Advances and Recent Applications of 5G: the Model of 5G Infrastructure and Ecosystem in India

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Abstract

5G deployment already started in several countries. This communication network enables applications demanding low-latency and high throughput. The potential vertical sectors potentially impacted are different. In India, several applications have been identified from tourism to education. Trials already started to be carried out. The paper presents a review of the main applications and related trials for 5G deployment in India. It results in an overall ecosystem where potential innovative applications can be developed.

Keywords

Blockchain, Smart Contract, Internet Of Things,

1. Introduction

India has already established itself as a major player in the global telecom arena since it has the second-largest mobile internet base. India is ready for a digital revolution now that the eagerly awaited 5G spectrum auctions have concluded as a result of structural and legislative changes [1], also considering the evolution of electronic devices [2, 3, 4, 5]. It is anticipated that next-generation digital services will change how individuals use government services, how businesses engage with consumers, and how Communications Service Providers (CSPs) connect the existing network transition with future communication needs. In an era of hyperconnectivity and rapid technological innovation, 5G is poised to become a connectivity fabric that links people, machines, devices, and ecosystems [6, 7, 8].

The present paper aims to describes the main applications and relative initiatives established in India regarding 5G. The Section II presents the objectives and the main activities of the Department of Telecommunication of the Indian Ministry of Telecommunication. From section III to the Section XI the main vertical sector impacted by 5G are described. Finally, in section XII conclusions are drawn.

The Department of Telecommunication belonging to the Indian Ministry of Telecommunication is strongly focused on the 5G network and related applications. In particular, the Department is committed to:

- build competencies and engagement in 5G technologies in students and academic fraternity.
- enable projects at UG and PG level for students using 5G environment.
- encourage academia-industry engagement to ideate and develop 5G use cases.
- provide local access to 5G test setup for Startups and MSMEs around the institution.
- making Indian academia & startup ecosystem 6G read

The main activities carried out by the Department of Telecommunication regard:

- It improves NTN LoRaWAN's connectivity by, for instance, further refining the long range-frequency hopping spread spectrum (LR-FHSS), which allows LoRaWAN to far outpace the anticipated demands of the enormous IoT on network capacity [9].
- selection of Institutions & empanelment of domestic vendors (EoI).
- floating of RFP/Tender, selection of vendors (competitive bidding) and price discovery for CAPEX & OPEX.
- installation coordination for setting up of Labs at selected institutions (100+).
- oversight and coordination for O&M and utilization of labs (100+) for period of 5 years
- hosting of dedicated portal reg call for proposals, performance monitoring, Remote O&M support, release of installments.
- digital platform for networking and utilization of labs.
- supporting institution/institutions to host hackathons.

- knowledge disseminating platform for other institutions/students/startups etc., on use-cases being tested/developed/demonstrated.
- database of 5G domestic vendors available, 5G devices (incl IoT), successful 5G projects/pilots related to Health, Agriculture, Intelligent Transport systems, Industry 4.0 etc.

In addition, several potential vertical applications enabled by 5G have been identified, as follows [10].

2. Agriculture

By offering affordable technology solutions that support evidence-based methods in both crop production and livestock management, 5G adoption in agriculture transforms the sector. Precision farming methods are made possible by 5G's high-speed connectivity and low-latency transmission, which guarantee the proper application of pesticides and fertilizers based on real-time data and analytics [11, 12, 13]. 5G-enabled online systems give farmers information about crop health and yield status, enabling them to make more educated decisions and providing better support in the form of loans and insurance [14, 15]. In terms of soil conservation, 5G enables real-time soil condition assessment through monitoring systems, supporting sustainable land management techniques. 5G-enabled solutions assist fisheries and livestock by giving farmers and fishermen the tools they need for efficient management and monitoring. Furthermore, 5G enhances the safety of fisherman by facilitating instantaneous communication and tracking mechanisms, guaranteeing prompt action during crises. To summarise, the use of 5G technology in agriculture facilitates data-driven and cost-effective practises, which in turn promote sustainability, increase yields, and improve the general safety and productivity of farmers and fishermen.

3. eHealth

The advent of 5G technology is a turning point for the healthcare sector, presenting hitherto unheard-of chances for change. 5G, with its extremely fast data transfer speeds, low latency, and large bandwidth, is expected to completely transform healthcare in a number of ways [16]. It allows massive medical files to be transmitted quickly, which speeds up the diagnostic process and makes treatment decisions more quickly. 5G-enabled real-time remote patient monitoring enables medical practitioners to act quickly, improving results for patients with chronic illnesses. Additionally, the technology makes it easier for telemedicine to function smoothly and for virtual consultations to take place, hence reducing geographical obstacles and improving access to healthcare

[17, 18, 19, 20, 21]. 5G's low latency enables the integration of augmented reality (AR) and virtual reality (VR) applications in surgical planning, therapeutic treatments, and medical training. 5G helps the Internet of Medical Things (IoMT) by forming a unified ecosystem that facilitates more efficient data collecting and better patient care. Advances in precision medicine are made possible by 5G, which makes it possible to analyze large datasets for individualized treatment plans that customize therapy to meet the needs of each patient. 5G's high-bandwidth, low-latency connections improve robotic system precision in surgery, enabling remote control of less invasive treatments. 5G enables prompt and effective healthcare services during emergencies by enabling remote consultations, data sharing, and professional coordination. Although these developments have the potential to enhance accessibility and patient outcomes, it is crucial to address issues like data security and privacy to ensure the ethical and responsible application of 5G technology in healthcare.

