# 6G Enabled Smart Infrastructure

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6G is expected to have data rates in the order of terabits per second and a latency of less than 1ms. It is expected to drive the Internet of Everything, with 10,000,000 connections per square km.

6G wireless communication 6G vision 6G requirements 6G enabling technologies 6G challenges 6G applications

## 1. Introduction

The commercialization of 5G commenced in 2019, and further adoption is expected in 2021 and beyond. There has been tangential research interest on future 6G wireless networks [1]. The COVID-19 pandemic forced more businesses online, birthing a “New Normal” with a borderless workplace. Ericsson has forecasted that there will be faster commercialization of 5G as more people embrace this shift to a borderless workplace. The resulting surge in Internet usage beams light on the need for better connectivity to meet the growing demand for more stringent network requirements. This is required to facilitate emerging technologies such as extended reality [2], haptics [3], connected autonomous systems [4], telemedicine, Industrial Internet of Things (IIoT) [5], which are sensitive to latency and require ultra-fast data speed. For example, ultra-low latency and ultra-fast data speed reduce the collision rates and improve the safety of the autonomous vehicle. These applications are necessary to facilitate autonomous and smart life, multisensory virtual experience, intelligent cities, smart agriculture, and more. Unfortunately, the promising 5G networks cannot meet these growing demands [6][7]. Thus, there is an imperative need for the development of 6G communication networks. 6G wireless networks are also proposed to ameliorate social needs, thereby facilitating the actualization of the Sustainable Development Goals (SDGs) [8]. The proposed network requirements of 6G can be summarized as (1) Ultra-fast data rates as high as 1Tbps (2) Ultra-low latency of less than 1ms (3) Increased mobility and coverage (4) Flexible, and efficient connection of trillion level objects [9] (5) Peak spectral efficiency of 60 b/s/Hz (6) Very high system reliability (7) Improved network security.

6G is expected to have data rates in the order of terabits per second and a latency of less than 1ms. It is expected to drive the Internet of Everything, with $10^7$ connections per $km^2$ [10]. To achieve this, 6G will leverage on subterahertz and Terahertz spectrum (300 GHz to 10 THz) [11][12], which provides a higher frequency spectrum as against the millimeter wave spectrum (30–300 GHz) adopted in 5G [13]. Exploring a higher frequency spectrum is necessary because the sub-6GHz range is already crowded. Apart from giving room for more spectrum, the Terahertz spectrum gives rise to higher data rates desirable in 6G networks. However, transmitting at a higher frequency spectrum is prone to high path loss, making the distance for transmission limited. This and other challenges with THz transmissions, such as hardware constraints, are treated in this paper. Additionally, Optical wireless technologies [14] such as Visible Light Communication (VLC) [15] and Free Space Optical communication [16] are discussed extensively.

Additionally, technologies such as Reconfigurable Intelligent Surfaces (RIS) [17][18][19], cell-free massive MIMO [20], Artificial Intelligence (AI), which are expected to drive the actualization of 6G, are broached. We consider RIS, which will be deployed on doors, windows of buildings to reflect received signal without interference. Furthermore, we explore why the RIS technology is a preferable candidate to the existing relays. The massive MIMO technology is introduced in 5G with a more dense network of access points (APs) [21]. This is further developed in 6G to include a network with no cells (cell-free) [22]. The benefits are tremendous as it improves spectral efficiency in communication networks. However, there are challenges with obtaining channel information and concerns about health risks associated with such a dense network of APs. There is limited literature to address these concerns; thus, the need for this review. We also believe Pervasive AI is critical in actualizing 6G. Artificial Neural Networks [23][24], Deep Neural Networks [25] have been proposed to enable intelligent networks.

Despite the auspicious view of this technology, challenges with complex data and more have been highlighted. These challenges have been delineated in this article. Other enabling technologies such as Quantum Communication [26], Ambient Backscatter Communication Systems (ABCS) [27], Blockchain [28], UAVs [29], and more have also been proposed and treated extensively in this paper. Future generation networks are desired to have high speed and low latency and secured communication. Quantum communication has been proposed to enable security and facilitate faster processing power for future wireless networks [30]. However, there are doubts if research in quantum communication will be ripe enough to facilitate the 6G communication systems [31]. However, this technology will see more light beyond 6G, towards the 7G era. Blockchain is another technology proposed to facilitate security, and we have examined this with the hope that it would provide the desired privacy and integrity in future wireless networks. Blockchain technology has been introduced in 5G [32].

