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Comparison of 5G and 6G Wireless Systems and Proposing of 7G, A New Era

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***Abstract*—: Internet of everything (IoE)-based smart services are expected to gain immense popularity in the future and also which raises the need for next-generation wireless networks. The fifth-generation (5G) networks can support various IoE services, they might not be able to completely fulfill the requirements of novel applications and the sixth-generation (6G) wireless systems are envisioned to overcome 5G network limitations. In this article, compare 5G and 6G wireless systems, by exploring recent advances made toward enabling these systems. Also presents a complete understanding of variations between 5G and 6G wireless network architectures, the comparisons, and the evolvement through all these years. Then finally propose 7G systems, the 7G will be the most advanced generation in mobile communication. 7G (seventh-generation wireless) is the inevitable intelligent cellular technology and research is being done daily.**

Keywords*— *5G, 6G, 7G, Architecture, Wireless, Internet of Things, Internet of Everything,

I. INTRODUCTION

With the advent of telecommunication and the advancement of mobile network generations, inventive applications have been introduced. The remarkable upsurge of Internet of everything (IoE)- based smart applications has paved the way for the evolution of wireless networks. The term IoE refers to bringing together things, data, people and process, via emerging technologies to offer a wide variety of smart services and also the emerging IoE services include autonomous connected vehicles, brain-computer interfaces, extended reality, haptics, and flying vehicles etc. These services are mostly based on ultra-high reliability, high data rates, unmanned mobility management, and also long-distance communication. Fifth-generation wireless networks are envisioned to enable a wide variety of smart IoE based services. The 5G targeted tactile network is accessed via different approaches, such as simultaneous use of unlicensed and licensed bands, intelligent spectrum management, and 5G new radio, that will enable different smart applications .5G has several inherent limitations and difficulties to completely fulfil its target goals until now. The development of different datacentric, automated processes are proving to exceed the capabilities defined by key performance indicators of 5G wireless networks. For instance, several applications, such as haptics, telemedicine, and connected autonomous vehicles, are intended to use long packets with ultra-high reliability, high data rates etc. Such packets with ultra-high reliability and high data rates. Such applications violate the notion of generally using short packets for ultra-reliable low-latency communication (URLLC) in 5G networks. The next generation of virtual and augmented reality-based application, such as holographic teleportation will require microsecond-level latency and Tbps -level data rates. Such a type of requirements seems difficult to be fulfilled by 5G networks.

To overcome the limitations of 5G networks sixth-generation (6G) wireless systems must be developed. 6G will use artificial intelligence (AI) as an integral part, that has the capability to optimize a variety of wireless network problems. Typically, mathematical optimization techniques are used to optimize wireless network problems, to solve these mathematical optimization problems, use convex optimization schemes, matching theory, game theory, heuristic, and brute force algorithms. However, these solution approaches might suffer from the issue of high complexity, which in turn degrades the capacity of the system. Machine learning is capable of optimizing various complex mathematical problems including the problems that cannot be modeled using mathematical equations.6G networks will be able to use higher frequencies than 5G networks and provide substantially higher capacity and much lower latency compared to 5G. One of the goals of the 6th generation internet is to support one microsecond latency communications.

The 6G technology market is expected to facilitate large improvements in the areas of imaging, presence technologies and location awareness technologies. Working in conjunction with artificial intelligence (AI), the 6G computational infrastructure will be able to identify the best place for computing, this includes decisions about data storage, processing and sharing. It is important that 6G is not yet a functioning technology. Some of the vendors are investing in the next-generation wireless standard, industry specifications for 6G-enabled network products. The 6G mobile wireless network will support local voice coverage and many other services. The Seventh-Generation (7G) will be the most advance generation in mobile communication but there will be some research on demanding issues like the use of mobile phone during moving condition from one country to another country. Because satellite is also moving inconstant speed and in specific orbit, the standards and protocols for cellular to satellite system and for satellite-to-satellite communication system. The 7th Generation can only

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be true when all standards and protocols are defined and may be this is possible in next generation after 7G and can be named as 7.5G.

