

The Internet of Things

Enabling Technologies,
Platforms, and Use Cases

Pethuru Raj and Anupama C. Raman



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As more and more devices become interconnected through the Internet of Things (IoT), there is an even greater need for this book, which explains the technology, the internetworking, and applications that are making IoT an everyday reality.

The book begins with a discussion of IoT “ecosystems” and the technology that enables them, which includes:

- Wireless
- Infrastructure and Service Discovery Protocols
- Integration Technologies and Tools
- Application and Analytics Enablement Platforms

A chapter on next-generation cloud infrastructure explains hosting IoT platforms and applications. A chapter on data analytics throws light on IoT data collection, storage, translation, real-time processing, mining, and analysis, all of which can yield actionable insights from the data collected by IoT applications. There is also a chapter on edge/fog computing.

The second half of the book presents various IoT ecosystem use cases. One chapter discusses smart airports and highlights the role of IoT integration. It explains how mobile devices, mobile technology, wearables, RFID sensors, and beacons work together as the core technologies of a smart airport. Integrating these components into the airport ecosystem is examined in detail, and use cases and real-life examples illustrate this IoT ecosystem in operation. Another in-depth look is on envisioning smart healthcare systems in a connected world. This chapter focuses on the requirements, promising applications, and roles of cloud computing and data analytics. The book also examines smart homes, smart cities, and smart governments.

The book concludes with a chapter on IoT security and privacy. This chapter examines the emerging security and privacy requirements of IoT environments. The security issues and an assortment of surmounting techniques and best practices are also discussed in this chapter.

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6000 Broken Sound Parkway, NW
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711 Third Avenue
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2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK

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The Internet of Things

Foreword

Articulating technology trends, its potency, and impact is truly one of the most difficult tasks for a practitioner. It is not because there are so many points of view nor is it because the mortality rate here of an “idea or breakthrough” is high. The former is made tougher as there are no true experts (technologists, consultants, users, or analysts) who have gotten it right every time. On the mortality rate, it is important to appreciate that an idea or trend is made irrelevant as something else took over or was eclipsed by a series of changes that can be likened to nuclear reactions where an idea is either split into many ideas (fission) or when two or more smaller ideas fuse together, creating a larger, bigger trend (fusion).

In such a backdrop, it is imperative that we look at internalizing the trend appropriately aligned to business outcomes and appreciate its potency and power, all at the speed of thought. This book precisely attempts this in a rather focused and appreciative way.

At the start of this millennium, we started looking at the inevitable digitally connected world. The pace and potency of connecting computing devices grew exponentially as we, the citizens of the world, are wired to the world omnipotently present everywhere. The power of this connectivity has, in many ways, been prophesied long ago by those who set forth to define the meaning of telecommunications. However, the sheer pace at which the Internet of Things (IoT) paradigm is moving is truly amazing. Every common, casual, and cheap thing in our everyday environments gets systematically digitized through the lustrous use of edge/fog technologies (disposable, diminutive yet smart sensors, bar codes, microchips and controllers, RFID tags, specks, phones, etc.) to be elegantly sensitive, perceptive, reflective, and responsive, plus reliable.

All kinds of physical, mechanical, electrical, and electronic objects are thereby instrumented and interconnected with others in the vicinity as well as with remotely held software applications and datasets. With the addition of a bevy of devices (for smarter homes, smarter buildings, and smarter everything), the number of software services getting developed and deployed in central application repositories is growing rapidly. In short, by the year 2020, there will be billions of software applications and trillions of connected devices and digitized entities on this planet. The possible impacts are really mesmerizing for consumers and organizations, let alone for technologists. To us, this is no longer science fiction because it is truly *the art of the impossible*. The implications, impact, and imperative of this trend are truly irreversible, and the momentum is truly nuclear.

This book presents all the enabling technologies and tools for setting up and sustaining IoT applications and environments through a well laid out flow that is focused at the start on getting us to appreciate the nuances and nitty-gritty of the IoT concept. As we internalize this, the book moves seamlessly into defining the importance of the imperatives for the sustenance of the IoT ecosystem, and the need of the day is to devise protocols and technologies that are customized for their operations. These protocols and technologies are covered in Chapters 2–4 with an increased focus on IoT device connectivity and data transmission, nay telecommunication.

