DOI: 10.56452/2021SP-8-003

ISSN: 0974-5823 Vol. 6 (Special Issue 3, November 2021)

International Journal of Mechanical Engineering

Role of 5G Technology in the Internet of Things based system – Challenges and Solutions

Pardeep Kumar Jindal[a,1], Manbir Kaur Brar[a,2], Bhupinder Kaur[a,3] and Sanskar Kedia[b,4]

[a]Assistant Professor in ECED, CEC Jhanjeri – Mohali

[b]Student in ECED, CEC Jhanjeri - Mohali

[1]pardeep.alkra@gmail.com, [2]erbhupinder24@gmail.com, [3]manbirbrar90@gmail.com, [4]sanskar2001kedia@gmail.com

Abstract: The Internet, a revolutionary invention, is continuously transforming into some new kind of hardware and software, making it unavoidable for anyone. Internet of Things (IoT) promises a great future for the Internet where the type of communication is machine-machine (M2M). IoT - centric concepts like augmented reality, high-resolution video streaming, self-driven cars, smart environment, e-health care etc., are ubiquitous now. In contrast, IoT can revolutionize by providing seamless connectivity between heterogeneous networks (HetNets) worldwide. The main aim of IoT is to introduce plug-and-play technology, providing the end-user with ease of operation and remote access control. The paper presents a detailed and extensive overview of the emerging 5G-IoT scenario. Fifth Generation (5G) cellular networks provide vital enabling technologies for ubiquitous deployment of the IoT technology. This paper presents an exhaustive review of these key enabling technologies. Also, it discusses the new emerging use cases of 5G-IoT driven by the advances in artificial intelligence, machine, and deep learning, ongoing 5G initiatives, quality of service (QoS) requirements in 5G, and its standardization of issues. Finally, the paper discusses challenges in implementing 5G-IoT due to high data rates requiring both cloud-based platforms and IoT devices-based edge computing.

Keywords*:* Internet of Things, IoT, 5G, carrier aggregation, QoS, HetNets

Introduction

Significant advances in wireless sensor networks, telecommunications, and information science have paved the way for the acquisition of comprehensive intelligence [1], [2], envisioning the IoT of the future. The genesis of IoT goes back to the 1980s with the idea of ubiquitous computing, whose objective was to embed technology in everyday life [3]. Currently, the IoT is envisaged both at the individual and professional levels. For an individual, IoT plays a pivotal role in enhancing living standards in e-health, smart home, and intelligent learning. For a professional, IoT finds its application in automation, intelligent supply chain, transportation, remote monitoring, and logistics. A vision of an all-communicating world states as the system provides per area data volume to be increased by 1000 times, the number of connected devices, and the user data-rate is to be increased by 10 to 100 times. Furthermore, the extended battery life is up to 10 times for massive machine communication devices, and end-to-end latency is reduced by five times [4]. Hence, recent trends show that many researchers are interested in the amalgam of various technologies like the integration of sensors and embedded systems with cyber-physical systems (CPS), device-to-device communications (D2D), and 5G wireless systems with IoT as a centre. New business models for IoT implementation require massive connectivity, high privacy and security, complete coverage, ultra-high reliability, and ultra-low latency. The trending 5G-enabled IoT encompasses increased data rates, better range, and high throughput, providing solutions to business models and enabling IoT for robots, actuators, and drones [5]. Kevin Ashton coined the term IoT in 1999 regarding supply chain management [6]. IoT revolves around the word "smartness" – "an ability to obtain and apply knowledge" [7] independently. Therefore, IoT refers to the "things or devices and sensors" that are innovative, uniquely addressable based on their communication protocols, and are adaptable and autonomous with inherent security [8]. Atzori et al. [3] have characterized IoT in three visions. Internet

DOI: 10.56452/2021SP-8-003

Oriented - the vision focuses on connectivity between the objects; Things oriented – the concept focuses on generic; and Knowledge Oriented – the ideas on how to represent, store and organize information.

