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Key performance requirement of future next wireless networks (6G)

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ABSTRACT

Given the massive potentials of 5G communication networks and their foreseeable evolution, what should there be in 6G that is not in 5G or its long-term evolution? 6G communication networks are estimated to integrate the terrestrial, aerial, and maritime communications into a forceful network which would be faster, more reliable, and can support a massive number of devices with ultra-low latency requirements. This article presents a complete overview of potential 6G communication networks. The major contribution of this study is to present a broad overview of key performance indicators (KPIs) of 6G networks that cover the latest manufacturing progress in the environment of the principal areas of research application, and challenges.

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1. INTRODUCTION

Figure 1 summarizes the major milestones of the five generations (1G-5G) of wireless communication networks. 5G communications have been standardized and are already being used all over the world [1]. ITU defines the vision and requirements; 5G would get together eight key performance indicators (KPIs) and three common scenarios [2]. The three challenging technical indicators for all three scenarios are the millions of interconnects per square kilometer (1M/km²) of huge machine-type communications, the millisecond (ms) air interface delay of ultra-reliable low-latency communications (URLLC), and millions of square kilometers (ms) of interconnection. Enhanced mobile broadband (eMBB) (mMTC). A collection of enabling technologies was proposed argued in standardizations, and tested in technological trials to achieve these KPIs [3]. Massive MIMO, advanced coding and modulation, mmWave communication, non-orthogonal multiple access, ultra-dense networking (UDN), dual connection architecture, and adjustable frame structure are only a few examples of wireless technology [4], [5].

However, because of the significant increase in the number of interconnected devices, which could reach hundreds of devices per cubic meter, a tremendous increase in data exchange is expected; Apart from the growing number of new applications like virtual/augmented reality (VR/AR), self-driving cars, three-dimensional integrated communications, and yet-to-be-conceived applications [4], [6], 5G networks would require even higher data rates and lower latency. These constraints are seen as a key driver in the

development of 6G communication technologies. What could be better in 6G that is not included in 5G, given the vast potentials of 5G networks and their anticipated evolution? Academic, industry, and research organizations are busy describing and identifying important essential enabling technologies that could characterize 6G, with deployment estimated by 2030 [7], [8].

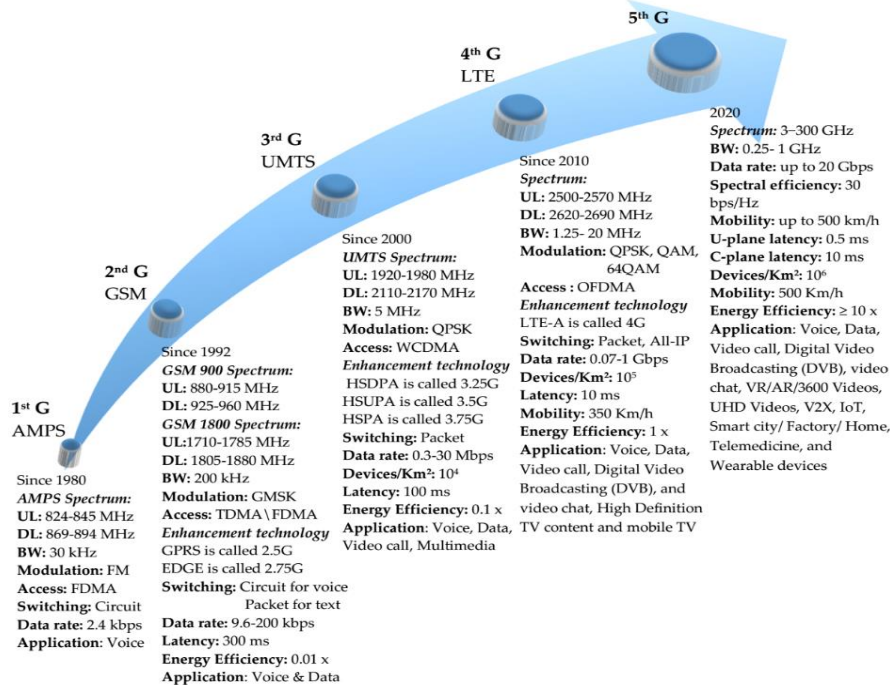


Figure 1. Different generations of communications (1G–5G) Major milestones

Based on the vision and expansion of a universal smart Mobile Sphere, 6G will be improved and broadened to allow for a 10 to 100-fold increase in data throughput, increased system capacity, wider and deeper coverage, higher resource utilization, higher spectrum efficiency, support higher moving speeds, lower delay, and entirely support the progress of a universal smart Mobile Sphere. The vision's expected requirements will be discussed in great detail in the following paragraphs:

- 6G ought to be an omnipresent and well-connected system with larger and wider coverage, incorporating terrestrial, short-range device-to-device communication, and satellite, among other things. 6G can operate in a variety of situations, including airspace, land, and sea, thanks to sophisticated mobility management technologies, resulting in a universal, inescapable mobile broadband communication system.
- 6G is a network that is extremely tailored and intelligent. The combination of 6G and artificial intelligence makes personal mobile communications virtual, and the network is transformed from the traditional centralized function to the new 3-centralized type of centralized user-centric, data-centric and full-content services.
- 6G is estimated to run at upper frequencies, like 4×10^{14} to 8×10^{14} Hz (visible light), higher frequency radio bands ranging from 24GHz to 40GHz (mmWave), frequencies between 100 GHz and 10 THz (terahertz), and so on, in order to achieve a wider bandwidth. When compared to 5G, 6G can increase data rates by up to 100 times, allowing for peak data rates of Tb/s and user data rates of 10Gb/s. Furthermore, 6G can make use of the reconfigurable frequency sharing technique to increase the efficiency of frequency reuse even further.
- The 6G network will adopt an endogenous safety system or an integrated functional safety design. By combining trust and security procedures, 6G can achieve self-awareness, dynamic real-time analysis, flexible risk, and trust assessment, all of which will contribute to cyberspace security.
- 6G communications will include computing, navigation, and detection. Satellite communication systems, satellite navigation and positioning systems, and perhaps radar detection systems, will all become part of 6G. 6G will have a more open architecture with a software-defined core network and wireless access network, allowing faster and more conscious development and dynamic deployment of network operations.

- Because of the internet of things (IoT), 6G can generate massive amounts of data; It can also be combined with new technologies, such as artificial intelligence, edge computing, cloud computing, and blockchain. 6G can support the ubiquitous intelligent mobile society by realizing everything related to intelligence and collective intelligence (swarm intelligence).

This paper intends to highlight the significant concerns of key performance indicators (KPIs) of 6G networks that are not covered by 5G, as well as the most current developments in the sector in terms of the main application areas and challenges. To that purpose, our research attempted to take as many approaches as workable. Due to space constraints, this work examined disputed research topics in-depth based on their sub-domains in order to get a precise and concise conclusion. This publication will open up new research possibilities for scholars by providing various new references that could aid in the goal of creating 6G networks. The rest of the article is structured as follows. The primary KPIs of 6G wireless systems discussed in section 2 include max data rate, needs for mobility, connected devices/Km², dependability, area traffic capacity, latency, network spectrum, and energy efficiency, followed by a comparison of KPIs between 5G and 6G networks. The work comes to a close in section 3.

2. KEY PERFORMANCE INDICATORS OF 6G NETWORKS

The prime KPIs of 6G wireless systems are discussed in this section. Figure 2 shows the key performance indicators (KPIs) for max data rate, dependability, needs for mobility, connected devices/Km², area traffic capacity, latency, network spectrum, and efficiency in terms of energy. In addition, Figure 3 shows a comparison of KPIs across 5G and 6G networks.

