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Introduction to M2M

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M2M (Machine-to-Machine) has come of age. It has been almost a decade since the idea of expanding the scope of entities connected to "the network" (wireless, wireline; private, public) beyond mere humans and their preferred communication gadgets has emerged around the notions of the "Internet of Things" (IoT), the "Internet of Objects" or M2M. The initial vision was that of a myriad of new devices, largely unnoticed by humans, working together to expand the footprint of end-user services. This will create new ways to care for safety or comfort, optimizing a variety of goods-delivery mechanisms, enabling efficient tracking of people or vehicles, and at the same time creating new systems and generating new value.

As with every vision, it has taken time to materialize. Early efforts concentrated on refining the initial vision by testing new business models, developing point solutions to test feasibility, and also forecasting the impact of insufficient interoperability. Over the past few years, the realization that there are new viable sources of demand that can be met and monetized has created the push for a joint effort by industry to turn a patchwork of standalone elements and solutions into a coherent "system of systems", gradually turning the focus from the "what" to the "how" and developing the appropriate technologies and standards.

This chapter introduces the M2M concept and proposes a definition from the multitude of definitions available today. It outlines the main characteristics of the emerging M2M business and presents a high-level view of the M2M framework that is further analyzed and dissected in subsequent chapters. Moreover, this chapter analyzes some of the main changes that have occurred recently and that have largely enabled the development of M2M, namely the emergence of regulation and standards as market shapers. The role of

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standards is one of this book's central themes and a presentation of the main actors and the latest status of related work is provided as a guide through this complex ecosystem.

The reader will finally be introduced to the structure and content of this book, which is actually the first of a set of two. In the hands of the reader in paper format or on an eBook reader after being loaded by an M2M application, the first book *M2M Communications: A Systems Approach* essentially introduces the M2M framework – requirements, high-level architecture – and some of its main systems aspects, such as network optimization for M2M, security, or the role of IP.

The second book *Internet of Things: Key Applications and Protocols* will address more specifically the domain in which the "Internet of Objects" will be acting, namely the M2M area networks, in particular the associated protocols and the interconnection of such networks. It will also analyze, from this perspective, some of the future M2M applications, such as Smart Grids and Home Automation.

1.1 What is M2M?

Many attempts have been made to propose a single definition of the M(s) of the M2M acronym: Machine-to-Machine, Machine-to-Mobile (or vice versa), Machine-to-Man, etc. Throughout this book, M2M is considered to be "Machine-to-Machine". This being decided, defining the complete "Machine-to-Machine" concept is not a simple task either: the scope of M2M is, by nature, elastic, and the boundaries are not always clearly defined.

Perhaps the most basic way to describe M2M is shown in Figure 1.1 (the "essence" of M2M). The role of M2M is to establish the conditions that allow a device to (bidirectionally) exchange information with a business application via a communication network, so that the device and/or application can act as the basis for this information exchange. In this definition, the communication network has a key role: a collocated application and device can hardly be considered as having an M2M relationship. This is why M2M will often be a shortened synonym for M2M communications, which is itself a shortened acronym for M2(CN2)M: Machine-to-(Communication-Network-to-)Machine).

In itself, this description still does not fully characterize M2M. For instance, a mobile phone interacting with a call center application is not seen as an M2M application because a human is in command. Some of the more complex characteristics of the M2M relationship are discussed below in order to clarify this.

In many cases, M2M involves a group of similar devices interacting with a single application, as depicted in Figure 1.2. Fleet management is an example of such an application, where devices are, for example, trucks, and the communication network is a mobile network. In some cases, as shown in Figure 1.3, the devices in the group may not directly interact with the application owing to having only limited capacities. In this scenario, the relationship is mediated by another device (e.g., a gateway) that enables some form of consolidation of the communication. "Smart metering" is an example of such an application where the devices are smart meters and the communication network can be a mobile network or the public Internet.

To take this into account, the term "M2M area network" has been introduced by the European Telecommunication Standards Institute (ETSI). An M2M area network provides physical and MAC layer connectivity between different M2M devices connected

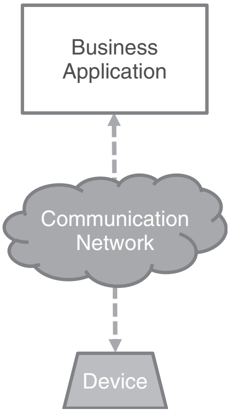

Figure 1.1 The essence of M2M.

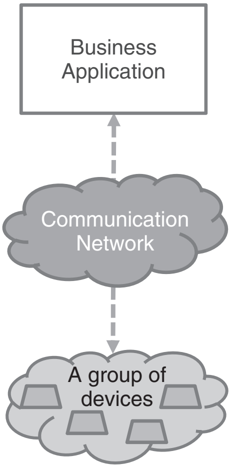

Figure 1.2 Group of devices in an M2M relationship.

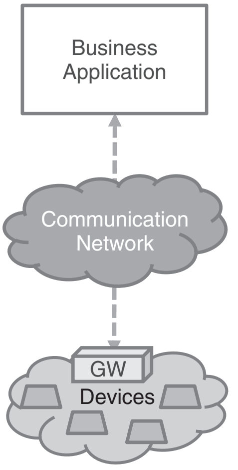

Figure 1.3 The mediated M2M relationship.

to the same M2M area network, thus allowing M2M devices to gain access to a public network via a router or a gateway.

M2M's unique characteristic is largely due to the key role of the end-device. Devices are not new in the world of information and communication technologies (ICT), but with M2M that market is seeing a new family of devices with very specific characteristics. These characteristics are further discussed below, particularly their impact on the requirements for applications and networks that have not until now been fully taken into account.

- **Multitude** – This is the most advocated change brought about by M2M. It is generally agreed that the number of "devices" connected in M2M relationships will soon largely exceed the sum of all those that directly interact with humans (e.g., mobile phones, PCs, tablets, etc.). An increased order of magnitude in the number of devices results in significantly more pressure on applications architectures, as well as on network load, creating in particular scalability problems on systems that have been designed to accommodate fewer "actors" and far greater levels and types of traffic. One of the early instances of such problems is the impact of M2M devices on mobile networks that have not been designed with this set of devices in mind and are in the process of being adapted to allow large numbers of devices with non-standard usage patterns (this will be discussed later in this chapter).
- **Variety** – There are already a particularly large number of documented possible use cases for M2M that apply to a variety of contexts and business domains. The initial implementations of M2M applications have already led to the emergence of a large variety of devices with extremely diverse requirements in terms of data exchange rate, form factor, computing, or communication capabilities. One result of the wide variety is heterogeneity, which is in itself a major challenge to interoperability. This can be a major obstacle to the generalization of M2M. It is also a challenge for the frameworks

on which M2M applications have to be built, in order to define and develop common-enabling capabilities.

- **Invisibility** – This is a strong requirement in many M2M applications: the devices have to routinely deliver their service with very little or no human control. In particular, this is preventing humans from correcting mistakes (and also from creating new ones). As a result, device management more than ever becomes a key part of service and network management and needs to be integrated seamlessly.
- **Criticality** – Some devices are life-savers, such as in the field of eHealth (blood captors, fall detectors, etc.). Some are key elements of life-critical infrastructures, such as voltage or phase detectors, breakers, etc, in the Smart Grid. Their usage places stringent requirements upon latency or reliability, which may challenge or exceed the capabilities of today's networks.
- **Intrusiveness** – Many new M2M devices are designed with the explicit intention to "better manage" some of the systems that deal with the end-users' well-being, health, etc. Examples are the eHealth devices already mentioned, smart meters for measuring and/or controlling electrical consumption in the home, etc. This in turn leads to issues of privacy. In essence, this is not a new issue for ICT systems but it is likely that privacy may present a major obstacle in the deployment of M2M systems. This may occur when the large deployment of smart meters demands prior arbitration between the rights of end-users to privacy and the needs of energy distributors to better shape household energy consumption.

In addition to the above-listed characteristics and their impact on the architecture of M2M systems, it is important to consider the other specificities of M2M devices that put additional constraints on the way they communicate through the network. This may require new ways to group the devices together (the "mediated" approach mentioned in Figure 1.3). Among other things, devices can be:

- **limited in functionality** – Most M2M devices have computational capabilities several orders of magnitude below what is currently present in a modern portable computer or a smart phone. In particular, devices may be lack remote software update capabilities. One of the main reasons for this design choice is cost, often because the business model requires very competitively priced devices (e.g., smart meters in many cases). Limited functionality also results from rational decisions based on the nature of the exchanged information and performable actions: most sensors are not meant to be talkative and operationally complex.
- **low-powered** – Although many M2M devices are connected to a power network, many of them have to be powered differently (often on batteries) for a variety of reasons. For instance, a large number of them are, or will be, located outdoors and cannot be easily connected to a power supply (e.g., industrial process sensors, water meters, roadside captors). This will reduce the amount of interaction between such devices and the M2M applications (e.g., in the frequency and quantity of information exchanged).
- **embedded** – Many devices are, and will be, deployed in systems with specific (hostile, secure) operating conditions that will make them difficult to change without a significant impact on the system itself. Examples are systems embedded in buildings or in cars that are hard to replace (e.g., when they are soldered to the car engine, as is the case with some M2M devices).

- **here to stay** – Last but not least, many of the new M2M devices are and will be deployed in non-ICT applications with very different lifetime expectancy. The rate of equipment change in many potential M2M business domains may be lower than in the ICT industry. This may be linked to cost issues due to different business models (e.g., no subsidization of devices by the operators), to the fact that they are embedded, but also to the complexity of evolution of the industrial process in which the device is operating (e.g., criticality of the service makes changing equipment in a electricity network very difficult, which leads to long life cycle of equipment in the field).

Two final remarks regarding the scope of M2M and the difficulty of defining clear-cut boundaries.

Firstly, a separation between “regular” ICT applications versus M2M applications is to a large extent purely artificial since, in some cases, devices are able to operate both in “regular” and M2M modes. A classical example of this is Amazon’s Kindle™. Although it is a “regular” ICT device centered on both human-to-machine function (enabling eBooks) and interface (the eBook reader), it is also an M2M device in its role of providing an eBook to an end-user. When the end-user has decided to buy an eBook and clicks to get it, the Kindle™ device enters M2M mode with a server (providing the appropriate file with the appropriate format) and a network (a “regular” mobile network). This is perfectly transparent to the end-user, thanks to a set of enablers, including the SIM card in the device, the secure identification of the device by the network, and the pre-provisioning of the device in the operator network.

Secondly, it is important to outline some differences between M2M devices and what is referred to as “Things” or “Objects” in the so-called “Internet of Things” (IoT). Actually, M2M and IoT largely overlap but neither is a subset of the other and there are areas that are particularly specific to each:

- IoT is dealing with Things or Objects that may not be in an M2M relationship with an ICT system. An example of this is in the supermarket where radio-frequency identification (RFID) “tagged” objects are offered to the customer. These objects are “passive” and have no direct means with which to communicate “upstream” with the M2M application but they can be “read” by an M2M scanner which will be able to consolidate the bill, as well as making additional purchase recommendations to the customer. From this perspective, the M2M scanner is the “end point” of the M2M relationship.
- There are M2M relationships initiated by devices that are to be seen as direct human–machine interface extensions of a person (e.g., the above-mentioned end-user Kindle™) rather than as Things (e.g., the end-user refrigerator).

In the longer term, it is quite likely that the rather artificial distinctions, on the one hand, between traditional and M2M communication types and, on the other, between IoT and M2M domains will become further blurred with the advance of M2M and its ability to integrate more objects within existing systems.

