to the characteristics of LTE norm. In LTE the data rate for uplink is 300Mb/s and for downlink the data rate is 1GB/s. The bandwidth used is 100MHz.LTE-A system uses OFDMA for downlink as access methods and SCFDMA for uplink. For antennas a very advanced technique used is MIMO. [4].

4G technology provides ultra broadband access for mobile devices. For this access the International Telecommunications Union Radio communication sector (IYU-R) has made a set of standards, according to which the network must meet all the standards in order to be considered as 4G. The specification used is called the International Mobile Telecommunication Advanced (IMT-Advanced). Earlier circuit switched technology was used, which was then replaced by all internet protocol packet switched technology. For data transmission, the current spread spectrum radio technology was also replaced by a multi carrier transmission method called OFDMA and frequency domain equalization called FDE. For a user in highly denser network the maximum data rate for 4G networks is set to be approximately 100mega bits per second. For a local wireless access and for a nomadic connection the data rate is set to be 1 gigabits per second. The handovers across different networks must also be smooth and without data loss. It must also be able to provide a high quality of service for next generation system. By using Internet Protocol version 6 (IPv6), the parallel circuit switched and packet switched technology has been replaced by nodes in which IPv6 protocols were used. This is one of the very important aspect of $G technology. IPv4 standard was having the limitation of finite number of IP addresses, assigned to different devices. IPv6 provides a much larger number of IP addresses and streamlined experience for users.

Applications of OFDM: During past few decades, many wireless communication standards like European digital audio broadcasting, terrestrial digital video broadcasting and satellite-terrestrial interactive multiservice infrastructure in China have been accepted OFDM 802.15.3a and IEEE 802.16d/a like IEEE 802.11a/g/n, IEEE. It has also been accepted by some IEEE standards working groups. OFDM is used in wireless personal area networks, wireless local area networks and wireless metropolitan networks.

Disadvantages of OFDM: One of the main disadvantage of OFDM is its complexity. Being a multicarrier modulation system, it is more complicated than a single carrier modulation. OFDM requires more number of linear power amplifiers. Other disadvantages are- Multipath fading should be minimized in order to avoid any mismatch in orthogonality. Distortion occurs due to superposition of signals. More compounds and more linear power amplifiers are required as compared to single carrier system. OFDM is more sensitive to offset and drift in carrier frequency. Other disadvantages of OFDM are phase noise and frequency offset sensitivity, which creates intercarrier interference (ICI) due to its long symbol length. Therefore, frequency compensation and estimation is required. Another major drawback of OFDM is its high PAPR which occurs due to the addition of a large number of independent subcarriers [10]

IV 5G standards

5G is not owned by a company or a person. But there are so many companies in the mobile ecosystem, which desire to launch the 5G. However, Qualcomm has introduced many

technologies that derive the industry forward and develop 5G, which is the next wireless standard. There are eight specifications required by 5G technology, which are-

- Data rate must be 10Gbps.
- Speed development must be up to 10 to 100x over 4G and 4.5G networks.
- Maximum permissible delay is 1 millisecond
- Bandwidth must be 1000x per unit area
- Number of connected devices per unit area must be up to 100x as compared with 4G LTE
- 99.999% availability
- Must provide 100% coverage
- Reduction in at least 90%.

The 5G network uses shorter frequencies ranges from 30GHz to 300GHz, called millimeter waves. That's why 5G is faster compared to earlier generations. The download speed of 5G varies widely by area. [14]

Despite of all the advantages, there are some challenges have that have been faced by the designers of 5G technology like, the allotted radio frequency spectra for cellular communication is small. This allotted frequency spectra is fully utilized and there is no extra spectra available in the existing cellular bands. Another problem is that for the operation of advanced wireless technologies, higher energy consumption is required. It has been informed by the cellular operators that the energy consumed by the base stations contributes to the 70% of their total electricity bill. It has also been clear that the multiple access techniques used in the network are less and also they need to be upgraded. The technology used currently like OFDMA is able to survive for at least next 50 years and no extra changes are required in this technology. Despite of all these things, there are some advantages of 5G over 4G, such as:

- 1000 times the system capacity
- 10 times the spectral efficiency
- Energy efficiency
- Data rate
- 25 times the average cell throughput