To realize the maximum value from IoT as a technology, we have to necessarily leverage and integrate programs with other underlying technologies such as cloud and analytics. Chapter 6 describes the unique capabilities of next-generation cloud infrastructure for hosting IoT platforms and applications. The data analytics chapter throws light on the IoT data collection, ingestion, storage, translation, real-time processing, mining, and analysis techniques that are required to squeeze out actionable insights from the data that are collected from IoT applications. This book also contains a dedicated chapter on edge/fog computing. The prominent IoT application enablement platforms (AEPs) and data analytics platforms in the marketplace are also covered in this book not just in passing but to the point of being a useful run book.

The second half of the book highlights the prominent use cases of IoT across the two main groups: consumer-centric IoT and Industrial IoT. The prominent examples that come under each of these categories are very well articulated. Some of the prominent use cases discussed are as follows:

- Smart cities
- Smart airports
- Smart industry
- Smart healthcare

The latest topics of study and research, such as cognitive clouds and cognitive IoT, are also discussed in detail, so that the journey to “the art of the impossible” can begin now. There are widely expressed concerns about IoT security, and this, too, has been explained by discussing in detail the various security breaches and the viable solution approaches to surmount them comprehensively. This is an area that will see even more action, as technology is quite secular and its power is harnessed by every section of society for all types of uses.

Welcome to the IoT journey. As you go through these pages, I am sure you will emerge with a bagful of ideas for your workplace, home, or society in general.

S. Premkumar

*Executive Vice Chairman & Managing Director, HCL Infosystems Ltd.
Chief Mentor, HCL Talent Care Private Limited.*

Preface

The recent announcements and articulations clearly show that there is a greater awareness and overwhelming acceptance that the future undoubtedly belongs to the Internet of Things (IoT). Hence university professors and IT industry professionals are in unison in unearthing pioneering technologies and toolsets to set everything right for the dreamed IoT era. A variety of concerted endeavors by different stakeholders is to substantially speed up the establishment and sustenance of the IoT-inspired smarter planet vision in a systematic and streamlined manner. In worldwide academic institutions and research labs, IoT has become the subject of deeper study and intensive research to explore and experiment any IoT-associated concerns and challenges and to expound viable and venerable solutions to boost the confidence of end users. There are conferences and confluences aplenty across the globe in order to accentuate and articulate the grandiose distinctions of the fast blossoming concept of the IoT.

This book has been consciously crafted with the sincere intention of telling all about the proven, promising, and potential IoT realization technologies and tools. A couple of chapters have been specially incorporated for clearly decoding and describing some of the prominent and dominant use cases across different industry verticals. Security, being brandished as the most inhibiting factor for IoT, is given extra thrust in this book in order to explain the nitty-gritty of security risks and vulnerabilities and to detail the path-breaking solution approaches, algorithms, and accomplishments.

Chapter 1 is exclusively written to decisively decipher the IoT conundrum. The IoT journey has been enumerated with finer details in order to empower prospective readers with the right and relevant knowledge so that they can easily understand the subsequent chapters without much difficulty. All the trends and transitions happening in the IoT space are illustrated in this chapter to showcase how the disruptive and transformative IoT notion is to significantly enhance the care, choice, comfort, convenience, and connectivity of people in the days to unfurl.

Chapter 2 is titled “Realization of IoT Ecosystem Using Wireless Technologies.” In the first half of this chapter, we have discussed some of the key wireless technologies that have evolved or are evolving in order to support the requirements that are specific to an IoT system. Some of the protocols and technologies that we have discussed in this section are 5G, NFC, UWB, and ISO 18000 7 DASH7. In the second half of the chapter, we have tried to focus on low power wide area networking (LPWAN) technologies that are prominently used for interconnection of devices and applications in the IoT ecosystem. Some of the prominent ones discussed in this chapter are Sigfox, Weightless, Nwave, Ingenu, and LoRa.

