Int J Wireless Inf Networks (2017) 24:240–242
DOI 10.1007/s10776-017-0362-3

Recent Advances in M2M Communications and Internet of Things (IoT)

Sassan Iraji[1] · Preben Mogensen[2] · Rapeepat Ratasuk[2]

Published online: 21 June 2017

Internet of Things (IoT) is expected to dramatically increase the number of connected devices. Multiple forecasts estimate that the number of IoT devices to go beyond 100 billion. The only question is when exactly this will take place. However, there is consensus that it will happen.

Over the last approximately three decades, Internet has brought a significant impact on our society. And during last decade, the Internet usage has been dramatically boosted by the availability of powerful smartphones and fast connectivity using Wi-Fi and cellular systems. IoT is expected to become the next big leap of the Internet, where almost anything can be connected. For upcoming 5G systems, the requirements aim to support 1000,000 devices per square kilometers.

M2M communications is seen as the nerve system for the Internet of Things (IoT). In the past, M2M communications was typically materialized using wired communication in order to achieve high reliability. Additionally the power consumption of the devices was so high that they required external power supply. With the evolution of wireless communication technologies and further evolution of sensor and actuator technologies, the power consumption and cost of wireless machine-type communications have been reduced significantly; and it is expected that this trend continues during forthcoming years. Applications for M2M communications can be divided into two main categories of massive and mission-critical M2M communications depending on their requirements. With massive M2M communications, we mean that the services typically span a very large numbers of devices that are usually equipped with sensors or actuators. Obviously, the amount of data generated by these devices and sensors is normally very small, and having very low latency is not required. In mission-critical M2M communications, on the other hand, very high reliability and availability as well as very low latency are required. Examples for these systems are traffic safety or control, control of critical infrastructure and wireless connectivity for industrial processes. These systems require different type of communications what it is known as Ultra-Reliable and Low-Latency Communications (URLLC).

Wireless has several obvious advantages over wired: ease and reduced cost of installation, higher flexibility, and the support of mobility, to mention a few. M2M communications is often divided into local area and wide area technologies. Local area technologies are providing access from a few meters and up to hundreds of meters, whereas wide area technologies provide a link budget allowing connectivity distances up to tens of kilometers.

The GSM system has been the most deployed wide area communication system used for M2M communications. However, many operators have recently announced to decommission GSM systems. This calls for new cellular wide-area M2M connectivity solutions, which can be either standalone or fully embedded into already deployed 4G/LTE networks by means of software upgrades. 3GPP (Third Generation Partnership Project), the standardization body responsible for standardizing cellular systems, has specified both Narrowband IoT (NB-IoT) and enhanced Machine-Type Communications (eMTC) in LTE release 13, which both have approximately 20 dB better link budget than LTE, and a modem complexity reduced to about 10% of LTE. They are also considered as low power technologies. The approximately 20 dB improved link

✉ Sassan Iraji
sassan.iraji@aalto.fi

1 Aalto University, Espoo, Finland

2 Nokia Bell Labs, Arlington Heights, IL, USA

budget ensures the same indoor coverage for NB-IoT and eMTC as in LTE for outdoor environment. Two other major low-power wide-area M2M communications technologies operating in unlicensed bands have also seen the light: LoRa and Sigfox. From an end-user perspective, the main difference between LoRa and Sigfox is in the business model. These low-power wide-area M2M technologies either have been recently or will be soon ready for commercial usage. Deployment is expected to mature fast during 2017 and 2018, and power consumption and price of modems are expected to reduce fast over the coming technology releases. In addition to the wide area M2M communications technologies, there exist also a palette of local area technologies such as Wi-Fi, low power Bluetooth (BLE), IEEE 802.15.4 (e.g., Zigbee and Z-wave), M-bus etc.

Battery lifetime is paramount in some IoT use cases, whereas in other use cases battery replacement is less critical. Taking for example a water meter; here the M2M connectivity electronics and battery are fully integrated and sealed—not allowing battery replacement. In practice this means that the water meter must be replaced by means of pluming work, when the battery runs out of power. In some cases the requirements to battery lifetime is 16 years. Due to battery self-drain, where approx. half the battery energy is lost to self-drain, the battery volume and cost start to play a significant role compared to the M2M connectivity electronics. Hence energy harvesting becomes a critical aspect for obtaining low volume and low weight IoT devices with long battery life time—in principle infinite.

Works on M2M Communications and IoT are intensive, with lots of standardization efforts going on to exploit these technologies in 5G era. The interest in the fields of M2M communications and IoT is clearly reflected in the amount of papers being published in journals and magazines as well as in conferences recently. The 27th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2016), held in Valencia, Spain in September 2016, is clearly an example of this, where many high-quality papers on M2M communications and IoT were presented. In particular, there was a dedicated full-day workshop titled "From M2M Communications to Internet of Things". This special issue of the International Journal of Wireless Information Networks captures the academic and industrial interests in the areas of M2M communications and IoT. It provides a set of seven selected papers among the best qualified contributions in PIMRC 2016, which have been updated and extended in contents and coverage.

