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IoT System Design

Project Based Approach

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Dedicated to

Our beloved parents

James Joseph

Gladys James

Late Nitin Vijay Seth

Zenobia Nitin Seth

Late Dyutindra Nath Mukhopadhyay

Rabi Rani Mukhopadhyay

Preface

We live in an age where Internet technology has enabled a global network in which people and devices are closer than ever before. The origin of the idea of the 'Internet' dates back to the early 1960s when scientists and researchers were trying to find a means to create a global network to share information. However, the Internet was truly enabled and commercialized with the creation of the World Wide Web in 1989. With its wide compatibility among different types of technologies, Internet technology soon became an available feature in most devices. The characteristic feature of Internet functionality that is enabled in these things led to the development of the term Internet of Things or 'IoT'. The 'thing' may be an entity, a physical item, or a device with the ability to transmit/receive data over a network. The hardware is integrated with sensors, firmware, and other features with the goal of communication between different devices and systems over the Internet.

The applications of IoT in today's world have increased as innovation pushes the paradigm for new technology. Consumer applications of IoT such as vehicular networks, smart health care, smart wearables, and home automation have grown in recent times. In the industrial sector, with the introduction of Industry 4.0, IoT applications have skyrocketed. It includes applications in transport, manufacturing, agriculture, and supply chain. Some of the new terms coined include Enterprise IoT (EIoT), Internet of Medical Things (IoMT), and Ocean of Things to name a few.

With the level of importance and wide application area, the need to research and design such systems is essential and challenging. For somebody who is just starting to learn about the concept of IoT, it can be a confusing subject. To add to the confusion, the number of resources one needs to study to get even a basic grasp on the topic is tremendous. With many of the resources only providing a theoretical perspective to these concepts, the practical understanding of a user could be lacking.

This book aims to provide a brief introduction to the core concepts of IoT with unique detail to the system design process. It provides a practical approach to designing and developing these IoT systems. The intended readers of this book include college and academics who are specialized in electronics engineering, telecommunication engineering, and information technology, data scientists,

researchers working with electronic systems, hobbyists, professionals, and anybody interested in a project-based approach to IoT.

The majority of the material from this book was used to teach undergraduate and postgraduate engineering students at Macquarie University, Sydney. The students performed the laboratory exercises in groups of 2–3 in a time frame of 3–4 h. The practicals provide a mix of guided exercise, theory, and self-performing tasks to enable a deeper understanding of the concepts. In the initial weeks, all the students perform a common task based on the week's guidelines. However, in the concluding weeks, the student groups perform an IoT group project. In this manner, the material in this book provides a sufficient introduction to building a practical IoT-based project for users.

The complete book is divided into twelve chapters. It is our view that expertise in designing IoT systems is achieved by using it in different applications. Many types of projects have also been detailed. With hardware projects, a special emphasis on software-based simulation projects has been shown for readers having minimal access to hardware components.

Chapter 1 aims to provide a brief overview of the IoT systems design. It explains the role IoT plays in the big picture. The chapter introduces the fundamentals of sensors, a fundamental element of IoT, and building blocks of IoT, and also describes the purpose of the book.

Chapter 2 describes a project implementation towards designing an IoT-based device. The chapter goes into great detail to explain the execution process of the IoT project, providing step-by-step guidelines along with source code for the user to perform it on the first go. A great skill that comes in handy when prototyping is mastering the ability to troubleshoot any problem. The topics also go into detail to mention the common debugging issues and challenges faced while performing the projects.

Chapter 3 provides essential inputs to the design perspective of building an IoT project. Designing an IoT node requires careful technical considerations that need to be fulfilled before the deployment of a device. The chapter looks into the individual elements that constitute an IoT node, from sensors to data analytics, providing design considerations and application-specific estimations. A key parameter to note when designing is making appropriate assumptions whenever necessary.

Chapter 4 introduces the single-board computer systems in depth. It provides a brief comparison between the commercially available computing boards that are suited for IoT-based systems. The chapter also provides the fundamental programming knowledge required to code these microprocessors. The Raspberry Pi, a popular single-board computer, is introduced with guidelines provided for the set-up and installations of software to make it an IoT device.

Chapter 5 introduces programming implemented on microcontrollers. The highly popular microcontroller board, Arduino, is used here. The Arduino boards have various types of different embedded microcontroller boards that enable simple to complex IoT projects. Coding them for IoT applications is extremely useful for users.

Chapters 6–8 feature the wireless transmission protocols used by IoT devices. These chapters provide hands-on exercises and tasks for users to learn and practically implement the concepts on the microcontroller/microprocessor boards. The top three protocols used by IoT devices, i.e. Wi-Fi, Bluetooth (BLE), and LoRaWAN technologies, are discussed here.

The topics and concepts of cloud computing in IoT-based projects are discussed in Chap. 9. This chapter provides the importance of the cloud in IoT systems. It also discusses some of the useful concepts of cloud development services like PaaS, IaaS, and SaaS.

The concepts of AI and machine learning are discussed in Chap. 10. Machine learning applications have seen tremendous growth in almost all sectors. The chapter discusses the links and connections between IoT and machine learning. It also shows how AI can be used in IoT-based projects. Further, key concepts of edge computing and data analysis are also explained briefly in this chapter.

Chapter 11 provides readers some key simulation software ideas. The chapter also shows projects performed on these IoT device simulation-based services for users who wish to get a hands-on experience but have low availability of hardware equipment.

Lastly, Chap. 12 showcases some of the projects performed by the students of Macquarie University. The projects provide the wide applications of IoT in today's life. The projects go in depth to explain the hardware, software, and programs written to execute the prototype of IoT devices.

The authors would like to express their sincere gratitude towards Macquarie University for providing the research laboratories and resources which made this book possible. We would like to thank many of the students and colleagues that were involved in the projects of this book.

Alice is very grateful to her parents Gladys and James for their immense love and support. A very special mention to her grandparents for their blessings, dear Aunts Sheeba and Salomy for their constant motivation, and her loving cousins Sheldon, Suzanne, Joshua, and Johann for always being there for her. Avishkar is truly thankful to his parents Zenobia and Nitin for their love and blessings, and a special mention to her grandparents and sister Karishma for their constant motivation.

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