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Roadmap from 4G to 6G in Smart Cities Impact and Challenges

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Abstract: The world is now turning towards automation also the use of virtual reality is expanding day by day, the need for faster and reliable communication has been increased. This technology will play a key role towards the development of Smart Cities, where government is majorly focusing. The urge of quicker and more secure communication (wireless) is making us switch towards the 6G or sixth generation communication. To the benefit of its citizens and businesses, a smart city is a location where the traditional networks and services have been enhanced via the use of digital and telecommunication technology. Infrastructure, social capital, which also includes traditional skills and community institutions, and digital technologies are all combined in smart cities to promote sustainable economic growth and provide a desirable environment for all residents. By 2035, the publisher believes that as smart city infrastructure develops, 6G will be a crucial component of communications, applications, content, and commerce in smart cities. We go over the progress of beyond 5G and advanced 5G features in order to forecast important 6G requirements and showcase 6G potential. In comparison to 5G, we will also discuss 6G scenarios, requirements, and technology components. There are lots of challenges associated with 5G's wireless communication network one of them is limited data speed. We will also be focusing on these challenges associated with technology and also the plans to use this technology towards the development of smart cities. The 5G wireless communication network is currently facing the challenge of limited data speed and billions of data-intensive applications are used. To resolve this problem many developers and researchers are working on advanced technologies so that they can consummate the wireless service demands. So that we can shift ourselves from 5G to 6G and fulfil our expectations towards smart city. In addition, there are varied use cases of the wireless 6G technology in education, media and entertainment, tourism.

Index Terms: Smart City, Technological development, 1G, 2G, 3G,4G, 5G,6G.

1. Introduction

The new generation that is 6G is focusing on how to establish connection and monitor more than millions of devices from macro to micro and further to nano in our upcoming digital future. Extreme reliability can be achieved with lightning-fast speed. 6G will serve us for years by creating a framework which is worldwide wireless intelligence [1]. With the help of 6G our future will be boosted by innovations that act as grooming technologies in several domains come together with an exhilarating pace. 6G will contribute in improving privacy and security, transportation, overall heath (global), logistic and many more things. These all advantages will definitely add contribution in building smart cities. The Internet of Things, Automotive Energy, High-speed Digitalization, AI, Data Analytics, Satellite, Optics, and Cybersecurity are only a few of the crucial correct solutions [2]. Mobility, connectivity, electricity, water, platforms, monitoring/control, performance management, predictability, and forecasting are all interconnected systems and resources. Large amount of data can be sensed by 6G in a faster way also it computes and controls them in a feasible way because of which we get better experience.

In1980s the first-generation cellular networks were introduced that was known as 1G. Since, then a lot of significant developments have been made in networking and telecommunication technology during the 2G, 3G, and 4G mobile data networks. 5G (fifth generation) has been in the deployment phase since 2020, and it will continue to develop on a technology platform until 2025, with comprehensive coverage. The cloudification of networks with micro service-based architecture is the most outstanding aspect of fifth generation wireless communication. In several countries with billions of 5G customers the 5G (fifth generation) mobile communication technology is now widely available [3]. That's why it's right time for business and academia to focus on the upcoming new generation.

There are many challenges associated with upliftment of wireless communication like in past few years the overhaul filled with instabilities and variability by mobile internet because of the specific features of Internet Protocol. If we look at 4G era the subscribers were easily satisfied by the services offered by 4G. The user's experience when viewing movies and purchasing online is unaffected by minimal network delay and packet loss. Contrarily, 5G and 6G networks offer high levels of dependability because it is now easier for us to make online payments with respectable security, which necessitates the assurance of delivering low latency [4].

In order to provide the end-to-end network services capabilities promised by SLA (Service-level agreement), network segmentation, MEC (Multi-access edge computing), and other pertinent technologies are implemented in 5th generation [5]. In order to rethink many scenarios across a variety of industries, developers are hoping and concentrating more on reducing the uncertainties of network services in the 6G era.

As sharing and openness are two key aspects of the internet that enable its growth, customization and openness are the second crucial point. In contrast to the use of specialized technologies, the operation of mobile communication networks slows evolution to some degree. As we move into the fifth generation, the integration of CT and IT should be positively pushed by mobile networks to explore new innovative applications in all potential businesses. This will help all industries move into a digital world. The capacity to customize and be open will advance in the sixth generation, which can support agile services and provide more freedom with APIs (Application Programming Interfaces) for industry customers to fulfill the demands of creating custom networks and applications.

