Developing Home Care Intelligent Environments: From Theory to Practice

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Abstract. One of the main aims of the pervasive systems is to be able to adapt themselves in execution time to the changes in the number of resources available, the mobility of the users, variability in the needs of the users and failures of the system. This work presents HoCa, a multi-agent based architecture designed to facilitate the development of pervasive systems. HoCa presents a new model where multi-agent systems and service oriented architectures are integrated to facilitate compatible services. HoCa has been applied to case study in a real scenario, aimed to provide automatic assistance to dependent people at their home, and the results obtained are presented in this paper.

Keywords: Dependent environments, Pervasive Systems, Multiagent Systems, Home Care.

1 Introduction

Nowadays, there is a considerable growth in the development of automation technologies as well as intelligent environments as demonstrated by the relevance acquired by the Pervasive Systems. One of the main objectives of these systems is to look after the user's well-being at their home, at work, etc. [2] [16]. Pervasive systems demand their integration with computational applications in a non intrusive way, facilitating intelligent interfaces characterized to be natural, simple and transparent [16]. There are several benefits provided by Pervasive System [12]: users get easier access to services that are contracted, access to services is independent of the terminal which is used and use of services is simpler, and allowing a rapid assimilation by the user. In addition, users can receive personalized services entirely, so they have quick access to what they call their personal needs.

Home Care requires the improvement of the services offered to the users as well as the way they can be accessed. Moreover, it is necessary to adopt the trends already tested and proven in technological environments [1]. Intelligent environments are focused on the user, since the user is the centre of the new technological facilities and demands access to unified services [2]. In this sense, multi-agent systems can facilitate the development of pervasive home care environments.

The importance acquired by the dependency people sector has dramatically increased the need for new home care solutions [6]. Besides, the commitments that have been acquired to meet the needs of this sector, suggest that it is necessary to modernize

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the current systems. Multiagent systems [16], and intelligent devices-based architectures have been recently explored as supervisor systems for health care scenarios [1] for elderly people and for Alzheimer patients [6]. These systems allow providing constant care in the daily life of dependent patients [5], predicting potentially dangerous situations and facilitating a cognitive and physical support for the dependent patient [2]. Taken into account these solutions, it is possible to think that multi-agent systems facilitate the design and development of pervasive environments [7] and improve the services currently available, incorporating new functionalities. Multi-agent systems add a high level of abstraction regarding to the traditional distributed computing solutions.

The main objective of this paper is to define a hybrid Multi-Agent architecture, HoCa, for the control and supervision of pervasive environments [7] [8]. The architecture provides innovative mechanisms to integrate multi-agent systems with service oriented architectures and intelligent interfaces to obtain context-aware information. The architecture incorporates technologies for automatic identification, location, alarms management and movement tracking. These technologies facilitate the monitoring and management of dependent patients at their home in a ubiquitous way. One of the main contributions of the HoCa architecture is the use of both reactive and deliberative BDI agents [7], specialized in the interaction with sensors and the distribution of complex tasks respectively. Moreover an alert system based on SMS and MMS technologies allows a quick response to dangerous situations requiring medical attention. Finally, advanced location technologies based on RFID (Radio Frequency IDentification) [13] and video surveillance provide location and tracking of patients, and Java Card [15] technology allows automatic identification.

The rest of the paper is structured as follows: Section 2 describes the proposed architecture and in Section 3 the preliminary results obtained is presented and the conclusions are discussed.

2 HoCa Architecture

The HoCa multi-agent architecture uses a series of components to offer a solution that includes all levels of service for various systems. It accomplishes this by incorporating intelligent agents, identification and localization technology, wireless networks and mobile devices. Additionally, it provides access mechanisms to multi-agent system services, through mobile devices, such as mobiles phones or PDA. The architecture integrates two types of agents, each of which behaves differently for specific tasks. The first group of agents is made up of deliberative BDI agents, which are in charge of the management and coordination of all system applications and services. The second group of agents is made up of reactive agents responsible for handling information and offer services in run time. The communications between agents within the platforms follows the FIPA ACL (Agent Communication Language) standard. The protocol for communication between agents and services is based on the SOAP standard. Access is provided via Wi-Fi wireless networks, a notification and alarm management module based on SMS and MMS technologies, and user identification and localization system based on Java Card and RFID technologies. This system is dynamic, flexible, robust and very adaptable to changes of context. For all these reasons the proposed architecture is very appropriate for pervasive environments. Pervasive systems are characterized by the complexity of its service, the number of devices and software components that manage and obligation to facilitate cooperation between all these elements. The HoCa architecture facilitates the integration and management of all devices integrated into a pervasive system. All this makes it an open system, easy to integrate into complex environments that it does not dependent of a specific platform.

