ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Vol. 5, Issue 10, October 2017

UMA: Ubiquitous Mobile Agent System for Healthcare Telemonitoring

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Abstract: Ubiquitous Telemonitoring Healthcare refers to the disposition of any type of health services such that medical staff members (physicians, emergency workers, other healthcare providers, etc.) through mobile computing devices can access them and expect data to be made available. But generally, distributed computing through a handheld/mobile device has to be considered with carefulness because of the limited capabilities on these devices. In this paper, we present a new system based on ubiquitous agents to assist telemonitoring employees, not only any-time and any-where but also on any-device.

Keywords: Telemonitoring; Ubiquitous healthcare; Ubiquitous agents

I. INTRODUCTION

Several studies point to the aging of population during the next decades. While being a good result of increasing of life expectation, this also implies some problems. The percentage of population with health problems will increase and it will be very difficult to Hospitals to maintain all patients. Our society is faced with the responsibility to care for these people in the best possible social and economic ways. Thus, there is a clear interest to create Ubiquitous Telemonitoring Healthcare, where devices and environments allow patients to be followed in their own homes or during their day-by-day life. Ubiquitous telemonitoring healthcare refers to the disposition of any type of health services such that individual consumers through mobile computing devices can access them. Patients will be monitored at long distance, and medical control support devices may be embedded in clothes, like T-shirts, collecting vital-sign information from sensors (blood pressure, temperature, etc.), [1]. Telemonitoring healthcare systems work with two important components; the system itself and network construction. The systems have the following important goals [2,3]. Provides an electronic healthcare record for the patient conditions in the past and in the present time.

- Issues and alarm if there is anything wrong with the patient's vital signs or if one of his/her family member's see something is wrong.
- Sends a report, to include general information about the patient's health status.
- Presents the patient's health status such as temperature and other vital signs to the medical experts to analyze and they can offer advice.
- Offers support service in emergency situations (first-aid).

It is clear that these systems must be permanently connected with the medical staff, which is not evident in the context of ubiquitous environments where devices have reduced energy autonomy and can be off-line at any time. One key aspect in any ubiquitous system, and especially in healthcare systems, is the use of context-aware technologies. Therefore, a correct information management is vital. It is not enough to gather information about the context, but that information must be processed by self-adaptable and dynamic mechanisms and methods that can react independently of each particular situation that arises. In this sense, agents and Multi-Agent Systems comprise one of the areas that can contribute expanding the possibilities of ubiquitous healthcare systems and telemonitoring systems. An agent can be defined as a computational system situated in an environment and is able to act autonomously in this environment to achieve its design goals [4]. On the other hand, such as many other users, medical staff members are surrounded by many mobile and ubiquitous devices. We want to take advantage of this diversity to let them always connected. For that, we propose in this paper an approach based on Ubiquitous Mobile Agent System. Its goal is to recognize medical staff devices; with the ability to migrate from one device to another. The rest of the paper is organized as follow: section 2 summarizes some works based on the use of agents in telemonitoring systems. We present in section three our contribution, the implementation and experimentations on JADE-LEAP. Finally, some conclusions are drawn.

II. RELATED WORK

Intelligent agents have the ability to make decisions defined by their inherent properties, such as: reactivity, pro-activity and sociability. These properties are intended to enable the agent to meet the objectives for which they were designed, following rules of behaviour that enable them to communicate with their environment [4]. Recent research has discussed the benefits of using agent technology and applications in the health care and telemonitoring domain [5].

De Paz et al. presented a project: Autonomous aGent for monitoring ALZheimer's patients (AGALZ), which facilitates the monitoring and tracking of patients with Alzheimer's [6]. A telemonitoring system aimed at enhancing remote healthcare of dependent people at their homes has also been developed. The main contribution is the use of an experimental architecture that allows the interconnection of heterogeneous Wireless Sensor Networks [7]. De Meo et al. presented multi-agent system that supports personalized patient access to health care services. The proposed system combines submitted queries with the corresponding patient profiles to identify services likely to satisfy patient needs and desires [8]. Vaidehi et al. presented a design for a health care monitoring system based on multi-agent and wireless sensor networks which can collect, retrieve, store and analyse patient vital signs. The multi-agent system is applied to manage these sensors and to collect and store data in a database [9]. Camarinha-Matos and Vieira presented an MA-based architecture for health care centers to remotely observe and help elderly people living alone at home [10]. Wu et al. proposed a multi-agent web service framework based on a service-oriented architecture to support qualified and optimized medical data translation in an e-healthcare information system [11]. Su and Wu designed a highly distributed information infrastructure—MADIP—by using the multi-agent and MA paradigm, which can automatically notify the responsible care-provider of abnormalities, offer remote medical advice, and perform continuous health monitoring as needed [12]. Kim proposed a methodology for the design and implementation of u-healthcare, linking distributed mobile agents with medical entities into a collaborative environment [13]. S Chuan-Jun et al. [14] presents the design and development of a mobile multi-agent platform based open information systems (IMAIS) with an automated diagnosis engine to support intensive and distributed ubiquitous fetal monitoring. In most of presented systems, permanent connection is needed with healthcare staff. It is easy when using traditional wire-based communication systems, where users are connected to their desk PC. But nowadays, users (including healthcare staff) need to have information anywhere and anytime to monitor patients and disabled persons.

