Chapter 18
Internet of Things: The Next Generation Internet

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1 Introduction

Internet is growing all over the world. With this, many new technologies and inventions are emerging which will help to make human life a lot easier. Internet of Things is one of such inventions. This is a trending concept in which objects being used in our daily life are connected to the Internet and make themselves available to the other devices. Internet of things encourages communication, exchange of data, aggregation and integration among the objects in the surrounding [1, 2].

So, we can define IoT as a structure of interconnected computing devices, machines, objects, animals or people that are given unique identification numbers (UIDs) and the capacity to exchange information over a system without any kind of human-to-human or human-to-PC collaboration. In IoT, all things connected can be categorized into three different types:

1. **Things that gather data and then send it further**: These are basically sensors that sense or gather required information from the source and pass it further. There are different types of sensors like temperature sensors, motion sensors, humidity sensors, air quality sensors, light sensors, heart beat sensors, rain sensors, smoke sensors, etc. The working of sensors includes automatic collection of data which helps in more precise results.
2. **Things that get data and then follow up on it:** Machines of these types are everywhere around us. These machines receive information from us and then

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acts on it. Some of the examples of such machines are printers and automatic washing machines.

3. **Things that do both things**: Smart farming is its best example. Sensors are deployed in the field which gathers data about the amount of moisture in the soil and forward this information to irrigation system. The irrigation system automatically turns on/off according to need thus avoiding the presence of farmer. This system can be improved further by connecting it to Internet for weather forecast so that if there are chances of rain, the irrigation system will not water the crops [3].

2 History of IoT

Internet of Things may be 16 years old technology but its work started long ago in 1970s. The term "Internet of Things" was given by Kevin Ashton in 1999 at P and G when he was working there. He wanted to attract the attention of his seniors to the new technology named radio frequency identification (RFID) and with the Internet as a new trend; Kevin named his invention as "Internet of Things." In spite of his efforts, Internet of Things did not get much attention till 2009. Coke machine at Carnegie Mellon University in 1980 was the first machine with Internet connection. This makes the programmers to check whether there is any cold drink in the machine so they can go and grab it, while sitting on their seats. It was also able to check that the cold drinks in the machine are cold or not. Machine-to-machine interaction gave the main lead for the development of IoT.

3 How IoT Works

An IoT environment contains Internet enabled devices that consists of sensors, processors and hardware that collects and forwards the data so that an appropriate action can be taken on it. The data collected by the sensors is sent further for analysis. All the data collected is not useful, therefore, devices can select only the significant data and execute an action. IoT devices can also communicate with other devices and acts on the information they receive from the other device. In this whole process, there is no human interference but they can instruct/set them up. There are some components of IoT that helps in the working of IoT devices discussed below:

Sensors: A large number of smart objects in IoT network generate enormous amount of data with the help of sensors that helps in taking critical decisions in various real-time applications [4]. The data collected by sensors can be very complex/simple in form. A device can also be equipped with more than one sensor so that different tasks can be performed by it. Latest example is of smart rooms in which light and heat sensors detect the human entering the room and will switch on/off the light or adjust the AC temperature according to the time of day outside.

Connectivity: After the sensor collects the data, it is sent further to cloud for analysis. For this, a medium is required which can be a cellular network, Wi-Fi, Bluetooth, etc. The medium selected should be such that it provides the best possible connectivity in every term (range, bandwidth, etc.) to the IoT system.

Data Processing: After data collection and connectivity, data processing starts. Software is used for processing of data. The whole process can be simple or complex depending on type of task; this may also require user interaction.

User Interface: At the end of the whole process, the required information is to be made available to the user. For this a user interface is required, like we can check the cameras installed in our house on our phone screens or we can switch on the AC of our room with the help of our phones before reaching home.

4 Architecture of IoT

Mainly, there are three main layers in the architecture of IoT but to make it more generalize and understandable for research purposes, the five layer architecture was proposed [5].

The perception layer consists of sensors and actuators which help in sensing and gathering the information from the surrounding environment. It senses by identifying different conditions around or by identifying other smart objects. The transport layer sends the data collected by sensors from the perception layer to the processing layer and the other way around. The transfer of data is done by different connectivity technologies like cellular networks, Wi-Fi, Bluetooth, NFC and many others depending on the one being used. The third layer is the processing layer also known as middleware layer analyzes and processes the data send by the transport layer. It also provides services to the lower layers. The application layer which is responsible for providing application-based service like for smart homes, smart cars, health care and many more, to the end user. And the last one is the business layer that has the responsibility to manage the entire IoT system. It looks after different aspects of IoT system like applications, policies, etc.

