BUILDING THE INTERNET OF THINGS WITH IPv6 AND MIPv6

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The Evolving World of M2M Communications

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For Anna

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PREFACE

The proliferation of an enlarged gamut of devices able to be directly connected to the Internet is leading to a new ubiquitous-computing paradigm: the Internet of Things (IoT). The IoT is a new type of Internet application that endeavors to make the thing's information (whatever that may be) available on a global scale. It has two attributes: (i) being an Internet application, and (ii) dealing with thing's information. The IoT is predicated on the expansion of the scope, network reach, and possibly even architecture of Internet through the inclusion of physical, instrumented objects. IoT aims at providing smarter services to the environment or the end-user as more *in situ*, transferable data becomes available. Thus, the IoT is seen as a new-generation information network that realizes machine-to-machine communication. The IoT eliminates time and space isolation between geographical space and virtual space, forming what proponents label as "smart geographical space," and creating new human–environment relationships. The latter implies that the IoT can advance the goal of integration of human beings and their surroundings. Applications range from energy efficiency to logistics, and many more.

At the "low end" of the spectrum, the thing's information is typically coded by the Unique Identification (UID) and/or Electronic Product Code (EPC); the information is (typically) stored in a Radio Frequency Identification (RFID) electronic tag; and, the information is uploaded by noncontact reading using an RFID reader. More generally, smart cards (SCs) will also play an important role in IoT; SCs typically incorporate a microprocessor and storage. At the mid-range of the spectrum one finds devices with embedded intelligence (microprocessors) and embedded active wireless capabilities to perform a variety of data gathering and possibly control functions. On-body biomedical sensors (supporting body area networks), home appliance and power management, and industrial control are some examples of these applications. At the

other end of the spectrum, more sophisticated sensors can be employed in the IoT: some of these sensor approaches use distributed wireless sensor networks (WSNs) systems that can collect, process, and forward a wide variety of environmental data such as temperature, atmospheric and environmental chemical content, or even low or high resolution ambient video images from geographic dispersed locations; these objects may span a city, region, or large distribution grid.

The IoT is receiving a large amount of interest on the part of researchers, with thousands of papers published on this topic in the recent past. While specific applications have existed for several years, perhaps supported on private enterprise networks, Internet-based systems along with system supporting a broader application scope are now beginning to be deployed. *The capabilities offered by IP Version 6 (IPv6) are critical to the wide-spread deployment of the technology.*

This text aims at exploring these evolving trends and offering practical suggestions of how these technologies can be implemented in the service provider networks to support cost-effective applications, and how new revenue-generating services could be brought to the market. All the latest physical layer, MAC layer, and upper layer IoT and Machine to Machine (M2M) protocols are discussed.

Planners are asking questions such as: What is the Internet of Things? How does M2M apply? How can it help my specific operation? What is the cost of deploying such a system? Will standardization help? What are the security implications? This text addresses the following IoT aspects: evolving wireless standards, especially low energy and medical applications; IPv6 technologies; Mobile IPv6 (MIPv6) technologies; applications; key underlying technologies for IoT applications; implementation approaches; implementation challenges; and mid-range and long-range opportunities.

More specifically, the text reviews the latest technologies, the emerging commercial applications (especially health care), and the recently evolving standards, including all layers of the protocol stack applicable to IoT/M2M. The text focuses on extensively IPv6, MIPv6, and 6LowPAN/RPL and argues that the IoT/M2M may be the killer app for IPv6. It covers the latest standards supporting the IoT and the M2M applications, including home area networking (HAN), AMI, IEEE 802.15.4, 6LowPAN/RPL, Smart Energy 2.0, ETSI M2M, ZigBee IP (ZIP); ZigBee Personal Home and Hospital Care (PHHC) Profile; IP in Smart Objects (IPSO); BLE; IEEE 802.15.6 wireless body area networks (WBAN); IEEE 802.15 WPAN Task Group 4j (TG4j) medical body area networks; ETSI TR 101 557; near field communication (NFC); dedicated short-range communications (DSRC)/WAVE and related protocols; the Internet Engineering Task Force (IETF) IPv6 Routing Protocol for Low power and lossy networks (RPL)/Routing Over Low power and Lossy networks (ROLL); IETF Constrained Application Protocol (CoAP); IETF Constrained RESTful environments (CoRE); 3rd Generation Partnership Project (3GPP) Machine-Type Communications (MTC); long term evolution (LTE) cellular systems; and IEEE 1901.