II. 5G WIRELESS SYSTEM

A. *Working of 5G*

The requirements expected from 3G and 4G were not met by the features these networks possessed. Hence a new, exceptional, and progressive network was to be launched. To bring a radical adjustment in the designing of 3G and 4G networks, the 5G network architecture was introduced. A new development called the Internet of things or IoT will take things to the next level, enabling communications to take place between different devices. IoT will be a colossal part of 5G and will develop not only connected devices at home but devices from all around the world from all different sectors and industries. To communicate efficiently indoors and outdoors a network was required that overcame the interferences and transmitted excellent signals so all people can communicate without any hindrances, 5G was designed to provide both indoor and outdoor schemes. The Fifth Generation will have a better network capacity for bringing different technologies that include a better Quality of Service (QoS) and new features as compared to 4G, but in hindsight, 5G will evolve and improve the everyday living standards.

B. *5G Features*

A few of the changes and advancements that 5G is going to bring are:

- 5G is provide the remote management.
- 5G allows enormous broadcasting of data.
- High resolution is offered in many devices.
- 5G connectivity speed is 50 Mbps and up.
- Support Virtual Private Network (VPN).
- Applications that aggregate AI can also be obtained by 5G.
- Cloud Computing, the future of Storage.
- Nanotechnology.
- Internet Protocol or IP Platforms.

The terminals that are a part of 5G consist of modulation schemes and radios that are defined by software. These terminals will be strong and capable to access many wireless technologies and will have the capability to associate many different flows from disparate technologies, and every terminal will be culpable to shaft user-mobility.

C. *5G Concepts*

5G is based on 3 concepts that are All IP Platforms, Cloud Computing, and Nano Technology.

1. All IP Networks

They are packet-based networks where data is conveyed the same way and is still autonomous of the transport and access to technology. Consistent services will be provided to the users by the derived mobility it possesses. Cable-Network services like VOIP (Voice over Internet Protocol) and SIP (Session Initiation Protocol) are facilitated after the shifting to packet cable standards. The Core- Network in the voice service from the circuit switching should be shifted to VOIP.

2. Cloud Computing

Is a technology where information, pictures, and data are shared with the help of the Internet. Cloud is famous because of its storage capacity. It is an amorphous technology that is rapidly used by big and small companies all over the world. A user can access to download or upload data anytime anywhere with a good internet connection.

3. Nano Technology

A functional system engineering where the molecular scale lies between 0.1 nanometers to 1.0 nanometer. Different technologies, devices communicate using different links that are responsible to perform specific functions. Each links performance changes with the change of the IoT device and the functionalities that alter accordingly.

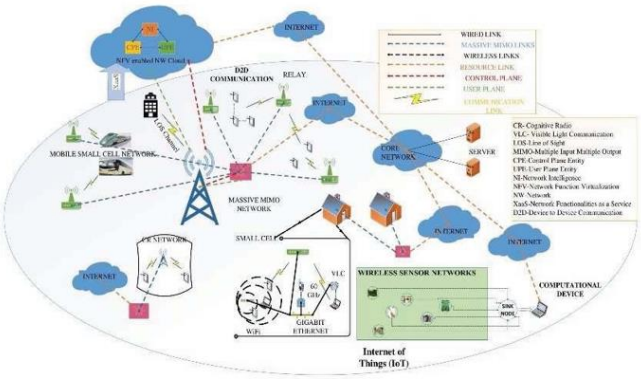

Fig1. 5G Network Architecture

D. *Technologies used in 5G*

The pivotal technologies that differentiate 5G from the previous generations are proving to be a crucial part of this technology.

1. Massive MIMO

Just like MIMO but it is an evolved technology that is now used by 5G. Hundreds of antennas serve tens of user terminals at the same time in one single frame. The assistance of MIMO is derived by Massive MIMO on a large scale. This technology hinges on the phase-coherent signals gathered from the antennas located at the base stations but the processing of these signals is said to be easy. Massive MIMO features are:

- Latency is declined if there is an interference.
- Multiple access layer is made easy.
- Costly equipment and high power are not necessary.
- The strength is heightened as much as there are man- made interference and predetermined interference.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

2. Spectrum Sharing

Bandwidth and spectrum sharing is required for a better and advanced network. Spectrum sharing contributes to reliability and financing positive assurance for cellular mobile broadband systems. The spectrums are available in two forms, vertical and horizontal. Networks that use spectrum sharing are said to be balanced and well-functioning.