AI (Artificial Intelligence) has been already booming in various domains such as voice identification, automated translation, AI images identification and many more. Higher requirements of network latency, reliability and user services are needed in development of network services. The more challenging and complicated work in network is to maintain and enhance the network KPIs (Key Performance Indicator) by traditional operations. The developers are trying to introduce AI in network so that they can overcome the shortcomings and facilitate intelligent transformation and network automation [6]. To exert the value of AI engine at maximum massive data and computing resources are required. Interaction between network and AI is mandatory in 5G and 6G network.

The most important and essential part is to provide 100% coverage to users. We can lead a very easy and convenient life with a mobile phone today, but there are more than over three billion people all over the world who cannot make use of internet. In remote areas it is more difficult for the service providers to establish their base station and optical fiber cables in addition geographical condition of such areas are unsupportive.

So, to overcome this problem deployment of space-earth integration is very important in 6^{th} generation to achieve the target of 100% coverage. A base station that can fully provide network signals to far places should be installed on a LEO satellite's platform in order to construct a space-Earth integration network. This solution investigates the potential of numerous new applications [7]. 6^{th} generation uses multi-connectivity and cell-less architecture. Perfect scheduling is needed for smooth mobility and integration of various kinds of links like VLC (VideoLAN Client), THz, mmwave (millimeter wave), sub-6GHz. UE (User Equipment) connect to the RAN (Radio Access Network) not to a single cell in cell-less infrastructure. The main obstacle here is to construct new network architecture.

For communication part 6G uses THz (Terahertz) frequencies, and therefore the disadvantages of THz can be considered as drawbacks of 6G wireless technology. The THz frequency refers to the amid between 0.1 to 10 terahertz EMW (Electromagnetic Waves) with a wavelength ranging between 30 to 3000 micrometers [8]. In space communications THz waves are widely used specifically for use between satellites. Terahertz signal is highly sensitive to the contour which has significant impact on coverage. Large free space fading can be incurred by lower frequency THz. Ultra-large-scale signal transmitter (antenna) requires massive quantitative high resolution and high bandwidth which is considered to be a major challenge. In designing low cost and low power 6G devices processing power is another big challenge. For part of its communication 6^{th} generation make use of visible light frequencies, hence disadvantage of VLC can be considered as drawback of 6G wireless technology. And we know that wavelength of visible light ranges from 390 to 700 nm. To manage high number of terminals and network equipment energy consumption should be inversely proportional to efficiency (in other words in less energy we can obtain high efficiency). So, to fulfill this requirement terminal equipment circuitry and communication protocol stack design along with network is a major challenge. To handle this requirement energy harvesting are used. The known challenges with 6G technology are relatively negligible. 6G technology is highly expensive as compared to previously used technology [9]. The most highlighted issue of 6^{th} generation technology is its compatibility issues with older devices which is not at all user friendly as they are interested in using 6G technology but as devices are not supporting it, they are unable to use it. Also, developers believe that this could cause issues in far future when it will be widely used around the globe on regular basis. Humans can be negatively affected by the acceptance of 6G technology. Like disclosure of high frequency radiation can affect human health and can cause serious medical issues like ADHD, PTSD, autism, experience dizziness, nausea, blurred vision OCD (obsessive-compulsive disorder) and headaches. Also, RF (radio

frequency) released from mobile phone can cause deadly disease like cancer. As many scientists have proposed that long-term use of mobile phones can affect some parts of human cells. The following fig-1 shows the phases for the development of new technologies [10].

