The Advancements in 6G Technology based on its Applications, Research Challenges and Problems: A Review

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ABSTRACT

Continuous placement of cellular networks keeps on revealing because of the inbuilt limitations of the network. To overcome these flaws, there is the next generation 6G concept which could properly assimilate important rate-hungry applications such as stretched reality, wireless brain-computer connections, independent automobiles, and others. 6G will also help in handling huge data transmission in rural areas. Many state-of-the-art trends and technologies are combined in it with the aim of providing higher data rates for ultra-reliable and low-dormancy communications. This article deals with the conceptualization of 6G cellular addressing system requirements, potential trends, technologies, services, applications, and research progress. This research includes a summary of open research issues and current research groups to benefit readers with the technology roadmap and for consideration of challenges in their research regarding 6G research. The fourth industrial revolution in the textile sector can greatly benefit from 5G and 6G technologies in automated processes of textiles such as in spinning, weaving, and especially in garments manufacturing to meet competitive advantages, excellent communication, and for better and more flexible production. 3D modeling, simulation of virtual clothes on avatars, automation of robotics, and data communication can be improved by the concept of 5G and 6G technologies.

KEYWORDS

6G Technology, Mobile Networks, Communication Systems, Industrial 4.0, Automation

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1 INTRODUCTION

The need for higher rates is the primary driver for the wireless network evolution. It is expected to mandate a continuous 1000x increase of the network capacity based on the continuous demand. The reason behind this tremendous need for higher rates is the emergence of the Internet of Things (IoT) in almost all industries to form industry 4.0. There is no doubt that 5G has been evolutionary in supporting rate-hungry eMBB services, working on high-frequency millimeter-wave (mmWave), and enabling heterogeneous IoT services [1].

These challenges can be overcome by 6G cellular network which could inherently modify requirements to perform in each IoT application/scenario in which the concept of adequate technological trend will be utilized for improvement of thing-to-thing communication [2]. Everything worldwide will be connected by the 6G concept using extreme communication techniques [3]. Moreover, artificial intelligence (AI) algorithms (eg, network monitoring, business decisions driven by data, preventive maintenance, detection of fraud, etc.) and security systems (eg, blockchain for data validation) are also paramount to be realized in the 6G [4, 5]. Many research centers are currently working on 6G and their trends and applications such as South Korea, Finland, China, and the United States (see Table 1).

This article is organized as follows; Section 2 summarizes the previous and current cellular networks with the need for the 6G. Section 3 answers the challenges mentioned through the vision and key features of the network. Section 4 reviews and proposes the applications and services that are expected to be deployed by 6G cellular networks. Section 5 reviews the on-going research activities and unanswered problems. Finally, Section 6 concludes the work.

2 THE FUTURE OF NETWORKS

Several countries have already deployed 5G wireless networks. Since 1980, there have been ten-year intervals between the introduction of new generations of wireless cellular communication, with each generation appearing in 1981, 1992, 2001, 2011, and 2020. Multimedia, online gaming, video streaming, and other data-hungry applications have flourished over the past decade, thanks in large part to the rapid development seen in the telecommunications sector. Mobile internet technology is becoming more popular, which is opening the door to new services like mobile shopping and payments, smart homes, cities, and industries, gaming in mobiles, and other user specified services and IoT.

5G has finished standardization and will be deployed globally within the next few years. The 5G commercial/trial/research developments coverage map is assessed (see Figure 1). In South Korea, a distributed system using a 3.5 GHz (sub-6) spectrum supports data rates of 193 to 430 Mbit/s in only six of these 85 cities, including Seoul, Busan, and Daegu [13]. By the year 2025, it is predicted that 65 percent of the global population will have access to 5G networks [14]. Several different types of new services for 5G cellular networks, including enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (uRLLC), and massive machine-type communications, have been proposed (mMTC). For a more in-depth look at 5G's goals, infrastructure, and specifications, check out the aforementioned works. [15-17]. The trend toward "smartening" everyday objects in homes, municipalities, and utilities is expected to result in a dramatic increase in the number of wirelessly connected devices and the volume of wireless data. Data-intensive app creation (such as virtual reality gaming) has been aided by 5G technology.

