Chapter 1
Internet of Everything: Background and Challenges

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1.1 Introduction

The exponential growth in fields of embedded systems and their computing and communication power leads to the generation of a new era of Internet Technologies. It leads to the generation of the field named the Internet of Things (IoT). The term was first given by Kevin Aston in 1999. IoT is a collection of objects called Things that have sensing capability. These objects also have limited computational power. They can communicate the sensed data using standard protocols. The data on network could be used for further processing and analysis purposes. In simple terms, it is a network of smart objects having sensing and computational capacity. With the advancement in embedded technologies, the production capacity of these smart objects has increased exponentially. Along with its production, the digital transformation era has brought about huge demand for IoT based application. As per an estimate [1], there were 5.8 billion IoT endpoints were there in the market and the demand continues to surge in coming years.

1.1.1 Working of IoT

IoT works on a principle of *Connect, Communicate, Compute, and Action*. It consists of various IoT sensors that connect through wired or wireless manner to the Internet through a gateway node. Sensors measure the state of the environment and

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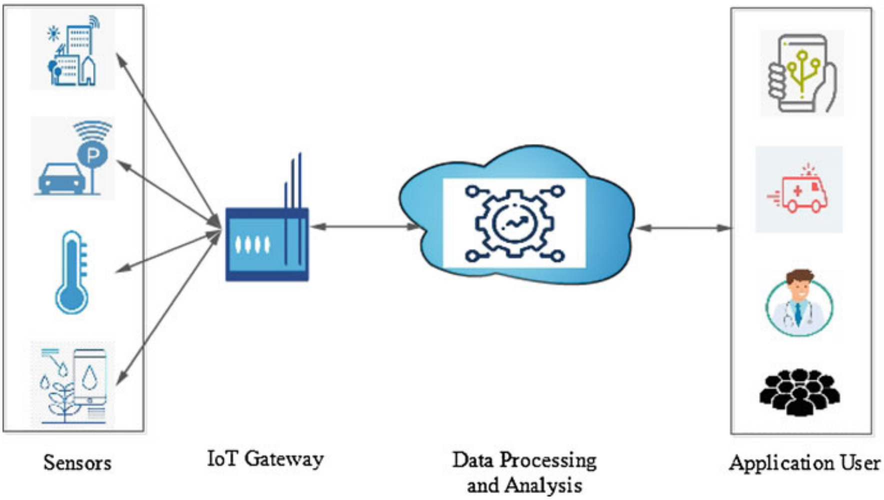

Fig. 1.1 Working of Internet of Things

other measurements and communicate data to the Internet cloud. The Internet uses its huge computational power to perform the required processing on the received data and converts it into useful information. The end-user through the interface application analyzes the information and performs action accordingly [2].

For example, smart homes may have a temperature sensor and air conditioner relay switch connected to IoT controller using standard IoT procedure. It is further connected to the Internet that receives the sensor data. Homeowner acting as end-user continuously monitors the temperature of his home and gives a remote command to control air conditioner as and when required. Figure 1.1 describes the complete working of IoT. It consists of four basic components for its complete working procedure. Following are the description of the components.

1.1.1.1 Sensors

The sensors are electronic components having sense and digital measurement capabilities. These are fitted into the devices called smart objects. A smart object is an electronic component that consists of one or more sensors to monitor the surrounding environmental conditions such as mobile phone. A smart object consists of multiple sensors like an accelerometer, camera, and location tracker. These sensors are majorly playing the role of *collecting* the data. These objects are working in large number of fields such as healthcare, agriculture, medicine, manufacturing, logistics delivery, smart home, smart cities, etc. Figure 1.2 shows some prominent application areas that employ the IoT for more effective operating. These objects are continuously measuring the surrounding environmental conditions and generate data regularly. This leads to the generation of a huge volume of

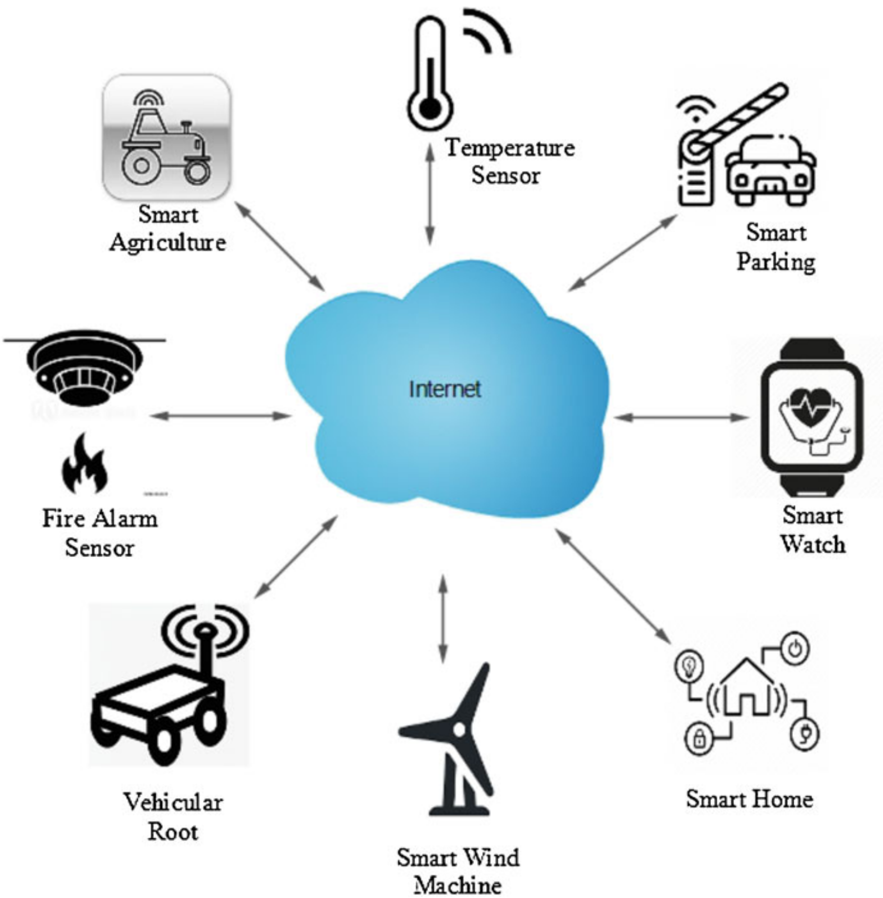

Fig. 1.2 Smart objects used in Internet of Things

data. As the smart objects work in different application areas, the data generated by them are multidisciplinary. These objects are further connected to a controller device called the IoT Gateway node. So the huge volume of multidisciplinary data is also communicated to cloud or edge through gateway node in certain IoT architectures [2].

1.1.1.2 Gateway Node

The gateway node acts as an entry/exit point for IoT devices with the rest of the network. The devices are connected to gateway nodes using standard IoT protocols. It plays a major role of communicating the data. It uses standard protocols like Bluetooth, Wi-Fi, 6LoWPAN, Zigbee, RF Link, Z wave, etc. These protocols work on the different capacity for parameters like topology, range, bandwidth, power consumption, bit rate, etc. The other techniques like RFID and NFC are used for connecting IoT objects. Table 1.1 depicts these parameters for different protocols. Based on a comparison of protocols, different techniques are used to connect different IoT objects. The gateway node has to support multiple ports having different mechanisms if they have to connect multiple functional devices. Other than connecting devices, it connects to the Internet on the other side using standard IP-based protocols.

In an ideal scenario, gateway node transfers the multifunctional data received from connected devices. The huge volume of data generated by the sensors is transferred to the Internet cloud through these gateways. But with the evolution of new paradigms like edge and fog computing, there are gateway nodes that provide additional computational power other than connectivity of smart objects [3]. Handling of this huge volume of data by sensors at source end has been receiving a lot of attention from the research community. This has also led to development of intelligent system that can be integrated with traditional gateway nodes to achieve efficient information dissemination. In such integrated scenarios *compute* along with *communication* of data is performed [4].

1.1.1.3 Data Processing and Analysis

The Data transmitted from sensors through gateways should be received by the devices having enough computational power. Since the amount of data is very large and also multidimensional, it requires intelligent systems that can process the data. The application running on IoT based systems is basically processing the data and converting it into useful information. The data processing techniques have to perform a number of basic functions like denoising of data, feature extraction from data, data fusion, and data aggregation. These processing techniques should be lightweight to implement so that these functions are performed efficiently. The requirement for the type of processing algorithm depends upon the nature of data generated by sensors. The resulted processed data turns out to be information for further course of actions [5].

