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Introduction to the Internet of Things

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1.1 Introduction

The Internet of Things (IoT) is a cutting-edge technique that facilitates interface, communications, and data sharing among IoT devices. In the IoT, the information is transmitted since many sources are gathered for the purpose of creating up-to-date decisions and conducting analysis. Developing IoT applications encounters numerous problems, with security being a significant one. The IoT holds the possibility to enhance the overall quality of human existence by offering sophisticated applications that cater to the diverse requirements of humans across various domains, such as commercial, private, and industry. The IoT is constructed using the existing style of cyberspace and integrates mutually the Internet structure and developing engineering. The outcome of this amalgamation facilitates the seamless interconnection of an immense number of embedded systems, resulting in cost-effective service management, as well as enhanced scalability and flexibility.

The IoT has immense possibilities for creating value and is becoming recognized as the subsequent phase in the extensive digitization of the global economy. A rising phenomenon involves the interconnection of all devices that might benefit from a connection in a smart, energy-efficient, and profitable method. This revolutionizes the way individuals and companies connect to the physical world and with one other, to impact several aspects of everyday life, with its application domains spanning different sectors like health care, intelligent grids, transportation systems, automation in industry, and agriculture [1–6].

The IoT is a technique that involves interconnecting almost all items with intelligence, communication skills, and the ability to sense and act through Internet Protocol (IP) networks. The current state of the Internet has experienced a significant shift, moving away from being primarily driven by physical components such as computers, fibers, and Ethernet connections, to being driven by market forces and opportunities. This phenomenon has occurred as a consequence of the integration of seemingly separate intranets with robust software competences [7–9]. The IoT requires the use of open environments and a unified architecture consisting of interoperable platforms. Smart products and cyber-physical systems, commonly referred to as “things,” are the most recent devices of the IoT. Such items are common products that have been improved using microcomputers, optoelectronic and/or radio transceivers, actuators and sensors, and interface stacks. They can gather data from their surroundings, act on that data, and interact with the physical world in environments with limited resources.

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The IoT, as a developing technology, is anticipated to provide innovative solutions for revolutionizing the function and purpose of several established industrial systems, including transportation and manufacturing systems. IoT devices are essential for the general advancement of IoT as they provide several applications in various domains [10–18]. Considering the growing demand and speedy advancement in sensors, particularly, have greatly impacted and transformed our daily lives, it is necessary to conduct an in-depth investigation of embedded platforms and boards.

1.2 Evolution of IoT

The Apollo Guidance Computer (AGC) was initially introduced by the National Aeronautics and Space Administration (NASA) in 1965. NASA purposefully designed this computer for the Apollo moon landing mission. NASA outfitted the Apollo Lunar Module and Command Module with a device that offered interfaces and processing capabilities for spacecraft control and navigation. Afterward, a sequence of important events occurred, influencing the direction of the IoT industry. These milestones encompass the founding of N M Electronics, presently Intel in 1968, the debut mobile phone call took place in 1973, the release of the initial personal computer in 1975, and the dedicated endeavors toward internet development in the 1990s. The evolution of the IoT technique is shown in Figure 1.1.

In the 1980s, a group of university students initially explored the idea of incorporating sensors and advanced capabilities into tangible items by enabling a Coca-Cola vending machine to remotely monitor its inventory. However, the cumbersome nature of the technology limited its advancements. The term "IoT" originated in 1999, credited to computer scientist Kevin Ashton. During Ashton's tenure at Procter & Gamble, he suggested the implementation of radio-frequency identification (RFID) chips on items as a means of monitoring their movement around the supply chain. Allegedly, he incorporated the popular term "internet" into his presentation in order to capture the executives' interest. The phrase became firmly established. In the following decade, there was a surge in public interest in IoT technology as an increasing number of interconnected products became available on the market. LG launched the first smart refrigerator in 2000, while Apple released the first iPhone in 2007. By 2008, the number of interconnected devices had surpassed

