

Machine-to-Machine: Emerging market and consequences on existing regulatory framework

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Abstract—In order to improve business more and more different systems nowadays rely on M2M communication. It provides benefits to companies in various industries, individuals, communities, and organizations in both public and private sector. Automated services and data management, remote diagnostics and real-time statistics are just a few of many benefits of using M2M communication. This paper discusses current situation of M2M systems, with emphasis on mobile networks as their enablers, provides analysis of M2M market and business models, gives insight in current standardization efforts and what needs to be done through regulation of numbering plans to encourage emergence of new M2M services. The paper also gives a short overview of the current situation of M2M regulation in Croatia and outlines several ongoing regulatory challenges.

Keywords—Machine-to-Machine; mobile network operator; M2M regulation;

I. INTRODUCTION

Machine-to-Machine (M2M) services have recently come into the spotlight of mobile network operators (MNO) as traditional services started to either decline or dramatically slow their revenue growth: global mobile voice and messaging market will decline from U.S.\$758 billion in 2012 to U.S.\$746 billion in 2013 [1]. Predictions made by Yankee Group introduce M2M as the flagship communication technology in the following period of 3 to 5 years with compounded annual growth rate (CAGR) of 23% [2]. The availability of wireless access networks, declining prices of M2M modules, as well as widespread government and regulatory incentives in the European Union (EU) have all contributed to the overall positive atmosphere in the M2M markets. EU plans to achieve 80% smart metering coverage of households by 2020 and regulate through an eCall initiative that all new cars must have a built-in M2M device for collision alerts [3]. Apart from these examples backed by the governments, private businesses have also found interest in numerous applications of the M2M technology such as eHealth, cargo tracking, or utilities management, and have started to heavily invest in their development and implementations.

Machine-to-Machine and Internet of Things (IoT) systems largely overlap, but given the following definitions, they

cannot be considered completely the same. IoT, as its name suggests, is composed of numerous devices (including static, non-intelligent devices, and their context) capable of connecting to the Internet, i.e. devices with Internet Protocol (IP) support. Devices (“things”) in such systems include large variety of device types with typically constrained computational or battery resources at their disposal, so much effort is directed into simplifying Hypertext Transfer Protocol (HTTP)/Transmission Control Protocol (TCP)/IP protocol stack which is the basis of Internet applications today: CoAP (Constrained Application Protocol) [4] is used as a simplified version of HTTP, then tinyTCP, IP for Smart Objects, etc. M2M systems, on the other hand, in their architecture outlined in [5] define M2M Area Networks which can include devices connected using non-IP connectivity technologies such as Bluetooth, ZigBee, or wireless M-BUS [6]. Some authors consider M2M communication as one of the most important enablers of IoT, but according to [7] although their domains largely overlap, neither can be considered subset of the other.

Both technologies largely focus on ubiquitous connectivity of geographically distributed devices/machines, and the notion that human intervention in such systems is minimal or non-existent. Abi Research’s definition of M2M paradigm involves machines that communicate with remote application infrastructure using available network resources for the purpose of monitoring or control [8]. Idea of automated systems comprised of distributed entities is over 20 years old, but just recently, in the last few years, has encountered perfect prerequisites for significant growth. Mark Weiser during his tenure at Xerox Research Center at the beginning of 1990s coined the term “ubiquitous computing” to describe the miniaturization of devices and sensors, and their integration in everyday life [9]. End of the 1990s saw the continuation of these initial efforts, as Auto-ID Center of the Massachusetts Institute of Technology (MIT) standardized radio-frequency identification (RFID) technology which became the basis of what Kevin Ashton named IoT. Around that same time, the term M2M emerged in Siemens research labs as they developed and launched a GSM data module called “M1”. It was based on the Siemens mobile phone S6 for M2M industrial applications and enabled machine communication over mobile networks [10]. Today, M2M systems ought to be wireless,

robust, scalable, and energy efficient. Thanks to the rapid development of access networks, the price decline of communication modules that enable M2M connectivity, and the widespread standardization efforts, M2M systems are growing and rapidly changing our everyday lives.