4. Logistics

The adoption of 5G technology in logistics represents a paradigm change, with significant advantages for increasing productivity, cutting costs, and raising the bar for logistics management as a whole. In order to improve supply chain efficiency, 5G is essential for enabling real-time tracking and monitoring of shipments and vehicles. It does this by delivering accurate and fast information. The technology's low latency and fast data transfer speeds enable more effective fleet optimization, traffic management, and route planning, especially in emergency, which lowers fuel consumption and saves operating costs [22]. Surveillance and security systems enabled by 5G technology help reduce losses, waste, and thefts by utilizing advanced monitoring technologies, such as IoT devices and real-time video analytics [23, 24, 25, 26, 27, 28]. Furthermore, 5G makes predictive maintenance possible, giving logistics firms the ability to track the state of equipment and vehicles in real time, reducing downtime and averting unplanned malfunctions. Smart freight corridors improve transportation efficiency by intelligent traffic control, dynamic rerouting, and vehicle-to-vehicle communication, such as automotive and railway, including Non-Terrestrial Network (NTN) [9]. 5G-enabled automation and robotics in logistics increase productivity, lower labor costs, and speed up order delivery. The utilization of technology enhances supply chain visibility by providing stakeholders with up-to-date information on inventory levels, order status, and production schedules. This facilitates well-informed decision-making and optimizes the logistics process as a whole. In conclusion, 5G integration enables logistics firms to efficiently handle

obstacles, resulting in a more efficient and economical supply chain management system.

5. Education

The introduction of 5G technology into the classroom is a revolutionary change that offers a plethora of opportunities for educators and students alike, as in the case of "School on Wheels" [29]. 5G has the potential to completely change the educational environment thanks to its unmatched speed, low latency, and strong connectivity. This is especially true for STEM education, industrial skill training, remote help, and intelligent learning solutions. 5G's fast connectivity revolutionizes STEM education by enabling interactive virtual simulations [30], augmented reality, and real-time collaboration all of which help students better understand difficult ideas. Additionally, 5G makes industrial skill training easier by bridging the theory-practice divide by offering immersive and remote learning experiences through augmented and virtual reality apps. This revolutionary adoption of 5G in education not only increases student engagement and effectiveness but also promotes inclusivity by guaranteeing that high-quality instruction is available to a wider range of students globally, ultimately equipping them for success in the rapidly changing Fourth Industrial Revolution.

6. Power and Energy

The power industry is experiencing a revolutionary change as a result of the integration of 5G technology, which is propelling improvements in energy distribution, grid management, and operational efficiency. With 5G, rea[31]l-time communication throughout the electrical grid is made possible, allowing for instantaneous data transfer between sensors, meters, and control centers for smart grid management. With 5G, remote repair and monitoring of power infrastructure—including substations and power lines becomes more effective. Proactive defect identification and prompt reactions are made possible, eventually reducing downtime and improving dependability. High-speed, low-latency connectivity that supports Distributed Energy Resources (DERs) like wind turbines and solar panels guarantees efficient coordination and use of renewable energy sources inside the grid. 5G's strong security features make the grid more resilient to cyberattacks and guarantee a safe energy infrastructure [32, 33, 34]. 5G also supports environmental monitoring, as in the case of the Advanced Air Pollution Monitoring Device (AAPMD) [35].

7. Mining port and airports

Significant improvements are achieved in operational economies, production processes, quality inspections, worker safety, and security when 5G technology is integrated into ports, airports, and mining operations. 5G offers high-speed, low-latency access to remote mining sites, enabling efficient extraction processes and facilitating real-time communication for machinery coordination. Constant observation with 5G-enabled sensors and cameras improves quality checks, guaranteeing prompt problem detection and upholding production standards. The use of drones and driverless cars, made possible by 5G, improves mining exploration and transit efficiency and safety. 5G enhances the effectiveness of cargo handling in ports by providing real-time tracking and monitoring, streamlining processes, and improving quality inspections via ongoing surveillance. Predictive maintenance is made possible by connected sensors, which lowers downtime and improves overall operational reliability. 5G transforms operations at airports by enabling cutting-edge surveillance and monitoring technologies for quality checks, guaranteeing integrity and safety [36]. 5G-enabled wearables and IoT devices improve worker safety by providing real-time information for quick emergency action. Furthermore, 5G-enabled security systems improve surveillance capabilities, which lessens unlawful access and improves overall airport security. To sum up, the incorporation of 5G technology in these crucial industries leads to a comprehensive improvement in productivity, security, and safety, resulting in an enhanced and optimized operational environment.