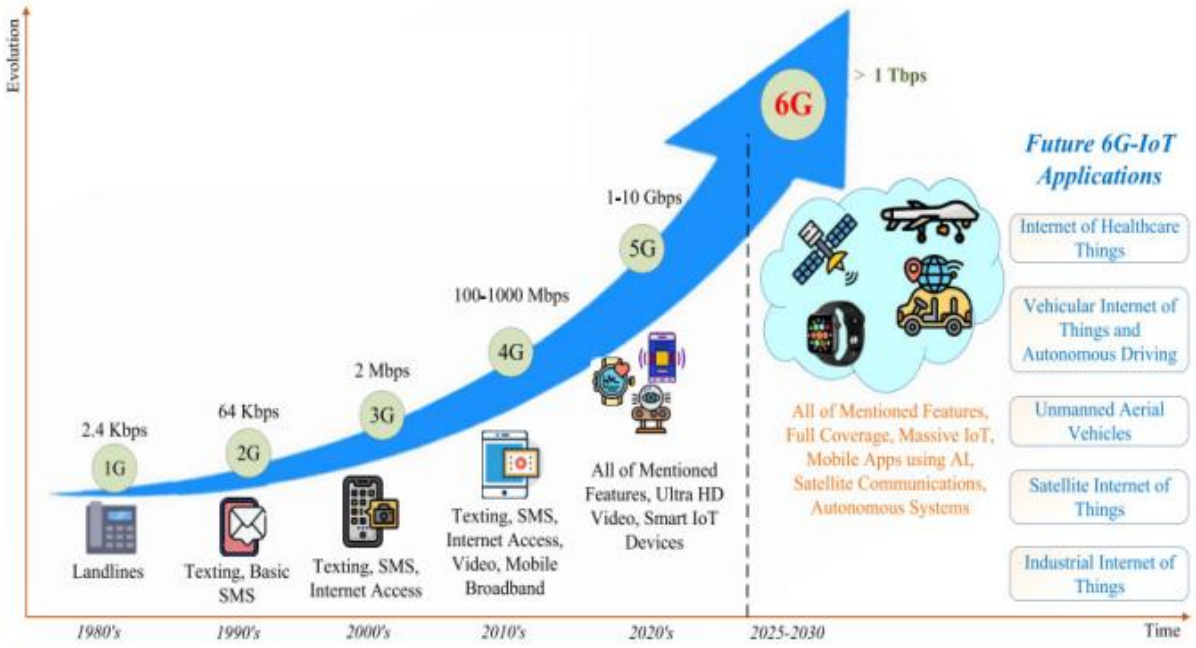

Fig.1. Development of New Technology

The major research objectives of the paper are –

1. Exploring the challenges associated with the technological implementation of 6G technology.
2. Investigating the influence of 6G technology on smart cities.
3. Discussing emerging technologies for the development of smart cities.
4. Examining the status of work done in this area.
5. Understanding the impact of 6G technology on technological implementations.
6. Analyzing the applications of 6G technology in smart cities.
7. Explaining critical energy-efficient 6G IoT trends in smart cities.

Rest of the paper is structured as follows Section 2 discusses about the Challenges on Technological Implementations, Section 3 discusses about the Influence of 6G on Smart Cities, Section 4 is discussion about the Emerging Technologies for the development of smart cities, Section 5 discusses about the status of work done in this area, Section 6 explains about the Impact on Technological Implementations, Section 6 discusses about the applications of 6G Technology in Smart Cities, Section 7 explains about the Critical Energy-efficient 6G IoT Trends in Smart Cities, Section 8 Concludes the paper.

2. Challenges on Technological Implementations

As we are planning to shift from 5G to 6G we need to cope up with few challenges associated with the technological implementation of 6G technology. Some of them are given below:

2.1 From possibility to certainty:

Due to the unique characteristics of Internet Protocol [11], mobile internet services have historically been rife with instability and uncertainty. With packet loss and minimal network latency, 4G services may easily satisfy subscribers without interfering with their ability to purchase online, browse the internet, or view movies. After all, the adoption of 5G and 6G networks will increase across all sectors, including those where the need for high reliability and low latency is a given. For this reason, network slicing, MEC (Mobile Edge Computing), and other pertinent technologies are included in 5G to provide the end-to-end network services capabilities promised by Service-level arguments (SLA). It is anticipated that network service accuracy would improve in the 6G future to accommodate varied scenarios across all types of companies.

2.2 Openness and personalization:

On the one hand, we are aware that the Internet's essential characteristics of openness and sharing, which promote the growth of the Internet, are On the other hand, the ecosystem of mobile communication networks restricts the development of a proprietary technology to some extent. In order to explore additional applications across a wide range of businesses in the 5G era and enable all sectors to participate in the digital revolution, mobile networks should effectively stimulate the convergence of IT and CT.

2.3 Artificial Intelligence Network:

AI (Artificial Intelligence) has been already implemented in various areas like voice identification, automated translation, voice identification, AI image identification and so on. Development in network services requires appreciable network latency, users experience, reliability [12]. The process of maintaining and improving the network's KPIs (Key performance indicators) by conventional operation gets more difficult as the network becomes more intricate, as do its accompanying problems. In order to allow intelligent transformation and network automation, equipment manufacturers and operators are attempting to integrate AI into the current network [13]. To maximize an AI engine's value, however, a significant amount of data and computer power are required. The interplay between networks and AI is therefore necessary for the development of artificial intelligence in the next generation, including the 5G and 6G eras.

2.4 100% Coverage:

We can lead an easy and convenient life with a mobile phone today, but still according to research over three billion people across the world cannot access the internet. One of the reasons for failure in constructing networks in remote areas is high deploying charges needed for base stations and optical fiber cables. Also, geographical conditions result in failure of network installation. To guarantee complete global coverage in the 6G era, space-earth integration is crucial [14]. The base station for the space-earth integration system must be on a platform in the high stratosphere, and a LEO satellite that can reach remote places with full network signal must be used.

