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A REVIEW ON ENHANCING THE TECHNOLOGICAL TRENDS FOR INTELLIGENT INTERNET OF THINGS IN HEALTH CARE SYSTEMS USING 6G

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Abstract : The Sixth Generation (6G) with full support of AI is expected to be launched in 2027. Healthcare will be fully AI-driven and dependant on 6G communication Technology. The key barriers to health care are time and space and these barriers can be overcome by 6G. New methodologies like Quality of Life (QoL), Intelligent Wearable Devices (IWD), Intelligent Internet of Medical Things (IIoMT), Hospital – to – Home (H2H) services can be greatly achieved by 6G communication Technology. 6G wireless communication networks are envisioned to revolutionize customer services and its applications via Internet of Things (IoT) towards a future of fully intelligent and autonomous systems. In this survey paper, the emerging opportunities brought by 6G technologies in IoT networks and its applications are explored by conducting a holistic survey on the convergence of 6G and IoT. Initially, the most fundamental 6G technologies that are expected to empower future IoT networks, including edge intelligence, reconfigurable intelligent surfaces, space-air-ground underwater communications, Terahertz communications, massive ultra-reliable and low-latency communications and block chain are also discussed. Compared to the other related survey papers, this paper provides an in-depth discussion of the roles of 6G in a wide range of prospective IoT applications through five key domains, like, Industrial Internet of Things, Unmanned Aerial Vehicles, Vehicular Internet of Things and Autonomous Driving, Satellite Internet of Things, and Healthcare Internet of Things. Finally, interesting research challenges and potential directions to spur further research in this promising area have also been discussed.

IndexTerms - Sixth Generation (6G) - Holographic communication – Telesurgery - Telestration - Haptic technology - Hassle free treatment - Network Intelligence

I. INTRODUCTION TO 6G

A wide range of technologies in both hardware and software are required for future networks such as smart Internet of Things (IoT) devices and autonomous vehicles. Many countries have already started 6G communication technology [16]. Firstly Finland initiated the 6G project in 2018. Secondly United States, South Korea and China have started 6G project in 2019. Recently Japan has also initiated this project in 2020. Future networks ensure an intelligent healthcare system, where ambulance services to be replaced, wearable devices need to be redefined, hospitals are required to get restructured, health services to be provided in real time and health monitoring along with elderly services need to be refined. Other requirements of an intelligent health care system include, Hospital -to-Home service, Blood Sample Reader (BSR) sensor, Intelligent Wearable Devices (IWD), Health Insurance at Hospital (HIH) business model etc. Moreover, the fundamental issues need to be addressed beyond 5G includes, higher system capacity, higher data rate, lower latency, higher security and improved quality of service compared to 5G[5].

Almost all medical things will be able to connect to the Internet and as a result instant decisions can be taken. Therefore, IIoMT will be able to overcome the barrier of time, space and money. Another example of Intelligent Internet of Medical Things includes, cancer patients who can be easily treated by remote doctors. At present it takes time to detect whether the cancer patients are having benign or malignant tumours. Probably, cancer can be detected in real time in the near future using 6G communication technology. As a result, the doctors and patients need not visit specialised hospitals as it consumes time and money [6]. The, remote doctors will treat the cancer patients in collaboration with the local doctors. Hence early detection of cancer patients can thereby reduce the mortality rate. This scenario not only applies to cancer, but also applies to many other diseases.

1.1 Vision of 6G

Experts believe that the wide scale adoption of 5G lies in the future, which has implications for the release of 6G in the 2030s. Discussion on the role of machine learning in 6G networks, especially its ability to intelligently reallocate resources are also addressed [10]. However, many experts believe it's necessary to move away from centralized network configurations towards a more dynamic environment. This change will not only help networks to save energy, but it will also allow networks to take advantage of a neat concept known as mobile edge computing (MEC) [9]. In MEC, network providers run applications and services on the network's edge that is, in close proximity to consumer devices and end-users from a central server to and from which data must travel. This configuration improves data speed and lowers the latency. It also allows devices to keep their data stored, rather than sending it off across the network. That means there is a chance to rethink device security in 6G.

