

Tracing The Evolution of Internet of Things (IoT): From Sensor Networks to Smart Ecosystems

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Abstract

The Internet of Things (IoT) has become one of the most well-known technologies in recent years, reaching new heights and setting global standards. Indeed, it is the communication of the future that has made real-world objects intelligent. The goal of the Internet of Things is to bring the world's items together under a single infrastructure so people can not only operate them but also receive timely, frequent updates on their current state. The Internet is a groundbreaking technology that is constantly evolving into new devices and applications, making it impossible to avoid. Current communication is either human-to-human or human-to-device, but machine-to-machine (M2M) communication offers a promising future for the internet through the IoT. The Internet of Things (IoT) is a network of sensors, actuators, RFID tags, software, storage, and connectivity that collect and process data to monitor and manage the intended environment. Every part of our everyday life is impacted by IoT, which is expanding rapidly in almost every industry. The IoT is a standard in which devices equipped with sensors, actuators, and processors interact with each other to accomplish significant tasks. This paper presents the IoT and its growth. This paper's goal is to provide an overview of the IoT, its architecture and levels, some fundamental words related to it, and the services offered.

Keywords: *Internet of Things; Journey of IoT; Applications; Components and Architecture; Use Cases.*

1. Introduction

The IoT is a network of physical items, like gadgets, tools, vehicles, constructions, and more, that are equipped with electronics, circuits, software, sensors, and network connections to gather and transmit data. The IoT enables a closer connection of the physical environment with computing-based processes, which makes things perceptible and remotely controlled across current network infrastructure, leading to enhanced accuracy and efficiency. This technology can communicate without the need for human interaction. The transportation, medical care, and automobile areas have already developed numerous early IoT applications. Although IoT skills are still in their initial stages, a number of significant advancements have been made in the Internet's integration of things with sensors [1]. The IoT is a cutting-edge and quickly developing technology that has the potential to transform how we interact with our environment [2], [3]. As a result of the emergence of advanced technology, the extension of standard communication channels, and the development of new tools for data analysis, IoT is at this time an increasingly common term, which describes a network of connected devices that monitor and interconnect different variables present in the environment [4], [5]. The lifecycle of IoT is conception, development, deployment, maintenance, and retirement. Every stage entails particular tasks that guarantee the efficient administration of IoT devices for the duration of their lives. Identifying consumer demands and outlining the product's vision are the main goals of conception. Market opportunities, trends, and potential barriers are explored by stakeholders. During this stage, it is crucial to comprehend user requirements. Development encompasses the design and build of the IoT device, as well as the software. The hardware parts are created by the developers, who also combine them with the required software. When the device is prepared, deployment takes place [6]. Once devices are plugged into the network, the installation processes begin. At this point, users learn about the procedures and make modifications. Maintenance is responsible for keeping the device performing after the deployment, by means of any kind of normal upgrade or monitoring. At this time, it is important to upgrade the firmware and patch any security vulnerabilities. Optimal gadget longevity is ensured by efficient operation. When an IoT device reaches the end of its useful life, it is considered retired. Some of the reasons for gadgets to reach retirement age include technology obsolescence, security issues, or changing user needs. Appropriate data removal management ensures environmental responsibility through proper disposal techniques.

2. Internet of Things (IoT)

The IoT is a unified network of physical objects, such as vehicles, sensors, machines, and household appliances that communicate through the internet to collect, share, and process data, enhancing the intelligence and efficiency of everyday life. Now, we all know about IoT, as

it has been present in our lives around the clock—from Smart Cities, managing traffic and power, to Smart Homes—automatic lights, automatic security, and much more. The term Internet of Things was coined by Kevin Ashton in 1999 at Procter & Gamble. He explained the possibility of linking physical substances to the internet and using the data collected for decision-making purposes. The wireless technologies of Wi-Fi, smartphones, cloud computing, and 5G have gradually taken over our lives, and IoT has become a part of it. It will eventually converge with edge computing, AI, and digital twins. The current use of IoT is in the fields of smart agriculture, connected cars, and industrial automation. It is also shaping the development of autonomous systems, smart cities, and international cybersecurity standards [7].

