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Internet of Things: An Overview

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ABSTRACT

The Internet of things (IoT) refers to the networking of physical object, or "things," that independently talk to each other over the Internet and exchange information. These "things" can range from everyday household appliances to complex industrial machinery. The IoT simplifies and automates tasks that are complicated and sometimes beyond the scope of human capabilities. IoT has transformed the way people interact with the world around them. It has led to the development of smart homes, smart cities, and industries. Due to the advent of inexpensive computer chips and high bandwidth telecommunication, we now have billions of devices connected to the Internet. This means everyday devices like toothbrushes, vacuums, cars, and machines can use sensors to collect data and respond intelligently to users. This paper provides an overview of the Internet of things.

KEYWORDS: *Internet of things, IoT, industrial Internet of things, IIoT, smart devices, IoT applications.*

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INTRODUCTION

The Internet of things (IoT) refers to objects that have sensors, software, and network connectivity, and can exchange data over the Internet. These objects, known as "smart" objects, devices, or machines, can operate and interact with their environment on their own, without human intervention. They can communicate with each other, share data, and perform tasks [1]. IoT allows us to connect anything to the IoT ecosystem and make it available on the web with the help of sensors that collect data, processors, and high-coverage connections. Using IoT platforms brings smart buildings, smart home devices, wearable devices, and fleet management into a central IoT platform for managing physical devices.

The Internet of things (IoT) consists of a vast number of "things" that are connected to the Internet so they can share data with other things. A "thing" in the Internet of things can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low, or any other human-made object that can be assigned an Internet Protocol (IP) address. These things or devices share sensor data by connecting to an IoT gateway, which acts as a central hub where IoT devices can send data. They communicate with related devices and act on the information they get from one another [2].

The IoT harnesses the power of the Internet to connect physical devices in real-time. It is making devices smarter and is responsible for innovative changes in many industries. Real-world Internet of things examples range from a smart home that automatically adjusts heating and lighting to a smart factory that monitors industrial machines to look for problems, then automatically adjusts to avoid failures. Today, we are living in a world where there are more IoT-connected devices than humans. IoT connected devices and machines predict problems before they occur [3].

OVERVIEW OF INTERNET OF THINGS

The concept of the Internet of things (IoT) has been around since the late 1990s, but it gained momentum in the 2000s with the rise of Internet-connected devices. The Internet began with some military computers in the Pentagon called Arpanet in 1969. It expanded throughout the 1980s as a set of four

parallel military networks, each at a different security level. The core technology which gives the Internet its particular characteristics is called Transmission Control Protocol/Internet Protocol (TCP/IP), which is essentially a set of rules for communication [4].

Internet of things (IoT) is a worldwide network that connects devices to the Internet and to each other using wireless technology. These devices contain hardware such as sensors and electronics which give them the ability to interact with other objects and to be monitored and controlled from afar. The idea is that the physical devices with sensors or the ability to capture data, shares that data with websites. The information is then used or analyzed in real time or at a later time, to create efficiencies. 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, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc. Figure 1 illustrates the Internet of things [5].

There are four main technologies that enable IoT [6]: (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 [7]. Communications technologies in Internet of things are portrayed in Figure 2 [5].

At the foundation of the IoT is Internet Protocol (IP) and Transmission Control Protocol (TCP). These standards and rules form the basis for sensors, devices, and systems to connect with the Internet and with each other. The seven layers of IoT are the components that work together to enable the communication and exchange of data between IoT devices. They are [1]:

1. *Physical layer:* The physical components of the IoT system, including sensors, actuators, and other devices that capture and transmit data.
2. *Data link layer:* Manages the communication between devices, including protocols such as Wi-Fi, Bluetooth, and Zigbee.
3. *Network layer:* Handles the routing and delivery of data between devices using protocols.
4. *Transport layer:* Controls the end-to-end communication between devices using protocols.
5. *Session layer:* Responsible for the establishment and termination of sessions between devices.
6. *Presentation layer:* Runs the formatting and encoding of data using protocols.
7. *Application layer:* Represents the applications and services that run on top of the IoT system.

INDUSTRIAL INTERNET OF THINGS

The growth of the internet of things (IoT) is drastically making impact on home and industry. While the IoT affects among others transportation, healthcare, or smart homes, the Industrial Internet of Things (IIoT) refers in particular to industrial environments. IIoT is a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine-human collaboration to improve productivity, efficiency and reliability. It is bringing about a world where smart, connected embedded systems and products operate as part of larger systems [8].