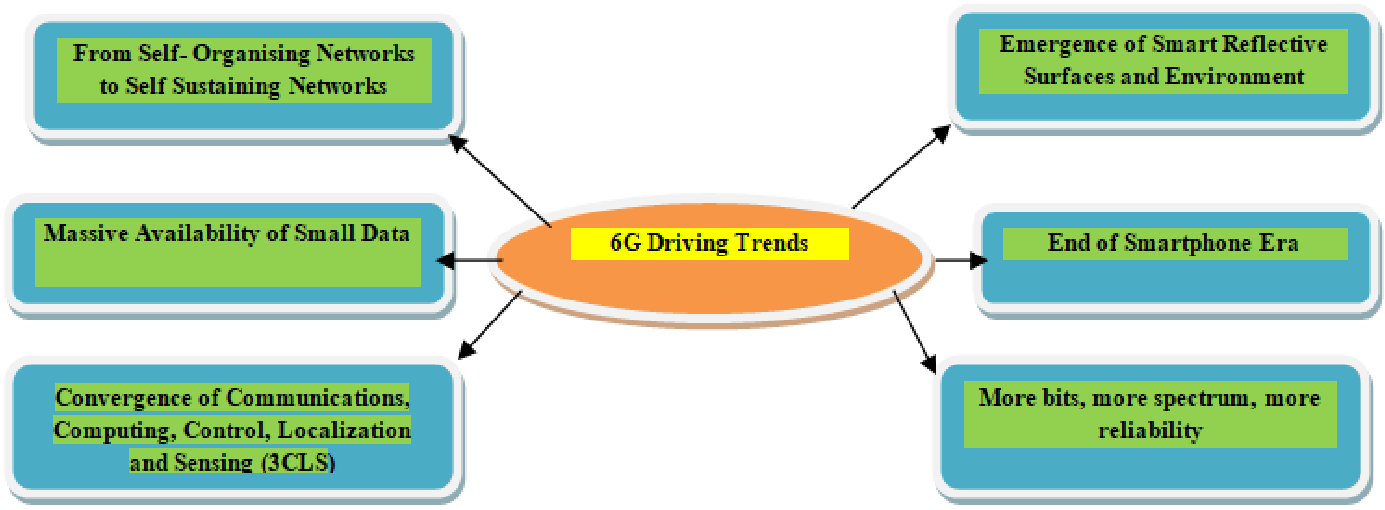


Figure 1. Driving Trends of 6G

Driving Trends of 6G is the focus of 6G researches, as it is expected that the amount of devices and their sophistication will make software patching indefensible. Thereby, 6G networks are widely expected to have AI embedded in them which improves security.

2 LITERATURE REVIEW

L. Chettri et al. [1] have described the role of IoT in 5G Wireless systems. This paper illustrates the fact that 5G system will be a game changing system in future generation. The inefficiency and insufficient sources of LTE (4G) to meet the demands of multiple device connectivity, high data rate, more bandwidth, low latency, Quality of service and Low interference are also discussed.The challenges and visions of various communication industries in 5G IoT systems are discussed in detail along with the different layers in 5G IoT systems. The Technology drivers for 5G wireless technology like multiple-input-multiple –output antenna with the beam formation technology, mm – wave communication technology, the role of augmented reality (AR) in IoT, 5G new radio (NR) are discussed elaborately.

A.Yadav et al. [2] have proposed algorithms for 6G wireless technology to visualize and revolutionize multiple customer services with the Internet of Things (IoT), thereby contributing to a ubiquitous intelligent society comprising autonomous systems. This paper conducts a detailed survey on the IoT networks with 6G wireless networks and investigate the trending possibilities provided by the 6G technology within the IoT networks and the related utilization. Firstly, a detailed breakthrough IoT technologies and the technological drivers which are anticipated to strengthen IoT networks in future. Next, a relevant use case detailing the discussion on the role of the 6G technology within a broad spectrum of IoT potential applications. Lastly, several research scopes and challenges and list the potential research needs and encourage further research within the thrust area of IoT enabled by 6G are also discussed.

W. Saadand et al. [3] have discussed the ongoing deployment of 5G cellular systems which continuously exposes the inherent limitations of the system, compared to its original premise as an enabler for Internet of Everything applications. The 5G drawbacks are spurring worldwide activities focused on defining the next-generation 6G wireless system that can truly integrate far-reaching applications ranging from autonomous systems to extended reality. Inspite of recent 6G initiatives (like the 6 Genesis project in Finland), the basic architectural and performance components of 6G remain greatly undefined. In this paper a holistic, forward-looking vision that defines the tenets of a 6G system is discussed. It is discussed that 6G will not be a mere exploration of more spectrum at high-frequency bands, but it will rather be a convergence of upcoming technological trends driven by exciting, underlying services.

