Basic principles of Machine-to-Machine communication and its impact on telecommunications industry

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It has been estimated that by the end of 2020 there will be 50 billion connected devices world-wide. Such projections entice the industry to explore and tap a wide range of opportunities that the M2M (Machine-to-Machine) communication concept offers, enabling novel business cases, enhanced workflow efficiency and improved quality of life. It is therefore no surprise that prominent telecommunication association and standardisation bodies such as 3GPP and ETSI are largely involved in providing standards and recommendations in the context of M2M communication. In order to engage in the prospective area of M2M and fully exploit its potential, a thorough understanding of M2M basic architecture and principles is essential. A systematic approach is also necessary in continuously keeping track of current M2M related activities and achievements by industrial parties of various verticals such as automotive, healthcare, transport etc. This paper brings forward an overview of M2M basic architecture and principles, development of standards and proposed requirements, as well as an insight into its current industry adoption accompanied by a selection of specific examples.

I. INTRODUCTION

The abbreviation M2M denotes various concepts, namely: Man-to-Machine, Machine-to-Man (meaning communication between a human operated device and a machine), Machine-to-Mobile and Mobile-to-Machine [1]. However, the most common meaning is Machine-to-Machine, which is referred to in this paper. Essentially, Machine-to-Machine (M2M) communication refers to communication between computers, embedded processors, smart sensors, actuators and mobile devices without, or with only limited, human intervention [2].

M2M is a new business concept originating from the telemetry technology, used for automatic transmission and measurement of data from remote sources by wire, radio or other means [3]. The main difference between telemetry and M2M is the business and operational aspects that allow M2M to proliferate in many ways. Typically, M2M is based on very common and ubiquitously used technologies – wireless sensors, mobile networks and the Internet. Even though both telemetry communication and M2M communications are based on the transmission of sensor data, there is a major difference between the two – whereas older telemetric solutions used a random radio signal, M2M communications use existing networks, such as wireless networks used by the public, as a means to transmit the data.

M2M employs and reinforces a convergence of various technology families, such as IP, RFID, sensor networks, home networks, smart metering, etc. Its communication principles are present in many different industry verticals. Some of the most prominent M2M supported application areas are [1]:

- security – surveillance applications, alarms, object/human tracking, etc.;
- transportation – fleet management, emission control, toll payment, road safety, etc.; remarkably interwoven with Intelligent Transport Systems (ITS) concepts;
- e-Health – remote patient monitoring, Mobile Health, telecare;
- manufacturing – production chain monitoring and automation;
- utilities – measurement, provisioning and billing of utilities such as oil, water, electricity, heat, etc.;
- industrial supply and provisioning – freight supply and distribution monitoring, vending machines, etc.;
- facility management – informatisation and automation of various home/building/campus-related resource management.

Many industry participants, especially in the telecommunications domain, have recognised the business opportunities that M2M represents and are striving to exploit its full potential, as it will be further discussed later in this paper.

This paper is organised as follows. In Section 2, we introduce basic M2M architecture explaining M2M devices, gateways and area networks components. Section 3 gives an overview of standardization efforts in the M2M domain, while Section 4 brings forth some real word examples where different machines interact in M2M manner. Finally, Section 5 concludes the paper.

