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A Journey Towards Next Generation: 6G

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Abstract: With the rapid proliferation of wireless technologies and the emergence of artificial intelligence (AI) empowered wireless devices, the demands for high data rates, low latency, massive connectivity, and ubiquitous coverage are continually increasing. Since 5th Generation (5G) of cellular networks offer relatively lower data rates and latency than the requirements, therefore, world's giant companies and academia have started working beyond 5G and conceptualize their vision about the 6th Generation (6G). This paper envisions the need to move towards a new generation by carefully observing three primary aspects. Firstly, the technological gaps that the current 5G standards are facing are highlighted by specifying the pre-requisite for 6G. Secondly, exploiting the newly adopted AI-based potential services such ashologram, self-automated vehicles, 3D connectivity, etc. are discussed. Thirdly, investigating the new frequency spectrum resources for 6G, i.e., Terahertz (THz) and Visible Light Communication (VLC), that ensure high transmission rates across the networks. Furthermore, the key issues and challenges are also highlighted to explore the grand 6G vision.

Index Terms: 6G, potential services, adaptive architecture, new spectrum resources.

I. Introduction

Over the past decades, mobile communications have grown much rapidly and now become an indispensable part of everyone's life. The 5th generation of cellular networks (5G), outperforms all the preceding standards by enabling diverse networking and computational features integrated into a single intelligent system. The 5G technology covers a broad range of communication services such as cellular communications, Industrial-internet 4.0, self-driving vehicles, massive machine-type communications (mMTC), and the Internet of Things (IoT) [1]. These services not only revolutionize the way people communicate with each other, but also provides a new concept of communication between machines, sensors, and other devices. Among all the services, one of the most amazing service provided by 5G is IoT, which totally changes the lifestyle of every individual. IoT services can be beneficial for information sharing and connecting millions, even billions of devices together to communicate with each other through small sensors. These sensors can transmit the data of industries to gateway stations and also judge different traffic route conditions by communicating with Access Points (APs) [2]. Moreover, data mining and big data systems can manage huge amounts of data through 5G. Similarly, 5G provides a unified infrastructure containing networking, computing, and storage resources, which allows the optimization of all the distributed resources along with the convergence of fixed, mobile, and broadcast services. Besides, 5G supports multi-tenancy models, enabling operators and other players to collaborate in new ways. High data rates upto 20Gbps downlink and low latency in milliseconds are the major contributions of 5G [3], [4]. 5G technology uses millimeter waves (mmWaves), ranging from 10mm to 1mm to transmit massive amounts of data by utilizing higher frequencies. Another prominent change that 5G brings is exploiting massive multiple-input, multiple-output (mMIMO) links for achieving spatial antenna diversity. Through this technique, high data rates can be achieved by combining multiple antenna arrays and complex algorithms on both sides of mobile devices as well as on the network systems. The advanced beam-forming techniques are widely adopted to improve the signal strength in a particular direction. High data rates can be achieved by deploying ultra-dense networks resulting in increasing the number of cells. Carrier bandwidths can be increased from 20 MHz to 100 MHz and even more than this by enabling carrier-aggregation techniques. Another key technology, i.e., non-orthogonal multiple-access (NOMA) can be used to improve throughput, reduce latency and increase spectral efficiency by executing superposition coding (SC) at transmitters and successive interference cancellation (SIC) at receivers. Furthermore, polar codes are used to reduce noise. All the techniques mentioned above successively enhance the spectral efficiency upto three times more than 4G [5].
The 5G technologies continue enhancing the capacity of consumers as well as digitizing the vertical industries. This evolution will generate a large number of new applications with diverse communication demands such as high data rate, low latency, massive connectivity, and low energy consumption. Since all the predecessors of 5G, i.e., 1G, 2G, 3G, and 4G, provide less data rates as compared to 5G, that can deliver data rates upto 20Gbps with billions of high-capacity connected devices.

Therefore, moving towards 6G will be considered as a more holistic approach that will make devices more intelligent and improve their quality of services (QoSs) as well. Recently, research community has highlighted many technical issues that the upcoming wireless generations may face, and few of them are listed below in the form of requirements. Furthermore, essential key performance indicators (KPIs) and trends are also explored.