This paper is structured as follows. In section 2 we discuss actual trends in the M2M market with focus on M2M systems based on mobile networks as their dominant wide-area solution, while section 3 brings standardization challenges in mobile networks used for M2M communication. Section 4 deals with regulation of numbering plans for M2M services and analyses several important ongoing M2M regulatory issues. Section 5 concludes the paper and brings future work considerations.

II. M2M MOBILE NETWORK OPERATOR MARKET

As it was suggested in the introduction, M2M as a communication paradigm is not a revolutionary idea of the last few years because it exists, even in practice, for last two decades. However, only recently the necessary technology became available at an appropriate cost so that M2M systems bring meaningful revenues to the operators. According to [11], IoT and M2M communication market in 2011 was worth \$44.0 billion, and is expected to grow \$290.0 billion by 2017. Europe accounted most of the global revenue (about 30%), with Asia-Pacific and North America regions following on second and third place. From 2012 to 2017 Europe's M2M market CAGR is going to be 27.4%, while Asia-Pacific and North America will grow at a CAGR of 33.2% and 28.3%, respectively [11].

Currently, it could be said that mobile networks are at the brink of a change. More than 5.75 billion mobile devices, including 5.2 billion devices connected to Global System for Mobile Communications-Long Term Evolution (GSM-LTE) networks, are in service around the world [1]. Obviously, the potential scale of M2M communication is much larger than that of human users. This is one of the reasons despite the fact that M2M devices provide low average revenue per unit (ARPU) compared to handsets (2-10\$ a month vs. \$50 per month), their sheer numbers help mobile network operators to maximize revenues. They offer high margins and a new path to profits. It was analyzed that even enterprises with substantial initial M2M deployment costs can realize a quick return on investment (ROI) as they minimize unnecessary expenditures and maximize productivity within their businesses [2]. This encourages MNO's and other stakeholders in the market to invest even further in the development of new M2M systems and the accompanying business models.

When discussing current M2M systems it is still important to emphasize that, despite their variety, they are still dominantly vertical [12]. This means that such systems are specialized and strictly attached to one certain application (e.g. cargo tracking), and the interoperability between them or between them and M2M systems based on other applications is still limited. Therefore, significant effort is invested into the development of horizontal M2M platforms that are capable of reusing and redeveloping specific vertical solutions by relaxing the vertical barriers and facilitating the development of applications that would productively integrate data from

different device domains. "Horizontal" means that M2M platform is a coherent framework valid across a large variety of business domains, networks, and devices and enables functional separation between application and network layers. It is based on a set of capabilities in the form of software modules that are offered to the M2M services in order to accelerate their development, test, and deployment life cycles, and most importantly reduce cost [7]. Strategic partnerships that have emerged over the last few years between mobile network operators and specialized platform developers are proof that they are fully aware of the platform's significance in developing new businesses and offering new types of services. Standardization of M2M communication and services, and network technologies used in their provisioning, are also very important trends that are currently being pursued and that have significant impact on M2M market growth. All these efforts should lower prize of the development of new M2M services, ease their integration into the systems, and enable interoperability. Discussion regarding standardization efforts in mobile networks, as well as the emergence of global standards initiative oneM2M, can be found in the following chapter.

A. M2M Communication in Mobile Networks

M2M systems are characterized by the diversity of deployed devices and the associated applications they provide. For example, some devices require minimal power consumption and occasionally send few bytes of data (e.g. reporting sensor measurements), while others are connected to power source and continuously send large amounts of data (e.g. streaming HD video). Also, some devices are stationary, while others are mobile. There are numerous categorizations of M2M devices that try to cover all of these possibilities, and one of them is in more details analyzed in the next section.

