A Cognitive Context-aware Approach for Adaptives Services Provisioning in Social Internet of Things

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***Abstract*--we propose architecture for adaptive services provisioning within *Social Internet of Things*; where both humans and objects interact via social structure of everything. Building on the socio-technical networks, we propose goal-driven, i.e. cognitive, context-awareness as the core for intelligence generation. Results shows reduced overhead of contextual data acquisition and processing.**

I. Introduction

Recently, the Internet has experienced a tremendous growth extending from a network of hundred hosts toward a platform globally linking billions of things like traditional computers and computerized devices i.e. smart phones, smart consumer electronics, sensors, etc. It allows people to communicate with each other as well as smart things to support smart services and applications for improving the quality of daily life. The growth of the Internet shows no sign of slowing down; it steadily becomes the cause of a novel ubiquitous computing paradigm, called Internet of Things (IoT) [1], [2].

The "Internet of Things" semantically means "a world-wide network of interconnected objects uniquely addressable based on standard communication protocols" [1]. It also represents an intelligent end-to-end system that covers a diverse range of technologies with respect to sensing, networking, computing, information processing, and intelligent control technologies [2]. This, however, implies a huge number of heterogeneous things involved in ubiquitous computing and communication processes for intelligent services surrounding us. In practical, such large scale and high heterogeneity obstruct realization and deployment of IoT technologies into our lives.

To overcome IoT challenges, recently there is a new research stream [3], [4], referred to as *Social Internet of Things (SIoT)*, taking into account adding sociality to things. SIoT builds on the evolution shifting "*smart things*" into "*social things*" where the latter is capable of exhibiting proactive and autonomous behavior. Accordingly, Interoperability, scalability and trust can be achieved via human-to-device social relationships resembling human-being's social actions in social networks.

Based on socio-technical networks, where trust-driven social structures of objects & people are introduced to shift the large-scale and heterogeneous nature of IoT networks into better navigable and interoperable ones, we move a step forward by exploiting the social properties of SIoT to make the adaptive and personalized smart services manageable. Since adaptive and personalized services rely on a large scale amount contextual data, our proposed cognitive approach can eventually improve the level of quality of experience (QoE) [5]. However, the nature of SIoT, i.e., ntegration o IoT

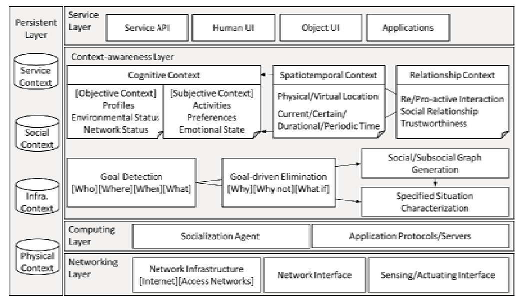

Fig. 1. Cognitive Context-aware Based Service Platform Architecture

and social networks, in fact, increases the quantity and the variety of contextual data needed to characterize user's situations for adaptive services provisioning. In which, not only external context, or *objective context*, which represents the physical environment surrounding the user, e.g., location, time, function, sound, and so on should be considered, but also cognitive context, or *subjective context*, which captures the internal elements of context such as preferences, moods, personal emotional states, etc., act as a core for intelligence generation [5]. In other words, although previous contributions in the domain of SIoT proposed things' social structure to provide network navigability and guaranteeing effective object and service discovery, we still need to narrow down a large amount of contextual data against scalability and complexity issues on data gathering and computing.

In this paper, therefore, we design adaptive service platform architecture. In which, goal-driven cognitive context-awareness for overcoming IoT challenges in terms of context acquisition and management is proposed. Finally, detailed procedures of context computing and service provisioning with two experiment results to prove performances of our proposed schemes are provided.

II. Adaptive Smart Service Architecture

A. System Platform Architecture Overview (Fig. 1)

In the networking layer, the networking infrastructure and interface are composed of network devices to configure SIoT including all access networks. Additionally, the communication with physical world via sensing and actuating is located in this layer. The computing layer contains servers of application layer protocols related to context acquisition; the socialization agent operates via SNSs platforms. All applications servers functioning within the application layer protocols interact with the persistent layer to make comprehensive context and infer cognitive context. The context acquisition relies on the application layer protocols running on traditional services and applications.