A. Bandwidth Requirements

5G covers many technologies like Vehicle-2-Vehicle (V2V) communications, Machine-2-Machine (M2M) communications, Vehicle-2-Infrastructure (V2I) communications, and many more. The communication among all these technologies becomes possible only through a large number of wireless devices and sensors. One recent survey states that only in New York, there will be about 2.7 million vehicles on the roads, millions of small sensors deployed in industrial internet 4.0, and a large number of interconnected mobile devices.

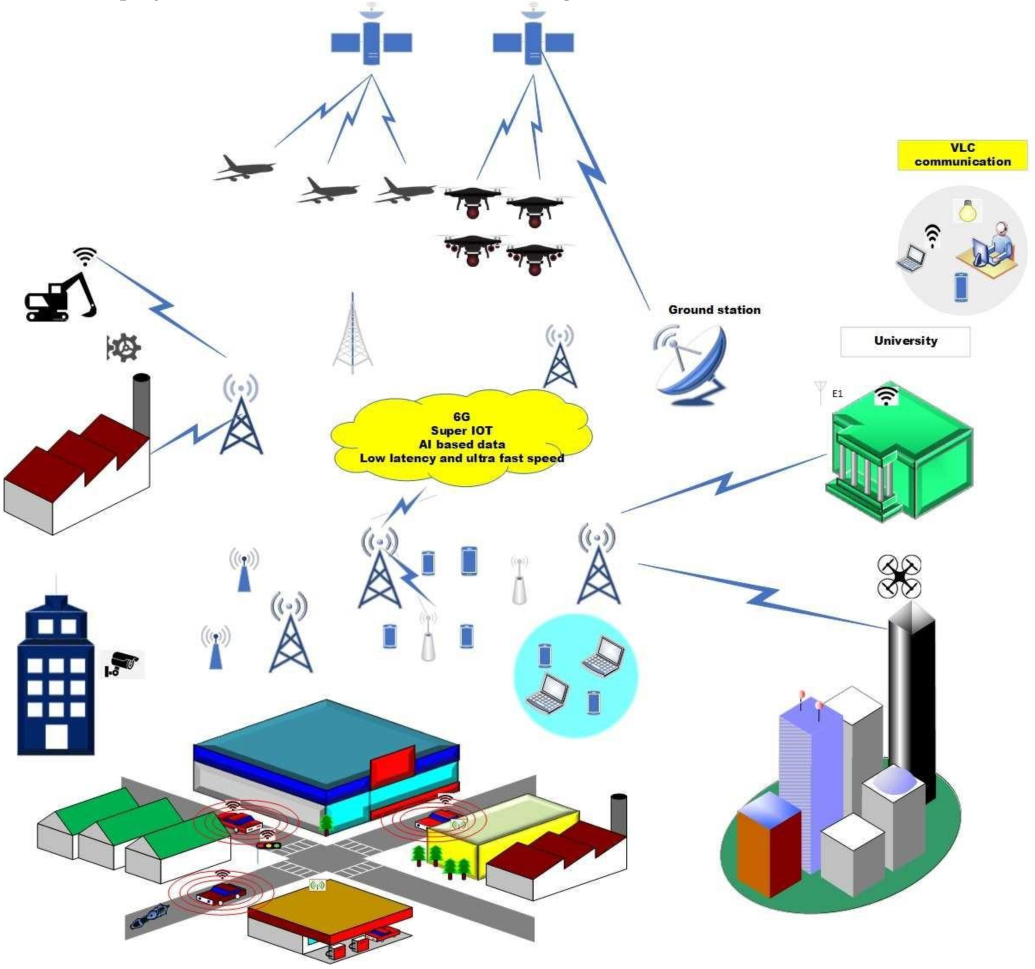

Fig. 1: 6G Network Architecture

Therefore, the frequency band reserved for 5G needed to serve billions of devices is not enough to entertain these diverse communication entities of the next generation. To satisfy these demands, huge bandwidth resources must be required. Thus, 6G emerges as an attractive solution due to its colossal frequency band (0.1THz to 1THz), which can serve up to trillions of devices as compared to 5G, where billions of devices are serviced. Recently, the Federal Communications Commission (FCC) granted a license for testing purposes that occupies frequency band ranges from 95 GHz to 3THz [6].

