EMERGING TRENDS AND INNOVATIVE APPROACHES IN 6G NETWORK

INTRODUCTION

Almost every ten years, a new communication system has been introduced, improving the QoS, providing new features and introducing new technologies. With the emergence of 5G network technology, data transfer rate has been increased 10 times than the rate with 4G networks. Many telecom companies and enterprises such as Nokia Bell Labs and Samsung are working to develop and implement 6G by around 2030. The advent of 5G networks has paved the way for many modern applications [3]. However, 5G still cannot fulfill the needs of future technological developments that require even faster networks, real time uninterrupted communication and data transfer rates. This can be understood with the help of self-driving cars [1]. In the coming future, it is inevitable that persondriven cars will be replaced by self-driven cars. The communication between cars on road will be essential to avoid collisions. But if the communication gets interrupted even for a second on a highspeed congested route, it can result in accidents. This can be prevented using 6G which is fast, low latency and satellite integrated network. Furthermore, the incursion of augmented reality (AR) in a person's day to day life would require real time connection to the world. 6G is roughly 100 times faster (1Tbps) than predecessing 5G network (100Gbps). End to end latency in 6G (1ms) is 10 times shorter than 5G (10ms). Moreover, the connectivity 6G mobile networks can be leveraged underwater and in the space. The advent of 6G communication technology will be helpful in healthcare as to establish electronic healthcare and remote surgeries [2]. Table I compares the main specifications and technologies in both 5G and 6G. 6G will be able to connect everything, integrate different technologies and applications, support holographic, haptic, space and underwater communications and it will also support the Internet of everything, Internet of Nano-Things and Internet of Bodies.

TABLE I
COMPARISON BETWEEN 5G AND 6G

Characteristic	5G	6G
Operating frequency	3 - 300 GHz	upto 1 THz
Uplink data rate	10 Gbps	1 Tbps
Downlink data rate	20 Gbps	1 Tbps
Spectral efficiency	10 bps/Hz/m^2	1000 bps/Hz/m^2
Reliability	10^{-5}	10^{-9}
Maximum mobility	500 km/h	1000 km/hr
U-plane latency	0.5 msec	0.1 msec
C-plane latency	10 msec	1 msec
Processing delay	100 ns	10 ns
Traffic capacity	10 Mbps/m^2	1 - 10 Gbps/m^2
Localization precision	10 cm on 2D	1 cm on 3D
Uniform user experience	50 Mbps 2D	10 Gbps 3D
Time buffer	not real-time	real-time
Center of gravity	user	service
Satellite integration	No	Fully
AI integration	Partially	Fully
XR integration	Partially	Fully
Haptic communication integration	Partially	Fully
Automation integration	Partially	Fully

The classical service classes of massive machine type communications (mMTC), ultra-reliable low latency communications (URLLC), and enhanced mobile broadband (eMBB) will be reshaped in next-generation 6G mobile networks to handle more demanding applications (like holographic telepresence and

immersive communication) and satisfy much stricter application requirements arising from the edgecloud continuum. These new applications will push the bounds of innovation and bring about revolutionary change throughout the architecture of future mobile networks, raising the bar for performance, ubiquity, trustworthiness, security, openness, and sustainability.
. In this paper, some emerging technologies and applications introduced and developed by the 6G communication technology are presented in section II and the main challenges facing the achievement of the 6G goals are addressed in section III.

EMERGING TECHNOLOGIES AND APPLICATION

New functions and applications are made possible by every communication system. The introduction of AI, automation, and smart cities was pioneered by 5G. But these technologies were only partly incorporated. More technologies and applications that offer faster data speeds, high dependability, low latency, and secure, efficient transmission are being introduced by 6G.
Fig. 1 depicts the importance of 6G communication.6G offered new uses, trends, and technologies. Some of these 6G technologies and applications are explored in this section.