While designing the 5G wireless cellular architecture, large changes in the policy is required in order to meet the user's requirement and the challenges which have been put forward in the 5G system. In order to communicate inside or outside the cell and for all the mobile to get connected, an outside base station is located in the center of the cell to help in communication. Inside the cell the signals travel along the walls and provide communication between outside and inside base station. Such type of communication creates high penetration loss and reduces the spectral efficiency and data rate. To overcome this problem, the design of 5G cellular architecture has been changed. The inside and outside setups were made distinct. This has reduced the losses which were occurring due to the penetration of the signals inside the walls of the building. This architecture was supported by the huge MIMO technology. In MIMO system, a large number of antennas, around tens or hundreds of antenna units are installed in different directions. These antenna units are used to obtain large gain. In MIM O network architecture, at the beginning with the help of hefty antenna arrays, the outside base station is

prepared. Antennas are arranged along the hexagonal cell and faster cables like optical fiber cables are used to connect them. All the mobile users which are outside the cell have only certain number of antennas. These antennas are already installed inside the mobile. Also a large number of antenna arrays installed at base station are in collaboration with the antennas inside the mobile. This forms the MIMO system. In the design of MIMO architecture a huge antenna array is installed outside every bug building. This provides the communication with outside base station as it also creates line of sight components. There are some wireless access points inside every building which are connected with the huge antenna arrays through cables. These points establish communication with users which are present indoor. MIMO technology improves the energy efficiency, average output of cell, data rate and spectral efficiency of cellular system. This also increases the overall cost of the system. With this architecture, the inside users have to communicate with the wireless access points inside the building. For indoor communication, which is in small range communication, some technologies like Wi-Fi, small cell, ultra wide band, millimeter wave communication and visible light communication are used. Visible light communication and millimeter wave communication require very high frequencies, hence they are seldom used in cellular communication. They are also not used in outside and for long distance applications because these waves cannot be filtered properly by the dense materials and rain droplets, gasses and flora can easily dissipate them. 5G wireless cellular network architecture consists of only two logical layers. They are

- A radio network
- Network cloud

Radio network consists of different types of components which perform different functions. All the advanced layer functions related to the users and control panel are performed by User plane entity i.e. UPE and a Control Plane Entity i.e. CPE are the part of network function virtualization (NFV) cloud. Connection between a radio network and a network cloud is established by XaaS. XaaS provides interconnectivity between different technologies like MIMO network, Cognitive Radio Networks and mobile and static small cell networks. Device to device communication (D2D), small cell communication and internet of things (IOT) are also introduced in the 5G cellular network architecture. [15]

V 5G Architecture

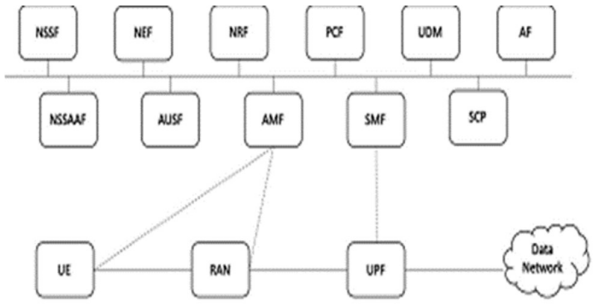

Figure below shows the high level representation of the 5GC.

High level representation of 5GC

5GC has a service based architecture, which supports network slicing and it also splits the user plane and control plane. The gateway to connect the RAN and external network is the user plane function (UPF). UPF also acts as an anchor point for intra/inter Radio Access Technology i.e. RAT mobility. The function performed by UPF are packet routing, forwarding and inspection, handling quality of service and managing traffic measurement.

The tasks performed by the control plane functions are as follows- In CPF the session management function (SMF) take care of session management and establishment. It allocated IP address to the UEs. It also facilitates roaming and controls the UPF. Services like, registration, reachability, mobility, connection and location services are managed by the access and Mobility management i.e. AMF facilitates idle – state mobility. AMF also performs access authentication and authorization.

There are two types of Stratum in the system. A non access stratum (NAS) and an access stratum i. e. AS. Non access stratum works between the AMF and device whereas Access Stratum works between the RAN and the device.