3. Ultra-Dense Network

The heterogeneous network means a network that connects various devices and computers, different protocols and operating systems will be required to fulfill the demands of increased traffic due to the increased number of users. To accomplish the ultra-dense networks a heterogeneous network is required. If there is an increase in the challenges faced by heterogeneous networks such as backhauling and interference, an extra layer of functionalities will be added to increase the performance of the networks.

4. Millimeter-Wave Solution

The increased demand for technology has escalated the use of wireless communication that will eventually lead to a growth in the congestion which can occur due to the high use of the internet. To combat these situations technologies where data rates triple must come up with solutions to increase these rates. These are possible when the antennas are steerable, and the millimeter-wave solution comes in to solve backhaul and communication problems. The millimeter- wave band coincides with a wavelength ranging from 10 millimeters at 30 GHz and decreasing to 1 millimeter at 300 GHz.

E. 5G Challenges

5G has faced some challenges after its deployment in the field of wireless technology. These challenges have been discussed along with their enablers and design principles.

1. End to End Latency

End-to-End latency refers to the amount of time needed for a packet to be broadcasted across a network from a certain source to a destination. Applications required for safety for houses, cars, vehicle-to-infrastructure (V2I), and vehicle- to-vehicle (V2V) communications need accuracy, authenticity, high availability for request and response cycles that take place. The networks used in applications must achieve the aim of E2E one millisecond latency with high reliability.

2. QoE

Quality of Experience explains how much a user is understanding and enjoying the application. It is user-specific and application-based. If the QoE of a device is too low and the user experiences dissatisfaction, then the quality needs to be worked on and if the QoE of an application is too high it culverts the resources used i.e. the battery of the device will drain out and will put a lot of strain on the transport network and the base station power.

3. Large Number of Connections

The diversity of devices must be taken into consideration. The growth of wireless technology has an unlimited number of connected devices and the numbers rise every day. Some devices are always-on connectivity, for example, the sensors and CCTV Cameras while other devices are not, for example, phone internet. Bolstering the diversification of devices and services is required to be done in an extensible and adequate manner.

4. Cost of 5G

Costs for the deployment maintenance, management, and sustainability of networks is necessary to bring improvements in the network. A cost on which service provider is viable should be introduced by 5G where users are happy to pay the price.

5. Data Rate and Systems Capacity

The thousand-fold increase in data rates and traffic clarifies how more capacity is required in the radio access networks. The willingness of customers to only pay for the data services and not for pricing models, will not help to conceal the data volume of increasing traffic.

III. 6G WIRELESS SYSTEMS

A. Working of 6G

6G (sixth-generation wireless) is the successor to 5G wireless technology. 6G networks will be able to use higher frequencies than 5G networks and which provide substantially higher capacity and much lower latency. One of the goals of the 6G network is to support one microsecond latency communications. This is 1,000 times faster than one millisecond throughput. 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, the 6G computational infrastructure will be able to identify the best place for computing to occur. This will include decisions about data storage, processing and sharing. It is important that 6G is not yet a functioning technology. While some vendors are investing in the next-generation wireless standard and industry specifications for 6G-enabled network products remain years always.

