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THE 6G NETWORK PROSPECTS: HOW IT WILL TRANSFORM THE WIRELESS COMMUNICATION LANDSCAPE

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ABSTRACT

The 5G is still in its early stages, yet many technical issues have arisen from its implementation due to increasing data use. The world data traffic is currently more than 49EB per month, and existing technologies like Virtual Reality (VR) needs more than 10Gbps offered by 5G – a factor that calls for action beyond the 5G network; the 6G. 6G developments will shifts 5G paradigms and employ new technologies to ensure cost efficiency, long-range connectivity, low jitter, delay and latency, and scalability and device reuse. This paper provides an overview of 6G, explores how the wireless landscape will be transformed in the wake of the 6G network and the potential benefits of such transformations.

Keywords: 6G, Wireless Communication, 5G, Paradigm's Shift, Networks, Data Traffic, Emerging Technologies.

I. INTRODUCTION

The rapid rise in data-intensive technologies has led to an urgent need for faster data connectivity. Technologies such as smart cities, big data, Machine learning, three-dimensional (3D) media, Internet of Things (IoT), among others, have led to massive data traffic in the recent past [1]. In 2020, the global mobile traffic volume (excluding the fixed wireless access) was 49EB per month and is projected to grow at a compound annual growth rate (CAGR) of 5% to reach more than 237EB per month by 2026[2]. Smartphone use and increase in video streaming account for the most incredible traffic, with video streaming services, account for more than 66% of the total mobile data, a share that is forecasted to increase to 77% by 2021[2,4]. Equally, Edholm's Law [3] postulates that the internet bandwidth in telecommunication networks doubles every 18 months, a similar approach in semiconductor developments described in Moore's law. These revelations show that wireless communication systems need more improved infrastructure to guarantee speed, better latency, and low delays with meteoric growth and adoption of automated life, consequently leading to fully automatic societies - from an autonomous vehicle, to space science.

Increased automation means that millions of sensors in wireless sensor networks need to be integrated into various environments and must communicate promptly with various network units to deliver data and feedback at the highest speed possible [5]. Hence, high data speed rates with high-reliability connections will be needed to support various automation frameworks. The development and full implementation of both fourth-generation (4G) provided higher speed. Still, this was not enough for existing and soon to be witnessed high data traffics – a factor that prompted the development and implementation of its predecessor, fifth-generation (5G). The 5G provides a better quality of service (QoS) than the 4G communication network [1]. However, even though 5G has provided adequate leverage to unlock automation potential [3], high data propensity in the global arena makes it inadequate to serve the expected data traffic and technologies in the next decade.

Ergo, there is a need to explore the sixth generation (6G) of networks for various reasons. Firstly,5G might be short-lived in our society because it might be overwhelmed by fast-growing data-centric technologies and automation. Secondly,5G concentrated on frequency bands (millimeter-wave and optical spectra), spectrum management and integration of licensed bands, and overlooked at the convergence of communication, systems intelligence, sensing, computing functionalities, and control [5]-[8], some of the major driving forces behind the 6Gof wireless communication. The development of the fourth industrial revolution (Industry 4.0), whose industrial internet of things (IIoT) is a critical component, dramatically relies on convergence, which is beyond 5G, calling for exploration beyond 5G [5]. Equally, these factors increase system threats such as eavesdropping, nefarious activity, outages, and physical attacks [6] while decreasing operability, reduce diversity in use and technological maturity [7]. Lastly, emerging technologies such as virtual reality are expected to operate beyond 10 Gigabytes per second (Gbps) -maximum speed offered by 5G [2] – calling for the need to go beyond 5G networks. Owing to these shortcomings, 6G design goals incorporate massive man-machine interfaces, enable ubiquitous computing (at local and cloud levels), precision sensing and controls, and enhance multi-sensory data fusion to create multi-verse maps and different mixed-reality experiences [4]-[6]. This will fulfill the laggings of the 5G system by introducing new synthesis of future services such as ambient sensing intelligence and new human-human and human-machine interaction, a pervasive introduction of AI, and the incorporation of new technologies such as terahertz (THz), 3-dimensional (3D) networking, quantum communications, holographic beam forming, backscatter communication, intelligent reflecting surface (IRS), and proactive caching [3].

This paper tries to view the 6G network and its paradigm shift from the 5G network. However, more concentration is taken on its overview and system requirements that led to understanding how it will transform the wireless data communication landscape in the near future.

