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Telecommunications Wireless Generations: Overview, Technological Differences, Evolutional Triggers, and the Future

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***Abstract*—This study expands on prior studies on wireless telecommunication generations by examining the technological differences and evolutional triggers that characterise each Generation (from 1G to 5G). Based on a systematic literature review approach, this study examines fifty (50) articles to enhance our understanding of wireless generation evolution. Specifically, this study analyses i) the triggers that necessitated the evolution of wireless telecommunication generations and ii) makes a case regarding why it is imperative to look beyond the fifth Generation (5G) network technologies. The authors propose areas for future research.**

***Keywords*—telecommunications; generations; wireless; triggers; evolution**

I. Introduction

MOBILE data traffic is rising rapidly, primarily due to video streaming. Overall mobile data traffic expects to grow to 77 Exabytes per month by 2022. Mobile technology has evolved tremendously from purely analog systems with no data capabilities (1G) to nascent, fifth-generation (5G) networks. Also, the evolution has led to changes in data rates, ranging from low (around 10 kilobits per second (kbps)) to very high speeds in a staggering magnitude of 1 terabit per second (Tbsp.). Theoretically, one terabit per second can be obtained via 5G technology [1]. Without a doubt, the transition from 1G to 5G was extensive, with considerable architectural modifications from one particular Generation to the other (e.g., the core network (CN) and radio access network (RAN)). Significant updates have been integrated into the various layers of the system's architecture (such as the physical, transport, application, and security) and other components. The road to 5G has led to end-user level evolution of user equipment (UEs), mobile equipment (MEs), mobile units (MUs), and mobile stations (MSs) in tandem with advancements in technology. As a result, there is a sharp contrast between the intelligent devices in today's world and the era where bulky UEs adopted universal SIMs (USIMs) and macro subscriber identity modules (SIMs) [1].

Every Generation is characterised by different standards, features, capabilities, and techniques that distinguish it. For instance, the first Generation (1G) wireless communication network was analog and supported only voice calls.

The second-generation (2G) was a digital platform that enabled text messaging. The third-generation (3G) mobile technology facilitated rapid data transmission, multimedia support, and increased capabilities. The fourth-generation (4G) combined 3G with internet technologies to facilitate the provision of wireless mobile Internet. This represents an evolution in mobile technology that overcomes the limitations prevalent in 3G. Also, it minimises the cost of resources and increases bandwidth [2].

Today, there is a buzz about a phenomenon called 'big data. Also, the Internet is considered an almost ubiquitous platform. The postmodern era has witnessed the diffusion of 'smart' resources and systems due to facilitating technologies such as machine-to-machine (M2M), the Internet of things (IoT), and cloud computing. Bandwidth-intensive M2M connections are becoming more prevalent. Globally, M2M connections will grow from just under a billion by 2022. The Internet of things (IoT) will require networks that must handle billions more devices. The phenomenal growth in smarter end-user devices and M2M connections is a clear indicator of the growth of IoT, which is bringing together people, processes data, and things to make networked connections more relevant and valuable. An important factor contributing to the growing adoption of IoT is the emergence of wearable devices, a category with high growth potential. Wearable devices, as the name suggests, can be worn on a person and have the capability to connect and communicate to the network either directly through embedded cellular connectivity or another device, primarily a smartphone using Wi-Fi Bluetooth or another technology. Technological advances in the cellular domain have several implications for service providers and system users.

Economically, studies project an excess of 20 million 5G-related jobs by 2035 [3]. Again, we are moving toward a truly "networked" society where objects, people, systems, and devices are interconnected, allowing us to access and share information everywhere seamlessly and at any time [2]. The advent of 5G will create numerous technical, commercial, and management challenges for the long-term realisation of the so-called networked society for service providers and consumers ([4], [5]). Lifestyles have changed; almost every adult in urban areas uses cellular phones for communication and business. Information is disseminated quickly to distant places in seconds

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using cellular phones and social media links. Also, privacy and cybersecurity are becoming significant issues. Amidst all these, the advantages of the cellular network are worth trumpeting.

II. OBJECTIVES

This study contributes to the general body of knowledge in Telecommunication wireless generations by examining the technological differences and evolutional triggers that characterise each Generation (from 1G to 5G). To achieve the main aim of the study, the following specific objectives were investigated:

i. To review the technological differences in each Generation (from 1G to 5G) and possibly future generations from literature.

ii. To critically analyse the evolutional triggers that characterise each Generation (from 1G to 5G).

iii. To examine why it is necessary to look beyond 5G network technologies.

The paper is structured as follows. The methodology adopted for the literature review is presented in the next section. This is followed by an analysis and discussion of the body of literature on the evolution of technology from 1G to 5G; an overview of each Generation (taking into consideration the core and radio networks), the technological differences, and the evolutional triggers for each Generation. This is followed by arguments on the necessity of looking beyond 5G. The study's conclusion and recommended areas for future research are presented in the last section.