Chapter 3 is titled “Infrastructure and Service Discovery Protocols for the IoT Ecosystem.” In this chapter, we have elucidated reference architecture for the IoT ecosystem. Based on this reference architecture, we have explained the various IoT infrastructure protocols, including RPL, IEEE 802.15.4, 6LoWPAN, Bluetooth Low Energy, EPCglobal, LTE-A, Z-Wave, and ZigBee.

In the second half of the chapter, we have explained the various service discovery protocols, including DNS Service Discovery (DNS-SD), multicast Domain Name System (mDNS), and Simple Service Discovery Protocol (part of UPnP).

Integration and orchestration (Chapter 4) are the key tasks for the attainment of originally envisaged benefits of the IoT idea. There are innumerable innovations, disruptions, and transformations in the information and communication technologies (ICT) space these days. The prominent ones include digitization, distribution, industrialization, consumerization, and compartmentalization (virtualization and containerization). The result is that there are trillions of miniaturized sensors, billions of connected devices, and millions of software applications and services. Further, with the number of data sources climbing and device ecosystem growing rapidly, there are highly synchronized and integrated platforms for design, development, debugging, deployment, delivery, and even for decommissioning. The cloud movement has brought in a bevy of advancements in order to have highly optimized and organized IT environments. In such a highly distributed and decentralized environment, integration middleware standards and solutions become handy in seamlessly and spontaneously integrating all kinds of sensors, actuators, instruments, appliances, machines, equipment, utensils, tools, and so on along with remotely held software applications and data sources.

Chapter 5 is for the erudition of the freshly crafted and intelligent platforms for quickly and easily implementing IoT services and applications. All kinds of integration, orchestration, access, security, governance, enrichment, intermediation, and connectivity services are being given a part of the platform in order to lessen the developers' workloads. A single click then takes any implemented application to be executed to the deployment environment. Thus, IoT application enablement platforms (AEPs) are an essential thing for the forthcoming IoT-induced knowledge era. Similarly, IoT data analytics platforms help extract hidden patterns, pragmatic tips, useful associations, fresh possibilities and viable opportunities, actionable insights, possible risks, and so on out of accumulated IoT data.

There is no doubt that cloud environments emerge as the one-stop IT infrastructures for hosting, managing, and delivering business and IT workloads. For anytime anywhere any device any network any media access of IoT applications, services, and data, clouds are being positioned as the best environment. In this chapter, we have explained the uniqueness of cloud infrastructures for the ensuing era of IoT. The cloud journey is discussed in detail with all the appropriate information in order to enhance the understanding of the key contributions of the cloud paradigm for the intended success of the IoT to our readers.

Data analytics is the most important aspect of any industry vertical to be steered in the right direction to the desired destination. Data are a strategic asset. Any organization has to take data capture seriously and on subjecting the collected data into a variety of investigations in order to squeeze out usable and useful information that in turn enable decision makers and business executives to make correct decisions in time. IoT data originating from sensors and actuators have to be gathered, cleansed, processed, queried, analyzed, and mined in order to retrieve beneficial knowledge that can be given to IT and business entities to take appropriate decisions to automate most of the manual tasks. This chapter is specially crafted to express and expose all that can be accomplished through analytics platforms that can be cloud-hosted.

Chapter 8 introduces the fog or edge computing model. With the realization that faster response and real-time insights are two essential things for realizing highly competent and cognitive environments, the idea of edge computing is flourishing and is being continuously nourished by various product vendors, including IBM. There are different techniques and edge platforms for accentuating the new concept of fog computing. We have illustrated how edge clouds are being

formed out of reasonably powerful edge devices in order to do service integration and orchestration. Further, how a large amount of IoT device data can be partitioned into smaller and easily manageable data modules to be allocated to those devices participating and contributing for the device cluster/cloud is discussed.