1.2 The Business of M2M

After a decade of gradual development, there is a vast quantity of documented use cases for M2M, some of which have never progressed past the drawing board, although some have

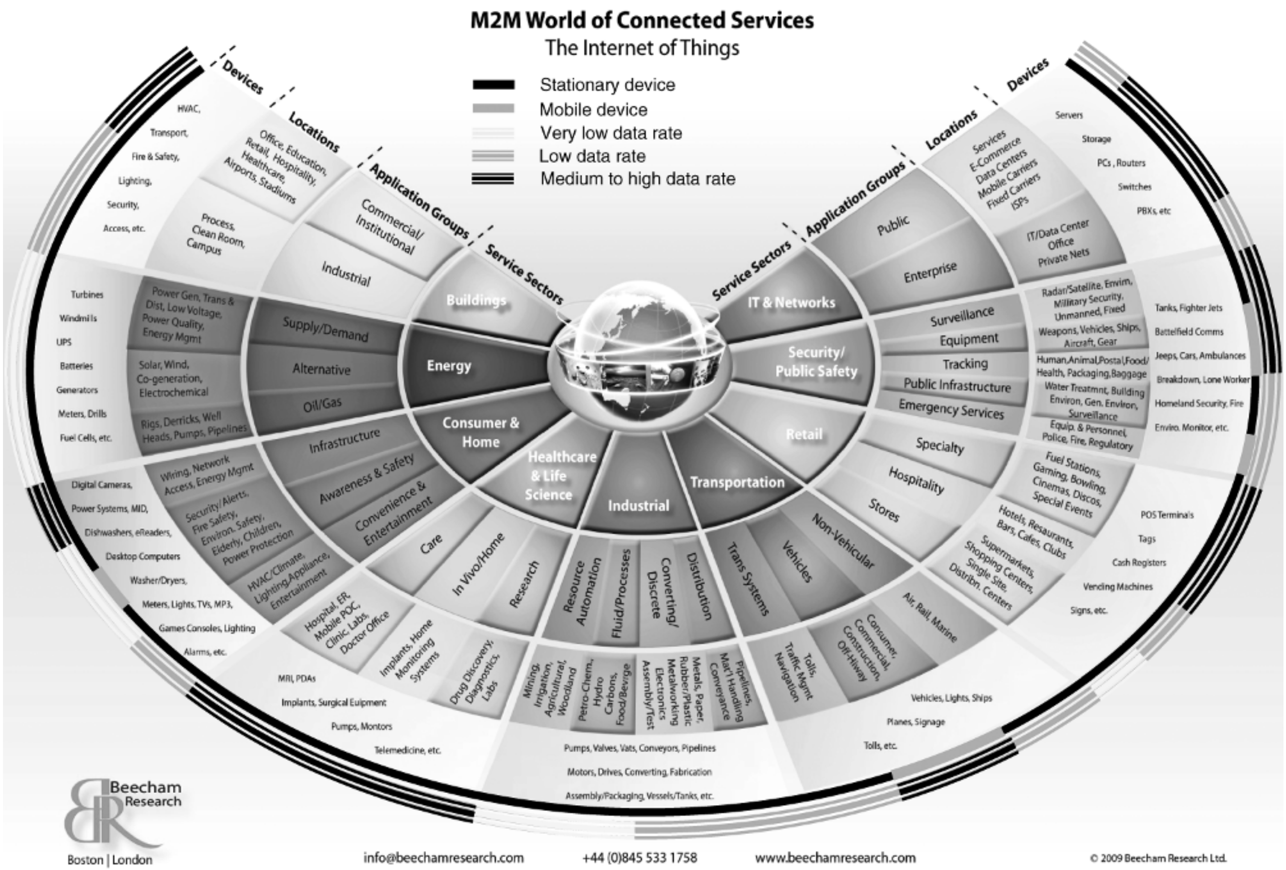

Figure 1.4 M2M services and devices. Reproduced by permission of Beecham Research, with additions from the authors to provide an indication on device mobility and data rates.

been subject to prototypes, early implementations, and commercial deployments. Only a few have led to the creation of significant business models in terms both of the revenue generated and the ecosystem of solid actors. However, the situation is evolving rapidly.

Figure 1.4 is an illustration by Beecham Research of the potential of M2M business that describes the major sectors that are applicable to M2M. From this perspective, the potential impact of M2M can be considered as important, and it is essential to fully understand the current status of M2M, as well as what has prevented it from emerging faster and what can be done to accelerate its emergence. This will be addressed at length in the first part of this book.

Another interesting aspect of Figure 1.4 is that it links the business domains with the associated devices from two major points of view: data rate and mobility. The former has been addressed above as one of the facets of the variety of M2M devices. The latter is also important since it is critical in some of the M2M applications that have recently emerged such as smart metering. Figure 1.4, in particular with the indication on the mobility of the device, suggests that there are potentially many more stationary devices involved than mobile devices. However, at this stage of M2M developments, it is mainly solutions based on wireless and cellular networks that have been investigated and deployed, as opposed to those based on wireline networks. One reason for this is that they benefit from some of the enabling aspects of cellular networks, for example the possibility of deploying M2M devices as mobile devices (e.g., by embedding a SIM card within the device), built-in authentication and security and easier deployment in industrial settings. Massive deployment of M2M applications over cellular networks drives clearly the need to optimize those networks for stationary or low mobility M2M devices as a means to reduce the overall connectivity cost.

Rather than trying to establish the list of all M2M domains and to provide application examples, this section investigates the maturity of each major M2M business in order to identify both obstacles to its emergence and possible enablers.

Figure 1.5 provides a staged view for M2M industry maturity. Three stages for M2M deployments are depicted with a far-reaching view (20 years).

The current "emergent" phase of M2M is cellular network-centric, where most applications are in the area of telemetry and fleet management. They mostly use existing cellular network infrastructure, while addressing predominantly business-to-business (B2B) applications. Considering that we are about to reach the end of this phase, it is important to see if the conditions are being met in order to enter the next phase ("transition") where a larger proportion of the M2M market will be developed, in particular business-to-consumer (B2C) applications that will be more demanding than the earlier B2B applications.