In addition to device diversity, M2M systems are characterized by their access network diversity. Unlike the supervisory control and data acquisition (SCADA) systems which are based on proprietary technologies, M2M systems are based on standardized technologies. They do not depend on underlying access network technology, and can be used in a wide range of wired or wireless solutions (digital subscriber line (DSL), Wi-Fi (IEEE 802.11), cellular/mobile 2G/3G/4G, satellite, etc.). Compared to mobile networks, ZigBee (IEEE 802.15.4) or Bluetooth (IEEE 802.15.1) offer cheaper chipsets and reduced power consumption. However, despite these benefits, they remain constrained by their short range and limited throughput, and therefore cannot be considered as a valid M2M access network solution, rather an M2M Area Network one.

Mobile virtual network operators (MVNOs) have been in the focus of M2M service provisioning in mobile networks for years because of their dominant role in the initial deployments of M2M systems [6]. During that time MNOs acted primarily as bandwidth providers, while MVNO's took care of the rest. However, revenue decline from traditional services and continuous rising need for M2M connectivity motivates MNOs to more actively engage and try to claim leading role in the M2M market. Many operators established dedicated M2M departments, formed strategic partnerships with M2M service platform providers (e.g. AT&T and Jasper Wireless) or even

deployed their own in-house solutions. Their partnership with MVNOs still offers clear benefits: MVNOs provide their specialized know-how in application and integration services, but analyses clearly show that in 2013 MNOs worldwide want to claim leading market positions from MVNOs.

Mobile networks today are composed of few cooperating generations of standards that provide services to end-users. Although LTE coverage is gaining momentum, which has instant impact on the operator's ability to provide data services, voice services are still dominantly 2G based, i.e. based on Global System for Mobile Communications (GSM). This has substantial effect on one particularly attractive feature of M2M systems, churn. In contrast to mobile handsets, M2M devices are supposed to work on same network for the next 10-15 years or even more. In other words, typically low or non-existent churn of deployed M2M devices could force operators to continue to operate and maintain their 2G networks, especially in the case of services which utilize small bandwidth resources.

M2M systems started to change the way business is conducted by creating greater visibility, transparency, and efficiency in multiple layers of the enterprise, including the following five key functions [2]:

- decreasing fuel costs – Varying oil prices with the tendency to rise represent an important business and everyday life factor. Location-based M2M applications enable optimization of vehicle routes and improvement of delivery schedules which significantly reduces fuel consumption.
- curtailing unnecessary jobs – M2M applications across all verticals help businesses automate simple tasks and allocate valuable human capital to higher revenue-generating activities. The well-known example is remote smart metering which eliminates the need for manual walking and reading of geographically dispersed metering devices.
- revolutionizing customer service models – M2M devices enable maintenance departments to create proactive service models. For example, remote monitoring allows companies to diagnose problems off site and with timely intervention prevent them from evolving and becoming more expensive.
- creating visibility into existing business processes – New M2M deployments generate large amounts of data which has significant business intelligence potential. Integrating the feedback from M2M devices into customer relationship management (CRM) and enterprise resource planning (ERP) back-end systems are some of the possibilities. For example, an enterprise with industrial machines can monitor their processes, study how they operate to design new models, and ultimately improve business operations.
- generating new revenue streams – The increased availability of 3G and 4G mobile networks and the associated M2M wireless modules enables enterprises to leverage mobility and create new revenue streams. Examples include, on the retail side, wireless point-of-

sale (PoS) systems and kiosks that allow retailers to capitalize on e.g. sporting events and seasonal trends.

B. Categories of Connected M2M Devices

Yankee Group in its M2M market analysis proposed three categories of M2M devices observing them in the context of solutions that bundle together related devices, network services, and applications [2]. Table I. presents such categorization with respect to applications and content specificities (e.g. machine vs. human interaction), device constraints (e.g. thin vs. thick client), and available network connectivity (e.g. narrowband vs. broadband network access).

Enterprise M2M devices are designed to save enterprises money, labor or both. They involve minimal human interaction, unlike consumer M2M devices or computing devices which involve human users as the final destination of processed information. In that regard, enterprise M2M devices are truly adhering to M2M communication paradigm without direct human intervention proposed in [13] [14]. They include thin clients with significant reliance on the underlying cloud infrastructure. Example services include fleet management, digital signage, or smart grid services.

Consumer M2M devices have similar requirements to enterprise M2M devices in the case of cloud dependence, but unlike them are focused on single consumer applications and not large enterprises. In that regard, these devices are rather similar to ETSI's Connected Consumer use case [15]. Typical example services include e-book readers, tracking devices, or remote mobile health monitoring devices.

Third category involves M2M computing devices with considerably higher processing requirements than that of the first two categories. Focus on rich multimedia services demands high data rates, broadband network access, and processor intensive thick clients with bigger batteries capable of supporting all that. Computing M2M devices include devices which are able to provide qualitative interface to human users such as tablets, laptops, and smartphones.

TABLE I. CATEGORIES OF CONNECTED M2M DEVICES (SOURCE: [2])

	Enterprise M2M	Consumer M2M	Computing Devices
Applications and Content	Enterprise applications, Process-specific, Machine interaction	Consumer applications, Single-application, Human interaction	Computing-oriented, Rich multimedia, Human interaction
Device Hardware	Thin clients, Significant processing in the cloud	Thin clients, Processor-light or processing in the cloud	Thick clients, Processor-heavy
Network Connectivity	Narrowband-broadband, Batch to real-time	Narrowband-broadband, Batch to real-time	Broadband, Real-time
Examples	Fleet telematics, Digital signage, Smart grid	E-readers, Tracking devices, mHealth	Tablets, Smart phones, Laptops, notebooks

C. M2M Business Models

M2M communication systems offer new possibilities to mobile network operators, and despite their potential scale, business models that are able to exploit them are still in its infancy. Typical deployment of M2M system may involve various combinations of stakeholders of the M2M market: MNO as a typical communications service provider (CSP), mobile virtual network operators (MVNO), original equipment manufacturers (OEM), application service providers (ASP), platform providers, system integrators, and of course various categories of customers. Also, there are models that do not involve commercial operators at all, because large corporate networks (e.g. in hospitals, airports, etc.) are able to handle localized M2M services on their own. Models described in the remainder of this chapter cover basic situations and show the complexities that can arise in evolving M2M systems [7].

1) Network Operator-Led Model

This model is rather straightforward: corporate customer who wishes to deploy M2M service approaches mobile network operator with his request. MNO in a role of CSP with the help of its partners (device vendor for devices, platform provider for M2M service platform, and application developer for writing applications for particular devices) provides an end-to-end solution. Used platform can be either home-grown solution or acquired through strategic partnership with specialized platform providers. Mobile network operator pays device vendors and application providers for their products, and shares ongoing revenue with M2M service platform provider. Typical example of such service offering involves small utility company providing smart metering solution which contacts mobile network operator. MNO provides its wide-area infrastructure to enable utility company reach households around the country.

2) MVNO-Led Model

As already discussed in the previous chapters, this model played a pivotal role in the early M2M deployments when there were not enough M2M devices to justify involvement of full-fledged mobile network operators [5]. MVNOs in this model offer bandwidth to their customers, and play a central role in arranging the M2M service. They contact device vendors, typically develop applications and provide system integration on their own, and of course, cooperate with mobile network operators whose infrastructure they use.

3) Corporate Customer-Led Model

Large companies sometimes deploy large number of M2M devices that makes them worthwhile to take over the leading role in providing M2M services. Then they negotiate with selected mobile network operators for the use of their communication infrastructure, and with MVNOs and service platform providers for additional services (M2M service platform, application development, etc.). In turn, MVNOs typically negotiate with equipment manufacturers to provide necessary M2M devices and modules. The most famous example of such an M2M service is Amazon Kindle™ e-book reader. Amazon has bandwidth agreement with AT&T and numerous operators worldwide which provide connectivity for M2M modules integrated in their e-book devices.

III. STANDARDIZATION

Mobile networks are considered the most popular wide-area solution for M2M communication. Building M2M systems in such environments heavily depends on the use of standardized interfaces which enable ubiquitous connectivity between M2M devices and access networks [2]. 3rd Generation Partnership Project (3GPP) developed few generations of mobile network access and core network technologies, each characterized by the specific bandwidth, latency or coverage values. The 3GPP family of mobile networks enables global connectivity between devices, and includes the following technologies among others: Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS), High Speed Packet Access (HSPA), and recently introduced Long Term Evolution (LTE). All of these technologies are still in certain extent active in different network deployments around the world, and with more than 5.2 billion connections have become de facto global standards for mobile communications.

Growing ownership of M2M devices depends on cooperation between numerous industry players, and their willingness to establish interoperability between different standards [2]. In our previous work [16], we presented efforts conducted in the field of M2M systems by European Telecommunications Standards Institute (ETSI). Also, oneM2M initiative [17], which encourages and participates in the development of a common M2M service layer that can be used to connect the myriad of M2M devices in the field over various underlying networking technologies (fixed, 3G, 4G, WiFi, etc.) with M2M application servers worldwide, was introduced. OneM2M initiative includes ETSI from Europe, and 6 other organizations from around the world: Association of Radio Industries and Businesses (ARIB) from Japan, Alliance for Telecommunications Industry Solutions (ATIS) and Telecommunications Industry Association (TIA) from the United States of America, China Communications Standards Association (CCSA) from China, and Telecommunications Technology Association (TTA) from South Korea. Apart from them, many other forums and organizations, such as 3GPP, Institute of Electrical and Electronics Engineers (IEEE), and International Telecommunication Union – Telecommunication Standardization Sector (ITU-T), have also actively engaged in network standards development [18] that directly affects their networks' ability to provide M2M services. From the perspective of this paper, most interest attracts standardization work done by 3GPP on their mobile networks.

Firstly, it is important to emphasize that 3GPP's terminology for machine-to-machine, person-to-machine and machine-to-person communications is unified in the term machine type communication (MTC). The main issue in the context of MTC today is the fact that current mobile networks are optimized for Human-to-Human (H2H) interactions, while future releases of 3GPP standards will address further scale requirements anticipated for embedded devices. Having that in mind, 3GPP continues to evolve its network architectures to integrate additional utilities into their mobile networks, simplify device design, reduce power consumption, increase network efficiency, and simplify operations [2].

3GPP is a collaboration effort established between telecommunication associations, known as “Organizational Partners”, to produce the reports and specifications that define 3GPP family of technologies. Most of its M2M/MTC related standardization efforts are conducted within several Service and System Aspects Working Groups: SA WG1 which focuses on services, SA WG2 which focuses on architecture considerations, and SA WG3 which focuses on security. Two additional groups are actively working on the improvements for radio access networks: GSM EDGE Radio Access Network Working Group (GERAN WG2) which focuses on protocol aspects of GPRS/EDGE networks, and Radio Access Network Working Group (RAN WG2) which focuses on Layer 2 and Layer 3 Radio Resource specification (Table II.) [19].