. There are some more entities and functions in the system and they are Unified data management (UDM), policy Control Function (PCF), Authentication Server Function (AUSF), Application function (AF), Network Exposure Function (NEF), Network Repository Function (NRF) etc. UDM authenticated and authorizes access. PCF provides policy rules, AUSF handles authentication, AF manages traffic routing, NEF provides error free information from external application to 3GPP network. NRF supports service discovery function, UDR (Unified Data Repository) is responsible for storage and retrieval of subscription data by UDM. UDSF (Unstructured Data Storage Function) is responsible of storage and retrieval of unstructured data by any network function, Network Data Analytics Function (NWDAF) manages network analytics. UCMF i. e. UE Radio Capability Management Function is responsible for storing all UE radio Capability ID and 5G-EIR (5G-Equipment Identity Register checks the status of Permanent Equipment Identifier (PEI) charging Function (CHF) manages charging information. [5G NR 16]

LTE Release 12 defines dual connectivity in which two different nodes (eNBs), a master node (MN) is connected to a secondary node (SN). These nodes offer radio resources to a certain UE. Radio resource aggregation is used to increase per user throughput and mobility robustness because UEs are scheduled through multiple eNBs. Unlike LTE, NR dual connectivity works for nodes belonging to two different RATs, gNB and eNB. Both the RATs provide NR and E-UTRA/NR access respectively. This gives tight internetworking between two radio technologies and permits NR to gradually adjust into the existing LTE networks. NR access has two modes of operation: non standalone and standalone. In non standalone operation there is a possibility to connect NR in the existing LTE networks, which speed up the 5G roll out. Whereas standalone operation gives the connection of NR to the 5GC and LTE to the 5GC. [16]

Table 1gives the LTE NR combines architecture design

DC Architecture	Core network	MN	SN	Terminology
Option 1	EPC	eNB	–	LTE/
Option 2	5GC	gNB	–	NR/.
Option 3	EPC	eNB	gNB	EN-
Option 4	5GC	gNB	eNB	NE-
Option 5	5GC	eNB	–	eL'
Option 7	5GC	eNB	gNB	NGE]

VI Comparison between 4G and 5G architecture and standards

Till 4G, all the wireless technologies focused on the availability of bandwidth, whereas 5G is working on making availability of prevalent connection to lay grounds for high speed and strong access to the internet users, whether they are on a top of a very tall building or down under a subway station.

5G standards are the combination of 2G, 3G, LTE-A, LTE WiMAX etc. 5G is designed in such a way that it can support a number of applications like, IoT, connected wearables, augmented reality and immersive gaming. 5G also has the ability to handle a multitude of traffic types and a large number of connected devices. As compared to 4G network, 5G will offer a very low latency which is less than one second. With third small delay we will be able to download and upload files very quickly and very easily.

As compared to 4G standards, the data rates offered by 5G technology is very high, almost 1gbps for tens of thousands of users.

Table 2 shows the comparison between 4G and 5G technologies

Standard	4G	5G
Start Form	2010	2016
Data Rate	2Mbps- 1Gbps	1 Gbps and higher
Frequency Domain	2-8 GHz	3-300GHz
Handover	Horizontal and Vertical	Horizontal and Vertical
Core network	All IP network	Flatter IP network, 5G network interfacing (5G-NI)
Multiple Aceess	CDMA	CDMA, BDMA

VII Conclusion

The main objective of this paper is to present an outline of 4G (LTE/LTE-A and WiMAX) standards, 5G standards and 4G and 5G architecture and also to analyze their performance. With the rapid growth of technologies and with the continuous demand of high data rates, 5G has now come into existence. LTE/LTE-A and mobile WiMAX technologies are two competing technologies and technically they are very much similar giving almost similar results. Hence it can be concluded that the combination of LTE and WiMAX help telecommunications operators to provide online connectivity anytime and anywhere. As

compared to 5G, some more developments are to be considered in 4G infrastructure like, for handling higher data rates, increased operating frequency in 4G is required. Frequency must be in millimeter range with the help of which higher bandwidth and a very low latency can be achieved. As a result it is clear that the merging of 4G and 5G technologies is almost impossible because of the difference in throughput, latency and their architecture. Hence almost all the telecommunications operators are trying to switch from present 4G to the 5G technology. At present some of the operators have already switched from 4G to 5G. In future more work needs to be done in order to achieve higher data rates and to reduce latency form the value offered by 5G technology.

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