Despite progress in M2M technologies, there remain many challenges, the most pressing ones being:

- **fragmentation of solutions** – In the vast majority of cases, the solutions developed and implemented to date have been addressing specific vertical applications requirements in isolation from all others. This has created "silo" solutions based on very heterogeneous forms of technology, platforms, and data models. Interoperability is in general very limited or non-existent. Overcoming this challenge requires effort on at least two fronts. First, it is essential to define more comprehensive standards, in particular regarding

data models. In addition, it is important to have service platforms that can be reused for multiple applications, avoiding the necessity to completely redesign solutions per application due to the lack of common capabilities.
- **network misalignment** – As already stated, communication networks have been designed with many requirements that differ substantially from those of M2M. One example of this is mobile networks that have not been designed to take into account the large numbers of devices generating very small amounts of data transport and potentially a very significant overload of the control and connectivity planes (not to mention that stationary devices do not require roaming capabilities). Some optimization of M2M traffic needs to be done which will essentially take place within standardization. Another example is latency. In some applications (e.g., in Smart Grids), latency requirements are largely below 10 ms, more than one order of teleprotection magnitude below those of voice over internet protocol (VoIP).
- **security** – As already outlined, some of the most promising M2M applications (eHealth, Smart Grids) are safety-critical and must be made robust against a large variety of security threats. This demands that security requirements be precisely understood and developed through standards and certification.
- **privacy** – To develop and resolve the sensitive issue of privacy, both regulation (an essential precondition) and standardization are required.
- **service capabilities** – In order to deal with the fragmented market, it is necessary to outline capabilities that can be reused across several applications. The history of ICT networks shows that this always requires that some separation be made between different architectural layers. In particular, separating applications from service capabilities (e.g., device management) and network capabilities (e.g., policy) will be key.
- **testing, certification** – A large number of M2M solutions will have to be developed outside of the traditional service silos, integrated with other M2M or traditional applications. This will require a larger degree of interoperability and vendor compliance, which will in turn necessitate the organization of (interoperability) testing and certification of devices and equipment. This will be the role of industry and/or standards organizations or forums.

Taking into account the above challenges, Figure 1.5 also outlines three major maturity accelerators for M2M, namely:

- **high-level frameworks** – This refers to an emerging set of standards-based architectures, platforms, and technologies integrated in a way that allows for the development of "non-silo," future-proof applications. These frameworks allow, in particular, for economies of scale that will change the dynamics of M2M business models.
- **policy and government incentives** – Based on the realization that some M2M challenges may not be addressed by the industry alone, public authorities and governments have started to play an active role both in stimulating the investment by setting up ambitious incentive programs and in policy-making. This is, in turn, drives more investment in the wider M2M ecosystem, as well as creating more trust in the viability of the M2M industry.
- **standards** – A large number of credible industrial partners, large and small, from various industries (including but not only ICT) have started to work together in order to create the new standards required to address M2M at the global system level.

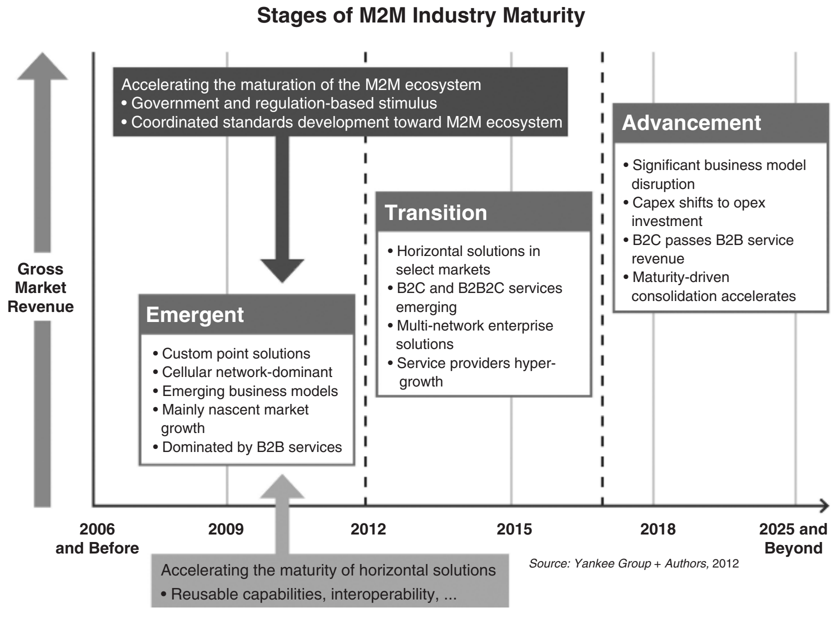

Figure 1.5 Stages of M2M industry maturity. Reproduced by permission of the Yankee Group.

This chapter and more broadly this book, will focus on these aspects, in particular standards, with the a priori view that these accelerators are already engaged and have already begun to change the landscape of M2M.

1.3 Accelerating M2M Maturity

1.3.1 High-Level M2M Frameworks

The largest part of the challenge facing the M2M actors is to transform vertical silos into a set of easily developable and incrementally deployable applications. Figure 1.5 shows that the transition to the phase two of M2M maturity will be marked by the advent and deployment of horizontal platforms.

What is meant by “horizontal” is a coherent framework valid across a large variety of business domains, networks, and devices, that is, a set of technologies, architectures, and processes that will enable functional separations, in particular application and network layers, as depicted in Figure 1.6.

Such a platform will be based on a set of capabilities in the form of software modules that are offered to the M2M applications in order to accelerate their development, test, and deployment life cycles. The confirmed need for, and possibility of, defining common service capabilities is the result of a thorough analysis within the industry of several M2M application Use Cases along with their related requirements.

The development and deployment of M2M applications could benefit from a set of building blocks that are carefully designed, tested, and optimized, irrespective of the type

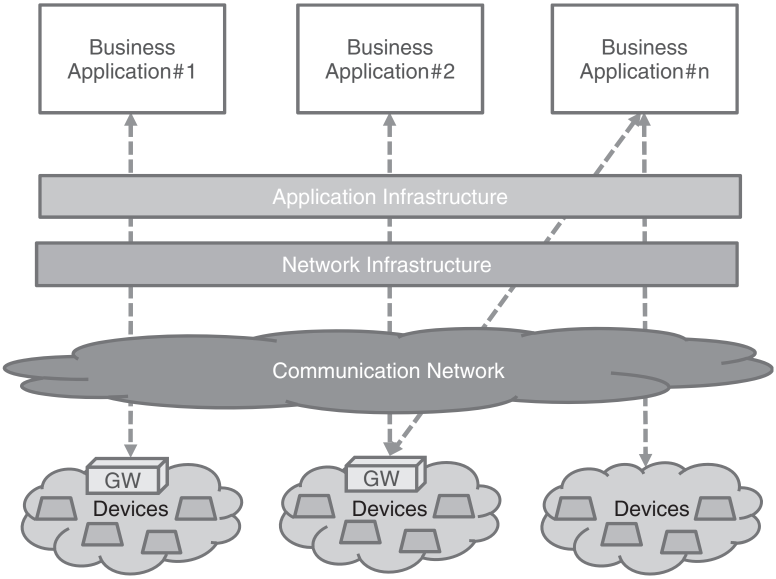

Figure 1.6 An M2M challenge: emergence of the M2M service layer.

of M2M application being deployed. Throughout the remainder of the book, these building blocks will be referred to as M2M service capabilities.

