The Internet *of* Things *in the* Cloud

A Middleware Perspective

Honbo Zhou

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This book is dedicated to Yizheng, Robert, and Alexander, with love, for their understanding and support throughout the years.

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Contents

List of Figures ..... **ix**
List of Tables ..... **xv**
Foreword ..... **xvii**
Preface ..... **xxi**
Author ..... **xxv**

SECTION I THE INTERNET OF THINGS

1 The Third ICT Wave **3**
1.1 Rise of the Machines 3
1.2 The IoT Kaleidoscope 8
1.3 Defining Internet of Things 14
1.4 IoT: A Web 3.0 View 22
1.5 Summary 24

2 Ubiquitous IoT Applications **27**
2.1 A Panoramic View of IoT Applications 27
2.2 Important Vertical IoT Applications 33
2.2.1 Telematics and Intelligent Transport Systems 33
2.2.2 Smart Grid and Electric Vehicles 45
2.2.3 Smarter Planet and Smart Buildings 53
2.3 Summary 58

3 Four Pillars of IoT **59**
3.1 The Horizontal, Verticals, and Four Pillars 59
3.2 M2M: The Internet of Devices 65

Downloaded by [ETRI] at 18:43 27 June 2014

3.3 RFID: The Internet of Objects 73
3.4 WSN: The Internet of Transducers.... 80
3.5 SCADA: The Internet of Controllers 88
3.6 Summary....94

4 The DNA of IoT....95
4.1 DCM: Device, Connect, and Manage 95
4.2 Device: Things That Talk 97
4.3 Connect: Via Pervasive Networks....104
4.3.1 Wired Networks....108
4.3.2 Wireless Networks.... 114
4.3.3 Satellite IoT 119
4.4 Manage: To Create New Business Value 122
4.4.1 More Ingredients: LBS, GNSS, RTLS, and Others 128
4.5 Summary....132

SECTION II MIDDLEWARE FOR IoT

5 Middleware and IoT....137
5.1 An Overview of Middleware 137
5.2 Communication Middleware for IoT.... 145
5.2.1 MTC/M2M Middleware....146
5.2.2 SCADA Middleware.... 153
5.2.3 RFID Middleware 155
5.2.4 WSN Middleware.... 158
5.3 LBS and Surveillance Middleware 163
5.4 Summary.... 167

6 Protocol Standardization for IoT 169
6.1 Web of Things versus Internet of Things....169
6.1.1 Two Pillars of the Web....172
6.2 IoT Protocol Standardization Efforts 177
6.2.1 M2M and WSN Protocols 182
6.2.2 SCADA and RFID Protocols....187
6.2.3 Issues with IoT Standardization 193

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6.3 Unified Data Standards: A Challenging Task 194
6.3.1 Unified Identification of Objects 202
6.4 Summary 214

7 Architecture Standardization for WoT 217
7.1 Platform Middleware for WoT 217
7.1.1 Standards for M2M 219
7.1.2 Frameworks for WSN 222
7.1.3 Standards for SCADA 225
7.1.4 Extensions on RFID Standards 228
7.2 Unified Multitier WoT Architecture 230
7.2.1 SOA/EAI versus SODA/MAI 231
7.2.2 OSGi: The Universal Middleware 238
7.2.3 WoT Framework Based on Data Standards 240
7.3 WoT Portals and Business Intelligence 246
7.4 Challenges of IoT Information Security 249
7.5 Summary 253

SECTION III THE CLOUD OF THINGS

8 Cloud Computing 257
8.1 What Is Cloud Computing? 257
8.2 Grid/SOA and Cloud Computing 259
8.3 Cloud Middleware 265
8.4 NIST's SPI Architecture and Cloud Standards 270
8.5 Cloud Providers and Systems 273
8.6 Summary 276

9 The Cloud of Things 279
9.1 The Internet of Things and Cloud Computing 279
9.2 Mobile Cloud Computing 283
9.3 MAI versus XaaS: The Long Tail and the Big Switch 289
9.4 The Cloud of Things Architecture 293
9.4.1 Four Deployment Models 295
9.4.2 Vertical Applications 296