Energy efficiency is another interesting topic for future wireless networks. It is desirable to have hardware that is compatible with the energy requirements of 6G. Ambient Backscatter Communication Systems (ABCS), and Energy Harvesting (EH) techniques, are proposed to enable wireless charging. This gives room for longer battery life, which has been proposed as a requirement for future wireless networks [33]. With the ABCS, devices have an alternative source of power from wireless communication. This is consequently extending the battery life of devices. Simultaneous Wireless and Information Power Transfer (SWIPT) [34], if enabled by 6G, will resolve energy requirements issues at the mobile unit [35]. We believe this will enable haptics [36], the Internet of Bio-Nano Things, and other applications with very restrictive energy requirements.

## 2. Related Works and Contributions

There are a few related works of literature that proposed the vision, requirements, enabling technologies, and design of 6G wireless networks [33][37][38][39][40]. In particular, David et al. [33] opined that 6G would enable wireless charging and high data rates. The authors also identified the need for socio-ethics in the 6G design. Nayak and

Patgiri [37] proposed 6G to change the perceptual experience in lifestyle, business, and society. The study also presents some technology-driven challenges in 6G wireless networks and the probable solutions. In [38], the authors examined critical features such as security, secrecy, and privacy to make 6G truly human-centric. Tariq et al. [39] present an extension to the existing vision of 5G and show speculatively how the 5G vision and technologies can be enhanced to drive the anticipated 6G. Yang et al. [40] proposed integrating machine learning and big data to facilitate intelligent transmission. The application of Big data and AI has also been considered in the scholarly works of literature [24][41][42]. Other enabling technologies such as Intelligent Reflecting Surfaces [17], Blockchain [28], Terahertz communication [11], and more, proposed for 6G communication, have also been surveyed. Additionally, the future projections of wireless communication presented in existing reports are highlighted.

This paper extensively considers existing research, clearly outlining the enabling technologies and the associated challenges, applications, and new applications such as the IoBNT and Digital Replica, which are not given adequate treatment in many related papers. Use cases in agriculture, education, media and entertainment, and more are discussed extensively. Apart from the technical challenges associated with the enabling technologies, this paper examines the social, psychological, and health concerns that could pose a challenge to 6G adoption. This paper also explores the recent research breakthroughs in 5G and the limitations of 5G, which make 6G a highly prospective candidate. A comparative review of some of the proposed enabling technologies, open research issues and lessons learned, and proposed future research directions are also discussed extensively.

In summary, Table 1 examines the limitations of some of the existing surveys and our contributions in this paper to fill the knowledge gap. We hope this paper gives the reader a panoramic view of what 6G will be, clearly outlining the possible challenges associated with the 6G-enabling technologies, applications, use cases, and more. Finally, this paper provides a future outlook of what needs to be done to facilitate this desirable generation of wireless communication towards achieving the United Nations Sustainable Development Goals.

**Table 1.** Limitations of some related surveys and our contributions.

| Ref. | Focus and Coverage | Limitations | This Paper's Contributions |
|---|---|---|---|
| [43] | Considers the vision, applications, research activities, challenges, and potential solutions. | ▪ Applications were limited to five.<br>▪ Challenges with each enabling technology were omitted. | ▪ More applications such as teleoperated driving, IoBNT, Digital replica, and more are treated in this paper.<br>▪ Provides a holistic review of the challenges of each technology.<br>▪ Additionally, it analyses enabling technologies not |

| Ref. | Focus and Coverage | Limitations | This Paper’s Contributions |
|---|---|---|---|
| | | | treated, such as RIS, CubeSats, ABCS, and more.<br>▪ Examines the most recent research trends and highlights future directions and lessons learned. |
| [9] | Vision and potential techniques. The study presents some technology-driven challenges such as power supply, security, hardware design, and probable solutions. | ▪ The space-air-ground integrated network was proposed, but the supporting technologies of UAV/CubeSats were not explained.<br>▪ Applications not clearly outlined. | ▪ An extensive analysis of UAV/Cubesats and how these will facilitate 6G requirements are presented.<br>▪ 6G applications are clearly outlined, and a comparative analysis of why the existing 5G is limited is shown.<br>▪ Enabling technologies such as Cell-Free massive MIMO, ABCS, quantum communication not presented in the paper were delineated in this paper. |
| [33] | The authors examine the vision, requirements, and Services. | ▪ The enabling technologies are not outlined.<br>▪ Future research directions not presented. | ▪ Vision, Requirements, Applications, and Enabling Technologies are discussed robustly.<br>▪ Open Research Issues and Future Research Directions outlined. |
| [39] | This work presents an extension to the existing vision of 5G and shows speculatively how the 5G vision and | ▪ Although use cases were discussed, the driving applications were omitted. | ▪ Driving trends and applications extensively discussed. Challenge with |