2.1. Brief journey of internet of things (IoT)

The roots of the IoT can be drawn back to the late 1960s, while examples of interconnected electrical equipment extend back to the early 19th century with the introduction of the telegraph and its capacity to transmit data over long distances using a coded signal. At that time, a team of eminent experts started looking at ways to link systems and computers. The Advanced Research Projects Agency, a division of the U.S. Department of Defense, created the ARPANET network (ARPA), a precursor to the modern Internet, which is a decent instance of this work [8]. Industries, administrations, and patrons started looking into ways to link PCs and other equipment to each other in the late 1970s. The ARPANET served as the basis for the IoT in the 1960s and 1980s. Kevin Ashton first used the word in 1999 to describe how sensors may link physical items to the internet for data-driven decision-making. The foundation for linked devices was established in the 1990s by networking technologies like RFID and TCP/IP. IoT adoption began in the 2000s and 2010s when the first smart gadgets were made possible by Wi-Fi, AWS, and Android OS. IoT became widely used between 2013 and 2020 thanks to cloud computing, 5G, Industry 4.0, and smart homes. IoT quickly spread into edge computing, industrial automation, and healthcare between 2021 and 2025. Local networks (LANs) provided a widely used and effective way for many PCs to share documents, data, and other content in real time by the 1980s [9]. Researchers and developers started looking into ways to improve human-machine communication by the mid-1990s, when the Internet prolonged those possibilities worldwide. British technologist Kevin Ashton, cofounder of MIT's Auto-ID Center, initially announced the term "the Internet of Things" in a 1999 address. In 1997, Ashton began investigating radio-frequency identification, a technological context that would permit physical things to interact via wireless signals and microchips.

Within a few years, cellphones, cloud computing, advances in software algorithms, and upsurges in processor power shaped a basis for collecting, storing, analysing, and sharing data more vigorously. At the same time, sophisticated sensors appeared that could identify a variety of conditions, such as motion, temperature, moisture content, wind direction, sound, light, images, atmospheres, and the capacity to find a being or a device using geolocation. These developments have made it conceivable to communicate in real time with both digital and physical objects. For example, a tracking chip, like an Apple AirTag, can be attached to a wallet or purse to view the whereabouts of an object. If a digital device is inappropriate or pilfered, its whereabouts can be tracked by the same chip. Then, with the arrival of ubiquitous wireless connectivity and the increasing use of mobile devices like smartphones and tablets, it became possible to connect people and things almost everywhere. Consequently, industrial robotics systems, linked storage tanks, and smart traffic networks became commonplace. The IoT is still emerging. These days, it enables an extensive range of use cases, such as AI for very complex simulations, sensing systems that identify contaminants in water sources, and systems that keep an eye on harvests and farm animals. For example, it is now feasible to remotely apply the ideal amounts of water, fertilizer, and pesticides IoT harvests and to monitor the whereabouts and well-being of animals [10].

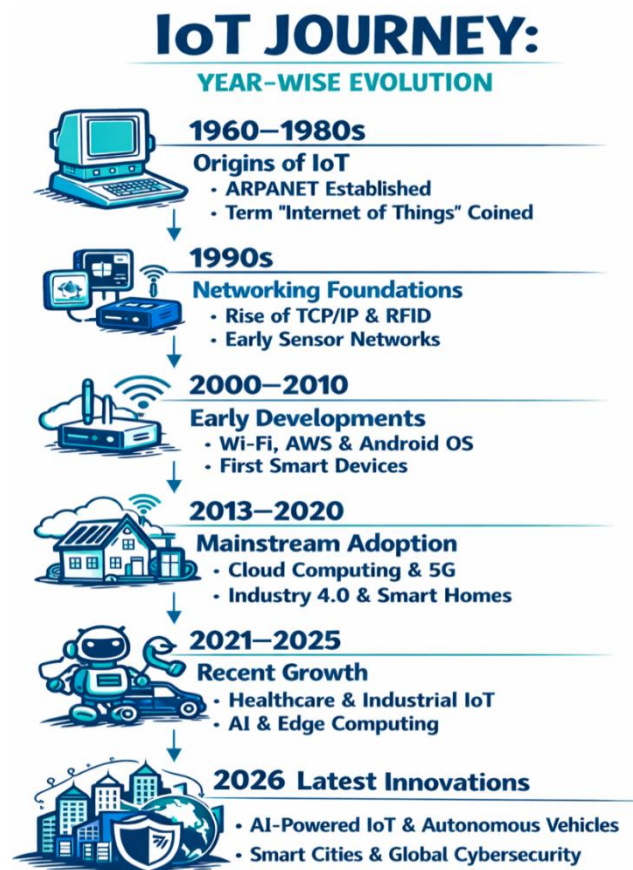


Fig.1: Roadmap of Internet of Things.

