Exploitation of Social IoT for Recommendation Services

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Abstract— **Internet of Things (IoT) applications are generally developed in a vertical manner, i.e., each IoT application is developed for a certain scenario which generally does not share data with IoT applications for recommendation services. This leads to an inefficient exploitation of other IoT service applications. In fact, such recommendation services can be achieved with the help of Social IoT (SIoT) by using data generated by various IoT applications. SIoT builds a profile of objects based on IoT applications data that can be exchanged with SIoT network for accessible to other IoT applications. In this manner, the SIoT network provides recommendation services for reusability of IoT applications' data among various IoT applications, as well as adapting IoT services according to users' needs which improve user experience. Additionally, the profiles built by a SIoT network can also help a single IoT application by looking for similar conditions that have been addressed in the past for the same IoT application. We propose a concept for exploiting the SIoT for recommendation services among various IoT applications with the help of a sample application scenario that highlights how the SIoT can help by providing recommendations. We also provide some implementation challenges for this concept.**

Index Terms— **Internet of Things, Social Internet of Things, recommendation services.**

I. Introduction

The Internet of Things (IoT) provides the interconnection of various network-embedded devices to the Internet and has recently attained considerable attention in a number of applications [1]. It has enabled interaction and cooperation among various devices (such as sensors, actuators, RFIDs and smartphones) to achieve common objectives, and it has automated many large systems, such as power distribution, security, health and agriculture. However, IoT applications are generally developed in a standalone and vertical manner, i.e., each IoT application is developed for a certain scenario, such as traffic monitoring, smart grid, building automation and e-health. Such IoT applications generally do not share and use other system's data for recommendation services, leading to an inefficient exploitation of the services offered by other IoT applications. Such recommendation services could be achieved with the help of the Social IoT (SIoT) by using the data from multiple IoT applications, thereby enhancing the services and performance of each IoT application.

The convergence of the IoT with social networks is becoming a reality, due to the increasing awareness that the SIoT can realize many of the future implications of intelligent devices used in our daily life. The SIoT has witnessed a shift in the IoT from a network of connected smart objects to a network of social objects. The application of social networking to the IoT (i.e., SIoT) helps to guarantee network navigability by shaping the structures as required for the effective discovery of objects and services, helps to establish trust for interactions among things (as with friends), and reuses the models designed for social networks for solving IoT issues related to networks of interconnected objects [2].

In the SIoT, objects can have social relationships between people-and-things and between things-and-things that behave like social circles. It builds profiles on the basis of various IoT applications' data. Such profiles are exchanged within a SIoT network that can be accessible to other IoT applications. In this manner, SIoT networks provide recommendation services for improving the performance of IoT applications by sharing and using other IoT applications' data. Additionally, the profiles built by SIoT networks can also help a single IoT application by looking for similar conditions that have been addressed in the past for the same IoT application.

The SIoT differs from social networks and from the IoT in three main aspects. Firstly, the SIoT establishes and exploits social relationships among *things*, rather than only among owners or *humans*. Humans can be involved for mediation, but the key roles are performed by things. Secondly, things can discover resources and services themselves through social relationships to the IoT, which provides a distributed solution and reduces human efforts. Thirdly, the SIoT does not only rely on Web technologies; instead it is a platform for social networking services (SNSs) which deals with objects rather than only dealing with humans [3].

We propose a concept for the exploitation of the SIoT for recommendation services among various IoT applications. We present a sample application scenario which highlights how the SIoT can have social relationships between people-and-things and between things-and-things in order to offer recommendation services. Some implementation challenges for this concept are also presented.

The paper is organized as follows. Section II provides the background of IoT and SIoT, and is followed by an overview of related work in Section III. Section IV discusses our proposed concept of exploiting the SIoT for recommendation services among various IoT applications with a sample application scenario. Section V presents implementation challenges, and Section VI concludes the paper.

978-1-5090-4130-5/16/$31.00 ©2016 IEEE.

II. Background

A. Internet of Things

Initially, the Internet provided connectivity for people-to-people and people-to-things. By 2008, the number of things connected to the Internet exceeded the number of people in the world, which has increased the impact of the IoT. The IoT is a network of physical objects or things that contain embedded technology to interact with their internal and external environments. These objects are connected to the Internet and can sense, control, analyze and decide in an autonomous, distributed and collaborated manner with other objects. Some of the objectives of the IoT are tracking, location identification, monitoring and management. The IoT is based on three main concepts: things-oriented, Internet-oriented and semantic-oriented. The things-oriented concept deals with smart objects such as sensors and actuators, and RFIDs. The Internet-oriented concept enables smart objects to communicate with other objects by using a number of telecommunication technologies, such as cellular communications and ZigBee, and connects them to the Internet. The semantic-oriented concept deals with applications that are built using smart objects or devices.

The IoT has attained considerable attention over the past few years in a number of applications. It has enabled the interconnection of network-embedded objects used in our daily life to the Internet, as well as the automation of many systems in power grids, agriculture and health care [4].

B. Social Internet of Things

The idea of using social networking concepts with the IoT to enable objects or things to autonomously establish social relationships is gaining popularity. Its main motivation is that social-oriented elements are expected to boost the selection, discovery and composition of services and information provided by networks and objects interacting with the physical world [2], [5]. The main concept of the SIoT is proposed in [2].

Five main types of relationships that can be used to define relationship profiles within SIoT system architecture can be derived from the envisaged SIoT. These relationships are parental object relationship (POR), co-location object relationship (CLOR), co-work object relationship (CWOR), ownership object relationship (OOR) and social object relationship (SOR) [2], [6]. POR is established among homogeneous objects of the same manufacturer in the same period in which the production batch plays the role of a family. CLOR is established among homogeneous and heterogeneous objects in the same environment (e.g., smart homes and smart cities). It can also be established among objects that cannot ordinarily collaborate with each other to achieve a specific goal. CWOR is established among objects that collaborate with each other in order to provide a common IoT application (such as telemedicine and emergency responses). CLOR and CWOR are established among objects similar to how humans share personal or public experiences. OOR is established among heterogeneous objects owned by the same user. SOR is established among objects when they come into contact with each other, either continuously or sporadically. This relationship is mainly related to relations among the owners of objects (e.g., sensors/devices associated with friends).

All of these relationships are established and updated based on objects' activities and features (e.g., brand, type, computational power and battery life). These relationships are utilized by a service discovery module to locate the objects that can provide the required services, in a manner similar to how humans look for information and friendships. Moreover, SIoT architecture requires a relationship management module for managing the resulting relationships, which can introduce cognition into the SIoT, allowing objects to establish, maintain and terminate relationships. Relationships could be established on the basis of several parameters, such as required services, the distance between objects, a publish-subscribe model, and to connect disconnected objects. Such relationships and a new approach to friendship selection in the SIoT as a means to improve information diffusion are presented in [6].

III. Related Works

One of the early proposals for establishing social relationships among objects is presented in [7]. This work focused on establishing temporary relationships using wireless devices, specifically wireless sensor nodes, and on how the owners of sensors can control this relationship establishment. However, this work was performed in 2001 and at that time, the IoT and social networks were still in their infancy.

The authors in [8] distinguished the things connected to the Internet with the things involved in social networks, which they termed as the neologism Blogject (i.e., objects that blog). Another concept, Embodied Microblogging (EM), was presented in [9]. EM introduces two new roles that augment daily life objects rather than focusing on people-to-thing or thing-to-thing paradigms. These two roles are mediating people-to-people communication and supporting new procedures for considering the noticing and noticeable activities in daily life. The authors in [10] proposed a concept in which objects are able to participate in conversations previously reserved for humans. These objects are context-aware, and hence are able to create a networking infrastructure based on the dissemination of information, rather than information on the objects themselves.

Recently, integrating the two worlds of the IoT and social networks is proposed in the literature [11], [12], [13]. The authors in [11] visualize the future of the Internet as ubiquitous IoT architecture, which is similar to a social organization framework (SOF) model and provides an overview of future IoT network structure. However, this work does not exploit social network features into the IoT [2]. The authors in [12] suggest that as things are involved together with humans in the network, the social network can be more meaningful if it is built on the IoT by investigating the relationships of IoT objects. The main convergence of social networks and the IoT is also introduced in [13], in which the social network is a social network of humans that is used by things as an infrastructure for service discovery, access and advertisement. In this work, a person can share the services offered by his smart objects with his friends as well as sharing their things (or devices).