III. METHOD

In conducting this systematic review, we adopted Bendermacher et al. [6] methodological approach to (i) develop a search strategy for using several databases, (ii) define exclusion and inclusion criteria for publications – assess for eligibility, (iii) define review and coding scheme, (iv) analyse and synthesise data and (v) develop write-up. This methodology ensures transparency and rigor regarding the publication selection and analysis process. The researchers limited the database search to keywords, abstracts, and titles. Given the literature volume, the researchers adopted this strategy to reduce the number of publications to review while enhancing the precision of information search [7]. The goal was to identify relevant publications that explicitly discussed the concept of wireless mobile generations as a central theme [8].

We reduced the number of research publications to review by specifying the criteria for inclusion and exclusion. The inclusion criteria were that the publications should be book chapters, conference papers, and articles (conceptual and empirical studies) in peer-reviewed journals written in English and relevant newsletters of telecommunication vendors and operators. Furthermore, we excluded publications such as reports, policy documents, newspapers, and magazine reviews from our sample. The authors restricted the publications from 2000 to 2021 that contained vital definitions, concepts, and relevant information relating to the subject matter. The researchers adopted the pre-selection strategy to include pertinent publications that substantially contributed to the phenomenon under investigation in the systematic literature review process. Also, we examined abstracts, keywords, introduction, and conclusion of each article as a means of reducing selection errors. The eligibility assessment involved manually screening each publication to enhance the publication selection process's rigor, accuracy, and reliability. The researchers used only secondary data, which refers to data collected for some other purpose [9]. Secondary Data is helpful for this study's goal of analysing the literature on wireless mobile generations. To identify publications relevant to the concept under investigation, we explored four (5) databases: Scopus, IEEE Xplore, Association of Computing Machinery (ACM), Emerald Insight, and ScienceDirect. We employed the search string "wireless telecommunication generation" and "wireless generations" to search for publications in the various databases.

We retrieved 400 publications from the databases search, of which we selected 256 based on analysis of titles. A total of 152 publications were deemed irrelevant after analysing the abstracts of the publications. Also, 35 articles were taken out due to duplication, leaving 69 publications. Furthermore, ten (10) papers were excluded based on the criteria for inclusion and exclusion because they did not match the research aim. Then, the researchers took nine (9) publications out after analysing the text of the complete publications because the central focus of such publications did not conform to the research objectives, leaving a total sample size of 50 publications for detailed review and synthesis. It is worth noting that even though the authors worked with 50 articles, not all of them were useful in the analysis.

IV. ANALYSIS AND DISCUSSION

A. *Evolution of mobile networks*

Clark Maxwell proposed the theory of electromagnetic radiation in 1875. Based on the principles of this theory, Guglielmo Marconi developed radio transmission in 1901. Although it was considered an outstanding achievement in data transmission, radio transmission could not sustain a reasonable rate of data transfer for over half a century [10]. In the 1940s and 1950s, modern mobile technologies were introduced in the United States and Europe, respectively. Challenges such as limited mobility, extremely expensive, and poor service were some constraints that undermined the effectiveness and global adoption of early mobile phones. As a result, developers focused on manufacturing and improving mobile technologies to enhance user experience and performance.

The accelerating rate of mobile technology innovation and an upsurge in its adoption have engendered pressing demands for the continuous evolution of mobile technologies. Examining the progress made from 1G to 5G has created new use patterns from intended and unintended use scenarios. Also, progress in network capabilities or performance signifies the birthing of a new generation. For instance, enhancement in network capabilities and performance distinguishes each Generation from 1G to 5G. The subsequent section presents a brief history of mobile technology based on the various generations.

B. *First-generation (1G)*

The First Generation (1G) mobile networks were developed in the 1970s. Initially, these systems were described as cellular till they were renamed "cell" because of how signals between cell towers were handed off. The signals for the first-generation mobile phones were developed based on the principles of analog data transmission. Also, 1G mobile technologies were relatively less expensive and less heavy than earlier mobile technology models. Popular standards adopted for 1G technologies include Nordic Mobile Telephone (NMT), Advanced Mobile Phone System (AMPS), and Total Access Communication Systems (TACS). The emergence of the 1G network led to the growth of the mobile phone industry, from 30% to 50%. Additionally, the total number of mobile phone subscribers was approximately 20 million by 1990 [10].

C. Second Generation (2G)

The early 1990s witnessed the emergence of 2G mobile technologies, which deployed global systems for mobile communications (GSM). Although GSM uses digital modulation to enhance voice quality, the data service offered by this network is limited [10]. As demand for cell phones increased, carriers of 2G continuously improved the quality of transmission and coverage. Also, 2G carriers provided additional services such as voicemail, faxes, text messages, and paging. In the late 1990s, an intermediary phase of the 2G network was introduced known as 2.5G. 2.5G network used general packet radio services (GPRS) standards that facilitate the provision of packet-switching capabilities to existing GSM networks. Also, users were able to transfer rich-graphic data content as packets. The opportunities presented by packet-switching influenced the emergence of the Internet and internet protocol (IP). An example of 2.5G mobile technology is the enhanced data for global evolution (EDGE) network [10].

