Journal of Electrical Engineering, Vol. 74, No. 3, 2023, pp. 240–245

sciendo

LETTER

6G wireless system: The emerging trend in cellular technology

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Cellular technology has brought about a significant revolution in the way we communicate and share information. In the last four (4) decades, researchers in the field of wireless cellular technology have been consistently upscaling their designs in tech space which has led to the evolutions of 1G, 2G, 3G, 4G and 5G in close successions. The most recent is 5G which is currently being implemented in various continents across the globe. 5G encompasses a technological framework that can support machine-to-machine (m2m) communication, virtual and augmented reality and smart manufacturing. However, its drawbacks are now coming into bare as its being deployed globally which suggests that 5G may not stand test of time beyond this decade. This has necessitated early research work into the evolution of next generation technology, the 6G. This paper therefore chronicles the emerging technologies in wireless cellular systems, their evolutionary trends, likely features and prospects of the next generation, the 6G.
Keywords: internet of everything (IoE), evolution, virtual reality, smart system, machine learning, wireless energy transfer (WET)

1. Introduction

The mobile technology space has witnessed major innovations and produced increasingly dynamic changes in communication services which have transformed human endeavors and activities globally [1]. These transformations have led to the roll-out of different versions of wireless cellular technology ranging from 1G, 2G 3G and 4G. The recently rolled out version is tagged 5G which stands for fifth generation mobile communication evolution. This is an improvement over all other existing releases. 5G is designed to be a system of all systems that will bring flexibility to mobile system technology in all ramifications. Upon full deployment and implementation, it is expected the 5G will support car automation, smart manufacturing, internet of things (IoT) and will guarantee the connection of thousands of devices with less human interfaces. It also undoubtedly has the capacity to connect virtually, everyone and everything with higher degrees of reliability and low latency. Though, 5G could be taken as an enabler of current communication technology, but it may not stand the test of time beyond this decade due to increasing demands and high expectations in wireless cellular services. This has stimulated research interests by researchers in the academia and industries towards the development of next generation technology, the 6G. Expectedly, 6G would improve on the current evolutions in terms of provision of higher data rates, higher reliability, a much lower latency, efficient and seamless transmission.

Several initiatives are currently being made globally towards the development of structural and technical framework for 6G. The University of Oulu, Finland inaugurated a 6G research group known as 6Genesis. The group has the responsibility of developing a technical framework for 6G with the target of functionality till Year 2040. In a similar manner, the South Korea Electronics and Telecommunications Research Institute is conducting a research into 6G technology [2]. This group has considered a terahertz band for 6G which will make the technology ten-times faster than 5G networks. The United State of America is also investing heavily on early research-work into 6G and is suggesting frequency range between 95GHz and 3 Terahertz [3-4]. In all of these, one common agreement so far globally on 6G is that the technology should open up a new spectrum in the terahertz band. This, being a millimeter wave, obviously will provide the opportunity for a wide channel bandwidth.

2. Evolutionary trends of wireless cellular systems

2.1 First generation (1G): The era of voice only

This is called first generation wireless cellular technology and is tagged 1G. It was introduced in year 1980 as a pure analog system. It uses Frequency Division Multiple access (FDMA) with a channel capacity of 30KHz. Its data transfer rate is 2Kbps. This technology offers voice communication service only. In this era, phones were exceptionally big and heavy. They lacked displays and were powered by enormous batteries and large antennae. The network coverage was inconsistent, and the battery life was pathetic. Nonetheless, here is where the tale of mobile networks began. The initial iteration allowed a wireless connection between

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https://doi.org/10.2478/jee-2023-0030, Print (till 2015) ISSN 1335-3632, On-line ISSN 1339-309X

two compatible devices. Being an analogue technology, its voice quality is poor due to interference. Furthermore, due to the network's lack of roaming capabilities, 1G only functioned in a limited geographical region.

2.2 Second generation (2G): the era of digital telephony

This technology was adopted in 1990 as a replacement for 1G due to its (1G) shortfall. 2G is purely a digital wireless system and uses both Time Division Multiple access (TDMA) and Code Division Access (CDMA) schemes [1]. Its frequency band is around 850MHz and 1800MHz which falls within the two (2) frequency bands reserved for Global System for Mobile Communication (GSM). This is the reason why 2G technology is synonymous with GSM [3]. 2G provides both voice and data services like short message service (SMS), MMS etc. it has a data transfer rate of 10 – 500Kbps which is extremely enhanced compared with 1G.

