MOBILIGHT 2010

TUTORIAL

I. Machine-to-Machine: An Emerging Communication Paradigm

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Duration
½ Day Tutorial

Abstract

An unprecedented communication paradigm facilitating the connection between a prior unseen number of devices is currently gripping both industrial as well as academic communities. Referred to as machine-to-machine (M2M) communication, it is essentially composed of three key ingredients:
1) a wireless end-device,
2) an infrastructure-based or infrastructure-less wireless carrier network, and
3) the back-end server network.
The gamut of application for such a composite scenario mixing short-range and wide-range communication systems is vast, including e.g. consumer electronics, smart energy, telemetry, health care, industrial control, and general means of boosting the usage of existing telecoms infrastructures by offering communications and connectivity at large. Market prospects of M2M are thus very encouraging, which was estimated at €20bn in 2005 already and is expected to reach €200bn in Q4 2010 connecting more than 100bn communicating devices.
The aim of this tutorial is to provide a detailed technical insight into latest key aspects of M2M networks. To this end, we will discuss the heterogeneous set of available end-device technologies applicable to M2M systems. We will then dwell on different approaches to provide the infrastructure of M2M end-devices so that back-end servers can be reached at minimum delay and minimum energy expenditure. The tutorial will be complemented by a discussion on latest standardization efforts pertaining to M2M as well as a thorough summary on open research challenges.

Lectures

M2M systems bear very specific and unparalleled challenges in both research and development. Prime design drivers here are the need for virtually zero-outage, immediate response and high-efficiency to support reliable, green, long-living and delay-constrained M2M applications. With no clear winner established so far, two orthogonal approaches have thus commenced to contend for the M2M market, i.e. 1) cellular solutions relying on wide coverage; and 2) purely embedded solutions for short-range or local area communications relying on cheap deployments. The prime objective of this tutorial is therefore to acquaint an academic and industrial audience with crucial design approaches and architectural elements to facilitate a viable and efficient deployment of said networks. To this end, the tutorial is structured in the three parts:
In the first part, we will discuss the cradle of M2M systems and the reasoning of their emergence. We will discuss the peculiarities of these systems with emphasis on the very differing rate, delay and energy requirements. We will also dwell on their commercial importance, i.e. business projections, commercial activities worldwide, etc. A considerable part will also be dedicated to current standardization approaches, such as the GSMA SACG, 3GPP SA/RAN/CT, ETSI M2M/SCP/RRS, CDG M2M, IEEE 802.15.4(e), IETF 6LoWPAN, IETF ROLL, OpenADR, etc. Finally, canonical M2M architectures will be summarized which are then used throughout the remainder of the tutorial.

In the second part, we will deal with embedded systems which generally deliver M2M traffic via multiple hops towards a gateway which in turn is connected to the back-end server network. We will commence by reviewing and explaining solutions proposed within the academic community for MAC and networking protocols. Notably, we will dwell on latest preamble sampling and channel hopping MAC protocols, as well as virtual coordinate and gradient routing protocols, both known to exhibit superior energy efficiency in the context of M2M traffic. We will then dwell on technical details of lately standardized solutions, i.e. the IEEE 802.15.4 PHY, IEEE 802.15.4e MAC and IETF 6LowPAN/RPL networking protocols. We will show, corroborated by experimental results, that a tight coupling of these protocols yields excellent performance. Finally, we will briefly discuss some important proprietary M2M solutions which have successfully penetrated the market.
In the third part, we will discuss in great details the tradeoff between node performance (throughput, delay), network performance (outage, lifetime) and cost (CAPEX, OPEX). We will briefly introduce cellular and hybrid embedded/cellular architectures. Finally, we will summarize and highlight a large set of open problems which are likely to occupy the community for years to come.

1. Introducing M2M
    a. Peculiarities of M2M
        i. zero-outage, immediate response, high-efficiency
        ii. heterogeneity of devices
        iii. security issues
    b. Business & Markets
        i. general market drivers
        ii. health care markets
        iii. smart energy markets
        iv. industrial control markets
    c. Standardization Efforts
        i. importance of standardization
        ii. cellular (3GPP, ETSI & CDG)
        iii. embedded (IEEE, IETF)
    d. Canonical Architectures
        i. cellular architectures
        ii. embedded architectures
        iii. hybrid architectures
2. Embedded M2M Designs
    a. Specificities of Embedded Systems
        i. reliability, low-power
        ii. need for multihop
        iii. protocol design drivers
    b. Academic Protocol Developments
        i. misconceptions about wireless medium
        ii. MAC protocols & taxonomy
        iii. networking protocols & taxonomy
        iv. pros and cons
    c. Standardized Embedded Systems
        i. IEEE 802.15.4x PHY/MAC layers
        ii. IETF 6LoWPAN HC and ND
        iii. IETF ROLL RPL routing protocol
        iv. industrial standards: WirelessHART, ISA100
    d. Proprietary Solutions
        i. Dust Networks
        ii. Coronis/Elster
        iii. Worldsensing