Three components form the basis of IoT architecture:

(1) Hardware:-It comprises sensor nodes, embedded communication, and interfacing circuitry.

(2) Middleware: It comprises data storage, analysis, and handling of resources.

(3) Presentation layer: It comprises efficient visualization tools compatible with various platforms for different applications and presents the data to the end-user in an understandable form.

The parameters affecting the architecture of IoT are manifold. Hence, the present research work to devise the most optimized architecture that handles network issues such as scalability, security, addressability, and efficient energy utilization. As for the future, the number of devices connected to the network will rise. Hence, the architecture of IoT must cater to it. Scalability, energy consumption, and addressing issues are considered challenges for IoT's successful deployment.

Handling a considerable amount of big IoT data from all the network nodes is tedious. Also, must consider the energy efficiency of the data centres must. Hence, to cater to these issues must deploy artificial intelligence techniques, novel fusion algorithms, state-of-the-art temporal machine learning methods, and neural networks must be deployed for automated decision-making and energy efficiency [10].

5G NETWORK

5th Generation (5G) wireless communication systems expect to address unprecedented challenges to cope with a high degree of heterogeneity in terms of - (a) services (mobile broadband, massive machine, and mission-critical communication, and broad/multi-cast service); (b) device class (low-end to high-end sensors); (c) deployment type (macro/small cell); (d) environments (low-density to ultra-dense urban); (e) mobility levels (static to high-speed transport) [11]. Therefore, 5G will provide an order of magnitude improvement in some key characteristics to efficiently support such heterogeneity with a diverse set of requirements including, but not limited to, capacity/user rates, latency, reliability, coverage, mobility, massive number of devices, and cost/energy consumption. More specifically, a 5G air interface will achieve:

(i) 1000× higher mobile data volume per geo area;

(ii) 10 to 100× more connected devices and higher typical user data rate;

(iv) 10x lower energy consumption;

(v) sub-millisecond level end-to-end latency;

(vi) ubiquitous 5G access in low-density areas [2].

Fig 1. Achievements of 5G

DOI: 10.56452/2021SP-8-003

The above-mentioned fundamental characteristic is envisioned based on several emerging use cases and scenarios specified by the 5G research community. For example, Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society (METIS) introduced five different plans and 12 test cases based on these scenarios [12]. Ranging from high-speed entertainment applications in a vehicle to smart meters installed in homes, from ultra-low latency vehicle-to-vehicle communication to delay-tolerant ubiquitous things communicating, and from ultra-reliable applications to best-effort services; different applications and use cases can be categorized into four main communication scenarios [13]:

(i) Bitpipe communication: targets ultra-high user data rates and ultra-high traffic volume density in local indoor and outdoor hot-spot areas.

(ii) Internet of Things (IoT): this scenario targets sensory and data collecting use cases such as smart grid, health, and environmental measurements, monitoring, etc.

(iii) Tactile Internet: this scenario focuses on particular applications and uses cases of IoT and vertical industries with real-time constraints such as Internet of Vehicles (IoV) and industrial control.

(iv) Wireless Regional Area Network (WRAN): coverage of low-populated remote areas which suffer from low data rates and unreliable solutions.

5G IoT

5G is a new communication system with a primarily new core network and a 5G New Radio framework that aims to improve wireless connections worldwide. It also contains multiple access to technologies such as satellite, Wi-Fi, fixed-lines, and cellular network. With IoT-enabled devices, it may connect more devices at a higher speed. Further, 5G creates an excellent user experience regardless of application, machine, or service.

Massive cellular IoT technologies have features as low-cost, low-power consumption solutions. These features can boom in deep and broad coverage indoors and outdoors. They deliver secure connectivity and authentication and are easy to deploy to any network topology—the design for capacity and full-scope scalability upgrades. With the power of 5G adaptability, the users like city developers and other industrial organizations can connect more devices with better capability at low cost and high speed at their fingertips.