Furthermore, this mobile network supported roaming, allowing users to attend calls as well as send and receive messages and multimedia material while on the road. True telephone services were made possible with the 2G network. It subsequently gained internet access through GPRS (General Packet Radio Service) and EDGE (Enhanced Data GSM Evolution), However, this was not enough to cause a generational transition. As a result, 2.5G existed before the globe shifted to 3G.

2.3 Third generation (3G): The app age

The 3G or third generation network was launched in year 2001. Its technology is based on I.P. It incorporates multimedia features like Video conferencing, VOIP calls, 3D Gamming, WLAN, Universal Mobile Telecommunication Systems (UMTS), Wideband CDMA etc. Its data transfer rate extends up to 30Mbps. The third-generation mobile network brought high-speed internet services, paving the way for smart phones and app ecosystems. It is the 3G that introduced the notion of mobile television, online radio services, and email on phones. This era was the period when iPhones and Android smart phones began to gain global attraction.

There was no direct transition from 3G to 4G, as there was with 1G to 2G. There was a 3.5G standard, which was intended to improve internet speeds in megabytes per second (Mbps) with the introduction of technologies such as HSDPA (High-Speed Downlink Packet Access) and HSUPA (High-Speed Uplink Packet Access).

2.4 Fourth generation (4G): The era of internet communication

This technology (4G) was deployed in year 2008 and provided services which centred on secured I.P based solutions. It has a data transfer rate of up to 1Gbps. Due to its high speed and data transfer rate, it supports services such as Digital Video Broadcasting (DVB), Mobile TV, Multimedia Messaging Services (MMS) Video Chat and HDTV. Its technology supports WIMAX and Long Term Evolution (LTE). The third generation established the groundwork for 4G, which is the current generation of mobile networks. The concepts offered by 3G, such as high-definition phone calls, video calls, and other internet services, become a reality in 4G, owing to the mobile network's increased data rate and sophisticated multimedia capabilities. It refined the LTE (Long Term Evolution) technology, which dramatically enhances the data rate and enables simultaneous voice and data transfer. One of the numerous benefits of the 4G mobile network is internet calling, often known as VoLTE (Voice over LTE). The network also supports voice-over Wi-Fi (VoWi-Fi), allowing voice calls to be made in places with poor or no network reception.

2.5 Fifth generation (5G): The era of IoT

5G stands for fifth generation wireless mobile technology and is tagged the era of Internet of Things (IoT). Its technology is built around iPV4 and offers CDMA and BDMA multiple access schemes. From 1G to 4G, each generation of communication technology brought about major improvements in the network, refining previous generations' use cases and introducing new ones. 5G, on the other hand, is projected to be a little different in that it will be more than simply another mobile network oriented toward smartphone consumers, but also companies. In terms of core services, 5G is designed to provide network backbone that will support virtual and augmented reality, machine-to-machine communication (M2M), artificial intelligence etc. 5G is a flexible network and provides fast internet speeds (both downloads and uploads) and has capacity to handle multiple connectivity as compared to previous generations.

Table 1 Comparison between features of each technology

Generation	Commencement Year	Technology	Access Scheme	Frequency Band	Data Rate	Core Services
1G	1980	Analogue wireless	FDMA	30kHz	2 kbps	Voice Communication
2G	1991	Digital wireless	TDMA, CDMA	850 MHz and 1900 MHz	10 to 500 kbps	Voice communication. and Data Services
3G	2001	Broadband, I.P Tech	CDMA	1800 MHz to 2.5 GHz	Up to 300 Mbps	Voice, data, multimedia, VoIP, Video calling
4G	2008	Unified I.P, LTE, WiMAX	CDMA	2 GHz to 8 GHz	Up to 1 Gbps	Voice, data, mms, Digital video broadcasting (DVB)
5G	2020	IPv4	CDMA & BDMA	3GHz to 300GHz	Above 1 Gbps	Supporting virtual and augment reality, smart manufacturing, M2M communication

3. Limitations of 5G networks

Since 2020, the deployment of 5G technology has begun in some parts of the globe. It is an innovative technology that offers a faster speed which by implication, allows network operators and mobile users to process data over the network at a faster rate. Conceptually, 5G has been designed to tackle the challenges of increasing traffic volume and also connectivity challenges. Also, 5G is expected to provide high reliability, low latency and high energy efficiency. It is an enabler of artificial intelligence (AI) integration, virtual and extended reality, haptic communication integration, robotic and autonomous system etc. However, due to the increasing growing demands in data traffic, smart system, battery power efficiency, expected QoS and integration of new technologies, 5G network will surely suffer a "performance hit" which by implication, may not be able to stand the test of time beyond this decade. In support of this, a global prediction (by the ITU) [2] on mobile traffic per month, from year 2020 to year 2030 is as presented in Fig. 1 below.

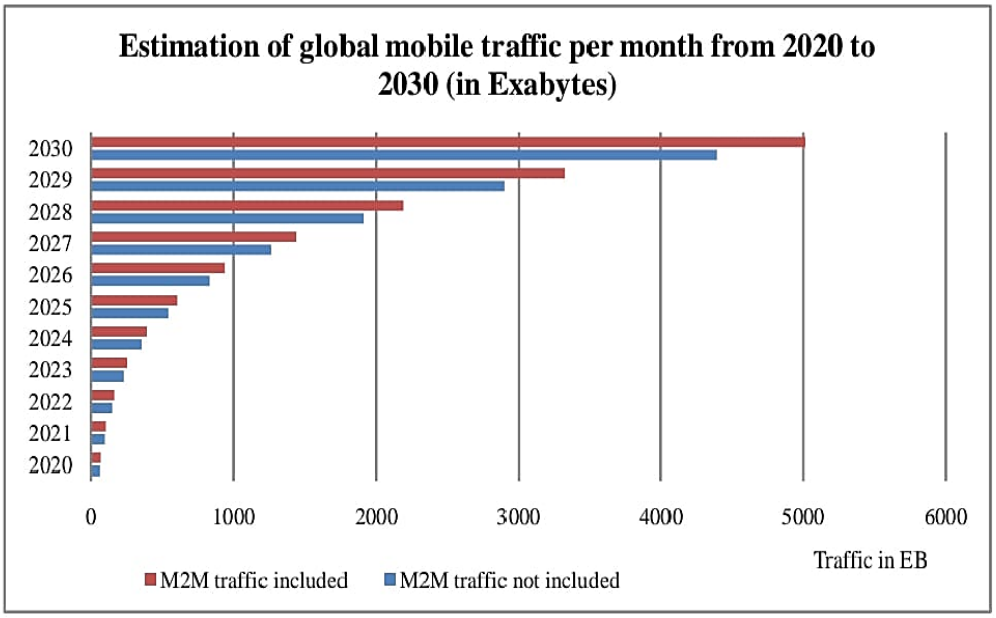

Fig. 1. Global mobile data prediction by ITU [2]

From the above, between year 2020 and 2030, an annual growth of 55% in data traffic volume has been forecasted considering M2M situation. The figure also shows that in year 2020, a total volume of 62 Exabytes (monthly average) of data traffic was consumed. This is projected to increase to 249 Exabytes in 2023, 938 Exabytes in 2026 and 5,016 Exabytes by the year 2030. Obviously, 5G technology that is currently at deployment stage with individual data rate of 1Gbps [5] would not be able to drive the projected traffic in the next few years. In addition, 5G has kickstarted the driving of A.I, autonomous system, virtual and augmented reality but does not have the capacity to drive them to full implementation due to required volume of data traffic as envisioned. Hence, the need for a more robust technology with capacity to accommodate the traffic demands. Table 2.0 below shows the comparison between 5G and 6G in terms of characteristic features and technology capability.

