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6G TECHNOLOGY AND ITS FUTURE SCOPE

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Abstract: 6G is the sixth-generation mobile system standard currently being developed for wireless communications over cellular data networks in telecommunications.6G, the upcoming sixth-generation mobile system, is being developed to revolutionize wireless communications. As the next step after 5G, it promises to be significantly faster. One of its ambitious goals is to achieve one microsecond latency, making it 1,000 times quicker than the current one millisecond latency. While 6G is still in the research and development phase, its potential to transform connectivity is already generating excitement.

Index Terms - Radio Technology, Future, 4G,5G, 6G, Wireless Communication, Capacity, Latency.

I. INTRODUCTION

1.1 6G Technology

The 6G technology market is expected to facilitate large improvements in the areas of imaging, presence technology and location awareness. Working in conjunction with artificial intelligence (AI), the 6G computational infrastructure will be able to identify the best place for computing to occur; this includes decisions about data storage, processing and sharing The 6G technology market is expected to bring significant advancements in imaging, presence technology, and location awareness. By integrating with artificial intelligence (AI), the 6G infrastructure will smartly manage computing tasks, deciding the best places for data storage, processing, and sharing. It's important to remember that 6G is still in development and not yet available. While some companies are already investing in this next-generation wireless standard, we are still years away from having industry specifications for 6G-enabled products. Figure 1 shows what 6G technology might look like. The International Telecommunication Union (ITU) updates wireless standards every decade.

Figure 1: 6G Technology

Typically, each new generation of wireless technology introduces a gap in the "air interface," marking a shift in transmissions or coding. This is done so that older devices cannot simply be updated to the new generation, which would otherwise create a lot of "noise" and "spectrum pollution." Each new generation uses more advanced digital encoding that older devices can't handle, and they rely on wider airwave bands that were previously unavailable. Additionally, they feature highly complex antenna arrays that weren't possible to construct before.

Today, we're in the fifth generation, with the first standard for 5G New Radio (NR) developed in 2017 and now being implemented worldwide. Looking ahead, 6G technology will combine the latest in radio and fiber optics, delivering through line-of-sight connections. This means we won't have to rely on copper cables or worry about speed diminishing with distance from the exchange.

II. ARCHITECTURE OF 6G

A new 6G system architecture with the following distinct design criteria or goals in mind: cloud platform, simplification and sustainability, flexibility, programmability, specialization, robustness and security, and native integration of AI/ML capabilities. In Fig 2 represents the architecture of 6G technology. Figure 2: Architecture of 6G Technology

Figure 2: Architecture of 6G Technology

All those design criteria and goals need to be considered when the new 6G system architecture is being developed, while individual actors in the value mesh may have different priorities based on the use cases they are targeting. The 6G architecture will come with advanced domain automation functionalities providing orchestration and automation across multiple network domains, possibly spanning multiple stakeholders, multiple administrative domains and additional resources in the far edge and on premises beyond the traditional mobile network. A significant increase in compute and storage capabilities, for example, is required to store and process the massive amount of data to be collected for services like AI/ML, extended reality (XR) and the metaverse. A dedicated data and information architecture is being proposed to collect and expose the required information from the various data sources across the whole 6G system in an efficient manner. Also, it is crucial to determine the optimal placement and selection of those resources and services from an overall system performance perspective, while respecting service constraints and system KPIs/KVIs.

2.1 Six Key Technologies for 6G

Figure 3: 6 Key Technologies for 6G

Researching multiple technologies that we believe will define the 6G networks of the future: new spectrum technologies, network sensing, AI/ML-defined air-interface frameworks, security and trust and extreme connectivity. The 6G system architecture will act as the glue and fabric for these technologies, giving us the foundation to make more radical changes to the way we craft networks. In Fig 3 represents the most important key technologies of 6G.

2.2 How will 6G work?

6G wireless sensing solutions are expected to revolutionize how we measure and adjust frequencies. By selectively using different frequencies, 6G can measure absorption because atoms and molecules emit and absorb electromagnetic radiation at specific frequencies. This capability will have significant implications for public safety and critical asset protection in both government and industry, including:

- Threat detection
- Health monitoring
- Feature and facial recognition
- Decision-making in law enforcement and social credit systems
- Air quality measurements
- Gas and toxicity sensing
- Sensory interfaces that feel incredibly lifelike

These improvements will also enhance smartphones, mobile networks, and emerging technologies such as smart cities, autonomous vehicles, virtual reality, and augmented reality.

III 4G vs. 5G vs. 6G:

6G promises more than just faster speeds and greater data transfer, although it will deliver those too. Looking back at the evolution from 4G to 5G, we see significant advancements in wireless technology. Comparing 5G to 6G is more complex, partly because 6G is still about a decade away. Figure 4 illustrates the progression from 4G to 5G and beyond to 6G, highlighting the anticipated advancements each generation brings.