As per GSMA, the mobile-IoT refers to licensed spectrum bands of cellular LPWA technology. Both 3GPP Narrowband-IoT and Long-Term Evolution Machine (LTE-M) - Type Communications technologies are integral to a new 5G technology. The cellular LPWA provides the path to 5G communication with undisrupted information/data flow. Therefore, 4G technology may be expected to continue under the support of the 5G network for many years.

It can provide smart energy control or optimum energy use in factories, warehouses and offices, where users can remotely access any particular in the world. These can monitor, control, and measure various environmental parameters by connecting multiple devices. All these are only possible with IoT and 5G technology. The existing cellular networks have needed billions of new devices to grow speed/connectivity solutions, making the grade primarily in business and technology.

Many enterprises are deploying their IoT projects based on either NB-IoT or LTE-M as future-proofing of 5G-IoT technology. IoT solutions will connect to over 50 billion devices up to 2030. The 5G evolution in communication will bring the world a faster and more brilliant future. Substantial efforts are underway to merge cross-domain research activities spanning machine-to-machine (M2M) communication, wireless sensor network (WSN), and RFID into a unified IoT framework [10].

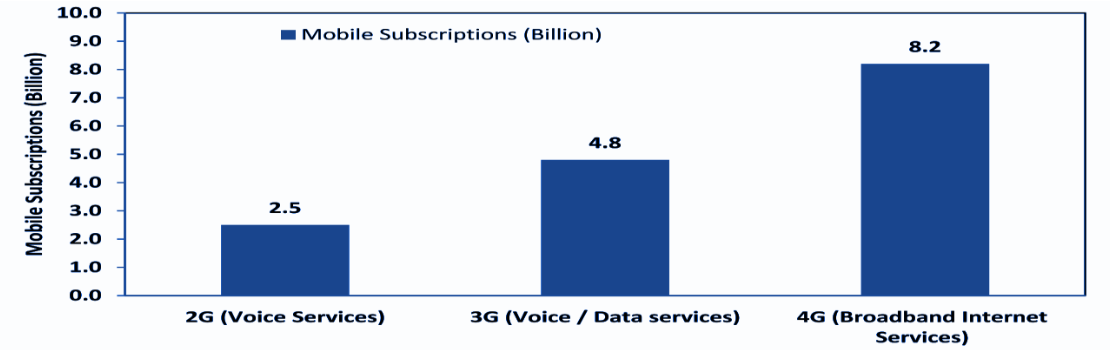

Fig 2. Mobile device subscriptions for different wireless technologies

5G IoT APPLICATION

The 4G standards like NB-IoT and LTE-M are an integral part of 5G technology, which currently provides mobile IoT solutions for smart cities and intelligent logistics. The 5G applications have focused on enterprises and high-speed industrial networking, customer premise equipment (CPE), mobile computing, video broadcasting, and fixed wireless access (FWA).

As adoption grows with more network rollouts, they will evolve and be used to stream augmented reality and 3D video (which requires high bandwidth) and for critical communications like factory automation, UAVs, and more.

Imagine parking an intelligent car in a parking garage, gaining wireless charging through the city grid. At the same time, people work and then message the vehicle to drive itself from the parking garage to the office door.

