INTERNET OF THINGS

APPROACH AND APPLICABILITY IN MANUFACTURING

Ravi Ramakrishnan
Loveleen Gaur

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A CHAPMAN & HALL BOOK

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Approach and Applicability in Manufacturing

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Preface

The Internet of Things (IoT) has arrived as one of the biggest changes to disrupt the digital world and in a much bigger way than what the internet did a few decades ago or evolution of computers did half a century before. It seems very likely that the traffic generated by the IoT devices will far surpass the total traffic generated by human beings so far and that there is an imperative need to rethink the way we have designed our information systems and our computing infrastructure. A number of adoptions of the IoT concepts are visible in all walks of life globally and the number is all set to increase to billions of connected objects before the turn of the decade. This book presents some of the use cases of the IoT in different business facets and processes, focusing more on the manufacturing sector and, hence, there is a distinct coverage of Industrial IoT (IIoT) as well. This book is unique as it highlights a variety of topics and practical implementations, all of them of crucial importance for the futuristic objects-driven internet world.

Many of the definitions of the IoT are still not comprehensive but people have tried defining them. Somewhere, we need to revisit whether the IoT will be complete without people, animals, and all things living becoming connected to the objects there by extending to an Internet of Everything (IoE). This book provides a comprehensive overview of the IoT concept starting from the very basic definition and current technologies, moving over to business models that can and will come in play with IoT adoption. It also goes into detail into different business operations such as manufacturing, energy, logistics, and distribution becoming affected by the IoT along with use cases derived from primary data collection or literature review.

The next thing is to gauge the perception of the IoT (domestic as well as industrial) including a model to gauge the maturity of an IoT-enabled organization. It would be very interesting for readers to try and understand what would be the future trends in the IoT; this is what is listed out in another chapter based on insights and focus interviews with experts and inputs from development labs. Security and privacy are one the most significant concerns for technology adoption amongst people and businesses. The recent spurt in attacks relating to information technology had further aggravated this concern and hence an entire chapter is focused on this subject. It seems clear that human beings will slowly be forced to become secondary citizens of the World Wide Web and objects will claim the first position by virtue of their count and data-transmitting capabilities.

We trust that reading this book and its chapters will provide you with a broader insight of the Internet of Things, its adoption, and future trends.

Ravi Ramakrishnan
Loveleen Gaur
India, December 2018

Abbreviations

AI	Artificial Intelligence
AMT	Advanced Manufacturing Technology
BLE	Bluetooth Low Energy
BOM	Bill of Material
CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
CPS	Cyber Physical Systems
CRM	Customer Relationship Management
DSC	Distributed Control Systems
DSS	Decision Support Systems
EER	Energy Efficient Rating
ERP	Enterprise Resource Planning
HMI	Human Machine Interface
IAB	Internet Architecture Board
IBEF	Indian Brand Equity Foundation (www.ibef.org)
ICS	Industrial Control Systems
ICT	Information and Communication Technology
IoE	Internet of Everything consisting of people, process, data
IoT	Internet of Things
IT	Information Technology
JIT	Just-in-Time Inventory Concept
KPI	Key Performance Indicator
LTE-M	Long Term Evolution for Machines
MCDM	Multiple Criteria Decision-Making
MIS	Management Information Systems
NB	Narrowband
NFC	Near Field Communication
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnection
OT	Operational Technology (shop floor machine operating technology)
PLC	Programmable Logic Controller
RTU	Remote Terminal Units
RFID	Radio Frequency Identification
SCADA	Supervisory Control and Data Acquisition
SOC	System On a Chip
SQL	Structured Query Language
TEC	Telecommunications Engineering Center
TDMA	Time Division Multiple Access
VR/AR	Virtual Reality and Augmented Reality
WAN	Wide Area Network

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Ravi Ramakrishnan, PhD, is an acclaimed Information Technology professional with more than 21 years of global experience in the corporate world. As an award-winning Global CIO with a strong technical and managerial background, he has done numerous global rollouts of Enterprise Information Systems—ERP/CRM/BI and M2M/Mobility and IoT solutions that have been widely acknowledged and awarded in different forums. He has submitted his thesis for Doctorate in Information Technology Management with focus on the IoT strategies and technologies and has published papers on the IoT in Springer, Pertanika, and IEEE Xplore and book chapters on the IoT in IGI Global.