The resulted information can be analyzed using various Artificial Intelligence (AI) based techniques. It also employs the other techniques like machine learning and deep learning to analyze the data without human involvement. The output produced by above intelligent techniques should be able to produce the correct and useful information required for decision-making and knowledge generation [6]. The decision-making process then results in certain values that are then converted into some physical actions performed by actuators. This knowledge is also stored for further behavioral study of the sensor. The above-discussed process could also get elaborated by Fig. 1.3

The data processing and analysis are generally performed on cloud-centric applications. This leads to generation of huge amount of data on networks that needs to be transferred from the gateway to the cloud. With the advancement in

Table 1.1 Internet of Things protocols

Standard	Bluetooth	Bluetooth 4.0 IE	Zigbee	Wi-fi	6LoWPAN	RF link	Zwave
IEEE Spec.	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.11 a/b/g/n	IEEE 802.15.4-2006	IEEE C95.1-2005	Z-wave alliance
Topology	Star	Star	Mesh, Star, Tree	Star	Mesh, Star	–	Mesh
Bandwidth	1 Mbps	1 Mbps	250 Kbps	Up to 54 Mbps	250 Kbps	18 MHz	900 MHz
Power consumption	Very low	Very low	Very low	Low	Very low	Very low	Very low
Max. data rate (Mbits/s)	0.72	5–10	0.25	54	800(Sub-GHz)	1	9600 bits or 40 kbits
Range	≤30m	5–10 m	10–300 m	4–20 m	800 m	≤ 3m	30m
Spectrum	2.4 GHz	2.4 GHz	2.4 GHz	2.4–5 GHz	2.4 GHz	2.4 GHz	2.4 GHz
Channel bandwidth	1 MHz	2400–2480 MHz	0.3/0.6 MHz, 2 MHz	22 MHz	868–868.6 MHz (EU), 902–928 MHz (NA), 2400–2483.5 MHz (WW)	–	868 MHz

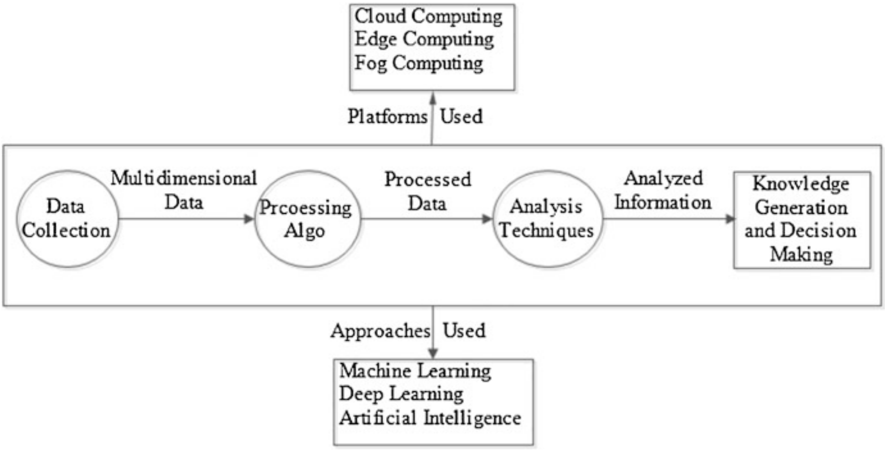

Fig. 1.3 Data processing and analysis

the computing field, edge/fog computing has also been integrated with traditional IoT. They support lightweight data processing and analysis at the source end. This results in an efficient architecture where huge processing is performed on devices connected with sensors results in the transfer of only the required data to the cloud. There is lots of research going in fields on cloud/edge/fog interplay that results in the selection of data processing and analysis at the required end [7, 8].