Chapter 9 is titled “Envisioning Futuristic Smart Airports Using IoT Integration.” In this chapter, we have focused on the usage of the IoT concept to build futuristic intelligent airports. Various components of the IoT ecosystem that form the core pillars of the intelligent airport are the following: mobile devices, mobile technology, wearables, RFID/sensors, and beacons. The integration of each of these components into the airport ecosystem is examined in detail in this chapter. Ample use cases and real-life examples are provided in this chapter in order to provide an interesting reading experience for the readers.

Chapter 10 is titled “Envisioning Smart Health Care Systems in a Connected World.” In this chapter, we have focused on the IoT use cases for the health care industry. The foundation technologies that are required for using IoT in the health care sector, challenges posed by the use of IoT for the health care sector, and the future promises of IoT for the health care sector are also discussed in detail in this chapter. In the second half of the chapter, we have focused on how the IoT supporting technologies, that is, cloud computing and big data analytics, are used in the health care industry.

Chapter 11 is titled “Smart Use Cases of IoT.” In this chapter, we have uncovered three broad categories of use cases pertaining to the IoT ecosystem: industrial use cases, consumer use cases, and governance use cases. Under industrial use cases, we have mainly focused on two broad use cases: smart energy and smart transportation systems. Under consumer use cases, we have mainly focused on the following: smart homes, smart buildings, and smart education systems. Under governance use case, we have mainly considered smart cities.

Chapter 12 is titled “Security Management of an IoT Ecosystem.” In this chapter, we have examined the various security requirements of the IOT infrastructure. We have also discussed the security threats that exist in each IoT component. Starting with the cloud platform, the threats that exist for each of the underlying platforms such as big data and mobile devices are examined in detail. The various ways and means to tackle the security challenges are also discussed elaborately in the chapter. The different types of use cases that form a part of an IOT ecosystem are smart buildings, intelligent transportation systems, smart water systems, smart grids, and so on. The security threats for some of these applications and the techniques to safeguard them are also discussed in this chapter. This chapter concludes with a framework that can be adopted in order to build and maintain a safe and secure IT framework.

Hopefully, this book is an informative and inspiring one for our readers.

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Pethuru Raj

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Anupama C. Raman

About the Authors

Pethuru Raj, PhD, has been working as a cloud infrastructure architect at the IBM Global Cloud Center of Excellence (CoE), IBM India, Bangalore. He finished the CSIR-sponsored PhD degree in Anna University, Chennai, and continued the UGC-sponsored postdoctoral research in the Department of Computer Science and Automation, Indian Institute of Science, Bangalore. He was also granted a couple of international research fellowships (JSPS and JST) to work as a research scientist for 3.5 years in two leading Japanese universities. He has been contributing book chapters to a number of technology books that are being edited by internationally acclaimed professionals. The CRC Press/Taylor & Francis Group had also released his first solo book, *Cloud Enterprise Architecture*, in the year 2012. He has edited and authored a book titled *Cloud Infrastructures for Big Data Analytics* published by IGI International in March 2014. In association with another IBMer, he finished a book, *Smarter Cities: The Enabling Technologies and Tools*, published by the CRC Press/Taylor & Francis in 2015. He has also authored a book on the Docker technology, and it is being published by Packtpub, the United Kingdom, in 2015. He has also published a book entitled *High Performance Big Data Analytics* by Springer-Verlag in 2015.

Anupama C. Raman is currently working as a curriculum architect for the Smarter Cities Brand of IBM and is a member of the Business Analytics team of IBM. She is a certified storage area networking expert and is also a certified data center architect. She is also certified in cloud infrastructure and services management. Apart from these technical certifications, in the field of writing, she is a certified information mapping professional and in the field of project management, she is a certified scrum master. She holds an MTech degree in computer science and engineering and is currently pursuing an MBA in IT management. She has presented and published more than 20 research papers in various national and international conferences, and has also written numerous book chapters with various national and international publishers. She has authored a book, *Intelligent Cities: Enabling Technologies and Platforms*, which was published by CRC Press/Taylor & Francis Group in June 2015. She has also written a book on big data analytics, which will be published by Springer-Verlag in December 2015. She is a regular columnist of *Forbes* and has authored several articles for *Forbes India*.

