Composition of Advanced (μ)Services for the Next Generation of the Internet of Things

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Abstract. In recent years, technologies such as Machine to Machine (M2M) and the Internet of Things (IoT) have become core technologies of tomorrow's world that probably we will go to inhabit. Potentially, everything that belongs to the environment around us is or will be connected, and it will produce data or provide services of some kind. The big penetration of technologies such as sensors, electronic tags, microcontrollers, etc., and the inexorable growth of the Internet, improve the understanding of the physical environment, from industrial buildings or the workplace, up to the farmland. The proliferation of all these devices, often able to host in a very small footprint, an entire TCP/IP stack, has meant that the M2M world was incorporated into the world IoT establishing an environment where things and people are able to communicate, share information and generate knowledge.

It is now clear that to support the growth and development of a global network of devices connected in an autonomous way to the Internet and with the ability to communicate and exchange information between them, two key actors are need: first, the adoption of a technological standard that can "disconnect" the Things from a specific application, in order to shift towards application independent Things; and second, to transform Things into systems able to make decisions or support decisions.

In our visionary paper, we will describe a high level software architecture based on features from *embedded SIM* (eSIM) technology and (μ)services technology, in order to develop IoT systems of new generation, able to leverage on LTE or 3G cellular networks to combine services provided not only from the Cloud, but also by Things themselves, and from of them networks.

Keywords: IoT · Service composition · Embedded SIM

1 Introduction

In the longer term, a new IoT [2] and M2M [6] ecosystem will enable intelligent creatures exchanging information, interacting with people, supporting business processes of enterprises, and creating knowledge. Thanks to wireless and cellular

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technologies and rapid deployment of cellular 3G and 4G or Long Term Evolution (LTE) systems on global scale, the instant access to the Internet is available virtually everywhere today. Furthermore, the IoT technologies will play a central role in the optimization for citizens and enterprises within the urban realm, and it is evident that now it is absolutely necessary to increase significantly the levels of **system integration** and **standards development**. The bold requirements are relevant for the following considerations:

1. IoT solutions bring together devices, networks, applications, software platforms, cloud computing platforms, business processing systems, knowledge management, visualization, and advanced data analysis techniques.
2. Embedded processing is evolving, and this enable very constrained devices with a very low power consumption, to be capable of hosting an entire TCP/IP stack including a small web server or web container.
3. Decision support or even decision-making systems will therefore become very important in different application domains for IoT, as well the set of tools required to process data, aggregate information, and create knowledge. Knowledge representation across domains and heterogeneous systems are also important, as are semantics and linked-data.

Since the considerations above, we will introduce a new software architecture in order to address the challenges posed by these systems, and provide preliminary guidelines to build next-generation of IoT systems.

2 Motivation

In the first part of this section, we will give a brief description of the "implementation" of current IoT systems. However, in the second part, we give you a different view of an IoT system in order to address the bold points introduced in the Sect. 1.

Figure 1 shows the way in which currently is possible to implement an IoT system: the integration of device in several processes merely implies the acquisition of data from device layer, its transportation (Network layer) to the Enterprise systems (in general, the Cloud), its assessment, and once a decision is made, potentially the control (management) of the device, which adjust its behaviour. However, in the future, such implementation could be not viable due to:

- the large scale of IoT, as well as the huge data that the devices will generate, the heterogeneity of the data type and the continuous stream of data;
- access and use of enterprise systems is often characterised by free accounts, that are often strongly limited in the number of allowed accesses, quantity of data, assigned resources, etc.;
- data transport from the place where the data originates or collected to the backend system where evaluate their usefulness, will not be practical for communication reasons, as well as due to the processing load that it will incur at the enterprise side, thus resulting in an highly centralised approach;