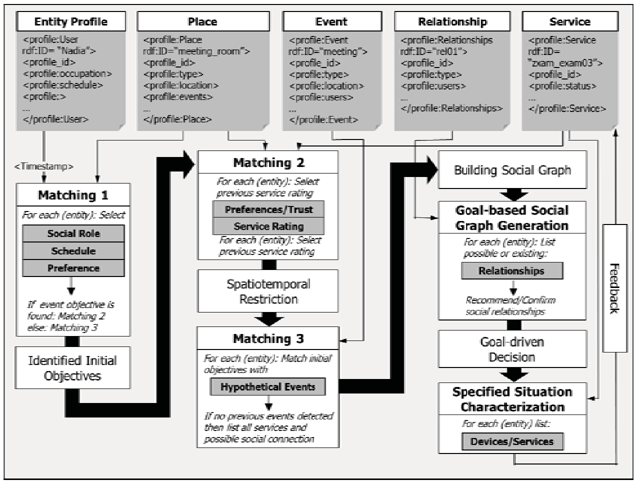

Fig. 2. Goal-driven context-aware Computing and Service Provision

There are three features to function as social objects that we consider in this paper. First, based on TCP/IP protocol stack with global unique IP address, it can communicate with the other entity through any application layer protocol such as HTTP, SNMP, SIP, SOAP, etc; so, it can function as the standalone objects. The second feature of social objects is clustering schemes of IP devices. Although social devices contain the TCP/IP stack and the application layer protocols including compressed versions like CoAP, 6lowpan, etc., the social objects should be clustered as a local domain due to physical/logical restriction as well as configuration policy of the domain. In practical, there can be gateways to be interpreted between application layer protocols such as interoperation between HTTP/SOAP, e.g., RESTful approach/DPWS, SNMP/SIP or SNMP/HTTP. (We define as Application Layer Protocol Transaction Agent.) Finally, the third feature is the interoperation with non-IP based networks such as traditional wireless sensor networks where sensor nodes report data to a base station providing gathered data and tasks queries to sensor nodes. We call it IP/Non-IP gateways that could be carried out as a social object logically.

The context-awareness layer consists of three controllers. The cognitive context controller monitors and gather entities' context; the relationship context controller figures out and establishes diverse social relationships between entities; and the spatiotemporal context controller creates entity's situations in a specific time and position.

B. Goal-driven Context-awareness

As shown in Fig. 2, the goal-driven context-awareness can be realized via a framework of asymmetric interactions mainly initiated by a person or a smart object. The main controllers perform context acquisition/storage in profiles, accordingly data discovery and mining methods are performed with the goal of detecting various events. Events are a spatiotemporal limited context including a set of actions and aims at fulfilling a goal, event (and goal) detection in this sense are the first step towards narrowing down the scope of objects and services visibility (Matching 1). While it is carried out by exploiting location and basic context or running basic queries, detecting the goal behind the event is about understanding user's situations, current interests, relationships and whom they trust is considered, this contextual reasoning is carried out to build rules that narrow down the scope of services and objects further (Matching 2). Comparing with previous similar events is then performed in order to detect previous service decisions undertaken (Matching 3). Consequently, the goal-driven service control is responsible for listing services which match the set of rules based on a goal involved in the detected event. First goal-based social graph is initiated to interconnect social information of people and devices. Decision is resulted based on a short list of services which matches the goal. Virtual relationships which are created on top of the social graph are used for service provisioning and consumption. After providing a service, feedback of the end-point entities act as an essential contextual data for the learning process carried out by adaptive service manager.

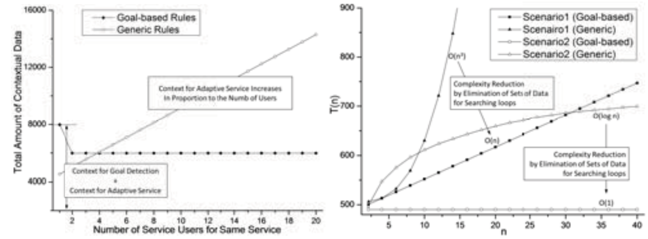

Fig. 3. Experiments Results: Scalability (Left) and Complexity (Right)

The experiments results prove our proposed scheme can overcome computing challenges on scalability and complexity due to goal-based reduction and elimination of the number and the length of context sets for services as shown in Fig. 3.

III. Conclusion

This paper proposes a framework for adaptive and personalized smart services provisioning relying on the cognitive context-aware computing. Our proposed cognitive intelligence approach can eventually achieves a better level of QoE based on the improved services adaptability, a lower level of networking as well as computing overhead within the large-scale and heterogeneous SIoT environment is also proved in this paper.

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