

FUTURE OF INTERNET OF THINGS

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Abstract

Internet of Things (IoT) consists of smart electronic devices, local area networks, the Internet, cloud servers, and the user applications. It has emerged as a leading technology worldwide. The technology has become a mainstream technology and is showing no signs of slowing down in terms of innovation. No business can grow without the implementation of IoT. The future of IoT presents the opportunity for new business models. IoT will benefit in the future through improved efficiency, enhanced safety, advanced healthcare solutions, smart cities, and data-driven decision-making. This paper predicts the future of the Internet of things.

Keywords: Internet of things, industrial Internet of things, IoT, IoT devices, future of IoT.

INTRODUCTION

Technology has taken a quantum leap in the past few years. One of the most rapidly growing sectors of technology is the Internet of things (IoT), where devices interact with each other. IoT allows smart devices to communicate, send, receive, and interpret data from connected devices anywhere in the world, anytime. In essence, the Internet of things (IoT) is about connected devices. IoT is the umbrella term for anything that connects to the Internet. As illustrated in Figure 1, anything that can be connected is connected to IoT [1]. It is a rapidly expanding field that has enabled connected devices to enter every aspect of our lives, including fitness and health, home computerization, logistics, and smart cities. Over the last two decades, the IoT has been adopted in industries all over the globe.

WHAT IS INTERNET OF THINGS?

The term “Internet of things” was introduced by Kevin Ashton from the United Kingdom in 1999. Internet of Things (IoT) is a network of connecting devices embedded with sensors. It is a collection of identifiable things with the ability to communicate over wired or wireless networks. The devices or things can be connected to the Internet through three main technology components: physical devices and sensors (connected things), connection and infrastructure, and analytics and applications.

The IoT is a worldwide network that connects devices to the Internet and to each other using wireless technology. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, pet monitors, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc.

There are four main technologies that enable IoT [2]:

- (1) Radio-frequency identification (RFID) and near-field communication.
- (2) Optical tags and quick response codes: This is used for low cost tagging.
- (3) Bluetooth low energy (BLE).
- (4) Wireless sensor network: They are usually connected as wireless sensor networks to monitor physical properties in specific environments.

Other related technologies are cloud computing, machine learning, and big data.

The Internet of things (IoT) technology enables people and objects to interact with each other. It is employed in many areas such as smart transportation, smart cities, smart energy, emergency services, healthcare, data security, industrial control, logistics, retails, government, traffic congestion, manufacturing, industry, security, agriculture, environment, and waste management. Figure 2 shows the most widely used areas of IoT [3].

IoT supports many input-output devices such as camera, microphone, keyboard, speaker, displays, microcontrollers, and transceivers. It is the most promising trend in the healthcare industry. This rapidly proliferating collection of Internet-connected devices, including wearables, implants, skin sensors, smart scales, smart bandages, and home monitoring tools has the potential to connect patients and their providers in a unique way.

Today, smartphone acts as the main driver of IoT. The smartphone is provided with healthcare applications.

To predict the future of IoT would be difficult without knowing the its trends in leading industries. So we consider the future of IoT in healthcare, education, business, manufacturing, agriculture, and smart technologies. The future of IoT technology lies in each of these trends and beyond with possibilities of extending into many other areas.

FUTURE OF IOT IN HEALTHCARE

Healthcare is the fastest domain to adopt IoT. The healthcare industry has benefited greatly from IoT technology. IoT has proved to be one of the best tools for the healthcare sector. The integration of IoT features with medical devices significantly improves the quality and effectiveness of service. IoT applications in healthcare can offer a seamless connection and data-sharing process. The IoT devices used in healthcare can track, collect, analyze, and share data using a cloud base.