| Ref. | Focus and Coverage | Limitations | This Paper's Contributions |
|---|---|---|---|
| | technologies can be enhanced to drive the anticipated 6G. | ▪ Open Research Issues and Future Research Directions not clearly outlined. | each enabling technology clearly outlined.<br>▪ Open Research Issues and Future Research Directions are clearly outlined. |
| [38] | 6G vision, key features, potential applications, enabling technologies. Emphasizes critical features such as security, secrecy, and privacy to make 6G truly human-centric. The system framework, key technologies, and challenges are outlined to support the 6G vision. | ▪ Challenges with enabling technologies are not clearly outlined.<br>▪ Applications such as IoBNT, digital replica not considered. | ▪ Enabling Technologies such as Blockchain, ABCS discussed.<br>▪ Challenges with enabling technologies are clearly outlined.<br>▪ Applications such as IoBNT, digital replica, and wireless BCI are discussed.<br>▪ Research activities updated to include the most recent research activities. |
| [44] | The work presents topics in human-machine interface, multi-sensory data fusion, ubiquitous computing, and precision sensing. The authors added key disruptive technologies that include new architecture, new security, and a new spectrum. | ▪ Enabling Technologies limited to six and did not include technologies such as blockchain, ABCS.<br>▪ Applications not clearly outlined. | ▪ Enabling Technologies and challenges are discussed extensively.<br>▪ Additionally, the existing and probable solutions to some of these challenges are highlighted<br>▪ 6G Applications are clearly outlined. |
| [45] | The authors present a vision on 6G, considering the applications, service | ▪ Enabling Technologies discussed, but the | ▪ A robust discussion on Blockchain as an emerging |

| Ref. | Focus and Coverage | Limitations | This Paper's Contributions |
|---|---|---|---|
| | classes, essential requirements, and trends. The enabling technologies and open research problems were highlighted. | challenges were not clearly outlined.<br>▪ Additionally, non-technical challenges such as commercialization and psychological challenges are not discussed. | technology is reported.<br>▪ Technical challenges associated with the enabling technologies and non-technical challenges such as commercialization are discussed. |
| [46] | This survey focuses on 6G applications, requirements, challenges, and critical areas of research focus. The survey also covers key technologies such as THz, blockchain, AI, and optical wireless communication (OWC). | ▪ The challenges with the enabling technologies proposed are not discussed.<br>▪ Use cases not discussed. | ▪ Discusses the challenges with enabling technologies.<br>▪ Presents use cases in education, media, entertainment, and more.<br>▪ Examines the proposed applications, the requirements, and why existing 5G cannot meet the requirements. |
| [47] | Presents the enabling technologies, including the holographic radio characteristics and targeted application scenarios. Additionally, considers non-technical challenges such as industry barrier and consumer habits. | ▪ Applications not clearly outlined.<br>▪ Open research issues and future research directions not discussed. | ▪ More enabling technologies are discussed.<br>▪ Technical and non-technical challenges are presented.<br>▪ 6G applications are clearly outlined.<br>▪ Open research issues, future research directions, and lessons learned are outlined. |

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GSM was
set up by
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technology [48]. This was developed as the wireless counterpart of the land-lined Integrated Services Digital Network (ISDN) system. The acronym was later changed to refer to "Global Systems for Mobile Communication." The GSM standard was deployed in 1991, using the 900 MHz bands [49].