TABLE II. 3GPP M2M STANDARDS (SOURCE: [19])

Standard	Description
TR 22.868	SA1 – M2M Study Report
TS 22.368	SA1 – MTC Service Requirements
TR 22.888	SA1 – Study on Enhancements for MTC
TR 23.888	SA2 – System Improvements for MTC
TR 33.812	SA3 – M2M Security Aspect for Remote Provisioning and Subscription Change
TR 33.868	SA3 – Security Aspect of M2M
TR 37.868	3GPP Study on RAN Improvements for MTC
TR 43.868	3GPP Study on GERAN Improvements for MTC

Enhancements and optimizations are needed for MTC communication to address issues such as scalability, shortages of IP addresses and telephone numbers to successfully manage network overloads, then how to easily distinguish MTC applications that have different characteristics, and how to enable connectivity between all actors in the MTC environment (MTC devices/gateways, network, and the application servers) [19]. As a result of diversity of MTC applications, 3GPP in [20] identifies a set of 14 characteristics helpful in categorizing different MTC application features: Low Mobility, Time Controlled, Time Tolerant, Packet Switched (PS) Only, Small Data Transmissions, Mobile Originated Only, Infrequent Mobile Terminated, MTC Monitoring, Priority Alarm, Secure Connection, Location-Specific Trigger, Network Provided Destination for Uplink Data, Infrequent Transmission, and Group Based MTC Features. For further details on particular feature please consult the accompanied bibliography.

Many connected M2M device solutions involve large numbers of modules, and even small hardware price advantages can add up to a significantly decreased total cost of ownership (TCO) across an overall M2M deployment [2]. Technical success enjoyed by 3GPP network technologies is a result of not only 10-20% lower chipset retail prices than comparable Code Division Multiple Access (CDMA) chipsets, but also a vigorous, transparent, and disciplined consensus standards process.

IV. REGULATION

Growing number of M2M applications and their use in numerous systems mostly challenges regulation through the use of numbering plans. Specifically, in the majority of countries usage of existing numbering plans is in accordance with E.164 standard defined by ITU-T [21]. ITU-T standardization defines ranges for use in the Public Switched Telephone Network (PSTN), mobile, and other networks. Consequently, the increase of M2M services is creating a situation in which National Regulatory Agencies (NRAs) have to open a new numbering range that will be used exclusively by M2M services. In order to satisfy demand, the suggestion is to increase the number of digits in the numbers for M2M services (in the case of E.164 numbers, maximum 15 digits ITU-T Rec E.164.). Furthermore, since a full transition to IPv6 is expected in the near future, NRA must take into account that at one point instead of the numbering plans operators will use unique IP address per M2M device. For the foregoing reasons, the role of the regulator is to enable the transition to a new numbering plan and IPv6 in a way that does not affect the market and jeopardize the competition. Defining a new numbering plan for M2M should not replace the existing plans that M2M services use at the moment. New numbering plan is necessary because the existing is insufficient. Furthermore, in the case that there are barriers for the virtual operators that will provide access for M2M services entering the market, the NRAs have to find a way and help them to begin providing the desired services.

Most countries in the European Union (EU) have so far implemented changes within its own numbering plans and opened ranges for M2M services so that existing numbering plans are not used for M2M services. Croatian NRA, like in other European states, regulates numbering issues for M2M services in a way that the number in international format has thirteen digits according to predictions of a sufficient quantity of numbers for M2M services.

A. Open regulatory issues

Apart from the numbering plans, there are several other important issues that regulatory authorities need to address in relation to M2M services: data privacy, new operator market entrance, roaming, operator switching, and connectivity platform interoperability.

Huge value lies in the data present in M2M systems. Healthcare records, tracking data, or smart metering data that reveals customers’ habits are just few typical examples. Today there is a paradigm shift from centralized to distributed computing, so applications that used to run on one server now run in the cloud. Many M2M systems also leverage the cloud to handle computational tasks. This change brings new opportunities for M2M services, but also has significant implications on the customer privacy. The foundations of data privacy regulation were created 30 years ago when information technology was centralized and hierarchical. With a certain degree of effort, one was able to establish who created information, who was collecting it, who controlled it, and who was in charge of supervision that everything was being handled appropriately. Paradigm shift to distributed computing (e.g. cloud) changed that from a clear technical perspective. Adding

the fact big network operators today operate in numerous countries bring new administrative complexities that also need to be tackled with. Organization for Economic Cooperation and Development (OECD) set in 1980 foundations of The Data Protection Directive [22] that is still in use today. Two fundamental principles of the directive are notice and consent. First assumes customers should be given notice before any personal information is collected from them, while the latter means giving customers options as to how any personal information collected from them may be used. However, the directive does not take important aspects like globalization and technological developments (e.g. social networks, cloud computing) sufficiently into account, so new guidelines for data protection and privacy (General Data Protection Regulation [23]) are currently under consideration, and are planned to take effect in 2016. Each of the member states of the EU will implement their own data protection legislation based on the mentioned proposal. Given the sensitivity of the problem like privacy, one also has to have in mind that governmental regulation has potential to slow future industry innovation. Therefore, the implementation of personal data protection in M2M systems will be one of the most important regulatory tasks in the following years.

Another important trend is the possible emergence of new MVNOs. In section II discussing current situation on the M2M market it was suggested that MNOs will try to strengthen their status on the market, mostly because MVNOs had important role in the earlier M2M deployments. MVNOs today are generally important part of the M2M value chain because many of them have developed expertise that numerous M2M solution providers lack. Given the widespread efforts for standardization of interfaces that will enable application development totally independent of the underlying hardware, there is a reasonable possibility that many MVNOs will also take a more active role in the M2M application development. Also, large M2M customers themselves could also be willing to participate. It is conceivable that they could develop a role as their own service providers. There are many mobile virtual network enablers (MVNEs) in the growing domains of utilities or automotive services that could effectively establish themselves as MVNOs. New open source products like Actility Cocoon M2M gateway are aimed at hardware manufacturers who want to build ETSI M2M compliant Gateways for the mass market and M2M application developers who target the upcoming M2M “app stores” in the vein of App Store or Google Play [24]. It will be interesting to see to what extent M2M market will become open to new entrants, especially in the domain of M2M application development. Croatian M2M market on the other hand is still in its infancy. Only several MNOs offer M2M services, but still there are no any important (traditional) MVNO players. In case of access problems for MVNO operators to MNO’s network in order to provide M2M services, NRA will intervene in accordance with the Electronic Communication Act and Access Directive [25] and direct MNO operators to comply with legal obligations that impose a commitment for them to provide access to their network elements. The purpose of such action is to increase the competitiveness of the market that in the broader sense contributes to innovation on telecommunications market.

Roaming can in the M2M context be a potential problem. Some M2M applications (e.g. healthcare solutions) typically rely on full national coverage, which might require national roaming. Also, some other applications such as cargo tracking through several countries may need support for international roaming. There may be some data to report, or a signal coverage failure which might initiate network swapping, but the connection, once made, needs to be maintained. Critical applications such as monitoring a heart patient during moving him to another jurisdiction need to be always on. Roaming in such situations needs to be managed perfectly, no matter if it involves national or international data agreements. There are several solutions to the mentioned problem, and some of them involve unpopular (at least from the telco perspective) switching of the M2M service provider. The first and simplest solution assumes that visited network becomes the permanent owner of the SIM (Subscriber Identity Module) card of the moving M2M device. Therefore, all the responsibilities and services would then be supplied locally. The other possibility for an M2M provider is to use foreign SIM cards from operators with full international roaming coverage. In Croatian case, that would involve operators like T-Mobile or Vodafone i.e. their local partners. Third mechanism would involve dynamic downloading of SIM card software (solution popularly known as “soft SIM”) in the country where M2M device currently resides. Of the three mentioned solutions, first two are more plausible, at least in the current global operator ecosystem, and would involve mostly administrative and regulatory barriers. Third is additionally an active technological challenge and research problem.