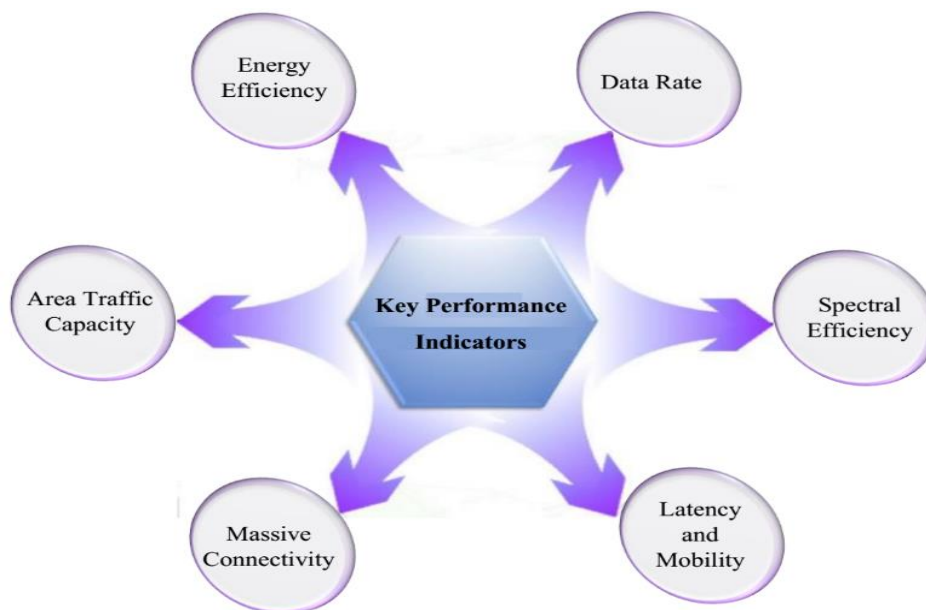


Figure 2. The main KPIs of 6G wireless networks

2.1. Data rate

Since the inception of wireless communications, users' data rate requirements have risen. The data speeds in 1G were a small number of kbps, which grew to 10⁶ bps in 5G. These data rates are insufficient for several applications. As a result, 6G is planned to have more bandwidth by operating at a higher frequency, such as visible light and Terahertz. 6G can boost data rates by 10 to 100 times compared to 5G, allowing for Tbps peak data rates. The general view is that data rates would increase to 1 Tbps in the future smart city to enable autonomous management of many operations. Individual data rates are predicted to rise from 1 Gbps in 5G to at least 10 Gbps for every user in upcoming 6G systems, and up to 100 Gbps in specific use cases [9]. 6G can take advantage of flexible frequency sharing technologies to improve frequency reuse efficiency even more. As a result, we may download HD videos in a matter of seconds [10].