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9.4.3 Fifteen Essential Features 297
9.4.4 Four Technological Pillars 298
9.4.5 Three Layers of IoT Systems 298
9.4.6 Foundational Technological Enablers 299
9.5 Summary 299

References 301

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List of Figures

Figure 1.1 Cyber-physical system (CPS). 4
Figure 1.2 Number of intelligent devices. 6
Figure 1.3 IoT-related terms. 13
Figure 1.4 IoT development. 15
Figure 1.5 IoT development in China. 16
Figure 1.6 SWOT analysis of China's IoT. 17
Figure 1.7 Intranet/Extranet/Internet. 21
Figure 1.8 Blending of IoT and Enterprise 2.0. 23
Figure 1.9 Web 3.0: The Internet of Things. 25
Figure 2.1 A panoramic view of IoT applications. 31
Figure 2.2 Telematics/fleet management/ITS and IoT. 34
Figure 2.3 Telematics terminal. 35
Figure 2.4 In-vehicle networking. 36
Figure 2.5 Telematics functions/services. 37
Figure 2.6 Telematics terminal architecture. 39
Figure 2.7 e-Logistics user interface. 42
Figure 2.8 DSRC-based systems. 44
Figure 2.9 The smart grid. 45

Figure 2.10 Smart grid value chain and stakeholders..... 46
Figure 2.11 Smart grid technologies..... 48
Figure 2.12 Integrated building system. 55
Figure 2.13 IoT applications for buildings. 58
Figure 3.1 3I and 5A. 60
Figure 3.2 The four pillars of IoT paradigms and related networks.....65
Figure 3.3 BiTX M2M architecture based on middleware. ...69
Figure 3.4 RFID system components. 74
Figure 3.5 Evolution of identifications. 75
Figure 3.6 Bar code formats. 76
Figure 3.7 RFID value chain and vendors. 77
Figure 3.8 Example of RFID application..... 80
Figure 3.9 Body sensor networks. 81
Figure 3.10 Sensor network architecture. 82
Figure 3.11 Context-aware system based on WSN. 86
Figure 3.12 Examples of SCADA graphics and animations....89
Figure 3.13 Components of a SCADA system.....91
Figure 3.14 SCADA sits in the center. 92
Figure 3.15 Middleware-based SCADA systems. 92
Figure 4.1 Examples of three-layer architecture of IoT. 96
Figure 4.2 DCM (DNA) of IoT. 97
Figure 4.3 Examples of sensors..... 99
Figure 4.4 Triple network convergence. 106
Figure 4.5 Protocol stacks of the "three networks." 108
Figure 4.6 Short- and long-range wireless networks. 116

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Figure 4.7 iPhone M2M application. 123
Figure 4.8 The industrial automation stack..... 124
Figure 4.9 Unified IoT architecture efforts in China..... 127
Figure 5.1 Omnipresent middleware..... 138
Figure 5.2 Platform middleware. 144
Figure 5.3 SCADA middleware architecture. 154
Figure 5.4 RFID architecture. 156
Figure 5.5 Physical markup language sample..... 157
Figure 5.6 WSN middleware architecture. 159
Figure 5.7 The Agilla middleware model. 162
Figure 6.1 Major Internet applications..... 170
Figure 6.2 Three-tiered architecture. 173
Figure 6.3 Java-based application servers. 174
Figure 6.4 Two pillars of the web. 175
Figure 6.5 Java variants for devices..... 176
Figure 6.6 Working groups of IoT standards. 179
Figure 6.7 All-IP networks..... 180
Figure 6.8 China Mobile's WMMP standard. 184
Figure 6.9 IEEE Std. C37.1 SCADA architecture. 188
Figure 6.10 OPC standard for device connection. 190
Figure 6.11 ISO/IEC 14443/15693 smart card standards..... 192
Figure 6.12 Evolution of the web. 195
Figure 6.13 SVG graphics of ezM2M. 197
Figure 6.14 oBIX schema..... 201
Figure 6.15 Unified Data Standard approaches. 204
Figure 6.16 Structure of UUID. 211