The mm Wave spectrum is ideal for some uses, but it is not yet wide enough for others (like sending holographic videos) [18]. Recent advances in artificial intelligence (AI) and edge computing algorithms have led to a proliferation of diverse mobile applications, which in turn have sparked important discussions about the direction wireless communications will take in the future 4 (see Figure 2) [9]. First, the most important ML applications in the physical layer include non-linear and non-stationary channel estimation, adaptive and real-time massive MIMO beamforming, mobile positioning for non-line-of-sight (NLoS) multi-paths, and prediction of the channel coding for larger numbers of bits [19]-[21].

Many works have introduced a virtualization network based on the cloud-radio access networks (C-RAN) architecture, called a virtualized-radio access network (V-RAN) or Fog-RAN (F-RAN) [22]. The C-RAN combines the advantages of a centralized data center with those of a collaborative radio network and a real-time cloud RAN. It enables many RRHs to link up with the shared BBU pool, and it enables any BBU to communicate with any other BBU at very high bandwidth (>10Gbit/s) and low latency (10 m) [23]. The V-RAN makes it possible for edge devices to perform intensive computation [24-26].

Finally, in order to achieve massive access in 6G, many multi-access techniques have been introduced. These include delta-orthogonal multiple access (D-OMA), sparse code multiple access (SCMA), and filter bank multi-carrier (FBMC). SCMA uses SISO to maximize the total sum rate in C-RAN while taking into account user QoS, user association, and power constraints all within a low complexity algorithm [27, 28]. The D-OMA approach, on the other hand, uses partially overlapping sub-bands for NOMA clusters and the concept of distributed large coordinated multi-point (CoMP) to enable NOMA transmission [29-31].

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3 SYSTEM REQUIREMENTS, VISION, AND KEY FEATURES

The 6G design is proposed for the up and coming age of cell organizations (see Figure 3). These security and protection issues include access control, noxious way of behaving, encryption of information, and information correspondence, and the subtleties of these issues and alleviation strategies are examined (see Table 3). In any case, these issues are extremely vital to keep up with the appropriate security and protection, however the examination bunches didn't think about the vast majority of them in the 6G necessities, and some of them are supposed to be implanted in the accompanying framework prerequisites.

- •More data rate, spectrum, and reliability
- •Spectral and energy efficiency
- •Incorporation of smart surfaces with environments [49, 50]
- •Network automation and monitoring
- •Self-organizing networks (SON) and self-sustaining networks (SSN)

More wearable devices around 4G and 5G, smartphones used to be in the limelight, but wearable technology has recently increased, and new features are continuously being implemented to the systems. The drive towards the network that manages anything from wearable appliances to smart body implants is powered by XR and BCI applications.

Some research teams have considered the use of additional technologies in 6G to meet trends, network objectives, and application needs.

1. Beyond 6 GHz:
2. Transceivers with integrated frequency bands: [51, 52]
3. Collective network and edge intelligence: [53, 54]
4. Integrated terrestrial, airborne, and satellite networks: [55, 56]
5. Wireless energy transfer (WET) and harvesting (WEH):
6. Quantum computing and communication:

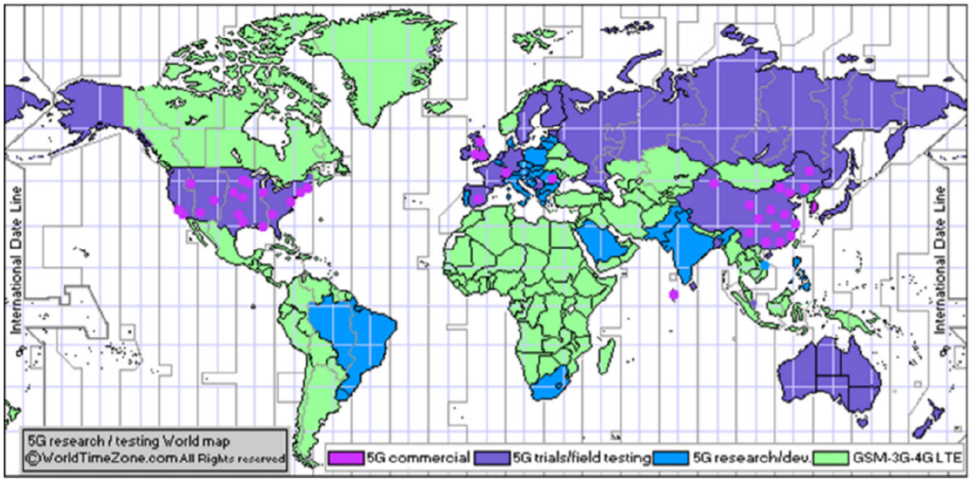

Figure 1: 5G coverage map in December 2019 [35]

