Fundamentals of IoT

Get familiar with the building blocks of IoT

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About the Authors

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- **Prof. (Dr.) Supriya Madan**, Dean, School of IT at Vivekananda Institute of Professional Studies has versatile experience and is an erudite scholar in her own right. Her association with the field of Information Technology is a testimony of her fruitful and ongoing journey. She started her professional career in 1989 as a senior programmer and EDP manager of a reputed public limited finance company. After gaining practical knowledge and successful completion of projects, her zeal and enthusiasm for teaching brought her into full-time academics in the year 2000. She has published patents and her research work has been published in reputed national and international conferences and International Journals and are quoted as references.

About the Reviewer

Brij Mohan Sharma is a passionate IoT developer with a diverse background in working on various IoT and IIoT projects. He has over 6 years of experience in the field, and his expertise spans a wide range of applications, including indoor local positioning systems, asset management, connected cars, and IoT system benchmarking. He is proficient in working with Azure IoT, AWS, and using core languages such as Java, Python, and Embedded C for edge and cloud-based IoT solutions.

Brij Mohan Sharma has worked for esteemed companies like Boeing, Wipro, and Sopra Steria, where he has gained valuable insights and hands-on experience in tackling real-world challenges through IoT. At Boeing, he contributed to the development of an Asset Monitoring System, including implementing auto-deployment and designing secure Over-The-Air (OTA) update mechanisms.

During his tenure at Wipro as a Senior Project Engineer, Brij Mohan Sharma successfully delivered stages of a digital twin monitoring health feature project and developed a custom Azure dashboard for monitoring Azure services. He also collaborated with the team to construct APIs that determined the overall health state of Azure instances.

As a Full Stack IoT Developer at Sopra Steria, Brij Mohan Sharma worked on various projects, including the design of a digital twin for a connected car in collaboration with Blockchain and AI/ML teams. He also engaged in IoT initiatives for asset monitoring and predictive maintenance, as well as benchmarking studies on cloud platforms like Azure, AWS, and ThingWorx.

Currently employed by Intel as a member of NEX (Network and Edge), Brij Mohan Sharma continues to leverage his expertise and passion for IoT to address real-world problems. His experience and technical proficiency allow him to navigate the complexities of IoT development and deliver innovative solutions.

With a strong foundation in IoT technologies, programming languages, and a drive to find practical solutions, Brij Mohan Sharma remains committed to utilizing IoT as a powerful tool for problem-solving and creating positive impact in various industries.

Acknowledgement

First and foremost, praises and thanks to the God, the Almighty, for his showers of blessings.

We are overwhelmed, humbled and feel grateful to be able to acknowledge our depth gratitude to the Management of Vivekananda Institute of Professional Studies – Technical Campus for always encouraging and motivating us to achieve greater heights.

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Our gratitude also goes to the team at BPB Publications for being supportive enough to provide us with a long time to finish the book and allow us to publish the book.

Finally, our thanks go to all the people who have supported us in completing the book directly or indirectly.

Preface

Welcome to the fascinating world of the Internet of Things! This book serves as your comprehensive guide to understanding and harnessing the power of IoT and Arduino to create innovative and intelligent solutions. The Internet of Things has emerged as a game-changing technology that has the potential to transform industries, revolutionize everyday life, and unlock endless possibilities. By connecting physical objects and devices to the internet, IoT enables seamless communication, data exchange, and intelligent decision-making.

Arduino is a versatile open-source platform widely used for building interactive projects and prototyping IoT applications. Its user-friendly interface and robust ecosystem make it an ideal choice for beginners and professionals alike. In this book, we aim to provide a holistic approach to exploring the Internet of Things and Arduino programming. Whether you are a student, educator, hobbyist, or industry professional, this book is designed to equip you with the knowledge and skills necessary to dive into the world of IoT.

