Samuel Greengard, **The Internet of Things**, Cambridge, MA: MIT Press, 2015, 232 pp., $12.95 (paperback).

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Today's physical world contains about 1.5 trillion types of "things." When 99% of these objects are connected, a new era will be born. The technology that ushers in this new era is the *Internet of Things* (IoT), which is the concept of basically connecting any phycial object with an on/off switch to the Internet (and to each other). Believed by many to be the innovation leading the "Industrial Revolution 4.0," IoT has stirred much discussion among policy makers, business people, scholars, and consumers. What are the building blocks of IoT? How will it change the life of every consumer? How will it change the way business and manufacturing are operated, managed, and governed? What kinds of unprecedented challenges will IoT impose? In **The Internet of Things**, Samuel Greengard— with his vivid and accessible writing—provides timely answers to those pressing questions. Using his keen observation and witty comments, Greengard presents to the reader a fascinating snapshot of the brave new world created by IoT.
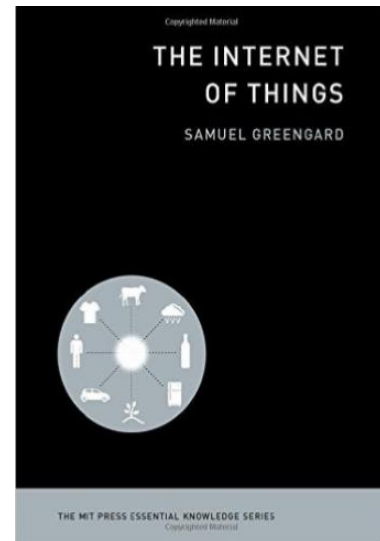
The Origins of IoT

Although it is widely recognized that the concept of IoT was first proposed by Kevin Ashton in 1999 (Said & Masud, 2013; Suresh, Daniel, Parthasarathy & Aswathy, 2014; Yan, 2008), Greengard traces the origin of IoT back to the early deployment of Ethernet and local area networks. Catalyzed by the later commercialization of the National Science Foundation Network in 1995, the foundation of IoT— global connectedness—was established. Of particular importance was the introduction of the iPhone in 2007: In Greengard's words, it "lights the fire for today's emerging IoT" (p. 10). The global connectedness enabled by the Internet; the always-on, always-connected culture spurred by the large-scale adoption of connected mobile devices; and the objects-to-objects, objects-to-people communications enabled by ubiquitous communication networks and advanced sensors with radio frequency identification (RFID) technology are the pillars of IoT.

The implications of these technologies and their combination are profound. The large-scale adoption of connected, mobile devices means everyone with a smartphone can be a data point. Once connected to the Internet, the sensor with built-in RFID technology will break the barrier between the physical and digital worlds and enable things to talk. Based on his deep understanding of the far-reaching impact of these new technologies, Greengard insightfully points out that the way IoT revolutionizes our world is by exponentially expanding the sources of data input from a small number of people to almost

everybody and from digital devices to almost everything. The increased number of data sources combined with the capability to analyze big data will change almost every aspect of business operation, manufacturing, and people's lives.

How IoT Can Change the World

The integration of machines with sensors, reliable communication networks, and high-capacity data analysis software will give birth to the Industrial Internet (IIoT). IoT and IIoT share the same technological foundation, and both aim to break the boundary between the digital and physical worlds. Greengard believes the IIoT lies at the heart of IoT and enthusiastically introduces five new possibilities that can grow from IIoT: location awareness, enhanced situation awareness, sensor-based decision analytics, automation, and connected military operation. With numerous real-world examples, Greengard shows the reader how these new capabilities can revolutionize industrial and business operations. Nevertheless, after reading this chapter, readers with intellectual curiosity may be unsatisfied because Greengard does not explain much about the distinction between IoT and IIoT. Admittedly, these terms are often used interchangeably, and debates about their definitions are ongoing in both industry and academia. It is understandable that in a book for readers who have little knowledge about IoT, excessive discussion of the technical definitions is unnecessary. Regardless, what the author can and should do, at least, is talk about the controversy and his stance.

If the impact of IoT on industries is revolutionary, then the way it changes people's lives is fundamental. When the 200 to 300 devices a person typically uses every day are all connected and communicate with each other, people will change not only the ways they think about things but also their behaviors. Greengard's argument resonates well with the proposition of media theorists such as Marshall McLuhan (1964) and Joshua Meyrowitz (1985). Humans are shaped by the technologies they create, particularly those they use to communicate with each other and with the world. With more objects able to collect data individually and talk, *things* will be redefined, the meaning of connections will be changed, and we will become different human beings. To illustrate this point, Greengard provides the reader with a scenario in which home automation, intelligent health services, and smart finance have become part of people's daily lives. Objects such as refrigerators and cameras are no longer just machines but also our consultants, helpers, and even friends. Humans, who used to be the center of communications, become "only a piece of the overall IoT puzzle." (p. 83). Greengard's vision of the future is inspiring, and his sci-fi-style depiction is reasonable and supported by current technological development, although some of the exciting prospects he discusses might be attributed to other technologies such as voice recognition and three-dimensional printing.