2.2. Applications, components and architecture layer of IoT

IoT is a paradigm that seeks to encompass every aspect of the world, including social media, smart cities, health, transportation, healthcare, smart environments, farming, and more. As such, it can never be a stand-alone area. Current Internet technology is continuously developing into a network of interconnected objects with a range of objectives, such as gathering data from the target environment (sensing), interacting with the physical world (actuation/command/control), and using current Internet standards to offer services for communications, data transfer, analytics, and applications. Wi-Fi, BLE, ZigBee, NFC, and other communication technologies are used to connect IoT devices that are utilized for detecting, acting, and monitoring to the Internet. These devices generate massive volumes of data that need to be saved, processed, and sent to consumers. However, IoT cannot handle, store, or analyse the massive amounts of data collected from trillions of sensors on its own. Smart buildings, health monitoring, industrial automation, agricultural optimization, and connected cars are all made possible by the widespread use of IoT in daily life and various industries [12], [13].

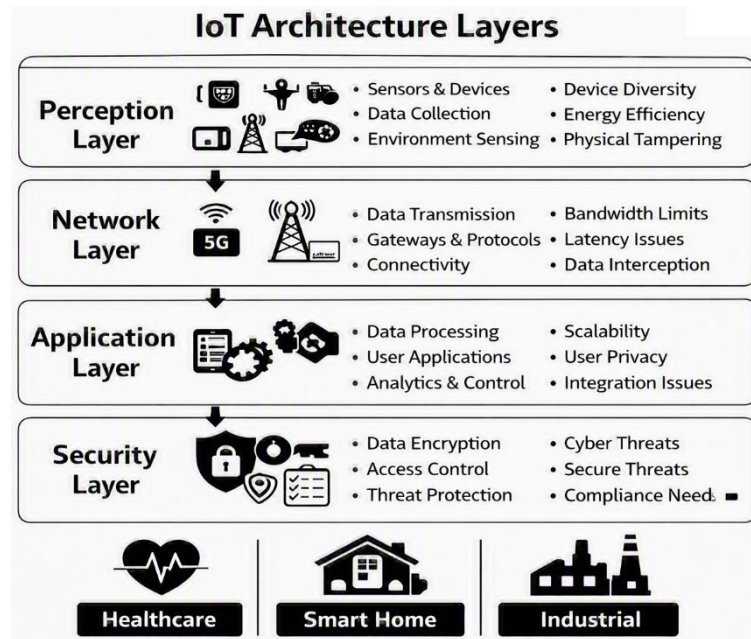


Fig. 2: Layered Architecture of IoT.

3. USE Cases

IoT enables numerous business applications. Businesses can incorporate IoT technologies into their future investment decisions by being aware of those IoT examples and use cases.