B. Data rate Requirements

Some future technologies like V-R (Virtual Reality), A-R (Augmented Reality), hologram technology, and 3D video/imaging techniques require very high data rates to easily view and identify things. An ultra-high-definition (UHD) video browsing (hologram technology for making a 3D video call) requires higher data rates up to 25Gbps as compared to 5G technology with a maximum of 20Gbps download speed. Recently, Verizon USA based company did 5G technology tests using a 28GHz frequency band, and they got a data rate of

1.4Gbps [7]. Therefore, 6G technology will be designed to use higher-frequency bands that can deliver data rates as 100 to 1000 times faster than 5G.

C. Connectivity Requirements

The dis-connectivity problem arises due to the usage of high-frequency radio signals, which limits the signal wavelengths and stops the signal penetration through the walls of the buildings. The upcoming 6G technology will work in a distributed manner, where every home has a dedicated router that acts as a base station; significantly enhances the performance in indoor environments.

D. Latency Requirements

The 5G technology supports ultra-reliable and low-latency communications (URLLC) with 1ms latency and less than 5ms end-to-end (ETE) system delay mostly for tactile internet, robotics, and massive IoT applications. The future industrial internet 4.0 aimed at inter connectivity, automation, machine learning, and real-time data; will require micro-seconds latency, which makes the movement of sensors and machines faster than the human movement [8].

E. KPI Enablers

The growing technology trends pose several challenges for the developers to build a system that can seamlessly integrate the previous techniques to accomplish the newly generated services. In this regard, 6G will define the new technological KPIs as tabulated in Table 1, along with its comparison with former generation [8]–[11].

KPI Enablers	5G	6G
Frequency Spectrum	1-6GHz, mmWave	THz band (0.1-3THz) VLC band (440-770THz)
Data rate Uplink	10Gbps	1Tbps
Data rate Downlink	20Gbps	1Tbps
Coverage area	2D everywhere	3D everywhere
Capacity	1000*capacity/Km2	NA
Modulation Schemes	OFDMA, NOMA	OTFS,FBMC,WAM
Latency (ETE Delay)	5 milli-seconds	¡ 1 milli-second
Jitter	NA	1s
Reliability	10-5	10-9

F. Trends towards 6G

By clearly stating the potential gaps and requirements while keeping in mind the set of objectives, some research trends are provided below that should be invoked to meet the grand 6G vision.

- Almost zero latency is expected to facilitate delay-sensitivedata applications, allowing efficient inter-device connectivity like in Industrial internet, where densely deployed small sensors and moving machines require latency in microseconds. • By experiencing a high transmission rate, the user will be able to watch UHD videos, play games that hardly will take time equal to switching on the television.
- 6G technologies will develop an eco-system by integratingsatellites, airborne, and terrestrial networks, which sufficiently enhances the user experiences by providing ubiquitous 3D super connectivity. Similarly, 3D imaging models, civil or mechanical projects, go very near to reality [12].
- The use of higher frequencies, i.e., THz, will make 6G technology more secure as compared to its precedent technologies. Ultra MIMO antennas will be designed to exercise spatial modulation techniques for spectrum efficiency.
- 6G will be considered more reliable as it will employmore sophisticated AI algorithms; that successively embeds intelligence to support real-time communications, handling handovers, network selection, and offloading decisions. This paper is categorized into four sections. The first section highlights 5G and provides reasoning to move towards 6G by considering certain requirements in the sense of bandwidth, data rate, connectivity, and latency. Second section deals with the adoption of AI-based potential services making sense of reality. The third section is all about promising spectrum resources for 6G, such as THz and VLC, with their ability to carry high data rates in minimum time to fulfill 6G requirements. The fourth section offers a critical analysis of challenges 6G may face in terms of path-loss, energy, and hardware. Finally, the conclusion is drawn and presented in section five.

II. Potential Services

This part aims to visualize the potential services 6G will provide in the areas of information and communication, medical, industrial internet, and global internet systems that will contribute to enhance users experiences.