He is a Senior IEEE member and has implemented projects in the United States, Europe, Asia, Africa, and the Middle East across multiple cultures, industry domain verticals, and technologies. He did his doctorate from Amity University with focus on IoT in manufacturing, did his MBA at the Faculty of Management Studies, Delhi University, and has further done a Post Graduate Diploma at AIMA in IT systems. He is DOEACC A level certified and has a Postgraduate Diploma in Operations Management from IGNOU after a Bachelors in Science. He is a Prince 2 certified professional, Microsoft Certified Professional, and an Oracle Certified professional.

His global awards include Computerworld 2016 Global 100 CIO honoree (Florida), IDG–CIO 100 India Award winner consecutively 2011, 2013, 2014, 2015, IDC–CIO 100 award winner 2014, 2015, Dataquest CIO award winner in Mobility and the IoT categories, Chief Information Security award winner CISO 2013, 2014, Oracle Best Implementation award winner 2016, Innovative CIO award winner 2015, 2016, C-Change Awards CIOL 2015, Business World CIO 3.0 award winner 2016, Information Week CIO and Business Impact Leader award 2015, Information Week Edge Award 2014, and CIO Power List IoT Icon and Manufacturing Icon Award winner 2017 from Core Media. He has been a key note speaker at many forums including Oracle Openworld on topics ranging from the IoT, the cloud, and mobility.

He also conducts corporate trainings and trainings for professional management programs and mentors startups working in the field of the IoT, mobility, machine learning, and computer vision.

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Prof. Dr. Loveleen Gaur, PhD, Research Head and Faculty, Amity International Business School, Amity University, Noida, is an established author, researcher, teacher, educator, consultant, administrator, and program leader. For more than 13 years, she served in India and abroad in different capacities. Before Amity University, she worked with various education institutions and worked as faculty and has done volunteer research work at the University of Maryland, USA. She is actively involved in teaching information systems, research methodology, data analytics, and software tools like SPSS, R, and EXCEL to postgraduate students.

Prof. Gaur has significantly contributed to enhancing scientific understanding by participating in over three hundred scientific conferences, symposia, and seminars, by chairing technical sessions, and delivering plenary and invited talks. She has specialized in the fields of information science, the IoT, data analytics, e-commerce and e-Business, data mining, and business intelligence. Prof. Gaur pursued research in truly interdisciplinary areas and has published six books and more than fifty research papers in referred journals.

Prof. Gaur holds various prestigious positions in India and abroad as a member of the Area Advisory Board of Various Business Institutions in India and Abroad, Board of Studies (BOS), and IQAC (Quality) team, and member of Student Research Committee (SRC) and Department Research Committee (DRC). She is actively involved in curriculum development, outcome assessment, and quality of assignment. She is serves as editor for many national and international journals. She is actively involved in various projects of the government of India and abroad. She has been honored with prestigious national and international awards such as "Senior Women Educator Scholar Award" by the National Foundation for Entrepreneurship Development on Women's Day, the "Sri Ram Award" by Delhi Management Association (DMA), the "Distinguished Research Award" by Allied Academies presented in Jacksonville, Florida, and the "Outstanding Research Contributor" award by Amity University. Apart from teaching, she is actively involved in providing talks to reduce the gap between academia and corporate and provides consultation to new ventures.

