A Framework for Social Device Networking

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***Abstract*—The concept of *connectivity*, as inspired by Social Networking Service, is a key factor which participates in changing the way people interact with each other over the Internet. On the other hand, *connected world* as envisioned by the Internet of Things aims to expand the idea of connectivity to include everything in the physical world to a big network called the Internet. In order to realize the integration between the world of connected people and the world of connected devices, intelligence including semantics and recommendation acts as a major factor in expanding the basic communication functionalities to include search, discovery, mashup of new services and filtering. We propose a framework to facilitate the next generation of communication between people and devices, and a preliminary prototype including three modules DPWSim, ThingsGate, ThingsChat along with a use case discussion.**

Keywords—SNS; internet of things; DPWS

I. INTRODUCTION

Social Networking Service (SNS) since its proliferation has evolved rapidly bringing a new trend in social interactions. SNS has emerged as an *inter-connectivity* forum facilitating and encouraging individuals to stay in touch with their own network of friends/acquaintances and also provide means to widen this network. With the rich contextual information provided by SNS as rich *user profiles* containing users' preferences, list of friends, etc., the concept of *sharing* is considered one of the basic cornerstones in the formation and expansion of SNS. A rich set of resources in textual and multimedia formats can be easilyand almost instantly disseminated across interrelated communities of individuals. All those features of SNS have been helping to change social interaction over the Internet, from enhancing the way we reach information to enhancing the way we reach for each other. This paper proposes an infrastructure to expand the social interaction among us to include our devices too. *Is it possible to be connected with my colleagues at the office and with the coffee machine we share at the same time?*

The prevalence of mobile devices came then to harness the success of SNS, the former greatly helps to answer two kinds of questions *Where are you now?* and *What's happening?* [2]. Mobile devices, most commonly smartphones with their embedded sensing and geo-location capabilities made it very easy to provide answers to these questions, sharing them among a network of interested friends and hence maintain the concept of *inter-connectivity* as brought by SNS. And even beyond the network of people, this concept of *inter-connectivity* can be applied for connected smart devices which are storming in recently. According to Cisco CTO Padmasree Warrior, more than 1 trillion devices, or 140 devices per person, are going to be connected to the Internet in the year of 2013. Many of them have made their debuts in the recent International Consumer Electronics Show (CES) 2013 such as a door lock controlled by smartphone or a car started remotely via wireless connection or medical devices such as smart-home thermostat, smart scale, etc. This trend is recently mentioned by the media as *connected world* or *connected revolution*. It is about the shift toward the post-mobile devices era, in which, not only smartphones are concerned but also any other devices with sensing capabilities, connection to the Internet can communicate with others or even with people. These devices help people to connect with device through Internet to improve their physical life with the smart adaptability to environment context. Besides, the Internet of Things (IoT) paradigm [4] is driving us toward a connected future with ubiquitous computing behind. Thanks to efforts from academia and industry, we can now afford inexpensive sensors, low-power wireless communication protocols, which make it possible for sensing the physical world and communicating it to the Internet.

Our research presented here is motivated by the idea of utilizing the social interaction between people represented through SNS for devices world. As aforementioned, these devices could be in any type of devices with sensing capabilities, connection to the Internet which enables them to communicate with other devices or even with people. We propose a framework to establish such communication between people and devices using embedded Web Service technology. This framework consists of four layers: Device Layer for implementing and exposing Web services, Service Layer for encapsulating device functionalities into Social Device API to help Web applications to communicate with devices, Intelligence Layer to realize the semantic search and recommendation, and the Socialization Layer with a SNS providing interfaces using Social Device Application Programming Interface (API) to bring devices into SNS environment.

The rest of the paper is organized as follows. A use case initiating discussion and raising some research issues is presented in the next section. In section III, we go through the state-of-the-art technologies. Our proposed framework arrives in section IV. In section V, we provide a preliminary prototype of the framework and finally, the conclusion and future work take place in section VI.

II. USE CASE SCENARIO

Nadia is living with her elderly mother Aisha. Imagine a normal day for both of them, Nadia kisses her mother goodbye and heads to work. She is having a meeting at 9:30 AM. On her way to her office, she receives SNS notification on her smartphone from the robot vacuum cleaner at home; it hasn't cleaned the house for 5 days now. Nadia sends back asking the machine to do its job.