The further development of that concept allows the M2M application to primarily focus on the business logic, leaving the M2M service capabilities with all other aspects of the applications, such as device activation, device monitoring, device localization, data storage, and mediation to the horizontal platform (running the M2M service capabilities), to name but a few.

Once a set of solid M2M service capabilities has been specified, the logical next step is to expose them to the M2M applications through the use of application programming interfaces (APIs). This will be addressed in the following sections on standards.

1.3.2 Policy and Government Incentives

After initial slow progress, public authorities and governments have now realized that they have a key role to play in the take-off of M2M communications, especially because M2M is an integral element in many of the new systems that are deemed to be essential for the future of their countries or regions. Several lessons have been learnt and measures applied in the definition of incentives regarding, in particular, the role of standards to allow for infrastructure optimization, or the positive effect of economies of scale and reusability of service capabilities as a major enabler for mainstream deployments. A number of policy and government incentives have recently been put in place that play an important – sometimes pivotal – role for the following reasons:

- **Economic incentives** provide an attractive and stable framework that creates additional opportunities for investment in new projects and operational deployments. The most notable example is the American Recovery and Reinvestment Act (ARRA) signed into law in 2009 by President Obama that allocates more than $27 billion to energy efficiency and renewable energy research and investment in the form of loan guarantees, R&D grants, workers' training, etc.

- **Regulation** provides precise directions for the development of the set of standards applicable or to be enforced within a country or a region. Examples include the European Commission mandates for smart metering [M/441] or for ICT applied to RFID and systems [M/436]. The other notable example is the US Energy Independence and Security Act of 2007 (EISA) where the National Institute of Standards and Technology (NIST) is assigned the "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems . . . " [EISA].
- **Funding** of cooperative research and development projects can be either a step leading to standards development or a means of developing proof of concepts, validating existing standards. An important example is the 8th Framework Program (FP8) of the European Union.

1.3.2.1 Impact of Regulation on M2M Markets and Standards

Regulation plays an important role for M2M market growth, once it mandates new services that in turn mandate the use of M2M architectures (e.g., to achieve a certain compliance level in global systems) or the use of M2M technology and equipment. This is true in various parts of the world, and Europe can be taken as an example of how regulation mandating M2M technology is making great progress.

A prime example is climate change. The European Union has passed a new regulation for the energy sector by putting forward the "20-20-20" objective as a global target for EU Member States, that is, 20% reduction in emissions, 20% renewable energies, and 20% improvement in energy efficiency by the year 2020. As part of this objective, smart metering is becoming mandated across various EU Member States. France, for instance, has adopted a law mandating that all new houses must be equipped with smart meters starting in 2012.

The other notable example is eCall, the project of the European Commission intended to bring rapid assistance to drivers involved in a collision anywhere in the European Union. The aim is to deploy vehicles with "black box" cellular equipment that will send accident information (based on airbag deployment and impact sensor information) as well as GPS coordinates to local emergency agencies. Aside from early implementation by different car manufacturers such as BMW, PSA, and Volvo, the European Commission expects implementation by 2014. Once eCall has been massively deployed, other telematics services, such as traffic information, can also be installed and leverage existing eCall equipment.

The current wave of standards activities should help the migration to the next M2M phase ("Transition") where horizontal architectures become massively deployed, and total cost of ownership provides an attractive pricing model for the emergence of B2C M2M applications. This transition phase clearly benefits from different incentives in the USA, Europe, and Asia aimed at both funding research and prototype projects and also catalyzing the development of the interoperability standards to be used as a basis for global deployments.

1.3.2.2 Impact of Government Initiatives on M2M Standards

The eCall project is a typical example where a standard has been specifically developed to respond to a regulatory requirement: 3GPP (Third-generation Partnership Project) has developed two specifications to address eCall requirements (3GPP TS 26.267: "eCall Data Transfer; In-band modem solution; General Description" and 3GPP TS 26.268: "eCall Data Transfer; In-band modem solution; ANSI-C reference code"). These two standards specify the eCall in-band modem for the reliable transmission of accident data from an In-Vehicle System (IVS) to the Public Safety Answering Point (PSAP) via the voice channel of cellular and PST networks.

The European Commission has also issued the [M/441] Mandate on smart metering asking CEN, CENELEC, and ETSI, the three European Standard Organisations (ESOs), to provide the set of standards needed to deploy interoperable smart metering systems. The EC mandates also set target dates for the delivery for the needed standards, placing considerable time pressure for their delivery. The smart metering mandate has served as a catalyst and a major use case for the ETSI M2M Technical Committee whose members have rapidly agreed not to take the direction of creating yet another vertical architecture targeted at smart metering per se. The approach taken has been to address the [M/441] mandate requirements as only one part of broader M2M application requirements, thus enabling a strong push of the industry toward a horizontal architecture (the model where capabilities reusable in different M2M market segments are exposed to M2M applications via open APIs) as the only sustainable and cost-effective model.