A. Holographic Technologies

The expectations about 2030 confirm that the technology disruption will bring several innovations in different sectors, including communication, intelligence, computation, building, transportation, etc. [13]. A new form of communication will emerge that allows people to see and feel the movement of each other with the help of a 3D video. A sense of reality may be contacted through real-time capturing, transmission, and adaptation of the 3D holographic presence of a person in a conference meeting. These 3D graphical representations will become possible by combining a group of avatars and capturing the moments of data with the help of sensors and cameras. Recently, scientists have found unseen specks in the air that may be utilized to make 3D images that look real, unlike the signals we acquire by bouncing light on glass, water, or smoke [14]. Moreover, holographic technology will also decrease the time for 3D printing as well. In this sense, 3D printers will be designed that hardly take just one second to print a good quality chair as compared to current technology that would require about 6 hours making a chair [15]. Holographic technology will be helpful for medical diagnosis as it can work on more than two dimensions. Live 3D X-rays and live 3D cardiac ultrasound imaging will provide more accurate results in few seconds as compared to current 3D technologies that merge MRI, CT scan, and other techniques to generate 3D images after taking a lot of time [16]. Holographic technology can be beneficial as it can predict the position of aero-plans and Unmanned Aerial Vehicles (UAVs) to avoid incidents.

B. Automated self-driving vehicles

In 2030, there will be millions of autonomous and self-driving vehicles operating at different levels of coordination to make transportation and logistics services smart. These autonomous systems may include drone-delivery systems, drone swarms, vehicle platoons, robotics, cars, buses, and trucks to deliver different goods. The capability of 6G to utilize AI technology to create unlimited network connections and also to communicate with millions of other devices in less than a millisecond will immensely change the way how AI devices like self-driving cars operate [17]. These devices will become aware of changes on the roads, changes to cars around them, changes to traffic and everything else that will help them to safely navigate the roads filled with other cars, cyclists as well as pedestrians. In one discussion, Elon Musk, the pioneer of AI technologies, states that AI technology will make self-driving cars three times safer than nowadays cars. Autonomous and reliable driving applications demanding high precision of location, very low ETE latency (less than one millisecond), and high data rate links will significantly improve the communication efficiency between vehicles and road APs and also reduces the risk of accidents [18].

C. Intelligent Brain-Computer Interaction (IBCI)

Future wireless systems will facilitate the human brain to communicate directly with other devices like sensors and intelligent computing systems and give them orders. Initially, IBCI applications were only limited to healthcare situations, where humans can control prosthetic limbs or neighboring computing devices using brain implants. However, the recent advancements have totally changed the brain-computer interface (BCI) scenarios by introducing some use-cases ranging from enabling the brain-controlled movie input to fully-fledged multibrain-controlled cinema [19]. Instead of using smartphones, wireless BCI technologies will allow people to interact with their environment as well as with other humans using discrete devices: some worn, some implanted and some embedded into the world around them. This will allow individuals to control their environments through gestures and communicate with loved ones through haptic messages. Such empathic and haptic communications coupled with related ideas such as effective computing, in which emotion-driven devices can match their functions to their user's mood, will constitute important 6G use cases. Wireless BCI services will require fundamentally different performance metrics compared to what 5G delivers. Similar to Extended Reality (XR), wireless BCI services need high transmission rates, ultra-low latency, and high reliability. However, they are much more sensitive than XR to physical perceptions [20].

D. Smart City Concept

Several surveys predict that at the beginning of 2030, most of the world's population, around 60 percent will start to live in cities, and there would be more than 100 uprising megacities [21]. To efficiently meet individual demands and provide the best services in the areas of education, healthcare, transportation, and utilities, etc. is a huge task. 6G technology will contain edge cloud computing, internet of everything (IOE), and intelligent sensing services that will enhance the quality of life. In the areas of IoT and IOE, devices usually sensors have limited resources like power and storage, which reflects their smart nature [22]. The word Smart city may include smart home, smart grid, smart-water utilization, etc. In a smart home, everything will be inter-connected through intelligent small sensors; that can sense the human mind and works accordingly, such as internet router will work more than simply providing internet; it will monitor the person's body condition and send it to the healthcare center. A smart grid will be able to overcome the power losses and distribute electric power efficiently according to demands. Whereas, smart-water utilization will help to control rainwater, agricultural farming water, and wastage of water in many other cases as well. Moreover, these smart sensors will also contribute to overcome the pollution problem as well [23]. 6G devices will connect the physical world with the digital world, such as controlling the traffic signals, security cameras, monitoring carbon-di-oxide (CO2) rate in the environment, electric /gas metering systems that can help to save energy, and so on. This technology will also empower vertical agricultural farms to grow more quality foods and vegetables by continuously monitoring the smart and intelligent sensors.