2.5 Terahertz Communication:

Terahertz frequency band, which will be used in the 6G era, is the range of frequencies from 100GHz to 10THz. Since it has a lot of bandwidth and has never been utilized before, there are no restrictions on how it can be used for profit. The 6G era is thought to be the root of the millimeter wave issue that exists today, including its poor coverage capabilities, expensive deployment costs, premature ecosystem of terminals, and other issues. As a result, the entire telecom industry must work together to tackle this.

2.6 Perception and location:

The mobile operators' use of the radio spectrum should be implemented in telecommunication. As we discuss the 6G era, radio spectrums are not only to be used for communications but also for sensor and location functions, giving services like communication, environment awareness, and location tracing, which can enable more novel applications [15].

For example:

- Maintain all industries by assessing the local climate for plangency, temperature, moisture, and other components.
- Along with accurate location, consider new services.
- The user experience can be improved and made more complete by using radio signals to identify gestures, postures, and the environment.

2.7 Make the best use of spectrum:

The radio spectrum serves as a valuable resource and is an important conduit for innovation in the digital age. The framework for licensing and allocating spectrum in mobile networks is developed at the national level. The system in the past encouraged network development, but over time, spectrum was wasted as a result. Therefore, the sharing technology of the dynamic spectrum will be researched in the 6G future. The wireless sector is introducing blockchain, AI, and other pertinent technologies in an effort to share and regulate the spectrum more nimbly and intelligently.

2.8 Network Security:

Network security is crucial to the development of the digital economy. Wide bandwidth, great reliability, and network security are all components of the 5th generation's value. The network will implement PQC (Post-quantum Cryptography), QKD (Quantum Key Distribution), and other technologies as we enter the 6G era to guarantee complete network security.

2.9 Redundancy, adaptability, and the capacity for self-healing:

5G/6G technology is the tangible foundation for supporting digital manufacture, administration, and operation, which requires a higher quality of network stability and dependability due to the numerous applications of 5G/6G in all industries. A flexible, self-healing, and redundant network can offer reliable network service after a network breakdown. Therefore, building this form of network should be a priority for all telecom sectors [16].

2.10 Low-carbon transformation:

The goal of the entire globe and the primary trend in the ICT sector is to promote low-carbon transformation. Deploying low-carbon and energy-saving networks is a necessary strategy for operators to save OPEX and demonstrate ethical conduct by fulfilling societal obligations in the face of the dramatically increased network throughput and escalating resource consumption.

3. Influence of 6G on Smart Cities

Wireless technology is developing rapidly as a result we are soon going to enter the world of 6th generation networks i.e., 6G (Sixth Generation) technology. As compared to 4G and 5G it is having higher frequency bands and agile, microsecond latency also a cloud-based networking technology used to deliver record breaking speed. As per the researchers, 6G is not only going to support mobile phones but also it can be used for some advanced technologies like smart home networks and automated cars [17]. It will undoubtedly allow us to create a robust connectivity between everyday life and the internet. The 6th generation of the internet is smarter than other generations like 4G and 5G therefore, by adopting this advanced technology, smart cities can become even smarter by enhancing their technology.

To the benefit of its citizens and businesses, a smart city is a location where the traditional networks and services have been enhanced via the use of digital and telecommunication technology. Infrastructure, social capital, which also includes traditional skills and community institutions, and digital technologies are all combined in smart cities to promote sustainable economic growth and provide a desirable environment for all residents. By 2035, the publisher believes that as smart city infrastructure develops, 6G will be a crucial component of communications, applications, content, and commerce in smart cities.

The main reason behind smart cities getting influenced towards the new generation is the increase in consumption of the internet at record rates because of which speed is decreasing day by day [18]. And wireless firms are stepping up their efforts to compete with traditional broadband internet providers in order to meet consumer demand by offering adaptable cellular and strong networks. We also include additional performance metrics for technology activation, such as 3D localization accuracy, end-to-end synchrony for architecture and service, and 3D coverage and mobility.

We can imagine three important service scenarios in 6th generation. They are massive broadband URLLC (ultra-reliable low latency communications), Zero energy massive IOT and ultra-broadband [19]. In a 6G world with a minimum energy consumption we can fulfill the massive broadband dual LLC demand. To develop new access technology there are multiple big challenges such as multiplexes, channel coding, modulation multiplexes, waveforms, and full duplex etc. The desired features and necessity in 6G are to achieve low processing latency, low complexity and other technical requirements.