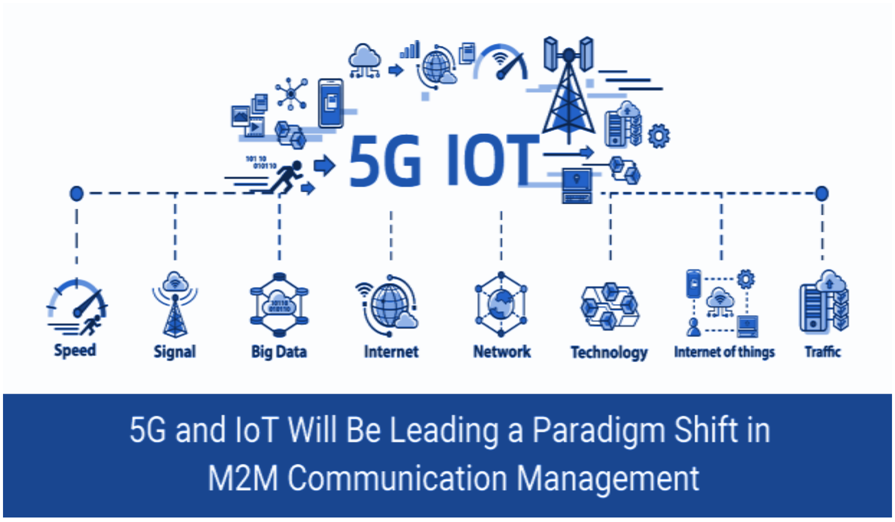

Fig 3. 5G IoT

Farmers in agriculture will be able to monitor and track crop growing conditions and livestock and control machinery more efficiently by using drones and super-dense sensor networks.

DOI: 10.56452/2021SP-8-003

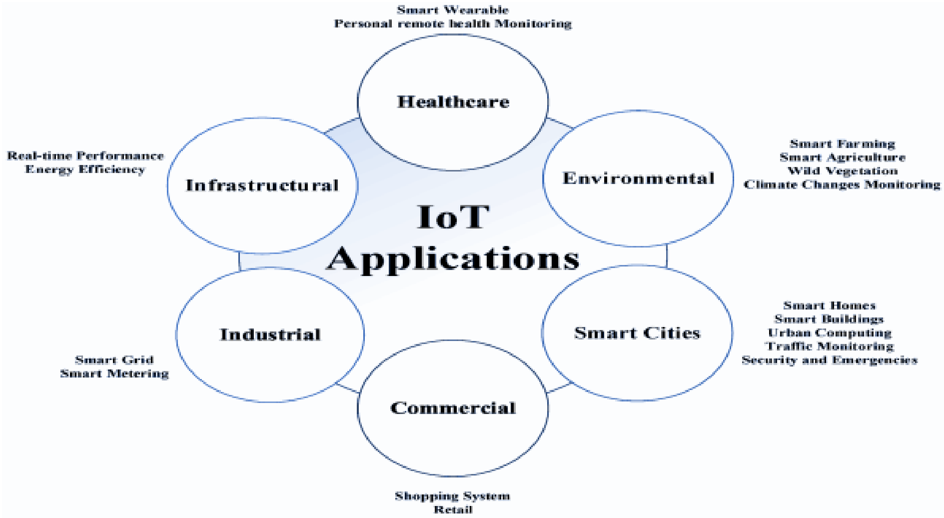

Fig 4. IoT Applications

Nowadays, the smartphone, synced smartwatches and smart home automation applications are commonly used and may grow due to the high-speed capability of 5G technology. The IoT-5G future will be completely different in the next 20 or so years because of the heavy dependence on IoT applications on a grand scale today. Further, the researchers are working on many vehicle automation, waste monitoring and controlling system, smart energy development, and smart environment monitoring and managing solutions for air and water pollution.

Fig 5. Advantages of 5G

The users will fully integrate the COVID-led work-from-home paradigm, which will survive the pandemic as a new corporate norm. Additionally, the users will be capable of optimizing power usage and streaming their favourite entertainment from anywhere. Society will be more efficient, smart cities will live up to their name, and users can expect personalized streams of information catered to their liking. 5G IoT will improve everyday users' quality of life from personal application to fundamentally changing how we work and live. With 5G IoT, facilities will continue improving to send critical upgrades to entire networks without freezing functionality, halting operations, or overloading servers.

5G IoT CHALLENGES

Current trends show that the future 5G-IoT network should be capable of supporting the massive connectivity of devices by providing high and consistent QoS. A 5G network has to cater to massive and critical IoT.