Table 1: Uses of Internet of Things in Various Sectors

Smart Factories		
Focus Area	IoT Role & Benefits	Creative Insight
Enterprise asset management	Real-time IoT sensor data enables asset monitoring, work management, scheduling, supply chain tracking, and EHS initiatives. Benefits: operational efficiency, lifecycle control, compliance checks, responsive environments.	Think of it as a digital nervous system — sensing, reacting, and optimizing assets across logistics, retail, and manufacturing.
Predictive maintenance	IoT sensors predict component failures before they occur, reducing downtime. Example: robotics firms use predictive analytics to avoid unnecessary checks.	Like a crystal ball for machines — only the parts likely to fail are checked, saving time and cost.
Industrial automation	IoT + IP networks record machine metrics in real time. Data drives workflow automation and production optimization. Market for industrial robots projected to hit \$165B by 2028.	Imagine a self-orchestrating symphony — machines harmonize output, cut costs, and boost quality.
Energy management	IoT devices track energy consumption, optimize distribution, and reduce bills, carbon footprint, and operational costs. Supports compliance with government efficiency standards.	Functions as a green heartbeat — pulsing efficiency while lowering emissions and expenses.
Smart Cities Use Case	IoT Role & Benefits	Creative Insight
Outdoor surveillance	AI + IoT CCTV cameras automate monitoring, process video feeds, and provide actionable insights for law enforcement. Requires strong encryption and oversight.	Acts like a digital guardian angel — watching streets, ensuring safety, but needing ethical safeguards.
Smart lighting	Sensors adjust lighting based on traffic/pedestrian flow, saving up to 70% energy. Extends to smart buildings and industrial IoT.	Functions as a city's adaptive glow — bright when needed, dim when not, conserving energy.
Traffic & toll management	IoT sensors + ML optimize traffic signals, reduce congestion, and streamline toll collection.	Like a digital traffic maestro — orchestrating smooth vehicle flow across busy roads.
Public transport optimization	Real-time updates on schedules, delays, and arrivals. IoT platforms optimize routes, schedules, and energy use.	A smart commuter's compass — guiding passengers efficiently through the city.
Smart parking	Sensors detect vacant spots, cloud + apps guide drivers, reducing congestion and search time.	Works as a parking genie — instantly pointing to the nearest available space.
Noise monitoring	IoT devices track sound levels, alert violators, and ensure compliance with noise regulations.	A city's sound tuner — keeping urban life harmonious and liveable.

Structural health monitoring	IoT sensors monitor vibrations, wear, and conditions of bridges/buildings. ML predicts failures, ensuring safety.	Serves as a structural stethoscope — listening to the heartbeat of infrastructure.
Digital Health Use Case	IoT Role & Benefits	Creative Insight
UV radiation monitoring	Sensors measure UV rays and warn people during peak exposure hours, preventing risks like skin cancer, cataracts, and immune suppression.	Acts as a personal sun shield — protecting citizens from invisible dangers in sunlight.
Fall detection	IoT sensors + geolocation detect falls, summon help, and reduce time elderly remain unattended.	Functions as a guardian angel for seniors — instantly alerting caregivers when accidents occur.
Companion robots	IoT sensors enable robots to detect surroundings and move safely, providing companionship to elderly and children.	Serves as a digital friend — easing loneliness and offering emotional support.
Medical fridges	IoT sensors monitor vaccine/medicine storage temperatures, ensuring compliance with safety standards. Vendors like Efento provide wireless monitoring solutions.	Operates as a pharma guardian — keeping life-saving medicines safe and effective.
Remote patient monitoring	Wearables track vitals post-surgery, enabling early diagnosis and reducing hospital readmissions. Vendors like Telit enhance RPM solutions.	Works as a virtual doctor's eye — observing patients remotely and preventing complications.
Smart Retail Use Case	IoT Role & Benefits	Creative Insight
Supply chain control	Sensors track goods via GPS, monitor speed for ETA, and check warehouse conditions (temperature, humidity, light).	Acts as a digital logistics compass — guiding products safely and efficiently from source to shelf.
NFC payment	Enables contactless transactions via smartphones and POS systems with NFC support.	Functions as a tap-and-go magic wand — making payments seamless and secure.
Layout optimization	Sensors collect voice, image, and video data to analyze customer habits, helping retailers redesign store layouts to boost sales.	Serves as a store architect's lens — reshaping spaces to match shopper behavior.
Smart product management	IoT sensors automate product rotation on shelves and in warehouses, optimizing merchandising decisions.	Operates like a digital merchandiser — ensuring shelves are always fresh and appealing.
Smart workplace	Sociometric badges measure interactions, proximity, and activity levels. Vendors like Humanyze use this data for people analytics to improve team performance.	Acts as a workplace mirror — reflecting how teams interact to enhance collaboration and productivity.
Smart Homes Use Case	IoT Role & Benefits	Creative Insight
Remote control appliances	Residents use smartphone apps to switch devices on/off, save energy, and automate routines (lights, coffee maker, thermostat, music, locks).	Functions as a digital butler — anticipating needs and managing household tasks seamlessly.
Home intrusion detection	Smart locks + IoT cameras detect motion, send alerts, and allow remote monitoring of home safety.	Acts as a virtual watchdog — guarding the home even when residents are away.
Smart locks	Deliver real-time tracking and standard remote access control. Example: Eye lock offers iris-based authentication.	Serves as a guardian gatekeeper — unlocking only for trusted identities.
Motion detection	IoT sensors stream video and send alerts when activity is detected. Example: ManyThings offers real-time monitoring.	Operates like a silent sentinel — instantly noticing movement and alerting residents.
Banking Industry Use Case	IoT Role & Benefits	Creative Insight
Wearables & smart devices	NFC-enabled smartphones, rings, fitness trackers, and smartwatches allow secure contactless payments. Devices track spending habits, set limits, and send alerts to prevent overspending. Example: 7 Ring.	Acts as a financial fitness coach — keeping spending in check while enabling effortless transactions.
IoT-enabled ATMs	ATMs self-diagnose maintenance, automate cash replenishment, and monitor foot traffic. Some offer live-stream consultations with advisors.	Functions as a smart service kiosk — always ready, efficient, and interactive.
Blockchain banking	IoT + block chain ensures secure, transparent transactions. Smart contracts simplify international trade and reduce costs. Banks invest in block chain start-ups and solutions.	Serves as a trust vault — locking in transparency and security for global finance.
Indoor navigation	IoT devices monitor queues, estimate wait times, and guide customers to free counters. Apps allow booking and managing appointments.	Operates like a branch GPS — directing customers smoothly through banking halls.
Mobile banking chatbots	Chatbots with AI tools offer round-the-clock assistance to customers, automate questions, and speed up responses to customers. NLP + ML improve interactions over time.	Acts as a virtual banker — always available, responsive, and learning with every conversation. [14]