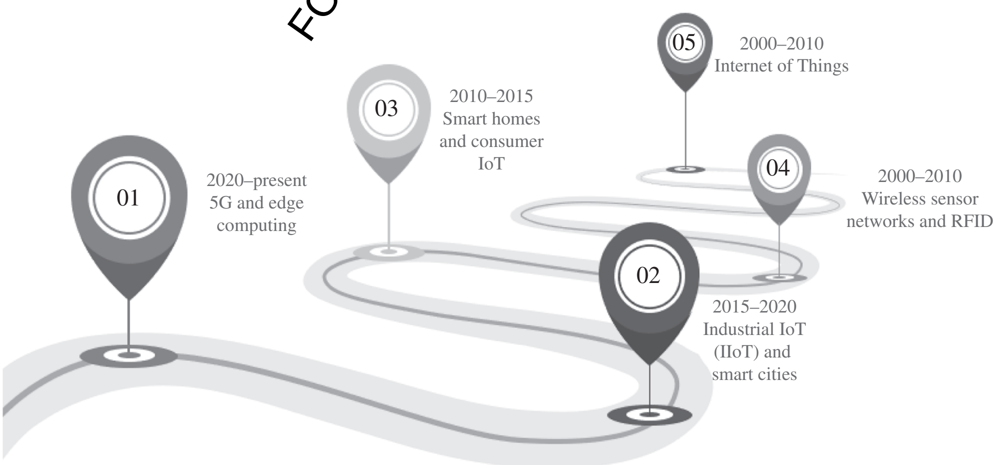

Figure 1.1 Evolution of IoT.

the global population. Google commenced trials of autonomous vehicles in 2009, and in 2011, Google introduced the Nest smart thermostat, enabling users to remotely regulate their central heating systems.

Developments in science and technology, along with the greater availability of the internet, have been the primary catalysts for the growth of the IoT in India. The IoT market in India has experienced growth since 2013 due to factors such as the growing recognition of cloud computing and data analytics, the expansion of data analytics, and a higher level of awareness. India has more than 100 proposed smart city initiatives that prioritize seamless communication and increased efficiency. By the end of 2019, the IoT will facilitate communication advancement, leading to a probable surge in business in India.

1.3 Need for IoT

The IoT empowers devices to autonomously perform everyday tasks without the need for human interaction. Companies can implement automation to streamline processes, reduce labor expenses, minimize waste, and improve service delivery efficiency. Figure 1.2 provides the requirements of the IoT technique. The IoT enables cost reduction in the manufacturing and delivery of goods, as well as visibility into customer transactions.

The IoT aims to establish connectivity between various items, enabling them to interact with each other over the internet. The connectivity enhances the security and convenience of human existence. The IoT enables a high level of interconnectedness in our world. In the present era, internet infrastructure is nearly ubiquitous, allowing us to access it at any time. Embedded computing equipment may be vulnerable to the internet's impact. Examples of embedded computer devices include MP3 players, MRI machines, signals, microwave ovens, washing machines, dishwashers, Global Positioning System (GPS) devices, heart monitoring implants, and biochips. The IoT intends toward building enhanced connectivity among various devices, systems, and services with the

Figure 1.2 Requirements for IoT.

assistance of the internet. This gradual process enables automation in several domains. Imagine a scenario where various protocols interconnect all things and send information across different domains and applications. The IoT aims to establish connectivity between various items, enabling them to interact with each other over the internet. The goal of this connectivity is to improve human lives by offering security and convenience. Recent research indicates that by 2020, there will be more than 20 billion IoT devices in operation [19–25]. The IoT's ability to control devices and reduce radio expenses is due to its implementation. However, these vast areas present issues such as a scarcity of IP addresses and the need to design compatible and functional protocols and environments.

1.3.1 Environmental Monitoring

IoT is employed in the following process and monitors the status of the health of the system:

- Water, soil, or air measurement device
- Earthquake or tsunami warning systems
- Monitor wildlife habit

1.3.2 Infrastructure Management

- Infrastructure organization is a valuable tool for keeping track of potential issues in both urban and rural infrastructures, such as bridges and railways.
- Its purpose is to mitigate and minimize the risk of danger and any structural failures. It quickly assesses the infrastructure's strength and alerts for immediate repairs.

1.3.3 Industrial Applications

In real time, industrial applications analyze product quality to optimize marketing strategies. This involves identifying the target audience for each product and determining how little modification might enhance its marketability.

1.4 Energy Management

Energy management systems are classified as internet-connected systems that use sensors to reduce power consumption. Examples include cloud-based systems and remote control for appliances such as ovens and lamps.

1.4.1 Medical Systems

Medical and care systems enhance patient well-being by observing and regulating vital signs such as heart rate, blood pressure, and dietary intake. A smart tablet shows the exact dosage needed at various angles, assisting patients in their recuperation.

1.4.2 Building and Home Automation

Home automation encompasses any devices within a household that may be automatically controlled and governed, notably the air conditioning system, security locks, lighting, heating, ventilation, telephone systems, and televisions. Its purpose is to create a comfortable, secure, and energy-efficient living environment.

Table 1.1 Features of IoT.

S. no.	Parameters	Features
1	Efficiency	Processes is streamlined and eliminates manual control
2	Data insights	Real-time data is collected and utilized for decision-making
3	Cost savings	It maximizes resource efficiency and minimizes operational expenses
4	Automation	Remotely observing and regulating the devices
5	Improved security	Effective security protocols for interconnected devices
6	Environmental impact	Ensures sustainability through resource conservation
7	Innovation	It supports technological advancements and creates new business opportunities
8	Quality of life	Improves everyday life with intelligent home systems and healthcare solutions

1.4.3 Transport Systems

Transport systems implement various technologies to optimize urban and environmental transportation. These include automated traffic light systems, intelligent parking solutions, traffic cameras that identify congested roads and suggest alternate routes, and smart cameras that issue fines to speeding drivers.