D. Third Generation (3G)

3G allowed mobile users to use video, audio, and graphic applications. For instance, users could stream videos and engage in video telephony via the possibilities made available by 3G networks. However, network bottlenecks and issues of over-usage constrained such activities. 3G networks were developed to standardise network protocols for global data transmission or exchange. Under optimal conditions, 3G mobile technologies deliver up to 2 megabits per second (Mbps). Universal Mobile Telecommunications Systems (UMTS) is a 3G cellular service that facilitates packet data transmission. UMTS enables Internet-style applications. Also, UMTS sustains circuit data transmission and provides a global standard or protocol to promote compatibility across several mobile devices. Fundamentally, UMTS represents the first possibility for global roaming and internet access regardless of the location [10].

Generally, 3G allows smartphone users to download at a speed of 2 Mbps. In comparison, the fourth Generation (4G) offers about 5Mbps; approximately the speed personal computers use in data exchange via cable modems or digital subscriber line (DSL). The fifth-generation (5G) offers a peek down the speed of approximately 20,480 Mbps, reflecting a massive leap compared to the previous Generation. This implies that the higher the network generation, the higher the network capabilities and performance opportunities. This implies that 5G can support a more significant number of users at any given time. In addition, higher network capabilities imply higher data transmission rates that ensure smooth streaming of multimedia applications such as video calls and video clips. 3G cell tower enables a range of between 60 to 100 people to exchange signals and obtain fast and reliable services. 4G cellular tower empowers a range of between 300 to 400 people to obtain fast and reliable data exchange services. Computer network developers, programmers, and engineers ensure that digital signals are optimised in each radio signal to enhance the speed and efficiency of networks. The difference between network generations is performance capabilities due to improved internet experience and not necessarily because 4G is twice as good as 3G.

E. Fourth Generation (4G)

The fourth-generation (4G) network provides a data transmission rate of 20 Mbps while simultaneously ensuring the quality of service (QoS). QoS enables users and mobile technology carriers to prioritise traffic based on the type of application using the bandwidth and adapt between various telephone requirements speedily [10]. 4G facilitates high-performance multimedia content streaming smoothly [11]. 4G focused on delivering much faster mobile broadband services than 3G. Additionally, a 4G network improves video conference functionality and delivers wider bandwidth to devices such as vehicles that move at high speeds within a network area. Spectrally, 4G is deemed more efficient than 3G, just as 5G is deemed more spectrally efficient than 4G. Every Generation provides more data per hertz than the previous ones. For example, 3G functions up to 2.1 gigahertz, 2.5 gigahertz, and 95 gigahertz for 4G and 5G, respectively. This accounts for the global prioritisation and increased adoption of 5G.

F. Fifth-generation (5G)

The fifth-generation mobile network is referred to as 5G. After the previous generations' networks, it is a new worldwide wireless standard that is designed to support a multiple of 100 increase in traffic capacity and network efficiency. 5G has significantly lowered latency than the previous generations to deliver more instantaneous, real-time access, a multiple of 10 decreases in end-to-end latency down to 1 millisecond with a unified, capable platform that elevates not only mobile broadband experiences but also supports new services such as mission-critical communications and the massive IoT. 5G allows for creating a new network that connects nearly everyone and everything, including machines, objects, and gadgets. It is envisioned that the 5G network will offer speeds as high as 15 or 20 gigabits per second (Gbps). Also, the exceptional scalability feature of 5G networks enables several devices to be connected to the network concurrently while minimising latency drastically. Thus, mobile technologies running on 5G networks can load a full-length feature movie in high definition (HD) in seconds. The capabilities of the 5G network are faster and more efficient than in previous generations. It has been designed with an extended capacity to enable next-generation user experiences to empower new deployment models and deliver new services. With high speeds, superior reliability, and negligible latency. 5G will expand the mobile ecosystem into new realms. As a result, the 5G network extends the evolution of mobile Internet to accommodate the Internet of things (IoT). Thus, more objects can be connected, including smart cities, smart homes, vehicles, and other intelligent systems. Also, the speed and reliability of 5G networks present possibilities for the smooth running of electronic healthcare (e-healthcare) systems. Unlike 4G networks that use "macrocells," 5G networks use "small cells." This implies that 5G networks consume less power. Also, installation is much faster compared to previous generations. Therefore, 5G overcomes the limitations associated with bandwidth as seen in previous generations, till system use scales up to keep up with it. 5G is considered a game-changer for mobile Internet and IoT, increasing the number of connected devices and faster and more reliable data exchange. Also, an increase in connected devices enables more sensors to connect smart cities and buildings. Currently, the number of sensors deployed for intelligent cities is relatively small. These sensors are usually placed on lamp posts and coarsely cover an area. Therefore, 5G enables the saturation of an area with sensors and impacts every industry making safer transportation, remote healthcare, precision agriculture, digitized, logistics, and more.

G. 5G application scenarios

1) Traffic regulation using artificial intelligence (AI.)