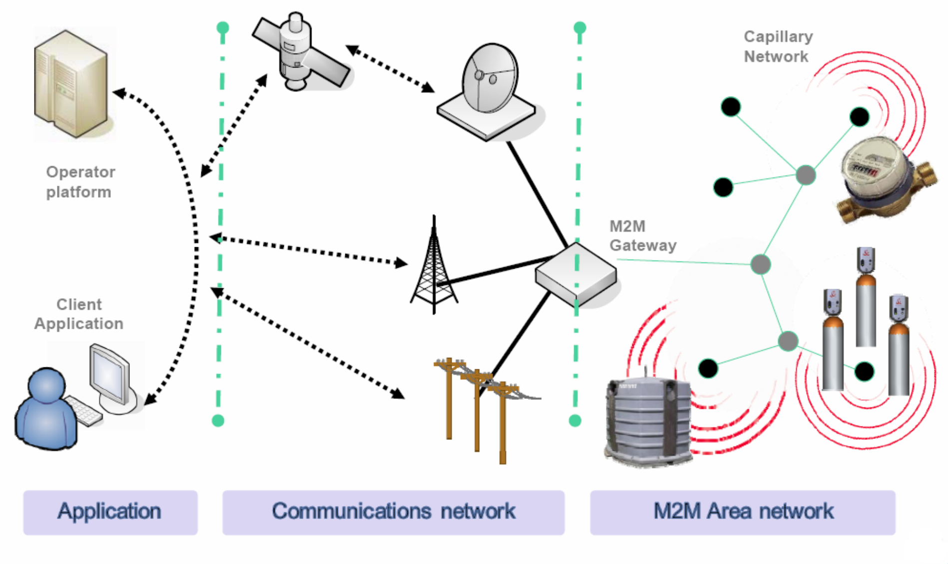

Figure 1 - Basic M2M architecture

II. M2M DATA MANAGEMENT AND BASIC ARCHITECTURE

Although every particular deployment of M2M is unique, there are four basic stages that are common to most M2M based applications [4]:

- collection of data;
- transmission of data through a communication network;
- assessment of data;
- response to the available information.

The M2M basic architecture is depicted in Figure 1. M2M devices reply to requests for data contained within them or transmit the data automatically. They can be of various kinds – temperature sensors, motion detectors, level indicators, etc. If the monitored machine is sufficiently complex, it can use the M2M module as its modem enabling the transmission of the data. However, if the monitored machine is made of switches and simple circuits and is not able to exhibit a sufficiently intelligent behaviour, then it is appointed the slave role and is controlled by the M2M module.

M2M devices may constitute an M2M area network, which can be realised as, e.g. a Bluetooth based personal area network of body sensors. M2M gateway provides interconnection of M2M devices and forwards data collected from them to communications network.

The communications network serves as infrastructure for realising communication between M2M gateway and M2M end-user application or server. For this purpose cellular network, telephone lines and communication satellites can be used [4]. The widespread coverage of cellular packet based networks and their continuously decreasing costs are the one of the main reasons that M2M is getting increasingly spread world-wide. There are several means of sending data over the cellular network, such as CDMA and GPRS. The advantage of cellular data services is the ability to send large amounts of data frequently. This means of data transfer is usually most convenient as telephone lines require implementation that can be rather complicated, and satellite transmissions, which are of particular use in remote monitoring over large distances, are commonly very cost and energy-inefficient.

Finally, when data reach an M2M application, they can be analysed, reported and acted upon by a software agent or a process, depending on the specific system design.

III. STANDARDISATION EFFORTS IN THE M2M DOMAIN

The industry has become more active in the standardization process in the M2M domain because of the market demands. Although, M2M is mostly related to the application level (i.e. an area typically outside the scope of the standard bodies) some wireless access standard groups (e.g. IEEE, 3GPP and ETSI) are looking into the impacts to the existing network due to potentially heavy use of M2M devices. In this paragraph we will present some of the standards from the 3GPP and ETSI.

A. 3rd Generation Partnership Project standards

The 3GPP (3rd Generation Partnership Project) [5] is collaboration between groups of telecommunications associations, to make a globally applicable third-generation mobile phone system specification within the scope of the International Mobile Telecommunications-2000 project of the International Telecommunication Union. 3GPP specifications are based on evolved Global System for Mobile Communications specifications encompassing radio, core network and service architecture.

3GPP identified M2M (also called MTC (Machine Type Communication)) as a strategic topic in mid-

2007. Technical specification groups responsible for M2M/MTC standards are within Service and System Aspects groups, namely WG1 (Working Group) Services [6], WG2 Architecture [7], WG3 Security [8], GERAN WG2 [9] and RAN WG2 [10]. Table 1 shows a list of technical reports and specifications standardized from 3GPP.

Table 1 - Standardization of 3GPP in the field of M2M

TS 22.030 [11]	Man-Machine Interface of the User Equipment
TR 22.868 [12]	Study on facilitating M2M communication in GSM and UMTS
TR 22.888 [13]	Study on enhancements for MTCs
TR 22.988 [14]	Study on alternatives to E.164 for MTCs
TR 23.888 [15]	Architectural enhancements for MTCs
TR 33.812 [16]	Feasibility study on the security aspects of remote provisioning and change of subscription for M2M equipment
TR 37.868 [17]	Study on RAN improvements for MTCs
TR 43.868 [18]	Study on GERAN improvements for MTCs

3GPP standards in the M2M domain are mostly connected to improvements in radio access networks (i.e. TR 43.868 and TR 37.868) standardized by GERAN WG2 and RAN WG2. Another group of standards is related to identifying potential requirements to facilitate improvements in M2M communication and to the more efficient use of radio and network resources (i.e. TR 22.868 and TR 22.988). This group of standards is done by 3GPP WG1 Services. Additionally, 3GPP WG3 Security put some efforts to identify and standardize secure issues while provisioning new versions of software and changing network operators' subscription (i.e. TR 33.812), while WG2 Architecture provided some architectural enhancements for MTCs (i.e. TR 23.888).

B. *Standards of the European Telecommunications Standards Institute*

The ETSI (European Telecommunications Standards Institute) [19] produces globally-applicable standards for Information and Communications Technologies, including fixed, mobile, radio, converged, broadcast and Internet technologies. A new ETSI Technical Committee [20] is developing standards for M2M Communications. This group aims to provide an end-to-end view of M2M standardization cooperating with ETSI's activities on Next Generation Networks and 3GPP standards initiative for mobile communication technologies.

Table 2 - Standardization of ETSI in the field of M2M

TS 102 689 [21]	M2M service requirements
TS 102 690 [22]	M2M functional architecture
TR 102 691 [23]	Smart metering use cases
TR 102 725 [24]	M2M definitions
TR 102 732 [25]	M2M use case - eHealth
TR 102 857 [26]	M2M use case - Connected Consumer
TR 102 897 [27]	M2M use case - City Automation
TR 102 898 [28]	M2M use case - Automotive Applications
TS 102 921 [29]	M2M mIa, dIa and mId interfaces
TR 102 935 [30]	Impact of smart grids on M2M platform

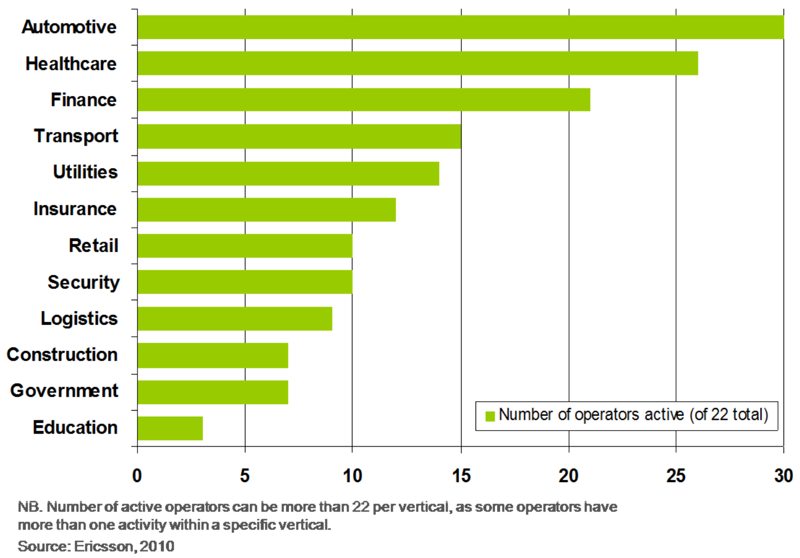

Figure 2 - Number of M2M operators engaged in various industry branches

In the M2M domain, ETSI standards mostly consider different use cases (i.e. TR 102 691, TR 102 732, TR 102 857, TR 102 897, TR 102 898). Nevertheless, some efforts have been also put in defining M2M concepts (i.e. TR 102 725), as well as in standardizing M2M service requirements (i.e. TS 102 689) and functional architecture (i.e. TS 102 690).

IV. BUSINESS IMPACT

It has already been mentioned that M2M paradigm offers a plethora of opportunities for development of novel business cases and significantly increasing the current. Many industries are being transformed with respect to their business processes, resulting from engineering market changes driven by substantial increase of M2M pervasiveness. E.g. in the energy sector, smart metering increases business efficiencies and decreases operational expenses for energy companies; transportation tracking solutions improve route optimization and safety for vehicles on the road; the healthcare industry is also looking into improvement of patient care through instant device communications, remote monitoring and disease management [31].

Mobile broadband plays a central role in the increased connectivity of things. It is forecast that the M2M communication industry's upcoming rapid increase is driven mainly by new initiatives by major mobile operator groups mostly from Europe and North America (Telenor, Orange, Vodafone, T-Mobile, Telefónica, AT&T, Verizon), which are geographically main market areas with about 50 percent of the total number of M2M connections worldwide [32].

Among industry verticals benefitting from M2M paradigm, automotive industry is assessed as the largest as it alone accounted for approximately 40 percent of total number of wireless M2M connections in 2009 [32]. Other industry verticals employing M2M principles are given in Figure 2.

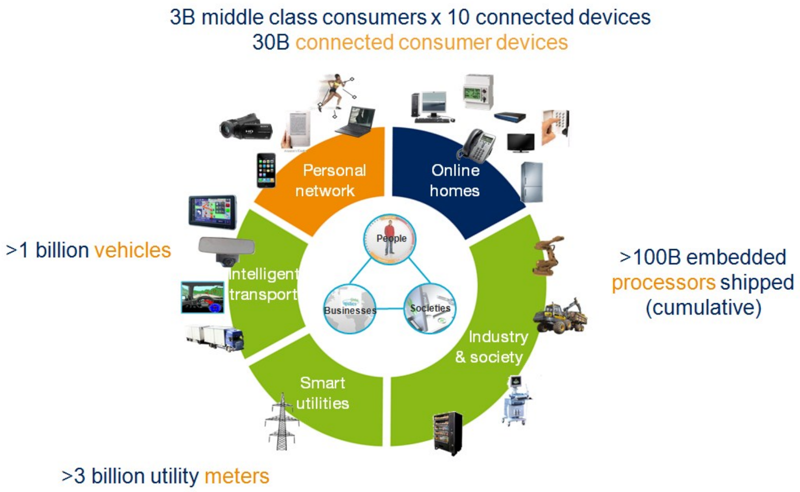

Figure 3 - Ericsson's projections for 2020 entailing the number of connected devices reaching 50 billion

A. *Ericsson's 50B programme*

50 Billion Connected Devices (shortly 50B) is Ericsson's current strategic programme of tapping new business opportunities resulting from a vast number of connected devices in near future. Namely, the programme owes its name to Ericsson's projection of approximately 50 billion connected devices by the year 2020. This projection is depicted by Figure 3.

The need for a uniform strategy concerning connection of a vast number of devices exists as prior to 50B programme Ericsson's coverage of the pertaining areas was spotty and therefore with weak prospects of gaining a serious market penetration momentum.

According to certain estimations (see [32]) the share of M2M enabled devices will take up to 3.1 per cent of total mobile subscriptions by 2014. It is clear that the 50B programme must therefore put a strong emphasis on the area of M2M type of communication.