5 Technologies Used in IoT

The IoT connectivity depends on various factors and environment conditions. Like, some options work well in limited closed space, whereas others work well in open area or outdoors. So, some of the factors that need to be kept in mind while considering connectivity options are coverage area, power consumption, bandwidth, infrastructure, security and other factors like noise, external interference, obstructions, etc.

There are different technologies that are being used in IoT, some of them we are going to discuss in this section. These technologies work in such a way that fulfills

Table 1 Specifications of different technologies used in IoT

Technology	Data rate	Power usage	Cost
Bluetooth	Up to 0.27 Mbps	Low	Low
Wi-Fi	Up to 54 Mbps	Medium	Low
Cellular network	Up to 1 Gbps	Large	High
NFC	Up to 430 kbps	Very low	Very low
Zigbee	Up to 250 kbps	Low	Low
RFID	30 kHz–3000 MHz Ranging from low to ultra-high frequency	Low	Low to high depending on the type of RFID used
Satellite	Up to 506 Mbps	Very high	Very high
LTE-M	Up to 380 kbps	High	Low

all the requirements of the IoT system. Different communication technologies have different specifications like data rate, power usage, cost and features (Table 1).

- **Bluetooth**: Bluetooth is used to share data between the devices over short distance. Its purpose was to replace the menace of wires. Today, this technology has become a part of our lives and most of the devices are Bluetooth enabled. One of its advantages is its low-power consumption but it is prone to network threats also [6].
- **Wi-Fi (Wireless Fidelity)**: Wi-Fi is available everywhere in offices, colleges, shops, home, restaurants, etc. It provides connectivity with LAN at no extra cost. Most of the current wireless network transmits data using Wi-Fi only, making use of Internet services [7]. Wi-Fi offers fast data transfer, can handle large amount of data and range of up to 20 m. This technology uses 2.5 GHz of ultra-high frequency and 5 GHz of super high frequency band and provides with the speed of up to 54 Mbps in 20 MHz channel [8, 9].
- **Cellular network**: The long distance IoT application can make use of cellular networks (3G, 4G or 5G). These networks are able to transfer large amount of data with high speed, but only disadvantage is their high power consumption and cost. Cellular network is a more concerned term with mobile market, video streaming applications and voice/video calls. The emergence of 5G technology made it viable for IoT applications also. It provides high data transfer rate and long-range connectivity with less latency. The 5G new radio network will cater for both massive and critical IoT use cases for connecting large number of smart devices [10].
- **NFC (Near Field Communication)**: It is a short-range communication technology which enables data exchange between the devices when they are 4–10 cm in distance. Due to their short range and high frequency, NFC provides higher degree of security than Bluetooth. It also helps in accessing digital content and connects electronic devices.

- **Zigbee**: Zigbee is a wireless technology designed especially for sensor networks. It is a low cost, low data rate and low-power wireless network, therefore, it is suitable for IoT systems.
- **RFID (Radio Frequency Identification)**: It uses radio waves to transfer data within a short-range using RFID reader from RFID enabled tag. RFID tags are applied on objects and have specific address. By adopting this technology in IoT, retail and logistic sectors will be profited. This will help in keeping check on objects even when they are not in our sight [11]. Inventories can be maintained in real time and will enable smart checkout and smart shelves applications.
- **Satellite**: Satellite provides the coverage all over the earth. It can handle very large amount of data that any other technology. It is highly reliable and provides high bandwidth. But setting a set up with satellite is very costly. In IoT, it is basically used to send data to remote areas, where the human presence is hardly available (mainly in oceans).
- **LTE-M**: LTE-M is short form of LTE-MTC (machine type communication). It has high bandwidth which means higher data rate and low latency. On the other hand, it consumes more energy. LTE-M can be used to replace 2G or 3G cellular network in some applications like fleet management. One of its additional advantages is that it supports mobility (in connected cars or asset tracking) and has voice connectivity.