Figure 4: 4G vs. 5G vs. 6G

The following table 3.1 shows that the comparison issues of 4G vs. 5G vs. 6G wireless technologies

Table 3.1 Comparison of 4G vs. 5G vs. 6G

Issue	*4G*	*5G*	*6G*
Per Device Peak Data Rate	1GBPS	10 GBPS	1 TBPS
End-to-End Latency	100 ms	10 ms	1 ms
Maximum Spectral Efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Mobility Support	Up to 350 KM/Hr	Up to 500 KM/Hr	Up to 1000 KM/Hr
Satellite Integration	No	No	Fully
AI	No	Partial	Fully
Autonomous Vehicle	No	Partial	Fully
HR	No	Partial	Fully
Haptic Communication	No	Partial	Fully
THz Communication	No	Very Limited	Wisely
Service Level	Video	VR,AR	Tactile
Architecture	MIMO	Massive MIMO	Intelligent Surface
Maximum Frequency	6 GHz	90 GHz	10 THz

IV.6G TECHNOLOGY CAPABILITIES:

6G technology will revolutionize data transmission worldwide, enabling several key advancements:

- **Technology convergence:** 6G will integrate previously separate technologies, such as deep learning and big data analytics, into a cohesive system.
- **Edge computing:** 6G will enhance edge computing, ensuring high throughput and low latency for extremely reliable communications.
- **Internet of Things (IoT):** 6G is expected to support the machine-to-machine communication essential for IoT operations.
- **High-performance computing (HPC):** 6G will be closely linked with high-performance computing, supporting centralized HPC resources for advanced processing.

These innovations will enhance connectivity, making technology more efficient and integrated into our daily lives.

4.1. Features of 6G:

6G networks may coexist with 5G for a while and will be a significant improvement over previous generations in several ways. This is because 6G will offer the following differentiated features:

1. The use of new spectrum bands
2. Very high data transfer speeds
3. Ultra-low latency network functions
4. Greater support for machine-to-machine (M2M) connections
5. A focus on energy efficiency
6. Greater network reliability
7. The rise of new architectures
8. The use of AI and ML for optimal connectivity

4.2 Advantages of 6G Networks

6G networks are anticipated to offer the following benefits:

- **Enforces security**

Cyber-attacks are increasingly focusing on networks of various types. The sheer unpredictability of these attacks necessitates the implementation of robust security solutions. 6G networks will have safeguards against threats like jamming. Privacy concerns must be addressed when creating new mixed-reality environments that include digital representations of actual and virtual objects.

- **Supports personalization**

Open RAN is a fresh and evolving technology that 5G utilizes. However, Open RAN will be a mature technology for 6G. The AI-powered RAN will allow operators of mobile networks to provide users with a bespoke network experience based on real-time user data gathered from multiple sources. The operators may further exploit real-time user data to provide superior services by personalizing quality of experience (QoE) and quality of service (QoS). The operators may customize several services using AI.

- **Extends the capabilities of 5G apps**

This degree of bandwidth and responsiveness will enhance 5G application performance. It will also broaden the spectrum of capabilities to enable new and innovative wireless networking, cognition, monitoring, and imaging applications. Using orthogonal frequency-division multiple access (OFDMA), 6G access points will be able to serve several customers at the same time.

- **Drives the development of wireless sensing technologies**

The sampling rate refers to the number of samples obtained from a continuous signal per second (or as per an equivalent time unit) to form a digital signal. 6G's frequencies will allow for much faster sample rates than 5G. Additionally, they will provide dramatically increased throughput and data rates. Moreover, the utilization of sub-mm waves (wavelengths lower than 1 millimeter) and frequency selectivity is expected to accelerate the advancement of wireless sensing technologies. The network will become a repository of situational data by collecting signals reflected from objects and detecting their type, shape, relative position, velocity, and possibly material qualities. Such a sensing method may facilitate the creation of a "mirror"

or digital counterpart of the actual environment. When combined with AI/ML, this information will provide fresh insights into the physical world, thereby rendering the network more intelligent.

- **Inspiring new technology innovations**

6G will benefit society as a whole since new technological innovations will emerge to support it. This includes:

More advanced data centers: 6G networks will generate significantly more data when compared to 5G networks, and computation will evolve to ultimately encompass edge and core platform coordination. As a result of these changes, data centers will need to develop.

Nano-cores that replace traditional processor cores: Nano-cores are anticipated to develop as a single computing core that combines HPC and AI. It is not necessary for the nano-core to be a tangible network node. Instead, it might consist of a conceptual aggregation of computing resources shared by several networks and systems.

- **Saves costs through reduced software dependency**

Software-defined operations are already being used by contemporary networks. Additional 6G components, like the media access control (MAC) and physical (PHY) layers, will be virtualized. Currently, PHY and MAC solutions require the deployment of specialized network hardware. Virtualization provided by 6G will lower the cost of networking equipment. Therefore, an immensely dense 6G rollout will become economically feasible.