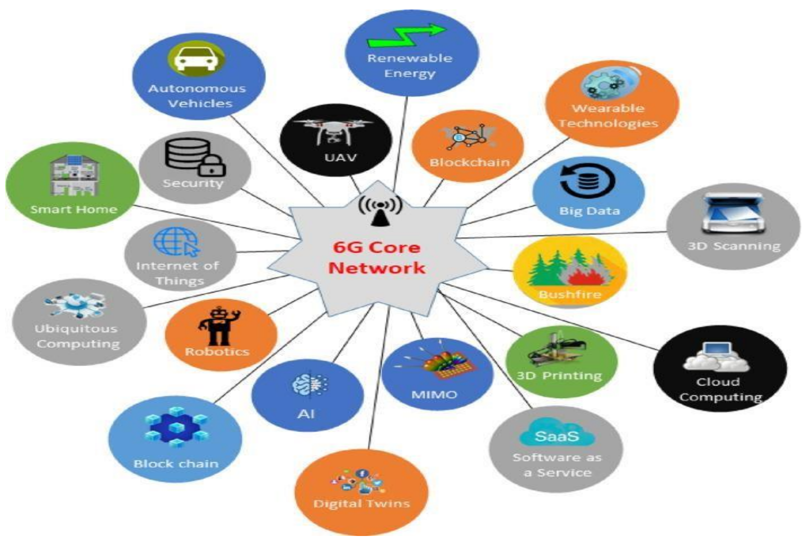

FIG.1 6G USES,TRENDS AND TECHNOLOGIES

A.TERA HERTZ COMMUNICATION

The RF spectrum is nearly filled and cannot accommodate the steadily rising demand for wireless technology. The THz spectrum, which spans 0.1 to 10 THz, will be essential to 6G's ability to deliver ultrahigh data rates, increased capacity, bandwidth, and secure transmission. The Internet of Nano-things will be facilitated by the THz band, which will enable the development of tiny cells with nanometer to micrometre dimensions. These cells will provide extremely fast communications up to a distance of 10 metres. Since Tbps communications cannot be supported by technologies utilising frequency bands smaller than 0.1 THz, 6G will be the first wireless communication system to support Tbps for high-speed communication.

B.ARTIFICIAL INTELLIGENCE

Neither 4G nor any of the earlier versions included artificial intelligence (AI). It is partly backed by 5G, which is revolutionising the telecoms industry and creating doors for new and exciting applications such.

Nonetheless, 6G will completely support AI for automation. It will be engaged in resource allocation, network selection, and handover, all of which will improve performance, particularly in applications where delays are an issue. The key technologies of 6G are machine learning and artificial intelligence.

C.EXTENDED REALITY

A new word that encompasses Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) is Extended Reality (XR). Virtual reality (VR) is a computer-simulated reality experience that uses a headset to produce sounds and visuals to create an artificial environment. AR makes use of the physical world and enhances it using a particular gadget, like a smartphone. The Global Positioning System (GPS), movies, and audios can all be utilised to create an engaging atmosphere. One well-known example of AR is Pokemon. With mixed reality (MR), the real and virtual worlds combine to create a complex experience. The entire combined real and virtual environment is called XR. Because of its robust connectivity, fast data rate, high resolution, and low latency, 6G will be highly helpful for this function.

D.WIRELESS- BRAIN COMPUTER INTERFACE

The use of wearable technology has grown recently, and some of these applications involve braincomputer interfaces (BCIs). Smart body implants, smart embedded devices, and smart wearable headsets are examples of BCI applications. Brain-computer interface (BCI) technologies provide brain-toexternal discrete device communication, with the devices handling the analysis and translation of brain signals. Affective computing technologies, which allow devices to change in operation based on the user's mood, will also be incorporated into BCI. Because BCI applications need greater spectrum resources, large bit rates, very low latency, and high dependability, their use has been restricted. More applications, such as the five sense information transfer—which transfers data produced by a person's five senses to enable interaction with the environment—will be supported by 6G, nevertheless.

E.HOLOGRAPHIC BEAFORMING

Beamforming is the process of focusing power in a limited angular range to create a focused, narrow beam with a high gain for transmitting and receiving utilising antenna arrays. It provides increased signal to interference and noise ratio (SINR), improved throughput, and the ability to track users. A sophisticated beamforming method that makes use of Software-Defined Antenna (SDA) is holographic beamforming. Holographic refers to the use of an optical hologram in conjunction with an antenna to achieve beam steering; the antenna functions as an optical hologram's holographic plate. Since C-SWaP (Cost, Size, Weight, and Power) is regarded as the primary obstacle in the design of any communication system, the use of SDAs in HBF will enable adaptable and effective sending and receiving in 6G.

F. BLOCKCHAIN TECHNOLOGY

Blockchain technology represents data as dispersed, cryptographically secured chunks that are connected to one another. As in Fig 2,Blockchain will be utilised to manage massive connectivity in 6G as well as to organise and manage enormous data. It will also be utilised in spectrum sharing, which enables users to share the same spectrum, resolving the issue of 6G's enormous spectrum requirements and ensuring safe, affordable, intelligent, and effective spectrum utilisation. Enhancing the quality of service (QoS) through deep reinforcement learning and blockchain integration with artificial intelligence would enable smart resource sharing, enable the use of an improved caching scheme, and increase network flexibility.