In this regard, the primary drivers of 6G systems, in terms of applications and accompanying technological trends. Then a new set of service classes and target of 6G performance requirements is visualized. The enabling technologies for the introduced 6G services and outline a comprehensive research agenda that leverages those technologies are discussed. It is concluded by providing concrete recommendations for the roadmap toward 6G. Ultimately, the intent of this paper is to serve as a basis for stimulating more out-of-the-box research around 6G.

G. Gui et al. [5] have introduced the innovations provided by sixth generation wireless communication (6G) as compared to fifth generation (5G) are considered in this paper based on analysis of related works. The motive of achieving diverse performance improvements for various 6G requirements like, five 6G core services are identified. Two centricities and eight key performance indices (KPIs) are detailed to describe the services, then enabling technologies to fulfill the KPIs are discussed. 6G architecture is proposed as an integrated system for enabling technologies and it is illustrated using four typical urban application scenarios. Thus, opportunities for exploring 6G are well analyzed in order to guide future researches.

L. Bariah et al. [6] have proposed the fifth generation (5G) mobile networks are envisaged to enable a plethora of breakthrough advancements in wireless technologies, providing support of a diverse set of services over a single platform. As the deployment of 5G systems are raising up world wide, it is time to look ahead for beyond 5G systems. It is mainly driven by the emerging societal trends, calling for fully automated systems and intelligent services supported by haptics communications and extended reality. To adapt the stringent requirements of their prospective applications, that are data-driven and defined by extremely low-latency, ultra-reliable, fast and seamless wireless connectivity, research initiatives are presently focusing on an intensifying roadmap towards 6G networks, which are expected to bring transformative changes.

In this paper, the authors have discussed the major enabling technologies for 6G, which are expected to revolutionize the fundamental architectures of cellular networks and provide multiple homogeneous artificial intelligence-empowered services, including distributed communications, computing, control, sensing, and energy, from its core to its end nodes. The authors have addressed these questions by presenting a comprehensive study of the 6G vision and outlining seven of its disruptive technologies, i.e., mm Wave communications, backscatter communications and tactile internet drone-based communications, terahertz communications, optical wireless communications, programmable meta surfaces as well as their potential applications. Then, by leveraging the state-of-the-art literature surveyed for each technology, the associated requirements, key challenges, and open research problems are discussed.

X. You et al. [7] have introduced the fifth generation (5G) wireless communication networks that are being deployed globally from 2020. There are more capabilities in the process of being standardized, like mass connectivity, ultra-reliability, and guaranteed low latency. Since 5G cannot meet all requirements of the future in 2030 and beyond, and sixth generation (6G) wireless communication networks are expected to provide better intelligence level and security, enhanced spectral/energy/cost efficiency and global coverage. To fulfill these requirements, 6G networks will rely on new enabling technologies like, air interface and transmission technologies and novel network architecture, such as multiple access, multi-antenna technologies, network slicing, cell-free architecture, waveform design, channel coding schemes, and cloud/fog/edge computing.

The vision on 6G has four new paradigm shifts. Initially, to satisfy the requirement of global coverage, 6G will not be limited to terrestrial communication networks, which needs to be complemented with non-terrestrial networks like unmanned aerial vehicle (UAV) and satellite communication networks by achieving a space-air-ground-sea integrated communication network. Secondly, all spectra will be fully explored to further enhance data rates and connection density, including millimeter wave (mmWave), terahertz (THz), and optical frequency bands. Thirdly, facing the big datasets generated by the use of extremely heterogeneous networks like, diverse communication scenarios, large numbers of antennas, wide bandwidths and new service requirements, 6G networks are enabling a new range of smart applications with the help of big data technologies and artificial intelligence (AI). Finally, network security should be boosted when developing 6G networks.

M. Giordani et al. [11] have proposed reliable data connectivity is important for the ever rising intelligent, automated and ubiquitous digital world. Mobile networks are the data highways which are fully connected, intelligent digital world, that will need to connect everything, including people to vehicles, sensors, data, cloud resources, and even robotic agents. The fifth generation (5G) wireless networks, that are currently being deployed, offers remarkable advances beyond LTE, but may be unable to meet the full connectivity demands of the future digital society. Thus, this paper discusses technologies that will evolve wireless networks towards 6G which will be considered as enablers for several potential 6G use cases. It provides system-level perspective on 6G scenarios and requirements, select 6G technologies and fullstack that can satisfy either by improving the 5G design or by introducing completely new communication paradigms is also provided.

M. Z. Chowdhury et al. [13] have introduced the demand for wireless connectivity which has grown exponentially over the last few decades. Fifth-generation (5G) communications, with more features than 4G communications, is likely to be deployed worldwide. Beyond 5G, some basic issues which need to be addressed are higher security, higher data rate, higher system capacity, lower latency and improved quality of service (QoS) compared to the 5G communication system.