II. THE 6G OVERVIEW

The 6G network is expected to be fully operational by 2030. The paradigms will reduce 5G technologies trade-offs, such as throughput, delays, energy efficiency, reliability, hardware complexity, and deployment cost reduction. According to International Telecommunication Union -Radio communication Sector(ITU-R), the target key performance indicators(KPI) for 6G are as follows; peak rate of 1 Terabyte per second(Tbps)(1000 time that of 5G), 0.1 latency, 20 years battery life, device connectivity of 100/m3, the traffic handling capacity of 10,000 times, ten times energy efficiency, maximum outage of 1 out of 1 million, and 10 centimeters (cm) indoor and 1 m outdoor precision in positioning[1,7-9], as shown in Figure 1. It aims to objectively deliver an extremely high data rate per device, support robust connectivity, foster global connectivity, and reduce network latency, and lower power consumption by introducing battery-free IoT devices and providing device intelligence.

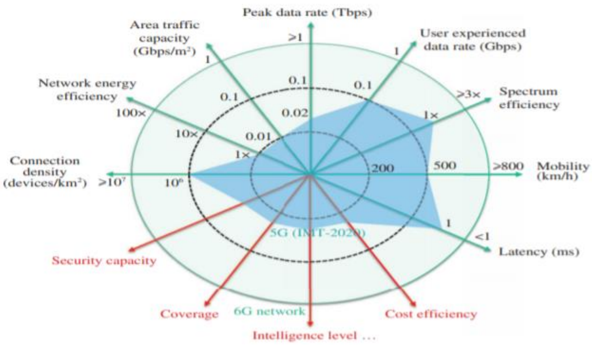

Figure 1: Expected key performance indicator for 6G network

Such technological intensive achievements call for interoperability and synchronization of several enabling forces [11]. Firstly, the 6G ought to improve band connectivity by use of the Terahertz band. The current broadband is usually 275GHz -3THz, for which most of it is not yet exploited or allocated for any purpose worldwide. Thus, 6G will control such a band by adding a THZ bar to the mm-Wave band (300-300GHz) to accomplish a higher data rate [1]. If such ventures are successful, the total band capacity becomes more than 11 times that of 5G networks [10,11]. Multiple inputs, multiple-output (MIMO) is also an alternative proxy to Thz communication in 6G. A second enabling technology is intelligence systems (incorporating Artificial intelligence, AI) -a factor transforming the radio signal landscape from cognitive to intelligence radio signals [12,15]. AI will also be crucial in data analytics, human to machine interfaces to increase communication efficiency and reduce the communication steps' processing delay.

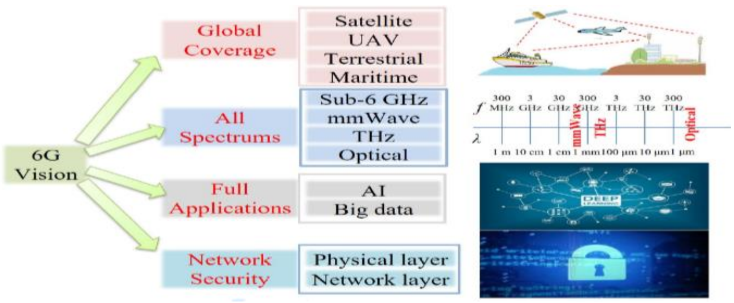

Figure 2: The 6G vision

Figure 2 shows the 6G vision. Optical wireless communication comes as for enabling and improve 6G connectivity through light fidelity (LiFi), visible light communication (VLC), visual camera communication, and optical (FSO) communication based on the optical band [12]. Equally, industrial verticals such as cloud VR, Internet of things (IoT) industry automation, cellular vehicle to everything (C-V2X), digital twin body area network, energy-efficient wireless network control, and federated learning systems act as push factors for the developments of 6G wireless communication networks. Application scenarios such as VR, video streaming, and communication also force the increased need for ultra-reliable low latency (uRLL) services, Enhanced Mobile Broadband(eMBB), massive Machine Type Communication(mMMTC), among others, further spurring the need for 6G communication. Figure 2 shows the expected shift in paradigms from 5G to 6G network framework. All described driving forces will force the need for a shift in network paradigms of 6G to increase global coverage, improve band spectrums by including all bands, enhance full application use and bolster internet security.