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Demystifying the Industrial IoT Paradigm

1.1 Primer

Internet of Things is considered by many as the most disruptive revolution, primarily driven by the need of organizations and people to be able to follow objects and make them communicate (Lianos & Douglas 2000) in the field of pervasive and omnipresent computing, the biggest technological change the world has ever seen after the advent of the internet. First coined by the British technologist Kevin Ashton in the 1990s, the demand and potential for IoT-connected devices and objects (Ferguson, 2002) and genesis of associated business models has increased multifold. IoT has two distinct yet overlapping connotations, the first being Consumer IoT for which numerous literature exists and the second being Industrial IoT. In this chapter, we will understand what exactly Internet of Things (both IIoT and domestic) is as defined by authentic literature. The Internet of Things blends the physical and digital world, which offers unlimited opportunities, but also faces a lot of challenges in terms of interoperability, limited compute power, power consumption, and ethical aspects of privacy and security. In short, the IoT can be defined as a well-defined network (Nunberg, 2012) comprising of physical objects or real-world devices, moving vehicles that may be autonomous or human driven, architectural places and other daily use objects incorporating electronic sensors, embedded software, and provision for data network connect—allowing them to collect and interchange data (Kosmatos et al., 2011). This arrangement allows objects and devices to be sensed and also controlled remotely using digital networks. The recent years have seen increasing interest and adoption in the field of IoT, powered by technological advances in embedded systems hardware, software, and connectivity. As more and more tiny, cheap, power-efficient microcontrollers and peripherals are becoming available, there is an increased proliferation of a new category of computers: the IoT low-end devices. Most of the IoT low-end devices have enough resources to run newer operating systems and cross-platform application code.

The Internet of Things has shown rapid evolution with widespread technical, social, and economic impact. This has resulted in a paradigm shift, machines taking over the role of human beings when it comes to data generation and usage. It is projected that by 2020, 100 billion connected IoT devices could be in existence (Biddlecombe, 2009).

The concept itself is quite old and has existed from the late 1970s or earlier when telecom networks started connecting to transmit voice data. Remote monitoring of the electrical grid's supply of domestic power has been in commercial use since the 1950s. The 1990s ushered in an era of Machine 2 Machine (M2M) communication (Reinhardt, 2004) between industrial machines, which existed as closed and proprietary solutions. Later on, the advent of RFID-based solutions, both passive and active, were used for extending object's capability to transmit information, although they were not smart and could just transmit an identifier information (Kosmatos et al., 2011). RFID was widely used in logistics movement and for tracking material and inventory (Sun, 2012). Today, the world has moved on to embrace IP-based networks, which still pose challenges for migrating such solutions due to basic design differences.

It would be very relevant to define the Internet of Things and look at some standard definitions.

The Internet Engineering Task Force (IETF) has defined the IoT as:

> The basic idea is that IoT will connect objects around us (electronic, electrical, and non-electrical) To provide seamless communication and contextual services provided by them. Development of RFID tags, sensors, actuators, mobile phones make it possible to materialize IoT which interact and co-operate each other to make the service better and accessible anytime, from anywhere.
>
> **Z. Shelby**
> *News from the 75th IETF, August 3, 2009*

The National Institute of Standards and Technology (NIST) defines the IoT as:

> Cyber physical systems (CPS) – sometimes referred to as the Internet of Things (IoT) – involves connecting smart devices and systems in diverse sectors like transportation, energy, manufacturing and healthcare in fundamentally new ways. Smart cities/communities are increasingly adopting CPS/IoT technologies to enhance the efficiency and sustainability of their operation and improve the quality of life.
>
> **NIST**
> *Global city teams, 2014*

W3C addresses the IoT as a Web of Things:

> The Web of Things is essentially about the role of web technologies to facilitate the development of applications and services for the Internet of Things, i.e., physical objects and their virtual representation. This includes sensors and actuators, as well as physical objects tagged with a bar code or nfc. Some relevant web technologies include HTTP for accessing restful services, and for naming objects as a basis for linked

> data and rich descriptions, and javascript apis for virtual objects acting as proxies for real world.
>
> **W3C**
> *Web of Services, 2019*

IEEE has defined the IoT comprehensively as a three-layer structure comprising of Applications, Networking, and Data Communications and Sensing.