E. Intelligent Industries

Unlike the automobile, manufacturing, and several other industries, the communication industry developed so fast. In the future, almost all these industries will be integrated with the communication industry. The notion behind industrial IoT is that every industry comprised of intelligent sensors and modules reserved for specific functionality; such as each product piece has the radio frequency identification system (RFID) chip that will tell the module about the already completed and the remaining processes [24]. Furthermore, these sensors will also keep track of spare parts shortage information and also informs the control system if there exists any such case. All these inter-connected sensors, products, and their related systems are known as cyber-physical systems. Nowadays, most of the industries process analog data such as the vibration of machines, light, location, voltage, sound, motion, current, wind, radio signals, etc. [25]. This amount of data will reach terabytes (TBs), which could be handled by 6G technologies only.

F. Adaptive Network Architecture

The emergence of 6G technology demands to support deterministic services, as it requires high precision for manufacturing industrial internet to guarantee very high physical limitations, like very low latency and energy consumption. This revolutionary move also expects an architecture that comes with the convergence of vertical services, i.e., communication, computation, localization, sensing, and control, to mash-up in a single network. The modern architecture will offer new data planes, controlling systems, and different operating modes that will support high data rates (one terabit per second), which will utilize innovative path routing protocols to form deterministic systems to provide high-precision and low latency for manufacturing. The expectations about 6G also confirms that the new structure will bring several autonomic services containing self-configuration, self-optimization, and self-sustaining (adapting to keep resource usage by exploiting spectrum and energy harvesting) capabilities to strongly support AI technologies [26]. Furthermore, since 5G technology contains a substantial amount of RAN resources deployments that enable dynamic features like network slicing and programmability by leveraging the mmWave frequencies. On the other hand, 6G will have even more dense networks, which will be operated on high frequencies, i.e., THz, with very small coverage areas having the massive number of antennas virtually placed everywhere [27]. The prediction about 6G and future networks will give a way to assume their structure like mesh networks due to complicated interaction among the devices, connected through a web of radio frequency signals acting as APs as well as the nodal connectivity and back haul for larger frequency aggregation-hubs, presently known as cell sites. Strictly speaking, it is expected that the current RAN, which primarily depends upon hubs and hotspots may be replaced with much more distributed radio access system in near future.

G. 3D Connectivity

The motivation towards 6G stimulates to cover up the shortcomings of the 5G, by ensuring ubiquitous connectivity becomes possible only with 3D super-connectivity. This 3Dcommunication will integrate all technologies, i.e., Terrestrial HetNets (macro, micro, and pico-BSs), Flying-BSs (at an altitude of several 100m), High altitude platforms (at an altitude of 20KM), Very Low Earth Orbit (VLEO) satellites (ranging upto 1000KM) and Geo-stationary Earth Orbit (GEO) satellites (placed at 35,786KM) from the surface to space [28]. The UAVs in 3D-communication replaces the terrestrial APs to temporarily facilitate the users by providing first aid services in emergency cases. Furthermore, satellites are considered the major drivers in the provision of 3D coverage. Recently, many private organizations have decided to launch their own small satellites for business purposes. In this regard, SpaceX, a famous space organization, announced a project named Star-link, which consists of sending 12000 micro-satellites into an orbit that will provide internet access even faster than fiber cable [29]. These satellites will provide internet services to airplanes, cars, ships in the sea, remote areas, online conference events, and gaming.

H. Semantic Communication

Shannons mathematical model, known as the mother of all models in communication theory, treats the communication process as a collection of six components, namely sender, encoder, channel, noise, decoder, and receiver. This model was designed to detect minor communication errors that would be corrected by re-transmission only. On the other hand, the deterministic network nature of 6G technology poses several challenges to deal with huge amounts of data. This is because medium THz and sub-THz waves are quite sensitive to environmental changes; the appearance of obstacles worstly impact sub-millimeter waves. Therefore, AI technology will be employed to extract actual information at the receiver end. By executing machine learning algorithms, the nodes will be able to self-learn and self-configure to enhance their protection capabilities by removing errors from the extracted data. Moreover, semantic techniques (setting up priority levels for different data) got much attention and employed extensively to improve communication efficiency. These techniques can be implemented by exploiting shared knowledge of both parties, i.e., sender and receiver, to enable semantic inference. Let's suppose there is a person from another city who wants to have a hologram video call; which requires a large amount of data to be transmitted and in case if some data is lost or corrupted, then through semantic help information, the exact data can be recovered quickly; which will facilitate the conference person to easily convey his/her message to other people [30].