Downloaded by [ETRI] at 18:43 27 June 2014

Figure 6.17 Hierarchy of OID. 213

Figure 7.1 Object-oriented and real-world object programming. 218

Figure 7.2 OGC services, operations, and example calls. ... 223

Figure 7.3 OPC unified architecture. 226

Figure 7.4 RESTful web services. 232

Figure 7.5 Enterprise service bus. 234

Figure 7.6 B2B technologies. 236

Figure 7.7 SODA architecture. 237

Figure 7.8 Example of the device description language of SODA. 237

Figure 7.9 OSGi architecture. 239

Figure 7.10 ezM2M platform middleware. 240

Figure 7.11 ezStudio IoT application IDE. 241

Figure 7.12 Multitiered IoT middleware. 242

Figure 7.13 IoT graphics with animation. 243

Figure 7.14 The unified IoT middleware framework. 244

Figure 8.1 Cloud hierarchy. 259

Figure 8.2 Hadoop is a batch system for embarrassingly parallel niche applications. 260

Figure 8.3 Condor scheduler in Amazon Web Services. 261

Figure 8.4 Single system image is the core. 262

Figure 8.5 Earliest hypervisor. 262

Figure 8.6 Many-to-one virtualization is the foundation of cloud computing. 264

Figure 8.7 Cloud computing is the fusion of grid and SOA. ... 265

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Figure 8.8 Multitiered cloud architecture based on middleware. 266

Figure 8.9 PaaS and cloud middleware. 268

Figure 8.10 Cloud middleware. 269

Figure 8.11 Five-layer panoramic view of cloud vendors and products. 276

Figure 9.1 IoT versus cloud computing. 280

Figure 9.2 M2M versus cloud computing. 280

Figure 9.3 Cloud computing and IoT. 281

Figure 9.4 Schlage IoT application. 286

Figure 9.5 Evolution of IoT in the cloud. 290

Figure 9.6 The Long Tail of IoT. 291

Figure 9.7 IoT Red Ocean versus Blue Ocean. 292

Figure 9.8 The Cloud of Things architectural specification. ..294

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List of Tables

Table 2.1 Telematics Brands Worldwide 38

Table 2.2 Fleet Management Brands and Vehicle Manufacturers 40

Table 3.1 Four Pillars of IoT and Their Relevance to Networks 64

Table 3.2 Application Areas for Cellular M2M 67

Table 3.3 M2M Service Enablement Middleware 70

Table 3.4 Operator's Participation in Value Chain 71

Table 3.5 RFID Frequency Ranges 78

Table 3.6 RFID Platforms 84

Table 4.1 List of Sensors and Types 100

Table 4.2 List of Field Bus Standards 110

Table 4.3 IoT Technologies 128

Table 5.1 Embedded IoT Middleware 143

Table 5.2 MTC Characteristics 149

Table 5.3 Sample WSN Middleware and WSN Languages 161

Table 6.1 CBRN Data Standard Efforts: Standards Activities for CBRN Sensors 203

Table 6.2 Unified IoT Data Standard Based on Existing Data Formats and Protocols 205

Table 8.1 List of Standardization Efforts 272

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Foreword

Imagine a world where everything around you, from smartphones, smart TVs, and light bulbs, to refrigerators, air conditioners, and motor vehicles, as well as countless instrumented objects including livestock, are connected, monitored, and sometimes, actuating and interacting among themselves, with or without human intervention, this is the world of the Internet of Things (IoT).

We have seen those applications today in real life such as GPS navigation systems for cars, mobile payment, smart city and intelligent building management, automatic meter reading, truck fleet locating, security surveillance and emergency management, natural resources and environment protection, air quality monitoring, space shuttle tracking, as well as scenarios in science-fiction movies. Many see this as the ultimate futuristic world, a world where ubiquitous smart devices and assets are connected to make human living easier and more convenient, and everything becomes smarter. With the introduction and development of IoT vision and technologies, this future world may be a lot closer to us than we think. Having worked on an Internet startup during the dotcom time right after receiving my PhD at Stanford, I feel that now is the time for IoT, just like 1999 was for the Internet and the web.