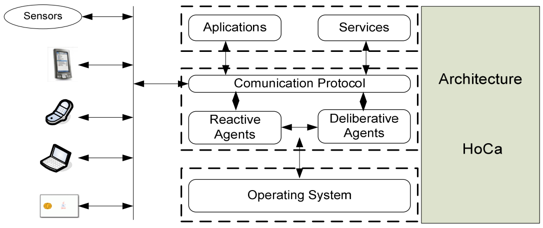

Fig. 1. HoCa Framework

HoCa architecture describes four basic blocks that can be seen in Figure 1 Applications, Services, Agents Platform and Communication Protocol. These blocks constitute the whole functionality of the architecture. HoCa allows the use of devices such as PDAs, mobile phones, laptops, sensors or Java Card chip with RFID technology. The agent's platform consists of deliberative agents and reactive agents. Reactive agents are responsible for monitoring sensors and actuators and deliberative agents are responsible for monitoring services and applications architecture. Reactive agents perform actions that you ask the agents deliberative and also provide information to agents deliberative. The agent platform is installed on the operating system of the architecture. This union is the architecture basis. The agents control the security, communications and each of the features offered HoCa. This architecture design allows us to be able to add new agents at any time with new features to the system. It follows mounting flexible and adaptable architecture to dynamic pervasive environments.

In the following subsections are the four basic building blocks of architecture and localization, identification and alerts systems that incorporate HoCa. In subsection 2.1 describes the agent's platform and the agent's types that interact in HoCa. In subsection 2.2 explains the communication protocol. Subsection 2.3 describes the location and identification system that is integrated into HoCa and subsection 2.4 describes the alerts system.

2.1 Agents

The Agents platform is the core of the architecture and integrates two types of agents, each of which behaves differently for specific tasks, as shown in Figure 2. The first group of agents is made up of deliberative BDI agents, who are in charge of the management and coordination of all system applications and services [6]. These agents are able to modify their behaviour according to the preferences and knowledge acquired in previous experiences, thus making them capable of choosing the best solution [4].

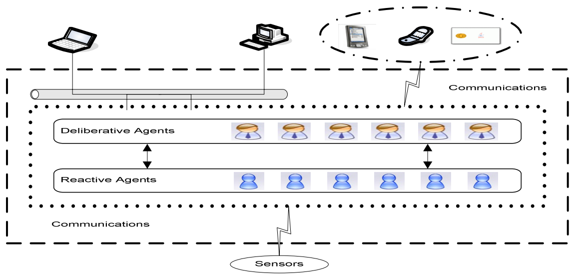

Fig. 2. Agents platform structure in the HoCa architecture

Deliberative agents constantly deal with information and knowledge [9]. Because they can be executed on mobile devices, they are always available and they provide ubiquitous access for the users [3]. There are different kinds of agents in the architecture, each one with specific roles, capabilities and characteristics. This fact facilitates the flexibility of the architecture to incorporate new agents.

However, there are pre-defined agents which provide the basic functionalities of the architecture:

- CoAp Agent: This agent is responsible for all communications between applications and the platform.
- CoSe Agent: It is responsible for all communications between services and the platform.
- Directory Agent. Manages the list of services that can be used by the system.
- Supervisor Agent. This agent supervises the correct functioning of the agents in the system.
- Security Agent. This agent analyzes the structure and syntax of all incoming and outgoing XML messages.
- Manager Agent. Decides which agent must be called taking into account the QoS and users preferences.
- Interface Agent. This kind of agent has been designed to be embedded in users' applications. Interface agents communicate directly with the agents in HoCa so there is no need to employ the communication protocol, but FIPA ACL specification.

The figure 3 along with a simple example helps to understand the communication between different types of agents in the architecture. A patient is visited by the medical service due to a feverish that suffers by an infection. The medical service went to the house before the patient's explicit request made through the alerts system. The patient through an application has inserted the alert in the system. The CoAp agent is responsible for registering this information into the system and notifies the supervisor agent. The security agent confirmed the credentials of the user who enters the information and validates the information entered. The supervisor agent at the same time performs two tasks, requests the directory agent you select the service to run to launch the alert and through the interface agent informs the manager agent of operations performed. The CoSe agent runs the service that launches the alert and finally the alert is sent