Essentially every industrial sector has experienced growth due to the IoT. Smart farms are used by farmers, and IoT is used by businesses to improve customer service. Smart homes and wearable technologies are two examples of IoT applications that have popularized this technology. IoT has made daily life more convenient, from personalizing groceries to identifying signs of illness. Some few other examples of IoT areas which define benefits on the depth basis.

Smart Manufacturing	Smart Shelves	Smart Security Cameras	Smart Insulin Pens
- Increases production efficiency. - Reduces waste and errors. - Enables real-time quality control. - Improves worker safety. - Allows flexible manufacturing.	- Prevents stock-outs. - Reduces inventory costs. - Improves planogram compliance. - Enables dynamic pricing. - Enhances customer experience.	- Supports two-way communication with visitors. - Notifies and alerts when motion is detected. - Records and saves in the cloud. - Allows remote monitoring from throughout the world. - Works with other home smart devices.	- Inevitably archives insulin doses. - Provide reminder regarding medication. - Provide data with healthcare providers. - Support in maintaining glucose levels. - Improvement in treatment



Fig. 3: Areas with Benefits in Detail [15]

With an estimated 294 billion US dollars in revenue—roughly one-third of the global industry—China is expected to lead the Internet of Things (IoT) market by 2034. In terms of regional revenue, North America and Europe are expected to lag somewhat behind [16].

Internet of Things (IoT) annual revenue from 2020 to 2034, by region

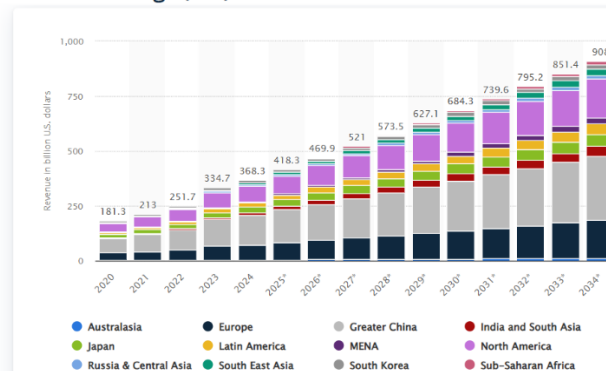


Fig. 4: IoT Annual Revenue Data.