Another work on the SIoT investigates the integration of social networks and the IoT with some sample applications [14]. However, it neither discusses how social relationships can be established by objects nor provides any solution for the required protocols and architectures. In [15], the authors investigate the social attributes or relations among mobile nodes by considering two parameters, i.e., an interaction factor and a discount factor, as well as investigating the behavior of mobile nodes by applying social networks. However, their approach assumes a one-to-one relation between objects and humans, whereas in the IoT, many objects are associated with a single human, and hence a large number of objects would not be considered in this work [2].

Some work has been done on recommendation services in smart homes to allow smart assistance [16], [17]. The humans' current situation, needs, preferences and habits are stored in repositories which are used by recommendation systems. The recommendation systems adapt themselves according to these humans' preferences. However, [16] does not consider context-awareness (i.e., humans long-term and short terms goals and preferences, events, localization information) from social networks to identify the current context of the user and provide intelligent recommendations. The work in [17] does address this issue, but it is specifically designed for task-oriented recommendations in smart homes. Neither of these works considers recommendation services among various IoT applications, developed in a vertical and standalone manner.

IV. Introducing SIoT For Recommendation Services Among Various IoT Applications

A. Proposed Concept

In this section, we present the proposed concept of exploiting SIoT for recommendation services among various IoT applications (depicted in Fig. 1).

The SIoT perception layer is responsible for sensing and collecting information from IoT devices. It consists of various heterogeneous devices, such as sensors and actuators, RFIDs, smartphones and cameras. After collecting the information, IoT devices establish social relationships and friendship circles among themselves using SIoT technique. Subsequently, the collected sensing and friendship circles information are forwarded to network layer in order to utilize this information by IoT applications The network layer is composed of various telecommunication networks (e.g., private wireless networks, public mobile networks and satellite networks) and the Internet. It maps IoT devices' data received from the perception layer to the telecommunication protocols, and forwards it to the upper layer for processing and to be converted into useful information for the realization of various IoT applications.

Generally, IoT applications are developed in a vertical manner with different structures and semantics. The SIoT recommendation system requires data sharing among IoT applications; providing recommendation services based on this shared data. Interoperability is required for data sharing among various IoT applications due to the different semantics of each IoT application. Nowadays, there are two main IoT interoperability platforms, oneM2M [18] and FIWARE [19]. IoT applications can thus be developed using either oneM2M or FIWARE or both, or semantic technologies can be applied to achieve interoperability and data sharing among IoT applications. In [20], the authors worked on creating a semantic service for the SIoT. Once interoperability is achieved, IoT applications' data can easily be shared with an SIoT recommendation system. The SIoT recommendation system can receive data from the interoperability layer, as well as applications data from IoT applications. Since IoT applications contain SIoT data (friendship circles) of IoT devices received from SIoT perception layer, the social IoT recommendation system uses this SIoT data to build and maintain social relationships and profiles between people-and-things, and between things-and-things that behave like social circles. These profiles are used for recommendation services among various IoT applications.

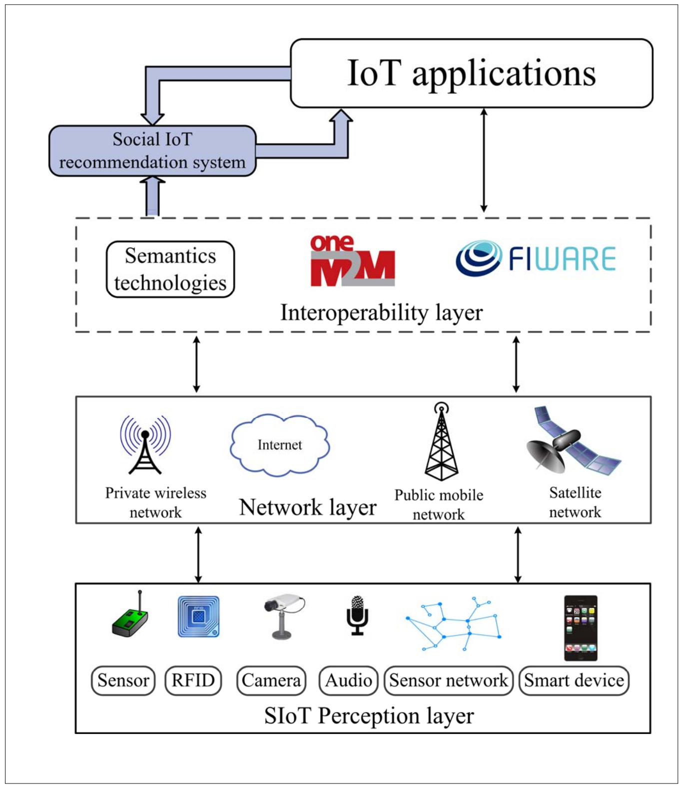

Fig. 1. Proposed concept of exploiting the SIoT for recommendation services among various IoT applications.