The GSM architecture comprises the Mobile Station, Network and Switching Subsystem, and the Base Station Subsystem (BSS), also known as the radio network. Additionally, included is an intelligent network subsystem that enables intelligent functionality such as prepaid services and short message services (SMS). GSM utilized Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) for simultaneous communication between the subscriber and the base station [50]. The former allowed communication using multiple frequencies, while the latter enabled communication through multiplexing by time slots. General Packet Radio Service (GPRS) was developed to facilitate features such as always-on, higher capacity, internet-based content, packet-based data services, enabling services such as color internet service, email on the move, and visual communications, multimedia messages, and location-based services [51].

In the early twenty-first century, 3G was developed as an upgrade to the features in 2G. It permitted faster data rates in the range of 300 kbps–30 Mbps and services such as video conferencing, remote supervision systems, and enabled information services. Technologies such as Wideband Code Division Multiple Access (WCDMA), Universal Mobile Telephone Service (UMTS) were key to achieving the 3G. The 3rd Generation Partnership Programme (3GPP) was formed in 1998 to oversee UMTS implementation and other enabling technology for 3G. 3GPP2 was also formed in the United States to develop global specifications for 3G systems. Critical concepts for evolution toward beyond 3G networks are presented in [52].

Long-Term Evolution (LTE) was deployed in 2009. With the proliferation of smartphones and tablets, online gaming, and other services, 4G has been a significant success, enabling these services with its data speed of 100 Mbps–1000 Mbps. Although the first release of LTE was in 2005 by 3GPP in release 6, the full development was only achieved in release 8 in 2008. Further details on the technical solutions for the 3G long-term evolution are reported in [53]. The LTE is often regarded as the 4G; however, the LTE-Advanced features such as increased peak data rate, spectral efficiency, simultaneous active subscribers, and improved cell-edge performance make it the true 4G. Key performance indicators for 4G LTE are given by [54][55], and radial basis function neural network pathloss prediction model in LTE network was reported in [56]. A higher data rate was achieved and lower latency in 20 ms–100 ms, which was lower than that obtained in 3G. 4G facilitated video streaming, online gaming, and more. The need for a higher data rate and lower latency gave room for interest in 5G.

5G commercialization started in 2019, and it opens up new use cases in the Internet of Things (IoT), immersive gaming, virtual reality, and more. 6G is expected to have a higher data rate in the range of 100 Gbps–1 Tbps and latency lower than 1ms. This opens up applications in holographic communication, tactile internet, extended reality, and more. Table 2 summarizes the technology, data rates, and supporting applications from 1G to 6G. The change in latency from 1G to 6G is also shown. Furthermore, a comparative analysis of 5G, Beyond 5G (B5G), and 6G is presented in Table 3.

**Table 2.** Comparing the different generations of wireless communication from 1G to 6G.

| Features | 1G | 2G | 3G | 4G | 5G | 6G |
|---|---|---|---|---|---|---|
| Technology | AMPS [57], | GSM [58], GPRS, | WCDMA [60], | LTE [63], MIMO [64] | Massive MIMO, network | RIS [65], Cell-free Massive |

| Features | 1G | 2G | 3G | 4G | 5G | 6G |
|---|---|---|---|---|---|---|
| | IMTS, PTT | CDMA [59], EDGE | UMTS, TD-SDMA, CDMA2000 [61], WiMAX [62] | | densification, millimeter- wave transmission | MIMO [66], Terahertz spectrum [67], AI [24] |
| Data-rate range | >3 kbps | 10 kbps–200 kps | 300 kbps–30 Mbps | 100 Mps–1000 Mbps | 1–30 Gbps | 100 Gbps–1 Tbs |
| Latency | >1000 ms | 300 ms–1000 ms | 100 ms–500 ms | 20 ms–100 ms | 1 ms–10 ms | <1 ms |
| Multiple Access/ Multiplexing schemes | FDMA [68] | TDMA, CDMA | CDMA [69] | OFDMA [70] | OFDM, GFDM [71] FBMC [72], Adaptive Time-Frequency. Multiplexing [73] | OMA [74], NOMA [74], OAM [75], Spatial Multiplexing [76] |
| **Applications** | Calls, Fax | Encrypted and data services | Faster Data, Video calling, remote supervision systems | HD Television content, Online Gaming | Internet of Things [5], Virtual reality, Immersive gaming | Autonomous systems, tactile devices, Internet of Everything, BCI, Telemedicine |

This table compares the different generations of wireless communication from 1G to 6G with respect to the supporting technologies, data features, and enabling applications. It shows that with higher data rates and lower latency, more sophisticated applications are enabled.

