

Rethinking the Internet of Things

A Scalable Approach to Connecting Everything



Francis daCosta



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To Gautama Buddha, whose teachings inspired me to explore a more nature based approach to edge networking as described in this book.

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About the Author

Francis daCosta founded and acted as CTO for MeshDynamics (wireless mesh networking), Advanced Cybernetics Group (embedded software for robot control systems and other mission-critical military applications), and Knowmadic (web-based big data extraction). Previously, he served as an adviser to the United States Air Force Robotics and Automation Center of Excellence (RACE). He also held senior technical positions at MITRE, Northrop Grumman, Ingersoll-Rand, and Xerox. His entrepreneurial projects have also included autonomous robotic systems and adaptive process controllers.

Mr. daCosta has a MS from Stanford University and a BS from the Indian Institute of Technology, along with post-graduate work in artificial intelligence at the University of California, Los Angeles. He is currently involved in a stealth-mode Internet of Things start-up and has authored or co-authored 15 patents incorporating a variety of technology innovations including adaptive control, self-healing mesh networks, sensor fusion, machine learning, distributed control, and automatic robot programming. His intellectual interests include machine intelligence, subsumption architectures, emergence, and consilience.

About the Project Manager

Byron Henderson has been working in data communications and networking for thirty years in a variety of marketing, product management, sales, and general management roles. Companies have included MeshDynamics, Cisco Systems, Stratacom, Fibermux (later ADC Telecommunications), MICOM Systems (later Nortel Networks), and ComDesign (later Network Equipment Technologies). His areas of technology focus have included wireless networking, voice-over-IP, routing and switching, security, and more. Before discovering that communications offered a better career path than crustaceans, he studied aquatic biology at the University of California, Santa Barbara.

About the Technical Reviewer

John Aiken took his BSEE at Cornell University. He worked in silicon fabrication process engineering in implant, diffusion and thin films for several chip companies. John moved into development, as a founder of one of the first companies providing low cost, high performance satellite television receivers to the consumer market. He developed high reliability power avionics for the defense and space sectors, designed broadcast video-graphics systems and managed development of pioneering graphics supercomputers for space shuttle flight simulation at NASA Johnson Space Center. Working at Lockheed Martin, John provided software and systems engineering expertise in the communications, navigation and training markets. He developed protocols for networked simulation and performed operations planning for the Air Force Satellite Control Network. At Intel, John managed development of software for server applications and developed specifications for open communications systems.

Working in global telecommunications standards, John managed development of requirements, architectures, protocols and interoperability testing for 4G mobile networks and devices.

Recently John has done business process re-engineering for the utility industry. He has aided in the development of technical educational infrastructure and is facilitating the advancement of initiatives in network, software tools and in the architecture of the Internet of Things.

John invented, patented and licensed key display and image processing technologies for the smartphone and tablet computer markets. He has held certification as a Project Management Professional since 2003.

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Managing Editor Byron Henderson has been a valued colleague for years and helped me to turn dense technical details into more readable prose while offering ideas and suggestions to improve the final result. His knowledge of and enthusiasm for the biological principles of massive natural systems informed many of the concepts in this book.

All of these, and many more unnamed, contributed to the completion of this book, but any errors that remain are my own.

Foreword

With the rise of machines talking with machines in the Internet of Things, a new category of applications will demand evolutionary changes in the infrastructure of networks. Traditional networks were built to keep the enterprise at the center, resulting in star topologies and round-trip communications from edge devices to the servers at the center of the network. The Internet was similarly designed around information at the center of the network connected to people at the edges.

But machines are different from people, with different communications needs. Machines operate more independently in real-time and their actions affect the physical world immediately. Feedback and control of these local actions is critical for top performance and safety. Unlike the traditional end-to-end Internet, the Internet of Things must address these deterministic local control loops to insure business process reliability.

The different needs of machine communications can be seen in three aspects: real-time response, deterministic performance, and security and safety. All three aspects make demands on networking – closed control loops near the machines (to reduce latency), reduced costs of data transmission (in light of the rapidly expanding population of machines), and segregation of communications (to reduce noise and increase security).