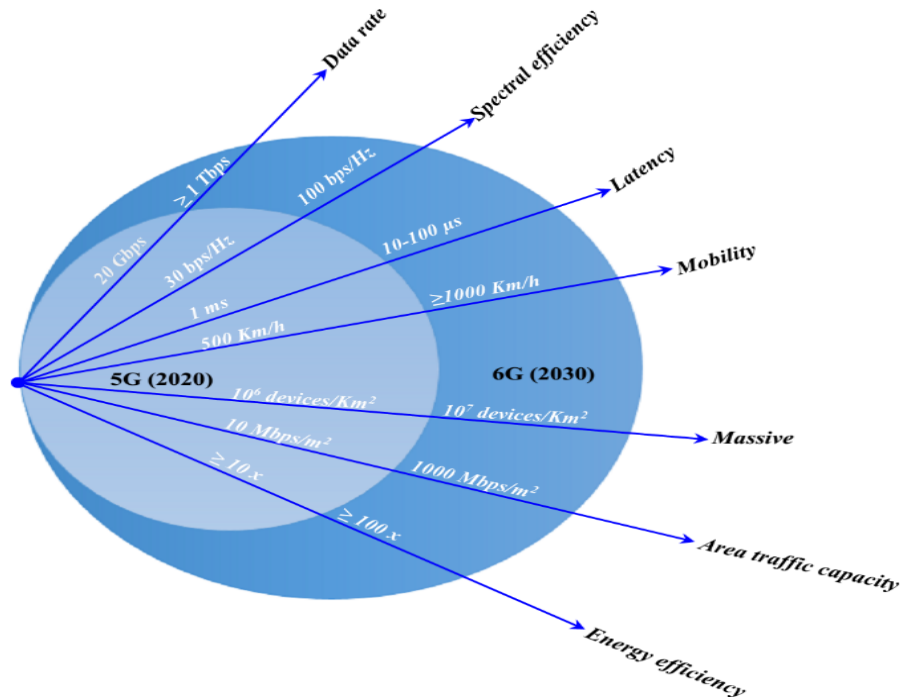


Figure 3. KPIs for 5G versus 6G

2.2. Spectral efficiency

Smart buildings will be employed in 6G to give another degree of freedom (DoF) to wireless networks, allowing them to deliver unprecedented capacity. On a large scale, buildings will be installed with smart reflecting surfaces [11]. The smart surfaces would effectively enlarge the antenna aperture to gather as many previously unavailable radio signals as it can for better energy and spectrum efficiency. Furthermore, employing polarization diversity and orbital angular momentum (OAM) mode multiplexing, it has been shown that a large capacity wireless communication system can be developed to operate within a few meters. Several independent data streams can be broadcast over the same spatial wireless channel, resulting in a tenfold increase in area spectral efficiency. The performance over a short distance is particularly encouraging, which could be valuable in automating several industries. According to reports, the millimeter-wave OAM system in [12] has achieved a rate exceeding 2.5 Tbps and has a huge spectral efficiency of 95.7bps/Hz. This may be a profitable technology for Industry 4.0 and is expected to become one of the most important 6G use cases. In contrast, 6G is expected to work in conjunction with satellites to provide worldwide mobile coverage. In 6G, volume spectral efficiency (in bps/Hz/m³) will be more appropriate for measuring system capability in a three-dimensional working space than the commonly employed area spectral efficiency (bps/Hz/m²).

2.3. Latency

The term “low latency” refers to communication that is swift and efficient. We want our packets to be sent in a quick length of time with little processing delay. In 6G, the maximum permitted latency is 10 seconds [13]. High dependability and ultra-low latency will be required for the future network of intelligent mobiles and robotics. The cities of the future will have smart cars, smart homes, smart schools/universities, smart industries, and smart industries. bullet trains, Ships, airplanes, and unmanned aerial vehicles (UAVs) will all need to be connected to smart cities. defense, health care, surveillance, and monitoring are just a few of the key applications that will cause ultra-reliability and low latency [14].

High dependability and minimal latency are required for online gaming services. The ERLCS security feature on the 6G wireless system will be integrated with the mMTC and uRLLC on the 5G, and the reliability standard exceeds 99.999999% (Nine-Nine) [15]. Self-driving vehicles must be linked to one another, and the link between them must be very reliable, otherwise, lives may be lost in accidents. Many houses and other sensors will connect with one other in 6G networks, causing ultra-reliability to avoid any mishaps.

2.4. Mobility

A number of heterogeneous radios will be supported in 6G devices. Users are connected to the network as a whole rather than to a single cell, allowing multi-connectivity techniques to extend cell borders. Without manual intervention or configuration, the device will be able to seamlessly transition between different heterogeneous links (such as sub6 GHz, millimeter wave, terahertz, or VLC), providing QoS guarantees that meet the most demanding mobility requirements envisaged by 6G, such as Low latency even in ultra-high mobility scenarios (up to 1000 km/h) [13].

2.5. Massive connectivity

mMTC is additional usage for next-generation wireless communication. The IoT eliminates the need for human interaction using machine-to-machine communication. From one machine to another, calls, messages, and commands are sent. The acts are not carried out by humans. The machines, rather than humans, are the ones who converse with one another. Wireless networks in the next generation are anticipated to have a capacity of 10⁷ devices/km² [15], [16].

Sensor networks and the IoT will cooperate with each other and connect to many base stations. Portable devices, control and monitoring equipment, autonomous vehicles, smart grids, industrial automation, and control equipment, and medical and health-related devices are just some of the projects and applications in this field. Peer-to-peer or cooperative multi-hop relay communication is possible between these devices. A network infrastructure design capable of supporting a variety of content-driven applications and networks is required for various applications or devices. Taking all these factors into account, the next generation of wireless networks will require a new optimization and planning method.