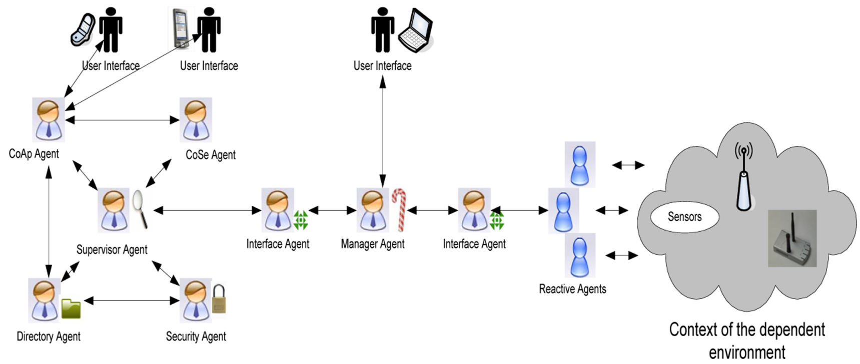

Fig. 3. Agents Workflow in the HoCa architecture

through the reactive agents of the architecture. At all times the manager agent is informed of the steps being taken in the system and is responsible for validating the alert sending through the interface agent to the corresponding reactive agent. Once the patient enters the information into the system, this process seems very laborious and slow is running in a few thousandths of a second.

The second group is made up of reactive agents. Most of the research conducted within the field of multi-agent pervasive systems focuses on designing architectures that incorporate complicated negotiation schemes as well as high level task resolution, but don't focus on temporal restrictions. In general, the multi-agent architectures assume a reliable channel of communication and, while some establish deadlines for the interaction processes, they don't provide solutions for limiting the time the system may take to react to events. It is possible to define a run-time agent as an agent with temporal restrictions for some of its responsibilities or tasks [11]. The use of run-time multi-agent system makes sense within an environment of temporal restrictions, where the system can be controlled by autonomous agents that need to communicate among themselves in order to improve the degree of system task completion. In this kind of environments every agent requires autonomy as well as certain cooperation skills to achieve a common goal.

2.2 HoCa Communication Protocol

Communication protocol allows applications, services and sensors to be connected directly to the platform agents. The protocol presented in this work is open and independent of programming languages. It is based on the SOAP (Simple Object Access Protocol) standard and allows messages to be exchanged between applications and services as shown in Figure 4.

SOAP is a standard protocol that defines how two objects in different processes can communicate through XML data exchange. For example, here are displayed as a HoCa user since the supervisor application, which can run on a PDA asks the agent CoAp (see Figure 3) the patient location in his home. The application requests the patient location with a SOAP message and the CoAp agent when has the patient location

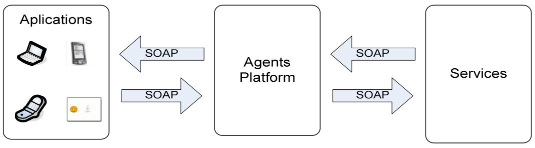

Fig. 4. Communication using SOAP messages in HoCa

gets to communicate with the application back in another SOAP message the information requested.

The communications between agents within the platforms follows the FIPA ACL (Agent Communication Language) standard. This way, the applications can use the platform to communicate directly with the agents. The agent's messages structure are key-value row. These rows are written in an agent's communications language as FIPA ACL. The messages include the names of the sender and the receiver and may contain other messages recursively. Moreover defining protocols for high-level interaction between the agents, called talks and it is possible to define new primitives from a core of primitive by composition. You can see a message ACL in Figure 5.

```
(inform
        :senderCoApAgent
        :receiverSupervisorAgent
        :content
                (patient location 6267581)
        :in-reply-toround-4
        :reply-withbid04
        :languagesl
        :protocol FIPA-request
        :ontologyontolocation
)
```

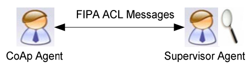

Fig. 5. Example of ACL message between two agents in HoCa

In Figure 5 shows the communication between two agents of the HoCa architecture. In this case the example of ACL message corresponds to the request for location of a patient seen in the example of SOAP messages. CoAp agent sends an ACL message to supervisor agent asking the location of a patient. Talks between agents tend to follow a certain pattern, typical sequence of messages called conversation protocols. An agent informs the protocol you want to use it with parameter ':protocol'. Basic protocols defined by FIPA are: (i) FIPA-request, (ii) FIPA-query, (iii) FIPA-request-when, (iv) FIPA-contract-net, (v) FIPA-iteraterated-contract-net and (vi) FIPA-auction-english.

2.3 Identification and Location Systems in the HoCa Architecture

This system incorporates Java Card and RFID technologies. The primary purpose of the system is to convey the identity of an object or person, as with a unique serial number, using radio waves. Java Card is a technology that permits small Java applications (applets) to be run safely in microchip smart cards and similar embedded devices.

The radio frequency identification (RFID) [10] is a wireless communication technology used to identify and receive information on humans, animals or objects in motion. The main applications of RFID technology have occurred in industrial environment, transport, and other sectors, including medicine, are becoming increasingly important [10]. RFID provides more information than other auto-identification technologies, speeds up processes without losing reliability, and requires no human intervention. The combination of these two technologies allows us to both identify the user or identifiable element, and to locate it, by means of sensors and actuators, within the environment, at which time we can act on it and provide services. The microchip, which contains the identification data of the object to which it is adhered, generates a radio frequency signal with this data. The signal can be picked up by an RFID reader, which is responsible for reading the information and sending it, in digital format, to the specific application.