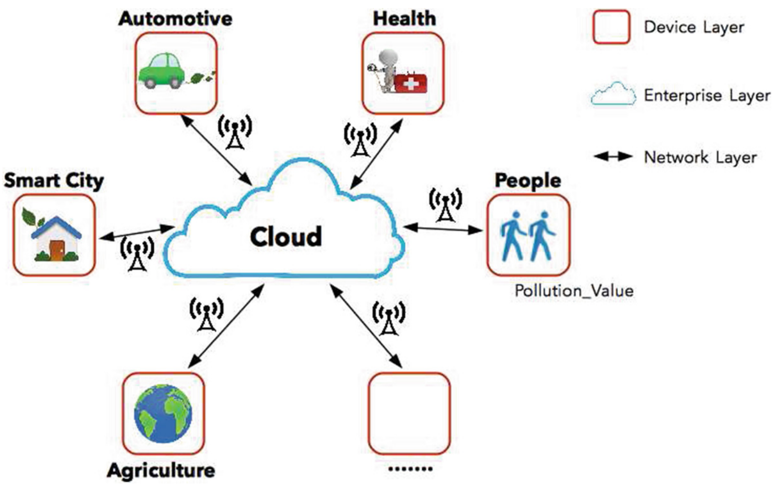

Fig. 1. Simplified description of actual IoT System

– often, the data is strongly linked to the application, despite by its nature can also be used in other contexts. For example, considering the Fig. 1, a *Pollution_Value* generated by *People* application, might also be used in *Automotive* or *Agriculture* application, etc.

Since the considerations above, it is clear that current solutions for the design and implementation of new generation IoT systems not meet those requirements of integration, scalability and standardisation desired. A new approach should:

– minimise communication with enterprise systems. With the increase on devices (more memory, multi-core CPUs, etc.), it makes sense not to host the intelligence and the computation required for it only on the enterprise side, but even on the device themselves;
– partially outsource functionality within the real devices, in order to realise distributed business processes whose sub-processes may execute outside the enterprise system;
– model businesses processes focusing on the functionality provided and that can be discovered dynamically during runtime, and not on concrete implementation of it; we care about what is provided but not how, indeed
– allow devices, as they are capable of computing, to realise the task of processing and evaluating business relevant information they generate by themselves or in clusters;
– allow heterogeneous devices to exploit the network to communicate between them, although physically distant. The goal is to make it "visible" on the net, without the need to pair it with other master devices. For example, many wearable smart devices on the market must be connected to a smart-phone, tablet or pc to share data collected.

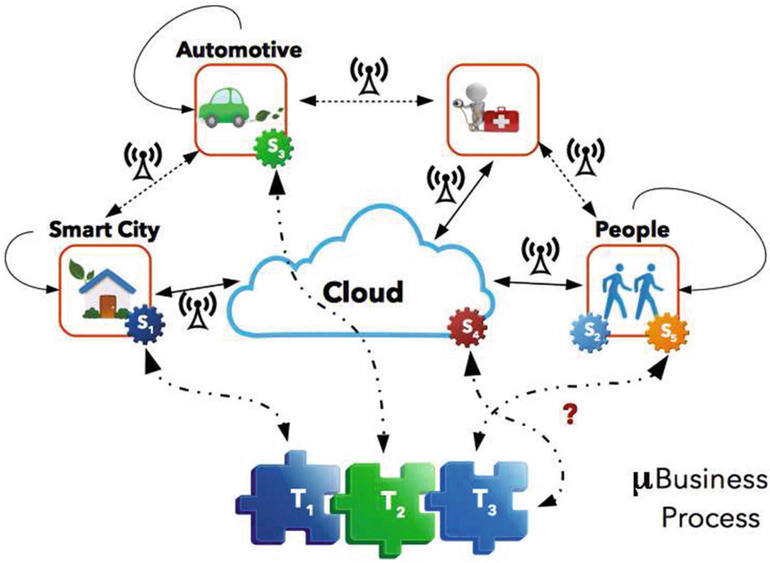

Fig. 2. Simplified new IoT system

In order to meet the challenges identified above, we offer a different view of IoT system, where the enterprise component (i.e. Cloud) is only one of several actors that can constitute the system but not the main one, Fig. 2.