8. Tourism

The tourism industry is poised to undergo a transformation in the tourist experience and increase operational efficiency with the advent of 5G technology. The tourism industry can benefit from 5G's high data transfer speeds, reduced latency, and improved connectivity. Faster and more dependable internet access is made possible by seamless connectivity, which also enhances navigational capabilities and offers travelers real-time maps and tailored suggestions. Visitors can enjoy interactive views of historical monuments and landmarks through immersive augmented reality (AR) and virtual reality (VR) experiences made possible by 5G's reduced latency. 5G enhances operational efficiency by streamlining luggage tracking, check-in procedures, and ticketing. Quicker data processing enables travel agencies to provide customized services and focused advertising, adjusting suggestions according to visitor preferences. The technology contributes to the development of smart tourism destinations through interconnected devices and sensors,

ensuring sustainable practices. In emergency situations, 5G facilitates rapid communication and data transfer, enhancing safety measures for both tourists and local residents. As 5G continues to evolve, its integration into the tourism sector holds immense potential to redefine how people engage with destinations, offering a more connected, efficient, and personalized travel experience, including rural tourism [37].

9. Smart Cities

To improve safety, maximize urban mobility, track environmental factors, and guarantee efficient service delivery, 5G integration is essential in smart cities. 5G offers improved safety and surveillance systems with high-speed, low-latency connectivity, facilitating real-time monitoring, emergency response coordination, and crime prevention. 5G makes it easier to implement technology-driven traffic management strategies, such as connected cars and smart traffic lights, which efficiently reduce traffic and enhance urban mobility. Utilizing the technology's real-time capabilities, pollution levels, sewage flow, and water and waste management systems are monitored, all of which support adaptive and sustainable urban growth. Furthermore, 5G can also constitute a decision support framework [38] and a critical infrastructure for the provision of basic services like healthcare and transportation since it offers telemedicine and smart transportation systems seamless connectivity and facilitates effective communication between city services and citizens [39].

10. 5G Initiatives in India

In September 2017, the Indian government established the 5G High-Level Forum (5H HLF) to outline the country's 5G vision and suggest policy measures and an action plan to bring it to fruition. In August 2018, the 5G HLF published a report titled "Making India 5G ready," which included recommendations for major trials, regulatory policies, education and awareness campaigns, application and use case labs, spectrum policy, major trials, technology demonstration, and participation in international standards. Building an End-to-End 5G Test Bed is a program that the government has started to promote 5G innovation and research. March 2018 marked the start of this three-year program, which has a Rs 224 crore budget authorization. IIT Madras, IIT Hyderabad, IIT Delhi, IIT Kanpur, CEWIT, SAMEER, and Indian Institute of Science (IISc), Bangalore, have all been given the program. The program envisions small technological enterprises and colleges working closely together. The program's objective is to construct 5G proof-of-concept prototypes that broadly adhere to 3GPP specifications. DST and MEITY

have also provided funding for several smaller university R&D projects centered on 5G issues. In July 2018, Ericsson set up the first 5G public test bed at IIT Delhi. This allowed industry and academic institutions to work on applications and use cases tailored to India while also creating applications in broadband and low-latency sectors. It is recommended that the sector take the initiative to set up additional public test beds across the nation. Regarding standards, India has been successful in getting the IMT 2020 specifications to accept the Low Mobility Large Cell (LMLC) use case. The demands of rural India and other comparable nations are reflected in LMLC. In terms of deployment of 5G services, the National Digital Communication Policy-2018 (NDCP-2018), which was unveiled on September 26, 2018, outlines the following goals: - "2.2... (d) Rolling out 5G technologies to enable M2M, Internet of Things, and high-speed internet:

- selection of Institutions and domestic vendors (EoI).
- Putting an action plan into place for the deployment of 5G services and applications
- Increasing backhaul capacity to facilitate the creation of 5G and other next-generation networks
- Making sure spectrum for 5G is available in 6 GHz bands
- Examining industry standards for traffic prioritization in order to deliver 5G-capable services and apps
- Creating a framework to ensure M2M device security and interception while accelerating the deployment of M2M services
- Establishing guidelines for EMF radiation for M2M devices and a supporting institutional framework to organize government-funded research specifically focused on India in this area.

11. Conclusions

5G system can enable a plethora of applications belonging to different vertical sectors. In India, the Ministry of Telecommunication defined several potential 5G applications. In addition, several trials have been identified and deployed. From the review presented in this paper, the different applications can be interacted among them with important cost savings. Future works are focused on the cost-saving estimation derived by the deployment of a 5G common infrastructure enabling different vertical applications.

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