1.4.4 Large-Scale Deployments

Smart cities are crowded with a wide range of IoT devices favored by wireless technology.

Connectivity is a crucial element that enables communication between devices. The IoT ecosystem incorporates a range of connectivity alternatives, such as Wi-Fi, cellular networks, Bluetooth, and others, to facilitate smooth data flow across different contexts. The IoT ecosystem flourishes through the collaborative synergy of its numerous components. The fundamental basis of IoT [26–28] is established by the integration of equipment, communication standards, and sophisticated data processing algorithms. By comprehending the complex interconnections among the various elements of the IoT, the knowledge about the extraordinary capacity of this technology to transform industries, improve productivity, and fundamentally change our everyday existence. Table 1.1 outlines the parameters used in this study to analyze the performance of IoT.

1.5 Main Components Used in IoT

Sensors and actuators serve as the sensory organs in the realm of the IoT. Temperature motion detectors and humidity sensors gather live data from their surroundings. Figure 1.3 shows the key components involved in the IoT technique.

On the other hand, actuators allow IoT equipment to trigger physical arrangements based on the data they have gathered. Sensors and actuators serve as a means of connecting the physical world with the digital world [29–31].

Connectivity modules are essential components of the IoT, as they enable devices to establish connections and transport data without any interruptions. Connectivity segments, such as Wi-Fi,

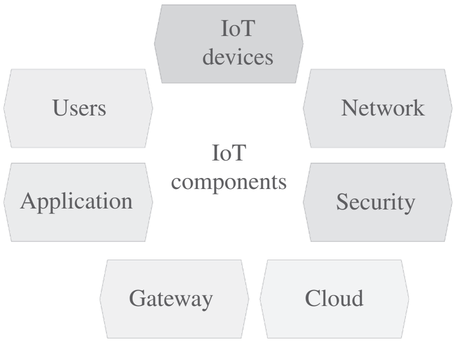

Figure 1.3 Components of IoT.

and Bluetooth, provide efficient inter-device communication, confirming the effective transmission and reception of collected data.

Data Processing Units: Gather the data, process it, and analyze it to extract significant insights. Data processing units, which encompass a variety of technologies such as edge computing devices and cloud servers, are responsible for doing the necessary computational activities to transform raw data into usable information.

Edge computing involves the computation of data near the vicinity of its origin, leading to decreased latency. In contrast, cloud servers are responsible for handling activities that require a higher number of resources.

Control Interfaces: The capability to govern and oversee IoT components is a notable benefit. Control gateways facilitate the interaction with IoT components, enabling operators to track and control their equipment, modify settings, and initiate activities. This architectural design highlights the primary elements of the IoT and their interconnectedness. The hardware elements of IoT, such as sensors, networking modules, data processing units, and control interfaces, combine to form a varying interconnected ecosystem.

The complex interplay of these components is crucial for the operation of IoT devices and enables the development of groundbreaking applications in several sectors, revolutionizing our interaction with technology and the world around us.

1.6 IoT Devices

Hardware components like sensors, actuators, gadgets, appliances, or machines, specifically configured for specific purposes and capable of data transfer via the internet or other networks, are known as IoT devices. Figure 1.4 provides various IoT devices in several applications that can integrate mobile devices, industrial equipment, etc. [32–35].

Nowadays, IoT devices incorporate artificial intelligence (AI) and machine learning to improve the intelligence and flexibility of many systems. This includes applications in automated e-vehicle, industry 4.0, medical devices, and residential automation.

Many of these devices are compact, reduce energy consumption, lower costs, and rely on microcontrollers as their core system. Increasing net bandwidth and evolving customer expectations about information security and functionality necessitate greater reliance on on-device processing. This involves processing data in the IoT endpoint compared to employing methods that are hosted in the cloud. Figure 1.5 illustrates the smart IoT revolution in various applications.

IoT devices are tangible gadgets that create wireless links to the web or within a neighborhood hub. These remote-managed gadgets can transmit and receive data from other devices.

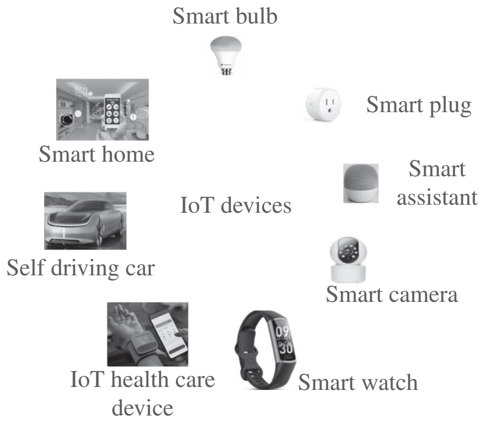

Figure 1.4 IoT devices.