A sample application scenario of how the SIoT can provide recommendation services among various IoT applications based on their shared data is presented next.

B. A Sample Application Scenario

The availability of social relationships between things-and-things and between people-and-things interconnected through a SIoT can help several IoT applications to benefit from other IoT applications' data. The main benefit of SIoT over traditional IoT is that smart objects can establish social relationships among themselves in an autonomous and ad hoc manner. This helps smart objects to learn about other (homogeneous and heterogeneous) objects in a distributed way, and subsequently take decisions/actions based on this information. Additionally, SIoT improves the scalability when the network is composed of a large number of objects. **Error! Reference source not found.** presents a sample application scenario in which different applications benefit from the SIoT by using other applications' data. In this figure, there are various IoT applications (i.e., skiing, friendship gathering appointment, traffic monitoring, wearables and vehicle-to-vehicle communication). The interoperability layer (shown in Fig. 1) provides interoperability between them so that social IoT recommendation system can use the data of these heterogeneous IoT applications and subsequently provides recommendation services to the user.

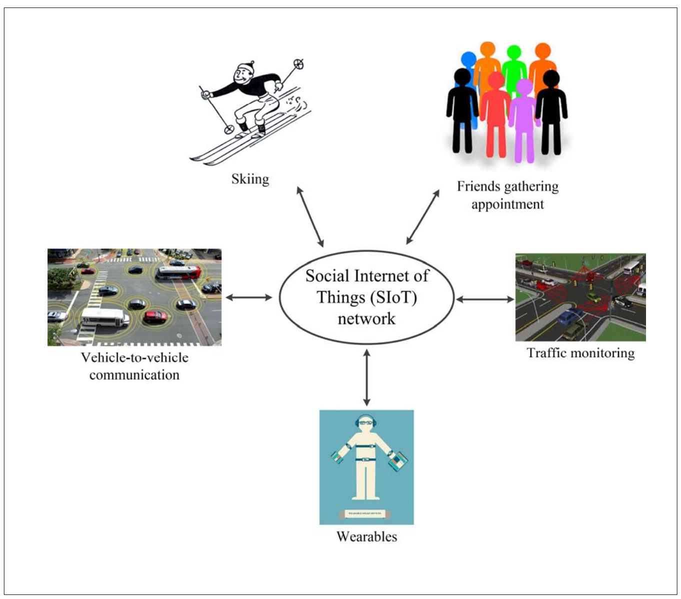

Fig. 2. A sample application scenario in which different applications benefit from the SIoT by using other application's data.

Let's consider a girl named Maria, who is a user of a SIoT network and a SIoT recommendation system. Maria is planning to get together with her friends over the weekend and she wants to set an appointment which should be feasible for all her friends based on their availability. For this purpose, she initiates an appointment using her system which is based on a SIoT network that contains the profiles of Maria and her friends. It is important to note that since Maria is using SIoT network, her IoT devices already have maintained social relationships with other IoT devices using SIoT perception layer as shown in Fig. 1. Her system coordinates with her friends' scheduling systems and proposes an appointment time to her and the other friends based on their availability. When Maria and her friends confirm this appointment, the system sets this appointment and sends invitation to all the friends. Suppose the appointment is set on Sunday at 6:00pm. On the same day, Maria also wants to go for skiing in the morning but she needs to return before 6:00pm to hang out with her friends. Accordingly, her system interacts with a traffic monitoring system to predict the traffic load during her return in the afternoon, and based on this prediction, interacts with the ski center's system by means of a SIoT network to suggest recommended slopes, so that Maria can ski and still return on time. Moreover, Maria has some health problems, and so a health profile built on a SIoT network through wearable devices attached to her body. In this manner, a SIoT network can recommend ski slopes to Maria based on her health condition. Based on these recommendations by SIoT networks, Maria is able to ski according to her health conditions and hang out with her friends at the scheduled time.