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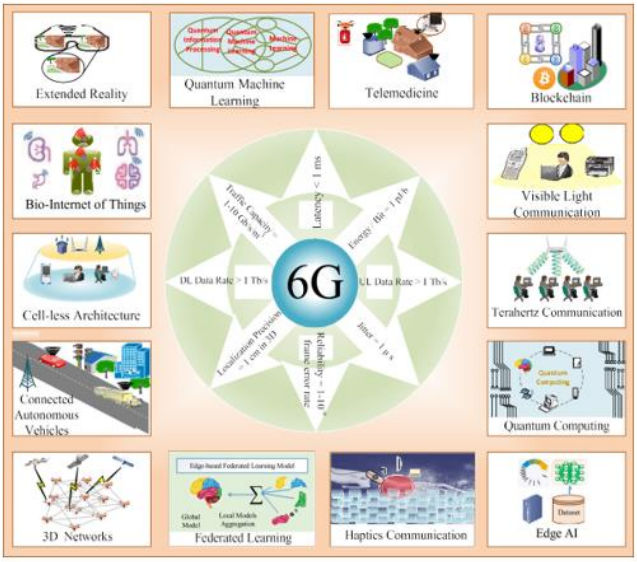

Fig2. 6G Wireless System Overview

B. 6G Features

- 6G is much Higher Data Rate.
- 6G has Lower Latency.
- Network Reliability and Accuracy.
- Emphasis on Energy-Efficiency.
- Machines as Primary Users.
- AI-Driven Wireless Communication Tools.
- Personalized Network Experience.

C. Taxonomy

a. Key Enablers

A 6G system will use a wide variety of computing, communication, networking, and sensing technologies to offer different novel applications. The key enablers of 6G wireless systems consist of edge intelligence, homomorphic encryption, blockchain, network slicing, AI, photonics-based cognitive radio, and space-air-ground-integrated network. Here network slicing was proposed in 5G as a key enabling networking technology, its true realization is expected in 6G. Network slicing based on software defined networking (SDN) and network function virtualization (NFV), which employs shared physical resources to enable slices of different applications. The process of network slicing was involving the optimization of a variety of network parameters.

b. Use Cases

5G wireless networks provide a wide variety of smart services, several services disrupt the vision of 5G design. Generally, 5G use cases have three main classes, such as URLLC, enhanced mobile broadband, and massive machine-type communication. However, several new applications are disrupting the vision of 5G use cases and need new use cases. For instance, consider XR (i.e., combining mixed reality, augmented reality, and virtual reality) and brain computer interaction that requires 5G-eMBB high data rates, low-latency, and high reliability. Therefore, must define new use cases for these emerging applications. The novel 6G services are haptics, autonomous connected vehicles, massive URLLC, human-centric services, bio-Internet of things (B-IoT), nano-Internet of things, and mobile broadband reliable, low-latency communication.

c. Emerging Machine Learning Schemes

Machine learning is considered one of the key drivers of 6G. Machine Learning recently elicited great attention in enabling numerous smart applications. In 6G, ML is expected to not only enable smart applications but also provide intelligent medium access control schemes and also intelligent transceiver. Hence, ML can be one of the fundamental pillars of the 6G wireless network. Generally, divide ML into several types: traditional machine learning, federated learning, meta learning, and quantum machine learning.

d. Communication Technologies

The 6G system will use novel communication technologies to enable various smart applications. These communication technologies involve terahertz communication, quantum communication, 3D wireless communication, visible light communication, nanoscale communication, and holographic communication. Recently, 3GPP has developed a new radio access technology; namely, 5G new radio using sub-6 GHz and mm Wave bands for enabling high data rates. To enable further higher data rates, 6G will use terahertz bands in addition to mm Wave bands. Generally, terahertz communication uses frequencies from 0:1 to 10 terahertz and also characterized by short-range, medium-power consumption, high security, and robustness to weather conditions.