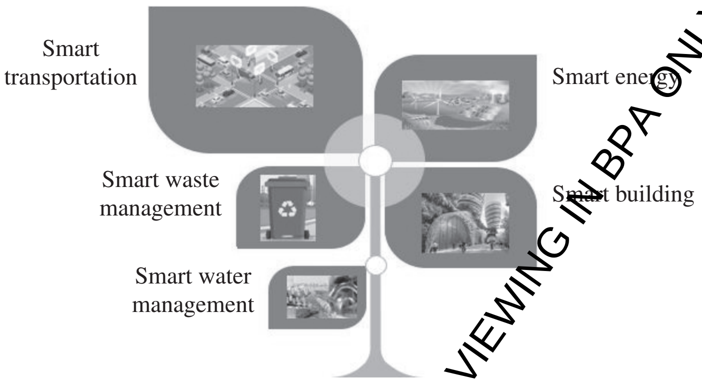

Figure 1.5 Smart device applications.

Everyday examples of smart devices include a smart automobile, a smart doorbell, and a smart refrigerator. IoT devices enable the transformation of everyday items into informational tools IoT devices gather data via their sensors and utilize software to interpret it, allowing machines to make choices based on the information. Usually, these devices make a link with a central server to obtain further information.

Additionally, these devices perform data comparisons and transmissions to community websites and services for the purpose of collecting data. They also establish connections with a message server that enables email, text, or call functionalities. In order to provide instructions, IoT devices have the capability to make links with other connected devices through the utilization of a common Wi-Fi network. IoT devices have advantages in improving productivity, facilitating simplicity, and growing task capacities. However, they also pose a potential threat to privacy and safety when they are targeted by hackers or compromised.

1.7 IoT Characteristics

The characteristics of IoT pertain to the distinctive qualities and aspects that differentiate IoT technology. These include connectivity, data gathering, live monitoring, scalability, and security. The Internet of Things, also referred to as IoT, is the central component of the ongoing technology revolution.

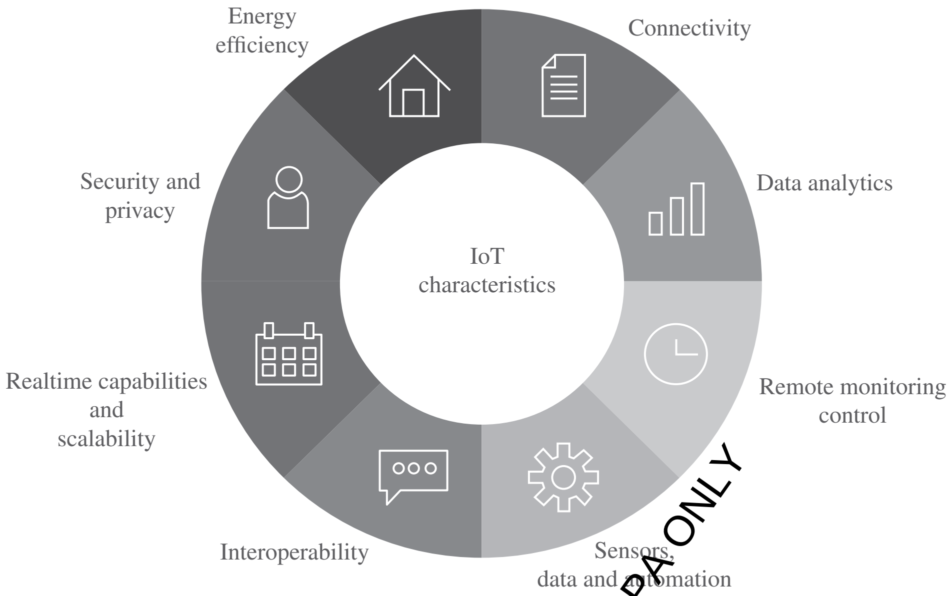

Figure 1.6 Characteristics of IoT.

The IoT is an extensive, interconnected network that includes tangible objects, household appliances, and cars. Figure 1.6 illustrates the various characteristics of the IoT. What distinguishes it is the incorporation of sensors, software, and networking into these items. This fusion enables them to go beyond mere existence, allowing them to gather, exchange, and interact with data and their environment [36–38].