The possibilities of IoT/M2M are unlimited; however, the challenges are as enormous and pervasive both technologically, existing in every link of the value chain, and sociologically, affected by government regulations and user privacy concerns,

and so on. For years, TCL Communication, which I joined right after the dotcom bust, has been known as one of the world's leading cellular phone makers (no. 3 in China and no. 7 worldwide) after the successful merge with Alcatel's cellular phone business. Now we are well positioned to take on the challenges with a synergic move together with the entire TCL Group, which has broader IoT/M2M–related product lines, and capture an even bigger slice of the trillion-dollar pie.

With the advent of cloud computing and IoT, along with the convergence of all types of intelligent devices, I believe mobile Internet is ready to take off. M2M terminals including smartphones are going to play a pivotal role in the mobile Internet revolution. Smart M2M devices are becoming the gateways to the converging fixed and mobile Internet just like personal computers for the Internet years ago. Currently, almost all the major Internet players, such as Google, Amazon, Microsoft, and even Facebook, are entering the smartphone business. Apple's success with iTunes, AppStore, and iCloud make it a competitive Internet (fixed and mobile) player. Almost all of the Telco operators such as AT&T, Orange, Verizon, and NTT DoCoMo, to name a few, have developed M2M business strategies and made substantial progress since 2004 in the M2M market. Telco equipment players such as Cisco also saw and embraced M2M or IoT as the next big thing. Mobile phone chip maker Qualcomm has quietly become the largest fleet telematics services provider (TSP) with 600,000 vehicles receiving its services. According to e-Principles, a market research organization, the number of cellular M2M devices surpassed the number of cell phones in West Europe in 2010.

At TCL Communication, we also realized the importance of a unified software platform with cloud services built on top for smartphones, smart TVs, smart home appliances, healthcare monitors, and other M2M devices. The TCL T-Cloud strategic blueprint was announced as a unified foundation for a variety of M2M/IoT vertical applications. A number of projects are in development to embrace the market potentials and take

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advantage of the great opportunities. This entire value chain and the associated technologies, as well as the enormous and ubiquitous application landscape, are a vast topic that encompasses many different subjects. This book brings timely, mind-provoking, and comprehensive materials to help you have a better understanding of the IoT/M2M technological and business landscape on top of cloud computing, and shape your business strategies. I also believe this book, which I highly recommend, is the first on the market that covers almost all of the related subjects.

George (Aiping) Guo, PhD
CEO of TCL Communication Technology Holdings Ltd.
Senior Vice President of TCL Group

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Preface

IoT was embraced by countries worldwide, especially in Asia and Europe; for example, IoT is part of national strategy in China; Japan has been promoting U-Japan since 2004; the EU is aiming to "lead the way" in the transformation to Web 3.0 with the Internet of Things; and so on. Although almost all of the new concepts in the IoT domain including the Internet of Things itself as well as other related terms such as M2M (Machine to Machine), CPS (Cyber-Physical Systems), Smarter Planet, Smart Grid, started their life in the United States and became buzzwords worldwide; the IoT term is not yet a catchphrase in the U.S. People in the U.S. seem busy enough with the social networking hype (Facebook, Twitter, etc.) and regard the Internet of Things as the Internet of Somebody-else's Things. Many people also believe that there is nothing new technologically about IoT. It's true that all of the technologies and most of the applications that enable and constitute IoT existed long before anyone ever began to talk about IoT. Just like the Internet and web, the Internet of Things is a revolutionary way of architecting and implementing systems and services based on evolutionary changes. The realization of the IoT vision brings ICT technologies closer to many aspects of real-world life instead of virtual life, and therefore has greater implications and sociological impacts in a world facing serious issues such as global warming, environment protection, and energy saving. It's hoped that this book would help bring

awareness for more people to know IoT and join forces to boost faster development of IoT.