For this, most of existing systems introduce ubiquitous devices and agents concept, but the problem is when these devices are offline (ex. problem of connection or insufficient battery), not available or does not have enough resources, (Table 1).

III. CONTRIBUTION: UBIQUITOUS MOBILE AGENT SYSTEM

Healthcare staff members, such as most of today's users, have many handheld devices (smart phones, laptops, tablet, smart swatch, etc.) that provide them access to patient information. The process may operate even if devices have limited energy capabilities or have no connectivity. The idea is to connect monitor physician (healthcare staff member) with his patient anywhere and anytime, through Ubiquitous Mobile Agent (UMA) that can migrate from one device to another and takes advantages from all of them especially in case of energy insufficiency, limited storage space or failure connectivity.

ISSN(Online): 2320-9801
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Systems	Domain	Type of Agents	Ubiquitous Devices	Devices Problems Considered	
				Autonomy energy	Connection Quality
De Meo et al. [8]	Personalized e-Health service access	Stationary	Yes	No	Yes
Wu et al. [11]	Medical data transmission	Stationary	Yes	No	No
Vaidehi [9]	In-home monitoring	Stationary	Yes	No	No
De Paz et al. [6]	In-home monitoring	Mobile	Yes	No	No
Su and Wu, [12]	Health care monitoring	Mobile	Yes	No	Yes
Alonso, et al. [2]	Health care monitoring	Stationary	Yes	No	No
Kim [13]	Ubiquitous health care systems	Mobile	Yes	No	No
Su and Chu[14]	biquitous fetal monitoring	Mobile	Yes	No	No

Table 1: Presented systems analysis.

3.1 UMA System Architecture

The system is composed essentially of Ubiquitous Mobile Agent (UMA) to assist monitor physician and Device Agents (DevA) embedded in each device. In patient side, we proposed Patient Agent (PatA) to assist patient, collect information from sensors and assure communication with the monitor physician. Below, we detail each agent. Mobile Ad Hoc Networks (MANETs) consists of a collection of mobile nodes which are not bounded in any infrastructure Figure 1.

3.1.1 Ubiquitous mobile agent:

- UMA is a Mobile agent, having the list of monitor physician devices: ListDevice= {D1, D2,.., Dn}. It is initially embedded on one of them (ex. smart phone).
- UMA establishes a wireless network including all list device devices.

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- UMA must have a permanent communication with the patient through Patient Agent (PatA) and with devices through Device Agent (DevA).
- UMA has a detailed status of each device StatusDevice including: EnergyCapacity (time of battery), Connected (yes or no), StorageCapacity.
- StatusDevice is collected from Device Agents. Table 2 summarizes example of status devices of laptop, smartphone and a tablet.

3.1.2 Device agent:

Device Agent (DevA) is a stationary agent embedded in each device. Its role is to collect and transmit Status Device to UMA.

Figure 1: Components of UMA system.

	Status Device		
Device	**Energy Capacity**	**Connected**	**Storage Capacity**
Lap Top	Low	Yes	Low
Smart Phone	Low	No	High
Tablet	Medium	Yes	Medium

Table 2: Example of status device of three devices.

3.1.3 Patient agent:

At the patient level, we planned to install Patient Agent (PatA) to communicate with UMA. It transmits health status information or alerts in emergency situations.

3.2 Process Description

- Initially, we suppose that UMA is embedded in Di from List Device**.**
- When UMA receives information from PatA (Health Status or Alert Messages), it verifies capabilities of its actual device.
- If Status Device is weak (Energy Capacity =low, Connected= No or Storage Capacity = low), UMA requests Status Device from all devices by contacting Dev A of each one.
- UMA evaluates the most powerful device, migrates and concludes its task (alert message or ordinary health status information).
- Figure 2 summarizes the proposed process between UMA agent, device agents (Dev Ai) and patient agents (Pat A).