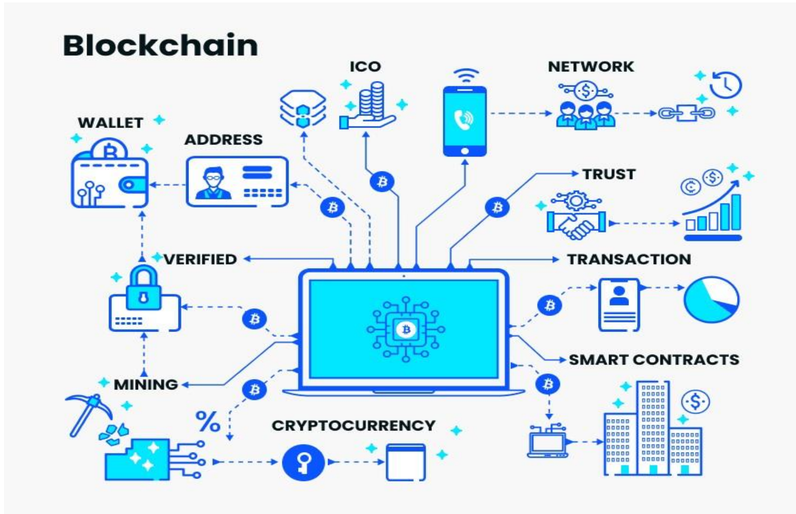

FIG.2 BLOCKCHAIN AND ITS FEATURES ENHANCING USNG 6G

G.CELL-FREE COMMUNICATION

It has been suggested that Unmanned Aerial Vehicles (UAV) be employed in areas lacking infrastructure in future generations. However, 6G will make full advantage of this technology to provide cell-free communication. The user's call should be routed to the other cell when the user equipment (UE) switches from one cell's coverage to another. The user's call may be disconnected and the system's quality of service may be compromised if this handover is unsuccessful .As in Fig.3, Cell coverage issues will be resolved by 6G since UEs would be connected to the entire network rather than just a single cell. By using UAVs, it will be possible to integrate various technologies and enable the UE to choose the one with the best coverage without requiring human device setups.

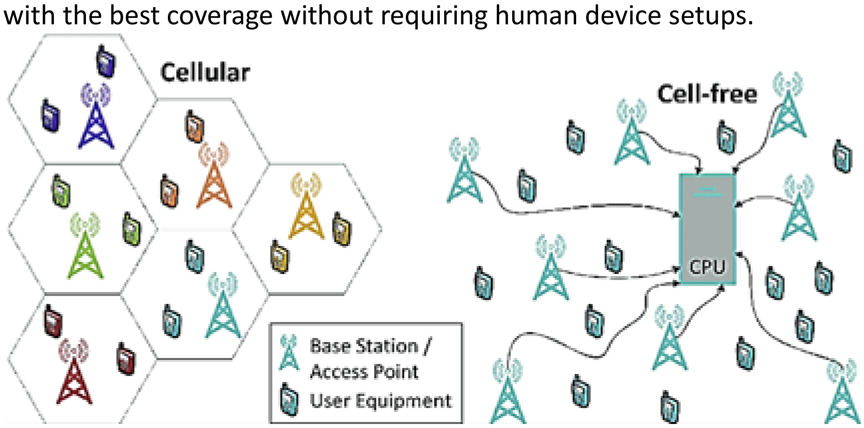

FIG.3

H. AUTOMATION

At the moment, robotics, automation, and autonomous systems are the main areas of study. These technologies—such as robot-to-robot and robot-to-server communication—will be supported by 6G, enabling direct communication between them and the server as well as between them. 6G will offer complete automation, which includes automated systems, devices, and control procedures. Unmanned aerial vehicles (UAVs), which will be utilised in wireless communications to provide high data rates in place of traditional base stations (BS), will be supported by 6G.

I.HEALTHCARE

The poor data rate and time delay in other wireless communication technologies led to the absence of electronic healthcare. With the use of XR, robotics, automation, and artificial intelligence, 6G will enable secure connection, high performance, ultra-low latency, high data rate, and high reliability, allowing for the full implementation of remote surgeries, as shown in Fig. 4. Additionally, the THz band's tiny wavelength facilitates communication and the development of nanosensors, opening the door to the creation of novel nanoscale technologies that can function inside the human body.

