AN RFID AND MULTI-AGENT BASED SYSTEM ENABLING ACCESS TO PATIENT MEDICAL HISTORY

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ABSTRACT

This paper presents an RFID-based multi-agent system in order to make patient emergency care as efficient and risk-free as possible. The authors describe a general purpose architecture and data model that is designed for collecting ambulatory data from various systems, as well as for storing and presenting clinically significant information to the emergency care physician. Thus, this system enables real time identification and monitoring of a patient in a medical facility, on the basis of passive RFID tag, entitled CIP (Personal Electronic Identity Card). The system is also able to integrate and exchange information with other clinical applications used in medical facilities.

KEYWORDS

Multi-agent system, RFID, patient identification, complete patient medical information

1. INTRODUCTION

Every year, thousands of people die because of medical errors. For example, in 2004 the Institute of Medicine estimated that each year, more than 98,000 people die in the U.S., because of medical errors, while according to the British Medical Journal, the number is 40,000 in the United Kingdom. An investigation conducted by Hearst Media Corporation showed that nearly 200,000 people die each year throughout the U.S due to medical errors and hospital infections [1]. Many of these errors can be avoided by using information technology. Still, in 2004 only 3% of the total 64,000 U.S. hospitals had integrated a Hospital Information System (HIS) to enable the management of patient records.

The medical history of a patient is very important for his diagnosis [2] and for providing the appropriate medical treatment. Unfortunately, at the present moment in many countries, the medical records of a patient are stored by the general practitioner and the healthcare providers in various healthcare units where the patient had been medically examined.

Radio Frequency Identification (RFID) technology allows healthcare professionals to have access to their patients' medical records by using a RFID tag that store relevant medical information. The tag content allows all authorized medical staff to have around-the-clock access

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to their patients' updated records and help them in taking the best healthcare and emergency decisions.

The increased mobility of today's patients influences the patients' medical information distribution. Thus, in many cases, the patient's medical information is stored by various geographically-distributed healthcare providers, such as hospitals, doctor's offices, etc.

Agent technology has proved to be a reliable tool with great potential for solving problems in large scale distributed systems. Multi-agent systems provide a solution for gathering heterogeneous information distributed in different healthcare specific systems and integrating it in order to build the complete medical history of a patient.

This paper outlines the most notable attempts to use RFID technology and multi-agent systems for solving healthcare problems. Next, the authors propose a system (named SIMOPAC [3]) that integrates RFID and multi-agent technologies in healthcare, in order to make patient emergency care as efficient and risk-free as possible, by providing doctors with the maximum amount of information about a patient in a minimum amount of time.

2. APPLYING RFID AND MULTI-AGENT TECHNOLOGIES IN HEALTHCARE

Currently, RFID technology is successfully applied in various fields. In this section, we will consider the integration of RFID technology in healthcare systems. The major challenge comes from the possibilities to incorporate RFID into medical practice, especially when relevant experience in the field is relatively low. By attaching RFID tags to persons (patients or healthcare staff) and objects (medical equipment, medical dressing, blood transfusion bags, etc.) this technology enables the identification, tracking and tracing of entities, security, and other healthcare specific capabilities [4].

An agent is a software component that has a well-defined role in the operation of a system. Also, an agent must have the ability to communicate with other agents or human users. A multi-agent system is a collection of such entities, each cooperating with the other.

In the medical field, multi-agent systems can offer services that facilitate the decision-making process of the medical staff, providing a larger amount of information about certain situations and reducing the number of operations performed by the human operator. So far, several multi-agent systems have been developed in the worldwide medical field. These systems provide patient monitoring, automatic information extraction from medical databases, medical images processing and many other facilities.

This paper shows a few examples of multi-agent systems developed to allow quick access to the complete medical information of a patient. It is difficult to implement a solution for developing large centralized databases to store information about all patients. Currently, in most cases, patient medical information is stored in databases of the healthcare unit, where the patient resides or underwent medical investigations. The heterogeneity of the information stored in different medical information systems from different healthcare units hinders easy access to comprehensive medical information of a patient.

Some of the agent-based systems, such as MAMIS (Multi-Agent Medical Information System), developed by Fonseca et al. [5] and eMAGS (electronic Medical Agent System), implemented by Orgun et al. [6], enable the adequate information search in a community of autonomous healthcare units and provide physicians and surgeons with easily accessible information. In MAMIS system, each medical unit must share, on request, a limited set of information about a patient. In this direction, the authors propose a common database architecture to be

implemented by each healthcare unit from the considered community. It is a supporting database, developed in addition to their existing private one. This database stores a limited set of information about patients and will be available within the community. The eMAGS system described by Orgun et al. [6] proposes a multi-agent architecture that uses an ontology based on the HL7 (Health Level Seven) standard to facilitate the flow of patient information within a healthcare organization. In the proposed model, several healthcare applications are tied together through servers of agents, one for each medical application registered in the network, a broker for agents and an ontology server.

The research performed over the years has shown that RFID and multi-agent technologies can provide solutions for problems in various fields.

In the medical field, Bajo et al. [7] present a multi-agent architecture, the Geriatric Residence Multi-agent System (GR-MAS), developed in order to facilitate healthcare services in geriatric residences. GRMAS contains different types of agents and takes into account the integration of RFID technology, Wi-Fi technologies and portable devices.

3. SIMOPAC SOLUTION TO ENABLE ACCESS TO COMPLETE PATIENT MEDICAL INFORMATION

According to Encyclopedia Britannica, “the medical history of a patient is the most useful and important element in making an accurate diagnosis, much more valuable than either physical examinations or diagnostic tests” [8]. Unfortunately, the access to the patient’s medical history is not always possible, and this may lead to errors in diagnosing or in providing the appropriate medical treatment, sometimes with unfortunate consequences for patients.

In this context, our research team proposed an RFID and multi-agent based system, named SIMOPAC, to enable access to complete patient medical information. In SIMOPAC infrastructure, every patient will be authenticated through an RFID-based card (named CIP). This card must contain patient personal information such as name, date of birth, identification number and medical information considered critical, e.g., blood type or certain chronic diseases. In addition, if the patient has carried out medical examinations in other medical units, another RFID card (named CIP2URI) is considered to store the addresses of the electronic health records (EHR) servers used in the medical units where the patient was consulted. Then, through SIMOPAC, the patient’s physician can use CIP2URI card to have access to the results of patient’s previous medical investigations. This information could be added to patient’s medical records and could also be stored in the SIMOPAC database.

A multi-agent system was designed and implemented within the SIMOPAC project to enable access to a patient's medical history. Developed agents allow retrieval of information of interest from different servers of healthcare units where the patient was consulted. Adopting agent technology does not require major changes in terms of software resources available in the healthcare units. Some of the medical informatics systems of healthcare units implement HL7 standard, while others do not. In the first case, the retrieval of medical information is based on the HL7 standard and existing software systems compliant with HL7 can be integrated directly with the multi-agent system. For healthcare information systems that do not comply with the HL7 standard (hereinafter referred to as non-HL7 servers), a partnership agreement shall be previously established. The partnership will determine the details of communication protocol to be used in the SIMOPAC system in order to enable patient information retrieval from their database. Additional agents will be developed in compliance with the accepted protocol for assuring retrieval of patient-specific information.

Figure 1 shows the flow of information within the multi-agent system which allows the updating of the patients' medical records with information retrieved from HL7-compliant servers and non-HL7 partner servers.