L. U. Khan et al. [14] have discussed that due to the rapid development of the fifth-generation (5G) applications and increased demand for even more faster communication networks, the birth of a new 6G technology within the next ten years is required. References suggest, that the 6G wireless network standard may arrive around 2030. Thus, this paper presents a descriptive analysis of 5G wireless networks. Significant technological limitations reviews the anticipated challenges of the 6G communication networks. In this work, the applications of three of the highly demanding domains, namely: energy, Internet-of-Things (IoT) and machine learning. To this end, the vision on how the 6G communication networks should look like to support the applications of these domains. The main contribution of this work is to provide a detailed perspective, challenges, requirements, and context for efficient work in the 6G communication standard.

A. Shahraki et al. [16] have introduced the Cellular Internet of Things (IoT) which is considered as de facto paradigm to improve the communication and computation systems. Cellular IoT connects enormous number of physical and virtual objects to the Internet using cellular networks. The latest generation of cellular networks like 5G, uses evolutionary and revolutionary technologies to improve the performance of wireless networks. It is envisioned that the next generation (6G) networks, need to play a vital role to alleviate the challenges in IoT by providing new communication services, network capacity, and Ultra-Low Latency Communications (URLLC). In this paper, the need for 6G networks is discussed followed by the potential 6G requirements and trends and latest research activities related to 6G like, Tactile Internet are introduced.

A. O. Balghusoon et al. [21] have discussed the Wireless Information and Energy Transfer (WIET) technology. Here in addition to information, the electromagnetic waves carry energy in the energy harvesting mode and wiring infrastructure to charge the battery is not required. WIET executes a vital role in the deployment and expansion of the 6G Internet of Nano Things (IoNT) devices are envisioned to operate with limited-battery usage.

6G technology enables the use of wireless information for energy transfer to the use of mm-wave/THz frequency for operation. The antennas used will be required at close proximity and thus, the Internet of Things/Internet of Everything/IoNT devices will be able to operate in near field regions as a result of electromagnetic wave will be able to carry significant energy to significantly charge the nano-devices. The overview of the expected design challenges which may occur during the implementation process, and identify the key research challenges that require timely solutions that are significant to stimulate further research in this challenging area. Through this survey, the discussion on possibility to maximize the applications of WIET in 6G IoNT may also occur.

M. R. Palattella et al. [22] have discussed the IoT paradigm holding the promise to revolutionize the way of life and work by means of a wealth of new services, based on seamless interactions between a large amount of heterogeneous devices. Over decades of conceptual initiation of the IoT, in recent years a huge variety of communication technologies have gradually emerged, reflecting a large diversity of application domains and communication requirements. Such heterogeneity and fragmentation of the connectivity landscape is currently inhibiting the full realization of the IoT vision, by posing several complex integration challenges. The present-day IoT connectivity landscape, as well as the main 5G enablers for the IoT are present. Illustration on the massive business shifts that a tight link between IoT and 5G may cause in the operator and vendors ecosystem is also carried out.

H. Wang et al. [24] have discussed exploiting unmanned aerial vehicles (UAVs) as flying base stations (BSs) to assist the terrestrial cellular network which is promising in 5G and beyond. The deployment problem as minimizing the number of UAVs and maximizing the load balance among them arises are discussed. It is subjected to two main constraints, i.e., UAVs should form a robust backbone network and should keep connected with the fixed BSs. To solve this optimization problem with low complexity, dividing the problem into two sub problems is required. Proposal of a hybrid algorithm to solve them stepwise is required. Initially, a centralized greedy search algorithm is used to obtain the minimum number of UAVs and their suboptimal positions in a discontinuous platform. Then, a distributed motion algorithm is adopted which enables each UAV to autonomously control its motion towards the optimal position in a continuous platform. The proposed algorithm is applicable to various scenarios where UAVs are deployed alone or with fixed base stations regardless of the user equipment (UE) distribution. Extensive simulations validate the proposed algorithm.

A. Nasrallah et al. [25] have proposed many network applications, e.g., industrial control, demand Ultra-Low Latency (ULL). The traditional packet networks can only reduce the end-to-end latencies. The IEEE 802.1 Time Sensitive Networking (TSN) standards have sought to provide link layer support for ULL networking. The paper provides an updated comprehensive survey of the IEEE TSN and IETF Det Net standards. The survey of these standards and research studies is organized according to the main categories of flow integrity, flow concept, flow synchronization, flow control and flow management. The ULL networking mechanisms play a critical role in the emerging fifth generation (5G) network access chain from wireless devices through access, backhaul, and core networks. The survey can thus serve as a basis for the development of standards enhancements and future ULL research studies that addresses the identified limitations.

