Wireless Sensor Networks in Home Care

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Abstract. Ambient Intelligence has acquired great importance in recent years and requires the development of new innovative solutions. This paper presents a novel architecture which integrates a service oriented approach into Wireless Sensor Networks to optimize the construction of Ambient Intelligence environments. The architecture proposes a new and easier method to develop distributed intelligent ubiquitous systems, where devices can communicate in a distributed way independent of time and location restrictions. The architecture is easily adapted to changing environments. A prototype system has been proposed to test this architecture. This system is aimed to improve health care and assistance to dependent persons in their homes. Preliminary results are presented in this paper.

Keywords: Ambient Intelligence, Wireless Sensor Networks, Service Oriented Architectures, Health Care, Tele-monitoring, Embedded Devices.

1 Introduction

People are currently surrounded by technology which tries to increase their quality of life and facilitate the daily activities. However, there are situations where technology is difficult to handle or people have a lack of knowledge to use it. For these reasons, Ambient Intelligence tries to adapt the technology to the people's needs by proposing three basic concepts: ubiquitous computing; ubiquitous communication; and intelligent user interfaces [1]. To reach these objectives, it is necessary to develop new functional architectures capable of providing adaptable and compatible frameworks, allowing personalized access to services and applications regardless of time and location restrictions. A functional architecture defines the physical and logical structure of the components that make up a system, as well as the interactions between those components [1].

This paper briefly describes SYLPH (Services laYers over Light PHysical devices), a Service Oriented Architecture (SOA) based architecture [2] [6] for Wireless Sensor Networks (WSNs) [5] [9] and explains how this architecture has been used to design a prototype system for a real case scenario. SYLPH is a novel architecture which integrates a SOA approach with WSNs for building systems based on the Ambient Intelligence paradigm [1]. The architecture focuses on distributing the systems'

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functionalities into services. This model provides a flexible distribution of resources and facilitates the inclusion of new functionalities in highly dynamic environments [4]. SYLPH is based on the Ambient Intelligence (AmI) paradigm [10]. The architecture formalizes the integration of services, communications and wireless technologies to automatically obtain information from users and the environment in an evenly distributed way, focusing on the characteristics of ubiquity, awareness, intelligence, mobility, personalization, participation, etc., all of which are concepts defined by Ambient Intelligence.

Next, the problem description is introduced and it is explained why there is a need for defining a new architecture. Then, the architecture is briefly described. Subsequently, a case study is presented, describing how SYLPH has been used to define a wireless infrastructure into a tele-monitoring home care scenario. Finally, the results and conclusions are presented, including future lines of work.

2 Ambient Intelligence in Health Care Environments

Ambient Intelligence is an emergent multidisciplinary area [7] [8] based on ubiquitous computing [11]. Ambient Intelligence has an influence on the design of protocols, communications, systems integration and devices [13]. Ambient Intelligence proposes new ways of interaction between people and technology, making the latter to be adapted to the people's necessities and the environment where they are [1] [4]. This kind of interaction is achieved by means of technology that is embedded, pervasive, non-invasive and transparent for users, with the aim of facilitating their daily necessities [1]. Thus, it is necessary to provide efficient solutions that allow building Ambient Intelligence environments. These environments require context-aware technologies to acquire data and intelligent systems to transform the data into knowledge.

One of the key aspects for the construction of Ambient Intelligence environments is obtaining context information through sensor networks. There are different technologies for implementing wireless sensor networks, such as ZigBee, Bluetooth or Wi-Fi [12] [14]. However, their main problem is the difficulty for integrating devices from different technologies in a single network [3]. Another key aspect is the knowledge management, and this can be done by means of distributed systems and architectures, as for example SOA.