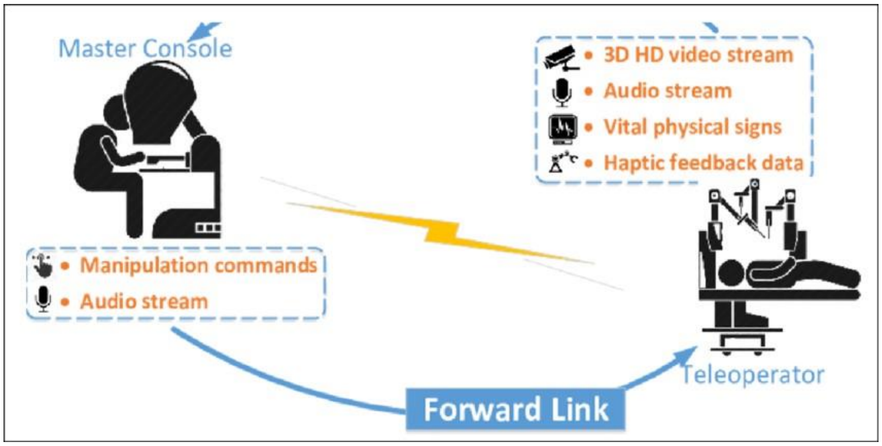

FIG.4 A loop explaining the communication between the master console and the tele-operator

SENSORY DATA IN 6G

The advancement of science and technology in recent years, along with the widespread adoption of the Internet of Things (IoT) and the emergence of 5G and 6G networks, has resulted in the progress of various computer technologies. This has facilitated improved connectivity among the billions of mobile smart sensor devices, such as smartphones, pads, and smart bracelets, which are omnipresent and possess enhanced processing and storage capabilities. Consequently, the concept of participant sensing has emerged, allowing individuals to utilize these devices and their integrated sensors, such as the gyroscope, accelerometer, and microphone, to gather and share sensing data. Through this, individuals can actively contribute to the monitoring of data in cities.

The potential of the 5G network lies in its ability to remotely transmit sensor data from different mobile devices equipped with diverse wireless interfaces [11]. Looking ahead, the 6G network is poised to create a globally interconnected society. By seamlessly merging terrestrial wireless and satellite communications, the integration of 5G and 6G networks will provide users with enhanced connectivity. Data reporting can be done more conveniently by selecting either cellular networks or Wi-Fi networks [83]. The heterogeneity of the options allows for flexibility in choosing the most suitable network. In a network, users typically encounter varying transmission expenses and levels of network accessibility. To be more precise, the cost associated with widespread availability The importance of the Tous cellular network cannot be underestimated, particularly for MCS applications that involve the transfer of substantial data such as photos or videos. While there may be a cost associated with transmission, it is a factor that cannot be ignored. While the coverage of a Wi-Fi network tends to be limited, resulting in lower availability, the user's mobile mode plays a crucial role in determining its accessibility [22]. Hence, the implementation of 5G and 6G technologies can offer valuable assistance in gathering sensory data.

5G APPLICATIONS IN 6G

The upcoming 6G mobile networks will redefine the existing 5G application types, such as massive Machine Type Communications (mMTC), Ultra-Reliable Low Latency Communications (URLLC), and enhanced Mobile Broadband (eMBB). This redefinition is necessary to accommodate more demanding applications like holographic telepresence and immersive communication, while also meeting stricter application requirements along the edge-cloud continuum. The introduction of these new applications will raise expectations for performance, reliability, ubiquity, trustworthiness, security, openness, and sustainability. As a result, the boundaries of innovation will be pushed, leading to transformative changes in the architecture of future mobile networks.

In order to meet these new expectations, we will need a completely new ecosystem co-design combining communication, control and computing functions, something that has been largely neglected to date. We will need seamless approaches to transform wireless systems into an autonomous, intelligent network fabric that can flexibly provision and orchestrate communications-computing, control-localisation and sensing resources that are tailored to the required scenario. This means that the mobile communications fabric of the future will have to be differently designed to meet the new, demanding applications that can't be served by today's 5G mobile network. The network evolution can happen in many different ways.