3 OBJECTIVES OF THE STUDY

The principle objective is to ceaselessly enhance the communication barriers caused by the previous network generations. This helps in achieving Intelligent Internet of Things for providing best health care facilities for patients, help clinicians at any level – essential, optional or tertiary, settle the best choices for every patient and to achieve the best in class health care facilities through Intelligent IoT.

4 CHLLENGES FOR 6G

6G needs to fulfil the laggings of 5G by introducing new synthesis of future services such as Ambient Sensing Intelligence, New Human-Human and Human-Man interaction. 6G communication technology consolidates its vision with the following perspectives:

- Intelligent Connectivity
- Deep Connectivity
- Holographic Connectivity
- Ubiquitous Connectivity

Among the mentioned consolidates the Intelligent Connectivity plays a vital role for the future superimposed technologies:

Deep Learning:

It is a machine learning technique that teaches computers to do what humans inculcate naturally. The technology's nomenclature is usually based on the number of additional "Layers" added to learn from the data. If it is not known already, when a deep learning model is learning, it is simply updating the weights through an optimization function. As far as 6G Technology is concerned, Deep learning includes Artificial Intelligence, Tactile Internet, Deep Mind (Telepathy- mind to mind communication)

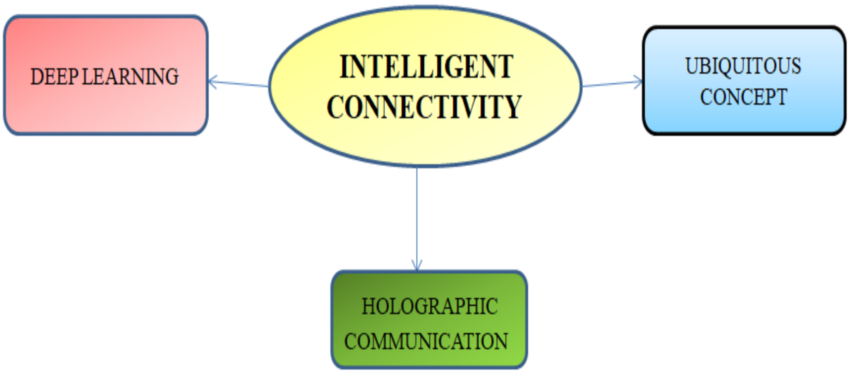
Holographic:

It includes holographic communications, AR /VR pervasive everywhere, ultra high fidelity AR/VR

Ubiquitous:

It refers to connection everywhere at anytime via air, space, ground and sea.

Figure 2. Classification of Intelligent Connectivity



4.1 Security, Secrecy and Privacy:

6G technology focuses on security, secrecy and privacy [5]. Therefore, it requires secure URLLC (sURLLC) to have an enhanced secure communication. This technology promises the highest level of security which will defend the attacks using federated AI, Quantum Machine Learning, Quantum Computing and THz communication. Healthcare requires a high level of security for data transmission over the network. Any alteration of health data can kill a patient. Therefore, it is crucial to protect health data from attackers. Moreover, 6G communication technology also focuses on secrecy of the most sensitive data. These sensitive data are very confidential that even the administrators are not permitted to view these data. For example: family history.

6G also focuses on privacy which is a crucial parameter of healthcare. To increase privacy, 6G will also rely on Edge technology. The Edge nodes are located closer to smart devices, the computed data are also analyzed in the same Edge nodes. Edge nodes have small memory, hence all data are not concentrated in one location. Therefore, Edge maintains the privacy of the user. Another important point is filtering of data by Edge nodes. Edge nodes filter the data and transmit only important information to the Cloud. It also leads to storage of less information about the user in the Cloud. Thus, it is easier for Cloud to provide security for lesser data. In the current scenario, Block chain provides a high degree of privacy for health data. It also provides a secure infrastructure for handling the health data. In future, Block chain with more advanced techniques will be very helpful in intelligent healthcare.

Recent advances in wireless communications and smart device technologies have promoted the proliferation of Internet of Things (IoT) with ubiquitous sensing and computing capabilities to interconnect millions of physical objects to the Internet. Thus IoT constitutes an integral part of the future Internet and has received much attention from both academia and industry due to its great potential to deliver customer services in many aspects of modern life [1]. Table 2 provides an analogy between 5G and 6G communication technologies.