These requirements are driving the need to scale to approaches that are capable of enabling intelligence directly on device, in order to improve the distribution of services and functionality between devices themselves. We need to develop a new generation of devices and services capable of aggregating information and generate knowledge, in order to shift from device-centric approaches to application-centric approaches, i.e. the (heterogeneous)devices must be able to offer services or change their behaviour in order to meet the (μ)business process.

3 ESIM Technology as Host for the Next Generation of (μ)Things

In this section, we will introduce the main concepts behind to Embedded Sim technology (eSIM) [4]. After a brief summary on benefits of the new technology, we will see as we can use and extend specific characteristic of it to build a new generation of IoT systems.

Embedded Sim Overview

One of the main challenges for the new generation of IoT is: *heterogeneous devices must be able to exploit the network to communicate between them, although physically distant. The goal is to make it visible on the net, without the need to pair* *it with other master devices*, see Sect. 2. In order to ensure that all Things of our environment can be visible to affected neighbours, it is necessary that they are equipped with radio modules to leverage on the 3G or 4G network (LTE). This condition is necessary for two reasons:

1. many connected devices are in remote locations and have simple functions, so they would not be suited to wifi or Bluetooth. Indeed, they may only need a 2G, 3G or 4G connection, and
2. *subscriber identification module (SIM)* [1] *cards are the de facto trust anchor of mobile devices worldwide. The cards protect the mobile identity of subscribers, associate devices with phone numbers,* etc.

Traditional SIMs cause significant challenges for insertion and replacement, raise costs and create barriers to sales and adoption. The GSMA has already developed a solution, the *embedded Universal Integrated Circuit Card* (eUICC) [5] SIM specification which lowers these barriers. The idea behind an eSIM is that it is embedded as a chip into the hardware device rather than being a removable card. This solution has the following advantages:

– the possibility to miniaturise radio modules, and the elimination of traditional sim slot, will allow to extend in a consistent way the type of heterogeneous device that can be equipped with this technology;
– the eSIM card will contain security information, such as private key information, which could be used in authenticating user equipment in a cellular network, and will make it easier to locate lost or stolen devices through *Data Loss Prevention* [13] and *Mobile Device Management* [8] solutions;
– embedded SIMs are generally more hardy than regular SIMs. They can be hermetically sealed (especially where devices are placed in wet or hot environments - like smart meters), which means the card can not be swapped.

Another important capability introduced with the new standard is the *Remote Provisioning*, i.e. the ability to remotely change the SIM profile on a deployed SIM without having to physically change the SIM itself. In order to achieve this, the SIM has extra memory and is therefore capable of holding more than one operator profile (rather than only one on the traditional SIM).

4 (μ)Services for (μ)Things

In the previous section, we illustrated a new technology that could be a good choice for next-generation of Internet of Things, satisfying the requirement related to access to radio networks in an autonomous way. These new features will create a source of data that will consist of a myriad of new “occasionally connected” devices, presenting associated challenges.

In a hypothetical scenario, where heterogenous and distributed devices populate the network, we may ask whether it is possible to take another step forward, in order to build systems that meet the vision represented in Fig. 2. In particular, as the device are capable of computing, they can either realize the task of processing, or provide information on resources able to satisfy that particular task. We want devices announcing themselves and reacting to the actions of other devices, people or vehicle. We believe that such a role can be played by micro services ((μ)Services) [3]. *Microservices are small, autonomous services that work together* [11].

How can the new generation of devices for the IoT exploit (μ)services? To answer this question, we can list some of the most important characteristics of micro services [11]:

– **autonomous**, each (μ)service is a isolated entity, and in order to enforce separation between services, all communication between the services themselves are via network calls, and they must be able to change independently of each other;
– **heterogeneity**, by their nature, the new IoT systems are heterogeneous, i.e. composed from many different devices with different computational capabilities. Consequently, any (μ)services may have features linked to the type of technology that hosts them;
– **scalability**, small and well confined services can run on other parts of a system on a smaller and less powerful hardware;
– **composability**, we allow for our functionality to be consumed in different ways for different purposes.