Fig. 2. Fundamental groups for 6G Technology

Fig 2 represents the groups for 6G technology. These groups include expanded coverage with non-cellular topologies, free space optics and line of sight MIMO, native AI for connected intelligence, and radio access technology.

The expansion of coverage with non-cellular topologies suggests that the deployment of 6G networks will aim to extend coverage beyond traditional cellular networks. This may include the use of alternative technologies or topologies to provide connectivity in areas that are traditionally difficult to reach.

Free space optics and line of sight MIMO refer to technologies that utilize optical communication in free space and leverage multiple-input multiple-output (MIMO) techniques to enhance performance and capacity. These technologies can offer high-speed and reliable connections, especially in scenarios where direct line-of-sight communication is possible.

AI will play a critical role in 6G networks, according to native AI for connected intelligence. AI-powered systems will be integrated into network infrastructure, allowing for intelligent and autonomous decision-making, resource optimization, and management to improve overall network performance and user experience.

Finally, radio access technology refers to wireless network access methods and techniques such as modulation and coding schemes, waveform designs, and novel communication protocols. Radio access technology advancements will be critical for meeting the low processing latency, high capacity, and other technical requirements of 6G networks.

It should be noted that while these groups represent the anticipated technologies and areas of focus in the development of 6G networks, specific implementations may differ as research and standardization efforts progress.

There are basically three parts of 6G: which include need-pull (societal requirement), policy lead (role of government) and tech-push (technological advancement). For the promotion of 6G these three parts play a complementary role with each other. With change in technology, we need to specify every corner of social issues in terms of individuals, households, city and country. To promote dead pool and touch upon social issues, policy leadership is a part of distant news. The arrival of the sixth life where humans are turning to be highly autonomous and intelligent machines live together in the same space (physical space and digital twins' space) [20]. The first key aspect machines (autonomous) interact with us (humans) ultra-fast and ultra-precisely and the second aspect is connecting live experience to humans including advanced tactile, it is a truly immersive service.

One of the four categories we'll use to categorize 6G technologies is extended coverage using non-cellular topologies. Unmanned aerial vehicles (UAVs), satellites, and airborne are all included. One of the most significant revolutions in the future generation will be the use of new spectrum and antenna technologies.

4. Emerging Technologies

As we know that 6G is a hypothetical and under testing currently as, after all it does not exist. But as per research papers and media interviews wireless industries and academics describe 6G as a completely integrated, internet-based system that permits instant communication between devices, vehicles, consumers, and the surrounding environment.

Presently we are making use of IOT (smartphones and smart home devices). Very soon we are expecting to reach an all-encompassing **Internet of Everything.** According to the experts 6G networks will very soon allow us to hit a maximum speed of 1 terabit per second on an internet device [21]. So, as compared to 1 Gbps, the speed available in 6G will be a hundred times faster. It is expected that by the end of 2030 100 trillion sensors will be manufactured and connected to the internet to revolutionize 6G. Hence one thousand times price reduction will be required to develop a sustainable smart society [22]

The 5G technology has already influenced several parts of the globe and it is expected that it will roll out completely by the end of 2022. As per the demand of high speed and automation this (5^{th} Generation) technology will stream out by 2030. The world-wide mobile evolution is expected to mature up to 700 times, if we compare to the knowledge of 2010.

Scientists have already started working on 6G i.e., surely going to revolutionize the digital world. 6G offers minimum human interface. 6G will be a complete package as it will acquire higher data rate which supports upcoming technologies like Artificial Intelligence and Virtual Reality (An imaginary 3D environment that allows users to interact and explore with a virtual surrounding in a way that is close to reality, as it is experienced through the user's senses). Underwater communication and space, medical implants, drones and self-driven vehicles are some smart wearable devices that can be associated with 6G technology to become accurate [23]. The devices based on virtual reality need a phlegmatic data transfer of up to a rate of 10 GBPS. It has been estimated that 6G system driven wireless characteristics would be nearly one thousand times more economical than 5G. All this research in the field of 6G network results in a wise designed society atmosphere observance and protection disaster mitigation and management.

5. Literature Survey

[24] The focus of the authors was on the need for dependable data communication in the ever-more automated, intelligent, and pervasive digital environment. In today's fully connected, intelligent digital world, which will need to connect everything from automobiles to people, robotic agents, sensors, data, and even cloud resources, mobile networks are seen as data highways. Although 5th generation (5G) wireless networks provide considerable advancements over LTE, they may not be able to fully meet connectivity demand for the future digital society (Long

Term Evolution). Because of this, this article discusses technologies that will prepare wireless networks for the upcoming generation and serve as support for a number of prospective 6G use cases.