I. Nano-scale Communication

Besides IoT in 2030, we will have internet of Nano-things (IONT) as well, allowing us to communicate with Nanodevices due to the availability of small wavelength frequencies in 6G. These Nano-devices will actively participate in many areas such as computing, data storing, sensing, biomedical, industrial manufacturing, monitoring systems and military fields such as advanced health monitoring (where Nano-sensors will collect data of the patients body condition and forward it to the health-care center for accurate monitoring) and drug delivery systems or wireless Nano-sensor networks for biological and chemical attack prevention [34]. Other health-care facilities, including tissue regeneration, medicine intake inside the body, surgical operations, and tumor detection processes, etc., will also be a part of IONT. The resource-constrained nature of these Nano-devices raises several challenges, including designing wireless communication protocols for them, establishing a secure connection among them, and transmitting data accurately [31]. One optimistic approach towards a solution is to use additional technology like wireless charging and also designing a new hierarchical network, where there must be one gateway station that will control all sensors.

III. New Spectrum Resource

To efficiently meet the desired performance measures in terms of data rate, latency, connectivity, spectral efficiency, and energy efficiency; 6G technology will utilize the unused THz and VLC bands along with sub-6GHz and mmWaves. Such high-frequency waves limit the signal wavelengths with a dominating line of sight (LOS) signal is received. A detailed analysis of both (THz and VLC) bands are mentioned in the following paragraphs.

A. THz

The future mobile communication systems will be designed to exploit THz frequency band ranges from 0.1 THz to 10 THz with wavelengths ranging from 30-3000 microns. In fact, this frequency band lies between mmWaves and infrared frequencies. Recently, European Telecommunications Standards Institute (ETSI), FCC, and other research organizations have started working beyond the 5G spectrum to provide high data rates in short distance ranges (5-20 meters) as well as medium distance ranges (50-200 meters). Due to limited wavelengths, these waves suffer from a lot of distortion from the atmosphere, sunlight, and water absorption and considered dangerous for health as well. These ionizing radiations carry enough energy lead to cause cancer diseases and may damage eyesight, whereas, THz waves have non-ionizing radiation energy ranging between 0.1-12.4 micro-electron Volt (meV) [32].

Furthermore, 6G technology will utilize advanced mMIMO that will provide very high data rates with less path loss attenuation effects by using highly directional antennas. Another important feature of the THz frequency band is that unlike infrared and visible light radiations, THz is transparent to many materials. Therefore, these frequencies can be used for industrial purposes such as product inspection as well as for security purposes. THz spectrum resources can also be utilized for cellular communications to replace fiber cable for back-hauling and front-hauling links to cover hundreds of meter distances. For achieving high data rates, high spectral modulation techniques should be designed. Whereas, at the start, even simpler modulation techniques incorporating lower frequencies would be enough as compared to high power-consuming electronic circuits and sophisticated algorithms. Recently, the hardware industry got much evolved when monolithic-microwave integrated circuits (MMICs) containing nanoscopic transistors aligned up to form chips were introduced. These tiny circuits occupy less space, low price, and proved to be faster than discrete electronic circuits. Heterojunction-Bipolar-Transistors (HBT) and High-ElectronMobility-Transistors (HEMT) are famous types of MMICs. Both of them have been made with different semiconducting materials having a different base and emitter logics with high doping density at the base region, enabling them to operate on high gain. Unlike traditional HBTs, this class of transistors has a very high cut-off frequency, better voltage handling ability, and decreased capacitive coupling. Galliumnitride (HEMT), also known as silicon of the future, will be a promising approach for wireless broadband connections due to its higher breakdown electric field and high saturation of carrier velocity as compared to gallium-arsenide (GaAs) and indium-phosphide (InP) enabled devices.

Although MMICs provide higher frequencies with high output powers in comparison with CMOS technology, still complementary metal-oxide semiconductor (CMOS) considered a preferable tool for THz communications due to its lower costs and high integration densities. It has been observed that THz amplification and oscillation steps limit the solid-state electronic devices (SSEDs) to operate on higher frequencies. In this regard, resonant tunnel diode (RTD) technology has been utilized, in which electrons pass through some resonantstates at specific energy levels. Due to the compact sizes and integration with Meta-material antennas, RTDs oscillators have successfully achieved 1THz, 1.42THz, 1.55THz, and 1.92THz frequencies, making them a suitable choice for upcoming 6G technologies [33].