1.1.1.4 End-User

IoT users are receiving the information through the application interface. There are several different categories for each user. These categories include expert users like healthcare experts, doctors, weather forecasters, engineers, and data scientists. These experts get the analyzed data and perform an action accordingly thereby helping to improve their productivity. The other categories of users are generic persons such as family members, friends, and community services. They have access to data generated by the sensor that they can monitor regularly like a person keeping his home under camera surveillance. The last category includes emergency services like ambulance, fire fighters, and police. These users will get activated by emergency events relevant to their respective domains [9, 10].

1.1.2 Internet of Everything

The key components of IoT are the objects that can form the communication channel. The evolution of distributed computing helps in grater processing capabilities

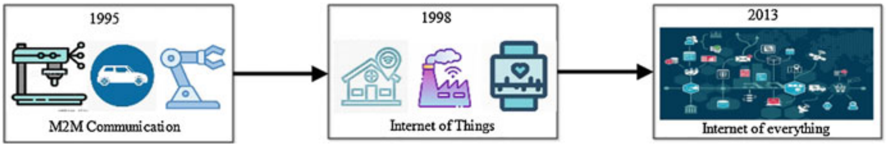

Fig. 1.4 Evolution of Internet of Everything

at the distributed end. The gaining trend of distributed computing has also resulted in emergence of a new field. This leads to the generation of a new Internet era called the Internet of Everything (IoE). The term was first used by Cisco in 2013 [11]. The field is also a result of further advancements in dynamic information handling at the source end. The integration of Fog and Edge computing results in decentralized processing capacity, providing increased computing power for these kinds of hybrid IoE networks. The primary aim of IoE is to connect anything with the Internet with enough information provided at right time in this digitally driven modern era [12]. Figure 1.4 shows the evolution of IoE from machine-to-machine communication through IoT.

As an intelligent network of people and objects, the scope of IoE is exponentially increasing in multidisciplinary domains across the globe. It is the fusion of advancements in technologies in multiple fields like Information technology, environmental, and biotechnology. It has emerged as the main player for future market growth. The overall growth in IoE will lead to millions of internetworked devices that could result in having increased processing capacity, intelligent decision-making, and improved sensing capacity. This has resulted in development of specialized products based on IoE for organizations that are helping them in improving their operations. It also impacts the interaction methods with the physical environment [13].

IoE can be considered as much broader system than IoT. It is considered to be a superset of IoT along with its variants like Internet of Drone, Internet of Healthcare. It evolves from machine-to-machine communication that is prevalent in IoT to people and people to machine communication formats. The evolvement of IoE results in a better network having better capacity to turn information into actions. It gives rise to new and exciting opportunities with richer experiences for individuals and organizations. It evolves from one pillar called things in IoT to four pillars called People, Process, Data, and Things. IoE is primarily concerned with bringing these pillars in an efficient manner. In simple terms, IoE can be thought as an intelligent network of People, Process, Data, and Things. Figure 1.5 shows the all four components and communication among them in IoE [14].

- *People:* IoE is responsible for making connections among the peoples in a more effective and relevant manner. The people are the main concern to interact with the Internet.
- *Process:* It consists of an efficient collection of processes that converts the collected information into the appropriate actions. It delivers accurate information to the concerned person or object at the appropriate time.