The following are the main characteristics and properties of IoT:

1) Network connectivity is an important aspect of IoT technology because it enables the interconnection of different Internet devices, such as laptops and mobiles. Information on any subject is readily accessible to everybody, regardless of their location or time. The IoT enables the connection of various wireless devices, such as sensors, mobile phones, and trackers. Users can operate these devices even when they are not online thanks to this connectivity.
2) The concept of identifying objects is crucial. The process of deriving knowledge from the collected data is crucial. For instance, only a correct understanding of the data produced by a sensor qualifies it as genuine. Every IoT device possesses a distinct and individual identity. This identity facilitates the monitoring of the equipment and enables the retrieval of its current condition.
3) Ability to scale: the IoT is experiencing continuous growth, and ensuring scalability is of the highest priority for the system because it is an essential attribute of IoT. Scalability refers to the capacity of a system to expand its size or scope without causing any negative impact on its performance. Augmenting the existing design with extra computing power or programming layers might accelerate the process.
4) Dynamics: the ability to self-adapt is crucial for the IoT, as it needs to possess the capability to comprehend and respond to alterations in its surroundings. Consider a camera, initially designed to capture images but later enhanced with the ability to alter the image's quality. As a result, dynamism is critical for system development.

5) Self-improvement: AI enables autonomous self-improvement on the IoT, eliminating the need for human intervention. It enables the network to configure new IoT devices. Consequently, the technology can commence functioning promptly.
6) IoT architecture cannot be uniform. The IoT network should be hybrid, accommodating various manufacturers. The IoT becomes a reality when many areas converge.
7) Compatibility between different systems or devices allows them to work together seamlessly. Interoperability, a key attribute of the IoT, refers to the capacity of IoT devices and systems to communicate and share data, irrespective of the underlying technology or manufacturer. It facilitates the smooth operation of various devices and systems, ensuring an optimal user experience.

   IoT devices utilize standardized communication protocols and technologies to establish communication with one another and other systems, as well as data formats to ensure compatibility. These standards facilitate uniform and dependable data comprehension and processing across various devices, enabling seamless data transmission across devices and systems, irrespective of the technology employed. Lack of interoperability restricts IoT systems to isolated data and device repositories, impeding information sharing and the development of novel services and applications.
8) Intelligence is a crucial attribute of the IoT. The intelligence of IoT devices refers to the cognitive abilities of smart sensors and devices to perceive data, communicate with one another, and gather data for analysis. Digital personal assistants such as Alexa, Cortana, and Siri exemplify the cognitive capabilities of electronic devices. To ensure the intelligence of your IoT gadget, it is imperative that you are well informed on the most recent technological advancements.
9) The growing number of IoT devices has led to the emergence of security concerns, particularly regarding the protection of personal data. Data leakage is a potential risk that might arise when a large amount of data is collected, transmitted, and generated. The unauthorized transfer of personal data is a significant cause for concern. In order to address this obstacle, the IoT has developed networks, systems, and devices that effectively protect privacy.
10) Ensuring safety and security is a significant challenge for the IoT. Nevertheless, it manages to handle it seamlessly. Self-configuring IoT devices have the capability to update their software as needed with minimal user involvement. In addition, they have the capability to establish the network, enabling the incorporation of new devices into an existing network. This is a crucial attribute of the IoT.
11) Network: as the number of IoT devices in a network increases, it becomes challenging to ensure smooth connections for optimal operation. Cloud services and gateways are effective and adaptive approaches to address these difficulties, as they enable communication between IoT devices, surpassing the capabilities of other existing technologies. Often, one device can utilize the connectivity of another device to establish a network connection, even if another device is not directly linked to the network.
12) Diversity: the presence of heterogeneity is a crucial characteristic of the IoT. The gadgets utilize many hardware platforms and networks. Through various networks, they establish communication with other devices or service platforms. The IoT design enables direct network communication between diverse networks. The fundamental design criteria for heterogeneous entities are scalability, modularity, extension, and interoperability.
13) The system integrates sensors and actuators. The analog input from the external environment is known as sensory information. IoT technology provides a deep comprehension of our intricate surroundings, which is one of its notable characteristics. IoT sensors identify and quantify environmental changes, producing data for environmental reporting or engagement.

Sensing technologies enable the creation of capabilities that provide precise representations of knowledge about the physical environment and its inhabitants.

14) The data IoT function facilitates the collection of data for future predictions. For instance, what is the daily caloric expenditure of our body? This feature facilitates the regulation of daily calorie intake. Therefore, the data gathered is utilized from these gadgets in various ways, greatly enhancing the accessibility of our lives.

1.7.1 Technology Behind IoT

A digital twin is a dynamic virtual representation of an object that captures real-time data collected by sensors, providing a comprehensive view of its whole existence. These ecosystems utilize IoT, big data analytics, and AI to oversee and trace products. Figure 1.7 shows the several technologies behind the growth of the IoT.