3. Open M2M Design Challenges
    a. Architectural Tradeoffs
        i. node performance
        ii. network performance
        iii. cost issues
    b. Cellular & Hybrid Architectures
        i. overview of architectures
        ii. high-level comparison
        iii. applicability
    c. Open Design Challenges
        i. wireless M2M end-device
        ii. wireless M2M carrier network
        iii. back-end server issues
    d. Time for Q&A

List of speakers

Mischa Dohler is now Senior Researcher with CTTC in Barcelona. Prior to this, from June 2005 to February 2008, he has been Senior Research Expert in the R&D division of France Telecom working on cooperative communication systems, cognitive radios and wireless sensor networks. From September 2003 to June 2005, he has been lecturer at King's College London, Centre for Telecommunications Research. At that time, he has also been London Technology Network Business Fellow for King's College London, as well as Student Representative of the IEEE UKRI Section and member of the Student Activity Committee of IEEE Region 8. He obtained his PhD in Telecommunications from King's College London, UK, in 2003, his Diploma in Electrical Engineering from Dresden University of Technology, Germany, in 2000, and his MSc degree in Telecommunications from King's College London, UK, in 1999. Prior to Telecommunications, he studied Physics in Moscow. He has won various competitions in Mathematics and Physics, and participated in the 3rd round of the International Physics Olympics for Germany. In the framework of the Mobile VCE, he has pioneered research on distributed cooperative space-time encoded communication systems, dating back to December 1999. He has published more than 110 technical journal and conference papers at a citation h-index of 20 and citation g-index of 40, holds several patents, co-edited and contributed to several books, has given numerous international short-courses, and participated in standardisation activities. He has been TPC member and co-chair of various conferences, technical chair of IEEE PIMRC 2008 held in Cannes, France, and is editor for the IEEE Communications Letters, the IEEE Transactions on Vehicular Technology, the IEEE Communications Magazine, the IEEE Wireless Communications, the IET Communications, the Elsevier Physical Communications journal, the EURASIP JWCN journal, the Bentham Science Recent Patents on Computer Science journal, and the International Journal of Parallel, Emergent and Distributes Systems. He is a Senior Member of the IEEE. In addition to being an experienced lecturer in academia (4 years of MSc and BSc courses at King's College London) and industry (7 years at Mobile VCE and 3 years in France Telecom), he has given over 20 international short-courses, such as on UMTS and Beyond, distributed cooperative systems, wireless sensor networks and issues pertaining to the design of the Internet of Things.

Thomas Watteyne is a postdoctoral researcher at the Berkeley Sensor & Actuator Center, University of California in Berkeley, working in Prof. Kristofer S.J. Pister's team. He is the coordinator of OpenWSN, an open-source initiative to promote the use of fully standards based protocol stacks in M2M applications. From October 2005 to September 2008, he was a research engineer at France Telecom R&D/Orange Labs working on energy efficiency and self-organizing for wireless multihop networks, together with the CITI Laboratory, France. At that time, he has also been a member of the Student Activity and Award and Recognitions Committees, while serving as the Electronic Communications Coordinator of IEEE Region 8

(Europe, Africa, Middle-East and Russia). He obtained his PhD in Computer Science (2008) and MSc in Telecommunications (2005) from INSA Lyon, France. He has published several journal and conference papers, holds two patents, has contributed to three books, has given several international short-courses, and participated in standardization activities. He has been TPC member and member of the organizing committee of various conferences. He is reviewer for numerous IEEE and non-IEEE journals and a Member of the IEEE.

Jesús Alonso Zárate received his M. Sc. and Ph. D degrees in Telecommunication Engineering from the Universitat Politècnica de Catalunya (UPC, Spain) in March 2004 and February 2009, respectively. From 2004 to 2005, he worked as an Information Technology consultant at Everis (former DMR Consulting). In 2005, his Master Thesis was awarded with the Prize to the Best Master Thesis in Multimedia Communications (given by the Colegio Oficial de Ingenieros de Telecomunicacion, Spain) and he was granted by the Centre Tecnològic de Telecomunicacions de Catalunya (CTTC) to obtain the Ph. D. on Signal Theory and Communications at the UPC. While completing his Ph. D. degree, he was granted in 2006 by the European Space Agency (ESA) and by the Generalitat de Catalunya to attend the Space Studies Program (SSP'06) at the International Space University (ISU) in Strasbourg, France. He has also been a visiting teacher assistant at the Escola Politècnica Superior de Castelldefels (EPSC) of the UPC during the second semester of 2007. He is now with the CTTC holding a Research Associate position. Since 2009, he has started to take part of Technical Committees for the organization of international conferences and is supervising a number of MSc and PhD students. He has published over 30 scientific papers in renowned international journals and international conferences over the last years and he has also participated in both public funded and industrial research projects. He is also author of a book and three book chapters devoted to wireless communications.