Recent advancements in IoT technology are enabling revolutionary advancements in healthcare. IoT helps provide advanced healthcare facilities to patients, doctors, and researchers. The last two decades has seen IoT advance into healthcare in the form of wearables to voice assistants and connected medical equipment. Today, patients conduct telehealth calls with doctors and cameras are installed to support real-time security monitoring. IoT applications can even protect the health and safety of employees by improving the indoor air quality and physical security of the facilities they occupy. With the help of IoT devices, the treatment of patients in the physical absence of doctors (in remote locations) has become possible. Some advantages of IoT in healthcare are shown in Figure 3 [4]. In the future, we will see wearables get smarter and incorporate sensors that can measure more parameters. We can also expect more at-home smart sensors to monitor patients' vitals [5]. IoT in healthcare will become more prevalent as healthcare providers look to reduce costs and drive better customer experience.

FUTURE OF IOT IN EDUCATION

IoT in education implies a better-connected and more collaborative future for students as well as teachers. The IoT solutions enable the automation of various tasks, improves school management, facilitates real-time data collection, powers smart lighting systems for better, and provides a safer learning environment through the use of smart cameras, smart ID cards, and smart access control. The virtually endless possibilities of IoT has already proved its worth in education [6]. It becoming increasingly apparent that the IoT may well shape and define the future of education. One of the most significant impacts if the IoT in education is the unprecedented capacity of this technology to

support interactive learning. IoT devices give students more opportunities to actively engage with the instructor, with classmates, and with the learning materials. A typical example of interactive learning is shown in Figure 4 [7].

Schools and universities around the world are taking bold steps towards smart education with IoT solutions to make educational plans up-to-date and engaging for students. The request for IoT in the education industry is expected to grow drastically in the next few years. The spreading of IoT-enabled gadgets, the expansion of storage capacities, and the growing demand for trendy education, will be the accelerators for demand. Its increasing integration in the classroom is promising to change our future.

FUTURE OF IOT IN BUSINESS

The combination of IoT, AI, and ML will define the business for the next few decades. IoT helps leaders to gain insights from the connected devices and enables them to make better business decisions. Businesses are understanding the value of IoT and are rapidly adopting it to streamline their processes and make them more efficient [8]. Businesses are playing a major role in the explosive growth of the IoT since it delivers a number of benefits to businesses. We have seen some successful experiments in the past few years. Businesses that are proactive in connecting more of their devices will benefit from increased insights into their critical infrastructures' performance. Businesses need to work toward positioning IoT applications strategically because the transformation would be disrupting the devices market. Using IoT devices allows retailers to gather useful data about customers in real-time. IoT businesses show hardware and software beginning to merge in domains such as smart home applications, and the trend will likely to continue. Market readiness is high, with both consumers and businesses expressing high interest in IoT. Products such as Alexa and FitBit have already become household names, and mobile devices are ubiquitous [9]. We cannot ignore the role of machine learning in IoT trends. Machine learning (ML) are techniques that empower artificial intelligence (AI) with the ability to learn. ML is the core of human speech applications such as Siri for Apple devices, Google Voice, or Alexa for Amazon.

FUTURE OF IOT IN MANUFACTURING

The driving force behind IoT adoption is the manufacturing industry. The manufacturing industry spends more on IoT solutions than any other industry. The Internet of things (IoT) and the industrial Internet of things (IIoT) have been prominent features in manufacturing shop floors throughout the last decade, and this will remain the same. Today, the IoT and IIoT are transforming manufacturing, addressing the increasing demand for product customization, and changing customer expectations. Industrial robots are an integral part of some manufacturing plants. A typical manufacturing floor with industrial robots is shown in Figure 5 [10]. Manufacturers interested in adopting IoT must understand the future to develop proper implementation plans. The future of IoT in manufacturing is highly dependent on the innovations that hardware vendors integrate into the development of IIoT devices. The next phase of IoT implementation will rely on interrelated technologies such as the digital twin. Advancements in digital twin technology coupled with the connected data streams IoT produces is expected to deliver accurate real-time planning and scheduling processes in the future [11].