[25] According to the authors, next-generation wireless networks can push the intelligent, data-driven functionalities made possible by the integration of Machine Learning (ML) principles beyond the edge and core infrastructure, spreading broadly around an area for Internet of Things (IoT) devices.

[26] The fifth generation (5G) mobile communication system is currently establishing itself in many other nations and is rapidly gaining customers in India. The moment is opportune for business and academia to start focusing on 6G, the upcoming generation. An evaluation of the state of the art today and an outlook on communications in the future are undoubtedly interesting at this juncture.

[27] Authors enlighten the drawbacks of 5G are the hot topics for discussion throughout the world, therefore researchers are focusing on defining the upcoming generation i.e., 6G wireless system which can integrate far reaching applications ranging from autonomous systems to extended reality (XR). Contradicting to some researchers one example project in Finland 6Genesis states that some performance components and fundamental architecture is still largely undefined. With respect to this initial identification of primary drivers in terms of accompanying technology trends and applications of 6G systems. As of now, higher rates that enhance network capacity by up to 1000 times are the main drivers of wireless network growth. The need for wireless technologies will only increase over time. The introduction of the Internet of Everything (IoE), which is tying together billions of machines and millions of people.

[28] The need for wireless communication has reportedly grown significantly over the previous few decades, according to authors. The fifth generation (5G) of communication, which will soon be used globally, includes many more features than the fourth generation (4G). With the full support of artificial intelligence and a new wireless communication paradigm, the sixth generation (6G) system is expected to make its debut between 2027 and 2030.

[29] Authors addresses the severe issue in many smart cities because of over populations but the futuristics smart cities are expected to follow the concept based on dense and artificial-intelligence-centric cities. For many inter-connected device communication networks are expected to provide on demand content, high quality of service with huge data traffic. For futuristics cities the 6G network is a problem-solving network with low latency and huge bandwidth. A scalable multilayer architecture called the "nested Beehive" was created to accommodate the requirements of future smart cities. Additionally, while designing the multilayer network infrastructure, we took into account the challenges posed by THz waves as well as the expectations from a network of smart cities in the far future. The performance of the suggested architecture is assessed through extensive simulations utilizing various pathfinding algorithms in the 3D multilayer environment, which also establish the dynamics of 6G communication in the future.

[30] A fault-tolerant and energy-efficient self-organization system is needed more and more, especially in smart cities, according to the authors. The Internet of Things (IoT) has shown to be capable of generating and processing data for watching and analyzing the environment. Nearly every industry may now use IoT, including those in agriculture, logistics and transportation, smart cities, and many more. Industries employ a variety of trackers, sensors, and meters to continuously monitor activity, improve processes, and automate operations. Observation-based big data analytics can be used to power decision-making processes. As a result, managing cities presents more difficulties. Smart cities need a self-organized network made of a significant number of notes dispersed throughout an area of interest in the sixth generation to handle the problems (6G). Traditional communication has a number of drawbacks, particularly when it comes to high data rates, latency, dynamic mobility, and the increasing expansion of vehicular communication. We're here to take advantage of wireless technology and big data analytics for the benefit of smart cities.

[31] Intelligent reflecting surfaces (IRSs) or reconfigurable intelligent surfaces (RISs), which authors proposed to improve the energy efficiency or spectrum of wireless systems, are recognized as one of the most revolutionary and promising techniques. These devices can change the wireless propagation environment by carefully adjusting the phase shifts of a large number of free passive reflecting elements.

6. Impact on Technological Implementations

Technically 6G is just a concept, as it is expected to widespread till 2030 but still it is exciting to explore. As per the IDTechEx report (IDTechEx conducts detailed examinations of emerging technologies based on extensive primary research carried out by our technical analysts around the world), 6G communications market, Materials 2021-2041, devices they are already introduced all over the world in 6G technology due to its many uses in electronics. We can look forward to the devices which doesn't require any battery to operate as 6G can provide power to them. It's not only about the availability of speed of internet but also, it will improvise the devices like smartwatches, smartphones and other gadgets to us in future.

As compared with 5G, 6G offers higher frequencies and higher capacity than 5G networks therefore many countries and corporations are interested in inviting this soon. Last year to examine the terahertz electronics with physics of 6G technology in space China has launched a satellite. With the help of these terahertz waves, the transmission speed will be boosted much higher than 5G. If it is so, then it may be possible for solar powered drones and terahertz transistors to work on upper atmosphere along with the satellites to provide surveillance and WiFi to remote areas most of the times it is much needed in developing countries. According to researcher's major companies

and corporates will certainly invest in this chance. As an illustration, Alphabet recently ended the loon project, which used solar-powered, AI-guided balloons to fly through the atmosphere and offer cellular service to isolated areas [32].