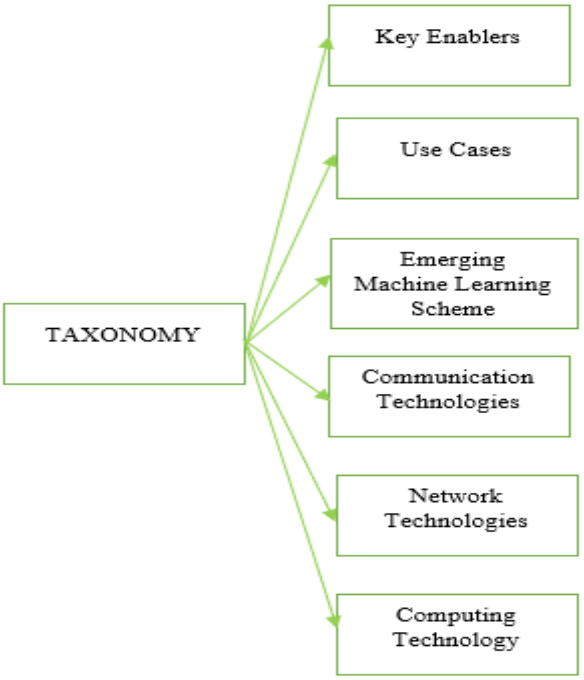

Fig3: Taxonomy of 6G Wireless system

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

e. Networking Technologies

Novel networking technologies for 6G consisting of nano-networking, bio-networking, optical networking, and 3D networking. The operation of the N-IoT technique is based on molecular communication. Different materials, such as graphene and meta materials can be used to build nanometers-range devices. B-IoT using biological cells are used for communication by using IoT. B-IoT and N-IoT are two integral parts of future 6G smart services.

f. Computing Technologies

A 6G system involves a wide variety of sources of different smart applications that will generate an enormous amount of data. High-performance computing and quantum computing must be used to enable the intelligent data analytics. Quantum computing is expected to revolutionize the field of computing by enabling higher speeds. The key feature of quantum communication is secure channels, here every channel carries its distinct security protocols. These features of security in addition to ultra-high speed make the quantum computing preferable for secure 6G smart applications. Other than quantum computing technology intelligent edge computing is required for 6G to provide intelligent on-demand computing and on-demand storage capabilities with extremely low latency to end nodes.

D. 6G Challenges

1. AI-Based Adaptive Transceivers

A typical 6G transceiver is expected to have numerous tunable parameters. These parameters can be adaptively tuned via machine learning algorithms. For instance, consider the training of a deep Q-learning agent for intelligent caching in XR applications. The Q-learning agent can be trained in two ways: traditional machine learning and federated learning. Traditional machine learning requires shifting of data from end devices to the edge/cloud server for the training of the deep Q-learning agent deployed at the edge/cloud server. The sending of data from end devices to the edge server has a substantial cost in terms of wireless communication resources. By contrast, federated learning can be used to train the deep Q-learning agent efficiently by reducing wireless resource usage through sending only model updates to the edge/cloud server. Similarly, federated learning can be used to enable intelligence in an adaptive transceiver.

2. Intelligent Wireless Energy Harvesting

Enabling 6G applications sustainably requires the use of energy-efficient devices and renewable energy sources. Wireless energy harvesting can be one of possible ways to enable sustainable operation of 6G. Wireless energy harvesting covers numerous harvesting scenarios: dedicated radio frequency harvesting sources, interference-aware harvesting, and ambient sunlight harvesting. However, substantial variations exist in harvested energy for these wireless energy- harvesting sources. Therefore, an intelligent power control must be developed for energy-harvesting devices. Traditional power control schemes for energy-harvesting devices assume the known system state, but this information is not available practically. Machine learning can be used to predict the future system state and address these challenges. In reinforcement learning have one of the possible solutions with unknown statistical knowledge and observable current system state. But it has a limitation of use in only finite system states. Another approach to cope with this limitation is the use of Lyapunov opportunistic optimization and online-learning- based schemes.

3. Decentralized and Secure Business Models

Novel decentralized, secure business models must be designed to enable a cost-effective interaction among various geographically distributed players in 6G economically and securely. A centralized business model will offer high latency, which is undesirable for ultra-high-speed 6G smart services. Therefore, new distributed business models for 6G must be developed. Different schemes can be used for security in business models. One of these schemes can be a blockchain-based secure service brokering between suppliers and providers.

4. Intelligent Cell-Less Architecture

A 6G system will be based on a true cell-less architecture to avoid handover issues and offer seamless communication with improved quality of experience to end users. Therefore, a novel architecture for 6G enables a seamless interaction between numerous communication technologies, such as visible light communication, millimeter-wave communication, and terahertz communication. All access points/base stations of different communication techniques should serve the users in collaboration to improve the signal-to-noise-plus-interference ratio. Intelli- gent operation of 6G can be enabled via intelligent cognitive radio with self-sustaining, adaptive features. A software- defined cognitive radio using machine learning can be used to perform several intelligent operations: self-protection against interference, self-fault recovery, self-optimization, and self-management. One possible way to enable software-defined cognitive radio is the use of deep Q-learning. Quantum machine learning can also be used to enable fast learning of machine learning models.