B. VLC

Most of the mobile traffic is generated by indoor wireless communication services such as offices, homes, online browsing games, and other services. This ratio will go to increase in future when 5G technology integrates with many new technologies like smart homes, UHD video calls, and industrial internet, etc.. The current Wi-Fi standard 802.11n achieves only 150 Mbps, which is far lower than one of the 6Gs application, i.e., hologram technology, where 3D video call requires a data rate of more than 20Gbps [34]. This limitation attracts researchers to utilize VLC for several applications, including indoor communications, traffic signals, vehicle headlights/tail lights, and also commercial displays. VLC spectrum occupies frequencies ranging from 440-770THz with 380nm-750nm wavelength, which is about 10000 times wider than the whole radio frequency spectrum providing data rates upto 100Gbps [35]. Due to minimum latency and less vulnerability against interference, along with security and privacy features achieved due to short-distance transmission, makes VLC technology a highly reliable option.

Many industries, including Philips, Disney, and NASA, have made several products using VLC technology. Similarly, several companies have also started making hardware such as light-emitting diodes (LEDs) made up of different materials being capable of generating electric signals [36]. Red LEDs are made up of 45THz-475THz frequencies. White LEDs can be designed by two methods: In the first method, the LED bulb is usually coated with a layer of phosphor, when light passes through it, the combination of yellow and blue photons produces white light. The second method is the combination of red, green, and blue (RGB) lights to produce white light. These LED sources proved to be energy efficient and cheap as compared to Wi-Fi routers. Recently, researchers are focusing on how LED sources can be utilized as reception points by using photocurrent phenomena. Generally, it is assumed that LED devices have the capability to detect the same light [43].

IV. Challenges For 6g

The motivation behind the newly adopted 5G technology draws several key-features about its limitations. This unprecedented growth in the mobile communications era leads to think about the next-generation, i.e., 6G, which will improve everyone's lifestyle by bringing numerous key innovations including ubiquitous connectivity, integrating intelligence, smarter infrastructures, etc., into the existing architecture. Although a number of research articles have been published focusing on 6G, its vision, use cases, and requirements, but actual deployment issues still remain untouched in many cases. The primary challenges needed to be addressed about 6G systems are highlighted below:

- 6G will be able to provide cloud technology services at the user's end with very low latency and high energy efficiency. This requires advanced artificial intelligence and machine learning algorithms running at the user's end.
- 6G supposed to be deterministic in nature; therefore, newencryption techniques like blockchain are required to ensure secure transmissions of data.

- At higher frequencies, there will be more attenuation andabsorption that would lead to high path losses; therefore, advanced antenna types like ultra mMIMO equipped with advanced beamforming techniques to radiate highly directional beams at target positions are required.
- Furthermore, 6G will also utilize ultra mMIMO antennas foruser sides as well; therefore, the demand for new and compact electronic circuitry that can operate with massive amounts of antennas is also increasing.
- The multi-user and complex network structure of coming6G technologies put a constraint on current channel coding techniques, which assumed to be point-to-point Gauss channels. So, advanced channel coding schemes should be designed to achieve accurate information in interference dominated environments.
- The distributed nature of 6G will make the coverage areaseven smaller than 5G, so we need a substantial number of APs to be deployed everywhere to serve trillions of devices simultaneously.
- Nano-sensors communications require new routing protocolswith minimal energy consumption; therefore, additional power supplies should be designed for them. Electronic circuitry working on higher frequencies would consume more energy; therefore, new electronic devices should be introduced that can utilize less power while functioning at higher frequencies.

V. Conclusion

In this paper, we presented an overview discussing the potential key services and their KPIs that the upcoming 6G systems will provide. A grand 6G vision has been explored, which will adopt advanced encryption techniques, advanced antenna designs, advanced channel coding techniques, advanced AI algorithms and above all, utilizing advanced spectrum resources to integrate coverage availability, network reliability, energy efficiency, and component intelligency to build fully automated advanced network architecture.

6G technology will be coming to provide a high transmission rate (terabits per second), massive connectivity (an average of 1000 devices per person), and ubiquitous coverage achieved with 3D super-connectivity, through which a fully automated global society will be made.

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