With the increased number of devices and variety of applications, Metcalfe's Law is exploding with the number of new machines and the amount of data they generate. The only way for technology to keep up with the coming expansion of the Internet of Things is to manage the machine data flows differently from the way human application-oriented traffic has been handled with current protocols.

This book describes a critical new approach for the Internet of Things that makes it possible to extract meaning in context from the billions of new data sources that will emerge. This new approach recognizes the different demands of machine-to-machine networks and proposes an evolutionary three-tiered architecture to enable the next phase of the Internet.

Francis daCosta is distinctively qualified to develop this new IoT architecture. His diverse background in autonomous robotics, embedded systems, big data analysis, and wireless networking places him at the center of the all of the different technologies which must combine to address the Internet of Things. When Francis talks about communications realms, segregation of data streams, determinism, security, and control loops, I know that he is taking an innovative and disruptive approach in the evolutionary world of networks. This new architecture provides the urgently needed tools to address the expanding needs of the machines that join the physical world to the digital world in the Internet of Things.

Alok Batra
CEO, MQIdentity, Inc.

Former CTO & Chief Architect, GE Global Software Center, Industrial Internet Platform

Introduction

I didn't set out to develop a new architecture for the Internet of Things (IoT). Rather, I was thinking about the implications of control and scheduling within machine social networks in the context of Metcalfe's Law. The coming tsunami of machine-to-machine interconnections could yield tremendous flows of information – and knowledge.

Once we free the machine social network (comprised of sensors and an unimaginable number of other devices) from the drag of human interaction, there is tremendous potential for creating autonomous communities of machines that require only occasional interaction with, or reporting to, humans.

The conventional wisdom is that the expansive address space of IPv6 solves the IoT problem of myriad end devices. But the host-to-host assumptions fossilized into the IP protocol in the 1970s fundamentally limited its utility for the very edge of the IoT network. As the Internet of Things expands exponentially over the coming years, it will be expected to connect to devices that are cheaper, dumber, and more diverse. Traditional networking thinking will fail for multiple reasons.

First, although IPv6 provides an address for these devices, the largest population of these appliances, sensors, and actuators will lack the horsepower in terms of processors, memory, and bandwidth to run the bloated IP protocol stack. It simply does not make financial sense to burden a simple sensor with all of the protocol overhead needed for host-to-host communications.

Second, the conventional implementation of IP protocols implies networking knowledge on the part of device manufacturers: without centrally authorized MAC IDs and end-to-end management, IP falls flat. Many of the hundreds of thousands of manufacturers of all sizes worldwide building moisture sensors, streetlights, and toasters lack the technical expertise to implement legacy network technology in traditional ways.

Third, the data needs of the IoT are completely different from the global Internet. Most of the communications will be terse machine-to-machine interchanges that are largely asymmetrical, with much more data flowing in one direction (sensor to server, for example) than in the other. And in most cases, losing an individual message to an intermittent or noisy connection will be no big deal. Unlike the traditional Internet, which is primarily human-oriented (and thus averse to data loss), much of the Internet of Things traffic will be analyzed over time, not acted upon immediately. Most of the end devices will be essentially autonomous, operating independently whether anyone is “listening” or not.

Fourth, when there are real-time sensing and response loops needed in the Internet of Things, traditional network architectures with their round-trip control loops will be problematic. Instead, a way would be needed to engender independent local control loops managing the “business” of appliances, sensors, and actuators while still permitting occasional “advise and consent” communications with central servers.

Finally, and most importantly, traditional IP peer-to-peer relationships lock out much of the potential richness of the Internet of Things. There will be vast streams of data flowing, many of which are unknown or unplanned. Only a publish/subscribe architecture allows us to tap into this knowledge by discovering interesting data flows and relationships. And only a publish/subscribe network can scale to the tremendous size of the coming Internet of Things.

The only systems on earth that have ever scaled to the size and scope of the Internet things are natural systems: pollen distribution, ant colonies, redwoods, and so on. From examining these natural systems, I developed the concept of a three-tiered IoT architecture described in this book: simple end devices; networking specialist propagator nodes, and information-seeking integrator functions. In these pages, I'll explain why terse, self-classified messages, networking overhead isolated to a specialized tier of devices, and the publish/subscribe relationships formed are the only way to fully distill the power of the coming Internet of Things.

Francis daCosta
Santa Clara, California, 2013