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An analysis of M2M platforms: challenges and opportunities for the Internet of Things

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***Abstract*—IoT (Internet of Things) resources could be conceived as service end-points for Machine-to-Machine (M2M) platforms, i.e. Things/Resources as a Service (TaaS or RaaS). Moreover, technologies involved in this platforms, provide to devices the needed capabilities to expose their services in a straightforward manner. Consequently, a solid, well-designed M2M/IoT platform should provide the basis for the simplified management of resources. The goal of this paper is to provide an initial analysis of the requirements for an M2M platform together with the considerations about IoT technologies, which will serve as a starting point for defining the actual services for IoT devices via M2M. Towards this direction, the current state of the art in M2M communications, in terms of standardization and already deployed platforms are taken into account, and an analysis of several of this platforms is done, showing up its main focuses and how all them have to evolve, in order to meet with upcoming requirements. The new trends about interaction between real and virtual worlds, and the challenges and opportunities identified, form the basis upon which every M2M/IoT standard platform should be built.**

Keywords: Machine-to-Machine (M2M); Internet of Things; Future Internet; Cloud Computing; Web of Things; CoAP.

I. INTRODUCTION

Machine-to-Machine (M2M) communications involve a wide set of technologies mainly based on the interconnection of distributed devices and heterogonous back-end systems. These solutions works as a huge collaborative and interoperable network for the transmission of the data gathered by the end-terminals, such as sensors and smart objects, to the backend, such as servers, where are running applications such as data processing solutions. These processing solutions carry out different inference steps, the conversion of the data into meaningful knowledge, involving several research fields and being the basis for the Future Internet of Things (IoT). However, this distributed architecture is characterized by a growing complexity and heterogeneity, so it should be managed with the adequate abstraction level in order to unify resources and capabilities, leading into a much more homogeneous and interoperable global system, simplifying management tasks, and easing discovery and interaction processes between entities. On this way, IoT resources can be considered as services exposing their capabilities, having the possibility of mashing up all this resources in service oriented systems due to it straightforward access or integration platforms in order to exploit the potential of all this resources and services working together.

M2M communications have become a market-changing force for the most of the data-based applications. This change has been motivated by, on the one hand, the adjusted deployment costs of M2M architectures, i.e. end devices and network access costs. On the other hand, other of the main factors that are driving the vertiginous development of these technologies has been the capacity of being elastic, in terms of scalability, such as the versatile applications that these technologies could offer in the real world, concretely regarding to remote monitoring for healthcare systems [1], smart cities, smart grid, remote management and monitoring [2], and business processes automation and optimization without the need for human intervention.

Thanks to the capabilities of M2M architectures, devices and the network itself will be able to enrich the environment of application with additional data that may be useful for improving performance and saving costs [3].

This is enabled from the networking point of view for the growing trend of having more network enabled devices, it will be possible to achieve a truly smart network, without relying in complex deployments or big and expensive systems. In terms of evolution of the communication technologies, in conjunction with the development of new devices such as wireless personal devices, embedded systems and smart objects.

In addition, the innovation of the services through the definition of cloud computing, online services, and ubiquitous access to information is combined in order to make feasible the connection to Internet of all the objects which are found around us, within the so-called IoT [4].

The objective of IoT allows devices to access to another systems, leading to provide ubiquitous computing and communications. These devices need to be organized in order to share complex operations and collaborate within the network environment, achieving a greater knowledge. They also present scalability challenges.

M2M platforms need to manage these challenges and also exploit these capabilities from these smart objects, and enable collaboration between different parts of the system.

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II. IoT Design Issues for a M2M Platform

At the same time that M2M architectures are becoming popular and the number of potential services grows, several standardization forces are being formed with the aim of providing a unified vision and definition of a M2M standard architecture (e.g. M2M Standardization Task Force). These forces safeguard the interoperability between different M2M solutions, establishing the basis of a standard architecture. However, it is necessary to set the concrete requirements and specifications during the standardization process, in order to be implemented for every M2M standard API (Application Protocol Interface) [5].

Moreover, we have to keep in mind that as we are more and more connected, all these tasks start involving not only machines and processes, but also people, making it social, and objects, leading into a new set of intelligent devices that can feed the systems and be used as an advantage in order to be conscious of every context change in a determined environment (see Figure 1).