Before entering her office building she reminds the coffee machine located in her office to make her the favorite coffee in 10 mins. The moment Nadia reaches her office; she recognizes that she needs to print a document for the meeting. She sends text to the printer asking for a document on her laptop to be printed, the printer informed Nadia that it is out of toner and immediately it recommends her another printer in a nearby office, since Nadia prefers her documents to be printed in colors the recommended printer was a colored one. Also the printer status was sent to the IT department asking for replacing the toner cartridge. Nadia prints her document.

After the meeting, Nadia receives a call from her mother Aisha, she is trying to install a new dish rack in the kitchen but she doesn't seem to succeed. Immediately, Nadia sends text to the camera mounted on the living room asking to connect her live. Nadia gives Aisha live explanation, they both managed to install the new gadget.

A while later Nadia is informed of Aishas friend Tina plan to visit her at home. When Tina checks in at Nadia's home through her SNS, a notification is sent to Nadia and she asks the door at the front yard to open because it is very cold outside for her mother to step out. Once Tina and Aisha are all seated, Nadia asks the camera at the living to take a photo for them. The camera sends her the photo and asks whether to share the photo. She accepts and the camera posts it on SNS. Nadia's remaining work day goes smoothly.

Once she reached home Nadia measures Aisha's blood pressure. The device then automatically updates to her health record at her clinic.

At the end of the day, when Nadia enters her room, the sensors detected her return, light is turned on and the heater adjusts to her preferred temperature.

Based on the scenario highlighted by the use case, we can draw attention to the inherited features of SNS which could be exhibited to establish and maintain next generation SNS between people and objects. *Inter-connectivity* is a major feature, *I no longer need to check status of objects around me*, these objects which is equipped with sensing capabilities should automatically update me with its current status. *Search* feature is essential, where devices are basically considered service provider and in case this service provider is down, search and recommendation of other services should be performed, these recommended services should match the preferences stored in users profile. Whereas *Sharing* is another important feature, content varying from text to rich multimedia formats can be shared between people and their objects. Moreover emphcontent mash-up is an essential feature, where users can share content, mix services or apps from various SNS into an integrated platform, enabling them to personalize the way they communicate with physical and virtual world according to their priorities and preferences. However, to realize such requirements, we discuss some design and implementation issues in the next sections.

III. State of The Art

Since the advent of SNS and especially recently along with the introduction of smartphones and new wireless communication technologies, there have been several solutions, in various aspects, partially or fully approaching to improve the social interaction between people and their physical world. Atzori *et al.* [5] introduce the concept of Social Internet of Things (SIoT) in which, social relationship among objects can be established similar to the one between human beings. Establishing a relationship among PC devices in the same neighborhood to seek solutions for some common technical problem was an introduced idea in this paper. The authors argue that most of the social interaction features among human beings can also take place in between objects. ShopLovers solution [6] offers a new social shopping experiences for cutstmers in shopping malls. It is based on RFID/NFC technology [7] to get shopping items connected to Internet and exploited to support customers. This solution aims to help people do more satisfying purchases, find and share information about products, as well as about shops and brands that better fit the consumers' needs. The interaction here between people and particular type of objects - shopping items, is more than traditional way but still a passive relationship as the RFID technology itself. Pachube platform [8] highlights the potential of combining social and technical networks and discuss about the implication of the so-called socio-technical networks in the context of the IoT. It is close to the idea of a social network of objects, allowing developers to connect sensor data to the Web to build applications. What the platform does not allow for objects to form social groups autonomously, for the benefit of people beings but without their intervention. Previously, SenseShare project [9] goes toward this direction as it allows users to share sensor data with their friends. It also allows owners to apply different filters to the data before sharing it. However, similarly to Pachube, SenseShare acts as a datastore between the sensors and the clients. It allows sharing the data coming from sensors but does not support direct interactions with the sensors. Furthermore, SenseShare uses Facebook as the only supported social network. Such a tight coupling with a single external SNS whose contract (API and allowed accesses) is subject to change over time, is problematic.