B. *Ericsson's M2M based projects*

Even before the commencement of the 50B strategy, Ericsson has conducted numerous M2M based projects. They are/were dealing with devising common infrastructures for facilitation of integration of M2M solution components, solving various communication and interoperability issues, as well as designing solutions for enhancing traffic safety. A brief introduction to selected projects representing each group is given in the rest of this section.

SENSEI (full name "Integrating the Physical with the Digital World of the Network of the Future") [33] was conducted during 2008 – 2010. The main vision was to deliver a highly scalable architectural framework with corresponding protocol solutions that enable plug and play integration of a large number of globally distributed WS&AN into a global system. Also, an open service interface and corresponding semantic specification were devised in order to unify the access to context information and actuation services offered by the system for services and applications.

The vision of the RUNES project (full name "Reconfigurable Ubiquitous Networked Embedded Systems"; 2005 – 2007) [34] was enabling the creation of large-scale, widely distributed, heterogeneous networked embedded systems that interoperate and adapt to their environments. Its main objective was to provide an adaptive middleware platform and application development tools that allow programmers the flexibility to interact with the environment where necessary, whilst affording a level of abstraction that facilitates application construction and use. The application areas range from healthcare, to emergency services, to factory automation, to in-home safety and security.

CoCar (full name "Connected Cars"; on-going) is a project co-funded by German Federal Ministry of Education and Research, which investigates the feasibility of cellular (3G+) communication technologies for the transmission of telematic information for future cooperative applications in the automotive domain. The project envisions an interconnection of traffic entities, both vehicular and infrastructural, in order to ensure a safer traffic with an efficient flow, endowed with various infotainment services. Certain requirements are addressed, such as quick response and short communication delay for safety related applications, high throughput for infotainment applications, and high spatial and temporal availability. A typical use case scenario is issuing a warning on a road hazard, such as accident, emergency breaking, bad road condition, or works in progress, to all vehicles in vicinity via wireless network in order to prevent further complications.

C. *Solutions from Nokia, Siemens and Motorola*

In 2002 Nokia introduced its own *M2M Platform* consists of two main elements: the *Nokia M2M Gateway* and the *Nokia GSM connectivity terminals* [36]. Nokia M2M Gateway is middleware bridging the GSM network and the Internet, while *Nokia GSM connectivity terminals are* M2M communications devices with versatile interfaces and advanced functions (e.g. wireless connectivity via GSM 850/1900/GPRS networks).

In 2006 Siemens launches the AyOne [38], a M2M multipurpose device that can be used in various monitoring scenario (e.g. as a baby monitor/alarm, a telephone for children, a fall detector for the elderly and handicapped) since it contains different sensors for temperature, noise, brightness, etc.

Motorola offers various embedded M2M Wireless Modules (e.g. HSPA modules, GSM/GPRS LGA wireless modules) [39] that allow wireless M2M communication to different remote devices.

V. CONCLUSION

The number of interconnected machines will very soon exceed the overall population count. Therefore, it is of vital importance to be able to understand Machine-to-Machine (M2M) interactions. In this article we focus on giving a short overview of M2M communication principles and basic architecture. Furthermore, we present efforts of different standardisation bodies and their recommendations concerning open issues in the M2M field. Additionally, we bring forward an introduction to Ericsson's *50 Billion Connected Devices* strategy, as well as provide a brief description of M2M based solutions from various leading telecommunications industry participants such as Ericsson, Nokia, Siemens and Motorola.