TABLE 2. ANALOGY BETWEEN 5G AND 6G

KEY FACTORS	5G	6G
Peak Data Rate	>10-20Gb/s	>100Gb/s
Uplink Data Rate	10 Gb/s	1 Tb/s
Downlink Data Rate	20 Gb/s	1 Tb/s
User Experience Data Rate	>10 Gb/s	1Tb /s
Rate Requirements	1 Gb/s	1 Tb/s

End-to-End Reliability	99.999 %	99.99999 %
Mobility	300 Km/hr	>1200 Km/hr
Spectral Efficiency	10 b/Hz/m^2/s	1000 b/Hz/m^2/s
Energy Efficiency	10 b/Hz/m^2/Joules	1000 b/Hz/m^2/Joules
Traffic Capacity	100 Mb/s	1000 Gb/s
Traffic Density	1 Tb/Km^2/s	100 Tb/Km^2/s
Delay	1ms	< 1ms
Radio-only Delay	100 ns	10 ns
Processing Delay	100 ns	10 ns
Architecture	Dense sub-6GHz small base stations, mmWave small cells	Cell-free smart surface, high frequency support, tiny THz cells, temporary hotspots by UAVs
Satellite Integration	No	Yes
AI Integration	Partial	Full
Time Buffer	No-Real Time	Real Time
Coverage	70 %	>99 %

5G presents energy, costs, trade-offs on latency, hardware and complexity, end –to-end reliability. In contrast 6G will be developing network demands like capacity, ultra high reliability low latency communication. Thus the characteristics of 6G have been reviewed along with the enabling technologies and relevant use cases.

TABLE 3 : COMPARISON OF 6G ENABLING TECHNOLOGIES AND RELEVANT USE CASES

SL.NO.	AUTHOR	PAPER TITLE	ENABLING TECHNOLOGY	POTENTIAL	CHALLENGES	USE CASES	YEAR
New Spectrum							
1	J.M Jornet and I.F. Akyildiz	Channel Modelling and Capacity Analysis for Electromagnetic Wireless Nanonetworks in the Terahertz Band	Terahertz	It provides High bandwidth, small antenna size and focused beams	High propagation loss and Circuit design need to be focussed	It is used in Pervasive connectivity, industry 4.0, holographic telepresence	2020
2	P.H.Pathak,X.Feng et al.	Visible Light Communication Networking and Sensing: A	VLC	It provides low interference, unlicensed spectrum, low-	There is a need for RF up-link and Limited coverage	It is used in eHealth and pervasive connectivity	2020

		Survey Potential And Challenges		cost hardware			
Novel PHY techniques							
3	S.Goyal and P.Liu et al.	Full duplex cellular systems: will doubling interference prevent doubling capacity?	Sensing and Localization	It provides Novel services and context-based control	Efficient multiplexing of communication and localization need to be addressed	It is used in eHealth, industry 4.0, unmanned mobility	2020
			Full duplex	It provides continuous Transmitter / Receiver and relaying	There is a need for management of interference scheduling	It is used in Pervasive connectivity and industry 4.0	
			Out-of-band channel estimation	It provides Flexible multi-spectrum communications	There is a need for reliable frequency mapping	It is used in holographic telepresence and Pervasive connectivity	
4	M.Wang and Y.Cui et al.	Machine Learning for Networking: Workflow, Advances and Opportunities	User-centric network Architecture	It provides distributed intelligence to the endpoints of the network	There is a need for Real-time and energy efficient processing	It is used in Pervasive connectivity, industry 4.0 and eHealth	2020
			Knowledge sharing learning for value of information assessment	Speed up learning in new scenarios is provided	There is a need to design novel sharing mechanisms	It is used in Pervasive connectivity and unmanned mobility	
				It provides Intelligent and autonomous selection of the information to transmit	There is a need for unsupervised learning and complexity	It is used in Pervasive connectivity, industry 4.0 , unmanned mobility, holographic telepresence and e-Health	
5	A.Ali and N.Gonzalez-Prelcic et al.	Millimeter wave beam selection using out-of-band spatial information	3D network architecture	It provides Ubiquitous 3D coverage, seamless service	There is a need for modelling, topology optimization and energy efficiency	It is used in Pervasive connectivity, unmanned mobility and eHealth	2020
			Energy-harvesting and low -power operations	It provides Energy efficient network operations and resiliency	There is a need to integrate energy source characteristics in protocols	It is used in Pervasive connectivity and eHealth	
			Disaggregation and virtualization	It provides lower costs for operators for massively-dense deployments	There is a need for High performance for PHY and MAC processing	It is used in Pervasive connectivity, industry 4.0 , unmanned mobility and holographic telepresence	

IoT enables seamless communications and automatic management between heterogeneous devices without human intervention which has the potential to revolutionize industries and provide significant benefits to society through fully intelligent and automated remote management systems.