The Sweden-based telecom giant Ericsson has been very active in the field with this idea, which is reflected in its User Experience Lab blog article [10] and its U.S. patent [11]. There is a conceptual prototype to show how networked objects interestingly interact with people over a specially designed social network. The video in the blog demonstrates the social interaction between a man and its home appliances such as refrigerator or robot cleaner. The so-called networked objects here are described in the patent as a small computer with Processing Control Unit, memory and also other peripheral devices. However, this can be a serious problem of concern to realize Ericsson's vision, the scalability and pluggability. Ericsson aims at high capacity computers under the cover of its networked objects with proprietary communication protocols which would not please the community to encourage the manufacture of such devices and the development of supporting services from third-party companies. Though, this conceptual prototype tosses a very important vision that *devices can become social*, just as we are.

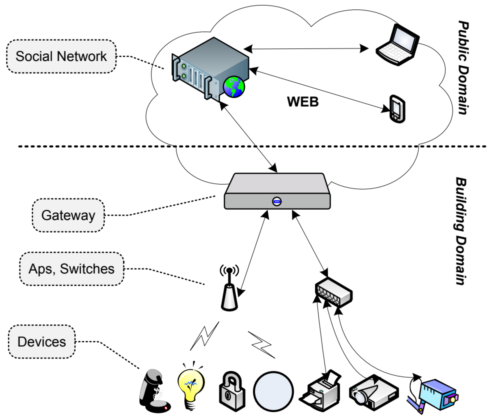

Fig. 1. Reference Infrastructure

Guinard *et al.* [12] presents a platform in which people can share their Web-enabled devices so that others can use them. It is based on Guinard's long-time research [**?**] on bringing Web Service technology, specifically REST [13] into resource constrained environment. This platform uses HTTP protocol for sharing Web-enabled devices via the Social Access Controller (SAC). SAC serves as authentication proxy between clients and embedded devices. First, smart things are connected to the Internet by embedding Web servers directly onboard. Then, the functionalities of smart devices are exposed as resources by applying the REST architectural style. The platform is simply to securely share devices over other SNS, Facebook in this case. However it is a significant proof of adopting Web Service technology into embedded devices and capability to integrate these devices into Web environment. There's another work following this REST approach to bring devices into social networking environment is Paraimpu [14]. It is a web-based platform for adding, sharing and establishing the communication between HTTP-enabled objects. The main motive behind this research was to allow an easy, user friendly mash-up between the physical and virtual objects like SNS. By representing those objects and the connections among them as REST resources, the idea is to build an environment capable of mashing-up these objects without extensive technological proficiency that is usually proposed by other approaches in the domain.

Apart from REST, there is another trend to bring Web Service technology into resource constrained environment, using wildly-supported W3C Web Service (WS-*) [15]. WS-* technology offers a lot of appealing features, however, at the same time, quite heavy for constrained devices. To deal with that, a lightweight version of WS-* called Device Profile for Web Services (DPWS) [16] was developed and debuted in 2004 by a consortium led by Microsoft. It is natively integrated in Microsoft's Windows Vista platform providing the communication of devices across a network via WS-* protocols. It defines a set of implementation constraints to provide secure and effective mechanism for describing, discovering, messaging and eventing of services for resource constrained devices. In this paper we take this WS-* approach to integrate devices/services seamlessly into Internet environment and propose a framework for the social interaction between people and devices.

IV. Framework Architecture

As discussed in previous section, what grounds our research here is the effort to bring Web Service technology into resource constrained environments. We use the open source implementation of DPWS from WS4D initiative [17] to facilitate the device platform of our proposed framework. Four core implementations are summarized in the Table I which support a wide range of hardware devices. DPWS-gSOAP provides C/C++ toolkits for deploying Web services consumers and providers. It is multi-platform implementation supporting Linux i386, Windows-native, Windows-cygwin and embedded Linux. DPWS-uDPWS is pure C DPWS implementation specially designed for highly resource constrained devices, paving the way for DPWS protocols directly over wireless sensor network without any intermediary gateway or so. DPWS-JMEDS is Java framework for DPWS supporting different Java editions. The latest release of DPWS-Android hosts the feature of Android OS. The following sub section describes a reference infrastructure with participating components and framework architecture is presented subsequently.

