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Agent-based framework for sensor-to-sensor personalization

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ABSTRACT

In Wireless Sensor Networks, personalization has been seen by researchers as the process of tailoring services to fulfill requests of different users with different profiles. This vision ignores that individual sensors commonly have different profiles and contexts and therefore different needs. In this paper, we aim at extending personalization by allowing sensors to support each other with services that mutually fit their differences. To this end, we propose an agent-based framework where sensor nodes delegate software agents (static or mobile) to collect valuable data about the neighboring sensors and the spatial characteristics of their surrounding environments. We also show how this framework may be used to make the routing process more convenient for relying nodes in terms of energy consumption and security.

1. Introduction

Personalization has been addressed and implemented in a variety of fields. Technological advances have been very beneficial in getting closer to users, acquiring their explicit and implicit data, as well as acquiring relevant data on their surroundings. In this context, Wireless Sensor Networks (WSNs) can improve and expand the quality of services across a wide variety of settings. This is particularly possible thanks to the context awareness ability of sensors and their ability to adapt and support new events of interest. Several research works (see Section 2) have benefited from those capabilities to deliver personalized services to the end-user. In this paper, we argue that further benefits could be obtained, not only by delivering personalized services to the end-user, but also by adding personalization within the sensor network itself. This means that sensors should not only sense/process/forward/move according to their own capabilities and/or the end-user's preferences. They have also to maintain one-to-one relationships with their neighbors, by understanding their mutual needs. Sensors have thus to offer personalized services to their next hops to achieve sensor-to-sensor personalization. For instance, a sensor node S would only send to its neighbor R data in the format that R can process while making sure that R is trustworthy and has enough resources. This requires from sensor S to have an updated knowledge about its neighbors' status, capabilities, and context. This implies exchanging an important volume of messages that may not be supported by the available bandwidth and the current level of energy and processing capabilities of the sensors. It may also require collecting contextual data (e.g. characteristics of the space where these neighbors are operating) which are not necessary available at any of these neighbors. To this end, we believe that it is important to endow sensors with autonomy and intelligence

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allowing them to provide peers with the right data at the right time. Agent technology appears then as a serious candidate for this task.

An agent is a computer system which acts autonomously in its environment to meet its design objectives [1]. Thanks to their autonomy, agents can operate in an environment which is open, highly dynamic, uncertain, or complex [1]. Similarly, sensors are required to behave autonomously within a distributed network and adapt their behaviors to the changing environment without human intervention. In addition, sensors have to collect data about their neighbors (to provide them with personalized services) without compromising the overall performance of the network. In this context, the agent community has an adequate set of formalisms, algorithms, and methodologies which can address these challenges [2].

In the reminder of this paper, Section 2 explores the related works in personalization and agent use in WSN. Section 3 presents our agent-based framework which provides sensor-to-sensor personalization by allowing sensors to act autonomously and more intelligently. Section 4 outlines our proof of concept. Finally, Section 5 summarizes our contributions and future works.

2. Related works

Several research works, particularly in healthcare applications [3], smart-spaces [4], and mobile applications [5], have benefited from WSN capabilities to provide users with personalized services. For example, in order to achieve pervasive healthcare environments, sensor networks were used for a variety of purposes that range from simply setting an alarm volume according to the user's hearing abilities and the ambient noise level, to the complex tailoring of the user's entire eHealth environment [6].

Furthermore, thanks to the micro–nano technologies, the recent types of biomedical sensors are allowing personalization to be achieved more efficiently by maintaining and updating user's profile and data related to his/her context, general and specific preferences, physical and mental abilities, and other relevant parameters [6]. In smart environments, applications generally require situated, individualized, and personalized information to give optimal support to the user [7]. In addition to the information stored beforehand about the user, data on the current situation and user's activities are commonly acquired by on-body and off-body sensors. On-body sensors (e.g., biological signal sensors) are helpful to get the implicit feedback of users while off-body sensors have been used to acquire data on a variety of issues, including persons' identities, locations, gestures, focus of attention, and emotion.

Many other examples can be found in the literature. However, most of personalization efforts have been performed at the level of services delivered by the sensor network to the end-users. To the best of our knowledge, no research work has tackled the issue of personalization within the sensor network at the level of sensor-to-sensor communications. This could be explained by the fact that personalization has been always seen as an effort aiming to deliver services to a human being (as an end-user).

Regarding the use of software agents, many agent-based approaches have indeed been proposed to solve various problems in sensor networks [8]. More recently, powerful mote platforms have been developed by using intelligent Wireless Sensor Networks (iWSNs) [8]. As energy conservation is one of the main concerns in WSN, most agent-based approaches in WSN aim at enhancing the node life, in particular by introducing mobile agents. Indeed, mobile agents, when used in WSN, reduce the message traffic and thus save energy [8]. For example, in [9], mobile agents are used to reduce the communication cost by moving the processing function to the data rather than bringing the data to the sink. Each mobile agent has to carry a code to the source nodes and brings back aggregated data to the sink. In [10], the authors propose to reduce energy consumption of the WSN – to forecast water quality – by using data aggregation algorithms whereby mobile intelligent agents act as dynamic clustering points in the network. In [11], mobile agents store and gather metadata from nodes while minimizing route cost and maximizing battery level of sensors. The use of agents (particularly the mobile ones) does not only save energy. They may also allow a more efficient use of sensors' memories [8]. Indeed, since running all codes on a given node is often expensive and sometimes infeasible due to restrictions on local memory and processor, mobile agents can be deployed to support code distribution between sensors [12,13]. In terms of conceptualization, several research works have modeled sensor nodes as software agents (not mobile) to achieve adaptive data sampling (e.g., [14]), improve task assignment (e.g., [2]), and make data routing more efficient (e.g., [15]). In the next section, we propose a framework where each sensor can delegate some of its tasks to a mobile agent. This latter migrates to other nodes/platforms to collect relevant data which are needed to offer personalized services to next hops.

3. Agent-based framework

3.1. General concepts

Fig. 1 shows a layered framework which design philosophy has been inspired by the layered simulation model in [16]. The framework builds a parallel between a Real World (where the WSN is deployed to manage/monitor real resources) and a Virtual World (where software agents can behave/act on behalf of the real sensors).

In order to offer a personalized service to its neighbor, a sensor node has to take into account the environment context, the requirements and constraints of its neighbors, as well as its own goals and restrictions. To this end, and under such circumstances, the Real World environment is not necessary the best place for the following four reasons: