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A SURVEY ON MOBILE COMMUNICATIONS AND NETWORK TECHNOLOGIES

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Abstract: Throughout the past few decades, wireless network systems have gone through several stages of progression. As there has been an extensive requirement for more connections worldwide, the wireless network standards have advanced rapidly in order to support more and more users. Smart phones gained popularity across the globe after the introduction of 3rd generation (3G) mobile communication system in which specific applications were developed for smart phones which catered to several features like e-mail, games, video calling, etc. 4G systems are enhanced versions of 3G networks which offer higher data rates and are designed to handle more advanced multi-media services. 5G is a new global wireless standard after the 4G network which provides more reliability and vast network capacity. 6G is the successor of 5G network system which will use higher frequencies to provide higher capacity and lower latency. This paper provides a comprehensive and comparative review on 3G, 4G, 5G and 6G wireless technologies.

Keywords: *3G, 4G, 5G, 6G, mobile communication systems, wireless network standards, wireless network systems.*

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I INTRODUCTION

Wireless technology has brought in a revolution in the digital world. It showed superiority over wired networks in many ways such as connectivity speed, longer range, less need for infrastructure and many more. Wireless technology uses radio frequency (RF) and infrared (IF) waves for data transmission. Establishing a novel signal transmission technique and advanced signal processing methods was the crucial aspect of this technology. These methods were necessary so that there was a significant increment in the wireless capacity with no ascent in bandwidth or power prerequisites [1]. Wireless network provided high speed connections without the need of installing any fibre optics or coaxial cables which are expensive. But due to high demand and connections, it has lead to congestion in the network, low speed connections and lower bandwidth. That is why there is a steady need to refresh these remote technologies to take care of the necessities of individuals utilizing it.

3G technology had the combination of both satellite and terrestrial components. Where 3G uses channel access schemes like TDMA (Time-Division Multiple Access), FDMA (Frequency-Division Multiple Access) and CDMA (Code-Division Multiple Access), 4G uses OFDMA and other technologies instead of CDMA. 5G is considered more spectrally efficient than the 4G network. The data per hertz delivered by these networks rise as the generations go forward. 5G, which is expected to deliver up to multi giga-bits per second is said to be capable of handling the network traffic explosion to happen in the upcoming years. Although there are many speculations about the 6th generation wireless network, it is expected to deliver global mobile coverage with speeds going up as high as 1 tera-bits per second. In this paper, all the technical aspects of 3G, 4G, 5G and 6G will be

detailed with comparison of all the key elements such as data rates, bandwidth, latency and standards.

II THIRD GENERATION (3G)

It's the foremost preliminary step for proceeding with 3Gwas first introduced in October 2001 by NTT DoCoMo in Japan. This wireless technology was a merger of various 2G wireless telecommunications system under a global system. The crucial feature of this generation technology that separated it from any other generations was its ability to unify the preexisting cellular technology standards such as CDMA, GSM and TDMA in one scope [1]. WCDMA, CDMA2000 and Wi-Max, the three interface modes were easily in sync with the previous network standards. All the protocols embedded in this technology resulted in high speeds of information and voice, audio and video abilities. The core functionalities of this network were General Packet Radio Service (GPRS) and voice call switching. Although 3G was partly based on the previous generations, it provided many superior features as compared to the preceding networks.

A. Key Features

3G was found having an upper hand in features as compared any other networks then. It had a promising speed of up to 2 Mbps. It provided vast spectrum of services including voice call, data and multimedia. It also provided personal and services mobility, communications of circuits and packages, simultaneous connection and support of voice and data. It had the ability to transmit both ways, synchronically and asymmetrically. It also provided large capacities of data transfers and bandwidth capabilities and also the ability to send and receive large emails. Mobile messaging, also known as Short Messaging Services (SMS) and Multimedia Messaging Services (MMS) was also a widely utilised service of this generation [2].

B. Applications

The introduction to 3G networks gave rise to many applications which made it stand out from its predecessors. Some of these applications are as mentioned: Video Calling feature offered connectivity via live video all over the world. This offered real time virtual meetings and gatherings for various purposes. It also enhanced the security of the network with acquiring large number of users and having a large coverage. Supporting various mobile applications was the main appealing factor of this generation as it incorporated many revolutionary applications. The third generation brought in the global positioning system (GPS) as location tracking and maps services. This became the most significant application further on. It also enhanced the web browsing experience with the help faster speeds and upgraded connectivity. This also added to streaming the television smoothly without any latency. 3D games became more popular as 3G offered a platform for these games to run without any lags or interruptions.

C. Drawbacks

3G was considered an expensive expenditure because of its high spectrum license. It also required costly but essential infrastructures like towers and control centres. It demanded expensive equipment and implementation. Although it supported higher data rates, it came at a cost of acquiring a higher bandwidth. To support 3G and its applications, customers had to buy expensive mobile devices. As it was a compilation of various 2G components, it was compatible with older generation 2G system and frequency band which affected its performance. As 3G became more and more widely accepted, getting the 3G service license became more and more challenging for the telecom operators. To increase capex and opex, network operators should have checked the network coverage area and the capacity of requirements for deployment [3]. Various standards of the 3G technology made it difficult to roam and interoperate among networks.