We will start with a solid foundation, introducing you to the core concepts of IoT and explaining the significance of this technology in today's interconnected world. We will explore the various components of IoT systems, including sensors, actuators, and communication protocols. Next, we will delve into the world of Arduino programming. You will learn the essentials of programming with Arduino, from understanding the syntax and control structures to utilizing libraries and creating interactive projects. We will guide you through hands-on examples and exercises that reinforce your learning and help you develop confidence in your programming skills.

Throughout the book, we will emphasize on practical application and real-world scenarios. You will have the opportunity to explore case studies and examples that showcase the integration of IoT and Arduino in different domains, such as smart homes, healthcare, agriculture, and industrial automation. Furthermore, we will address the critical aspects of IoT security and privacy, highlighting best practices and strategies to safeguard your IoT deployments from potential threats and vulnerabilities.

We hope this book will inspire you to explore the endless possibilities of IoT. Let your imagination soar as you embark on this exciting journey into the world of interconnected devices and intelligent systems.

This book is divided into **08 chapters**. It covers a wide range of topics, including:

Chapter 1: The book starts with a clear explanation of IoT principles, architectures, and applications, highlighting the impact of IoT on various industries and everyday life. Architecture and conceptual framework of IoT will be discussed in this chapter. The details about various technologies and sources of IoT are also discussed.

Chapter 2: It will cover hardware requirements for developing an IoT application. The chapter covers a wide range of sensors commonly used in IoT applications, including temperature, humidity, motion, and light sensors.

Chapter 3: It will cover Embedded systems in IoT, and explain different examples of embedded computing. The chapter will also discuss various IoT supported hardware platforms such as Arduino, Netduino, Raspberry Pi. Beagle Bone, intel Galileo and many more.

Chapter 4: Readers will learn the essentials of Arduino boards, providing a solid foundation for building IoT prototypes and projects. This chapter provides a step-by-step guide to programming Arduino boards using the Arduino IDE, exploring the syntax, Arduino libraries and functions necessary for creating effective IoT applications.

Chapter 5: This chapter explains IoT and M2M design standards, types of M2M communication such as RFID, NFC, WiFi, Cellular, ZigBee and Bluetooth. It will also explain IoT/M2M system layers and design standardization. IoT generates a massive amount of data, often in real-time. To derive meaningful insights and make informed decisions, this data needs to be processed and analyzed. Data consolidation and enrichment is discussed in this chapter.

Chapter 6: IoT devices are connected to the internet, allowing them to transmit and receive data. They can use various communication technologies, including Wi-Fi, Bluetooth, cellular networks, or low-power wide-area networks (LPWANs) like LoRaWAN or NB-IoT. Readers will delve into various communication protocols used in IoT, such as MQTT and HTTP, and learn how to establish connectivity between Arduino boards and IoT platforms. Data aggregation and dissemination is also discussed in this chapter.

Chapter 7: Explains different IoT challenges such as design and development challenges, and security challenges.

Chapter 8: Discusses various applications of IoT such as smart city, smart homes, e-health, smart automotives and smart cards. The use of IoT in mobile devices is explained in this chapter. Data communication between H/W units of IoT is also discussed in this chapter.

This book covers a wide range of sensors commonly used in IoT applications, including temperature, humidity, motion, and light sensors. The appendix at the end of the book explains how to interface these sensors with Arduino boards to collect real-time data.

We are confident that this book will be useful for the teaching faternity and students.

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Chapter 1
Introduction to Internet of Things

Introduction

Experts in the business coined the term **Internet of Things** (**IoT**) over a decade ago. However, it has only recently gained widespread acceptance and popularity. The term IoT refers to the overarching concept of smart gadgets' ability to detect and collect data about their immediate environments and then share that data with others over the Internet, where it may be analyzed and used in a variety of intriguing ways.