The introduction of 6G will be more than just a generational change because it offers the tech sector new opportunities especially for the development of smart cities. With the help of 6G, smart gadgets will develop into essential AI users and catalysts. They will download and use AI algorithms at various application levels to produce novel immersive experiences while also continuously gathering data to feed more sophisticated AI models. When it comes to how AI infers, learns, interacts, and is applied, 6G will radically change the field, resolving numerous long-standing issues in the field, including data silos and user privacy [33]. According to the vehicle's position and the surrounding physical environment, 6G networks, for instance, will assign the most suitable AI algorithm and the best communication connection in the event of autonomous vehicles (e.g., time of day, weather) [34]. The ability for the vehicle to instantly download and use AI algorithms will enable it to give the passenger the safest and most comfortable travel possible.

As per the recent reports, 6G technology will support industry solutions and government in public safety and asset protection. Health surveillance, threat detection and facial recognition are some included solutions.

Some technologically advanced countries are initiating conversations about the future of 6G. According to the Japanese government a comprehensive strategy is in place with some sound technical minds begin analysis and discussion about the potential utilization of the technology [35].

The integration of terrestrial, aerial, and maritime communications into the sixth generation (6G) wireless communication network is anticipated to result in a strong network that is more dependable, quick, and capable of supporting a sizable number of devices with ultra-low latency needs. In order to realize beyond 5G (B5G) and 6G communications, researchers from all over the world are proposing cutting-edge technologies like artificial intelligence (AI)/machine learning (ML), quantum communication/quantum machine learning (QML), blockchain, terahertz and millimeter wave communication, tactile Internet, non-orthogonal multiple access (NOMA), small cell communication, fog/edge computing, etc [36].

7. Application of 6G Technology in Smart Cities

Smart cities are supported by a variety of technologies. As platforms, monitoring/control, performance management, predictability, and forecasting all come together, systems and resources become linked. A few key areas, such home entertainment and cars, are where this convergence is first becoming apparent. Solution providers are adopting a much more integrated strategy as they build and implement infrastructure and service capabilities in response to the emergence of smart cities. As smart cities cater to the needs of several market sectors with numerous overlapping and occasionally mutually exclusive requirements, feature/functionality must be integrated to perform well across many distinct industry verticals. Following are the applications of 6G Technologies-

7.1 Terahertz Communication:

Demand for wireless communication technology is rising quickly, and the RF band that supports terahertz communication is nearly filled and unable to accommodate it. The terahertz range, which spans from 0.1 THz to 10 THz, can make it possible for 6G to have higher capacity, ultra-high data rates, and more bandwidth [37]. The Internet of Nano-Things will be supported by the THz band, which will enable the development of microscopic cells with nanoscale to micrometer dimensions, very high-speed communications, and coverage up to 10 m away. Since Tbps links cannot be supported by technologies operating in frequency ranges below 0.1 terahertz, 6G will be the first wireless technology to support Tbps connectivity.

7.2 Antenna and Transceiver Designs

Each wireless communication technology has a specific antenna and transceiver supporting the specification for that technology. In 5G, it was difficult to create devices with millimeter components; in 6G, the spectrum and resource sharing will be more difficult. And 6G wireless technology will support high frequency. The transceivers should be able to support this technology if their antennas are designed with the nanometer- and micrometer-sized components that are necessary for holographic beamforming [38]. This problem might be resolved by using meta surface-based transceivers, which would improve throughput and QoS. It is a significant issue to integrate the meta surface with OFDM-MIMO, nevertheless.

A hole in the technical development of 6G has been at the interface between terahertz spectrum and hard, optical transmission lines. The main idea behind connecting terahertz which is basically through the air spectrum found between infrared and microwaves to the transmission lines that will be required for large distance data transmission [39]. As the curvature of Earth limits the line of sight, hard wiring will be required for long distances. Short distances too can face problems because of environmental abstractions like rain, fog, blocking by objects becomes more apparent as the spectrum becomes higher and wavelength becomes shorter.

8. Critical Energy-efficient 6G IoT Trends in Smart Cities

As it can automate operations and make them smarter, IoT has gained enormous popularity across the globe. IoT offers a number of uses that are very advantageous to everyone in the world. Smart cities are one of the IoT's most important applications [40]. Many studies and developments are undergoing in this area to improve the usage of IoT applications in smart cities. The main flaws is that older technologies were unable to process and analyze the enormous amounts of data produced by IoT and smart cities [41]. However, by accelerating their speed and efficiency, 6G technology can improve the processing and transmission of devices in IoT. To encourage 6G wireless connection in smart cities that uses less energy, this section intends to highlight the major trends in the Internet of Things (IoT). Figure 3 shows the connectivity of IoT Devices & Smart Cities [10].

