Internet of Things: Concepts and System Design

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Preface

Internet of Things (IoT) systems deploy smart connected things that sense their environment and generate quantitative data about the physical world. In effect, IoT adds a new dimension to the Internet, awareness of the real world. This transformational change bridges the gap between physical and virtual/cyber worlds that has persisted since the invention of computing. Implementations of IoT technology are expected to create tremendous opportunities for new uses and applications. Their business impact is projected to be in the trillions of US dollars, comparable to the size of world's major economies.

The design of IoT systems spans multiple disciplines and requires diverse skills and knowledge in a number of areas. They include sensors, embedded systems, real-time systems, control systems, communications, protocols, Internet, cloud computing, large-scale distributed processing and storage systems, AI, and ML, coupled with the domain experience in the areas where they are to be applied, such as building management or manufacturing automation. Obviously, it is not reasonable to attempt to cover all those disciplines in detail in any single text.

This book is devoted to the design principles and practices for implementing IoT systems. Its primary purpose is to provide a foundation and a reference for students and practitioners to build upon when analyzing and designing IoT systems, as well as to understand how the specific parts they are working on fit into and interact with the rest of the system.

This book provides a comprehensive overview of the IoT systems architecture, including an in-depth treatment of all key components. The emphasis is on a complete and balanced treatment at roughly equal level of depth for all covered topics. The exposition takes a system's approach by describing the big picture and how the overall system works so that readers can interpret subsequent in-depth topical coverage in context. In addition to describing the functional and foundational aspects of all major IoT system components, the emphasis is on integration, i.e., how the components and building blocks are combined to create complete IoT systems. The book is organized as follows.

Chapter 1 describes the transformational impact and importance of adding the IoT real-world sensing dimension to the Internet. It also outlines key differences

between IoT systems and the Internet that pose some unique design requirements and challenges. Chapters 2, 3, 4, 5, and 6 treat the foundational aspects of IoT systems and design.

Chapter 2 covers the edge, starting with sensor data acquisition and processing, and continues with the edge functionality that includes event processing, storage, local control and scripting, and interfacing to sensors and actuators as well as to the external communications and the cloud. It discusses the tradeoffs involved in the functional placement of components in distributed systems on the edge-to-cloud continuum, including the fog, and concludes with a description of hardware and software considerations involved in the edge node design.

Chapter 3 focuses on communications. It describes a layered network design which is the underpinning of the Internet and a useful blueprint for the IoT system design. It continues with the coverage of wireless and constrained networks at the edge, followed by the IoT adaptations of the cellular networks in the licensed spectrum. The chapter concludes with the exposition of constrained protocols and the messaging and queuing publish-subscribe mechanisms designed for IoT systems.

Chapter 4 focuses on the cloud. It covers key elements and functions of the IoT cloud core components, including data ingestion via edge-cloud gateways, in-flight stream processing, and short- and long-term storage systems suitable for IoT applications. The rest of the chapter covers analytics and principles of machine learning, operation of artificial neural networks, and types and uses of ML systems.

Chapter 5 covers the control plane, security and management systems. It describes the types of security threats and attacks in IoT and OT systems, followed by the security analysis and planning steps. A section on cryptography overviews key foundational elements of security design, including symmetric and public-key cryptography. This is followed by the treatment of endpoint security, including hardware security and software isolation mechanisms, network security, and privacy.

Chapter 6 is devoted to the topic of data representation and semantic interoperability, which is a key new design requirement that IoT systems introduce. It describes approaches to addressing the issue, which is a prerequisite for enabling big IoT data aggregations for meaningful insights and effective applications of ML and AI techniques.

Chapter 7 contains an overview of representative IoT standards dealing with data and information models. Chapter 8 outlines key components and design choices of several commercial IoT platforms. These chapters illustrate how the underlying principles of IoT system design may be reduced to practical instantiations that can serve as the potential building blocks in IoT system designs.

Given the book's focus on system design and integration, most chapters contain the "putting it all together" sections to indicate how the concepts may be put together. Chapter 9 is devoted to system-level integration in its entirety. It also presents a detailed example of a complete IoT system, including conceptual design, implementation, results, post deployment user studies, and a discussion of tradeoffs and issues encountered in the process.

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All errors and omissions are mine.

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