This book provides a panoramic view of the IoT landscape and focuses on the overall technological architecture and design of a tentatively unified IoT system underpinned by different cloud computing paradigms from a middleware perspective. It is based on the author's two previous best-selling books (in Chinese) on IoT and cloud computing and more than 20 years of hands-on software/middleware programming and architecting experience in the United States. The author worked at Oak Ridge National Laboratory, IBM, BEA Systems, and Silicon Valley startups such as Doubletwist. While at Doubletwist, the author led a team that created a COW (cluster of workstations) or grid computing (now cloud computing) system (and a Software as a Service [SaaS] portal on top of it) that accomplished the complete annotation of the entire human genome for the first time in the world. This accomplishment was reported by the *San Francisco Chronicle* (http://www.sfgate.com/business/article/The-Gene-Team-High-tech-gurus-biologists-unite-3304818.php) and CNN, and media in Asia and Europe.

Most directly, this book is based on the author's research and development endeavors on the ezM2M middleware of the TongFang Co. Ltd. (the second largest system integrator and IT services provider in China) platform and more than 30 IoT vertical application suites on top of it since 2003. This platform has received more than 20 awards and recognitions in China and has been used in more than 800 projects including the radio-frequency identification (RFID)-based ticket management system for the 2008 Olympic Games, the M2M platform for China Mobile and e-Logistics vehicle tracking system, the national emergency management system, the building management system for the central television tower of China, and the smart building energy efficiency management system for

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the city of Beijing. The ezIBS building management application suite product has maintained the number one market share position since 2006, and is included in textbooks for college students of related majors in China. The author expresses his gratitude to all the members of the ezM2M R&D team.

This book is comprised of three sections. The first section describes the concept of Internet of Things. Other related concepts along with its development, and a number of important vertical IoT applications, as examples, are also demonstrated. The four pillars of IoT are introduced based on the author's extensive and exhaustive research and industry practices, and it is believed that those four paradigms represent the most comprehensive and holistic clarification and categorization that cover all of IoT's nuts and bolts. The three-layer value chain of IoT is described in the last chapter of Section I.

The Web of Things (WoT) is a better term to describe what the Internet of Things is meant to be, just like the World Wide Web is based on the Internet. It is more about the so-called grand integration and applications rather than the ubiquitous networks and the devices and sensors. So the middleware, just like the three-tiered application servers for the web, and the associated data formats, such as HTML- and XML-based data representations for EAI (Enterprise Application Integration) and B2B, play a pivotal role in the entire IoT value chain. The second section of the book focuses on middleware, the glue and building blocks of the holistic IoT system in every layer of the architecture. A comprehensive overview of all sorts of middleware and their roles in the four IoT pillar systems is presented in the first chapter of Section II. The data formats and protocols for all the four pillar IoT applications are summarized, and the possibility of creating a unified IoT data format and protocol standard for the four pillar segments is investigated in Chapter 6. The last chapter of Section II investigates the possibility of creating a unified IoT middleware architecture based on currently existing research efforts on standardization, such

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as IoT-A (Internet of Things Architecture) and ETSI (European Telecommunications Standards Institute) M2M functional architectures and a number of commercial products.

The third section of the book discusses cloud computing and IoT as well as their synergy based on the common background of distributed processing. The fundamentals of cloud computing are discussed in Chapter 8. The MAI (Machine to Machine Application Integration) similar to EAI integration inside a firewall, and the XaaS (Everything as a Service), similar to B2B/B2C based on SOA (Service Oriented Architecture) over the Internet, paradigms for IoT/WoT integration are introduced and discussed, and a comprehensive unified IoT framework specification is proposed and explained in the final chapter of the book.

The Internet of Things is a vast and dynamic territory and is evolving at a rapid pace. Books that offer a comprehensive and holistic view are not yet seen on the market. This book attempts to be a comprehensive guide to IoT technologies and system architectures. However, it is more like a research report that introduces a few new propositions based on the author's R&D endeavors rather than a textbook. The audience for this book could be software engineers, architects, post-graduate students, researchers, or anyone who wants to know more about IoT, especially its software technologies and system architectures.

The author can be found on Facebook, Twitter, and LinkedIn. He can also be reach at honbozhou@gmail.com. Comments and suggestions as well as criticisms are welcome.

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authored two related books in Chinese. He is a frequently invited speaker and evangelist of IoT and cloud computing, adjunct professor of several universities, and vice president of the Middleware Association, and he is a member of other related professional associations in China.

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