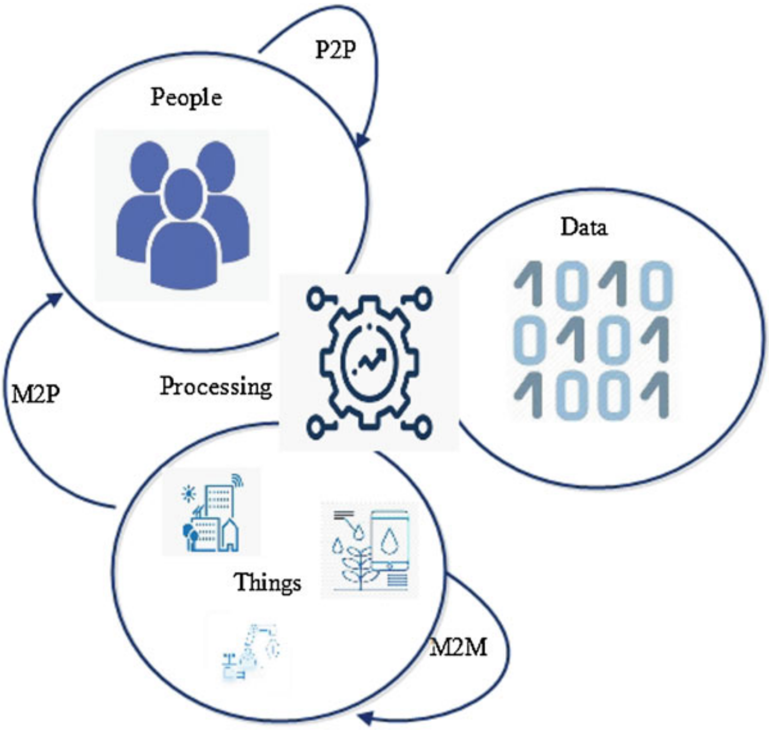

Fig. 1.5 Internet of Everything components

- *Data:* The data is generated during interaction with objects and peoples in multiple forms. There is a requirement of efficient processing and handling of data that could further support the decision-making process and knowledge generation.
- *Things:* These are physical objects having sensing and processing capabilities connected to the Internet. These could also be termed as smart objects.

Recently a broad spectrum of application domains has undergone revolutionary changes globally and produced exciting opportunities due to IoE. IoE has seen the evolution from a smart application in IoT to connecting applications with the user in a much more efficient manner. For example, in smart vehicle management and smart healthcare based IoE systems are helping to connect roads with hospitals for real-time monitoring to save lives. It integrates the people with objects and intelligent processes more efficiently and efficiently such as connecting homes for more comfortable living, connecting food and peoples in supply chain management, and connecting elderly population and their monitoring with healthcare experts. In general, applications of IoE have touched a number of different domains such as healthcare, digital transformation, home automation, energy conservation, security, information exchange and communication, and environmental monitoring[15]. Some of its major applications domains have been discussed in later sections.

1.2 Applications of Internet of Everything

The IoE is touching all aspects of life and it has numerous applications in all of domains . Some of the applications are discussed below.

- *Smart Healthcare:* In the healthcare support, IoE has significant application ranging from in-hospital support to smart wearable devices. There are IoE based techniques available for diagnosis purpose for various diseases. It also has application to assist patients for their regular activities like assisting Alzheimer patients. There are also trackers like smart watch to keep track of routine health related parameters like blood pressure, distance covered [16].
- *Smart Home:* The IoE based number of equipment are into the market that are related to household things. These devices are making a home connected with Internet. These devices can operate autonomously according to environment like air conditioner will get automatically on/off based on set temperature. Other than this there are basic electronic things in house like fan, fridge, washing machine, TV, lights that have to operate autonomously [17].
- *Smart City:* The IoE has huge potential to develop the infrastructure in more organized and efficient manner. There are applications available to upgrade a city to smart city. These applications could help in smart garbage collection, smart parking system, and smart street lights [18].
- *Smart Vehicular Technology:* There are vehicles equipped with sensors and connected with internet are making the drive more safer and comfortable. Even there are vehicles in development process that can run on roads without driver support. The vehicles can use numerous sensor that can help them in judgment of road conditions and traffic [19].
- *Smart Industry:* IOE has brings a revolutionary change in Industry like manufacturing, food and logistics, and packaging. It brings a new era of sensor fitted robots that can replace the humans in the factories. They can work more efficiently and accurately than the human beings. IoE based systems are also used for delivery of logistics in lesser time like Drones [8].
- *Smart Agriculture:* This is one of the major applications of IoE for agriculture based countries. It helps the farmers to check their soil moisture and other parameters digitally on regular basis. It also helps in developing latest equipment that can help the farmer to grow and sell their crops [20].

1.3 Challenges of Internet of Everything

With the growth in the field of IoE and to meet expectations of people and organizations, a number of opportunities have opened up in domains like research and business. However, this also brings some huge challenges along with it in its implementation at a large scale. These challenges are discussed below.

