Foreword

It has been almost two years since I first met Mr. Hwaiyu Geng at the SmartAmerica Expo in Washington DC, a program I established with Geoff Mulligan when we were serving as White House Presidential Innovation Fellows. I still have vivid memory of Mr. Geng then, as he was one of the few in the audience who sat through more than eight hours of presentations, from 24 teams, without pausing for lunch. At the event, I could see his deep passion for the new technologies—Internet of Things (IoT) and Cyber-Physical Systems (CPS)—and his desire to understand how they can help improve everyone's quality of life. Now, I am glad to see his passion for IoT and CPS bear fruit through this book.

IoT is an emerging concept and enabler that has the potential to completely reshape the future of industry. To be clear, IoT is not a completely new concept. It has been around for decades, as it can be found in many traditional centralized building-control systems dating back to the 1980s. However, its significance was rediscovered with the emergence of big data analytics, low-cost sensors, and ubiquitous connectivity powered by many modern-age communication technologies. Most importantly, businesses started to realize that new revenue models can be created by adding the IoT concept to their existing product lines, an approach that has fueled the adoption of IoT technologies.

Many people think IoT means "connected devices." Connectivity is just one piece of the puzzle that defines IoT. There are four layers in IoT.

- At the bottom, there is the "Hardware" layer. This layer contains sensors, actuators, chips, and radios—the physical objects that we can touch and feel. Some of the objects are physically small, but others are large, such as cars and airplanes.
- On top of the Hardware layer is the "Communications" layer. This layer enables the hardware objects to be connected via wireless or wired communication technologies. It is sometimes misunderstood that IoT is just about these two layers. This is not true.
- On top of the Communications layer, there is the "Data Analytics" layer. This is where the data collected from the bottom two layers are put together and analyzed to extract actionable and useful information. It should be noted that the Data Analytics layer does not necessarily mean big data analytics. For example, the Data Analytics can be a simple sensor data feed into the Proportional-Integral-Derivative (PID) control loop implemented on an 8-bit microcontroller.
- Finally, there is the "Service" layer on top of the Data Analytics layer. The Service layer makes decisions based on the information provided by the Data Analytics layer and

takes appropriate actions. The Service layer may include humans as part of the decision process, creating a "human-in-the-loop" system.

It is important to note that the most significant business value of an IoT system is produced at the Service layer when the action is taken. It is quite obvious from the customer's perspective, but it is not widely understood by most of the companies trying to jump into the new wave of IoT phenomena. As more hardware devices become available and connected, the value created by the hardware devices at the bottom layer will continuously decrease as they become gradually commoditized. This is especially true when the cost to manufacture such devices keeps dropping with the growth of the volume. Therefore, the businesses that rely on manufacturing and selling the hardware devices that do not carry a lot of intelligence will likely suffer more. On the other hand, the concentration of the value at the upper layers, such as Data Analytics and Service, will create new lucrative opportunities for the companies that work on extracting useful information from available data sets and monetizing actions based on it.

In this new era of IoT, every company is challenged to come up with new business models while still relying on their legacy product lines, but also adding new IoT concepts. This is a painful process that requires numerous trial-and-error processes, probably including some failures. Moreover, the business models created and validated by a company may not be readily transferred or duplicated by other companies. For example, a new business model created by a jet engine manufacturer using IoT may not be easily adopted by a consumer electronics company. This is a real challenge for many fast followers in the industry, but it is a tremendous opportunity for market leaders that are willing to embrace the new reality and are capable of making investments to create new business cases.

For IoT to be broadly adopted, it is important to apply the concept to many applications at scale in our everyday life. Using these advanced technologies, our communities and cities can be more intelligent, secure, and resilient. The Hardware and Communications layers can serve as part of the city infrastructure, and the Data Analytics and Service layers can provide optimal and synergistic services to the residents. IoT can create tangible benefits to the cities and communities, leading to sustainable smart cities.

The "smart city" concept, by definition, involves many different sectors, including water management, emergency response, public safety, healthcare, energy, transportation, smart home, and even smart manufacturing. Cities strive to coordinate many independent divisions to offer the maximum efficiency and highest quality of service to the residents. However, many smart city solutions are still isolated, fragmented, and built to be a one-off implementation that is lacking interoperability, scalability, and replicability. Due to this issue, many communities and cities do not enjoy the level of affordability and sustainability they deserve.

To address this issue, it is important to catalyze the development of new kinds of standards-based, replicable, and interoperable smart city models based on multi-stakeholder involvement and collaboration, so that the cities can leverage each other's investments, and the technology providers can create economies of scale. The Global City Teams Challenge (GCTC), a program I lead at the National Institute of Standards and Technology (NIST), is an attempt to encourage just such a transformation of the smart city landscape.

One of the essential elements in the success of IoT and smart city deployment is collaboration and integration among diverse sectors. The value of IoT can be maximized when seemingly unrelated sectors (for example, healthcare and transportation) get connected, and new services are invented using the unique combination of different sectors and businesses. In that sense, successful next-generation IoT and smart city solutions will likely stem from a broad understanding of diverse vertical applications, as well as a fundamental understanding of the cross-sector technical issues.

With over 40 participating authors covering various sectors and applications of IoT, this handbook can provide an overview of many issues and solutions in the complicated IoT ecosystem. I believe such an interdisciplinary approach is critical in helping readers and the developer community to understand numerous practical issues in IoT and smart cities and as you examine the contributions of the various authors, I hope you will come to agree with me.

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