The industrial Internet of things (IIoT) refers to the application of the Internet of things (IoT) across several industries such as manufacturing, logistics, oil and gas, transportation, energy/utilities, chemical, aviation and other industrial sectors. A typical industrial Internet of things is shown in Figure 3 [9].

IIoT is often used in the context of Industry 4.0, the Industrial Internet and related initiatives across the globe. Industry 4.0 describes a new industrial revolution with a focus on automation, innovation, data, cyber-physical systems, processes, and people [10]. With Industry 4.0, the fourth industrial revolution is set on merging automation and information domains into the industrial Internet of things, services, and people. The communication infrastructure of Industry 4.0 allows devices to be accessible in barrier-free manner in the industrial Internet of things, without sacrificing the integrity of safety and security [11]. Figure 4 shows a typical representation of IoT [12].

APPLICATIONS OF IOT

An IoT application is a collection of services and software that integrates data received from various IoT devices. IoT enables a range of applications within environmental monitoring, traffic control, healthcare, agriculture, manufacturing, and others. Some of the applications are shown in Figure 5 [13]. Common areas of application include the following [1,14]:

- *Telecommunications:* IoT technology is being widely adopted in the telecom industry. It offers a range of benefits such as enhanced network management, improved asset tracking, and an

elevated customer experience. Telcos are using IoT to offer new services. Telcos can enable devices with IoT to gather data, optimize network performance, and provide innovative services and solutions. IoT devices can be used to monitor and manage telecom networks. They can collect data on network performance, traffic patterns, and usage. As a result, telcos can optimize their networks for better performance and efficiency.

- *Transportation:* Transportation systems benefit from a variety of IoT applications. Fleets of cars, trucks, ships, and trains that carry inventory can be rerouted based on weather conditions, vehicle availability, or driver availability. The IoT can assist in the integration of communications, control, and information processing across various transportation systems. Application of the IoT extends to all aspects of transportation systems (i.e., the vehicle, the infrastructure, and the driver or user).
- *Agriculture:* There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, wind speed, pest infestation, and soil content. For example, farmers can now monitor soil temperature and moisture from afar and even apply IoT-acquired data to precision fertilization programs. The overall goal is that data from sensors, coupled with the farmer's knowledge and intuition about his or her farm, can help increase farm productivity, and also help reduce costs. IoT devices can be used in agriculture to monitor soil conditions, weather patterns, and crop growth. For example, sensors can be used to measure the moisture content of soil, ensuring that crops are irrigated at the optimal time.
- *Maritime Industry*: IoT devices are in use to monitor the environments and systems of boats and yachts. Many pleasure boats are left unattended for days in summer, and months in winter so such devices provide valuable early alerts of boat flooding, fire, and deep discharge of batteries.
- *Connected Cars:* There are many ways vehicles, such as cars, can be connected to the Internet. It can be through smart dashcams, infotainment systems, or even the vehicle's connected gateway. They collect data from the accelerator, brakes, speedometer, odometer, wheels, and fuel tanks to monitor both driver performance and vehicle health. Connected cars have a range of uses monitoring rental car fleets to increase fuel efficiency and reduce costs.

BENEFITS

The Internet of things can have a huge impact on our day-to-day lives. For example, it may be possible for humans to remain connected with their electronic devices without actually having to get close to them. The adoption rate for the IoT is increasing exponentially with each passing day due to the many benefits if offers. Other benefits of IoT include the following [2,15]:

- *Accessibility*: IoT offers easy access to information from anywhere at any time on any device. For example, IoT enhances the accessibility of information by providing real-time data and insights, intuitive interfaces, and proactive alerts. IoT improves communication between connected electronic devices by enabling efficient data exchange, extending network reach, conserving energy, and prioritizing critical communications.
- *Automation:* IoT automates tasks to improve the quality of a company's services and reduces the need for human intervention. For example, in agriculture, IoT-enabled irrigation systems can automatically adjust watering schedules based on soil moisture levels, weather forecasts and crop requirements.
- *Data-driven Decision-making:* Real-time data allows for informed decision-making based on accurate and up-to-date information. IoT devices generate vast amounts of data that can be used to make better-informed business decisions and new business models. By analyzing this data, businesses can gain insights into customer behavior, market trends, and operational performance, allowing them to make more informed decisions.
- *Improved Efficiency:* Automation and data-driven insights can lead to significant improvements in efficiency across various sectors. By using IoT devices to automate and optimize processes, businesses can improve efficiency and productivity. For example, IoT sensors can be used to monitor equipment performance and detect or even resolve potential issues before they cause downtime, reducing maintenance costs and improving uptime.
- *Cost-savings:* By optimizing processes and reducing waste, IoT can help lower costs in various applications. By reducing manual processes and automating repetitive tasks, IoT can help businesses reduce costs and improve profitability. For example, IoT devices can be used to monitor energy usage and optimize

consumption, reducing energy costs and improving sustainability.