FUTURE OF IOT IN AGRICULTURE

Food is one of the three basic human needs. As the population of the world is rapidly increasing, the agricultural industry is facing many challenges. To address the challenges and increase food productivity, the industry has adopted technology, including the use of precision farming, agricultural drones, and smart farming applications. All these are built on top of the application of IoT. The future of IoT in agriculture is important. The emergence of IoT and technological advancements has led to the creation of IoT-based greenhouses [4]. IoT can be used by farmers to help make informed decisions using agriculture drones. IoT solutions are focused on helping farmers close the supply demand gap, by ensuring high yields, profitability, and protection of the environment. Smart farming based on IoT technologies enables farmers to reduce waste and enhance productivity. Farmers have started to realize

that the IoT is a driving force for increasing agricultural production in a cost-effective way [12]. The future of IoT presents an opportunity to connect all sorts of different devices, collect many different types of data, and learn from it without having to sort it all out first. The future of IoT in agriculture allows predictive analytics to help you make better harvesting decisions [13].

FUTURE OF IOT IN SMART TECHNOLOGIES

Combining AI and IoT creates machines that have smart, intelligent behaviors and supports strong decision-making processes. It is no surprise that these technologies complement one another. The duo has revolutionized traditional industrial and corporate solutions. Some of the common IoT devices that we come across and use in day-to-day lives are smart TVs, refrigerators, and air conditioners. Smartphones and other media devices continue to be the most commonly used IoT devices in the consumer segment. Voice assistants have seen significant growth over the last year, with millennials making the most significant contributions. With widespread digitization and the availability of sensor technology, 2023 is expected to see a rapid proliferation of digital twins in more industries. More cities will be affected by IoT. More will be interconnected. Smart home systems will be programmed and monitored from your computer or smartphone from anywhere in the world. Automation will soon further explode. From smart cities to wearables, there is a persuasive argument for processing data as close to the source as possible. These advances are primarily driven by the popularity of AI in IoT solutions.

BENEFITS

IoT offers many benefits such as improved efficiency, enhanced decision-making, increased safety, improved quality of life, environmental sustainability, cost savings, better customer experience, real-time tracking, remote accessibility, and opportunities for innovation and new business models. The trend of IoT is in demand now for various reasons including technological advancements, cost reduction, increasing connectivity, potential benefits, industry transformation, and the demand for data-driven insights [14]. Other benefits of IoT include [15]:

- *Connectivity*: One thing all the IoT trends have in common is connectivity. IoT gives us connectivity to people and devices all over the world. In the future, people will choose the connectivity over security.
- *Efficiency*: IoT has made it possible for many of us to work from home. We can communicate with the office from anywhere.
- *Convenience*: IoT has made the lives of the human being straightforward and comfortable. It has made the lives of the people very convenient. IoT makes everything easier in our business and personal lives. We can even buy groceries, learn a language or earn an advanced degree without ever leaving home.
- *Health*: Wearable technology is enjoying immense popularity, and it will only continue to grow as wearable devices become smarter.
- *Environment*: IoT holds great promise for protecting our planet and making life on earth more sustainable. Smart technology can help us monitor and control our usage of water, energy, and natural resources.
- *Personalization*: If you use the Internet as a consumer, you are being profiled and your shopping journey is being personalized.

CHALLENGES

The future of IoT offers mixed bag of opportunities and challenges. The future of IoT is based on a complex infrastructure. Many providers were also criticized for poor implementation of the 5G standard. But in 2023, we can expect service providers to fix these issues and the technology to reach more people. Other challenges include [15-17]:

- *Security*: Along with the IoT comes the need for unprecedented levels of security. Security persists as a long-time concern with IoT, and IoT security is complex. As the IoT market matures, we are seeing more legislation around the security of IoT devices. The past couple of years has seen increasing awareness about the risks of IoT devices. Consumers have become aware of the privacy risks that IoT devices pose. Countries like Singapore and Germany have already produced labels that tell the consumer the security risks associated with an IoT device. Lack of security standards across various manufacturers and devices makes frequent updates imperative.
- *Privacy*: Data mining is a gross invasion of privacy. Personal privacy is becoming increasingly difficult to safeguard in a connected world.
- *Surveillance*: This goes beyond pilfering consumer data to invading your personal life. We know that smart devices can see, hear and read what we do, say and communicate. The potential of information for evil is enormous.
- *Cybercrime*: As we increasingly rely on IoT technology for everyday living, we make ourselves more vulnerable to cybercriminals. Sophisticated hackers can violate the security of any and all smart devices.
- *Connectivity*: Connecting too many devices will be one of the biggest challenges of the future of IoT, and it will defy the very structure of current communication models and the underlying technologies.
- *Compatibility and Longevity*: IoT is growing with many different technologies competing to become the standard. This will cause difficulties and require the deployment of extra hardware and software when connecting devices.
- *Standards*: Technology standards which include network protocols, communication protocols, and data-aggregation standards.
- *Intelligent Analysis & Actions*: Analysis is driven by cognitive technologies and the accompanying models that facilitate the use of cognitive technologies.

Some of these IoT challenges are displayed in Figure 7 [17].

CONCLUSION

The Internet of things is a network of physical objects connected to the Internet so that they can share information to improve productivity, efficiency, services, and more. It is a cornerstone technology in the era of digital transformation. We are just at the beginning of what is possible with the future of IoT. IoT will continue to form the backbone of many technologies that will change the way we all live. From smart homes to industrial automation, IoT has made its mark on virtually every industry and will continue to do so.

Since customer demands are changing constantly, IoT services need to develop correspondingly. The future of the Internet of things is looking bright with amazing opportunities and with new technologies and access to information that we may not previously have thought possible. The potential of the IoT devices is enormous and remains untapped. IoT is about to expand to limits unsurpassed by anything yet. It is hoped that the IoT trends covered in this paper and their implications will show you the importance of implementing IoT in your business. More information about the future of IoT can be found in the books in [18-22] and the following journal devoted to IoT: *IEEE Internet of Things Journal*.

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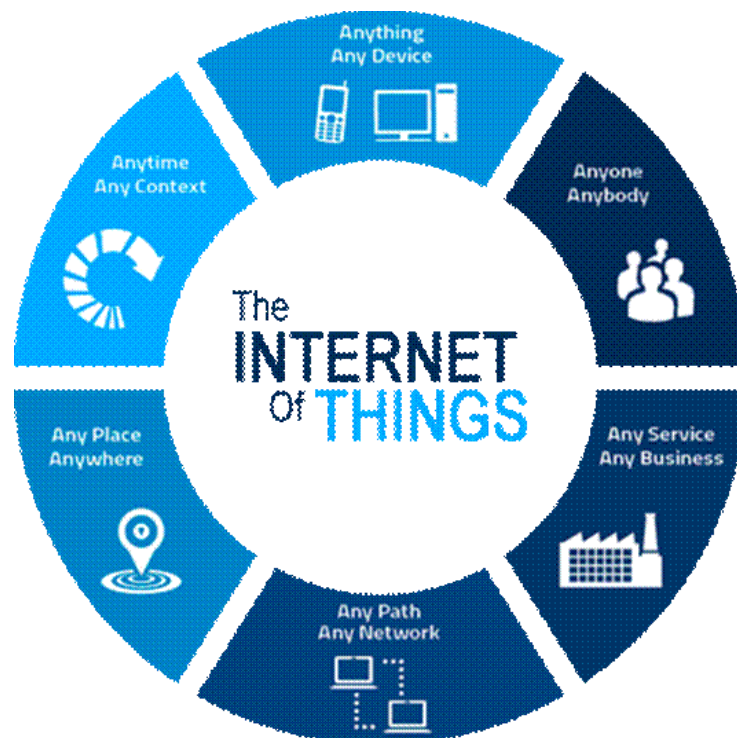


Figure 1 Anything that can be connected is connected to IoT [1].