Studies reveal that in the following 20 years, the capacity of the whole Internet will raise over the capacity of our brains at its high level of computation power [6]. It is estimated that by 2030 Internet will have more capacity than our senses and all the brains of the world's population, regarding to perceiving and processing information. Mankind is facing a new understanding of intelligence. Thereby a new generation of smart and small devices, context awareness services and applications can be defined.

This grows of the Internet presents serious challenges for scalability, manageability, addressing, identity, robustness, and the openness and ubiquity features of the Internet presents problems to offer a suitable support for security, privacy, and secure mobility [6].

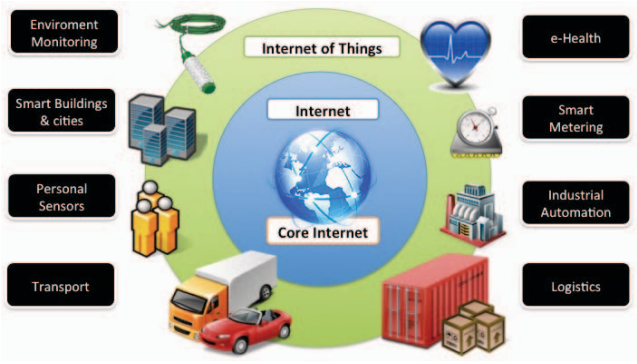

Figure 1. Towards an Internet of Things approach.

For this purpose, several projects from industrial and international collaboration are being carried out to define the Future Internet, which solves the limitations of the current architecture [7].

From the point of view of the characteristics that every M2M platform should meet, in the following lines are exposed some of the main desired features and capabilities for finally obtaining a highly scalable, secure and versatile technology:

- At the same time that enterprise needs are changing in a vertiginous velocity improving their processes day by day, user expectations have also changed, and even treating with M2M technologies it is necessary to keep in mind that we need to deal with this regard, or finally products or services will not be used.
- The platform as a whole should be able to manage from simple to highly complex protocols and scale at the same level that the system does, but keeping always transparent to end users.
- Ability to virtually connect every existing device with the platform, based in a simple, lightweight and standard messaging protocol, which every entity needs to know and understand.
- Need for a standard overlay operation set, in order to define a common transversal layer being able to translate from proprietary protocols used by different vendors to standard operations understandable for every M2M standard compliant platform and its devices.

The fulfillment of all this precepts will enable M2M systems to obtain improvements in some aspects such as reducing time-to-market for compatible devices and platforms, quickly and easily reconfiguration, and even reprogramming for devices already deployed without needing human intervention. Future innovations and evolutions over M2M platforms will not need of hardware swapping but just a software upgrade of the devices firmware, and finally, connecting new devices that have proprietary protocols to the platform will require just to use the concrete adaptor in order to be manageable by the whole system or just one for of the devices needed of its resources.

III. IoT/M2M Clouds

In the following sub-chapters there are analyzed different IoT/M2M platforms, going from the more concrete focus (objects), to a more global focus, based on people, objects, environment, and enterprise systems mixed together as a global platform with enriched capabilities in order to achieve a really smarter and global solution, scalable, adaptable, and with a really open connectivity model based on standards.

A. SEN.SE – Objects Intelligence

Sen.se [1]is a simple IoT/M2M platform that bases its behavior in a three-step configuration process (channels, applications and visualization).

In the first step you can add channels that send or receive data to/from the Sen.se platform. A channel is something that sends or receives data. It could be either a physical device connected somehow to the Internet, a web form trough which you enter data manually, or an open external online data source. Related to objects, you can either connect devices you have made using Arduinos or

[1] Sen.se - http://www.sen.se

similar trough the ready-to-use sketches or the open API that Sen.se offers, and also Sen.se compliant devices.

Related to online services, data can be retrieved entering data manually to a web form created with the Manual Logger App included in the platform, subscribing to a data feed, such as weather and using the received data, or using the data from a device that is already shared on the Sen.se network.