5. Distributed Security Models

A 6G wireless system will use AI to enable different smart applications and networking functions. Traditional machine learning models migrate user data to the edge/cloud server for training the learning model. Therefore, homomorphic encryption, which enables sending of encrypted data to the edge/cloud server rather than un-encrypted data, can be used to address this type of privacy concern. A novel distributed

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ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

authentication scheme must be proposed for 6G wireless systems. Distributed ledger technology-based authentication schemes can be one of the possible solutions for 6G-distributed authentication.

6. Reconfigurable Smart Reflecting Surfaces-Enabled 6G

To enable 6G with high capacity using millimeter-wave and terahertz communication, we can use massive multiple-input-multiple-output (MIMO) with antenna arrays for meeting increasing demands in capacity. Although an increase in frequency reduces the scattering and diffraction effect, it suffers from the blocking of electromagnetic waves by buildings. Additionally, high- frequency communication suffers from significant path loss. Coping with the aforementioned issues, we can use reconfigurable smart reflecting surfaces. A typical reconfigurable smart reflecting surface is comprised of several reconfigurable reflecting elements that can reflect impinging electro-magnetic waves.

IV. COMPARISON OF 5G AND 6G

The 5G network is barely commercialized with only few places enjoying its unparalleled benefits and have taken a step forward to research on the upcoming wireless technologies. On the research phase, it is being addressed as 6G follows the tradition from previous networks and keep it as simple for now. In this article explain the following differences between 6G and 5G networks.

- **Use of different spectrum**

5G and 6G use wireless spectrum of higher range for data transmission faster than other networks such as 2G, 3G and 4G. When comparing 5G vs 6G, the former one is allocated for low band frequency 6 GHz and high band frequency 24.25 GHz. The latter one is operative at the frequency range 95 GHz to 3 THz. Since, different spectrum is used, 5G vs 6G technology can have multiple use cases for the variety of industrial sectors to enhance their efficiency.

- **Faster than 5G technology**

Taking into the performance factor, 6G will contribute to higher performance which is better than newly deployed 5G wireless networks. Operating at terahertz frequency bands, a peak data rate of 1,000 gigabits/s having air latency less than 100 microseconds will deliver on 6G. When researched about 5G vs 6G network speed, 6G speed is expected to be 100 times faster than 5G with enhanced reliability and wider network coverage.

- **6G wireless accelerates IoT after 5G**

Internet of Things (IoT) is becoming a reality on today with the implementation of 5G based solutions following extensive 5G network testing which is not possible with previous networks like 4G LTE due to poor planning of frequency applied. Frequencies used were too narrow and crowded for transmitting data required by smart devices to get accurate results. This is where 5G filled in the gap and moving ahead with 6G expect to connect ten times more devices per square kilometre with increase in number of connected devices in the upcoming years.

- **Low latency in both G's**

The time taken by a packet of information that transmitted over a frequency is called latency. 4G networks had a latency of about 50 milliseconds whereas 5G networks had ten times lower latency than 4G networks i.e., 5ms. With 6G network, latency will slip down to range from 1millisecond to 1microsecond, lowering latency to five times than that of fifth-generation network making massive data transmissions possible in less than one second.