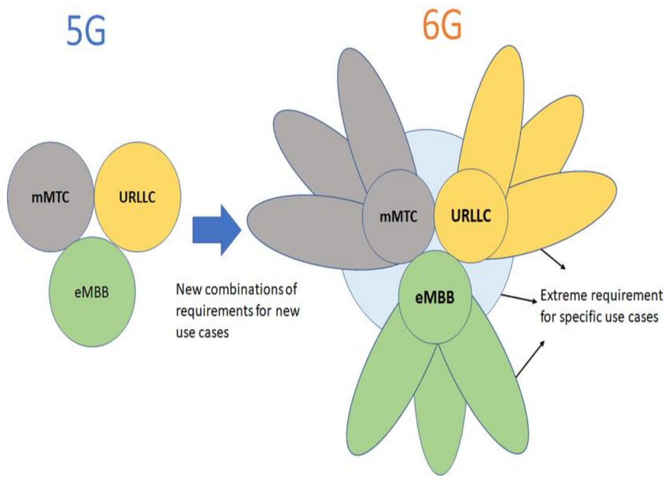

Figure 3: Paradigms shift from 5G to 6G

III. THE FUTURE OF WIRELESS COMMUNICATION IN FACE OF 6G NETWORK

6G comes with improved network speed, fidelity, and low latency, among others, improving system performance parameters [1]. A shift from only technology and productive oriented KPI, and sustainability and societal driven KPIs to combine above paradigms in addition to intelligent and secured paradigms 6G architecture will massively transform the wireless communication landscape. Figure 4 shows a typical example of how different paradigms will be deployed in 6G wireless communication systems.

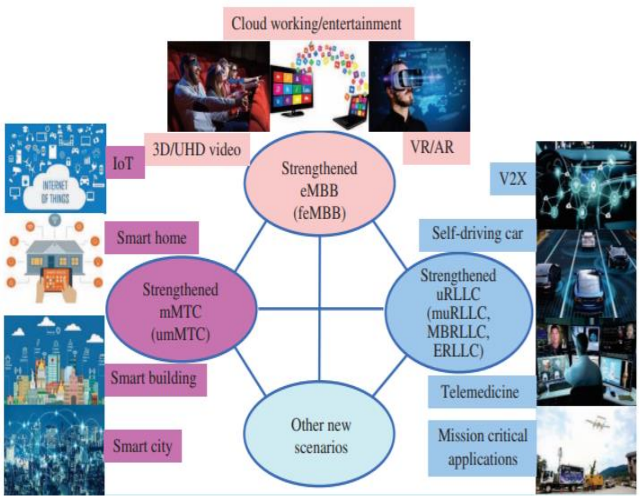

Figure 4: Typical Example Of How Different Paradigms Will Be Deployed In 6G Wireless Communication Systems.

A. Introduction of new Spectrum

The 6G cellular communication is poised to be improved by adding the THz band (275 GHz–3THz) to the mm-Wave band (30–300 GHz) [1,15]. Currently, the mm-Wave in 5G is not exploited since beam forming technologies are still in their fringing states [16]. One of the principals aims of 6G is to enhance improved beam forming algorithms that will use According to ITU-R [16,17,23], 6G seeks to merge Base stations (BS) and satellite communications into cellular communication, as opposed to the previous generation, whose spectrum is divided into several segments – television services, military communication, and cellular communication [20]. This calls for using unlicensed spectrum by using mm-Wave, Thz band, and visible light simultaneously, which bolster connectivity through higher speed and data distribution across the different band [23]-a factor that will make 6G networks connect 1000 times more wireless devices simultaneously than 5G. Gainsay, higher frequencies are associated with higher attenuation [17], which is solved by merging MIMO and beam forming to reduce attenuation rate to cover considerable distances [20]. The above two massively increase connectivity device density up to 10 million per square kilometer and increase wireless communication connectivity massively up to 10,000km in air and 20 nautical miles in the sea [20]. As such fully, functional 6G will improve long-distance communication, increase connectivity density

B. The shift from cognitive to Intelligent and more secured systems

The application of Machine learning techniques will massively increase system intelligence by reducing trade-offs, safe failure detection, and early failure awareness [19]. With growing intensity in the use of data for various decision-making, embedded intelligent algorithms in the wireless network will fully make the most accurate decision. A shift of paradigms from cognitive to more intelligent systems come with a lot of benefits. Firstly, it enhances the smart air interface enabling a more enhanced QoS through intelligence switching [19]. As proposed by ITU-R in the 5G-New radio specification, 6G networks should define multiple waveforms configuration and frequencies through variable numerologies, which leverages the transmitter's ability to self-organize and configure according to the channel condition and workload [22,23]. Such operation is critical in reducing symbol length, lowering latency, and increasing sub-carrier spaces – an essential factor in phase noise reduction in mm-Wave. Equally, optimized subcarrier width is vital in Doppler Shift compensation, especially in high mobility situations [19].

Secondly, the incorporation of ML/AI in 6G will go a long way in improving wireless telecommunication intelligence and improving decision-making processes. This means telecommunication devices such as satellites, smartphones, internet servers, etc., can detect systems flaws and issue an early warning, a paradigm shift toward less human-controlled wireless systems [18]. The incorporation of AI /ML in wireless 6G devices for various operations such as channel estimation, channel state information (CSI) feedback, decoding, etc., will instantly enable network resource management reducing broadband wastage to improve wireless network efficiency [16,23].