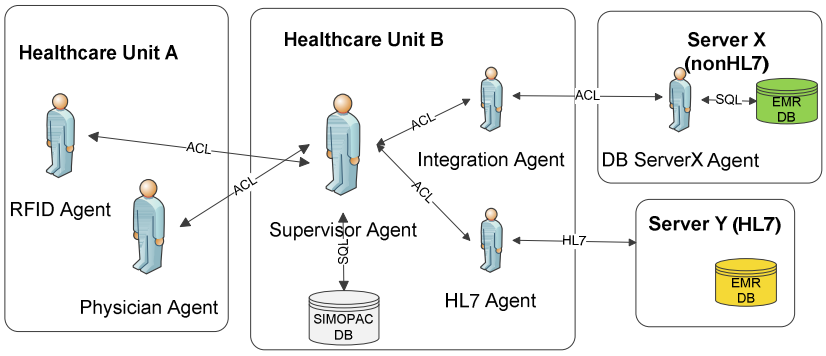

Figure 1. Updating patient electronic records with information from HL7 and non-HL7 servers

Figure 2 shows the agents taken into consideration in the multi-agent system of the SIMOPAC platform (SMA-SIMOPAC).

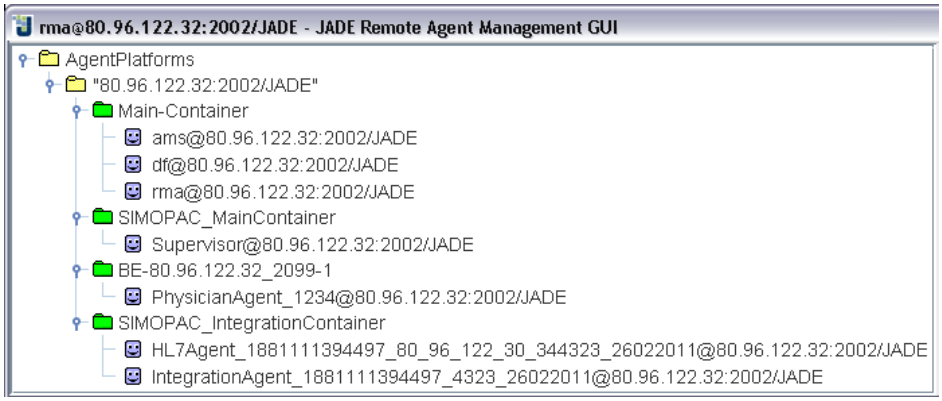

Figure 2. SMA-SIMOPAC Agents

Supervisor Agent – is the core agent within the platform. It acts as a coordinator and mediator of other agents' actions. Some of the most important responsibilities carried out by this agent are:

- the encapsulation of database connection details;
- creating HL7 and non-HL7 agents to communicate with the EHR servers of medical units in order to retrieve medical records of previous medical investigation of a patient;
- notifying family physicians of the investigation results received from other medical units.

HL7 Agent – an agent specifically designed for communication through HL7 messages. The agent relates to a specific HL7-compliant server and provides appropriate HL7 commands to retrieve the patient's observations file.

Integration Agent – an agent who mediates information gathered from non-HL7 servers. In order to get data from medical units that do not have HL7-compliant medical informatics systems, a partnership should be previously agreed upon. Thus, a protocol is designed for indicating the server address and the exact name of the DB-Server-type agent running on the server is set. To avoid overloading of the platform, the Integration Agent will be responsible for getting information from all non-HL7 servers of medical units where the patient carried out medical investigation.

DB-ServerX Agent – an agent implemented at the partner medical unit system, which knows the login details and the structure of this database medical unit. This agent extracts relevant information about patient medical investigations and sends it to the Integration agent that initiated the request. The DB-ServerX agent development is based on clear specifications regarding the response to requests of Integration Agents from various medical units. Thus, this agent receives the patient's identification number, extracts data from the database, transforms the data into a message according to a particular ontology (developed within the project) and then sends the message to the Integration agent. Use of ontologies for information retrieval is a good practice [9] to come up with semantic representations of extracted data.

Physician Agent – the agent that uses the services provided by the SIMOPAC multi-agent system, namely: requesting complete electronic patient medical records, initiating a process to update the information if it has not received the results of some medical investigations, analyzing the notifications received from the Supervisor agent regarding the received new results.