Regarding to applications, there can be performed several types of processes such as making calculations and transforming data; aggregating data from several sources through a data funnel in order to create an single value; comparing data and applying conditional rules; triggering actions in the physical or virtual realms; or visualizing data and its history in real time. For this purpose, it is possible to choose between pre-programmed applications offered in the Sen.se application libraries or creating a new one based on its open RESTful (Representational Estate Transfer) API.

Actions can be triggered on manual, automatic, conditional or scheduled ways, and could be used for sending custom notifications and messages in the virtual realm, or even controlling the behavior of all sorts of physical devices connected to Sen.se. Related to visualization, it is possible to create what Sen.se called *Sensemeters,* in order to be integrated on the Sen.se dashboard (*Senseboard*) enabling to show historical data graphs, gauges, current values, and even embedded information from other sources, and also operate the system with new data through channels or commands.

B. EVRTYHNG – Enhanced Objects Intelligence

EVRYTHNG [2]is a social platform with the aim of creating a unique Active Digital Identity (ADI) profile for any physical thing, giving it global access using a unique URI and APIs for that individual object, making it visible, accessible and controllable trough the global network. An ADI is simply a Web resource with information about a thing in the form of dynamic or static attributes.

This platform allows configuring products in order to store information about itself and its environment for being queried, displayed and analyzed. In order to enable connectivity in an straightforward manner, it provides a RESTful API that connects physical objects with the virtual world of things, accessing, creating, storing, manipulating, sharing, or searching the ADIs for every real-world object, and also a set of services and tools that can be useful for such applications.

EVRYTHNG also includes an information-sharing framework for commercial, public and private objects, such as a management infrastructure to operate with large volumes of object information and drive apps with computation and query capabilities. This allows connecting devices to the platform and share information with third party applications and services. Thanks to that, it is possible to integrate the profile with social networks, CRM (Customer Relationship Management), or other analytics applications, leading to a much more powerful and relevant type of marketing, denominated by EVRYTHNG as PRM (Product Relationship Management).

From the brand's point of view, a product with an Active Digital Identity enables powerful marketing experiences since products and consumers can communicate. Products can become an active participant in analytics so brands can extract data from the consumer interaction with their products.

Other platform similar to EVRYTHNG is PACHUBE [3]("patch-bay") that bases its system on the connection of people to devices, applications, and the Internet of Thing as a web-based service built to manage the world's real-time data.

C. AMEE – Environmental Intelligence

AMEE [4]focus its services in offering a platform as a service solution focused on innovation for environmental data. AMEE's Platform handles the infrastructure to reduce costs and accelerate time-to-market processes. It enables an easily accessible and manageable platform with an Appkit to quickly build apps by the customer, offering also services for developing applications by AMEE. It is scalable and secure, providing a complete enterprise set of services based in those precepts. One of the main points of AMEE is that the platform is open source, built on a RESTful API in order to harness collaboration.

In the following lines are described some of the main AMEE services. First of all, it will be presented AMEEDiscover. It is a search engine focused on energy and greenhouse gas emissions, providing access to all data in AMEE, so that consultants, researchers, and developers can learn about standards, methodologies, and specific data required for energy efficiency/emissions analyses. Used in conjunction with a code-generation tool, AMEEdiscover enables developers to rapidly build applications. In order to get interaction with real world devices, AMEE offers AMEEConnect, as a platform that gives automated access to the world's environmental information. It is offered as a Platform-as-a-Service (PaaS) web API that automates communication between applications and the AMEE Platform.

Finally, in order to monitorize supply chain processes, it is offered AMEEscore. It is the AMEE's supply chain solution, designed for businesses to quantify risks and liabilities, engage suppliers to collect data, improve insight, and enable the collaboration necessary to take determined actions. The resulting value is to improve awareness of risks, increase efficiency, and strengthen resilience within the supply chain.

D. RUNMYPROCESS – Enterprise Intelligence

RunMyProcess [5]platform allows its customers to design and run business 'processes'. These processes can interact with users and/or other 'web services'. The platform conformed by an on-demand infrastructure which relies on a centric

[2] EVRYTHNG - http://www.evrythng.com

[3] PACHUBE - http://www.pachube.com

[4] AMEE - http://www.amee.com

[5] RunMyProcess - http://www.runmyprocess.com

application platform enabling the development and deployment of applications simply dragging and dropping function boxes and assigning one of the predefined functions or defining a new one by the developer. This platform runs over an Amazon Web Service infrastructure, which means several replicated centres around the world, secured in order to prevent unauthorized access. Additionally, several authentication methods are supported such as Microsoft Azure, or Google 2-legged Open Authorization.