2.6. Area traffic capacity

As the number of connected devices per unit area increases, the demand for higher capacity channels and backhaul increases. On a daily basis, a densely distributed sensor network creates more than tera-bytes (TB) of data [17]. To handle the traffic, this data output requires a high-capacity backhauling line.

Wireless protocols in earlier wireless generations (1G-to-5G) were built for specific uses. With the rise of massive IoTs or mMTC, We will have to develop equipment that is both energy-efficient and cost-effective. This massive IoT connectivity resulted in the development of vehicle-to-vehicle communication, commonly known as V2X. The vehicle must interact with other vehicles, pedestrians, and various other sensors(vehicle-to-infrastructure). All of these communications must be highly reliable, low latency, and secure. Another case in point is industrial automation, which involves a huge number of sensors communicating and producing large amounts of data. For 6G, the minimum area traffic capacity limit is 1000 Mbps/m² [2].

2.7. Energy efficiency

Many expectations will be met and exceeded with 6G, including the supply of great energy performance, particularly in the context of widespread IoT usage and an eco-system of numerous minute sensors. In addition, because of the smartphone's ability to handle complex multimedia signal processing and the ability to increase by leaps and bounds with the increase in power consumption, it is imperative to expand the battery charging capacity [18]. Low power consumption and longer battery life are two research areas of 6G to solve the daily charging challenges faced by most communication devices and improve communication needs. As a result, a thorough energy-saving wireless communication strategy will be required for 6G. A key objective of 6G communication is to use battery-free communications whenever possible, with a communication efficiency of 1 Pico-joule per bit [7]. 6G communications provide the benefits of high-power terahertz waves, allowing devices to transmit power beams in specific directions, and use MIMO antenna arrays to guide beam communications. This method has the ability to offer enough power to devices inside the network's service area. According to the 6G vision and guidance outlined in [2], in 6G, research should focus on battery life and service categories, rather than latency and data throughput. To save energy, the processing operations of the user nodes should be transferred to intelligent base stations with a reliable power supply or general intelligent radio space [19]. Cooperative relay communication and network densification are also crucial for reducing the single-hop signal propagation gap and mobile node transmission power [20], [21]. Long battery life in 6G is achieved through a mix of divergent energy-harvesting technologies that collect energy not only from surreal RF waves but similarly from sunlight and micro-vibrations [22], [23]. Wireless power charging over a long distance could also be a viable option for extending battery life [24], [25]. Furthermore, decentralized laser charging is a system that might give 2-W power to mobile devices safely over a distance of up to 10 meters [1].

Finally, we can say that the real breakthrough will come when considering frequencies beyond 100 GHz. The large bandwidth available here is of particular interest, first in the D-band at about 140 GHz and then in the 300 GHz range. Of course, they still exist. Some major challenges require technology solutions

that can break the limits of silicon. Potential approaches also include hybrid silicon and III-V technologies, aiming to achieve the $F_{\max}=1$ THz transistor and very small antenna cointegration at the wafer or packet level. So far, the convergence of these solutions has not been found, but some trends are emerging. The CEALeti team is considering two specific aspects. In terms of transceivers, to avoid high bandwidth conversion and power consumption, channel bonding/aggregation has attracted people's attention and the 100Gbps performance of more than 16 channels has been proven. In terms of antennas, the focus of the work is to use a single transceiver/FEM transmission set, rather than the more classical phase shift architecture, which requires one transceiver/FEM per mosaic.

3. CONCLUSION

This research has taken a thorough and in-depth look at the fundamental key performance indicators that will be needed in the 6G era between 2025 and 2035. This study began by highlighting some of the most important aspects and implications of 6G wireless networks. The study then went over the key differences between 6G and 5G in terms of KPIs, such as max data rate, mobility needs, linked devices/Km², area traffic capacity, latency, dependability, network spectrum, and energy efficiency. 6G will upgrade and expand 10-100 times the data speed, larger system capacity, higher spectrum efficiency, lower latency, wider and deeper coverage, and fully empower the creation of a ubiquitous intelligent mobile society.

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