Fog computer: This horizontally structured system design facilitates the efficient distribution of computer resources. It enables objects from the cloud to be allocated storage, control points, and network bandwidth. These solutions facilitate the connection between the cloud and the object, resulting in the formation of more tightly integrated smart systems.

Edge computing involves the direct allocation of resources to applications, bypassing the need to rely on local area networks (LANs) for application availability. Studies predict that by 2025, network edge computing platforms will transmit around 45% of data.

1.7.2 Hurdles of IoT Adoption

1) Insufficient infrastructure and limited connectivity: a major obstacle to the widespread adoption of IoT in India is the insufficient infrastructure and connections in most areas. Although urban areas may have reliable internet connectivity, rural regions continue to encounter difficulties in accessing stable networks. In order to fully utilize the potential of the IoT, it is crucial to have uninterrupted and smooth connectivity. Nevertheless, the Digital India program and continuous endeavors to enhance internet infrastructure have demonstrated encouraging outcomes, progressively narrowing the disparity in connectivity between urban and rural areas.

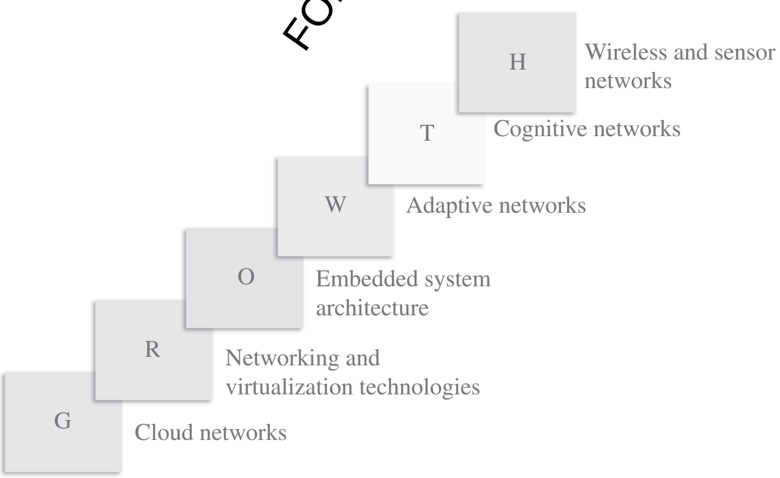

Figure 1.7 Technologies behind the growth of IoT.

2) Concerns about data privacy and security have emerged. The widespread use of IoT devices has led to significant concerns over data privacy and security, which are now essential priorities for both individuals and businesses. India's absence of comprehensive data protection legislation necessitates that IoT development companies emphasize the implementation of strong security measures. Users who address these concerns will gain confidence and be more likely to adopt IoT technologies.
3) The topic of discussion is the skill gap that exists in the field of IoT development. IoT development necessitates expertise in hardware and software engineering, data analytics, and cybersecurity. However, India's lack of IoT expertise hinders the advancement of innovative IoT solutions. To address this issue, it is imperative that the Indian government and business sector allocate resources toward upskilling programs and training projects. This will help cultivate a proficient workforce that can effectively contribute to the development of IoT services in the country.
4) Exorbitant implementation expenses: small and medium-sized organizations (SMEs) may find the initial expenditure needed to implement IoT solutions to be too expensive. Furthermore, the ongoing upkeep and operational expenses exacerbate the financial strain. In order to enhance the accessibility of IoT adoption, it is imperative for IoT development companies to prioritize the creation of cost-effective solutions and scalable models that can cater to the varied requirements of businesses in India.
5) A lack of uniformity: the absence of standardized norms and protocols in the IoT ecosystem has impeded smooth integration and compatibility. The lack of compatibility across IoT devices from various manufacturers might result in fragmentation and increased complexity. Promoting industry-wide standards adoption and advocating for open-source frameworks will facilitate collaboration and cultivate a flourishing IoT ecosystem in India.
6) The complexity entailed in implementing IoT solutions: deploying and overseeing IoT solutions can be complex and challenging. IoT ecosystems consist of several networked devices, sensors, networks, and software components that need to coordinate seamlessly. As deployment scale increases, so does the complexity of IoT projects. Therefore, it is essential for organizations to have the required technical experience and resources to effectively manage the intricacies of such projects.
7) Obstacles to realizing return on investment (ROI): quantifying the ROI of IoT technologies can present enterprises with intricate and demanding tasks. Although the IoT presents various advantages, such as increased efficiency, decreased expenses, and higher customer satisfaction, accurately measuring these advantages in financial terms can be challenging.

ROI assessments for IoT initiatives sometimes encompass numerous intangible aspects, hence rendering it more challenging to substantiate the initial expenditure. Moreover, the ROI for long-term IoT implementations may require a significant amount of time to become apparent, thus discouraging certain organizations from adopting IoT.