III FOURTH GENERATION (4G)

Fourth generation technology was launched commercially by TeliaSonera on December 14th 2009 and it is still used to-date all over the world. 4G is mainly based on convergence of elements like wireless GSM, LAN, Bluetooth as well as computers, other electronics, communication technology and many more. The 4G technology is established on the Open Wireless Architecture (OWA) to make sure that a single can automatically connect to a nearby high speed wireless system like the nearby Wifi. Based on this OWA model, 4G technology delivers the best business cases such as CDMA2000, WLAN and GPRS 3-in-1 product, WCDMA, OFDM, WLAN 3-in-1 product, etc to the wireless and mobile industries [4]. 4G is also referred to as ‘Beyond 3G’ or ‘MAGIC’ which stands for Mobile multimedia, Any-where, Global mobility solutions over, integrated wireless and Customized services.

A. Key Features

4G technology is solely an IP-based integrated system which provides around 100 Mbps for high mobility and 1Gbps for low mobility or stationary local networks. It also offers end to end QoS and high security. It operates at a higher frequency than the 3G network, of around (2-8Ghz) and also a higher bandwidth of more than 100MHz which helps in providing high speed connectivity and services. The convergence of various technologies offered many advantages such as, it increases the spectrum efficiency, ensure that the wireless terminal get the highest data rates available and also optimally manage the services and

multimedia applications [4]. Previous standards used phase-shift keying but in 4G, 64-QAM (Quadrature Amplitude Modulation), which is a more spectrally efficient modulation system, is used. 4G offers high data rates and high capacity both at a lower cost per bit. It also offers service portability and also global roaming which was not yet available.

B. Applications

As many modifications were incorporated in the 4G network, various applications followed. The demand for more sophisticated applications such as content-rich mobile commerce and high-end healthcare applications such as mobile telemedicine and wellness monitoring were fulfilled by this network. Some other basic applications include mobile telemedicine and monitoring, high-bandwidth mobile applications, and mobile entertainment and multiparty games [5]. Hybrid wireless networks are created by 4G using Adhoc networks to integrate intelligent routing so that the shortest path can be determined where the least amount of power is used. 4G also provides more integrity through OFDM using Wi-Max.

C. Drawbacks

Offering a wide range of features and applications attract vast number of users. This causes congestion in the network which ultimately leads to slower connectivity and data rates. The larger the interconnectivity and inter-working between networks, the more it is vulnerable to security threats such as viruses, worms, etc [6]. Commonly a core network is shared by all other network operators, so if this ore network fails, the whole network collapses resulting in a system failure. To reduce operating costs, 4G network was built on a very complex architecture which makes it harder to service.

IV FIFTH GENERATION (5G)

Although not one person or one company owns 5G, many telecom companies have came together to work in a ecosystem to bring 5G to life. As it is still in its testing phases, it is not available worldwide. 5G was first introduced in Chicago and parts of Minneapolis in April 2019. The 5G terminals have designed to have software defined radios and modulation schemes and new error control schemes that can be downloaded from the internet [7]. 5G is about to bring a great change in the wireless technology as it is supposed to offer multi Gbps speeds and ultra low latency. The 3rd Generation Partnership Project (3GPP) is driving many aspects in development of 5G. Connecting everyone and everything together is the main aim of this generation. 5G uses 5G nodes for transmission which are installed on light poles or electricity poles on the streets. 5G approach is supposed to be user-centric approach, since the mobile terminals are becoming highly computationally capable devices which can support more complex functionalities for performing calculations, as well as bigger memory space which will provide enough storage capability for control information [9]. 5G is also going to have a sizeable impact on the economy of countries with providing almost $2 trillion in GDP growth and many more jobs created.

A. Key Features

5G is destined to change the wireless communication technology forever. As 5G is launched in many cities around the world, the real time speed it offers is more than 20 Gbps which has never been offered before. To show how fast it really is, a survey was conducted in which several movies and other data were downloaded in which a movie of 2hr 30mins took only 10 seconds to fully download in full definition. 5G is also able to offer very low latency for immediate responses, more reliability, massive network capacity, and a more uniformed user experience. It also proposes ultra high definition streaming for users and also bi-directional large bandwidth shaping. 5G is based on policy to avoid errors which makes it more efficient. It also offers transporter class gateway with unparallel consistency. Other features of 5G includes offering remote diagnostics, remote management, traffic statistics, subscriber supervision and many more which puts this generation way ahead of the previous generations [7].