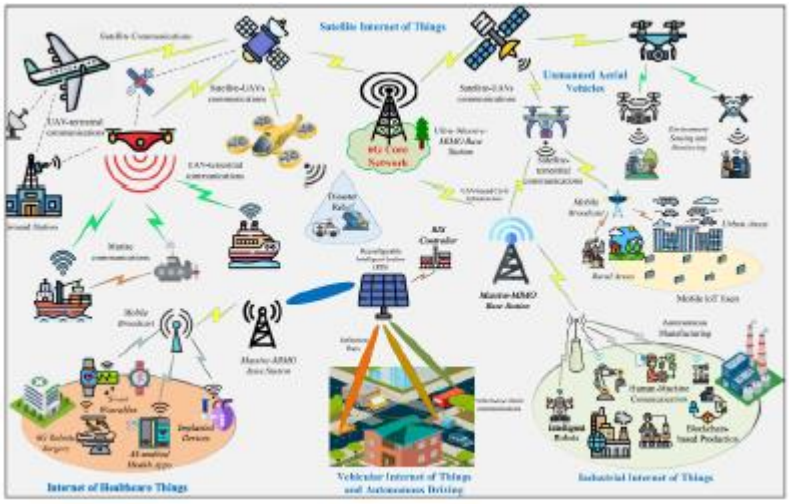

Fig. 3. IoT devices & Smart cities

Additionally, it is highlighted that the joint use of IoT systems and 6G technology results in the creation of a variety of designs that have the capacity to capture a lot of data. Smarter Reflective Surfaces and Ecosystems, for instance, could emerge as a new trend in driving as a result of the 6G wireless network. According to this hypothesis, the intelligent reflecting surfaces act as walls, roadways, entrances, and complete constructions. As a result, it is simpler to see clearly when driving and get clear signals [42]. Therefore, when a 6G communication network is established in the system, there will be little to no risk of loss or accidents on the roadways.

The adoption of 6G technology could result in the widespread deployment of IoT systems that incorporate AI and big data analytics. These solutions could pave the way for the creation of IoT systems in smart cities that would offer a more practical and secure transportation network. Additionally, it's possible that these systems will improve security in smart cities, making residents feel more secure. Deep learning-based AI computer vision, which has recently been developed for numerous applications, is another essential component of 6G technology [43]. 6G wireless connectivity may represent a substantial advancement in wireless energy transfer and collection in smart cities [44]. According to this method, 6G cellular networks can be used in smart cities to transfer energy for harvesting. The emergence of such trends will have a significant positive impact on the environment because they will lessen the enormous amount of carbon footprints. Researchers are attempting to develop substantial practical, effective and affordable, solutions that can be directly adopted to enhance the infrastructural capabilities of smart cities in light of these advantages of IoT and 6G technology [45].

9. Conclusion

In conclusion, the article emphasizes the importance of dependable data communication in today's increasingly automated and intelligent digital world. While 5G networks provide significant improvements over LTE, they may fall short of meeting the connectivity needs of the future digital society. As a result, the article delves into the technologies and advancements that will prepare wireless networks for the next generation while also supporting a variety of potential 6G use cases. Researchers are hard at work developing practical, effective, and cost-effective solutions to improve the infrastructure capabilities of smart cities through the use of IoT and 6G technology. Intelligent, data-driven functionalities can be enabled by incorporating machine learning principles in next-generation wireless networks. The rapid rate of urbanization presents unprecedented challenges for city planners around the world. With a significant increase in urban population expected by 2050, cities must implement smart policies and meet stringent targets to address climate change and other environmental challenges. Extensive simulations using various pathfinding algorithms

are used to evaluate the architecture for 6G networks, with the goal of establishing the dynamics of future 6G communication. The authors emphasize the importance of fault-tolerant and energy-efficient self-organization systems in smart cities, noting that IoT can generate and process data for environmental monitoring and analysis across industries such as agriculture, logistics, transportation, and others. Big data analytics derived from observational data can help inform decision-making processes. Overall, the importance of preparing wireless networks for the future digital society, addressing the connectivity demands of a fully connected, intelligent world, is emphasized in this paper. It also emphasizes the importance of incorporating advanced technologies such as machine learning and IoT in the development of smart cities in order to meet the challenges of urbanization and environmental concerns.

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