**Table 3.** A comparative analysis of 5G, B5G, and 6G.

| Description | 5G | Beyond 5G | 6G |
|---|---|---|---|
| Frequency bands | ▪ Sub-6GHz<br>▪ mmWave for fixed access | ▪ Sub-6GHz<br>▪ mmWave for fixed access | ▪ Sub-6GHz<br>▪ mmWave for mobile access |

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| Description | 5G | Beyond 5G | 6G |
|---|---|---|---|
| | | | ▪ Exploration of higher frequency and THz bands (above 300 GHz)<br>▪ Non-RF (optical, VLC) |
| Rates requirements | 20 Gb/s | 100 Gb/s | 1 Tb/s |
| Radio only delay requirements | 100 ns | 100 ns | 10 ns |
| End-to-End delay(latency) requirements | 5 ms | 1 ms | <1 ms |
| Processing delay | 100 ns | 50 ns | 10 ns |
| Device types | ▪ Sensors<br>▪ Smartphones<br>▪ Drones | ▪ Sensors<br>▪ Smartphones<br>▪ Drones<br>▪ XR equipment | ▪ Sensors and DLT<br>▪ CRAS<br>▪ XR and BCI<br>▪ Smart implants |
| Architecture | ▪ Dense sub-6 GHz small base stations with umbrella macro stations.<br>▪ mmWave small cells of about 100 m (about fixed access). | ▪ Denser sub-6 GHz small cells with umbrella macro base stations.<br>▪ <100 m tiny and dense mmWave cells. | ▪ Cell-free smart surfaces at high frequency supported by mmWave tiny cells for mobile and free access.<br>▪ Temporary hotspots are served by drone-carrier base stations or tethered balloons. |

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| Description | 5G | Beyond 5G | 6G |
|---|---|---|---|
| | | | ▪ Trials of tiny THz cells. |
| Services | ▪ eMBB<br>▪ URLLC<br>▪ mMTC | ▪ Reliable eMBB<br>▪ URLLC<br>▪ mMTC<br>▪ Hybrid (URLLC + eMBB) | ▪ HCS<br>▪ MPS<br>▪ MBRLLC<br>▪ mURLLC |

This table zooms in on the comparison of 5G, Beyond 5G, and 6G, presenting a specific latency, brief description of the architecture, and services such as MBRLLC, mURLLC that have been proposed. The device types are also shown to include BCI and smart implants in 6G.

## 4. Vision of 6G Wireless Communication

There have been different descriptions of what the 6G network should be by researchers [38][43][77][78][79]. Furthermore, the authors in [80] defined it as a technology that will make human society a "Ubiquitous Intelligent Mobile Society". In [39], the authors envisioned 6G to facilitate super smart cities with pervasive autonomous systems. It is expected that 6G will be supported by existing 5G infrastructure such as Software-Defined Networking [81], Network Function Virtualization (NFV) [82], and Network Slicing (NS) [83] together with new infrastructure. In order to give a future assessment of how well 6G has accomplished the required cases, this paper examines various visions and requirements projected by different researchers [40][41][42]. It presents a blend of what 6G will be. Just as we envisage, some researchers also believe there will be a pervasive application of AI to make 6G a reality [20][68]. There is also research on optical wireless communication to enable indoor and outdoor communication at high-data rates [84]. Simultaneous Wireless and Information Power Transfer (SWIPT) [35], which is an Energy Harvesting (EH) technique, has been proposed to improve the battery life of UEs [38][39].

6G is expected to support smart cities, the Internet of Everything (IoE) [37], tactile devices [9], and more. The requirements are high reliability [7], the high data rate in the order of 1 Tb/s, ultra-low latency of less than 1ms, high energy and spectral efficiency [85], security and privacy [86], and ubiquitous connectivity that connects everyone, including people in rural areas [87][88]. The Ultra-Reliable Low Latency Communication (URLLC) required in 6G networks is also under more stringent conditions than that obtainable in 5G, with delay jitters, context awareness, and UAV/Satellite compatibility being considered. Sustainability is also desirable in future wireless networks, and there is a need for Green Networking architecture that will be environmentally friendly [89]. Figure 1 shows a brief overview that compares the Key Performance Indicators in 5G and those expected in 6G.