6 Applications of IoT

As Internet of Things plays a vital role in transforming our lives, an insight into different areas in which it can be used is discussed below (Fig. 1):

Smart homes: Homes where smart devices are used are known as "Smart Homes." Homes are suitable place for smart devices as they already consist of many technical devices; homes are under controlled environment so devices can be easily maintained and can provide many different services and uses [12]. One of the famous examples of smart homes is "Jarvis," it is a home automation system deployed by Mark Zuckerberg.

Wearable: There are many companies releasing their wearable devices now and then, some of the popular ones are Apple smart watch, Galaxy watch and Fitbit. This is one of the earliest industries to adopt IoT as its service. These devices can monitor one's health and helps to access messages, calls, music and much more from the single interface.

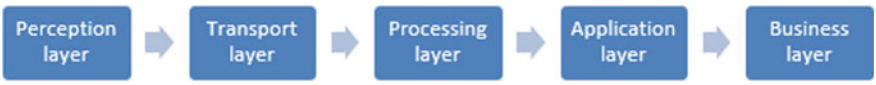


Fig. 1 Architecture of IoT

Smart City: Smart city concept varies from city to city. The problem faced by one city is different from another city. It is used for traffic management, security, congestion control, weather monitoring, pollution control, checking air quality and much more. Sensors are embedded at different places or devices to monitor the activity and control it accordingly. Example of smart city is Palo Alto in San Francisco, where the problem of car parking is solved by installing sensors at parking lots all over the city.

Smart grids: It is the latest trend in IoT. Smart grid will control electricity in different regions by studying the behavior of suppliers and consumers. This will improve the efficiency and reliability.

Smart cars: Smart car is the concept, where cars are provided with the sensors so that they can be monitored for any type of collision and accidents can be avoided. This concept can also be used to check traffic congestion. This idea is coming up slowly.

Health care: Connected healthcare system is one of the hidden gems in IoT. The potential of connected healthcare system and smart medical devices is more than what has been recognized by the people. With this concept, health reports can be sent regularly to the doctor with the help of wearable and he can monitor it from his place directly. Many countries and organizations around the world have developed policies and guidelines for setting up IoT technology in medical and healthcare [13].

Smart farming: To feed such a huge population, technology need to be introduced in agriculture. Crop monitoring and smart farming are the way outs. This will help the farmers to predict the growth of the crops and make required changes. Smart farming leads to better crop production as real-time status of the crops can be monitored. An automated water pump controller was developed that uses moisture sensor to detect level of moisture in the soil this will help farmers from manually operating the pumps to water the fields [14, 15].

Smart Industry: Industrial IoT is advancement of industry which will bring transformation in manufacturing and product designing, thus resulting in increase of economy. It will give more value to the customers and provide efficiency in terms of cost to the industry. Industrial IoT basically combines artificial intelligence with machine learning.

Smart Retail: IoT has gained popularity in the field of retailing with time. Retailers have now started to embed IoT systems to ensure automatic inventory management system, increase in purchase, improved customer shopping experience and reduced chances of theft. Retailers can use their smart phones to interact with the customers to serve them better. They can also track the areas in the store, where the customer traffic is more so that they can place their premium products there for their benefit.

Tracking and monitoring: IoT can be used to track assets using GPS or radio waves. Devices can be embedded with the chip with which they can track or verified over a long distance.

IoT in Education: IoT in educational field can be used to fill the gaps in our education system. The quality of education offered to the students can be improved without spending much. Moreover, students'/teacher's responsiveness and behavior

Table 2 IoT applications according to the communication technologies used in IoT

Technology	Application
Bluetooth	Wearable, smart phones
Wi-Fi	Smart homes, smart city, smart cars, smart retail
Cellular network	Smart farming, smart industries, health care, smart retail, logistic tracking
NFC	Contactless payments
Zigbee	Smart homes, smart industry
RFID	Smart retail, logistic tracking
Satellite	Remote monitoring and asset management at unmanned areas, smart grids
LTE-M	Smart cars, tracking and monitoring

can be monitored to increase the overall performance. IoT also helps in professional development of the teachers as they can learn and develop better strategies to educate students instead of following the old methods of teaching.

Smart Environment: IoT can also help us to prevent natural calamities like earthquakes, cyclones, landslides, forest fires, etc., by monitoring the environmental conditions. It can also detect emissions and wastes by factories and cars (Table 2) [16].