Features	**5G**	**6G**
Frequency Bands	• Sub 6 GHz • mm wave for fixed access	• Sub 6 GHz • mm wave for mobile access m exploration of THz bands (above 140 GHz), • Non-RF bands (e.g. optical, VLC) etc.
Data rate	• 1 Gbps to 20 Gbps	• 1 Tbps
Latency (End to End Delay)	• 5 ms (Radio: 1 msec)	• < 1 ms (Radio: 0.1 msec)
Architecture	• Dense sub 6 GHz smaller BSs with umbrella macro BSs • Mmwave small cells of about 100 meters • Cell free smart surfaces at high frequencies • Temporary hotspots served by drone mounted BSs or tethered Balloons. • Trials of tiny THz cells	• Cell free smart surfaces at high frequencies (mmwave tiny cells are used for fixed and mobile access) • Temporary hotspots served by drone mounted BSs or tethered Balloons. • Trials of tiny THz cells (under progress)
Application types	• eMBB (Enhanced Mobile Broadband) • URLLC (Ultra Reliable Low Latency Communications) • mMTC (Massive Machine Type Communications)	• MBRLLC • mURLLC • HCS • MPS
Device types	• Smartphones • Sensors • Drones	• Sensors & DLT devices • CRAS • XR and BCI equipment
Spectral and energy efficiency gain	• 10 x in bps/Hz/m^2	• 1000 x in bps/Hz/m^3
Reliability	• 10^{-5}	• 10^{-9}
Localization Precision	• 10 cm on 2D	• 1 cm on 3D
User experience	• 50Mbps 2D everywhere	• 10 Gbps 3D everywhere

Table 1: Differences between 5G and 6G

V. 7G WIRELESS SYSTEMS

7G networks will be able to use higher frequencies and provide substantially higher capacity and much lower latency on communication. The 7G will be the most advance generation in wireless technology and mainly research on mobile communication network. It is like the 6G for global

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coverage and it will also define the satellite functions for mobile communication. But in 7G, there will be occurring some research on demanding issues like the use of mobile phone during moving condition from one country to another country, because satellite is also moving in constant speed and specific orbit, the standards and protocols for cellular to satellite systems and for satellite-to-satellite communication systems. The dream of 7G can only be true when all the standards and protocols are defined. May be this is possible in next generation after 7G and is named as 7.5G. There is another way, which is direct to HD video broadcasting for news gathering purpose likewise. It can be the best solution of cost on lower-level users.

A. 7G Mobile communication system

7G mobile network is like the 6G for global coverage and it will also define the satellite functions for mobile communication. In satellite system, the telecommunication satellite will be for voice and multimedia communications; navigational satellite for global positional system (GPS) and earth image satellite for some extra information like weather update. The 6G mobile wireless network will support local voice coverage and various services. The 7G will be the most advance generation in mobile communication. The dream of 7G can only be true when all standards and protocols are well defined. May be this is possible in next generation after 7G and is 7.5G

B. 7G Space Roaming/Handoff System

The 7G system can be supported by the global navigation satellite system, the telecommunication satellite system, the earth image satellite system and also the 6G cellular system. The global navigation satellites systems are essentially determining a use's position. The telecommunication satellite system can have to supply the voice and multimedia data for user's communication requirement. The earth image satellite system consists of the weather information as extra service for mobile users and the 6G cellular network system can be a wireless local network system to supply local voice and multimedia data services. Comparing with the satellites the cellular base stations are much cheaper and stable. The satellites are expensive and to do movement to cover larger area. In fact, these satellites are constantly moving at speeds of 7,000 miles an hour, which are making two complete orbits in less than 24 hours. So, the handoff/roaming must happen between each satellite. Any two different satellite systems are necessary for handoff/roaming when the mobile users moving from one country to another country and this kind of handoff/roaming is space handoff/roaming.

VI. CONCLUSION

The world of wireless telecommunications is rapidly evolving day by day. The last few years have witnessed a phenomenal growth in the wireless industries. Their current development is the outcome of various generations. In this paper review the various generations of wireless technology, such as 5G, 6G and 7G. Here present features, working, concepts, technologies and challenges of 5G wireless system. Then presents the features, working, taxonomy and challenges in the 6G wireless system. Analyse the 5G and 6G wireless system and make a table to mention various differences between these two systems. Finally presents 7G wireless system that will able to use higher frequencies and provide substantially higher capacity and much lower latency on communication. The 7G will be the most advance generation in wireless technology and mainly research on mobile communication network. In future it is essential to research 7G system deeply and propose advantages compared to other wireless system.

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