Table 1: Research Initiatives into 6G Communications

Country	Research initiatives	Research areas
Finland (2018)	It is coordinated by the University of Oulu.	Terahertz spectrum. AI application. Localization and sensing.
US (2019)	The Federal Communications Commission with IEEE future networks under name "Enabling 5G and beyond." ITU-T Study Group no 13 for Network in 2030.	Terahertz spectrum (95 GHz and 3 THz). Reviewing service requirements. Edge intelligence.
EU (2019)	Terranova project. An EU-Japan project under Horizon 2020 funding, called "Networking Research beyond 5G."	Terahertz spectrum (with 400 Gbit per second) and (100 to 450 GHz)
South Korea (2019)	LG Electronics in collaboration with the Korea Advanced Institute of Science and Technology (AIST). In addition with a signed coloration agreement with the University of Oulu. Samsung Electronics and SK Telecom work together on developing technologies and business models. Also, SK Tele- com has signed agreements with Nokia firm in Finland and Ericsson in Sweden to conceptualize 6G network development.	6G applications. 6G vision and key features. Review of business models.
China (2019)	Two working groups to carry out the 6G research activities by orders from the ministry of science and technology; One with the government, and the second one with is made up of 37 universities, research institutes and companies.	Conceptualizing 6G.
China (2019)	Japan invested US$2 billion to support industry research. NTT and Intel have decided to form a partnership to work together.	Conceptualizing 6G.

7. Mobile edge computing (MEC):

4 DRIVING APPLICATIONS AND NEW SERVICES

The 6G aims to undoubtedly focus on compatible 5G applications, even on larger scale (supporting large networks including smart cities). Several emerging, expeditious solutions are expected to be used with the technologies mentioned above. Applications listed below are explained:

- Multisensory XR applications: Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR) are examples of extended Reality (XR) technologies.
- Connected robotics and autonomous systems (CRAS):
- Wireless brain-computer interactions (BCI): Smart body implants and BCI have become essential additions to the XR applications in 6G to enable the healthcare revolution.
- Blockchain and distributed ledger technologies (DLT):

The 6G services will reconsider those from the 5G by reshaping the traditional URLLC, mMTC and eMBB as well as by adding

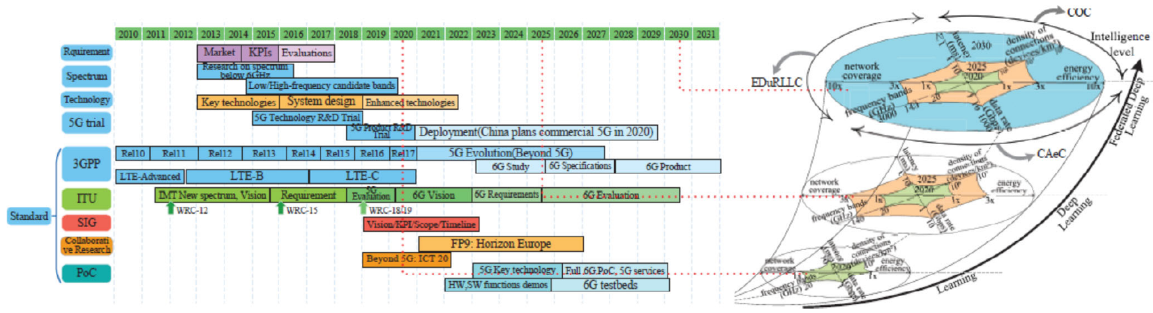

Figure 2: Timeline of 6G development networks [9]