Adapting artificial intelligence (AI) technology to monitor and control traffic in 5G networks from network data [28] is a viable path for addressing the problems discussed above. By drawing new insights from the networks and predicting network traffic conditions and user behavior, AI technologies will reduce manual interventions in network traffic management and enable better network performance, reliability, and more adaptive systems, enabling smarter decisions in an autonomous manner [29].

A good example is a smart city with several cameras installed at vantage points to direct people around traffic and indicate the most appropriate places to park vehicles [12]. In addition, self-driving cars or autonomous vehicles move around without causing traffic and harm to pedestrians. 5G network technologies, in conjunction with "smart vehicles," facilitate communication between "smart vehicles" and their environment to minimise the risk of accidents and promote more efficient traffic patterns. Machine learning (ML) and deep learning (DL) are two sophisticated AI approaches that have sparked much interest in overcoming the issues of 5G network traffic management [30]. Consequently, traffic jams will be reduced drastically, commute times will be shortened, and energy consumption will be lessened by reducing the time required for vehicles to stay idle at red lights or wait in line. Vehicle owners can quickly receive notifications of the condition of their oil, brakes, and other systems in their vehicles on their dashboards or even on their mobile devices. Self-driving cars can transmit data back to developers to improve both hardware and software features of such vehicle systems. Fu et al. [31] proposed a revolutionary AI assistant content retrieval algorithm framework for minimizing data traffic in the content retrieval services of future 5G networks. In 5G networks and mobile communication, several machine learning (ML) approaches were used to solve complicated problems that require much hand-tuning. Artificial intelligence includes machine learning (ML). It automates a systematic approach that detects patterns and makes judgments with minimal human intervention by processing and analyzing data, as shown in Figure 1.

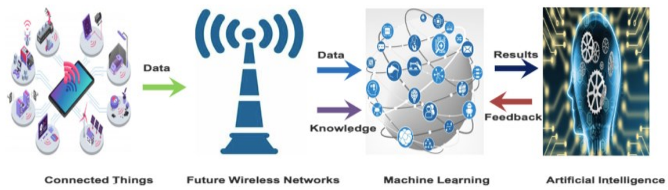

Fig. 1. View of Machine Learning (ML) with 5G

2) Remote healthcare delivery: telehealth

Telehealth can be described as providing or delivering healthcare services via telecommunication technologies. Healthcare executives are pondering how modern technology may aid in transforming healthcare delivery. The creation of better connected and coordinated IT services will drastically accelerate urgent healthcare delivery, thanks to 5G and integrated Multi-Access Edge Computing (MEC). Patients under their care will benefit from creating these new models, which will improve their experiences and increase their quality of life. A new linked healthcare ecosystem will emerge in predictive, preventative, customized, and participatory medicine as the usage of 5G in healthcare grows, with applications aided by robotics, IoT, and AI.

Currently, telehealth is relatively constrained by potential blackouts and poor internet connectivity in rural areas and developing countries. 5G improves internet speed in rural communities and remote areas, enabling specialist surgeons to work via robot technologies in small rural clinics. Also, contagious diseases can be diagnosed remotely without infected patients coming to the hospital or clinic. This minimises the spread of infectious diseases. In addition, wearable health monitors enable patients to consistently monitor their blood pressure and other vitals to help them stay healthy. The use of wearable health monitors also reduces the cost of checking vitals in clinics or hospitals.

3) Automated retail shops

The explosive expansion of e-commerce has taken its toll on traditional brick-and-mortar retail outlets. Retailers must create a convenient, engaging consumer experience to entice customers away from internet purchasing. Technology plays a significant role in reaching this goal. Cellular networks are used in many retail locations to support shop technologies such as point-of-sale (POS) and video surveillance. Retailers prefer cellular to Wi-Fi for use cases where POS systems must work in remote locations or be mobile. Drop-in cellular connectivity may require third-party firms that install kiosks and displays in retail venues without access to local infrastructure.

Technological advancement has given rise to possibilities such as smartphones and augmented reality (AR) glasses to help customers quickly identify items and products at shops. Smart tags and digital signatures improve the consumer shopping experience by quickly indicating the goods' price, health benefits, and product reviews. Retail space designers will use 5G's increased capacity to produce and offer more content to customers. High-bandwidth communication will enable further research into other AI applications. These will allow systems to adapt the information to customers depending on demographics and other criteria. 5G will also improve video security systems by detecting irregularities and possible threats with computer vision. Such systems need a large amount of bandwidth to send high-quality photos and video material. The larger data flow provided by 5G will further improve their features. There are also 3-dimensional printers that measure dresses and other items and print them out in 3D. This makes life comfortable and less stressful for clients.

4) Network slicing and integrated supply chains

Network operators are under pressure to reduce operational expenditure as users get used to flat-rate tariffs and do not wish to pay more. The mobile communication technology can enable new use cases for ultra-low latency or high-reliability cases and new applications for the industry opening up new revenue streams for operators. 5G network presents opportunities for the implementation of virtual networks. These virtual networks develop subnets that possess different traffic priorities. For instance, a hospital's network can be configured so that the connection between a surgeon and a robot is prioritised over the communication that exists among patients. Hence, emergency transmission can be secured if the network reaches total capacity.