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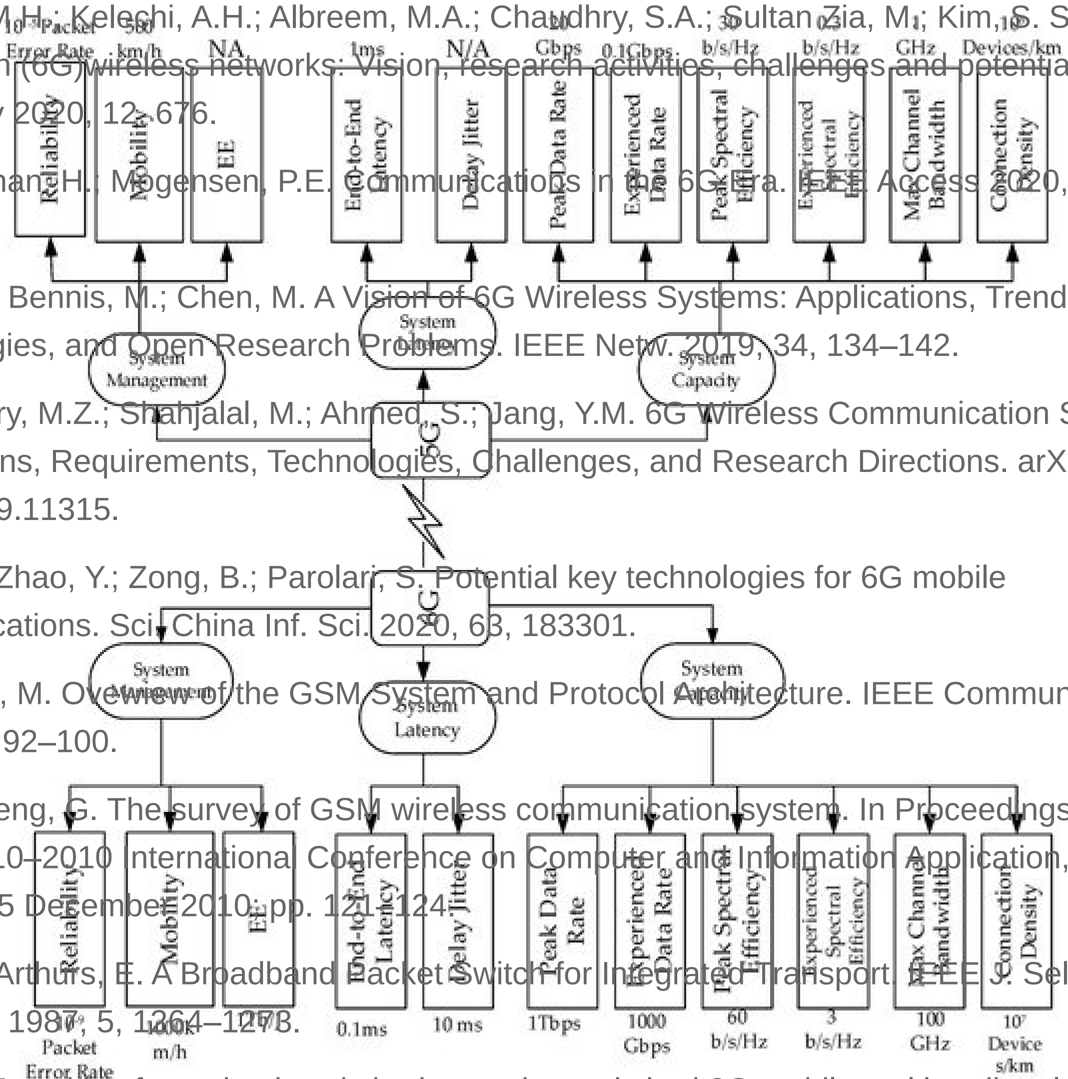


**Figure 1.** Comparative Analysis of 5G and 6G Key Performance Indicators.

## 5. Enabling Technologies and Challenges for 6G

Here, we present a robust discussion of the enabling technologies of the 6G communication system. We envision that Artificial Intelligence, which was introduced in 5G, will be further explored and central in achieving an intelligent 6G network. Reconfigurable Intelligent Surfaces will be deployed on doors, windows, buildings, and these reflect signals and help in places where maintaining Line of Sight (LoS) is tricky. The advantages of this over conventional relay systems are discussed. Cell-free Massive MIMO, TeraHertz, and Optical Wireless Technology, and more are also treated in this section. Quantum communication has been proposed, although research is in its inchoate state. This will improve the computing efficiency and security of future wireless networks. Unmanned Aerial Vehicles (UAV) and Cubesats are proposed to facilitate space communication. Some literature presents this as the Internet of Space Things [31][90]. This is important as it expands coverage and facilitates ubiquitous connectivity. The desirable wireless charging can be enabled by Ambient Backscatter Communication System (ABCS). Figure 2 gives a pictorial guide to the enabling technologies.