In the USA, as part of the implementation plan of the American Recovery and Reinvestment Act [ARRA], the NIST was awarded $10 million in funds transferred from the Department of Energy (DOE) to help develop a comprehensive framework for a nationwide, fully interoperable Smart Grid for the US electric power system. Consequently, NIST has developed the Smart Grid framework (NIST SG-FW) which provides a conceptual reference model for Smart Grids – identifying domains, actors, and interfaces – and defined 17 priority action plans (PAPs). The aim of these PAPs is to evaluate the standards gaps for which resolution is most urgently needed to support one or more of the Smart Grid priority areas. The PAPs specify organizations that have agreed to accomplish defined tasks with specific deliverables. Ultimately the objective is to make the necessary submissions to institutional standards organizations so as to deliver a coherent set of standards for the US Smart Grid deployments. There is particular focus on interoperability (with the creation of the NIST Smart Grid Interoperability Panel) that is seen by [NIST SG-FW] as an essential means to protect the Smart Grid investments:

> Deployment of various Smart Grid elements, including smart sensors on distribution lines, smart meters in homes, and widely dispersed sources of renewable energy, is already underway and will be accelerated as a result of Department of Energy (DOE) Smart Grid Investment Grants and other incentives, such as loan guarantees for renewable energy generation projects. Without standards, there is the potential for technologies developed or implemented with sizable public and private investments to become obsolete prematurely or to be implemented without measures necessary to ensure security.
>
> (NIST Smart Grid Interoperability Framework)

1.4 M2M Standards

Unlike in several other ICT segments where it may be possible to deploy operational systems despite a lack of standards, several M2M market segments demand strong standards to ensure long-term investment protection. For several M2M applications, including smart metering or Smart Grids, there is an expectation that the installed equipment will be deployed for more than 20 years. While such a lifetime may appear unrealistic (or at least unusual) for traditional Telco deployments, the infrastructures deployed by utilities have very long deployment cycles that could dramatically influence their design and henceforth the related standards.

While there is common agreement that the market is still lacking standards for M2M, the situation has been evolving, although the level of maturity of M2M standards still varies, depending on the standards segment. It is now becoming relatively clear what needs to be done and in which technical and geographic areas.

1.4.1 Which Standards for M2M?

The different areas where standards are needed for M2M are broadly classified below.

1.4.1.1 Data Models

Data models explicitly determine the structure of data exchanged primarily between M2M applications but also with other entities within an M2M system. The logic behind the use of, eventually standardized, data models is that if the same data structures are used to store and access data, then different applications can exchange data in an interoperable fashion. Data models for M2M are application and business-logic specific. It goes without saying that a data model built from scratch for a meter designed to provide reporting on consumption data to a utility application will not be useful as a sensor designed to report data on patient health monitoring.

1.4.1.2 M2M Area Networks

The term M2M area network was used for the first time in the ETSI TS 102 690 Technical Specification [TS 102 690]. An M2M area network is a generic term referring to any network technology providing physical and MAC layer connectivity between different M2M devices connected to the same M2M area network or allowing an M2M device to gain access to a public network via a router or a gateway. Examples of M2M area networks include: Wireless Personal Area Network (WPAN) technologies such as IEEE 802.15.x, ZigBee, KNX, Bluetooth, etc. or local networks such as power-line communication (PLC), meter bus (M-BUS), Wireless M-BUS, etc.

While several M2M area networks are based on wireless RF technologies, other wireline-based technologies are also considered. The most notable example beyond PLC is the G.hn family of standards [G.hn] which has been designed with the aim of providing multiple profiles adapted for both multimedia/bandwidth-hungry applications and low-complexity/lower-bandwidth terminals. This latter option fits naturally with M2M applications such as home energy management. At the time of the writing of this book, ITU-T Study Group 15 initiated work known as G.hnem (home network energy management) to specify how G.hn can be used for Smart Grid applications such as advanced metering infrastructure (AMI) [G.hnem].

As outlined above, critical requirements for the design of M2M area networks relate directly to the nature of the M2M devices themselves, for example:

- low CPU;
- limited memory;
- low data rate;
- battery-operated, low power;
- low cost;
- small size (placing further constraints on the battery size).

The Internet Engineering Task Force (IETF) has adopted the term constrained devices for devices that qualify for one or more of the above criteria. Constrained devices place new and challenging requirements on the communication protocols that are supported by the device. As an example, it is often expected that battery-operated M2M devices will have a battery life of 10–15 years. The only way this could be achieved is through self-switching the device into a "sleep mode" when there is no need to send or receive data. As such, network applications, for instance, cannot rely on the device being constantly available and able to send or receive data. Examples of IP-based communication protocol evolutions to cope with constrained devices include the work done in the IETF 6LoWPAN (IPv6 over low power and lossy networks) Working Group. The 6LoWPAN WG group has defined encapsulation and header compression mechanisms that allow IPv6 packets to be sent and received over IEEE 802.15.4-based networks. IEEE 802.15.4 maximum transfer unit (MTU) is limited to 127 bytes. Taking into account frame overhead and optional security headers, very little is left for upper layers, that is, TCP/IP and application payload, unless protocol overhead is optimized. In essence, the 6LowPAN work allows IP to be used all the way to constrained devices, a desirable feature to allow for an end-to-end IP-based communication.

1.4.1.3 Access and Core Network Optimizations for M2M

As opposed to M2M area networks where purpose-built (and often competing) standards have been defined, there is no need to design still further access and core networks for M2M operations. Telecommunications operators consider that improvements and enhancements to access and core networks can be achieved in order to cope with the additional M2M traffic. In particular, cellular networks providing circuit-based services (namely voice or SMS) and data services have been optimized for personal communications. After an initial deployment phase of M2M services, mostly driven by B2B applications such as telemetry or fleet management, cellular operators came to the conclusion that their networks need to become "M2M-enabled."

One key element of this adaptation is the special nature of M2M traffic. As already noted in Figure 1.5 on the M2M business, around 90% of the M2M devices across all applications are stationary. In 3GPP and 3GPP2 wireless access, the network has procedures in place to track the location (cell or cell group) of the device. For naturally stationary devices such as smart meters, constantly keeping track of the device location becomes cumbersome and consumes valuable radio resources on the air interface.

The other notable characteristic of a large variety of M2M devices is that they generate low volumes of data. As an example, a utility smart meter is required to generate meter data of around 200–500 bytes every hour (maybe slightly more frequently during peak hours). In a cellular network, sending data requires the establishment of a data bearer within the access network, which means several handshake messages back and forth between the device and other entities in the access and core network (for access to radio resource, authentication/security procedures, acquiring IP address, enforcement of bearer QoS parameters, confirmation, etc.). Data bearer establishment and its teardown after use require more than 20 handshakes (but not all are originated/terminated at the terminal), not including the often-used TCP transport protocol's three-way handshake, acknowledgments, and connection release.