In 2013, the Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as:

> The infrastructure of the information society. IoT in combination with sensors and actuators becomes an instance of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities.
>
> **ITU**
> *Internet of Things Global Standards Initiative, 2015*

As per the Internet Architecture Board (IAB), the phrase the "Internet of Things" denotes:

> A trend where a large number of embedded devices employ communication services offered by the Internet protocols. Many of these devices, often called "smart objects," are not directly operated by humans, but exist as components in buildings or vehicles, or are spread out in the environment.
>
> **IAB**
> *The Internet of Things, 2016*

Enterprises can benefit using the IoT from aspects of asset tracking, manufacturing automation, product innovation based on data, and the ability to physically control machine assets, which can further help in dynamic scheduling and real-time monitoring (Moeinfar et al., 2012).

With more stress on limited resources such as motor able roads, potable water, reducing forest and green cover, and an ageing society enabled by medical facilities, the IoT can prove to be the panacea required to economize the consumption, on one hand, while monitoring and prioritizing generation on the other (Butler, 2002).

At the same time, the adoption of the IoT has been fraught with a myriad of issues such as challenges in power consumption, security and privacy concerns, miniaturization yet reliable, roadmap for adoption, especially the cost of upgrades required for making assets and products compatible, and finally the human or emotional aspect of making "things" accountable and giving them control in our day-to-day lives (Arampatzis et al., 2005).

Some issues are more technical such as interoperability, standardization, compute power, and rapid innovation making investments redundant. Acceptability issues driven by the need for a higher "maturity quotient" is another challenge making businesses shy away from an enterprise level adoption and making them focus on a piece meal approach toward implementing the IoT technology enablers.

Today, the landscape is very different from what we foresee to be in store for the IoT tomorrow. The major ICT players like Google, Apple, Cisco, Salesforce, or Oracle, have changed their business models to cater to an expected demand for IoT, while telecom players have started interconnecting their telephony equipment as a core business strategy. The majority of governments, be it Asia, Europe, Middle East, or the Americas have set up a task force and implementation committees to usher in the IoT technology in different facets, be it Smart Cities, Industry 4, or Smart Transportation.

Further scope exists by integration of the IoT with technology trends like Big Data, Fog Computing, Augmented and Virtual Reality applications, wearables, and Cloud infrastructure adoption.

The situation tomorrow may expand the horizons of the IoT to include IoE, namely people, data, and process into a universally connected digital Earth where everyone and everything is just a few network hops away. The challenges will arise from fragmented and heterogeneous technology Siloed applications, vertically closed systems, enterprises closed mindset relating to exposing data, or facilities to collaboration. New ecosystems will need to evolve supported by new business modes, which are more digital focused than physical product focused, driven by large-scale pilot trials and consumer trials and a startup environment that develops peripheral yet value yielding use-case driven solutions for the IoT environment (Chen & Jin, 2012).

The success factors will involve a minimal commonality approach toward the IoT integration architecture development to reduce divergences among target systems, demonstrating value creation not observed by traditional people-centric manufacturing, ecosystem development for the IoT solutions involving policy governance and a positive culture, and a socioeconomic legal framework to define rules for machine interaction and accountability in business environments.

The world is heading toward a convergence of digital and physical and what traditionally was deemed fit will fall out of place in the new digital world order, where pervasiveness and ubiquitous computing will be the watch words. The ability to digitally track measurements, understand from them the failure patterns, and predict the failures in advance using patterns and data has made the adoption of the IoT even more compelling in manufacturing industries.

1.2 The IoT Adoption—Technology or Strategy Decision

Information Technology and associated developments have changed the way organizations do business. From bulk manufacturing to an order size of "one," manufacturing has become more and more customer preferences oriented,