Table 2: IoT Projects with Various Categories

Global IoT Projects in 2026

Total IoT Connections: 21.9 Billion | IoT Market Size: \$862.75 Billion

IoT Category	Connections / Devices	Market Size (2026)	Areas of Application
Total IoT Connections	21.9 Billion	\$862.75 Billion	Consumer & Industrial IoT
Industrial IoT	7–8 Billion	\$514 Billion	Manufacturing, Energy, Oil & Gas
Smart Cities	4–5 Billion	\$312 Billion	Transport, Water, Healthcare
Smart Homes	6–7 Billion	\$180.12 Billion	50% U.S. Household Adoption
Retail IoT	2 Billion	\$119.9 Billion	Inventory & Smart Checkout
Energy IoT	1.5 Billion	\$285.9 Billion	Smart Grids, Renewable Energy
Healthcare IoT	1 Billion	\$200+ Billion	Remote Monitoring, Wearables
Logistics & Supply Chain	1 Billion	\$86.43 Billion	Blockchain & IoT Solutions

In 2026, there will be more than 21.9 billion IoT connections worldwide, spanning sectors like manufacturing, healthcare, smart cities, and energy. The global IoT industry is projected to grow from its assessed \$862.75 billion in 2026 to above \$1.3 trillion by 2030[17].

3.1. Adoption of IoT by various companies in India

This Figure present contribution of some different companies.



Fig. 5: Adoption of IoT by Various Companies.

The way societies and organizations engage with technology has been entirely transformed by the Internet of Things. IoT is transforming industries all around the world, from smart cities and automated homes to industrial IoT and healthcare technologies. India has become a foremost contributor in the IoT industry thanks to its innovative companies and quickly mounting tech environment. In 2025, a number of Indian businesses are at the vanguard of IoT development, providing advanced solutions and establishing industry standards. Let's examine the top IoT-performing Indian businesses.



Fig. 6: Start-Ups in India Using IoT.

India is expected to become a global leader in the Internet of Things space if it continues to rise. The mounting use of IoT is urging innovation and the expansion of novel occupational models in segments like industrial, transport, healthcare, and cultivation. With sustainable and energy-efficient solutions, India's IoT initiatives are also serving to safeguard the situation because sustainability is a top emphasis. These are a few IoT initiatives that the Indian administration has sponsored.

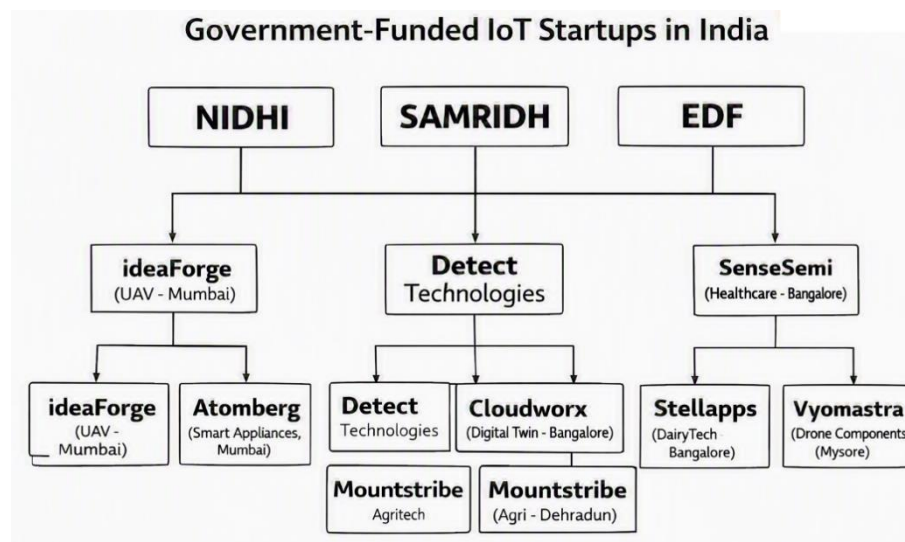


Fig. 7: Government Funded IoT Projects.