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IV. IMPLEMENTATION AND EXPERIMENTATION

4.1 Implementation using JADE-leap

JADE is a set of Java classes that allow a developer to build a FIPA-compliant multi-agent system quite easily, [15,16]. An add-on to JADE, called LEAP, was released. It replaces some parts of the JADE kernel, creating a modified environment called JADE-LEAP [17,18] which allows the implementation of agents in mobile devices with limited resources. Figure 3 shows an example of the JADE-LEAP execution environment. In this example there is a multi-agent system with six agents. Two of them are running on the main container of the platform, which is connected through Internet with a container on a PC that holds another two agents.

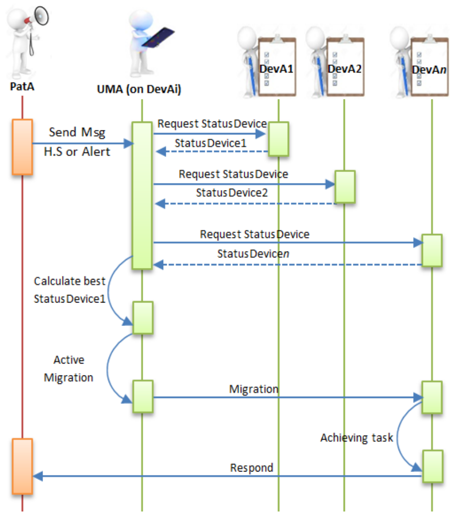

Figure 2: UMA agent's interaction.

These four agents communicate wirelessly with two agents running in mobile devices (one on a tablet and one on a smart phone). Note that in JADE-LEAP each agent is represented by a container. The rest of programing (behaviors, messages, etc.) is identic to JADE.

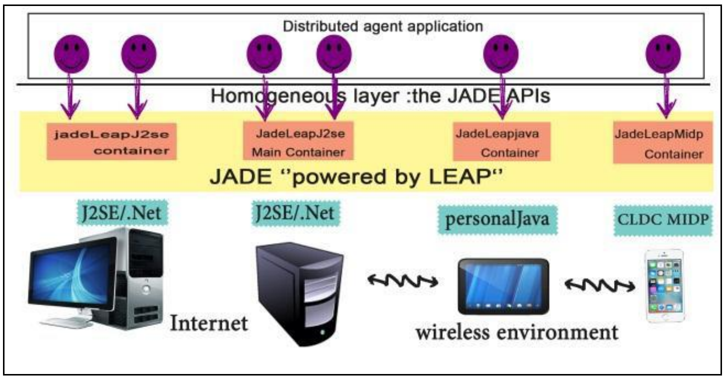

Figure 3: JADE-Leap agents' communication.

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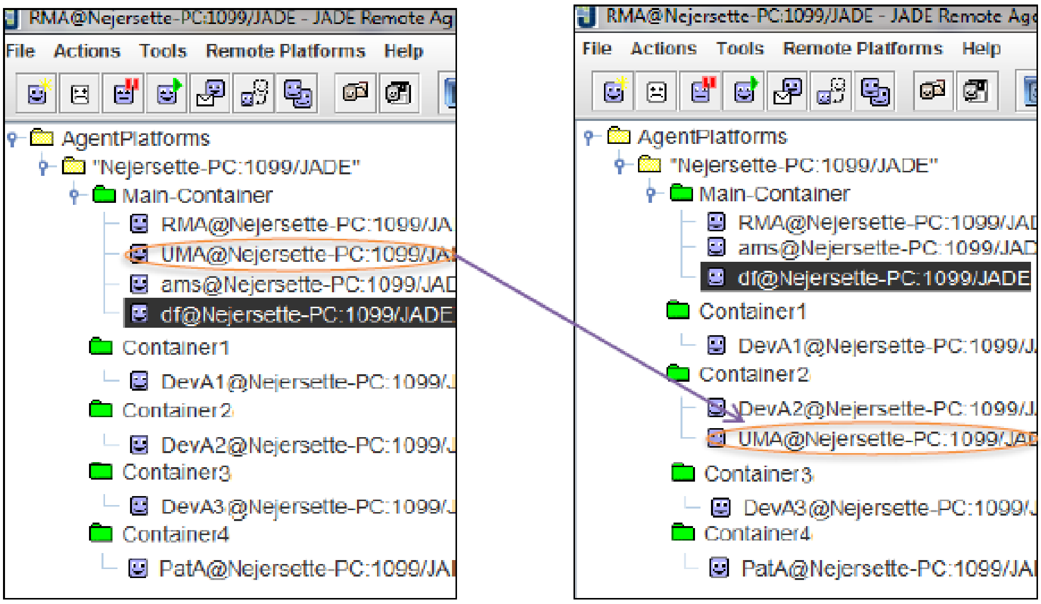

Figure 4: UMA migration from main container to container2.