Clearly, cellular access and core networks have not been designed to cope with data-traffic models where the control plane traffic becomes dominant (larger than 80%) compared to the actual application payload traffic.

These two examples make it very clear why it is important to optimize access and core networks for M2M traffic. This need is further amplified by new, emerging business models for M2M where the average revenue per user (ARPU) is often 10–15 times lower than in the case of personal communications. These new business models are also completely changing the paradigms, for example, how to perform charging and billing. As opposed to personal communications where charging and billing are performed for each device subscription, M2M often requires charging to be performed on a network application basis (the utility back-end application, the central fleet management application, etc.). A concrete example would be to send a single network usage bill for all utility smart meters connected to a network operator, as opposed to a bill per connected smart meter.

Network operators and equipment vendors alike have initiated work on access and core network optimization for 3GPP and 3GPP2 cellular systems. However, since the resulting standards will take time before being deployed in operational networks, operators have adopted *a two-step approach* to cope with the growth of M2M traffic:

- **Step 1** – Re-architect access and core networks so as to adapt better to the fundamental characteristics of M2M traffic while avoiding impacting the high-revenue services related to personal communications. Some of the considered scenarios include the deployment of dedicated equipment (home location register (HLR), gateway GPRS support node (GGSN)) and traffic isolation. In summary, Step 1 is the set of de facto "best current practices" for network architecture, allowing operators to make best use of the current toolbox of standards and products. All of this is to be done by taking into account the fundamental characteristics of M2M traffic, such as low data, non-predictive, low priority, and burstiness.
- **Step 2** – Progressively deploy new equipment, software upgrade, and network solutions that are optimized for M2M traffic types, based on the developing work on M2M standards in 3GPP and 3GPP2. While Step 1 is an intermediary step, Step 2 is believed to provide the longer-term fix that is essential for the massive growth M2M business.

To a large extent, Step 1 is the result of an initial ad hoc phase (or Step 0) where M2M modules have been deployed in cellular networks and handled as if they were mobile handsets. Several lessons have been learned in terms of the impact, sometimes harmful, of M2M traffic on the operator's network. Over time, operators have come to the conclusion that M2M would require a different approach from that of mobile personal communication services.

1.4.1.4 Horizontal Service Platforms and Related APIs

As outlined above, the emergence of the next phase of M2M business will rely on the deployment of horizontal platforms implementing a set of service capabilities, that is, software modules that are exposed to the M2M applications in order to expedite their development, test, and deployment life cycles. Examples of service capabilities include device activation, device monitoring, device localization, data storage, and Mediation to the horizontal platform (running the M2M service capabilities). Standardization will be used to specify a set of typical M2M service capabilities that can be exposed to the M2M applications through the use of APIs.

Telecom operators have designed several API sets in the past, but their level of adoption and deployment has often suffered from lack of visibility and expertise within the IT and application developer community. Today, it is becoming increasingly clear that a successful Telecoms application enablement strategy mandates the use of IT-friendly APIs inspired by the Web 2.0 framework. Representation state transfer (REST) APIs have in the past enjoyed wide-scale market adoption among the IT industry, and constitute, in the view of the authors of this book, a recipe for the success of new API work. As an example, in the context of M2M APIs, REST-based APIs using HTTP protocol are being specified by ETSI M2M.

1.4.1.5 Certification for M2M Modules and Terminals

Certification refers to the confirmation of certain characteristics (usually based on a standard) of items of equipment. Generally, certification is provided by some form of external review, education, or assessment performed by an independent entity. It has become an important requirement for deploying an item of equipment (in particular, terminals) in operational environments. Certification can be divided into:

- **mandatory regulatory certification** – European Member States mandate the following certifications for M2M modules: RoHS, WEE/RAEE, and R&TTE directives which pertain respectively to reducing risks of hazardous substances, GSM radio spectrum, electromagnetic compatibility, and low-voltage equipment. In the USA, all devices must comply with the Federal Communication Commission (FCC). Additionally, communication devices must be PTCRB-certified.
- **voluntary certification** – This is usually mandated by operators for devices deployed in their networks. The Global Certification Forum (GCF) runs an independent certification program aimed at ensuring compliance with 2G and 3G wireless standards. The program also mandates device testing on five GCF-qualified networks.

Additionally, certain operators impose additional certification for devices deployed in their networks.

Ultimately, the certification process aims at both ensuring that equipment adheres to certain environmental and electromagnetic compatibility characteristics, but also does not cause any harm when deployed in operational networks.

Besides the certification programs pertaining to devices directly connected to an operator access networks, several other certification programs exist for devices using short-range radio technologies. The most notable ones are ZigBee, Bluetooth, and KNX. In the case of KNX (provided as an example), certified products must show compliance to the following set of standards:

- quality system in accordance with ISO 9001;
- European standard EN 50090-2-2 (covering such aspects as EMC, electrical safety, and environmental conditions of bus products) and an appropriate product standard;
- Volumes 3 and 6 of the KNX specifications, the former being a toolbox of the KNX protocol features, the latter listing the permitted profiles of the KNX stack based on the toolbox as mentioned above;
- KNX interworking requirements as regards standardized data types and (optionally) agreed functional blocks.

As standards for M2M evolve, certification programs are also expected to evolve, in order to cope with these evolutions.

1.4.1.6 The Standards Organizations Ecosystem for M2M

Several standards organizations focus on one or multiple aspects of M2M, making duplication sometimes inevitable. Detailing the different initiatives surrounding M2M would almost necessitate a book on its own. This is particularly true when it comes to M2M area networks and application data models, where multiple standards exist (Part II of this book is dedicated to describing these two aspects).