Therefore, the decision support or decision-making systems will become very important in different application domains of IoT, as well as the set of tools required to process data, aggregate information, and create knowledge across domains and heterogeneous systems.

Given this not exhaustive list of characteristics, it is evident how the use of micro services for the implementation of a system composed of Thing with appropriate capacity, it will enable us to address many of the challenges enumerated in the previous sections.

5 (μ)Thing Architecure

In this section, we will introduce a new architecture in order to set some fundamental roles in a new generation of IoT system, based on previous sections. The goal is not to reinvent the wheel, but just to propose guidelines for the design and implementation of these new systems.

The concepts and technologies identified in the previous sections are relevant to Layer 3(**L3**), depicted in Fig. 3.

In **L3**, there are all Things that define our system. Through the use of eSIM, each of them can play an “active” role in the network, commensurate with the resources and services offered.

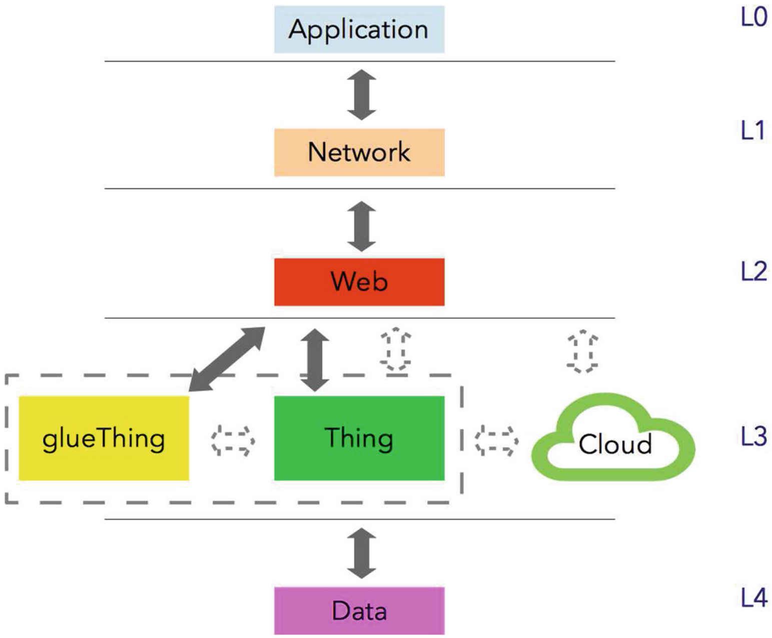

Fig. 3. (μ)Thing services architecture

In particular, we have identified two types of Thing:

- **glueThing.** These elements have high computational capability, such as to allow them to be interposed between the upper and lower layers, or between the Things of the same Layer (**L3**), in order to play a role of glue or an intermediary between the parties. The purpose is to allow the composition of services or functionality exposed by heterogeneous Things of the network.
- **Thing.** This network elements do not provide services or functionalities, but generate or collect data to be shared with the other layers of the stack. We can not say in advance whether they have capacity or computational resources reduced.

Obviously the two roles can be interpreted by the same Thing. From our point view, the Remote Provisioning capability, see Sect. 3, is quite interesting. The idea is to use the Remote Provisioning in order to inject profiles that can enable use, in *glueThing*/*Thing* mode, the functionalities provided/required by the device. The profile can be changed dynamically, allowing different behaviours according to the (μ)business process defined, Sect. 2.

6 Considerations and Future Works

In our visionary paper, we introduced a new informal service-based architecture with the aim of supporting the development and implementation of a new generation of Things, and service oriented system. In the previous sections, we have highlighted how every aspect of our environment will soon be an active component with which we will relate and collaborate.

One of the major problems that so huge and heterogeneous number of devices will present, is linked to the unambiguous identification in the network. Indeed, in the perspective in which even a "road user" will be able to expose data and offer services through a (smart)device, it will be essential to introduce or maintain a high level of security and reliability in the network. In our view, the adoption of *eSim* technology allows the respect of the safety and traceability required, delegating the security management to the telephone network operators and phone operators, and not to the developer or users of the services offered.