4.2 Experimentation Scenario

- We propose three devices to Dr. Reda (the monitor physician) and we create three agents: DevA1 for smartphone, DevA2 for tablet and DevA3 for laptop.
- Anissa is an elderly woman with heart failure, she lives alone and she is telemonitored by Dr. Reda.
- She has sensors to collect her health status and to alert Dr. Reda in emergency situation.
- We create PatA, an agent installed on a laptop. Its aim is to alert Dr. Reda in case of heart crisis and to transmit Anissa's health status.
- Tonight, Anissa has heart attack symptoms; her agent: PatA sends an alert message to UMA.
- Dr. Reda was sleeping and his phone and laptop were on offline mode. UMA looks for available devices (tablet), migrates and makes alerts to Dr. Reda.
- Figure 4 presents proposed agents and containers. We can see UMA migration from Main-container to Container2.

4.3 Experimentation Results

We have done experiments according to the power of smartphone battery and its storage capability. We propose smartphone because it is the most used device.

For this, we increase the power, we send alerts from PatA and we calculate the response time in two cases:

- When using UMA system, UMA migrates to another device in order to alert Dr. Reda.
- The second case without UMA system: when Dr. Reda does not respond, PatA resends the alert to another device.

In the second experiment, we calculate the response time according to the memory storage capability. We established graphs in Figure 5. We can see that the response time of the monitor physician is lesser, even if the battery energy or the memory storage capability is low. This is due to the migration of UMA to alert Dr. Reda.

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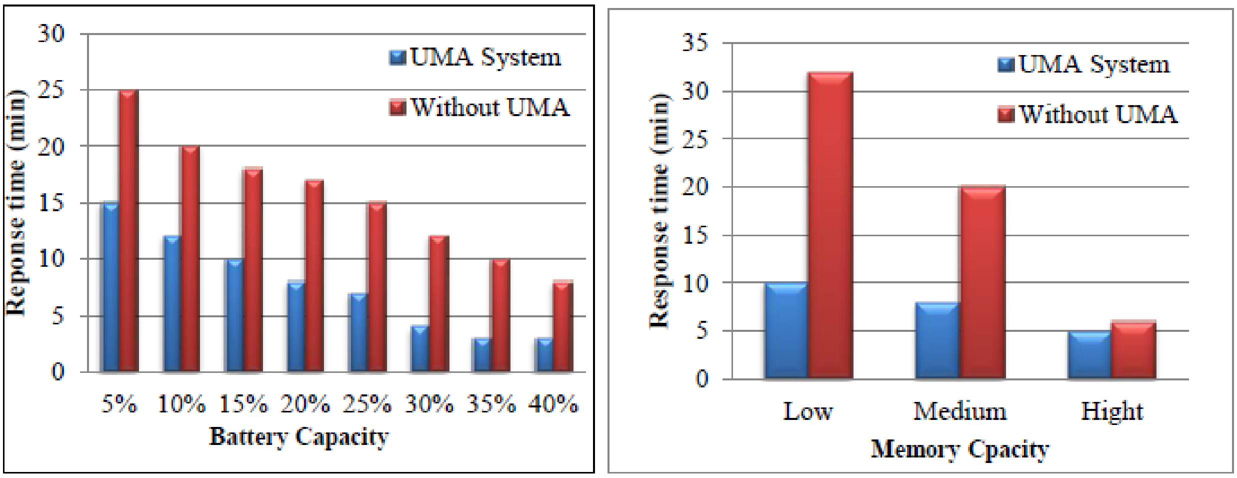

Figure 5: Response time using UMA system (according to battery and memory capacity).

V. CONCLUSION

We proposed in this paper an approach based on ubiquitous mobile agents in order to assist monitor physician to telemonitor his patient. The monitor physician hands several mobile, ubiquitous and restricted devices. Our proposal is to take advantage of all devices surrounding him by allowing the ubiquitous mobile agent to migrate on, in order to complete its task (alerting the physician or just receiving health status information). Also, at patient level we designed patient agent. Its role is to have permanent communication with UMA. We have done the implementation of our proposal using JADE-LEAP framework. In future works, we would like to detail patient level and to consider more than one patient.

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