As an enabler for supporting IoT networks and applications, mobile technologies from the first to the fifth generation have been already proposed and deployed commercially. It is enabled by inherent usage features such as enhanced mobile broadband (eMBB), massive machine type communication (mMTC), and ultra-reliable and low-latency communication (URLLC) services. The latest fifth generation (5G) technology has been proven to offer different service opportunities to IoT ecosystems with high throughput, low latency and energy-efficient service provision [2], [3].

However, the fast growth of automated and intelligent IoT networks is likely to exceed the capability of the 5G wireless systems. Moreover, the emergence of new IoT services and applications such as remote robotic surgery and flying vehicles also requires further advances in current 5G systems for improving the quality of IoT service delivery and business [4]. 6G is expected to provide an entirely new service quality and enhance user's experience in current IoT systems due to its superior features over the previous network generations, such as ultra low-latency communications, extremely high throughput, satellite-based customer services, massive and autonomous networks [6]–[8]. These levels of capacity will be unmatched and will enhance the applications and deployments of 6G-based IoT networks across the realms of IoT data sensing, device connectivity, wireless communication, and 6G network management.

A speculative study on 6G given in [13] where the authors indicated the visionary technologies to be potentially used in future 6G networks and applications. The use cases in 6G wireless networks were summarized in [14], while the recent advances in wireless communication toward 6G were presented in [15]. The works in [16], [17] presented a survey on the vision of future 6G wireless communication and its network architecture, with a focus on the analysis of enabling technologies for 6G networks. A more comprehensive survey on 6G wireless communications and networks was provided in [18], where the authors paid attention to the illustration of the tentative roadmap of definition, specification, standardization, and regulation in 6G technologies. The potential 6G requirements and the latest research activities related to 6G were also discussed in [19], while the survey in [20] provided a holistic discussion of various essential technologies in 6G.

6G has been studied extensively in the literature, there is no existing work to provide a comprehensive and dedicated survey on the integration of 6G and IoT, to the best of our knowledge. Notably, a holistic discussion on the emerging 6G-IoT applications such as Vehicular Internet of Things, Autonomous Driving, and Satellite Internet of Things is still missing in the open literature. These limitations motivate us to conduct a holistic review on the convergence of 6G and IoT. Particularly, the most fundamental 6G technologies for enabling IoT networks, including edge intelligence, reconfigurable intelligent surfaces, space-air-ground underwater communications, THz communications, massive URLLC communications, and block chain are identified and discussed.

The representative use cases on the integration of 6G technologies and IoT are also explored and analyzed. An extensive discussion on the use of these 6G technologies in a wide range of newly emerging IoT applications is presented. It includes five domains, i.e., Internet of Healthcare Things, Unmanned Aerial Vehicles, Vehicular Internet of Things and Autonomous Driving, Satellite Internet of Things, and Industrial Internet of Things. The opportunities brought by 6G in a number of newly emerging IoT applications are explored and discussed in a number of important domains, i.e., Healthcare Internet of Things (HIoT), Unmanned Aerial Vehicles (UAVs), Vehicular Internet of Things (VIoT) and Autonomous Driving, Satellite Internet of Things (SIoT), and Industrial Internet of Things (IIoT).

4.2 Enabling Technologies and Requirements of 6G

The requirements of 6G-IoT networks are also highlighted. 6G Driven by the unmatched augumentation of mobile devices and the exponential growth of mobile traffic, wireless communication technologies have rapidly developed in recent years as a key enabler for future customer services and applications. Here a brief discussion on the potential technologies for 6G to enable mobile AI applications and the analysis of the AI-enabled solutions for 6G network design and optimization is given. [13] Speculative study on 6G A short discussion to speculate on the visionary technologies for enabling 6G networks and applications, [14] 6G technologies and case studies, a short discussion on the enabling technologies for 6G and potential case studies are also discussed.