CHALLENGES IN 6G

6G is still in its early stages of innovation and standardisation, but there are a number of challenges researchers and engineers will likely encounter as they work to bring this technology to life. Here are some of them:

DEVICE CAPABILITIES :

New generations of wireless communication technologies, such as 6G, introduce a wide range of advanced features and capabilities, including higher data rates, lower latency, increased reliability, and support for massive connectivity. Implementing these features requires the integration of complex algorithms, protocols, and hardware components. 6G is expected to leverage advanced multiplexing techniques such as massive MIMO (Multiple Input Multiple Output), beamforming, and spatial division multiplexing to increase spectral efficiency and capacity. Managing the spatial, frequency, and time-domain aspects of these techniques adds to the complexity of 6G networks. Terahertz frequencies are being explored for 6G communication due to their potential for ultra-high data rates. However, terahertz communication presents several technical challenges, including propagation losses, atmospheric absorption, and material interactions. Overcoming these challenges requires novel antenna designs, signal processing algorithms, and modulation schemes. 6G is expected to feature intelligent and autonomous network management capabilities enabled by artificial intelligence (AI) and machine learning (ML) technologies. These intelligent networks will dynamically adapt to changing conditions, optimize resource allocation, and provide personalized services. Designing and implementing AI-driven network architectures introduces complexity in terms of algorithm development, training, and optimization.

SECURITY AND PRIVACY

6G networks will support a wide range of applications and services, including IoT, augmented reality (AR), virtual reality (VR), and critical infrastructure. These applications generate and handle vast amounts of sensitive data, making security and privacy essential to protect against unauthorized access, data breaches, and misuse. 6G networks will enable ubiquitous connectivity, allowing billions of devices and sensors to communicate seamlessly. This increased connectivity amplifies the potential risks of security vulnerabilities, cyber-attacks, and privacy violations, necessitating robust security measures and privacy safeguards. As 6G introduces new technologies such as terahertz communication, intelligent networks, and AI-driven services, it also introduces new security and privacy challenges. Adversaries may exploit vulnerabilities in these technologies to launch sophisticated cyber-attacks, espionage, or privacy breaches, highlighting the need for continuous monitoring, threat detection, and mitigation measures.

To address security and privacy concerns in 6G networks, researchers, engineers, policymakers, and industry stakeholders must collaborate to develop and implement comprehensive security frameworks, privacy-enhancing technologies, encryption protocols, access control mechanisms, and regulatory policies. By prioritizing security and privacy in the design, deployment, and operation of 6G networks, stakeholders can build trust, safeguard user rights, and ensure the integrity, confidentiality, and availability of data and services in the digital age.

ENERGY EFFICIENCY

With the proliferation of connected devices, higher data rates, and new applications such as augmented reality (AR), virtual reality (VR), and holographic communication, 6G networks are expected to experience a significant increase in data traffic. Managing this surge in data while maintaining energy efficiency poses a challenge, as higher data rates often correlate with increased power consumption. Massive MIMO (Multiple Input Multiple Output) and beamforming technologies are integral to achieving high spectral efficiency and data rates in 6G networks. However, these technologies require a large number of antennas and sophisticated signal processing algorithms, which can increase power consumption and hardware complexity. Addressing these energy efficiency challenges in 6G technology requires interdisciplinary research, innovation, and collaboration among telecommunications engineers, network architects, hardware designers, software developers, policymakers, and environmental scientists. By developing energy-efficient solutions and adopting sustainable practices, stakeholders can mitigate the environmental impact of 6G technology while delivering high-performance communication services to meet the demands of future generations.

SPECTRUM AVAILABILITY

As demand for wireless communication services continues to grow, there is a scarcity of available spectrum suitable for 6G networks. The spectrum allocated for previous generations of wireless technologies, such as 4G and 5G, is becoming increasingly congested, leaving limited frequency bands available for 6G. The allocation of spectrum is subject to regulatory policies and international agreements, with different stakeholders, including telecommunications companies, government agencies, satellite operators, and industry organizations, vying for access to available spectrum bands. The competition for spectrum can lead to delays and challenges in securing sufficient spectrum resources for 6G deployment. 6G technology may utilize higher frequency bands, including millimeter-wave (mmWave) and terahertz (THz) frequencies, to achieve ultra-high data rates and spectral efficiency. However, these frequency bands have unique propagation characteristics, such as higher path loss and susceptibility to atmospheric absorption, which may limit their practical deployment and coverage. Spectrum allocation is governed by regulatory frameworks and policies established by national and international regulatory authorities. Regulatory constraints, such as licensing requirements, interference mitigation measures, and spectrum sharing arrangements, can impact the availability and accessibility of spectrum for 6G deployment, particularly in densely populated areas or regions with competing interests.

Overall, addressing these challenges will require innovation and strategic planning to realize the full potential of 6G technology while ensuring its responsible and sustainable deployment.

CONCLUSION

As long as technological advancements are being progressing, the need for innovative and practical approaches to further improve the network system would arise. The upcoming 6G technology is bound to make future technological advancements possible. The new era of 6G network will pave the way for certain new technologies such as quantum cryptography, brain chips and automated systems to be included in day to day life of humankind.

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