- *Device Security:* It is one of the major concerns for the IoE field. As it encourages the decentralization of each process, we need security at the device level. There are still some design challenges available with many embedded devices. These make them more vulnerable to many security threats. This needs to be incorporated by manufacturers. Other than this, the increase in the computational capacity of devices makes them available for many processes and data for computational purposes. This makes the devices more vulnerable. It leads to attracting several cyberattacks. This points to the need for the generation of a mechanism to provide the security at device level [21].
- *Data Security:* As the data generated by the devices are multidimensional, the requirement for encryptions or any other data security techniques is also different for the type of data streams. The continuous data generation by the objects leads to the generation of a huge volume of multidimensional data. It gives rise to the need for computational mechanisms that are capable enough to provide data security when they are executed them on source end devices. These mechanisms should also be based on lightweight techniques as well as apply data security at the fog level along with other hierarchical levels of computing [21].
- *Scalability:* The data generated by the objects are continuously increasing with time frame. The cloud or edge devices that are going to process and analyze the data should be scalable. There is enough buffer support available with these computing paradigms to support the large volume of data. There should be flexibility to add a new device that generates data with new parameters that does not hamper the computing and analysis process for that data [22].
- *Privacy Issues:* As IoE is touching each domain of personal as well as professional life of a humans, maintaining privacy of data is a major concern. This is especially true for the fields such as healthcare and other domains that manage personalized data. The data generated by the sensors attached to the patient like blood pressure, heartbeat, etc. are critical. So there is the requirement of an efficient privacy policy for such type of healthcare data [22].
- *Need of Standards:* The goal of IoE is to connect anything with the Internet which leads to connecting different types of devices with the Internet. There is also the decentralization of processes to control the overall mechanism. This brings a new challenge in creating the standards to govern the full mechanisms. These standards should be developed by some well-established organizations or open communities. The standards should find the solution to streamline the various protocols and techniques used at the central level as well as distributed level to control the various process involved in implementation as well communication of all objects [23].

- *Device Heterogeneity:* The aim of IoE to connect anything to the Internet will bring a challenge to connect devices having different operating methods to connect. The working method to generate the data by different types of devices like electrical, electrochemical, and electromagnetic is different [23].
- *Compatibility Issues:* There are many heterogeneous devices available in market and the basic connecting mechanism of each of the devices is different. For example, creating an intelligent home system requires different types of IoE devices, based on disparate technologies like Bluetooth, Zigbee, Z-wave, etc. To incorporate these devices with each other on common platforms lead to the generation of huge compatibility issues [24].
- *Bandwidth Issues :* As the size of the market going to increase exponentially, the number of devices is also going to increase. The data transfer by these devices is also huge. Like there is the option to continuous live streaming of video camera of smart home on the mobile phone. These kinds of applications lead to huge bandwidth requirements at the network level to transfer this volume of data.
- *Intelligent Analysis:* The aim of this digital transformation is to ease life with an intelligent decision-making system without human involvement. For the same, there is the requirement of intelligent data analysis techniques deployed on any of the computing platforms. The accuracy of the decision-making depends upon the intelligence of the data analysis techniques. these techniques should be enough capable to handle the unpredictable behaviors of objects that are generating the data [25].
- *Cloud-Edge-Fog Interplay:* As the decentralization of work is increasing in fields like IoE, still many mechanisms need to be handled at a centralized level. Other than this, the availability of computational power at different platforms is not homogeneous. So there should be a smart selection of platforms like cloud, edge, or fog for specific data for its analysis and process to its execution [26].
- *Authentication Mechanism:* As the number of devices is going to increase exponentially, the authentication of such a huge number of devices from different manufacturers is a challenging task. Other than its number, the devices are also heterogeneous. This leads to a requirement of a standard authentication mechanism to tackle the above-discussed issues [24].

1.4 Conclusion

The advancement in embedded technologies has brought about a new era of smart devices that communicate and connect with Internet. Internet of Things has been one of the main technologies that has emerged as a result of this advancement. The integration of distributed computing and decentralization of processing capabilities has resulted in further development of Internet of Things field. However, heterogeneity of devices and application has been a major bottleneck in adaptability of Internet of Things. This leads to development of a new field called Internet of Things that connects people, process, data, and things in effective and efficient manner. With its evolvement and applicability in number of vital domains also brings number of challenges. Efficient handling of huge amount of multidimensional data generated by heterogeneous devices as well as need of standard process and protocols to define Internet of Everything are the major challenges. There is also a need to tackle security at device level as well as data level. So this chapter has discussed the above challenges and highlighted their importance for future models of IoE.

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