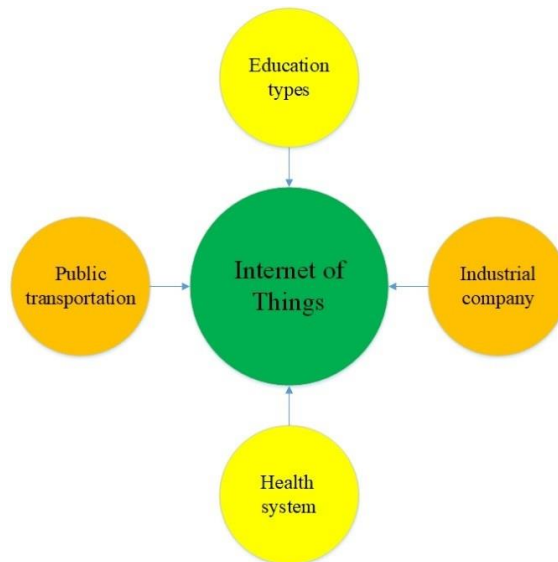


Figure 2 The most widely used IoT application areas [3].



Figure 3 Some advantages of IoT in healthcare [4].



Figure 4 A typical example of interactive learning [7].



Figure 5 A typical manufacturing floor with industrial robots [10].

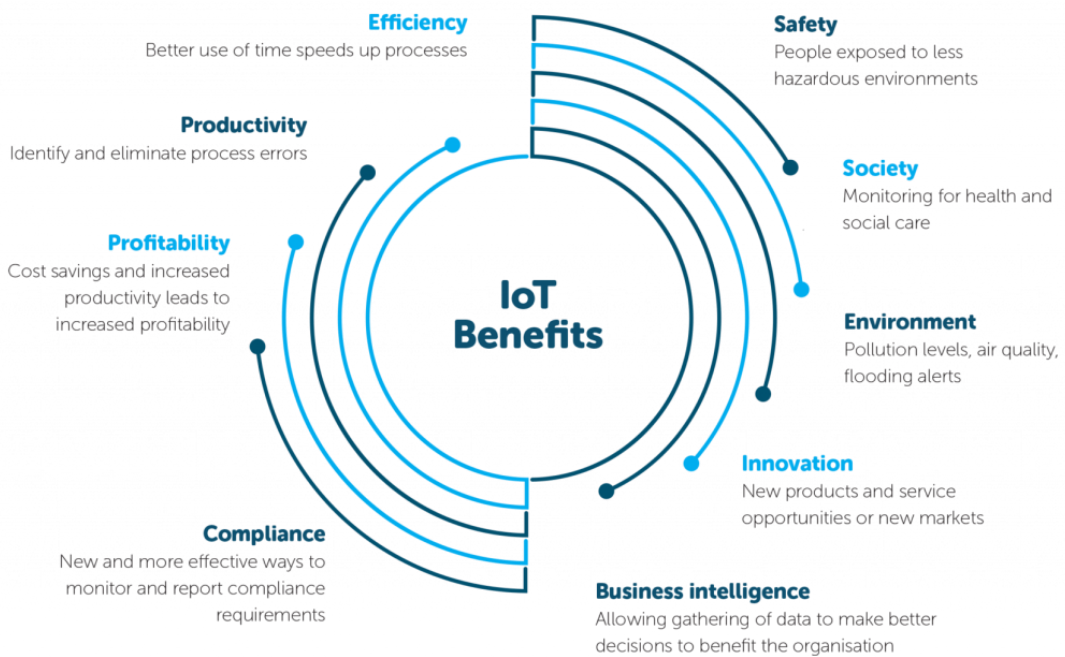


Figure 6 Some of the IoT benefits [4].



Figure 7 Some IoT challenges [17].