The Challenges of Building IoT

Although by and large an advocate of IoT, Greengard keeps a sober view and is fully aware of the challenges, risks, and concerns associated with the new technology. Indeed, many constituents of IoT need substantial improvement. More robust networks are needed to support seamless human–human, human–machine, and machine–machine communications. Computers with more computing power are needed to process the enormous amount of data generated by IoT. More advanced sensors need to be

developed for 360-degree monitoring of physical objects. Among these challenges, Greengard pays special attention to the issue of standardization. IoT has been built in various sectors and locations. Using different standards, protocols, and configurations, these separate IoT systems "deliver limited functionality, features and values in niche areas and specific spaces" (p. 114).

In his discussion about the solutions to these challenges, Greengard circumvents the technical details and focuses instead on the guiding principles, which is a wise choice. Nevertheless, some of the principles proposed, such as the need for standardization and distributed computing as a solution for big data analysis, are controversial. Premature standardization has long been a concern of scholars (Krechmer, 2004; Acemoglu, Gancia, & Zilibotti, 2012). Some scholars believe that the key to solving the computing power problem is centralized computing (Carr, 2008; Decman & Vintar, 2013). It is legitimate for an author to choose a position; however, because the purpose of this book is to give the reader a comprehensive overview of emerging IoT, it would be better to present the full picture of the controversy.

In addition to the technological challenges, it is questionable whether users, society, and the economy are ready to embrace IoT. In a world in which everything is connected and machines manage and operate themselves, any dysfunction in any part of the system can lead to disastrous outcomes. The paradox of "smart devices, dumb people" (p. 147) will become even more imminent. Furthermore, because IoT makes it extremely important to stay connected, the effective gap between the digital haves and have-nots will be even greater. IoT misused for terrorism and crimes will create severe threats to public safety. Above all, in such a brave new world with so many complex and controversial issues, new legal and regulatory models will be needed for more effective and efficient governance and policy making. As Greengard comments at the end of the book, "only time will tell us if a connected world equals a better world" (p. 189).

Conclusion

As an overview of the rising issues revolving around IoT, Greengard's book answers some of the most pressing questions. Specifically, how does this technology come into being? How will it change our lives and this world, both positively and negatively? For many writers, it is always a headache to explain technologies to general readers with balance between technical accuracy and readability; this is clearly not a problem for Greengard. Even readers with very limited knowledge of related topics will find this book fairly easy and enjoyable to read. Alternatively, the lack of discussion of the technical details makes this book somewhat shallow for readers who are not completely new to this topic. And some readers from academia may frown on reliance on personal observation and anecdotes as the basis for argument.

References

Acemoglu, D., Gancia, G., & Zilibotti, F. (2012). Competing engines of growth: Innovation and standardization. *Journal of Economic Theory, 147*(2), 570–601. doi:10.1016/j.jet.2010.09.001

Carr, N. G. (2008). *The big switch: Rewiring the world, from Edison to Google*. New York, NY: W. W. Norton.

Decman, M., & Vintar, M. (2013). A possible solution for digital preservation of e-government: A centralized repository within a cloud computing framework. *Aslib Proceedings, 65*(4), 406–424. doi:10.1108/AP-05-2012-0049

Krechmer, K. (2004). Standardization and innovation policies in the information age. *International Journal of IT Standards and Standardization Research, 2*(2), 49–60. doi:10.4018/jitsr.2004070104

McLuhan, M. (1964). *Understanding media: The extensions of man*. Cambridge, MA: MIT Press.

Meyrowitz, J. (1985*). No sense of place: The impact of electronic media on social behavior*. New York, NY: Oxford University Press.

Said, O., & Masud, M. (2013). Towards internet of things: Survey and future vision. *International Journal of Computer Networks, 5*(1), 1–17.

Suresh, P., Daniel, J. V., Parthasarathy, V., & Aswathy, R. H. (2014, November). A state of the art review on the Internet of things (IoT) history, technology and fields of deployment. Paper presented at the 2014 International Conference on Science Engineering and Management Research (ICSEMR), Chennai, India. doi:10.1109/ICSEMR.2014.704363

Yan, L. (2008). *The Internet of things: From RFID to the next-generation pervasive networked systems*. New York, NY: Auerbach Publications.