REFERENCES

[1] *M2M activities in ETSI*, Powerpoint presentation, SCS Conference, Sofia Antipolis, 2 July 2009

[2] Watson, D. S., *Machine to Machine (M2M) Technology in Demand Responsive Commercial Buildings*, presented on 2004 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, USA, August 2004

[3] Dye, S., *Machine-to-Machine (M2M) Communications*, http://www.mobilein.com/M2M.htm

[4] M2M Communications website, *What is M2M communications*, http://www.m2mcomm.com/about/what-is-m2m/index.html

[5] 3rd Generation Partnership Project website, http://www.3gpp.org/

[6] 3GPP Working Group 1 Services website, http://www.3gpp.org/-SA1-Services

[7] 3GPP Working Group 2 Architecture website, http://www.3gpp.org/-SA2-Architecture

[8] 3GPP Working Group 2 Security website, http://www.3gpp.org/-SA3-Security

[9] GERAN WG2, http://www.3gpp.org/GERAN-2-Protocol-Aspects?page=type_urls

[10] RAN WG2, http://www.3gpp.org/RAN2-Radio-layer-2-and-Radio-layer?page=type_urls

[11] 3GPP TS 22.030, http://www.3gpp.org/ftp/specs/html-info/22030.htm

[12] 3GPP TR 22.868, http://www.3gpp.org/ftp/specs/html-info/22868.htm

[13] 3GPP TR 22.888, http://www.3gpp.org/ftp/specs/html-info/22888.htm

[14] 3GPP TR 22.988, http://www.3gpp.org/ftp/specs/html-info/22988.htm

[15] 3GPP TR 23.888, http://www.3gpp.org/ftp/specs/html-info/23888.htm

[16] 3GPP TR 33.812, http://www.3gpp.org/ftp/specs/html-info/33812.htm

[17] 3GPP TR 37.868, http://www.3gpp.org/ftp/specs/html-info/37868.htm

[18] 3GPP TR 43.868, http://www.3gpp.org/ftp/Specs/html-info/43868.htm

[19] The European Telecommunications Standards Institute website, http://www.etsi.org/WebSite/homepage.aspx

[20] ETSI Technical Committee for M2M Communications website, http://portal.etsi.org/portal/server.pt/community/M2M/319

[21] ETSI TS 102 689, http://www.etsi.org/deliver/etsi_ts/102600_102699/102689/01.01.01_60/ts_102689v010101p.pdf

[22] ETSI TS 102 690, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=30459

[23] ETSI TR 102 691, http://www.etsi.org/deliver/etsi_tr/102600_102699/102691/01.01.01_60/tr_102691v010101p.pdf

[24] ETSI TR 102 725, http://docbox.etsi.org/M2M/Open/Latest_Drafts/00004v030.pdf

[25] ETSI TR 102 732, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=31429

[26] ETSI TR 102 857, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=31907

[27] ETSI TR 102 897, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=31967

[28] ETSI TR 102 898, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=31968

[29] ETSI TS 102 921, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=34000

[30] ETSI TR 102 935, http://webapp.etsi.org/WorkProgram/Report_WorkItem.asp?WKI_ID=34662

[31] Svensson, A., *Mobile broadband is shaping the M2M society*, in the theme in the theme *How can we make our cities sustainable?*, April 2009, http://www.ericsson.com/thinkingahead/idea/100422_m2m_20100422144733

[32] Ryberg, T., *The Global Wireless M2M Market*, Berg Insight report, 2009, https://ericoll.internal.ericsson.com/sites/RLAM_Info_Marketing/Documents/Reports/Berg%20Inside/The%20global%20wireless%20m2m%20market%202009-12-14.pdf

[33] SENSEI website, http://www.ict-sensei.org/

[34] RUNES website, http://www.ist-runes.org/

[35] CoCar website, http://www.aktiv-online.org/english/aktiv-cocar.html

[36] NOKIA M2M Platform website, http://www.nokia.com/press/press-releases/archive/archiveshowpressrelease?newsid=852459

[37] Nokia M2M Gateway, http://www.roundsolutions.com/pdf/m2m%20gateway.pdf

[38] Sensors-in-a-box: a novel Siemens M2M solution, http://securitysa.com/news.aspx?pklnewsid=21170

[39] Motorola M2M Wireless Modules, http://www.motorola.com/business/v/index.jsp?vgnextoid=fb55746773518110VgnVCM1000008406b00aRCRD