4. Future of IoT in India

In India, IoT is becoming more than just a pipe dream. It is predictable that by 2030, there will be around 2 billion associated devices, thus making IoT the mainstay of nations' digital revolution. The administration initiatives such as Digital India, Smart Cities Mission, and Make in India are fast driving the adoption of manufacturing, healthcare, agriculture and urban infrastructure. Remote patient monitoring is being implemented in hospitals, predictive maintenance systems in manufacturing, and precision irrigation in agriculture using IoT sensors. 5G connectivity with Artificial Intelligence + IoT enables real-time data transactions, refining the acumen and competence of processes. The invention will be scalable and maintainable because to the importance on in-house chip development, edge computing, and ecologically friendly IoT. In addition to impacting India's technological trail, IoT is also having an influence on how the nation works, survives, and advances. As of mid-2026, more than 1.8 million research papers and publications about IoT have been published globally, and there has been more than 18,000 peer-reviewed papers published in India on IoT have been indexed in Web of Science and Scopus.

The digital economy of India is now among the fastest-growing in the world. IoT adoption has risen in both urban and rural areas due to the growing use of smart devices and connected technology. Between 2026 and 2034, the IoT connection market in India is expected to expand at a CAGR of almost 17%. By 2030, the Indian market for IoT devices is projected to grow to over \$10 billion. In 2025, India's shipments of cellular IoT modules rose by 32% annually. Over 3,300 IoT start-ups in India are fostering innovation in a variety of industries. These figures show the quick growth of Internet of Things devices in India. Some examples related to IoT projects by different companies in India are:

- The Jaipur Development Authority and Cisco worked together to develop a smart city framework in Jaipur. IoT-based solutions for trash management, traffic control, and environmental monitoring are part of the project.

- For a sizable industrial complex, HCL deployed an Internet of Things-based energy management system. The technology tracks energy consumption in real time, finds inefficiencies, and recommends ways to improve it.
- Intelligent street lighting is part of Wipro's IoT solution for smart cities. The system minimizes energy usage and improves public safety through the deployment of linked sensors and analytics.
- In manufacturing facilities, Bosch used a typical industrial IoT solution for proactive upkeep. In order to minimize downtime and maintenance expenses, the system evaluates machine data to forecast probable faults.
- Farmers are able to track soil quality, automate irrigation, and increase crop yields thanks to Tech Mahindra's IoT-based smart agricultural system.

In the coming years, India's Internet of Things (IoT) is predicted to grow significantly, impacting smart industries, smart cities, smart agriculture, and smart healthcare. As digitalization extends throughout India, precision farming has the potential to revolutionize agriculture, increase industrial competitiveness, and enhance urban infrastructure. Customized Internet of Things solutions will improve the healthcare sector and help rural areas. Additionally, remote patient monitoring will be beneficial. India's economy is expected to benefit greatly from this expansion since it will promote innovation, job creation, and overall development. Even with a bright future, securing robust security and privacy protections is essential. As IoT devices grow increasingly common, maintaining and fostering trust depends more on safeguarding sensitive data through encryption, secure device management, and adherence to privacy regulations.

5. Conclusion

The Internet of Things has the potential to reform a number of trades, boost daily living, and hasten the changeover to a brighter and more consistent society. IoT devices have been inspected in a number of sectors, including transport, healthcare, and industry, and it has been discovered that it can enhance productivity, support innovation, and make things easier to use. IoT offers frequent benefits, such as better operational efficiency, real-time data analytics, and advanced automation, but it also presents significant challenges. Data privacy and security flaws are the most significant ones. In order to guarantee the ethical, sustainable, and secure deployment of IoT technologies, these matters must be effectively resolved. In order to improve usability and security, recent studies emphasize the necessity of integrating the Internet of Things with cutting-edge technologies like blockchain, edge computing, and AI. Innovations in these fields can help solve current problems and open up new possibilities for creative, sustainable applications. As IoT develops, strong security, calibration, and energy efficiency will be essential to achieving the technology's full potential. IoT will be crucial in assisting eco-friendly and intelligent technology as we move toward a sustainable and intelligent future. IoT will be crucial in assisting eco-friendly and intelligent technology as we move toward a sustainable and intelligent future. It contributes meaningfully to the advancement of the Sustainable Development Goals, especially in the areas of modified services, smart cities, and bearable resource management. By overcoming current limitations and embracing future developments, this technology offers the potential to shape a brighter, sustainable, and connected world.

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