A basic feature of RunMyProcess allows IT experts and business managers to collaborate in creating a diagram. The graphical editor of the platform complies with the BPMN (Business Process Modeling Notation) standard, and customer's diagrams can be based on complex rules like planning, task escalation, error management, choices, parallelism or loops. Customers are allowed to create independent applications or produce forms that are associated with a process. The system also features linking/connecting with processes based on JBoss, EJB (Enterprise JavaBeans), JPA (Java Persistence Api) or Hibernate, enabling users to configure processes via web services, human workflow or sub-processes.

RunMyProcess also features customizable RSS feeds that can be integrated with third party tools or portals, allowing enterprise users to take advantage of their existing portals. Customers can conduct real-time analysis of business activities utilizing graphs and dashboards exportable to Excel or accessible as RSS feeds. The platform offers business maps; enabling customers to visualize accomplishment of objectives related to higher-level targets like budget targets and IT deployment.

Related to integration aspects, the platform offers a large directory of pre-configured connectors and processes while the system supports a variety of standards like SOAP (Simple Object Access Protocol), XML (eXtensible Markup Language), REST, and some others.

E. AXEDA Platform – Global Intelligence

The Axeda Platform[6] is a complete M2M data integration and application development platform with infrastructure delivered as a cloud-based service. It is aware of the scalability and security needs, at the same time that offers a powerful development environment with flexible APIs, easing to build and deliver custom M2M applications for the most demanding requirements and integrate M2M data into enterprise applications and systems.

One of the main characteristics that make Axeda highly interoperable is the powerful open source API that offers a rich set of built-in functions to access the core of the platform. It provides the ability to manage assets, query historical data, and an extensive management for alarms. Additionally, the platform brings authentication, authorization, and transportation security services, enabling to exercise both Axeda platform APIs and custom logic developed in Groovy as easy-to-consume Web Services based on SOAP and RESTful. This provides an extensible solution built on standards-based message queue technology that accelerates integration between the Axeda Platform and enterprise systems including ERP (Enterprise Resource Planning), CRM, and almost every billing and data warehouse.

Related to connectors, the Axeda AnyDevice Codec Server bridges the gap between customer devices deployed over the network and the core platform. The Axeda AnyDevice Codec Server is a simple transversal solution that converts a protocol running on a device to a protocol that the Axeda Platform can understand. It enables customers, partners, and system integrators to easily install, configure and use M2M devices that communicate with a proprietary protocol that do not have the ability to add an Axeda Agent or Axeda Wireless Protocol (AWP). This option also gives you a wider set of devices to choose from since you can use M2M devices incapable of running an Axeda Agent or the AWP. For example, the Axeda AnyDevice Codec Server can process messages sent by an existing device by means of a codec implemented specifically for the protocol used by that device.

F. THINGWORX – Trasveral Global Intelligence

The ThingWorx[7] platform bases its operation model in treating all things (considering people, physical world and systems) at the same level. This enables to create processes connecting things in any possible combination. The platform stores information about this people, environment and systems, creating applications that evolve and grow together. On this way, applying the network effect to these applications produces a multiplier effect over data that enhances its value. ThingWorx enables a new type of transformational applications as they continuously evolve and increase in value over time, and allow users to answer questions, solve problems, and capture opportunities that have not been anticipated.

The connectivity model of this platform is based on dynamic RESTful APIs that enable easy integration with other applications and services. Additionally, remote connectivity is based on XMPP (eXtensible Messaging and Presence Protocol) providing a secure, real-time interaction between devices, people and business systems.

IV. LESSONS LEARNED

M2M communications, from the IoT point of view, involves not just machines communicating with machines, else it is also considered the integration of the systems that connect data (link data), people, things, processes, and knowledge. This is required in order to obtain a real collective intelligence, and real-life applicability.