Table 2 Comparison between 5G and 6G

Characteristics	5G	6G
Operating Frequency GHz	3-300	Up to 1 Thz
Individual data rate	1 Gbps	100 Gbps
Virtual/Augmented Reality	Not fully	Fully
A.I Integration	Not Fully	Fully
Satellite Integration	Not present	Present
Wireless Energy Transfer	Not present	Present
Centre of Gravity	User centric	Service centric
Traffic Capacity	10 Mbps/m^2	Up to 10 Gbps/m^2
Processing Delay	100 ns	10 ns
Internet Era	IoT	IoE
Reliability	Not Fully	Fully

4. Expected era of internet of everything (IoE)

By the year 2030, the world should be witnessing the emergence of a new wireless technology tagged 6G. This 6G stands for sixth generation wireless technology which is supposed to replace 5G. Currently, it is at a conceptualization stage with no well-defined framework and technical considerations. It is a build-up to the expected drawbacks on 5G technology. Generically, proponents and designers of wireless cellular technologies have maintained a trend of transition in which most recent releases outpace the previous version with improved key performance indicators (KPI). With 6G, it is conceived that everything around us would be intelligent, thus giving rise to the concept of Internet of Everything (IoE) with enormous amount of data-handling capability [5]. Being an IoE, it will be able to integrate radar technologies from which we can get a real time contextual information from small scale to large scale [5]. By extension, the concept of Radio Frequency (RF) energy harvesting would be fully explored coupled with wireless power transfer technique. This is a cutting-edge technology that will enable the development of wireless network charging and battery-free mobile devices. Here, all network nodes would be charged wirelessly. This would serve a good purpose of device battery-power sustainability, reduce usage and bring about energy optimization.

Also, 6G is being conceptualized to be a network that will allow multi-devices and multi-level connections. Thus, permitting a "Cell-Free" communication system. With this, there will be no need for handover situation and by implication, a roaming mobile subscriber could establish uninterrupted connection with a network for as long as he roams without experiencing dropped calls due to handover failure. This will obviously bring about improved QoS. On smart healthcare system, 6G would play a crucial role in driving the concept. Presently, a number of internet enabled healthcare solutions are in existence which are not operating optimally, possibly due to lack of sufficient data capacity needed to drive the system. With huge volume of data capability that 6G would attract, A.I, robotics and extended reality can be deployed seamlessly to activate smart healthcare system especially in the area of remote surgeries, medical diagnosis etc. Connectivity between healthcare providers and patients would reach a record breaking feat during the era of 6G and this will bridge the gap between the two parties. It is also anticipated that the smart healthcare system will bring down the cost of healthcare, considerably reduce the spread of diseases and improve reliability of precision equipment used in surgeries. Medical records of patients can be easily elicited from central database for quick presentations to consultants and this will accelerate the rate of consultations per persons per day. 6G will be a multidimensional communication network that will support industrial revolutions in terms of automation of processes and enabling smart system. This would lead the entire globe to an era of self-contained ecosystem with sufficient intelligence and decision-making skills comparable to humans [4]. Hence, it can be postulated that communication technology is progressing from being human-centric to being both human and machine centric [4].

Fig. 2. Conceptual view of 6G ecosystem

5. Expected challenges

Being a new technology to evolve, it is anticipated that a challenge in terms of infrastructure would occur. However, it is technically most reasonable that 6G rides on the existing infrastructure of 5G with some design modifications. For instance, considering the micro level of the signal wavelength, the antenna size for such propagation becomes miniaturized which may be difficult to fabricate. A new concept of transceiver designs should be thought of, with smaller antenna elements commensurate with the millimeter wavelength that will support high frequency band, high sensitivity and low noise figure. Also, signals of such wavelength are commonly used for short-range communications which are easily susceptible to attenuation due to channel impairment. To overcome this, the antenna aperture may be increased in order to enhance transmission and reception capacity. Being a network that will support multi-level connections, security of the network becomes a serious threat. Therefore, a new and advanced security technique must be developed with innovative cryptographic features.

6. Conclusion

This paper has presented an overview of the next generation of wireless cellular technology, the 6G that is expected to evolve very soon. It discusses justifications for its evolution, the expected features, technologies to be driven by 6G and its anticipated challenges. The 6G which is presently at conceptualization stage has been projected to be an enabler of modern wireless ecosystem that will guarantee super smart society with seamless connectivity. It has been projected to occupy the uppermost part of radio spectrum with capacity to operate at a higher data rate, higher mobility and higher connectivity density.

In conclusion, our paper has contributed to the body of knowledge that would eventually be used to develop technical framework in the design and formulation of 6G technology.

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