1.8 IoT Market Share

The IoT presents a lucrative market potential for manufacturers of equipment, distributors of Internet services, and developers of applications. By the end of 2020, projections indicate a global installation of 212 billion IoT smart objects [9]. By 2022, projections indicate that machine-to-machine (M2M) traffic will account for approximately 45% of the total Internet traffic. In addition to these forecasts, the McKinsey Global Institute has reported a 300% increase in the overall number of connected machines (units) during the past five years. Cellular network traffic monitoring in the United States also indicated a 250% surge in M2M traffic volume in 2011.

The economic growth resulting from the implementation of IoT-based services is significant for organizations. The healthcare and industrial sectors have the largest economic influence. By 2025, healthcare applications and IoT-based services like m-Health and telecare are projected to generate annual growth of $1.1–$2.5 trillion for the global economy. These services facilitate the efficient delivery of medical wellness, prevention, diagnosis, treatment, and monitoring through electronic media. By 2025, the anticipated yearly economic effect of the IoT is projected to reach between $2.7 trillion and $6.2 trillion.

However, Wiki Bon predicts that by 2020, the Industrial Internet will generate over $1279 billion in value, increasing the ROI from 13% in 2012 to 149%. Furthermore, Navigant recently projected a 60% growth in the Building Automation Systems (BAS) market, from $58.1 billion in 2013 to $100.8 billion by 2021. These figures indicate a potentially substantial and rapid expansion of the IoT in the near future, along with its associated industries and services. This development presents a distinct chance for conventional equipment and appliance makers to convert their products into “intelligent objects.” To expand the reach of the IoT and its associated services worldwide, internet service providers (ISPs) must configure their networks to ensure quality of service (QoS) for a combination of M2M, person-to-machine (P2M), and person-to-person (P2P) traffic.

Three prominent technologies primarily control the global connectivity of the IoT: Wi-Fi, Bluetooth, and cellular IoT.

1) **Wireless Fidelity:** Wi-Fi accounts for 31% of all IoT connections. Over 50% of Wi-Fi-enabled devices deployed globally in 2022 were built using the most recent Wi-Fi 6 and Wi-Fi 6E technologies, ensuring enhanced wireless connectivity with improved speed and reliability. The implementation of these technologies has strengthened the efficiency of communication to IoT devices, contributing to improved client experiences and productivity in general. Wi-Fi technology is the dominant form of connectivity for the IoT in industries like smart homes, buildings, and healthcare.
2) **Bluetooth Technology:** Bluetooth is the basis for 27% of all IoT connections worldwide. Bluetooth low energy (BLE), commonly denoted as Bluetooth Smart, has been continuously developed to ensure reliable connectivity for IoT devices while lowering power consumption. As a result, BLE has become the preferred option for IoT devices that depend on batteries, including intelligent home sensors and surveillance devices. There is a growing interest in IO-Link Wireless technology within the industrial sector. This technology employs IEEE 802.15.1, which is the technical standard for Bluetooth, to establish wireless links among sensors, actuators, and an input–output master.
3) **Cellular IoT**: Cellular IoT, which includes recently 5G, LTE-M, and narrowband Internet of Things (NB-IoT), currently accounts for around 20% of IoT connections worldwide. Based on the worldwide cellular IoT connectivity tracker and forecast from IoT analytics, worldwide cellular IoT connections experienced a 27% year-on-year rise in 2022, significantly outpacing the growth rate of global IoT connections. The increase in growth can be attributed to the implementation of more advanced technologies while older technologies like 2G and 3G are being gradually replaced. Despite a YoY gain of over 100% in 2022, the rate at which 5G module shipments increased was not as fast as anticipated by many.

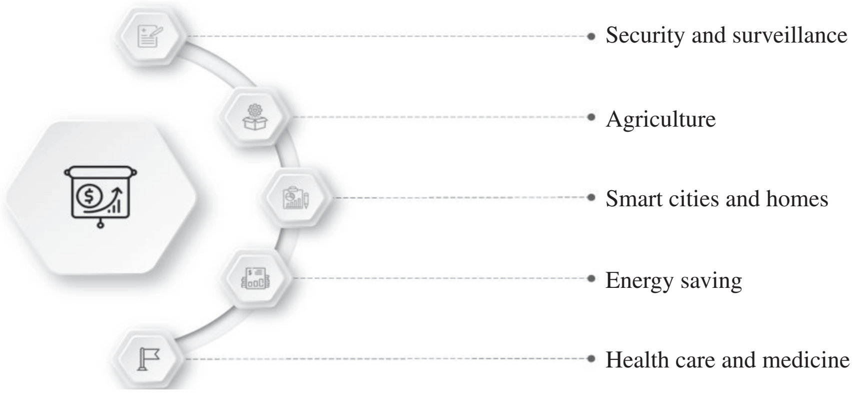

Figure 1.8 Applications of IoT.