C. Air Interface -Proxy to Improved Access Technologies and Security

The 6G network mainly focuses on the terahertz frequency range and extensive bandwidth, resulting from merging several spectrums [24]. Albeit wide bandwidths bring more obstacles due to the interaction of different frequencies [17], secured air interfaces and low power devices provide better all through connectivity. Incredible broadband emphasized widely by 6G developers will provide comprehensive spectral optimized solutions that are likely to improve wireless communication systems air interface, bringing to a new era of internet slicing and wireless interconnection. To enhance air interfaces, the 6G design will be designed using non -orthogonal multiple access (NOMA) or rate splitting multiple access (RSMA) [22,23] that successive interface cancellation (SIC) to decode information to the user [23]. This scheme will result in higher spectral efficiency than other double sideband modulation schemes in the previous network. The 6G technologies come with beam forming technologies that deploy intelligent reflecting surfaces (IRS) [23], can reflect or configure the incoming wave using remote software [19,20]. Also, IRS can use many low-power and cost-effective passive elements to reflect radio frequency waves with configurable phase shifts at no extra power demand, encoding, decoding, or (de) modulation requirements [20]. This enhances the better signal to interface plus noise ratio (SINR) without any infrastructural changes in the communication system, a factor that increases devices' reusability for an almost infinite period.

D. Extremely high Reliable devices -Improved reliability

Compared to 5G's eMBB, the 6G eMBB is expected to contain a ubiquitous mobile ultra-broadband (UMUB) that offers uRLL [13]. The URLL, which is already being implemented in the 5G network, will equally be a springboard in 6G communication by providing ultrahigh speed-with-low-latency communications (uHSLLC) by adding a salient feature like End-to-end delay of less than one millisecond, more than 99.9999% reliability and 1Tbps peak data rate [1]. Equally, 6G will be more centered on volume spectral efficiency than area spectral efficiency used by the previous generation of networks.

E. The arrival of hybrid, heterogeneous and low-power devices

The 5G network has been essential in facilitating network splitting and allowing multi-structural tiers in the same network. This way, a device is only connected to a nearby device reducing information delay and physical device communication. This trend is expected to continue in 6G and leverage edge computing advantages. In wireless communication, 6G eliminates the lack of convergence experienced by 5G. This facilitates multi-tier architecture and convergence of heterogeneous networks as well as the existence of hybrid networks in IoT devices or cloud /edge computing services. The use of OWC advocated in 6G systems, comes with small optical cells such as VLC and LiFi [24], adds extra high capacity in multi-tier wireless heterogeneous networks, enabling offloading of the macro data network to smaller cellular networks. In the same scenario, network slicing ensures the device is forwarded to a nearby receiving device quickly based on the loads' characteristics [23]. As OWC and RF signal have no system interferences [24], and 6G will exploit features in creating a heterogenous network system that can be used simultaneously. This means that RF link can be used source to destination path while OWC for a destination to source and vice versa. Alternatively, RF or OWC can be used as a parallel system to enable data offload or backup for each other in a wireless system [25]. The ability to coexist and work independently is a game-changer in developing a robust yet reliable system and providing an opportunity for load balancing and link reliability in future wireless systems. More also, LiFi is stable and fast, more secured, and cost effective [14].

On the same note, 6G aims at reducing critical power constrain, especially in supporting massive internet of Everything (IoE). Its design is to develop a low-power vast area network (LPWAN) with broader coverage in more than 20 km [24-25]. Extensive WAN massively supports IoT and cloud services, yet with a long battery life of more than ten years at a meagre deployment cost [25]. Equally, it ought to lower power consumption by introducing battery-free IoT devices, a feature that can support uMUB, uHLSLLC, and uHDD [24] – the salient 6G features.

IV. CONCLUSIONS

The 6G generation is a real deal for cost and efficiency. By offering extremely high KPI(as shown in Figure 1), 6G will provide vast leverage for wireless communication to unlock emerging technologies like VR, ML, and analytics. Its development is much needed due to increasing data-intensive societies. It is pulled /pushed through by numerous enabling technologies such as OWC, The band, MIMO, AI/ML, and pervasive computing. Complete development and implementation of 6G will go a long way in supporting ubiquitous computing, improving systems efficiency, reliability, scalability, and reuse. It will transform the wireless communication landscape by introducing a new frequency band, developing hybrid systems, developing intelligent and reliable devices, and a new era of the secured wireless air interface and battery-free IoT devices.

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