M2M applications are often bound to one MNO for the entire device lifetime, which can be as long as 10 or even 20 years. Typical large M2M systems involve thousands of M2M devices dispersed over large geographical areas. Switching M2M provider by manually changing SIM cards in each M2M device is a time and money consuming operation. Estimates conclude that changing 10,000 SIMs would cost over \$1 million [26]. To enable M2M customers to switch operators (providers) in the first place, changes in the mechanism of mobile network code (MNC) would need to be implemented. Currently, regulators issue to MNOs IMSI (International Mobile Subscriber Identity) numbers in blocks of 10 billion. The IMSI includes a unique identification of the network: the MNC (Mobile Network Code). Today the MNC in most countries has only two digits, which limits the number of maximum MNOs. However, it can be extended to three digits. If such large M2M systems, i.e. their owners, had their own MNCs, switching MNOs would be possible without changing the SIM cards. They could more flexibly choose on the wholesale market which network operator is offering the best service, and easily switch. Mechanisms most commonly discussed that would enable this are based on “soft SIM” solutions, which means downloading new MNO specifications similarly to software updates to M2M device. Such mechanisms, if they ever become widespread solutions, would most definitely bring new regulatory challenges.

Connectivity platform interoperability, i.e. the ability of a platform to connect different devices to different networks, is the last emerging regulatory issue that will be analyzed in this

paper. Important aspects of the application development platform interoperability have already been briefly discussed in the second section. Connectivity platforms serve both operators and enterprises in providing provisioning and device management capabilities [2], and are also very important aspect of MNO M2M business strategies. MNOs have been recently increasingly active in either developing their own in-house connectivity platforms, or acquiring them through acquisitions or partnerships. Following the first strategy, MNOs can gain incremental revenue per connection but take on more customer service responsibility. Partnering with third-party platform providers reduces the cost of supporting M2M solutions, but also divides the control of customers [2]. Each new M2M device has to be certified in order to be granted access to MNO network, and in the process also to the connectivity platform MNO has deployed. EU member states mandate the following certifications for new M2M modules: RoHS (Restriction of Hazardous Substances [27]), WEE (Waste Electrical and Electronic Equipment [28]), and R&TTE (Radio Equipment and Telecommunications Terminal Equipment and the Mutual Recognition of their Conformity [29]) directives which concern with reducing risks of hazardous substances, GSM radio spectrum, electromagnetic compatibility, and low-voltage equipment [7]. Some of the operators additionally employ their own customized certification protocols. The idea is to establish that new M2M devices will not cause any harm or/and security vulnerabilities when deployed in operational networks. So far, MNOs managed to shorten the certification process of new M2M devices from months to a matter of weeks and greatly expanded the number of approved devices on their networks. However, they have been strictly bounded to a single platform. Unified connectivity platform that would connect to multiple network operators would be a potential improvement, as would enable them to even further simplify their provisioning programs. An M2M device certified for use on one network could more easily be certified on another network that uses the same connectivity platform solution. However, the implication is to give up control by not being the sole platform provider.

Issues discussed in this chapter can be addressed twofold. First possibility is rigid standards development and early regulation, but the drawback can be negative effect on innovation. A contrary approach is to let technology develop naturally, through trial and error and user uptake. This approach needs more time, but can also cause too many problems if left totally uncontrolled. The best solution is probably somewhere in between.

V. CONCLUSION AND FUTURE WORK

Since M2M services are still not used in an amount that is expected, European countries including Croatia have so far completed all preparations so these services could easily develop. However, given that these are new services which include a number of technological and regulatory challenges and changes, Croatian NRA will carefully monitor the situation on an M2M market and try, within its jurisdiction, to remove all obstacles to encourage the development of new M2M services. The main goal of NRA is to facilitate innovation in

M2M systems and enable their widespread coverage, but without hindering currently deployed H2H oriented services.

ACKNOWLEDGMENT

This work was supported by two research projects: "Content Delivery and Mobility of Users and Services in New Generation Networks" (036-0362027-1639), funded by the Ministry of Science, Education and Sports of the Republic of Croatia and "Looking to the Future", funded by Croatian Post and Electronic Communications Agency.

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