5G wireless networks expect to address unprecedented challenges to cope with a high degree of heterogeneity, such as (a) services (mobile broadband, massive machine and mission-critical communication, vehicular

DOI: 10.56452/2021SP-8-003

communication, broad/multi-cast services; (b) deployment types (macro and small cells); (c) environments (low-density to ultra-dense urban); (d) mobility levels (static to high-speed transport) [1].

Table 1. Challenges and Solutions of 5G-IoT

S. No.	CHALLENGES	SOLUTIONS
1	Flexibility in the physical layer radio framework? of 5G technology to satisfy the diverse requirements of IoT	Suitable radio numerology is designed with a random-access channel to support massive connection density and can deal with channel impairment and imperfections in the transceiver.
2	Huge signaling overhead in network control schemes for network edge devices and leveraging Radio access technologies (RAT)	A review of client-controlled HetNets for 5G networks provides an in-depth distributed and hybrid control approach.
3	To cope with the needs of 5G, enable IoT such as better data rate, reduced latency, consistent quality of service, and substantial spectrum resources	5G cellular network architecture presents enabling technologies such as M-MIMO, and D2D communication. Other emerging technologies offer an ultra-dense network, cognitive radios, millimeter (mm) - wave solutions for 5G networks, cloud technologies, etc.
4	Efficient low power WAN (LPWAN) enabling technologies for IoT.	LORA presents the latest and most promising technology
5	The 5G-IoT scenarios consider the efficient recharging of ubiquitous IoT devices as a tedious task.	Solutions for the wireless powering of IoT devices using near and far-field techniques may provide. Furthermore, a new networking model called Wireless power communication network is introduced, integrating wireless power transmission and communication.

Therefore, 5G will provide an order of magnitude improvement in some key characteristics to efficiently support such heterogeneity with a diverse set of requirements including, but not limited to, capacity/user rates, latency, reliability, coverage, mobility, massive number of devices, and cost/energy consumption.

The traffic generated by such IoTs is different from that caused by cellular systems in many aspects. First, unlike the case of broadband access, most IoT traffic is in the uplink. Moreover, IoT networks' messages are typically small and sparse in time. Furthermore, IoT devices are limited in energy and computation resources. These IoT devices' characteristics make their access to 5G systems different from classical cellular devices [14]. Identifying the right system parameter configuration for the specific IoT use case is a big challenge [15].

The 5G cellular network's QoS can comprehend its spectral efficiency and latency [16]. The spectral efficiency of a 5G network can achieve using non-orthogonal signals and radio access methods. In contrast, latency demands vary in the case of a user and control plane traffic.

Conclusion

This paper presented an exhaustive review of the 5G wireless technologies that have become vital factors for the ubiquitous deployment of IoT technology. The survey shows a study of the evolution of cellular wireless technologies, making a case for how 5G wireless technology improved upon its predecessor technologies, making ubiquitous deployment of IoT possible. The various architectural components of the 5G networks are also discussed, with particular emphasis on the improvements to the physical and network layer of 5G networks over its predecessors. The paper also discusses the challenges of QoS requirements in modern-day 5G-IoT, whose traffic characteristics differ significantly from legacy 5G network applications, predominantly in the uplink direction instead of the downlink. High data transmission rates with low latency from the 5G-IoT nodes are vital for the cloud-based application layer programs running state-of-the-art artificial intelligence, machine, and deep learning algorithms for efficient real-time data processing and prediction. Such modern-day applications running on top of 5G-IoT, e.g. intelligent transport, innovative healthcare, etc., are also discussed. Benchmarks for good and key performance indicators (KPIs) are presented. Another challenge discussed in this paper is the standardization issues due to the several heterogeneous nodes participating in the 5G-IoT network (HetNets).