7 Scope and Challenges of IoT

With the day-to-day advancement in the technology, we are lucky to experience new things every day. One of the most recent and advanced one is IoT. It is like boom to mankind as with this we can manage or control anything from anywhere and in some cases even a human intervention is not required. IoT uses the concept of machine-to-machine communication [17]. With IoT, our personal devices can be connected to the Internet and it will help us to manage our lives easily. Alarms can be set in the house which can detect any unwanted human intrusion and inform us on our phones, devices can also be used as wearable which predict heart rate and strokes, automatic door locking systems can lock the doors of the house when it senses no movement, similarly the lights can be switched on or off when no one is there and much more. All these give companies a new scope to develop devices that will be helpful to consumers and thus lead to their economy.

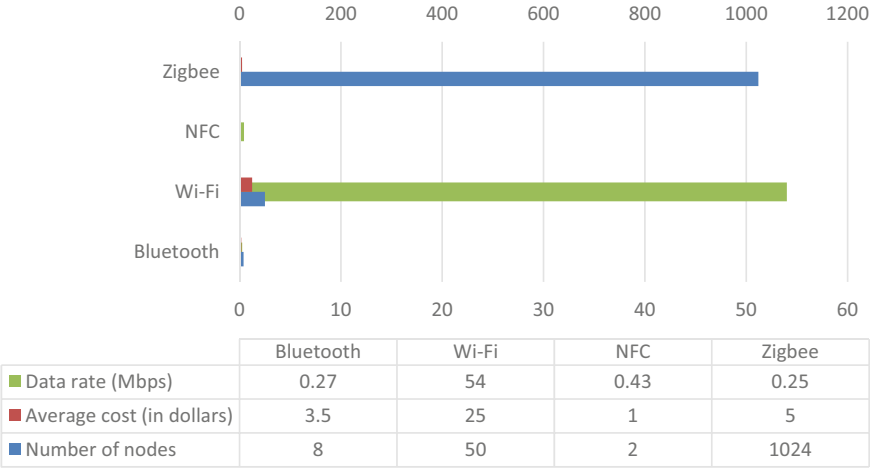
This dynamic environment of IoT gives way too many unseen opportunities which will change our view point on communication and networking. But at the same time, privacy, interoperability and security should also be carefully taken into consideration to prevent it from being transformed into a pervasive surveillance object [18, 19]. Like other emerging technologies, IoT is also facing challenges and issues. Being low powered and less secure, IoT devices can act as doorway for attackers to enter our homes and offices so that they can easily access our data [20]. In the countries like

India where the speed of Internet is not that fast as compared to USA, the quality and cost of receiving data are also an issue. Once the policies are properly implemented, the user will be able to make maximum use of this technology [21]. Moreover, as IoT is at its early stage, more awareness should be spread among the user. They should be given knowledge about its features, benefits and future scope.

8 Comparative Analysis of Communication Technologies in IoT

We have studied various wireless communication technologies in IoT that can be used for data transmission [22]. Their specifications and use in particular application are also considered. Now, we are going to compare few of these technologies on the basis of different matrices like data rate, number of nodes and cost. Bluetooth, NFC, Wi-Fi and Zigbee will be compared keeping in mind these metrices. Line graphs of the analysis done are shown in Fig. 2.

From the results, we have found that Zigbee can hold large number of nodes as compared to other three technologies whereas NFC is limited to two nodes only. Whereas in case of overall average cost, Wi-Fi is on higher side due to the requirement of hardware and other devices and NFC on lower. Number of data bits transferred per unit time is higher in Wi-Fi due to its bandwidth and higher data rata compared to Bluetooth, NFC and Zigbee.



	Bluetooth	Wi-Fi	NFC	Zigbee
Data rate (Mbps)	0.27	54	0.43	0.25
Average cost (in dollars)	3.5	25	1	5
Number of nodes	8	50	2	1024

Fig. 2 Comparison of number of nodes, average cost and data rate in communication technologies

9 Conclusion

Internet of Things connects virtual world with the real one making our life comfortable and a better one. But with the increasing widespread of this technology, it also bought some downside with it. As smart objects make us dependent, we will not be able to do anything or control our lives without them. Moreover, setting up an IoT environment requires proper infrastructure for communication and device setup.

Since it is a new technology, there are also concerns related to its security as no proper precautions are there to protect its data. So, a lot of work is still required to be in this field to make it a blessing not a punishment to the mankind. We have also done a comparative analysis of few communication technologies to find out which one is better depending on particular specification.

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