TABLE I. DPWS Implementations

Version	Language	Target	Operating System
DPWS-gSOAP	C	Embedded system	Linux, Windows, Embedded Linux
DPWS-uDPWS	C	Sensor/Actuator	Contiki
DPWS-JMEDS	Java	Embedded system	Embedded Linux
DPWS-Android	Java	Embedded system	Android

A. *Reference Infrastructure*

Fig. 1 shows the reference infrastructure of our framework with various hardware devices and a gateway at building domain, a SNS at public domain which can be accessed by users though laptop computers or smartphones. Devices in different hardware and platforms all are WS-enabled which can expose their hosted services to the building gateway. The building gateway acts as an intermediary for the communication between the SNS and devices or in another word, for the interaction between people and devices. It provides an API for wrapping functionalities of devices to deliver them to public domain where at the other end, SNS provides a common environment for the communication between people and devices by calling this API.

This framework support several types of devices which are all WS-enabled with a wide range of building appliances including sensors/actuators implemented by uDPWS, appliances with full TCP/IP stack and others with low power wireless protocols, and also Android devices which are applicable with DPWS-JMEDS. Android devices are attracting a lot of attention. In the year 2011 some electronics giants like Panasonic or Archos released several home appliances based on Android operating system. Google itself introduced the Android@Home in the 2011 Google's annual I/O developer conference with the intention of turning home into a network of Android accessories. Along with that event, Google also announced that it had collaborated with a partner to launch Android-enabled LED light bulbs. Though there has been some delay in the launching of aforementioned Android home appliances but with the constant development of Android platform these days, Android-based home and building devices and appliances are in a very promising products in the near future.

B. Overall Architecture

As shown in the Fig. 2, the overall architecture of the framework is divided into four layers which are: Device Layer, Service Layer, Intelligence and Socialization Layer. Device layer is a virtual abstraction of the physical devices. It includes the operating system, memory, networking connectivity, DPWS Stack for implementing functionalities of the devices and DPWS Implementation module responsible for operations implementation. The motivation of this layer is to provide transparency and independence of the operating system and DPWS stack to the higher layers of the architecture. The next layer is Service Layer. It carries out Service Discovery to maintain the service repository Service UDDI. Caching and transferring data to the devices and executing commands are carried out. Two modules called Device Management and Device Socialization provide a tool for the building admin or users to initiate the operation of devices. One important role of this layer is to encapsulate all the functionalities provided by device services into Social Device API which can be reused by external Web applications. The following Intelligence Layer is considered the core for carrying out semantics and recommendation operations. Profiles of users and devices are stored in Profiles. Using an inference engine to draw conclusions on the stored profiles Inferred Profile is built. Ontology for the devices socialization called Socialization Ontology is built. These data sources feed a semantic system where the later consists of semantic reasoner, text processor for supporting natural language communication and facilitating the search over the stored profiles. The forth Socialization Layer provides a full-featured SNS with a Social Networking Engine at the background and two other interfaces (Social User Interface and Social Device Interface) which call Social Device API provided between the Service Layer and the socialization Layer.

In the following section, we present a preliminary prototype of the framework mentioned above with small illustration following up the use case in section II.

V. Prototype and Use Case Discussion

A prototype shown in Fig. 3 includes 3 components: DPWSim, ThingsGate and ThingsChat. DPWSim is the simulator for DPWS devices using WS4D JMEDS stack version 5 (*ws4d-java-se-full-beta5.jar*). As all the DPWS devices share the same mechanism of exposing and discovering over the network, the simulator is very close to a real deployment of such DPWS devices at least with devices implemented by WS4D DPWS stacks. A class *DPWSDevice* extending JMEDS *DefaultDevice* class (*org.ws4d.java.service.DefaultDevice*) acts as the master class for various DPWS devices. Service and operations of each device are implemented by inheriting *DefaultService* and *Operation* classes respectively. Graphical User Interface wrapping device functionalities provides simple animation to illustrate device's operations such as a light on or off. On the public domain, we developed a SNS called ThingsChat over Linux with Apache/MySQL/PHP stacks and phpBB Social Network Engine [18] in the background. ThingsChat provides all basic features of a SNS such as *inter-connectivity*, sharing, etc. Social User Interface and Social Device Interface are implemented in PHP using API from gateway to call the services of devices. At the middle is ThingsGate gateway acting as an access point from public domain to devices in building. It is facilitated with Tomcat application server and a small application used to discover devices, store services and providing API to ThingsChat.