The paper "Comparison of IEEE 802.11ah, BLE and IEEE 802.15.4 for a home automation use case" by Luis Felipe Del Carpio Vega et al. contributes in better understanding of main short-range wireless technologies that operate in unlicensed bands. Authors selected IEEE 802.11ah, Bluetooth Low Energy and IEEE 802.15.4 for performance comparison in terms of delay, service ratio, traffic loss, activity factor and battery lifetime in a home automation scenario. They also consider heterogeneous devices and different traffic loads. Their results show advantages and disadvantages with respect to the different performance indicators.

The paper ''Bacterial Foraging Optimization Scheme for Mobile Sensing in Wireless Sensor Networks'' by Ado Adamou Abba Ari et al. deals with a biologically inspired scheme of collaborative mobile sensing by maintaining coverage, the energy efficiency and a high network availability. Authors take advantage of social foraging behaviors of the Escherichia coli bacteria modeled in the Bacterial Foraging Optimization (BFOA) to achieve their goals, especially by using the chemotaxis and the swarming features that allow bacteria to move. They demonstrate the effectiveness of their approach with some experiments.

In the paper ''Fault Recovery in Time-Synchronized Mission Critical ZigBee-based Wireless Sensor Networks'' by Davide Scazzoli et al., the problem of single points of failure (SPF) for a ZigBee-based wireless sensor network is addressed by using multiple coordinators with different personal area network identifiers (PAN IDs). They propose a solution where members of a network switch from one coordinator to another in case of failure by changing their respective PAN ID. In this way, they improve synchronization accuracy.

The paper ''Evaluating Bluetooth Low Energy Suitability for Time-Critical Industrial IoT Applications'' by Raúl Daniel Rondón et al., explores the potential of BLE in meeting the real-time demands from the domain of industrial process automation and industrial IoT. Authors evaluate the suitability of the protocol for these scenarios. They also investigate thoroughly the effect of adaptations in the retransmission scheme on the reliability and timeliness performance.

In the paper ''Feasibility and Fundamental Limits of Energy-Harvesting Based M2M Communications'', by Jukka Rinne et al., the feasibility and fundamental limits of energy harvesting based M2M communications systems are addressed. Authors derive the fundamental limits and available operational time of the communicating nodes and provide extensive numerical results evaluated in different practical scenarios for low-power sensor type communication applications.

The paper ''Up-link Capacity Derivation for Ultra-Narrow-Band IoT Wireless Networks'' by Yuqi Mo et al. exploits two theoretical expressions for the outage probability in an ultra-narrow-band transmission (UNB) based IoT network. Then they estimate the network capacity as a function of the path-loss exponent, by determining the maximum number of simultaneous supported nodes. They conclude that the bandwidth should be set according to the properties of propagation channel.

In the paper ''Resource Allocations for Ultra-Reliable Low-Latency Communications'', by Hamidreza Shariatmadari et al, the problem of resource allocations in URLLC systems for mission-critical applications has been addressed. Authors propose a communication model for URLLC systems and based on that model they derive the optimal and sub-optimal resource allocations.

We hope and believe that the reader will enjoy this special issue. We would like to thank our expert colleagues who have generously helped us in reviewing papers and the authors for their efforts toward the completion of the papers. Finally, we express our gratitude to Dr. Kaveh Pahlavan for initiating this special issue and inviting us to undertake this rewarding activity.

Sassan Iraji received the Ph.D. degree from Tampere University of Technology, Finland, and the M.Sc. (with distinction) from Helsinki University of Technology, all in electrical engineering. He worked for Nokia from 1997 to 2012 holding various positions from senior research engineer, to senior technology manager, principal researcher, and research leader. He was the founder of the Internet-of-Things team at Nokia research Center in 2007. He is currently with Aalto University as a Research Fellow, where he teaches, manages research projects and guides graduate students. He has been working extensively on system, hardware, software and algorithm design for cellular mobile communication systems such as 5G, 4G (LTE & LTE-A), 3G, as well as short-range connectivity such as UWB, UHF RFID, NFC. He also worked on wireless multi-radio system design and mobile device communication and computing architecture for Nokia Symbian phones. He has numerous patents and papers published in the field. He is a senior member of IEEE. His current research interests fall within the field of wireless communication systems towards 5G and in particular M2M communications, ultra-reliable low-latency communications, and Internet of Things (IoT). He is the co-founder of Klick Technologies Ltd, a company active in the IoT area.

Preben Mogensen Professor and head of Wireless Communication Networks (WCN) section at Aalborg University. He is also affiliated with Nokia Bell Labs as Principal Engineer and a Bell Labs Fellow. He received his M.Sc. and Ph.D. from Aalborg University in 1988 and 1996, respectively. He has been the main- or co-supervisor of more than 40 successfully graduating Ph.D. candidates. He is currently engaged with IoT and 5G technologies. He has published more than 400 papers in the field of wireless communication and his Google Scholar h-index is 52.

Rapeepat Ratasuk Principal Research Specialist with Nokia Bell Labs, Arlington Heights, IL, USA. He received his Ph.D. degree in electrical engineering from Northwestern University, Evanston, IL, USA, in 2000. He has extensive experience in 3G/4G cellular system design and analysis, including algorithm development, performance analysis and validation, physical-layer modeling, and simulations. He is a co-author of the book titled Essentials of LTE and LTE-A and has published more than 45 papers. His current research interests are in the areas of 5G wireless networks and machine-to-machine communications.