Particularly interesting are the potential capabilities offered to *Remote Provisioning* uses. Actually, the new standard allows to user to change "freely" the SIM profile: i.e., add a data or voice profile, or combining one or two of them, depending on the country where he/she/it is located, without replacing the SIM. A more sophisticated way of using this feature would be to change the role of a Thing within **L3**, so as to enable dynamically services or functionality, or inject a "new behavior" if the host allows it.

Given the great interest is generating the IoT world, there are tools [12], approaches [10], and protocols [7,9] that enable the design and development of IoT systems. The protocols implement *a messaging protocol* model that consists of a number of publishers and subscribers connected to a broker. Publishers send (publish) messages to the broker on a specific "topic". Subscribers register (subscribe) their interest in certain topics with the broker. The broker manages the connections to the publishers and subscribers and distributes the messages it receives from the publishers to the subscribers according to their subscribed topics. The [12] and [10] provides infrastructure for the design and development of IoT systems cloud based.

Our approach, presented in preliminary form, encourages the use of technologies that can relax the close relationship between devices and the cloud of the current framework, promoting the development of applications that leverage the full potential of new devices and benefits from applications based on the (μ)services composition. Based on these considerations, the next steps will be to test and evaluate new devices with eSim technology embedded and create profiles compliant with the new standards, allowing safely modify the behavior Things.

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References

1. 3rd Generation Partnership Project (3GPP). 3gpp home (2016). http://www.3gpp.org
2. Chen, S., Xu, H., Liu, D., Hu, B., Wang, H.: A vision of IoT: applications, challenges, and opportunities with china perspective. IEEE Internet Things J. **1**(4), 349–359 (2014)
3. Fowler, M., Lewis, J.: Microservices (2014). http://www.martinfowler.com/articles/microservices.html
4. GSMA documents (2016). www.gsma.com
5. GSMA: Remote provisioning architecture for embedded UICC technical specification (2016). http://www.gsma.com/connectedliving/wp-content/uploads/2014/01/2.-GSMA-Remote-Provisioning- Architecture-for-Embedded-UICC-Technical-Specification-Version-1.0.pdf
6. Hller, J., Tsiatsis, V., Mulligan, C., Karnouskos, S., Avesand, S., Boyle, D.: M2M and IoT technology fundamentals. In: Hller, J., Tsiatsis, V., Mulligan, C., Karnouskos, S., Avesand, S., Boyle, D. (eds.) From Machine-To-Machine to the Internet of Things, chap. 5, pp. 81–143. Academic Press, Oxford (2014)
7. Hunkeler, U., Truong, H.L., Stanford-Clark, A.: A publish/subscribe protocol for wireless sensor networks. In: 3rd International Conference on Communication Systems Software and Middleware and Workshops, COMSWARE 2008, pp. 791–798, January 2008
8. Jensen, C.S., Xie, X., Zadorozhny, V., Madria, S., Pitoura, E., Zheng, B., Chow, C. (eds.): 16th IEEE International Conference on Mobile Data Management, MDM 2015, Pittsburgh, PA, USA, 15–18 June 2015, vol. 1. IEEE (2015)
9. Kovatsch, M.: Coap for the web of things: from tiny resource-constrained devices to the web browser. In: Proceedings of the 4th International Workshop on the Web of Things (WoT 2013), Zurich, Switzerland, September 2013. (Best paper)
10. Microsoft: Microsoft's azure in IoT (2016). www.microsoft.com/en-us/server-cloud/internet-of-things/
11. Newman, S.: Building microservices: designing fine-grained systems (2015)
12. Samsung: Artik cloud (2016). https://artik.cloud
13. Shabtai, A., Elovici, Y., Rokach, L.: A Survey of Data Leakage Detection and Prevention Solutions. Springer Publishing Company Incorporated, New York (2012)