So it is not just about people connected to people, machines connected to machines, but about people communicating with machines, machines communicating

[6] AXEDA - http://www.axeda.com

[7] ThingWorx - http://www.thingworx.com

with people, people and machines interacting with the environment, and every other possible combination (See Figure 2), and fulfilling the requirements exposed in section II (See Figure 3).

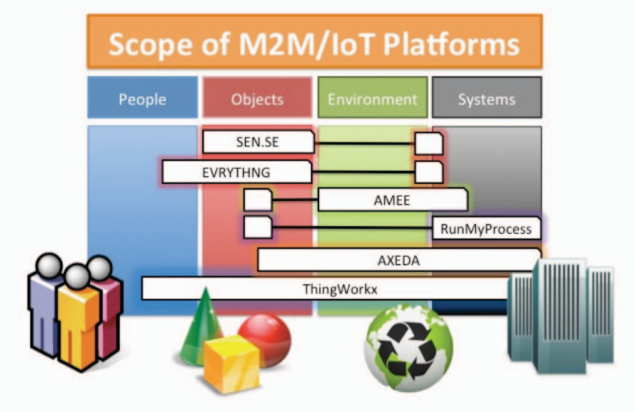

Figure 2. Scope of M2M/IoT Platforms analysed.

Each one of the platforms analyzed, focus its work at different levels of entities. Sen.se and EVRTHNG, focuses exclusively in objects, and possibly persons that interact with this objects, but the main area is referred to device communication. However, for the concrete case of EVRTHNG, it also implements connectors for CRM platforms, in order to process information retrieved by objects and enabling the post-analysis of this data.

Related to the AMEE Platform approach, it only concerns to environmental data, and its applications to the enterprise world. For this reason, it appears over the environment and systems levels, embracing both of them, and also with capabilities of being extended to connect with objects such as sensors and smart-meters, in order to feed the platform directly with real world data, not just with data-warehouses or datasets.

Following with the rest of platforms, RunMyProcess operates at enterprise system level as it offers connectors with virtually every ERP, BI (Business Intelligence), or CMR third party system. Additionally, if offers an API for connecting physical devices and other data-sources based on SOAP, XML, or REST, so it could be extended in an easy manner.

For the case of AXEDA, the focus embraces more than a level. Concretely, its platform deals with Systems, Environment, and Objects, and it is very conscious of the necessity of extending their capabilities more than in just one of the levels, but the most of them. For this reason, it offers a bridge to fill the gap between proprietary services or devices and the applications running in a closed environment.

Finally, related to ThingWorx, say that this platform offers a paradigm change respect to "traditional" platforms, treating data from people, objects, environment and systems with the same equity, converting this data in augmented representations of what is really happening between every entity, and how could affect the change in one of them over the rest. This characteristic enables process connecting diverse data in any combination to be rapidly analyzed.

Changing to a standard view, and in order to set the steps that will permit achieving the ideal IoT/M2M system, it is necessary to keep in mind that there is the need for a change, from simple device or information monitoring to models in which devices and data are aggregated into new systems that can permit a true network intelligence. With this, it is possible to get really smart devices and nodes with capacity of making decisions working together in an extremely networked platform, being aware of every change on its environment.

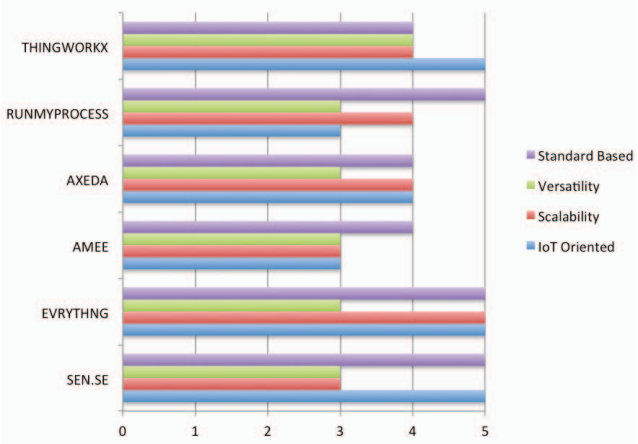

Figure 3. Valoration of M2M/IoT Design Issues

Regarding to change requirements, it is necessary to offer an easily configurable and maintainable connectivity model, of course, based on automation. Until today, every new device requires several processes of complex discovery, configuration, and authentication or inclusion in a network. It is necessary to develop software and hardware strictly based on standards for being able to automate these processes, enabling a really easy development, configuration, and deployment tasks, facilitating at the end the growth and spreading of this technologies over the world.