- *Enhanced Customer Experience:* By using IoT technology to gather data about customer behavior, businesses can create more personalized and engaging experiences for their customers. For example, retailers can use IoT sensors to track customer movements in stores and deliver personalized offers based on their behavior.

CHALLENGES

Connecting many different devices over the Internet offers scope for criminal activities. It offers cybercriminals easy entry doors to obtain sensitive information from private individuals or companies. Therefore, ensuring the protection of data during collection and transmission is the central challenge of the Internet of things. Although IoT adoption has quickly become a business enabler, security and privacy issues present a major challenge for this emerging technology as they are vulnerable to hacking and easy to breach. Other challenges of IoT include the following [14,16]:

- *Data Privacy:* One of the most important challenges for IoT devices is ensuring collecting data privacy and security. Multiple devices can collect data about their owner's details such as health, age, and other such related data. These devices need to be programmed to not collect or share this information without the consent of the user. Also, it becomes very important for such devices to use strong security tools so that access is permitted only by authorized personnel for specific purposes. Another concern is the use of surveillance cameras to track the movements of people, for when video data is combined with other types of data generated from sensors, cameras, cellular records, computer logs, and other systems, it is possible to identify where a person has been or what they have done at any given moment.
- *Security:* The Internet of things facilitates the sharing of IoT data between a large number of devices, which can result in the greater vulnerability of a data center if proper measures are not taken for protecting these devices from being hacked into. Hence, it becomes important to use strong passwords and install antivirus software that can protect these devices from being attacked by cybercriminals. Since they can be easily hacked into, many companies are reluctant to adopt IoT technology.
- *Managing Cost:* Implementing an IoT system can be costly and complex, requiring significant investments in hardware, software, and infrastructure. The deployment of the enterprise IoT is an expensive affair and it becomes important for the enterprises that intend to use this technology to manage their resources properly so that they can get good value for money spent on it. However, the cost of integrating computing power into small objects has now dropped considerably.
- *Skill Shortage:* There is a major skill gap that needs to be eliminated for the Internet of things to be successful. Only a limited number of professionals have expertise and skills in this field and it is expected to grow. Due to decreased human intervention in various tasks, IoT can result in job displacement for low-wage workers or those with limited experience.
- *Regulation:* As IoT devices become more widespread, regulatory, and legal challenges are emerging. Though still in their infancy, regulations and governance regarding issues of privacy, security, and data ownership continue to develop. IoT regulation depends on the country. An example of legislation that is relevant to privacy and data collection is the US Privacy Act of 1974. Governmental regulation is argued by some to be necessary to secure IoT devices and the wider Internet.
- *Data Storage:* The amount of data IoT collects requires large amounts of storage, meaning organizations must scale their storage infrastructure to match the amount of data they collect. A challenge for producers of IoT applications is to clean, process and interpret the vast amount of data which is gathered by the sensors. Another challenge is the storage of this bulk data. Depending on the application, there could be high data acquisition requirements, which in turn lead to high storage requirements. Data silos, although a common challenge of legacy systems, still commonly occur with the implementation of IoT devices, particularly within manufacturing.
- *Interoperability:* IoT devices from different manufacturers often use different standards and protocols, making it difficult for them to perform machine-to-machine communication. This can lead to interoperability issues and create silos of data that are difficult to integrate and analyze.

CONCLUSION

The Internet of things is an emerging technology with huge potential for advancement in various areas like healthcare, transportation, smart cities, and energy

asset management. It has opened up tremendous opportunities for individuals as well as businesses to do their work better than ever before. The technology is here to stay and is expected to revolutionize the way people live their lives in the future.