On her return from skiing, Maria's car developed a problem which appears to be difficult for her to fix on her own. Thanks to the SIoT, the junction box in her car has embedded sensors which collect information and build a profile of her car and of this problem. This profile is then shared with SIoT networks that look for similar problems which have been addressed before by other similar cars in the network. Subsequently, the SIoT network either recommends the suggested corrective actions to Maria so that she can fix the problem by herself, or it fixes the problem itself by coordinating with sensors and actuators embedded in the network. Vehicle-to-vehicle (V2V) communications also enables coordination among vehicles, and so the SIoT could search for a similar problem that has been fixed by other cars. If the SIoT network finds such a car running close to Maria, it could ask the car's driver to visit Maria and help her to fix her problem. This option also promotes social relationships and community help.

V. Implementation Challenges of the SIoT Recommendation System

In this section, we discuss the implementation challenges for the realization of a SIoT recommendation system for various IoT applications.

A. Interoperability

The lack of interoperability among IoT applications is one of the major challenges for the application of a SIoT recommendation system, as it restricts data sharing among various IoT applications. IoT applications are generally developed in a vertical and standalone manner. Each IoT application has different data structures and semantics, making it difficult for one IoT application's data to be used and understood by another IoT application. There is some ongoing work on interoperability in the IoT; the two main reference models for IoT interoperability are oneM2M [18] and FIWARE [19]. However, to date there is no standard protocol for the development of IoT applications. Therefore, there is a pressing need to consider interoperability in the IoT so that SIoT recommendation systems can utilize various IoT applications' data to provide recommendation services.

Furthermore, there is a project, named FIESTA-IoT [21], which works on achieving semantic interoperability between oneM2M and FIWARE. This can be a good reference for this achieving interoperability among IoT applications.

B. Social network management

A SIoT recommendation system uses social information residing on smart devices, each of which has their own view of this information. It is important to consider where this social information should be stored in the social network, and to ensure that other smart devices and actors are able to access this social information in an efficient manner in order to fully exploit a SIoT recommendation system. Moreover, it would be advantageous to perform social network management based on current contextual IoT application information so that SIoT recommendation systems could have all the required information readily available, minimizing any delay and improving user experience.

C. Trust, privacy and security

Since SIoT recommendation systems among various IoT applications requires access to data from various IoT applications, trust, privacy and security are very sensitive issues. The access to and exploitation of various IoT applications' data can lead to misuse and fraud without a secure technology. Hence, the success of a SIoT recommendation system requires secure technology that can ensure safe communication, user privacy and trustworthy interactions. Existing approaches for achieving user privacy, trustworthiness and data confidentiality developed for other platforms can be taken into account as guidelines while developing approaches for SIoT recommendation systems.

D. Self-management, Self-organization and Self-healing

In the SIoT, the establishment and management of social relationships is performed without human intervention, and the SIoT is expected to be composed of billions of devices. Therefore, it is imperative to have automatic operations, including self-management, self-organization and self-healing. Autonomic service discovery, composition and data analysis will also help to improve user experience. Moreover, a SIoT recommendation system should have self-learning capabilities and be self-adaptive based on the feedback from IoT applications in order to enhance its recommendation services.

E. Network Navigability

In SIoT, objects look for their required services using their friendship circles in a distributed way. However, since SIoT is composed of large number of objects, each object has to maintain a large number of friends which will slow down the search operation for finding the desired services. Hence, the network navigability is an important issue in SIoT which should be taken into account. Some work has been performed in [22] for network navigability in SIoT by analyzing possible solutions to enable smart objects to select the appropriate links which can benefit the overall network navigability. This can serve as a base reference for investigating network navigability in SIoT.

F. Proof of Concept

The idea of a SIoT recommendation system for various IoT applications is a novel paradigm which has not been explored before. Some of the challenges are discussed above; however, a number of new challenges may be faced while implementing this concept. Therefore, developing a proof of concept to accommodate new challenges that will need to be addressed during the actual implementation of this system is a vital first step and can be considered as step 0.

VI. Conclusion

In a SIoT, objects can have social relationships between people-and-things and between things-and-things that behave like social circles. These objects belong to different IoT applications, and a SIoT builds profiles of these objects. These profiles can be shared with a SIoT network which will be accessible to IoT applications. We have provided a concept of exploiting the SIoT for recommendation services among various IoT applications. We have also provided a sample application scenario for a more complete understanding this concept. Finally, we have discussed some implementation challenges that should be considered for the realization of this concept.

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