By 2023, the five leading network operators like China Mobile, Telecom, Unicom, Vodafone, and AT&T collectively controlled 84% of the total worldwide cellular IoT links. The top five network operators dominate the IoT network operator market, accounting for 64% of the revenue. These operators are the key players in this industry.

The projections indicate a 14.5% increase in IoT expenditure, reaching $1.1 trillion by the end of 2025, in terms of market size. The Indian market reached a value of $9 billion by the end of 2020, exhibiting a growth rate of 31%. Among the global population of 7.6 billion individuals, approximately 3.7 billion people possess the ability to connect to the internet.

Notably, India is home to almost 24% of this internet-connected population. Therefore, it is evident that the IoT has the potential to enhance connections and revolutionize communication in India. India presently has more than 120 specialized IoT companies equipped with the technical expertise required to facilitate this transformative transformation. Nearly 70% of the IoT startups operating in India today have their origins in recent times. The healthcare and manufacturing industries attracted significant investment, leading to the establishment of numerous companies. Few important applications of IoT are presented in Figure 1.8.

Among Indian companies, WeMakeIOT, QBurst, Altizon, Happiest Minds, and Traxroot appear to be maintaining their positions and performing well. About 65% of Indian firms that manage IoT applications are start-ups with the intention of expanding, and the total number of IoT devices in India exceeds 200 million.

- With the increasing use of digitalization and automation in India's economy, there are significant prospects for both domestic and international enterprises in the field of IoT development services. IoT development organizations could establish themselves as trailblazers in the rapidly growing Indian market by understanding its unique obstacles and customizing solutions accordingly.
- IoT development firms should strategically link their solutions with government efforts, such as the Smart Cities Mission and Make in India, in order to leverage the extensive opportunities presented by public–private collaborations.
- Customized solutions for businesses of all sizes: creating affordable and easily expandable IoT solutions customized for all types of businesses can encourage wider acceptance and promote economic development.
- Emphasize data security and privacy: prioritizing strong data security measures and adhering to growing data protection rules can increase customer trust and confidence.

- Investing in research and development (R&D) is crucial for firms to develop advanced IoT technology. This investment will help organizations establish themselves as leaders in the fast-changing IoT industry.

Researchers have intensively investigated the service selection problem, leading to the introduction of many study techniques. However, it is critical to acknowledge the address and rectify certain outstanding issues in the academic and industrial sectors in the near future. This section specifically addresses the obstacles and areas for future investigation regarding the advancement and establishment of capable and effective service selection solutions.

Challenges

- **Battery Life and Energy Efficiency:** The capacity of the battery is a limiting factor for mobile devices. Prolonging battery life and improving energy efficiency remain major challenges. Efficiently identifying and choosing suitable services from nearby cloud data centers help decrease energy usage in a mobile setting. Furthermore, tackling this problem necessitates optimizing the service selection in order to minimize device resource utilization.
- **QoS:** QoS poses a number of significant issues. Ensuring efficient and dependable communication is of utmost importance, as it guarantees users a satisfactory and constant level of service. This is particularly critical in situations where network conditions, service providers, and user requirements may vary.

1.9 Conclusion

This paper provides a concise overview of the development of context-aware technologies and their growing significance in contemporary applications. Initially, a wide range of IoT products to identify several areas for future work is analyzed, including scalability and interoperability, real-time adaptability, and economic considerations, particularly in the context of utilizing blockchain technology. Additionally, integration with emerging technologies, such as AI-driven access control, is imperative. Lastly, it is crucial to prioritize real-world implementations. Real-world implementations and assessments of access control systems in a variety of IoT deployments. When it comes to context-aware computing, there are a substantial number of IoT solutions available in the industry marketplace is discussed. These assessments can offer pragmatic observations and detect unexpected obstacles to further encourage innovation.

The concept of the IoT is gaining momentum in our contemporary society, with the goal of enhancing the overall quality of life through the interconnection of various intelligent devices, technologies, and applications. Overall, the IoT will allow the full mechanization of every aspect of our environment. This paper provides a comprehensive examination of the fundamental concept and the technology that facilitates it, the protocols employed, the potential applications, and the ongoing research that delves into various facets of the IoT. This will serve as a solid basis for researchers and practitioners who wish to get a deep understanding of IoT technologies and protocols. It will enable them to comprehend the comprehensive structure and function of all the parts and protocols of the IoT. Additionally, this paper has addressed certain obstacles and concerns related to the design and implementation of IoT solutions. Furthermore, it discusses the interaction between the IoT, big data analytics, cloud computing, etc. This chapter showcased comprehensive application use cases to exemplify common protocol integration scenarios, ultimately providing the necessary IoT services.

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