2.4 Alert System in HoCa

The alert system is integrated into the HoCa architecture and uses mobile technology to inform users about alerts, warnings and information specific to the daily routine of the application environment. It gets so improve service quality of communication and control at all times the performance of applications that are implemented in architecture. This is a very configurable system that allows users to select the type of information they are interested, and to receive it immediately on their mobile phone or PDA.

The system is proactive, that is, users should not bother to monitor the environment in which the service is implemented, to see if there is information that interests them. It alerts the system itself which cares for users to get information immediately on their mobile devices, with the benefits that this entails, so they can get all this information without having to meet at her workplace.

3 Results and Conclusions

HoCa has been used to develop a multi-agent system for monitoring dependent patients at home. The main features of this system include reasoning and planning mechanisms, and alert and response management. Most of these responses are reactions in run time to certain stimuli, and represent the abilities that the reactive agents have in the HoCa architecture based platform. The technologies used to test the system include mobile technology for managing service alerts through PDA and mobile phones, and Java Card and RFID technology for identification and access control. HoCa improved security at home to dependents because the monitors, alerting relatives or other services to emergency situations and ensures they are properly. HoCa architectures proposes a model that goes a step further in designing systems for home care, providing generality and offering features that make it easily adaptable to any pervasive environment.

One of the main contributions of the HoCa architecture is the alert system. We implemented several test cases to evaluate the management of alerts integrated into the system. This allowed us to determine the response time for warnings generated by the users, for which the results were very satisfactory, with response times shorter than those obtained prior to the implementation of HoCa. The system studies the information collected, and applies a reasoning process which allows alerts to be automatically generated. For these alerts, the system does not only take response time into account,

Table 1. Comparison between the HoCa and the ALZ-MAS architectures

Factor	HoCa	ALZ-MAS
Average Response Time to Incidents(min.)	4 minutes	7 minutes
Assisted Incidents	12	17
Average number of daily planned tasks	12	10
Average number of services completed daily	46	32
Time employed by the medical staff to attend to an alert (min.)	25 minutes	35 minutes

but also the time elapsed between alerts, and the user's profile and reliability, in order to generalize reactions to common situations.

Table 1 presents the results obtained after comparing the HoCa architecture to the previously developed ALZ-MAS architecture [7] in a case study on medical care for patients at home. The ALZ-MAS architecture allows the monitoring of patients in geriatric residences, but home care is carried out through traditional methods. The case study presented in this work consisted of analysing the functioning of both architectures in a test environment. The HoCa architecture was implemented in the home of 5 patients and was tested for 30 days. The results were very promising.

The data shown in Table 1 are the results obtained from the test cases. They show that the alert system improved the communication between the user and the dependent care services providers, whose work performance improved, allowing them to avoid unnecessary movement such as travels and visits simply oriented to control or supervise the patient. The user identification and location system in conjunction with the alert system has helped to notably reduce the percentage of incidents in the environment under study. Moreover, in addition to a reduction in the number of incidents, the time elapsed between the generation of a warning and solution decreased significantly. Finally, due to the many improvements, the level of user satisfaction increased with the introduction of HoCa architecture since patients can live in their own homes with the same level of care as those offered at the residence.

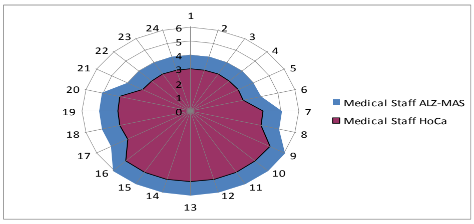

Fig. 6. Comparison of medical staff between the HoCa and the ALZ-MAS architectures

Figure 6 shows the comparison of the average medical personnel required in the two studies made with ALZ-MAS and HoCa. Figure 6 represents the number of people who are in need each hour of the day. The graph seen as the medical personnel necessary for both systems is lower during the hours of lesser activity of the patients. On the contrary during the hours of the morning and afternoon will need more health staff. It also looks like the HoCa system does not need as personal as ALZ-MAS.

As the result HoCa architecture creates an environment that facilitates intelligent and distributed and provides services to dependents at home. Automating tasks and patient monitoring improve the system security and efficiency of care to dependents. The use of RFID technology, JavaCard and mobiles with people provides a high level of interaction between users and patients through the system and is essential in building an intelligent environment. Moreover the good use of mobile devices can facilitate social interactions and knowledge transfer.

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