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Towards a dynamic discovery of smart services in the social internet of things☆

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ABSTRACT

The paradigm of the Social Internet of Things (SIoT) boosts a new trend wherein the connectivity and user friendliness benefits of Social Network Services (SNS) are exhibited within the network of connected objects, i.e. the Internet of Things (IoT). The SIoT exceeds the more traditional paradigm of IoT with an enhanced intelligence and context-awareness. In this paper, a novel service framework based on a cognitive reasoning approach for dynamic SIoT services discovery in smart spaces is proposed. That is, reasoning about users' situational needs, preferences, and other social aspects along with users' surrounding environment is proposed for generating a list of situation-aware services which matches users' needs. This reasoning approach is then implemented as a proof-of-concept prototype, namely Airport Dynamic Social, within a smart airport. Finally, an empirical study to evaluate the reasoning approach's efficiency shows improved services adaptability to situational needs compared to common approaches proposed in literature.

1. Introduction

The paradigm of the Internet of Things (IoT) covers a diverse range of technologies with respect to sensing, networking, computing, information processing, and intelligent control technologies [1,2]. This implies a huge amount of heterogeneity hidden in the computing and communication processes involved in reasoning and intelligent decision making. In practice, achieving scalability in managing IoT application while maintaining user-friendliness to bridge human-to-machine perceptions is a key challenge which hinders the realization of IoT on a wider scale. Thus a new research stream has come forward in literature known as the Social Internet of Things (SIoT) [3,4].

The SIoT paradigm represents an ecosystem which allows people and smart devices to interact within a social structure of relationships resembling traditional Social Network Services (SNS). On top of this framework, applications and services can

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be provided in a user-friendly manner relying on Web technologies. SIoT builds on the emerging concept of social objects [3]. In which, devices and objects, alternatively referred to as things, become exposed to the Web, allowing the autonomous and proactive interactions with other people and things to generate personalized user experience. The SIoT social structure can enhance the navigability of connected objects and provide a coherent manner for interacting with these objects [4].

However, the intelligence needed to integrate objects, services and people as the core of SIoT paradigm, increases the quantity and the variety of contextual data that must be handled for situation-aware services discovery.

Two kinds of contextual data exist typically in SIoT scenarios; objective and subjective context [5,6]. The objective context represents the physical aspects of the user's surrounding environment including location, time, device status, available services, etc. Whereas the subjective context represents the human and social factors including short-term goals, preferences, relationships, trusted services, etc. Combining these two kinds of context for intelligent decision making is not studied yet in literature despite being necessary for achieving situation-awareness (SA) in smart environments [6]. In this paper, we attempt to utilize such combination to build the intelligence core of what we call cognitive reasoning approach for characterizing users' situations and thus allow for dynamic services discovery in smart spaces.

Achieving SA would not only contribute to characterizing users' situations for adaptive services discovery, but it would also narrow down social objects and smart services discovery scope beyond the SIoT suggested social structures. In which, heterogeneity is managed within the boundaries of certain situations [6]. This paper builds on the SIoT architecture provided in the literature [5,6] but further extend it to achieve its implementation in a smart space i.e. airport.

This paper proposes a novel service discovery framework, wherein based on a cognitive reasoning approach, a temporal social structure combining users, objects and services can be established, namely the Dynamic Social Structure of Things (DSSoT). The proposed cognitive reasoning approach derives users' short term situational needs, and accordingly creates a filtered list of available objects and smart services which could meet such goals. To realize the cognitive reasoner, a semantic service matching algorithm is provided. In which, contextual data are first represented ontologically. Then users' situations are characterized according to a suggested criterion in two stages: (1) Situation Identification, (2) Situational Goal Detection. Matching the situational needs with available smart services that could meet these goals is finally accomplished before listing situation-aware services and their actuating smart objects in a temporal social structure. An empirical study to analyze the performance of the suggested reasoning approach in terms of run time complexity and the amount of contextual data growth rate is finally provided.

From a technical perspective, this paper attempts to explore advances of socially enhanced IoT applications in smart spaces beyond the typical applications of building and home automation.

Thus, an application is provided, namely Airport Dynamic Social to realize DSSoT in a smart airport. The goal of this application is to enable users to directly interact with available objects and smart services in an airport i.e. sensors at check-in counters, boarding gates, flights, smart beverages/food dispensing machines, etc. Additionally, the application aims at benefiting from Internet Protocol version 6 (IPv6) in order to demonstrate an effortless deployment of DSSoT without the need for a protocol translation gateway or an intermediary server to cope with a number of heterogeneous devices in a smart space.

The rest of the paper is organized as follows. A thorough analysis of the background and related works are provided in the next section. Section 3 compares two service discovery and interaction scenarios, the proposed service framework with the common service framework provided in literature. In Section 4, the proof-of-concept prototype to realize the proposed service discovery framework is presented. The cognitive reasoning approach utilized for situation-aware service discovery is presented in Section 5. In Section 6, an empirical performance analysis is provided. Finally, the paper is concluded in Section 7.

2. Background

We are witnessing a new era characterized by a computing and communication revolution where millions of objects such as sensors, RFID tags, and smart electronic/electromechanical devices, surrounding us are becoming connected. These gadgets are disappearing into the fabric of our daily lives to help us in carrying out quotidian tasks. This pervasive paradigm known as the Internet of Things (IoT) promotes the value of data generated by the interactions among people and connected objects, denoted by things, as well as the transformation of this data into knowledge for the benefit of mankind and society.

Prior to the proliferation of IoT, the paradigm of the intranet of things was presented in literature as a local network of connected objects. Examples of the intranet of things include Wireless Sensor Networks (WSNs), Machine-to-Machine (M2M), smart homes, etc. The intranet of things is capable of extracting mainly local, application and domain specific data from the connected objects [7]. The IoT paradigm however can provide a large scale data extraction to achieve the collaboration among different intranets of things. Furthermore, IoT enables the creation and composition of novel services and applications on top of its infrastructure to provide a new user experience with each service composition [8]. However, one of the biggest challenges in IoT is to manage the number of heterogeneous objects, communication protocols, and deployment goals.

In fact, there is a huge need to improve the connectivity of various objects with a variety of computational power in order to realize the vision of IoT, i.e. the availability of smart services anytime/anywhere. Thus, a number of research efforts promoted the adaptation of some features from SNS i.e. modeling social relationships, building rich profiling system, enabling a mashup of services to achieve a personalized user experience, etc. [9]. This influence which is caused by the huge

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