References

[1] L. Roselli, N. B. Carvalho, F. Alimenti, P. Mezzanotte, G. Orecchini, M. Virili, C. Mariotti, R. Goncalves, and P. Pinho, ‘‘Smart surfaces: Large area electronics systems for the Internet of Things enabled by energy harvesting,’’ Proc. IEEE, vol. 102, no. 11, pp. 1723–1746, Nov. 2014.

[2] A. Costanzo and D. Masotti, ‘‘Energizing 5G: Near- and far-field wireless energy and data transfer as an enabling technology for the 5G IoT,’’ IEEE Microw., vol. 18, no. 3, pp. 125–136, May 2017.

[3] L. Atzori, A. Iera, and G. Morabito, ‘‘The Internet of Things: A survey,’’ Comput. Netw., vol. 54, no. 15, pp. 2787–2805, Oct. 2010.

[4] A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, O. Queseth, M. Schellmann, H. Schotten, H. Taoka, H. Tullberg, M. A. Uusitalo, B. Timus, and M. Fallgren, ‘‘Scenarios for 5G mobile and wireless communications: The vision of the METIS project,’’ IEEE Commun. Mag., vol. 52, no. 5, pp. 26–35, May 2014.

[5] D. Niyato, M. Maso, D. I. Kim, A. Xhafa, M. Zorzi, and A. Dutta, ‘‘Practical perspectives on IoT in 5G networks: From theory to industrial challenges and business opportunities,’’ IEEE Commun. Mag., vol. 55, no. 2, pp. 68–69, Feb. 2017.

[6] K. Ashton, ‘‘Internet of Things,’’ RFID J., vol. 22, no. 7, pp. 97–114, 2009.

[7] E. Ahmed, I. Yaqoob, A. Gani, M. Imran, and M. Guizani, ‘‘Internet-of-things-based smart environments: State of the art, taxonomy, and open research challenges,’’ IEEE Wireless Commun., vol. 23, no. 5, pp. 10–16, Oct. 2016.

[8] Co-Operation With the Working Group RFID of the ETP EPOSS, Internet of Things in 2020, Roadmap for the Future, Version 1.1, INFSO D.4 Networked Enterprise RFID INFSO G.2 Micro Nanosystems, May 2008.

[9] The Internet of Things, document ITU Internet Reports, Nov. 2005.

[10] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, ‘‘Internet of Things (IoT): A vision, architectural elements and future directions,’’ Future Gener. Comput. Syst., vol. 29, no. 7, pp. 1645–1660, Sep. 2013

[11] F. Schaich et al., "FANTASTIC-5G: 5G-PPP project on 5G air interface below 6 GHz," in Proc. Eur. Conf. Netw. Commun., Jun.2015, accessedOnjun.27,2016. [Online] Available: http://fantastic5g.eu/wpcontent/uploads/2015/07/EuCNC-FANTASTIC-5G_final.pdf

[12] A. Osseiran et al., ‘‘Scenarios for 5G mobile and wireless communications: The vision of the METIS project,’’ IEEE Commun. Mag., vol. 52, no. 5, pp. 26–35, May 2014.

[13] 5G Waveform Candidate Selection, document 5GNOW_D3.2_v1.3, 5GNOW deliverable D3.2, 2014.

[14] B. Khalfi, B. Hamdaoui, and M. Guizani, ‘‘Extracting and exploiting inherent sparsity for efficient IoT support in 5G: Challenges and potential solutions,’’ IEEE Wireless Commun., vol. 24, no. 5, pp. 68–73, Oct. 2017.

[15] P. Annamalai, J. Bapat, and D. Das, ‘‘Emerging access technologies and open challenges in 5G IoT: From physical layer perspective,’’ in Proc. IEEE Int. Conf. Adv. Netw. Telecommun. Syst. (ANTS), Indore, India, Dec. 2018, pp. 1–6.

[16] A. Gupta and R. K. Jha, ‘‘A survey of 5G network: Architecture and emerging technologies,’’ IEEE Access, vol. 3, pp. 1206–1232, 2015.