The Internet of things market continues to grow with the increasing number of connected devices. The future of IoT is promising, with many exciting developments on the horizon. More information about Internet of things can be found in the books in [17-24] and the following related journal: *IEEE Internet of Things Journal.*

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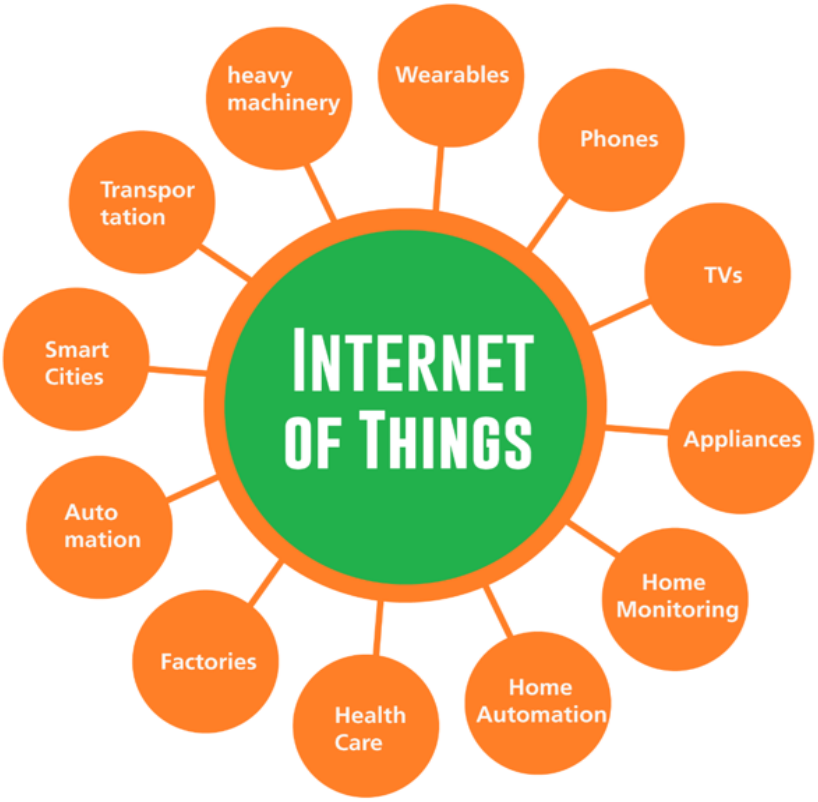

Figure 1 The Internet of things [5].

Figure 2 Communications technologies in Internet of things [5].

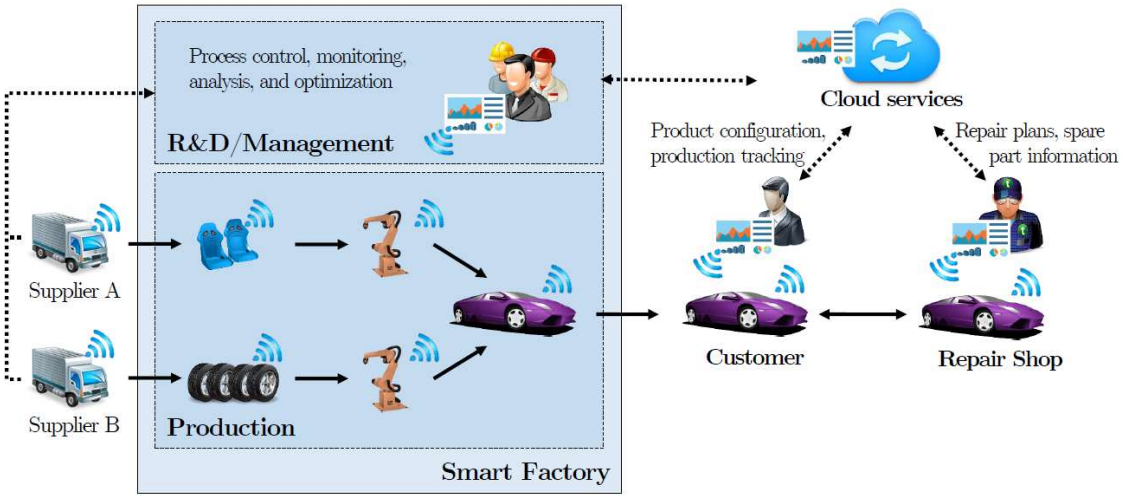

Figure 3 A typical industrial Internet of things [9].

Figure 4 A typical representation of IoT [12].

Figure 5 Some of the applications of IoT [13].