As a result, the concept of the IoT improves connection "anytime, anywhere" for "everyone." In most cases, IoT is expected to provide a fast-moving network of high-tech gadgets, services, and protocols that goes well beyond simple peer-to-peer data exchange. The pervasive nature of IoT connections necessitates the Internet connection of a surprisingly large number of devices. Connected devices are projected to be 30.9 billion by 2025.[1]

1 **https://www.statista.com/statistics/1101442/iot-number-of-connected-devices worldwide/#:~:text=IoT%20and%20non%2DIoT%20connections%20worldwide%202010%2D2025&text=The%20total%20installed%20base%20of,that%20are%20expected%20in%202021** .

Figure 1.1 shows a comparative chart of increase in IoT and non IoT devices:

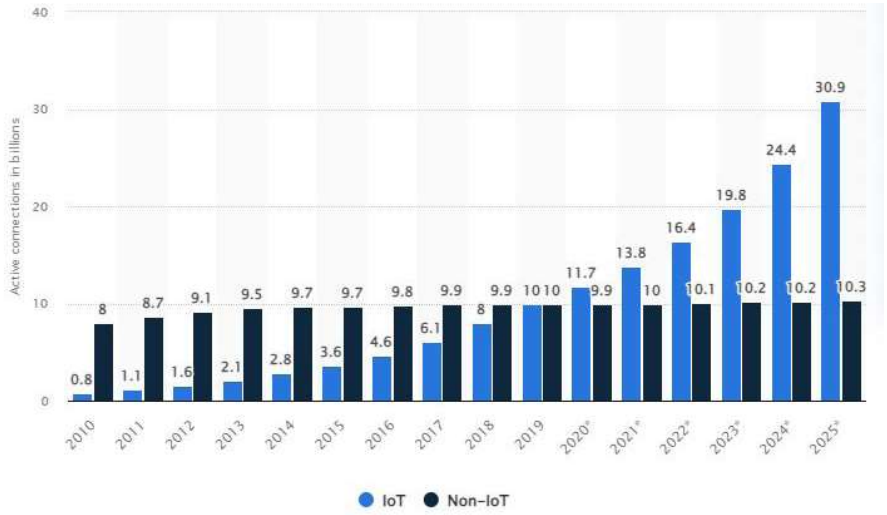

***Figure 1.1**: IoT and non IoT devices worldwide from 2010 to 2015*

When these devices are connected to the web, they will each be given a distinct number known as an IP address. To handle a wide variety of network devices, however, IPv6 needs to be used instead of IPv4, which has a finite number of available addresses. As a result, IPv6 will be crucial for the future growth of IoT.

IoT may be defined in several ways and encompasses many facets of modern life, from smart homes and cities to linked vehicles and infrastructure to personal tracking technology. It can help you count the number of windows, doors, electrical outlets, lights, machines, and air conditioners in your own home.

Structure

In this chapter, we will learn about the following topics:

- Internet of Things
- Conceptual Framework
- Architectural View of IoT
- Technologies behind IoT
- Sources of IoT

Objectives

This chapter provides a quick introduction to the basics of IoT. A reader who desires to learn about the ability and scope of IoT can study the vision and expansion of

IoT. After reading this chapter, the reader will be able to understand the conceptual framework and architecture of IoT. The reader can realize technologies that support IoT and different sources of IoT after reading this chapter.

Internet of Things

IoT has evolved from an abstract concept to a tangible reality since the term's inception in 1999. The proliferation of IP networks, the growth of always-on digital environments, and the maturation of data analytics are just some of the factors responsible for this. Forecasts predict that IoT devices will be almost 29 billion by 2030 just triple from 9.7 billion in 2020.[2] Despite its growth, IoT is still something of a mystery, a notion that is discussed in generalities despite its clear advantages. *Figure 1.2* illustrates the forecasted number of IoT connected devices worldwide from 2022 to 2030:

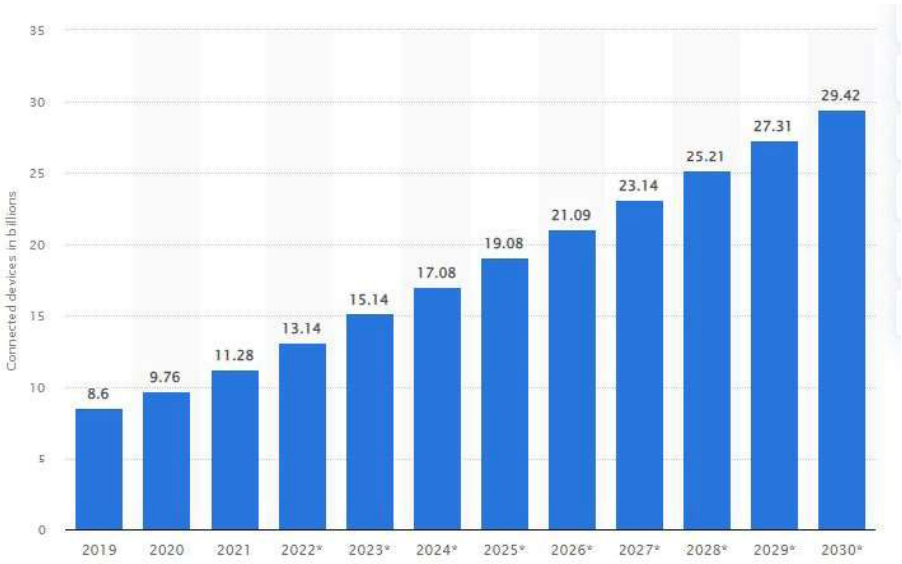

***Figure 1.2**: Number of IoT connected devices from 2019 to 2030*

IoT may be defined as the expansion of the internet and other network connections to various sensors and devices (or "things"), granting even seemingly insignificant items like lightbulbs, locks, and vents having enhanced computational and analytical capabilities.

The **Internet of Things** is the network of physical objects—devices, vehicles, buildings, and other items embedded with electronics, software, sensors, and network connectivity—that enables these objects to collect and exchange data. One

2 **https://www.statista.com/statistics/1183457/iot-connected-devices-worldwide/**

of the main factors in IoT's rising popularity is its interoperability. In IoT, the "things" are commonly referred to almost every physical object equipped with embedded hardware / software and connectivity features capable of collecting and exchanging data from their surroundings with other devices and networks. Devices may carry out their duties with little or no intervention by humans because of the data analysis and processing they undergo.

The exponential growth in the number of connected devices is driving the development of more complex algorithms that enables greater degrees of automation and the addition of new levels of insight into the data currently being shared and analyzed. As a result of the wide range of devices that may be linked to it, IoT has opened new possibilities for both individuals and whole businesses.

Two distinct “Internet-centric" and "thing-centric" approaches may be taken to understand IoT's ultimate goals and potential. The approach that focuses on Internet services are termed as Internet centric and the "things" create data, which is the primary emphasis of the things -centric design. Embedded electronics have a starring role in the "thing-centric" design. Following are few of the several forces that are driving the expansion of the IoT inside the digital economy:

- Innovative and highly effective mobile, wearable, or linked gadgets.
- Applications (apps) that push the limitations of mobile networks due to high data use.
- New **Platform-as-a-Service** (**PaaS**), mobile point-of-sale, and independent software vendor platforms will spur an uptick in the creation of cloud-based applications and those that rely on material stored in the cloud.
- Mobile video is an example of a new kind of application that will have a major impact on the need for costly capacity increases in existing network infrastructure.

The exponential development in demand for mobile-connected devices is guaranteed by device evolution, cloud-based application innovation, and the spread of communication technologies across all sectors. This means that over the next decade, both throughout and performance expectations for individual devices will rise.

Since everyone gives IoT their own meaning based on their own viewpoint, there are many different interpretations of the term coexisting together. The definition combines the concepts of the Internet and Things. The first makes it network-centric, while the second drives it toward items that are fused together and eventually settle into a single design.

IoT refers to a "*global network of linked items*" that may be specifically addressed using established means of digital communication. The basic problem with IoT is, coming