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**Figure 2.** 6G Enabling Technologies.

## 6. 6G Applications

Every generation of wireless networks has facilitated new applications, and 6G is not an exception. The need for higher data rates, lower latency, high reliability, and more have given rise to the development and deployment of new wireless generation networks. In this section, we examine the applications to be facilitated by 6G. Although these or similar applications have been proposed to be enabled by 5G, 5G cannot meet the requirements to facilitate these applications seamlessly at the current development stage. Some limitations in 5G, such as scarce bandwidth and high energy consumption, have been identified [91]. Although 5G tests have shown prospects with the actualization of a data rate of 8 Gbps [92] and 1 Gbps at 6.5 km distance [93], these are still below the peak data of 20 Gbps proposed in the literature. Therefore, existing 5G networks cannot meet high-speed intensive applications such as holographic communication, which require 1 Tbps for seamless communication [37]. Other limitations identified with 5G wireless networks are high interference due to massive interconnection, insufficient computing capacity, and lack of ubiquitous connectivity. Hence there is a need for 6G communication, which promises better features than 5G.

Some of the applications to be facilitated and fully enabled by 6G are holographic communication, teleoperated driving, tactile internet, Industry 4.0, and more. New applications that were not considered in the 5G context, such as IoBNT and Digital replica, are also introduced in this paper. Table 4 gives a summarized description of these applications. Furthermore, we outline the challenges in achieving some of these applications. Additionally, desirable features of these applications are considered. These applications, the 5G limitations, and how 6G wireless networks will enable them are highlighted in this section. In this literature, it has been established that the existing features of 5G are not efficient enough to enable the requirements of these technologies. We consider each application in this section, pointing out some of the requirements that make 6G an ideal candidate for these applications.

**Table 4.** Brief description of 6G applications.

| Applications | Brief Descriptions |
|---|---|
| Holographic Communication | This enables human communication through holographs-3D images in thin air. To improve the experience of remote communication as we embrace a borderless workplace. Latency and high bandwidths are some of the challenges associated with Holographic Communication. 6G will solve these challenges. |
| Tactile Internet | Enables human-to-machine interactions and machine-to-machine interactions. |
| Industry 4.0 and beyond | Comprises cyber-physical systems, IoT, and cloud computing. Additionally, AI and ultra-fast wireless networks will drive the 4th industrial revolution. This enables smart cities, factories which are some of the vision for 6G. |
| Teleoperated Driving | Allows cars to be controlled remotely. These cars are also referred to as semi-autonomous vehicles. Semi-autonomous cars require a fast and ubiquitous wireless network with ultra-low latency. |
| Internet Bio-Nano Things | An interconnection of biological nano-sized objects(nanomachines). Takes application largely in healthcare. 6G is proposed to provide the perceptual requirements and ultra-low latency required by IoBNT. |
| Multisensory XR Applications | AR/MR/VR that incorporates perceptual experience. Supported by URLLC and eMBB and perceptual factors to be supported by 6G. An excellent candidate to provide a better gaming experience. |
| Blockchain and Distributed Ledger | Blockchain is postulated to provide security for 6G networks. They also require low latency, reliable connectivity, and scalability, which 6G networks will provide. |

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| Applications | Brief Descriptions |
| --- | --- |
| Technologies | |
| Connected Robotics and Autonomous Systems (CRAS) | CRAS is required to improve industrialization through the use of robots and autonomous systems for industrial operations. They require a high rate and reliability and low latency. |
| Wireless Brain-Computer Interface (BCI) | BCI enables communication between the brain and electronic devices. This requires ultra-low latency, high reliability, and high data rate. |
| Digital Replica | These are also called digital twins, and they create a digital copy to replace people, places, systems, objects. This requires a very high data rate, which 6G will enable. |

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