The Challenge of M2M Communications for the Cellular Radio Access Network

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***Abstract*—Machine-to-machine (M2M) or machine-type communication (MTC) is expected to be one of the major drivers of cellular communications in the next decade. The term M2M communication covers a wide area of use cases and applications, thus resulting in context of cellular systems in highly diversified use cases, deployment scenarios and requirements. However, one common denominator is that today's mobile cellular systems are primarily designed for human communication.**

This contribution highlights the challenges which arise from the different M2M traffic and deployment characteristics on the radio interface of mobile cellular systems, as well as the current efforts in research and standardization to address the M2M communications requirements.

I. Introduction to M2M Communications

According to various market research forecasts, the number of M2M-capable devices, the generated traffic and, most important for mobile operators, the expected revenue of cellular M2M communications will grow strongly over the next decade. The numbers are up to half a billion for cellular M2M devices [1] in 2014, and expected revenue of $\$3.8\,$bln [2] in 2015, respectively.

The relatively broad definition of M2M communication, or more precisely, the wide range of associated use cases, constitutes a challenge for the design of mobile cellular networks. Although this variety is in principle beneficial in terms of opportunities, it also makes it more difficult to define common characteristics and, accordingly, requirements fundamental for the system design of M2M-optimized cellular systems.

In principle, M2M communication is not a new concept. Already today, many communication systems in the industrial area (e.g. fleet management, toll collect systems, goods tracking) are operational using today's mobile cellular infrastructure such as SMS over GSM systems. The main driver for the evolution of cellular systems for M2M is therefore the expected increase in data volume and, more important, number of connections.

II. Use Cases and Requirements for Cellular Systems

Typical use cases for M2M communications include [3], [4]

- Metering and control of electricity, gas, heat, and water. Smart meters are immobile devices with very long maintenance intervals (several years), which is a challenge for meters which are solely battery-powered. Communication between the meter devices and the providers today is characterized by long time intervals. However, for future smart power grids, much shorter time intervals may be necessary (several minutes down to seconds), as the abilities to control the energy-network are manifold and closed-loop control will be implemented.
- eHealth denotes the envisioned use of cellular devices to monitor the health state of the user, such as blood pressure, heart beat rate, etc. While this information is usually aggregated at the device and then transmitted as bulk message, the device could also react on emergency events, implying stronger requirements on latency and transmission reliability.
- Intelligent Transport Systems (ITS) describes the use of communication to enhance transport security and efficiency. Recently, cellular communication technologies are one of the candidates for car-to-x communication, which has strong requirements on latency and mobility.
- Surveillance is one aspect of the larger use case "public safety", where video cameras are transmitting either constantly, or at certain event triggers, a relatively low data rate video stream. The requirements on QoS corresponds thus to "normal" video streaming.

	Smart meters	eHealth	ITS	Surveillance
mobility	none	normal	high	none
message size	low	medium	medium	high
traffic pattern	regular	random	random	regular
device density	high	medium	high	low
latency req.	low	high	high	medium
power eff.	high	high	low	medium

TABLE I
Requirements of different M2M uses cases on communication network

Table I illustrates the diverse requirements and characteristics of different M2M use cases on the transport network. The design of M2M enhancements for cellular RAN focuses on areas where a deficit is recognized.

III. Challenges for Mobile Cellular Networks

An analysis of the M2M requirements, performed e.g. in [5], [4], reveals that the challenges from M2M communications arise mainly from the following requirements:

- Support for a very high number of devices per cell.
- Support for different traffic characteristics of M2M communications, such as small message size and regular transmission intervals.
- Low latency and high reliability.
- Low and ultra-low power consumption.
- Support for different mobility profiles
- Finally, the requirement that human-to-human communication (i.e. normal operating network) must not be negatively affected by M2M communications.

As an example, Fig. 1 shows the estimated number of smart meters vs. the cell radius in some typical urban and suburban scenarios, specifically in New York City, Washington D.C. and London. The data is based on the population density in the respective area, and the number of meters per house hold (in this case assumed to be 1). The black lines indicate typical cell radii and correspondingly, the number of meters. In the worst case, i.e. in the case of London with 2 km cell radius, the expected number of meters exceeds $35,000$, see [6] for further details of the London scenario.

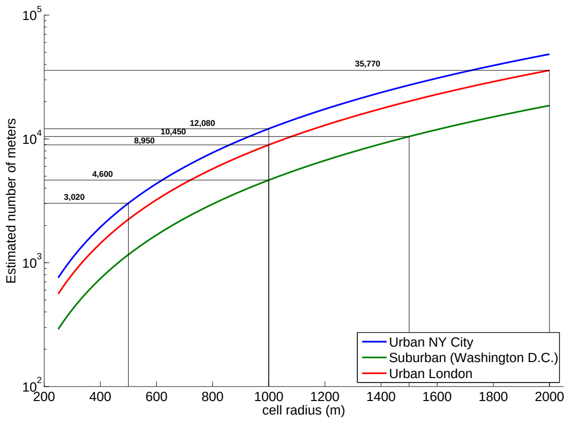

Fig. 1. Expected number of smart meters vs. cell radius

On the cellular RAN, some of the identified research challenges include:

- Congestion in the random access channel, both for network entry and for contention-based bandwidth request mechanisms. A large number of devices attempting to access the channel at the same time needs mechanisms for prioritization and isolation between different access classes and device types.
- Group management and addressing of devices.
- Very long idle times to reduce power consumption.
- Efficient, low-overhead handling of small message sizes in conjunction with large transmission intervals.
- Mobility management optimized for stationary or very high mobility scenarios.
- Lightweight and low-overhead security mechanisms.

IV. Standardization Efforts

Various standardization bodies are currently in the process to define specifications for M2M communications, such as 3GPP responsible for UMTS, LTE and LTE-A, and IEEE, covering the 802.16 WirelessMAN (mobile WiMAX) standard family.

A. 3GPP

In 3GPP, M2M communications is denoted as Machine-Type Communication (MTC). The work items titled Network Improvements for Machine Type Communications (NIMTC) and System Improvements for MTC (SIMTC) are active since 2008 and 2010, respectively. The focus both work items is mainly on LTE (NIMTC) and LTE-Advanced (SIMTC) [7], [8].

B. IEEE

In the IEEE 802 LAN/MAN Standards Committee, several task groups (TGs) are addressing the impact of M2M communication on the radio access network. The IEEE 802.16p TG aims for enhancing the mobile WiMAX base standards IEEE 802.16e and IEEE 802.16m for M2M, identifying a number of requirements for mainly MAC-related functions such as network entry, group and device addressing, etc [9].

Other working groups addressing M2M communications include IEEE 802.11 and IEEE 802.15.4, which is the base standard for the ZigBee standard family.

V. Conclusion

The growing market of M2M communication is one of the most active research areas for mobile cellular networks. The challenges for the cellular RAN arise mainly from the diverse characteristics of M2M traffic in conjunction with the massive number of devices, and the wide range of requirements on mobility, latency, reliability, security and power consumption. Both the research community as well as the standardization bodies have recognized the potential, and are in the process of addressing the challenges for future network M2M communications.

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