This text covers the latest standards supporting IoT/M2M from the perspective of Body Area Network/E-health/Assistive Technologies; it also covers over-the-air surveillance, object tracking, smart grid, smart cards, and home automation.

This is believed to be the first book on MIPv6 with applications to the IoT, especially in a mobile context. This work will be of interest to technology investors; planners with carriers and service providers; CTOs; logistics professionals; engineers at equipment developers; technology integrators; Internet and Internet Service Providers (ISP); and telcos, and wireless providers, both domestically and in the rest of the world.

ABOUT THE AUTHOR

Among other activities, Mr. Minoli has done extensive work in Internet engineering, design, and implementation over the years. The results presented in this book are based on the foundation work done while at *Telcordia, NYU, Stevens Institute of Technology, Rutgers University, AT&T*, and other engineering firms, starting in the early 1990s and continuing to the present. Some of his Internet- and wireless-related work that plays a role in the deployment of the Internet of Things has been documented in books he has authored, including:

- *Internet and Intranet Engineering* (McGraw-Hill, 1997)
- *Internet Architectures* (co-authored) (Wiley, 1999)
- *Hotspot Networks: Wi-Fi for Public Access Locations* (McGraw-Hill, 2002)
- *Wireless Sensor Networks* (co-authored) (Wiley 2007)
- *Handbook of IPv4 to IPv6 Transition Methodologies For Institutional & Corporate Networks* (co-authored) (Auerbach, 2008)
- *Satellite Systems Engineering in an IPv6 Environment* (Francis and Taylor 2009)
- *Mobile Video with Mobile IPv6* (Wiley 2012)

Mr. Minoli has many years of technical hands-on and managerial experience in planning, designing, deploying, and operating IP/IPv6, telecom, wireless, satellite, and video networks, and Data Center systems and subsystems for global Best-In-Class carriers and financial companies. He has worked on advanced network deployments at financial firms such as *AIG, Prudential Securities, Capital One Financial*, and service provider firms such as *Network Analysis Corporation, Bell Telephone Laboratories,*

ITT DTS/Worldcom, Bell Communications Research (now Telcordia), AT&T, Leading Edge Networks Inc., SES, and other institutions. In the recent past, Mr. Minoli has been responsible for (i) the development and deployment of IPTV systems, (ii) the development and deployment of terrestrial and mobile IP-based networking services; (iii) deployments of large aperture antenna at teleports in the United States and abroad; (iv) deployment of satellite monitoring services worldwide using IP/MPLS services; and (v) IPv6 services. He also played a founding role in the launching of two companies through the high tech incubator Leading Edge Networks Inc., which he ran in the early 2000s: *Global Wireless Services*, a provider of secure broadband hotspot mobile Internet and hotspot VoIP services; and, *InfoPort Communications Group*, an optical and Gigabit Ethernet metropolitan carrier supporting Data Center/SAN/channel extension and cloud network access services. For several years, he has been Session, Tutorial, and more recently overall Technical Program Chair for the IEEE ENTNET (Enterprise Networking) conference; ENTNET focuses on enterprise networking and security requirements for large financial firms and other corporate institutions.

Mr. Minoli has also written columns for *ComputerWorld, NetworkWorld*, and *Network Computing* (1985–2006). He has taught at *New York University* (Information Technology Institute), *Rutgers University*, and *Stevens Institute of Technology* (1984–2006). Also, he was a Technology Analyst At-Large, for Gartner/DataPro (1985–2001); based on extensive hand-on work at financial firms and carriers, he tracked technologies and wrote CTO/CIO-level technical scans in the area of telephony and data systems, including topics on security, disaster recovery, network management, LANs, WANs (ATM and MPLS), wireless (LAN and public hotspot), VoIP, network design/economics, carrier networks (such as metro Ethernet and CWDM/DWDM), and e-commerce. Over the years, he has advised Venture Capitals for investments of $150M in a dozen high tech companies.

Mr. Minoli has also acted as Expert Witness in a (won) $11B lawsuit regarding a VoIP-based wireless Air-to-Ground radio communication system for airplane in-cabin services, as well as for a large lawsuit related to digital scanning and transmission of bank documents/instruments (such as checks). He has also been engaged as a technical expert in a number of patent infringement proceedings in the digital imaging and VoIP space supporting law firms such as *Schiff Hardin LLP, Fulbright & Jaworski LLP, Dimock Stratton LLP/Smart & Biggar LLP,* and *Baker & McKenzie LLP*, among others.