B. Applications

The ultra high speed and low latency of this network make it suitable for many complex applications such as virtualized homes, in which you can control all aspects of your house no matter where you are. Smart cities are also in the picture as 5G network will make it easy to access everything remotely so that the work can be done more efficiently and precisely. The domain of 5G networks would be capable of supporting a vast range of UEs, from scalable to heterogeneous devices. Also data demands like multimedia data, voice communication, and web surfing would be satisfied while following the QoS requirements [8]. 5G will also contribute in the industrial field as more and more PLC and SCADA atomization is becoming popular for running factories and machines used in them. 5G will also implement perfect real world wireless also called as “WWWW” which stands for World Wide Wireless Web [7]. Smart grids would also be possible to implement so that better optimization of energy can be done to improve economic benefits and efficiency.

C. Drawbacks

As 5G is not widely available and we are still using 4G as our primary network, to access 5G, special phones which enable 5G are required which are very uncommon and expensive. We cannot use 5G network on our currently available smart phones as they don’t support 5G. 5G network

uses radio waves to travel in the wireless network which operate at frequency band of up to 100 Ghz. But these waves also have limitations. The higher frequency bands mean faster transmission speed but it also means smaller the range. Also these waves get easily affected by factors like obstacles (trees, cars, buildings, etc) and sometimes even weather. This leads to disruption is speed and connectivity. Also the small range of these waves force the 5G nodes to be installed closer which leads to manufacturing more nodes which leads to a rise in expense.

V SIXTH GENERATION (6G)

The successor of 5G is the newly speculated 6G network. This network is estimated to arrive in 2030 to the market. Although nothing is yet certain, researchers say it will have some abilities like truly immersive extended reality (XR), high-fidelity mobile hologram and digital replica. As 5G is still in its commercial stage, seeing the demands for this network, R&D have already started to pave the blocks for what's going to be beyond 5G. The 6G network is said to have much higher data transfer rates than its previous generations, also it can handle the network traffic more efficiently with very less or no latency whatsoever. The aim with 6G is to provide a network that can handle all the next-gen demands of the users as well as industries where various very high performances might be required for certain KPIs [10].

As 6G is still in its development stage, no accurate data is available, but we expect some key features that would shape the development of this generation which are: (1) AI and ML driven air interface for better optimization (2) New network architecture paradigms involving sub-networks and RAN-Core convergence (3) Enhanced security and privacy measures (4) Use of new and improved spectrum bands for better efficiency and range [11]. With this network it is said that almost everything will be controlled remotely. Smart homes, smart cities would be evolved and improved, self driving cars would become more efficient, with all the advancement in AI, ML and networks, machines would be capable to perform more difficult and complex tasks. All these factors would make 6G the next revolutionary change in the wireless technology.

Developing this kind of system takes years or R&D and also costs a lot of money. As advanced the system is, the more complex it is to develop. 6G will offer connectivity as no other network. But with this type of connectivity, it becomes more prone to threats like bugs and viruses that could harm the system completely. 6G would offer atomization of tasks, this would make humans more and more inefficient. Many challenges are to be faced in developing this complex architecture such as processing power, designing low cost and low power devices. Designing such a system that would have minimum effect on the environment but at the same time not compromising on any features is also another challenge [12]. These early-on visions and speculations help drive the future development of such technologies.

VI SUMMARY

TABLE I
THE FOLLOWING TABLE SUMMARIZES ALL THE ASPECTS OF 3G, 4G, 5G AND 6G:

	3G	**4G**	**5G**	**6G**
Data rates	7.2Mbps – 21.6Mbps	500Mbps – 1Gbps	Upto 20Gbps	Multi Gbps to 1Tbps
Bandwidth	15-20Mhz	2-8Ghz	24-52Ghz	NA
System	Broadband, CDMA, IP	Unified IP and combination of LAN/WAN /PAN/WLAN	Unified IP and combination of LAN/WAN /PAN/WLAN and wwww	NA
Service	Integrated high quality audio, video and data	Dynamic Information access	Dynamic Information Access, wearable devices with IA capabilities	NA
Core Network	Packet Network	Internet	Internet	Internet
Handoff	Horizontal	Horizontal and Vertical	Horizontal and Vertical	Horizontal and Vertical
Standards	WCDMA, CDMA2000	OFDMA, MCDMA	CDMA, BDMA	NA
Technology	WCDMA	LTE, WiMAX	MIMO, mm Waves	NA

VII CONCLUSION

In this paper we covered the technical as well as features and application scopes of the wireless network systems. We also discussed how these systems are vulnerable to various aspects. As the technology is evolving, the demand for more and more features is also rising. So it is important to keep up with user expectations. All these generations fulfilled the requirements of their eras and will continue to do so. Every generation has solved the demerits of the previous generations and added on to its features and then presented itself. Wireless technology has changed the way we access and connect to various other networks with more efficiency which has help us ease the way we do any tasks. Wireless communication systems have always been a major part of overall technological development and has helped reformed many problems of the society.

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