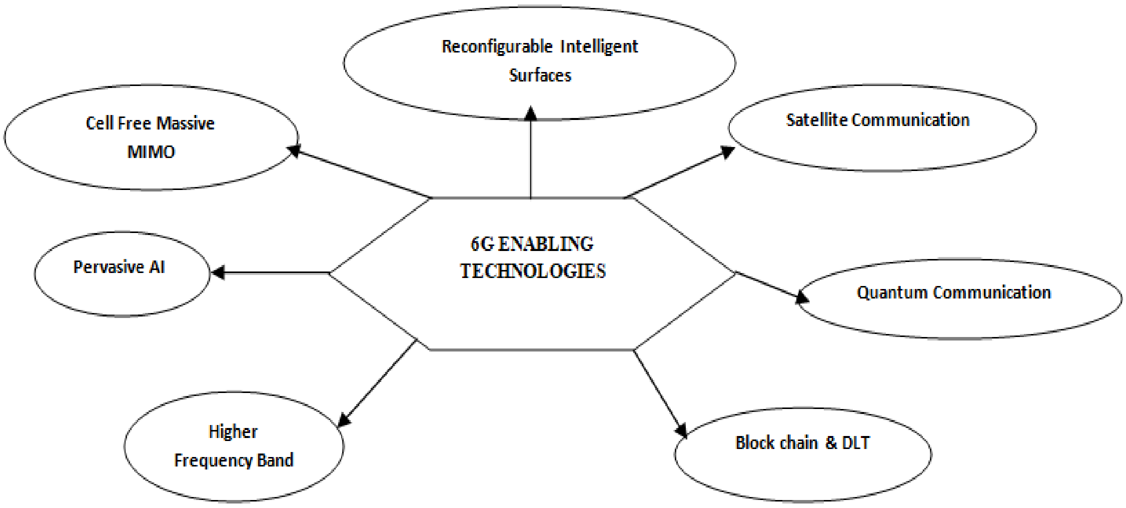


Figure 3. Enabling Technologies of 6G

TABLE 4. A COMBINED SUMMARY OF THE OPPORTUNITIES, CHALLENGES AND FUTURE DIRECTIONS OF THE PRESENTED USE CASES, IN THE CONTEXT OF 6G

Sector	Opportunities and Future Directions : 6G Offers	Challenges	Use Case
HEALTH CARE	1.High data rates 2.Ultra- low latency 3.Unlimited Number of sensing nodes by integrating in the 6G radio antennas 4.Utilising IRS	1. High Latency 2.Limited number of sensing nodes 3.Reliable communication of critical information	Human Activity Monitoring [31]
	1.Edge Computing 2.Ultra-low latency 3.Large network coverage	1.Limited number of object's classification 2.Limited computing power 3. Delay in video feed	Assistive Technologies for the Visually Impaired [32]
TRANSPORT	1.Connectivity for all things 2.Ultra- low latency 3.High data rates 4.Reliable communication links	Real – Time ubiquitous Communication between the driver and the car	Predicting the Intent to Return to a vehicle [27]
SMART GRID	1.Network Intelligence 2.High data rates 3.Service Intelligence 4.Unlimited number of energy sensing nodes 5.Ultra-Low Latency	1.Limited data loggings rates 2.Limited data resolution 3.Limited energy-load resolution	Promoting Energy- conscious Behaviour in the NHS [5]
INDUSTRY	1.Connectivity for all things 2.Ultra-low latency 3.High data rates 4.Reliable Communication links	1.Timely communication of information 2.Reliable connectivity	Festo Flexible Manufacturing System [28]

5 CONCLUSION

Therefore, 6G has induced interest in both industry and academic perspective due to its easing features compared to that of previous generations of wireless networks. The opportunities brought by the 6G technologies to support Intelligent IoT networks through an integrated survey has been explored. The entire work is motivated by the lack of a holistic survey on the use of 6G for IoT in healthcare system. A combined summary of the opportunities, challenges and future directions of the presented use cases, in the context of 6G is represented in Table 4.

In future 6G-based IoT networks concentrates more on how to achieve high energy efficiency that is considered to be a major concern, e.g., energy resources needed for data transmission, communications, and service delivery services. Building energy-efficient wireless communication protocols is highly needed for 6G-IoT networks. Energy harvesting techniques to exploit the renewable energy resources will be very useful to build 6G Intelligent IoT in healthcare systems [30]. The involvement in 6G communications and computation tasks demands new challenges into hardware designs for IoT devices. Due to the constraints of hardware, memory, and power resources, certain IoT sensors cannot meet these computational requirements in 6G-based customer applications [19]. In addition to the development of Intelligent IoT in healthcare systems in future, it is also desired to develop lightweight on-device hardware platforms to meet service computation demands, e.g., on-device edge intelligence in mobile 6G networks. Thus the standard specifications in 6G – IoT for healthcare along with their use cases are also discussed.

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