Fig. 4 illustrates the use case when a friend of Nadia's mother comes home and because it is too cold outside for her elderly mother to step out. Nadia asks the door to open by chatting with it. The door then opens to let the visitor in and at the same time updates its status on ThingsChat that it is open at 15:05.

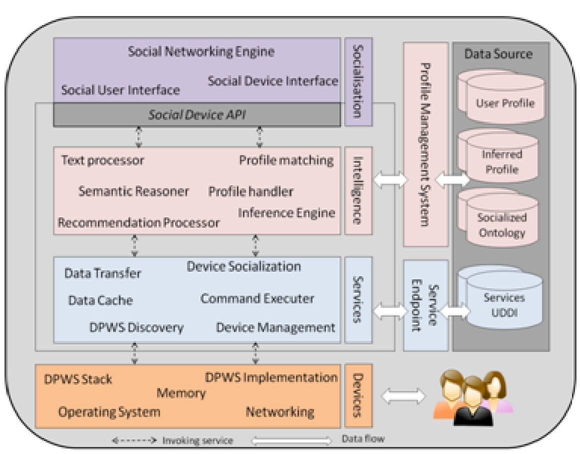

Fig. 2. Overall Architecture

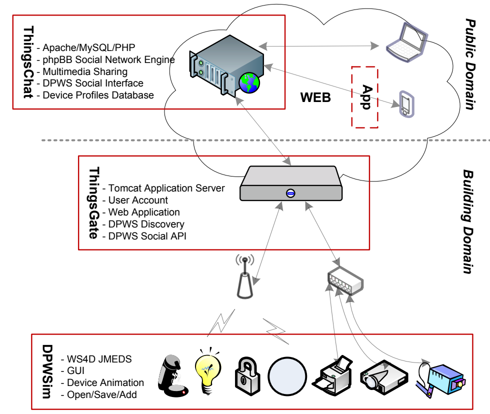

Fig. 3. Prototype: DPWSim, ThingsGate, ThingsChat

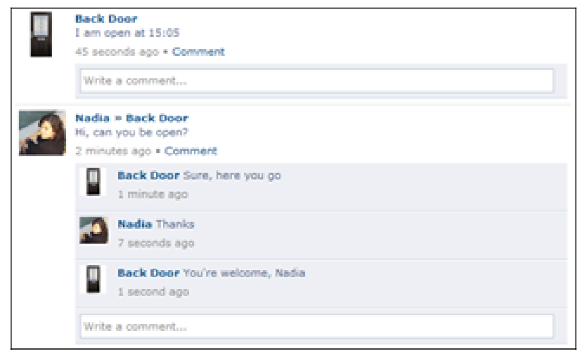

Fig. 4. Use Case: Nadia chats with Back Door

VI. Conclusion and Future Work

In this research, we have proposed a framework for next generation SNS, between people and devices, in which devices represented by Web services can be easily and efficiently integrated into Web environment. We also designed Social Device API for encapsulating the functionalities of devices by which external Web applications with appropriate social device interface using this API can communicate with underlying devices. Our preliminary prototype and use case discussion provides an outlook and the basic functionalities on the formation of a platform enabling people and devices interaction, we like to call it next generation SNS, from the technical point of view. The perspectives of encouraging third-party companies to manufacture WS-enabled devices under the DPWS specification and other service providers to create new services on that environment are also important among the contribution of this work.

With the proposed framework we hope to pave the way for the adoption of Web Service technology to approach the vision of connected world from IoT and the *connectedness* from SNS. However, we recognize it is still very far from a successful deployment as many issues remain untackled and need serious attention from the community. In addition to working on related enabling technologies, grabbing consumers' attention through interactive use cases and scenarios to show how new generation SNS can enhance their daily routine is very essential in the future. There is also a major concern over security and privacy that need to be handled thoroughly in the future. WS4D DPWS latest release of JMEDS stack version 7.0 already included an encryption module for the secure discovery and exposure of devices. However, it is just a part of the effort, improved security models or perhaps novel ones are really needed. Another problem is to develop the intelligence engines probably using cloud computing and Semantic Web to provide smartness to devices. At the same time, we have to persuade third-party hardware companies to take part in the manufacture of such WS-enabled devices. Testing and performance evaluation of hardware prototypes in various forms and many experiments are quite important in this issue.

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