There are several attempts to integrate WSNs and a SOA approach [5]. In SYLPH, unlike those approaches, services are directly embedded on the WSN nodes (i.e. an electronic device attached to a network) and can be invoked from other nodes in the same network or other network connected to the former one. Moreover, in those proposals it is not enough considered the necessity of minimize the overload of the services architecture on the devices. SYLPH focuses specially on devices with small resources in order to save CPU time, memory size and energy consumption. Furthermore, as said above, SYLPH considers the possibility of connecting multiple WSNs based on different radio and link technologies [13], whilst other approaches do not.

One of the priorities of the Ambient Intelligence is health care. There are several health care developments for tele-monitoring based on WSNs [9]. However, these developments do not take into account their integration with other systems and technologies, so they are difficult to be adapted to new situations. SYLPH has been designed in order to face some of these issues. As indicated in the next section, SYLPH is an architecture that enables the integration of WSNs focusing on providing a greater simplicity of deployment and optimizing the reutilization of the available resources in such networks.

3 SYLPH Architecture Description

SYLPH is a distributed architecture which integrates a SOA approach over WSNs for building systems based on the Ambient Intelligence paradigm. The main objective is to distribute resources over multiple WSNs by modeling the functionalities as independent services. A service oriented approach has been chosen because such architectures are asynchronous and non-dependent on context (i.e. previous states of the system). It is important to mention that the main objective of this paper is not to make an extensive description of SYLPH1[1] but its use for Ambient Intelligence environments, such as the home care scenario described in the next section.

SYLPH can be executed over multiple wireless devices independently of their microcontroller or the programming language they use. SYLPH works in a distributed way so that the most application code does not have to reside only on a central node. SYLPH allows the interconnection of several networks from different wireless technologies, such as ZigBee or Bluetooth. Thus, a node designed over a specific technology can be connected to a node from a different technology. In this case, both WSNs are interconnected by means of a set of intermediate gateways connected simultaneously to several wireless interfaces. SYLPH allows applications to work in a distributed way and independently of the lower layers related to the wireless sensor networks formation and the radio transmission amongst the nodes that conform them.

Figure 1 shows the different layers of SYLPH. These layers are added over the application layer of each WSN stack. The SYLPH Message Layer (SML) offers the possibility of sending asynchronous messages between two wireless devices through the SYLPH Services Protocol (SSP). The messages specify the origin and target nodes and the service invocation in a SYLPH Services Definition Language (SSDL) format. SSDL describes the service itself and its parameters to be invoked. Applications can communicate directly amongst devices using the SML layer or by means of the SYLPH Services Directory (SSD), that uses, in turn, the mentioned SML layer. The SSD is used as a directory of the services offered by the network nodes.

Figure 2 shows the basic schema of the communication between two ZigBee devices using SYLPH. In such figure can be seen the protocols that allow the peer-to-peer interaction between layers of the same level at the two wireless devices.

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[1] For further information about SYLPH, please visit the BISITE Research Group web page (http://bisite.usal.es).