The 5G increased operational performance, for example, increased spectral efficiency, higher data rates, low latency, and superior user experience near to fixed network but offering full mobility and coverage. 5G needs to cater to the massive deployment of the Internet of things while still offering acceptable energy consumption equipment cost and network deployment and operation cost. It needs to support a wide variety of applications and services. 5G wireless technology is meant to deliver higher multi-gigabit per second peak data speeds, ultra-low latency, more reliability, massive network capacity, increased availability, and a more consistent user experience to more users' higher performance and improved efficiency empower new user experiences and connects new industries.

IoT in combination with 5G technologies enables far-reaching connectivity and data transmission. Cities are becoming "smart," automated business processes and intelligent systems are integrated into our very lives. Factories and warehouses have deployed real-time tracking systems to manage inventory, monitor shipment, and control products and equipment throughout the manufacturing cycle. 5G capabilities in conjunction with supply chain technologies promote better customer service, minimise cost and reduce the loss of products in transit.

5) Internet of Things (IoT): The Future

5G facilitates and sustains IoT. IoT possesses infinite potential. Factors such as improved network agility and integrated AI accelerate industrial internet advancement. Also, automation, deployment, and security of several use scenarios at hyper-scale expedite industrial internet development. The goal is to enable and sustain the interconnectivity of several devices simultaneously and exploit voluminous actionable data to digitise business operations. The evolution of network technologies and IoT leverages technological advancement and AI to enable organizations and individuals to generate new revenue streams. Human-to-machine interactivity serves as a platform that gives rise to IoT applications. Huma-to-machine interactivity enables humans to engage in real-time interactions with machines and devices regardless of distance. As a result, new opportunities such as remote learning, remote shopping, and repair will become prevalent and easy to deploy. Furthermore, immersive mixed reality applications can become the next trending technological platform after mobile technologies. This is because 3D audio and haptic sensations become the primary interface to reality. Maximum exploitation of IoT functionality requires a synergy between network technologies and IoT platforms. It is estimated that the number of connected IoT devices will grow from 700 million to 3.2 billion by 2023. Smart homes, synchronized watch and phone gadgets, and fitness applications are now widespread, and 5G's speed and performance capabilities will make them much more so. With such a significant dependence on mobile IoT now, the 5G future will look radically different in the next 20 or so years. We will see large-scale automation of cars and utility services such as waste management and energy generation via smart grids and smart environmental monitoring to reduce greenhouse gas emissions and pollution. Imagine being able to park a smart car in a parking garage, connect to the city grid for wireless charging while one works, and then instruct a vehicle to drive itself from the parking garage to one's office door. Drones and super-dense sensor networks will make it easier for farmers in remote regions to monitor and track crops, animals, and machines. Home users will fully embrace the COVID-led work-from-home paradigm, which will very certainly survive the epidemic as a new corporate standard. Furthermore, home users will optimize power use and watch their favorite entertainment from anywhere. Society will be more efficient, smart cities will live up to their billing, and people may anticipate individualized information streams according to their preferences.

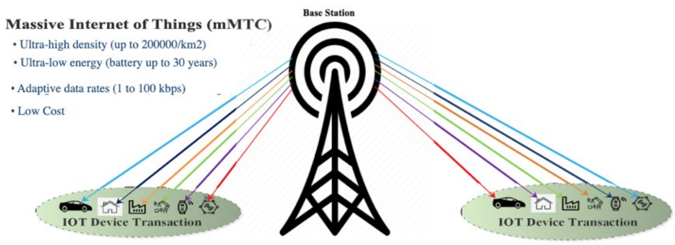

Fig. 2. Internet of Things (IoT) with 5G

As shown in figure 2, 5G with IoT is a new feature of next-generation mobile communication that allows for high-speed internet connectivity between regulated devices by enabling machine-to-machine (M2M) connection and information sharing across disparate devices without the need for human intervention. This combination offers smart homes, smart gadgets, sensors, smart transit systems, smart industries, and the like.

6) Rate of Data Transfer

The performance of IoT depends on how effectively, efficiently, and quickly the interconnected devices communicate with each other. Technologies like 5G networks improve the rate of data transfer significantly. 5G network is considered ten times better than existing Long-Term Evolution (LTE) networks. As a result, the data exchange rate among IoT devices will be faster than ever. For instance, increased speed regarding data exchange implies minimisation of lags and overall improvement in the performance of connected devices. Healthcare and industry application will benefit tremendously from this innovation.

7) Evolution from 5G to 6G

Standardisation and global deployment of 5G networks have commenced. Industry and academia synergy has conceptualised a sixth-generation (6G) wireless communication network [13]. Conceptualisation and gradual development of 6G aims to address the global communication needs to be estimated for the year 2030 [14].

Figure 3 shows the evolution of mobile phone communications from 1G to 5G discussed above. Table 1 shows the comparison of cellular generations based on Period of Evolution, Bandwidth, Frequency, Data Rate, Characteristics , and Technology, and then Table II, The differences in 1G to 5G in terms of the Period of evolution, Deployment, Data Rate, Famous standards, Technology behind, Service, Multiplexing, Type of Switching, Handoff, and Core Network. Figure 3 also shows the 5G to 6G Evolution path.

TABLE I
COMPARISON OF CELLULAR GENERATIONS BASED ON PERIOD OF EVOLUTION, BANDWIDTH, FREQUENCY, DATA RATE, CHARACTERISTICS, AND TECHNOLOGY

Technologies	1G	2G/2.5G	3G	4G	5G
Evolution	1970	1980	1990	2000	2010
Deployment	1984	1999	2002	2010	2015
Data rate	2 kbps	14.4 – 64 kbps	2 Mbps	200 Mbps to 1 Gbps for low mobility	10 Gbps to 100 Gbps
Famous Standards	AMPS	2G: GSM, CDMA 2.5G: GPRS EDGE, l x RTT	WCDMA, CDMA - 2000	LTA, WiMAX	Not yet defined
Technology behind	Analog cellular technology	Digital cellular technology	Broad bandwidth, CDMA, IP technology	Undefined IP and seamless combination of broadband. LAN/WAN/PAN/WLAN	Undefined IP and seamless combination of broadband. LAN/WAN/PAN/WLAN
Service	Voice	2G: Digital Voice, SMS 2.5G: Voice + Data	Integrated high-quality audio, video, and data	Dynamic information access, wearable devices	Dynamic information access, wearable devices with AI capabilities
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Type of switching	Circuit	2G: Circuit 2.5G: Circuit and packet	Packet	Packet	Packet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal and Vertical	Horizontal and Vertical
Core network	PSTN	PSTN	Packet network	Internet	Internet

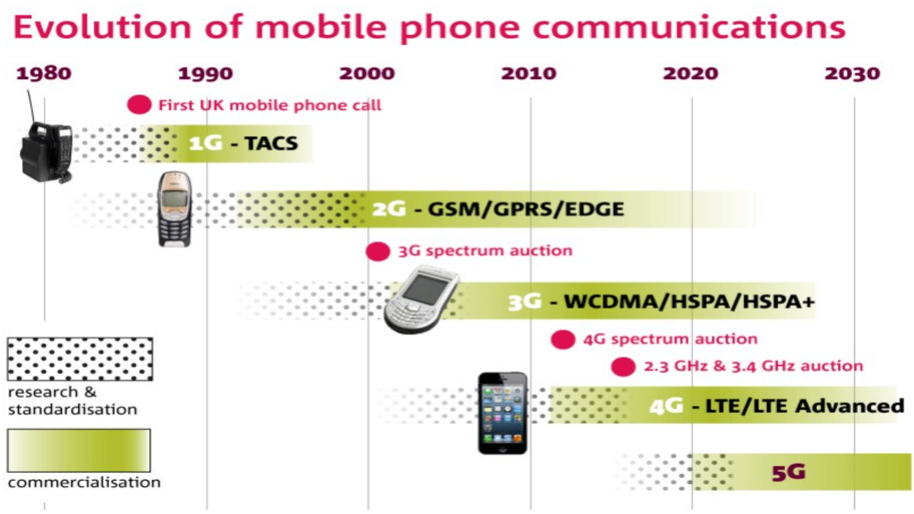

Fig. 3: Evolution from 1G to 5G

TABLE II
THE DIFFERENCES IN 1G TO 5G IN TERMS OF THE PERIOD OF EVOLUTION, DEPLOYMENT, DATA RATE, FAMOUS STANDARDS, TECHNOLOGY BEHIND, SERVICE, MULTIPLEXING, TYPE OF SWITCHING, HANDOFF, AND CORE NETWORK

	1G	2G	3G	4G	5G
Period	1980-1990	1990-2000	2000-2010	2010-(2020)	(2020-2030)
Bandwidth	150/900MHz	900MHz	100MHz	100MHz	1000 x BW per unit area
Frequency	Analog signal (30KHz)	1.8 GHz (digital)	1.6-2.0 GHz	2 – 8 GHz	3 – 300 GHz
Date rate	2kbps	64kbps	144kbps -	100Mbps -	1Gbps <
Characteristic	First wireless communication	Digital	Digital, broadband, increased speed	High speed, all IP.	
Technology	Analog cellular	Digital cellular (GSM)	CDMA, UMTS, EDGE	LTE, Wi-Fi	WWWW