- **improves cellular network penetration**

Among the many advantages of 6G networks is their vast coverage area. This implies that lesser towers are necessary to cover a given amount of space. This is useful if you want to construct towers where it showers regularly or where trees and vegetation abound. Additionally, 6G is intended to support additional mobile connections beyond 5G. This implies that there will be reduced interference between devices, resulting in improved service.

- **Optimizes indoor network usage**

The majority of cellular traffic today is produced indoors, yet cellular networks were never built to properly target indoor coverage. 6G overcomes these obstacles using femtocells (small cell sites) and Distributed Antenna Systems (DASs).

4.3 Disadvantages of 6G:

As with any new technology, there are also some potential disadvantages to 6G networks. For example, the increased speeds and reliability of 6G networks will require more energy, which could lead to higher energy costs for users. Additionally, the costs associated with building and maintaining 6G networks could be prohibitively expensive for some countries and regions.Finally, there is the potential for 6G networks to be used for surveillance and other nefarious purposes. This could lead to an increase in digital privacy issues and potential abuses of power.

V. CHALLENGES OF 6G TECHNOLOGIES:

With the high-speed development of telecommunication technology, all the industrial partners in telecom make an effort to promote the digital transformation. It can be seen that the 6G era is coming in the future. In Fig 5 represents the most important challenges of 6G. In the future, the intelligent network with end-to-end AI and perceptive capability will be able to help operators achieve the goal of energy saving

Figure 5: Challenges of 6G Technology

Compared to the 5G technology, what are the challenges and changes of 6G?

1. From the possibility to the certainty
2. Openness and customization
3. Artificial intelligence network
4. 100% Coverage
5. Terahertz communication
6. Perception and location
7. Make the best use of spectrum
8. Network security
9. Flexibility, redundancy and self-healing capability
10. Low-carbon transformation

VI. FUTURE SCOPE OF 6G NETWORKS:

Technologists, researchers, academics, vendors, operators, and governments worldwide are actively discussing the innovations, implementation, viability, and security concerns of 5G. About ten years ago, the term "Beyond 4G" (B4G) was coined to signify the need to advance beyond the LTE standard. At that time, it wasn't clear what 5G would look like, and only early prototypes were in development. The term B4G was used for a while to explore possibilities beyond 4G. Interestingly, the LTE standard continues to evolve, and 5G incorporates some aspects of it.

Figure 6: Future Scope of 6G Technology

Similar to how "Beyond 4G" (B4G) paved the way for 5G, "Beyond 5G" is seen as the path to 6G technologies that will surpass current capabilities and applications. The implementation of private 5G networks, involving LTE, 5G, and edge computing for enterprise and industrial customers, has laid the groundwork for 6G. Figure 6 illustrates the future scope of 6G.Next-generation 6G wireless networks will take connectivity a step further by creating a network of communications providers, many of which will be self-providers. This is similar to how photovoltaic solar power has enabled cogeneration within the smart grid. 6G could turn mesh networks from concept to reality, extending coverage beyond the reach of traditional cell towers.Data centers are already adapting to significant changes driven by 5G, such as virtualization, programmable networks, edge computing, and the simultaneous support of public and private networks. These advancements are setting the stage for the transformative potential of 6G.

For example, some business customers may want to combine on-premises RAN with hybrid on-premises and hosted computing -- for edge and core computing, respectively -- and data center-hosted core network elements for private business networks or alternative service providers. 6G radio networks will provide the communication and data gathering necessary to accumulate information. A systems approach is required for the 6G technology market that makes use of data analytics, AI and next-generation computation capabilities using HPC and quantum computing. In addition to profound changes within RAN technology, 6G will bring changes to the core communications network fabric as many new technologies converge. Notably, AI will take center stage with 6G.

Other changes 6G is likely to bring include the following:

- **Nano-core**. A so-called nano-core is expected to emerge as a common computing core that encompasses elements of HPC and AI. The nano-core does not need to be a physical network element. Instead, it could encompass a logical collection of computational resources, shared by many networks and systems.

- **Edge and core coordination.** 6G networks will create substantially more data than 5G networks, and computing will evolve to include coordination between edge and core platforms. In response to those changes, data centers will have to evolve.
- **Data management**. 6G capabilities in sensing, imaging and location determination will generate vast amounts of data that must be managed on behalf of the network owners, service providers and data owners.

VII. CONCLUSION:

6G is the next step in wireless technology and promises to transform what we currently know with 5G networks. As we start to compare 5G and 6G, businesses are already dreaming up innovative uses for 6G, even though it's still in development and not yet available. Looking ahead, the goal is to move into this new era of wireless technology and create groundbreaking inventions that will change the world. As soon as the next generation of wireless networks, i.e., 6G mobile network, reaches a broader area in the telecommunications industry, it is predicted that fascinating possibilities about speed and dependability will become a reality. Once 6G wireless networks become widely available, we'll see incredible advancements in speed and reliability. This new technology is expected to transform how we live and conduct business, opening up exciting new possibilities for the future.

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