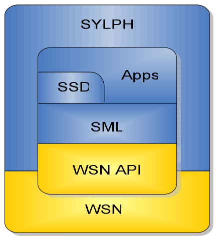

Fig. 1. SYLPH architecture layers

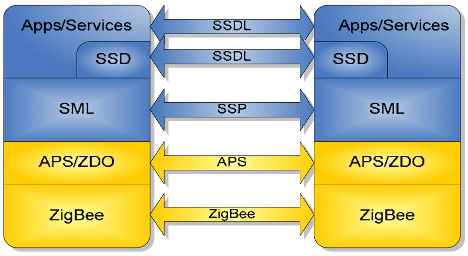

Fig. 2. Communication between two ZigBee devices using SYLPH

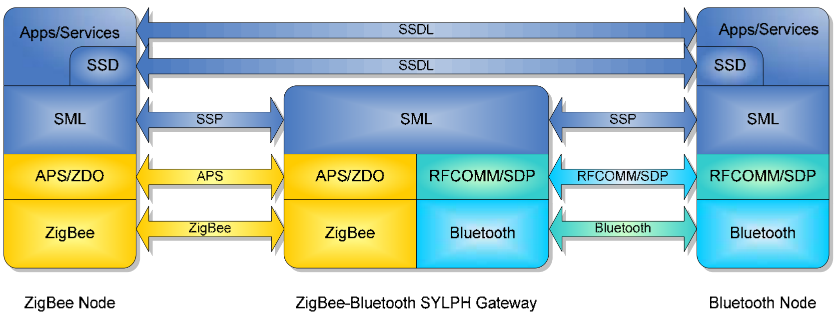

Fig. 3. SYLPH over ZigBee and Bluetooth networks

Several heterogeneous WSNs can be connected using a SYLPH Gateway. Figure 3 shows a ZigBee network and a Bluetooth network working together using SYLPH over them. The SYLPH Gateway is connected to several sensor networks through different hardware interfaces. Thus, it can forward messages amongst the different networks to which it belongs. From the application layers' point of view, there is no difference between invoking a service stored in a node in the same sensor network or in a different network. The interconnection of the different WSNs is transparent to the service invoking. Figure 3 is an example of this approach. If a ZigBee node invokes a service in a Bluetooth node, the ZigBee node will look for the service in a SSD belonging to the ZigBee network. The entry stored in the services table of the SSD points, in fact, to the SSP address of the SYLPH Gateway. When the ZigBee node invokes the service in the Bluetooth node, the SYLPH Gateway forwards the call message to the Bluetooth node through its Bluetooth hardware interface.

4 Case Study: Home Care Patients Monitoring

A tele-monitoring prototype system has been designed for improving health care of dependent people at their homes using the SYLPH architecture. The system makes use of several wireless sensor networks for obtaining context information in an automatic and ubiquitous way. A network of ZigBee devices are installed all over the home of each dependent patient to be monitored. Amongst the deployed ZigBee sensors there is a remote control carried by the monitored person that also includes a button which can be pressed in case of remote assistance or urgent help. Moreover, there is a set of ZigBee sensors for controlling the environment (light, smoke, temperature, etc.) in which the patient lives. Furthermore, there are several ZigBee actuators that physically respond to the changes in the environment (e.g. light dimmers and fire alarms). Finally, biomedical sensors [13] will allow the system to acquire continuously data with the vital signs of the patient. In this case, each patient carries three different sensors: an ECG (Electrocardiogram) monitor, an air pressure sensor acting as respiration monitor and a MEMS (Micro-Electro-Mechanical Systems) triaxial accelerometer for detecting falls.

All devices work as SYLPH nodes and can offer/invoke services all over the network. There is also a computer connected to Internet and to a remote health care centre. This computer also acts as a ZigBee master node through a physical wireless interface. On the other hand, the computer is the master node of a Bluetooth piconet (i.e. an ad-hoc network of Bluetooth devices) created by biomedical sensors acting as slave nodes. At the SYLPH level, the computer works as a SYLPH gateway so that it connects both wireless sensor networks each to other. Furthermore, it acts as a SSD and the rest of the nodes can register their own services.

Figure 4 shows a basic example of the system's communication and infrastructure. In this case, a smoke sensor detects a smoke level higher than the specified threshold. Then, the sensor invokes a service offered by the node which carries the fire alarm, making it to ring. At the same time, it also invokes a service offered by the master node, which sends an alarm through the Internet towards the remote health care centre. The caregivers can establish a communication over VoIP or by means of a webcam at home in order to check the incidence. The patient can also ask for assistance by pressing the alert button of the remote control or making a call through the VoIP terminal.

Furthermore, each patient is not only monitored at home, but also at its medical centre. The ZigBee remote control carried by each patient has a unique electronic label that identifies him or her. So, there are ZigBee and Bluetooth networks all over the medical centre so that the patient's ZigBee identification label and its Bluetooth biomedical sensors can automatically connect to the SYLPH network. Thus, when the patient goes into the centre the system realizes that he or she is inside. In fact, the system knows at every moment which patients and caregivers are inside the centre and at which point of the building.