Table 2: Requirements of 5G Versus 6G

	5G	6G
Release year	2020	2030
Spectrum	3-300 GHz	73-140 GHz and 1-10 THz
BW	0.25-1 GHz	up to 3 THz
Data rate	1-20 Gbps	>1 Tbps
Spectral efficiency	30 bps/Hz	100 bps/Hz
Mobility	up to 500 km/h	up to 1000 km/h
End-to-end delay	5 ms	<1ms
Radio-only delay requirement	100 ns	10 ns
Processing delay	100 ns	10 ns
End-to-end reliability	99.999%	99.99999%
Connected devices	Smart phones, sensors, and drones	Smart phones, implants sensors, DLT devices, CRAS, CR and BCI equipment
Application types	eMBB, URLLC, and mMTC	MBRLLC, mURLLC, HCS, and MPS

Table 3: Key Security and Privacy Issues In 6G

Issue	Solution	References
Unauthorized access control	Fine-tuned control processes using ML	[38]
	An improved access protocol using blockchain	[39]
	using unsupervised method in the authentication process to assure the genuinity of the authentication	[40]
	Identifying a disruption of molecular communication or its processes	[41]
	Perform analysis on Back-scattered data for high frequencies with narrow beams to detect eavesdropping	[42, 43]
	A new coding scheme that can improve the security of data transmission using molecular communication technologies	[44]
Data communication	An antenna design using ML that can be deployed in the PHY layer	[45]
	Different modes of quantum communication	[46]
	Using hashing power to validate transactions using Blockchain	[47]
	A secure protocol that can be used in the communication process using VLC technology	[48]

novel services, as mentioned in the 6G trends, technologies, and applications (see Table 4):

- Network slicing:
- Massive URLLC:
- Human-centric services (HCS):
- Multi-purpose 3CLS and energy services:

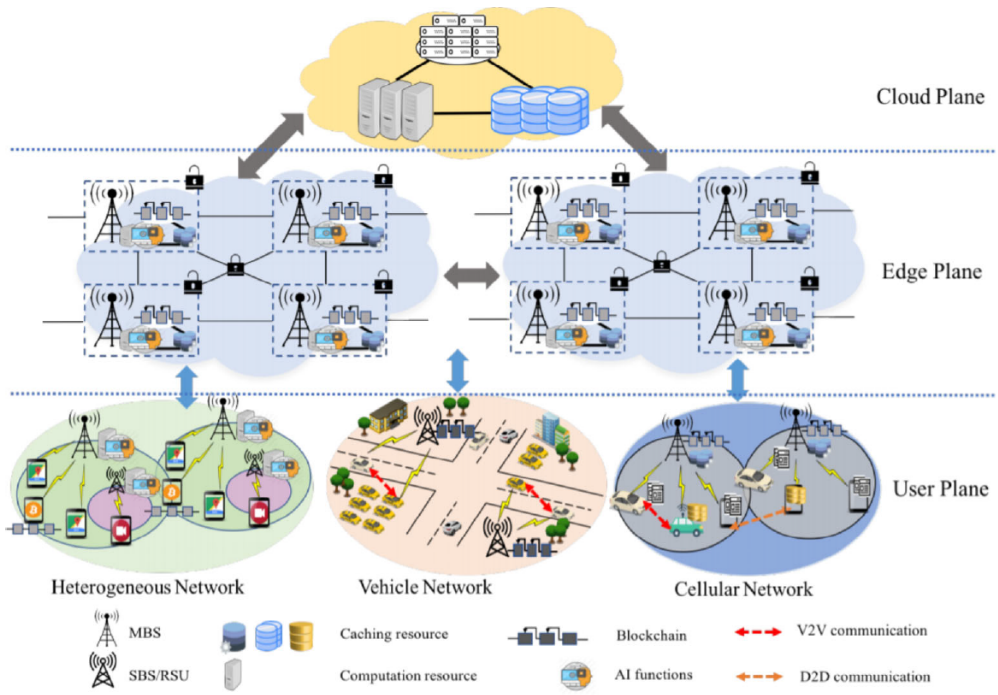

Figure 3: Different types of networks [57]

Table 4: 6G Summary Services [1]

Service	Performance indicators	Example applications
MBRLLC	Rate-reliability-latency in mobile environments. Stringent rate-reliability-latency requirements. Energy efficiency.	XR/VR/AR. Legacy eMBB and URLLC. Autonomous drones. Autonomous vehicular systems.
mURLLC	Ultra high reliability. Massive reliability. Massive connectivity. Scalable URLLC.	Classical Internet of Things. Autonomous robotics. User tracking. Blockchain and DLT. Massive sensing.
HCS	QoPE capturing raw wireless metrics as well as human and physical factors.	BCI, Affective communication Empathic communication.
MPS	Control stability, Computing latency. Sensing and mapping accuracy. Latency and reliabilit y for communications, Energy. Localization accuracy	CRAS Telemedicine. Some special cases of XR services. Environmental mapping and imaging.

5 ONGOING RESEARCH AND OPEN PROBLEMS

The areas of ongoing research and unsolved research questions related to 6G trends, technologies, and applications are the main topics of this section.

- Integrated heterogeneous multiple frequency bands: As THz serves as the foundation for greater data speeds, utilizing THz with mm Wave was main focus of several research groups. The present goal of mmWave research is to support high mobility.
- Resource allocation: Distributing actual assets for the virtualized processing, stockpiling, and correspondence assets in various organization cuts was a problematic issue in 5G frameworks that continue in 6G frameworks.

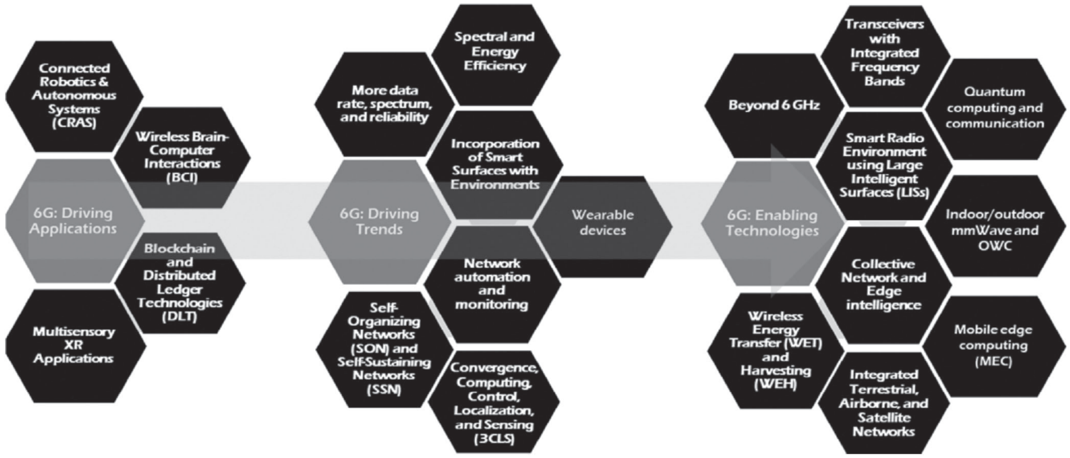

Figure 4: 6G applications, trends, and technologies [57]

- Ultra low latency: One of the primary necessities of the 6G is to have super low dormancy so that it can help numerous applications (e.g., XR, CRAN, BCI, and so forth.).
- Decentralization networks:
- Integration of terrestrial, airborne, and satellite: 5G has had the option to oblige heterogeneous organizations and various systems administration innovations (e.g., Wi-Fi, D2D, and so on.).
- AI use-cases: Artificial intelligence has been utilized for 6G in numerous media communications applications.
- Emerging LIS with environment: Arising LISs in the climate to fill in as a shrewd radio climate is the other open examination course.
- QoPE metrics: Plan of the following presentation metric that addresses the consistency of the existence of actual variables.
- 3CLS: The joint plan of calculation, correspondence, control, limitation, detecting, and energy should be tended to in future exploration.
- Dynamic multiple access and handover: Another extreme convention is required for the applications referenced.
- Trust, security, and privacy: Past cell networks focused on the center organization measurements (eg, throughput, dependability, and dormancy) with little consideration regarding security, mystery, and security issues.
- Potential health issues:

6 CONCLUSION

This paper completely forms a concept of the 6G cell framework by illustrating the framework prerequisites, expected patterns, advances, applications, and examination progress. The examination issues and flow of research groups with their exploration field are summed up to furnish per users with the guide of the innovation and the likely difficulties to consider in their examination toward 6G.

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