Figure 1.7 provides some examples of M2M area networks, namely:

- **ZigBee alliance** – A set of specifications of communication protocols (but also data models) using small low-power radio devices based on the IEEE 802.15.4. Target applications include switches with lamps, electricity meters with in-home displays, consumer electronics equipment, etc.
- **KNX** – A purpose-built radio frequency standard developed for home and building control. It is approved as an International Standard (ISO/IEC 14543-3) as well as a European Standard (CENELEC EN 50090 and CEN EN 13321-1) and Chinese Standard (GB/Z 20965).
- **Home grid** – Based on the ITU-T specification suite known as G.hn that is designed to provide communications within the home environment, making use of existing wires such as powerline, coax cable or copper pairs.
- **IETF protocol suite** – Based on 802.15.4 providing a specification for L1 and L2 WPAN, the IETF has developed a set of protocols aimed at bringing native IP support to constrained devices.

Figure 1.7 provides an example of data models used in the context of smart metering applications, the most notable of which is the device language message specification

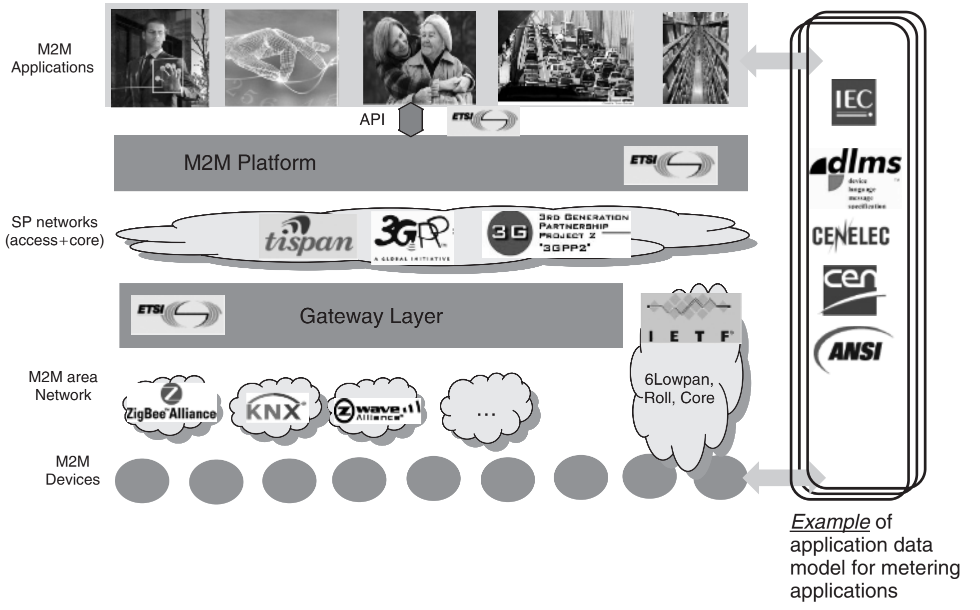

Figure 1.7 Mapping of standards organizations to the M2M framework.

(DLMS) that has been adopted at the European level by CEN and CENELEC and by IEC at the international level. ANSI C12.18 suite is the US counterpart for the DLMS data model. Standards organizations working on M2M area networks also frequently produce vertical application specific data models. This is the case for ZigBee and KNX.

When it comes to service provider access and core network optimizations, 3GPP and 3GPP2 are the natural organizations for cellular systems, while ETSI TISPAN provides the equivalent set of standards for wireline NGN (next generation network). However, it is commonly agreed that wireline standards will see less activity in this area.

3GPP TS 22.368 [TS 22.368] lists both common service requirements and specific service requirements for machine type communications (MTC). This specification has been elaborated with marked involvement of operators, cellular system vendors, and M2M module vendors and will be the basis for the ongoing work on network improvement for M2M. The level of maturity of this work is low compared, for instance, to the work already done on the data models.

Above and beyond the access and core networks, the ETSI M2M Technical Committee and the TIA TR50 Committee on Smart Devices are developing a service aimed at providing service capabilities to be exposed to M2M applications via open APIs. Neither group is starting the work from scratch and both are looking at means by which to endorse building blocks from existing standards, the most notable being the Open Mobile Alliance (OMA) device management and the Broadband Forum TR069 protocols. These two protocols have been designed to provide remote device configuration-related functions such as: configuration management, performance management, fault management and firmware, and software upgrade.

ETSI M2M has fully endorsed the HTTP/REST approach for its API work. Reuse of existing guidelines and API work from OMA has been identified as a target by ETSI M2M experts.

1.5 Roadmap of the Book

The authors hope that this introduction has captured the interest of the reader and paved the way for the following two parts.

Part I (Chapters 2 and 3) addresses the current state of the M2M landscape.

Chapter 2 describes in greater depth the business of M2M, by analyzing the market landscape with a realistic outlook as to whether M2M penetration can be achieved, given the recent evolution outlined in this introduction. Market drivers and market barriers will be addressed with possible roll-out scenarios.

Chapter 3: Feedback and lessons learned from early market deployments. This chapter provides a set of scenarios and related network configurations for an operational deployment of M2M over a 3GPP commercial network. It provides as a conclusion a list of lessons learned, as well as recommendations for future standards work.

Part II (Chapters 4–8) will address M2M architectures and protocols.

Chapter 4 analyzes M2M requirements using a Use-Case-driven approach to service requirements. It then introduces the high level architecture, focusing in particular on network, services, M2M traffic models, end-to-end architectures for M2M, vertical versus horizontal architectures and the M2M service deployment platform (SDP).

Chapter 5 introduces the M2M services architecture capabilities defined by ETSI. More specifically, it presents the M2M capabilities in the services domain, in the gateway and in the device. Specific points are made on the protocols and APIs. This is followed by considerations on interoperability and the REST-based architecture and the impact on device management protocols.

Chapter 6 addresses Access and Core Network optimizations for M2M. After introducing the problem, it outlines how it is handled in various standardization actions within 3GPP.

Chapter 7 investigates the role of IP in M2M, and in particular the IETF approach. It analyzes the IP protocol stack (6LoWPAN), routing for M2M area networks (roll) and REST for constrained devices (core).

Chapter 8 deals with horizontal security architecture for M2M.

Chapter 9 addresses M2M terminals and modules.

Chapter 10 presents standards evolutions in SIM cards and their impact on M2M.

Chapter 11 provides a set of concluding remarks as well as views on future developments.

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