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Smart things in the social loop: Paradigms, technologies, and potentials

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ABSTRACT

Information about human social activities and relationships are exploited by an ever increasing number of proposed applications and protocols in several scenarios, given the consequent increase in the system performance. Examples are data transmission over delay tolerant networks, content recommendation in search engines, and advertisement of products and services. An emerging field where social networks are being exploited is the Internet of Things, where smart objects connect to the network to bring the real world into the virtual dimension. Objects capable to communicate on social network sites are able to enter into their owners' social loop so as to automatically publish information of interest for selected communities of people and to perform some related automatic actions. In so doing, not only can objects be part of the human social networks but they can also build *their own* social network. As a consequence, interactions among them can be fostered towards the development of complex services for the direct benefit of people. Accordingly, objects mimic the human behavior towards a scalable and effective service discovery and composition as well as trustworthiness management.

On the basis of the importance achieved by this trend in the last couple of years, in this paper we intend to review the adopted approaches towards the exploitation of social network concepts by the Internet of Things, the technologies behind these, and the potentialities.

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1. Introduction

The number of objects that are currently accessing the Internet, side-by-side to human beings to advertise, search for, and accessing enhanced services is growing exponentially. Among them are sensors, actuators, wireless and mobile devices, or simply every-day-life objects enhanced with capabilities to interact with the external world through the Internet. This is a clear signal that the much-vaunted (and sometime abused) Internet of Things paradigm is already turned into a reality on which there is a strong convergence of the interests of researchers, users, and industries. As a main effect, we have today a new approach available to build enhanced applications and services involving the communications among objects on the Internet to the service of the human beings.

Several studies have focused their attention to the definition of architectural models and solutions towards the use and the inter-connection of Web-enabled objects using open protocols and well-known architectural styles, REST and SOAP based Web services (such as, [1,2]). As a consequence, the obvious evolutionary step of the IoT is the so called Web of Things (WoTs) that envisages new scenarios and applications where Internet enabled objects become

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active actors and peers in the Web. Sample services, applicable to Smart Cities or Smart Homes, are given below:

- The car driver knows about the status of her car and of the roads on the path towards her destination. Such awareness is achieved by accessing, through her mobile phone (or through any communication technology in her car), web services that are fed by data collected from sensors scattered both in her car and in the areas of interest.
- The domestic appliances may be accessed by the owner through web services from remote sites and some actions can be performed on them to prepare comfortable conditions for a better welcome home.
- Eco-compatible houses may be equipped with controllers and sensors able to measure the local energy production and consumption and manageable through web services towards a reduction of the environmental impact.

Besides the obvious advantages of the depicted sample scenarios, one cannot hide the doubts on the ability of the proposed solutions to effectively harness the full potential of the new paradigm without colliding with the limitations of the current Web service platforms in the presence of trillions of additional actors (objects, precisely).

In our opinion, Web of Things is a paradigm which goes in the right direction but is not the solution to the cited issues. To foster resource visibility, service discovery, object reputation assessment, source crowding, and service composition in a Web populated by people and countless things there is the necessity to strongly push towards solutions that exploit concepts directly derived from the sole platforms that currently seem to be able to effectively allow peer-to-peer exchanges among huge numbers of actors, i.e., Social Networks.

Even if several aspects of the social networking among humans cannot be directly applied to the objects' world due to the specific distinctive characteristics (e. g., high heterogeneity and limited intelligence), such a need has brought to a substantial convergence of the "Internet of Things" and "Social Networks" domains. Interesting ideas have recently appeared in the IoT arena, which testify to the interests in Social Network oriented solutions for the Internet of Things.

People at the User Experience Lab at Ericsson Research started from the idea that the complexity of network solutions that underlie the Internet of Things are hardly understood (and mentally accepted) by all users. Thus, it is wise to make this complexity completely transparent during the user-thing interactions. Differently, the concept of "friendship" and 'social relations' are understood by virtually everyone, as they are intuitive concepts. As a consequence, they proposed a solution to both the practical scalability and understand-ability issues which is simply "dressing" a network of things as if it was a social network [3]. They have been the first to introduce the concept of "Social Web of Things" and also made some applications' prototypes.

Further studies and implementations of this concept have been carried out around the world. An example is given by the work in [4], where the authors propose a Social Web of Thing Framework based on the Restful Web Service and Social Networks, discuss the relevant key technologies and use cases, and introduce a case study named MagicHome. Furthermore, even a prototype of a scalable architecture for a large scale social Web of Things for smart objects and services, named Paraimpu, has been developed [5].

In line with this evolutionary path, but from a different perspective, the authors of [6,7] introduce the concept of Social Internet of Things. In analogy with the social networks of human beings, they (i) define of a notion of social relationship among objects, (ii) design a reference architectural model implementing a social Internet of Things based on codified inter-object relationships, (iii) analyze the social network structure, which derives from the objects interactions based on the defined social relationships.

The examples above make us realize that the time is ripe for a serious reflection on the possible ways of integrating *objects* into *social networks*, whether they are shared with those of their owners or they are independent and autonomous.

Aim of the present paper is to analyze the potentials of a synergic use of Social Networks and Internet of Things concepts towards the deployment of effective service platforms able to face the future challenges of a future world of trillions of inter-connected objects. We will illustrate the main solutions that are appearing in the IoT arena to let things enter the so called "social loop" and compare their points of strength and their weaknesses by also highlighting their technological requirements and architectures.

This paper is organized as follows. In Section 2 we present the technologies behind the Web of Things as one of the prevailing approaches towards the integration of the objects into the Internet. In Section 3, we describe how this paradigm can be extended by providing the things with the capabilities to take part to the human social activities on relevant social network websites. In Section 4 we describe a complementary approach that allows objects to build their own social networks, so that interactions among them can be fostered towards the development of complex services. In Section 5 we present the ongoing projects that come out from the concepts described in the previous sections. Finally, in Section 6 we draw final conclusions.

2. Web of Things paradigm and technologies

The ongoing evolution of the Internet of Things towards the Web of Things (WoTs), where Web-enabled smart objects connect and communicate with each other by using the Web, has raised several research issues ranging from the adoption of the right protocol and communication paradigms to the choice of the most suitable architectural styles. WoT was not born as a field in academic research but rather as the attempt to build an ecosystem from an heterogeneous variety of services and products, often not conceived in a way to interoperate.

Several efforts have focused their attention to the definition of architectural models and solutions, towards the use and the interconnection of Web-enabled objects, which ex-

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