With a really connected network of automated things, it would be possible to optimize every asset in the environment where these technologies are deployed, keeping in mind, that this "things" are not just tangible things, but also intangible (services). To really succeed, there will be needed fully real-time collaboration platforms in order to obtain all the potential benefits exposed. For this purpose, it is extremely important to ensure the development of really flexible, scalable, compatible, and standard systems and protocols behind. As a set of requirements, in the following lines are exposed some of the main principles that every M2M/IoT platform must meet.

It should be defined a standard API, able to manage different technologies in a straightforward manner, seen as a transversal layer. Regarding hardware, it is necessary to

define the basic characteristics of gateways and integration platforms for data coming from different sensing, logging or data systems. Related to that, a lightweight and optimized communication protocol should be finally defined, standardized and adopted such as CoAP (Constrained Application Protocol) for CoRE environments (Constrained Resource Environments), without neglecting aspects such as QoS (Quality of Service). Additionally, it is necessary to develop self-healing mechanisms for self-detection of problems and errors not only in the core system, but also in data capture and data source software and devices, so that the scalability and stability of the platform will not be compromised by unforeseen situations.

Awareness of privacy is also an important asset, needed of novel techniques such as the exposed in the PIA (Privacy Impact Assessments), in order to offer a flexible adaptation of the platforms and its services, to needs, interests and indications from users and data sources.

V. CONCLUSSIONS

Today's society faces great challenges in the area of ICT (Information and Communication Technologies). It is obvious the potential impact on our lives, both in professional and personal aspects. The business world, has also found the need to evolve in line with a new generation of resources, technologies and opportunities during the so-called information age.

However, it has been reached a new turning point in the technological race, where the impact, integration and development based on information is exploited with greater capacities and amounts of data and knowledge, enabling to extend and improve the existing information systems. Any entity is able to exchange information with the rest, even when they are thousands of miles away. Also, this exchange of information is becoming faster, so the vast volume of data grows exponentially every day. The challenge of treating these large volumes of data is the main problem to be solved by all the technologies that embraces IoT and M2M communications, also known as the Big Data.

There is a question to answer, related to how to transmit, classify, store and interpret all this information in order to make the most of it. To deal with that, information must be treated appropriately. By applying different technologies, it could be possible to transform the data provided by different entities in real knowledge reefs, through several inference and feedback processes. At the end, that would provide a useful and accurate information pipeline that would help to making the best decisions, aware of the context and improving adherence and commitment in many processes in which we are involved daily. From the user's point of view, having useful information immediately, contextualized and enriched based on preferences and needs, will make it a much more satisfying experience with other users, systems, or real world elements with which it interacts.

So one of the greatest opportunities that lie ahead, is the transformation of this vast and growing universe of information in relevant and practical knowledge that will be used for a more efficient performance of the activities that take place everyday.

The ability to exploit all the information available, and the Internet capability for connecting objects and provide data of any "thing" in real time, leads us to conceive an explosion of opportunities.

From the authors' point of view, this is the beginning of a new era concerning to the interaction between physical and virtual worlds. Some of the symptoms have been exposed with the invasion of the social environment, that were highly characterized by face-to-face personal relationships, by a redefinition of the social concept, that directly leads into social networks as we know them today, where relationships are being carried out increasingly through virtual environments.

The new trends about interaction between real and virtual worlds, is extended with the conception of the Future Internet and the IoT. We have trespassed the limits of the network where at the beginning, information systems where only available for business and professional use, to an Internet of People trough the social networks, meeting now at the gates of an Internet of Everything, a real network of collaborative knowledge.

Research in this area shows that the variety and quantity of interesting data to be found and accessed through the network is growing exponentially, and it will do so more in the following years. The main challenge passes through balance this growth with a new concept of the Internet, an Internet working with us, aware of our existence.

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