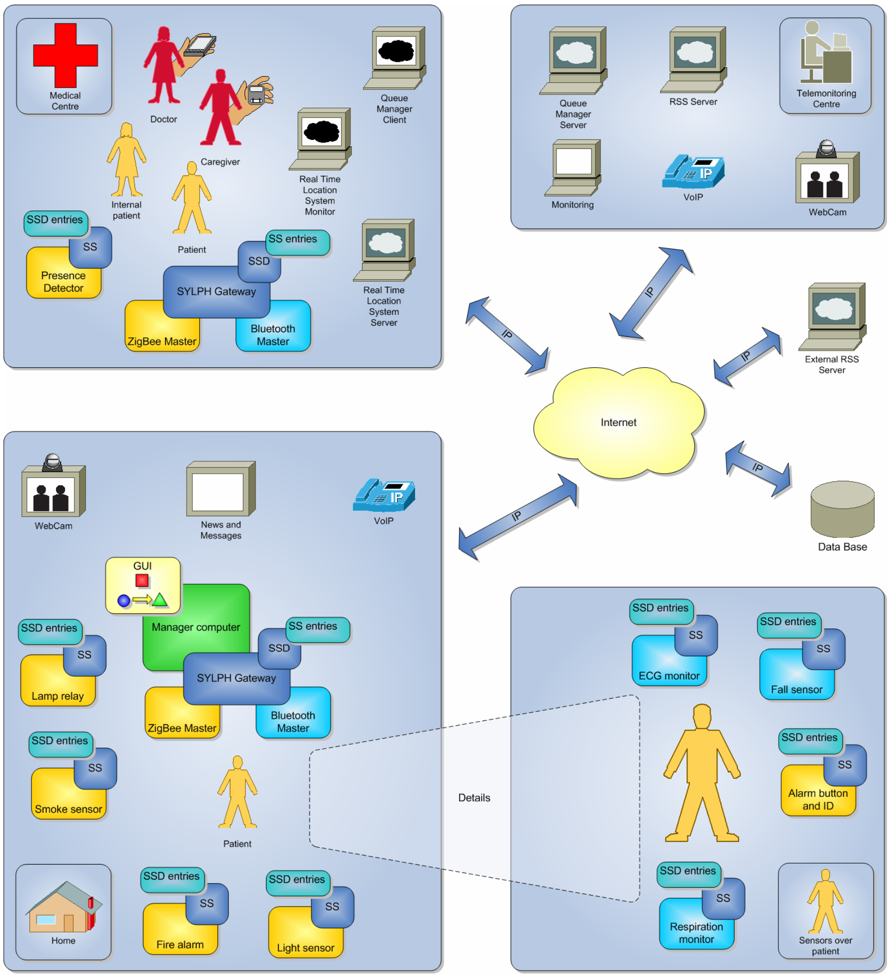

Fig. 4. Schema of the tele-monitoring system using SYLPH

5 Results and Conclusions

As described above, SYLPH allows wireless sensor devices from different technologies to work together in a distributed way. In addition, these devices do not require large memory chips or fast microprocessors in order to work with SYLPH.

SYLPH allows the possibility of adding new components at execution time. In this sense, SYLPH proposes a model that goes a step ahead in designing systems for Ambient Intelligence environments, such as home care, providing features that make it easily adaptable to several developments. SYLPH also allows the creation of WSNs that facilitates intelligent and distributed services. On the other hand, the automation of tasks and patient monitoring improves the system security and efficiency for care services to dependent patients.

Future works on SYLPH include the improvement of the SYLPH Gateways performance, support for other WSNs different from ZigBee or Bluetooth and the development of better tools for generating stubs and skeletons from the human-readable SSDL language. Regarding the tele-monitoring system described, the next steps consist on developing this proposal and implement it in a real scenario.

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