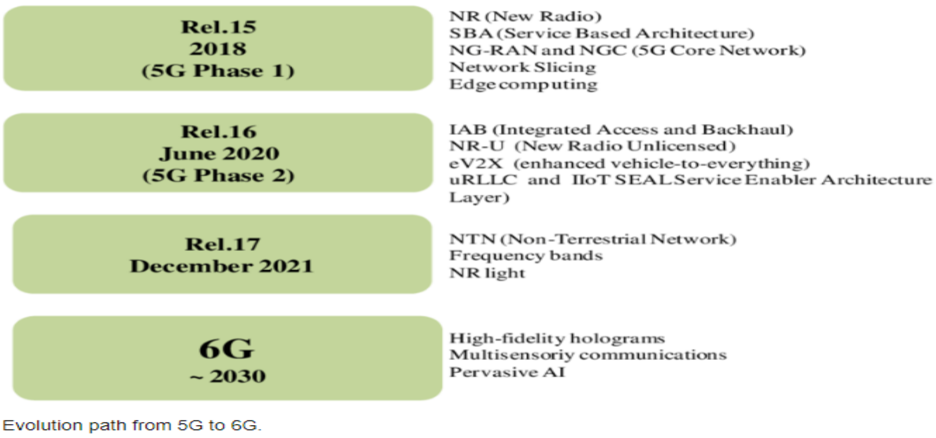

Fig. 4: 5G to 6G Evolution

8) Evolutional Triggers

There have been several technological advancements in the cellular phone domain since its invention in 1973. The invention of the mobile phone has shaped the foundations of our social interactions [15].

The scope of this study is centered on the evolutionary enhancements over the years across various technological generations in the wireless phone domain. Thus, from 1G to 5G. The subsequent section presents a detailed analysis and discussion of the evolutional trigger of each Generation, from 1G to 5G and beyond.

i. 1G to 5G Evolutional Triggers

This study gathered that the general enhancement for each “Generation” by researchers in the cellular phone industry mainly focused on higher data rates, low latency, improved voice quality, and coverage as a response to the interest stimulated by 2G when it was developed. Goyal & Lather [16] argued that the pursuit of competitive advantage by industry giants is one of the main reasons for technological advancement. However, Goyal & Lather’s [16] study did not categorise the industry giants in terms of phone producers, core equipment producers, and technical researchers to enhance our understanding of the industry giants being referred to. The increase in the patronage of telecommunication services by users at the various phases of each Generation (from 1G to 5G) was influenced by technological differences and advancements, coupled with service and transmission compatibilities. Therefore, these factors are considered the evolutional triggers of the wireless generations [2]. The subsequent section presents an overview of each Generation's evolutional data rate advancements.

ii. First Generation (1G)

Nippon Telegraph and Telephone (NTT) launched the First Generation of mobile networks in Tokyo in 1979, termed 1G in retrospect when the following Generation was released. NTT has completed the nationwide rollout of 1G by 1984. The United States permitted the first 1G operations in 1983, and Motorola's DynaTAC became one of the first 'mobile' phones to be widely used in the United States. A few years later, other nations such as Canada and the United Kingdom launched their own 1G networks. 1G thrived only on voice calls [17]—Max speed 2.4Kbps 150MHz. However, there were several disadvantages to 1G technology. The sound quality was terrible, and the coverage was poor. There was no roaming support across carriers, and there was no system compatibility because separate systems operated on distinct frequency bands. Worse, calls were not encrypted, allowing anybody with a radio scanner to listen in on a conversation. Developers sort to improve the effectiveness and efficiency of 1G to provide more and better services. This led to the development of 2G. 2G gave rise to further developments in the telecommunication industry.

iii. Second Generation (2G)

2G was introduced in 1991 as part of the GSM standard. Calls could be encrypted for the first time, and digital voice calls instead of analog systems were noticeably crisper, with less static and background crackling [18]. It used TDM and CDMA at 900 MHz. Initially, 2G provided opportunities for only voice calls and SMS. GPRS (2.5G) was introduced to improve data capability via packet switching. In addition, Multimedia Message Services (MMS) were developed to support internet browsing and allow users to send multimedia messages like pictures. Mobile devices were equipped with GPRS modems. Enhanced Data Rates for GSM Evolution, known as EDGE (2.75G), was introduced to provide higher data rates than GPRS. 2G served as the platform for developing higher-speed connections, which led to its mass adoption by consumers and businesses.

iv. Third Generation (3G)

3G was introduced in 1998, using WCDMA and UMTS standards [19]. WCDMA standard was based on GMS, while UMTS standard was based on 3GPP. These standards were mainly used in Europe. Maximum speed depended on device mobility. That is, moving 384 Kbps and stationary 2Mbps. 3G introduced video calling and streaming services in addition to mobile Internet and other services already present in 2G. HSPA (3.5G) was introduced for higher data rates than WCDMA/UMTS. Theoretically, data rates were 5.76 Mbps/14.4 Mbps for UL/DL, but the actual data rates were 200 Kbps/500 Kbps. HSPA+ was introduced as an improved version for the higher data exchange rate. It represented an evolved version of HSPA and thrived on MIMO. Theoretically, the data rate for HSPA+ was 22 Mbps/168 Mbps for UL/DL.

v. Fourth Generation (4G)

The advent of new technologies in mobile communication systems and the ever-increasing rise of user demand have prompted researchers and industry to develop a complete representation of the fourth generation (4G) mobile communication system. Unlike 3G, the new 4G framework will attempt to achieve new levels of user experience and multiservice capacity by combining all of the existing mobile technologies. 4G was standardised by ITU as LTE and contained WiMAX standardised by IEEE with IEEE 802.16 [20]. However, LTE is quite dominant. Theoretically, the data rate for LTE UL/DL is 50 Mbps/100 Mbps, LTE advance 500 Mbps/1 Gbps, and WiMAX 56 Mbps/128 Mbps. Also, the birth of 4G was based on higher data rates and low latency, which dominates this technological Generation.

LTE supports a range of frequencies (700/800/90/1700/1800/1900/2100/2600 Mhz), low latency, and high speed [21]. LTE presented IP Telephony opportunities such as VoIP, 3D Television, video conferencing with multiple active participants, and online gaming [22].

vi. Fifth Generation (5G)

The quest for higher data rates has been a catalyst for the incremental and evolutionary advancements from 1G to 4G. However, 5G data rates deviated from incremental and evolutionary development. 5G represents a revolutionary leap in terms of data rates [4]. Technological phenomena such as IoT, smart cities, massive sensors, self-driving cars, and remote medical operations engendered pressing demands for the development of 5G [23]. It uses beamforming and massive MIMO (64x64). Massive MIMO refers to a system having multiple antenna elements in an active antenna array used to transmit multiple data streams in the desired direction. It helps to increase system capacity, data throughput, and coverage. It uses a Time division duplex (TDD) base. The transmitter (or uplink) and receiver (downlink) both use the same frequency but transmit and receive traffic is switched in time. Table III shows theoretical maximum data rates from 1G to 5G.

TABLE III
THEORETICAL MAXIMUM DATA RATES FROM 1G TO 5G

Technology	Maximum Data Rate (DL)	Notable Advantages
1G	2.4Kbps	Voice only
2G	115Kbps(2.5G), 473Kbps (2.75)	Initially 2G and provided the only voice. 2.5G(GPRS) introduced data, then EDGE (2.7G)
3G	UMTS (2Mbps), HSPA (14.4Mbps), HSPA+(168Mbps)	Voice & Data
4G	LTE (100Mbps), LTE Advanced(1Gbps)	Very low latency
5G	10Gbps	Speed is quite revolutionary. Support for IoT devices

9) 5G and Beyond

Apart from excellent data rates and superior low latency it promises, 5G also provides connectivity for concentrated devices per unit routing area [24]. Traditionally, network elements had revolved around notable nodes such as switches, routers, firewalls, and servers. In modern times, almost every electronic or electrical object has a network node interconnected with other devices via IoT. Unlike traditional network nodes, IoT requires connectivity at low power consumption rates over wireless technologies. 5G and beyond are promising to respond to this demand, apart from the very high data rates and low latencies it offers in the telecommunications industry [25]. Dashtipour et al. [26] suggest that 5G faces challenges of optimal utilisation in the face of ultra-dense networks. IoT is bedevilled with performance criteria requirements regarding security, connectivity, reliability, radio coverage, high throughput, and low latency. The emergence of superior models for businesses and applications in future IoT devices calls for addressing performance requirements. 5G and beyond present technological capabilities that satisfy the performance requirements [27].

CONCLUSION

The study has been able to show the difference between 1G to 5G in terms of the following: Technologies employed, Evolution year, Deployment year, Operational Data rate, Operational Famous Standards, The Technology that supported them, The kind of service they gave to consumers, The Multiplexing employed, The Type of switching, The Type of Handoff, the Type of Core network employed, and The Notable advantages of each Generation.

Again, it came out clearly from the study that higher data rates, low latency, improved voice quality, and coverage as a response to the interest stimulated by 2G when it was developed were primary triggers for the next Generation. Moreover, it was also found that the increase in the patronage of telecommunication services by users at the various phases of each Generation (from 1G to 5G) was influenced by technological differences and advancements, coupled with service and transmission compatibilities.

In the case of beyond 5G, the talk of 6G has intensified, even though it is far-fetched, due to the apparent challenges with 5G and its operational devices such as optimal utilisation in the face of ultra-dense networks. Again, IoT that rides on 5G is bedeviled with performance criteria requirements regarding security, connectivity, reliability, radio coverage, high throughput, low latency, and connectivity at high power consumption rates over wireless technologies.

RECOMMENDATION

From the study's conclusion, it is clear that even though 5G is not fully explored, the talk of 6G has become necessary due to the seemingly challenges associated with 5G operational devices. To that aim, we have identified the next steps in Applying machine learning (ML) to resource management, power allocation, data minimization, and channel modeling should be the direction of research. Various machine learning algorithms may be executed intelligently when paired with a 6G wireless communication network. As a result, the solution must be developed for present ML and future 6G to address existing difficulties such as latency, power allocation, privacy, security, model interoperability, and the like at the application and infrastructure levels to improve smart applications. The researchers recommend a detailed study of 6G and its benefits to see whether it would address most of the challenges of 5G.

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