RFID Agent – is the agent specifically created for reading/writing RFID tags (CIPs). When reading a tag, according to the data retrieved from it, this agent performs the appropriate operations, i.e.: if the tag belongs to a family doctor/general practitioner, it creates the proper physician agent or, if the tag identifies a patient, it displays its own medical records. This agent is used for the authentication of multi-agent system users.

The agents are independent of each other, and in order to retrieve information about patients, other agents are created to run the query again for sources of data. The agents previously created are disposed of once when they accomplished the received task or after a preset time interval from the moment of receiving the task.

Communications between agents comply with the FIPA (Foundation for Intelligent Physical Agents) interaction protocol. Interaction between SIMOPAC agents is illustrated in Figure 3.

To develop the above-described multi-agent system, we choose the JADE platform. Jade is an open-source multi-agent platform that offers several advantages, such as: it is FIPA compliant, allows the agents execution on mobile devices (like PDA), provides a range of security services regarding the actions allowed for agents (via add-on module JADE-S) and provides intra and inter-platform mobility.

The SIMOPAC system presents various advantages. The integration of RFID technology provides the unique identification of patients, as well as fast retrieving of minimum patient health information, which is primordial in emergency cases. Moreover, given the fact that this system allows medical personnel to obtain information about the patient's medical history, it will increase the chances of accurate diagnoses and decrease the number of medical errors.

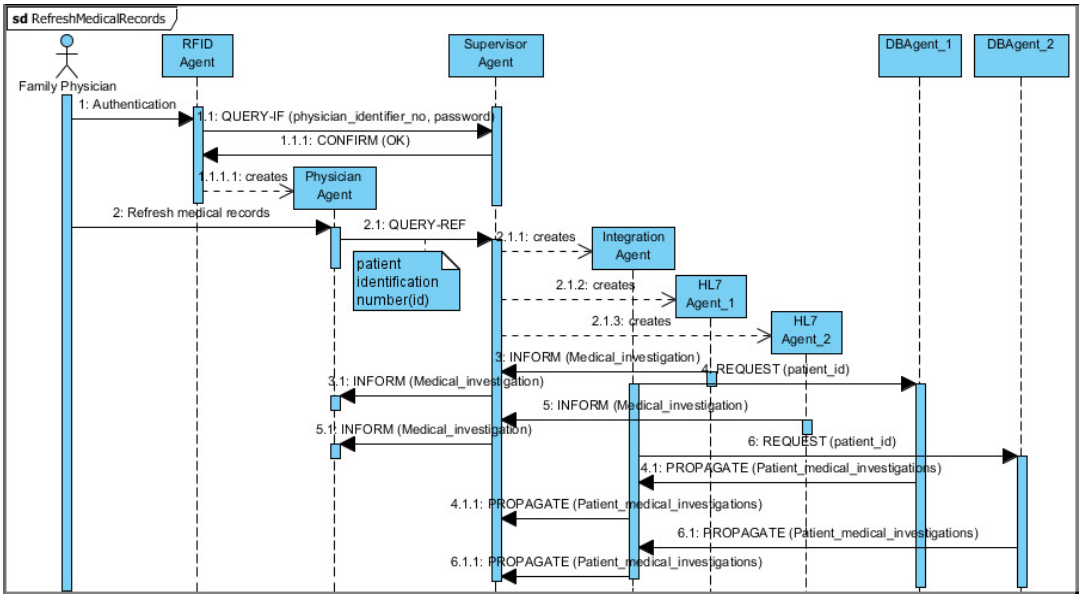

Figure 3. Agent communication for updating electronic medical records of patients

Regarding the information search performance, the afore-described eMAGS and MAMIS systems perform an exhaustive search for information related to a patient. The search is performed, in the first case on the servers that publish such services, and in the second case on servers from a particular community where medical units must register first. In the SIMOPAC approach, the information search is performed only on the servers of healthcare facilities where the patient has carried out medical examinations, leading to a general improvement of the system's efficiency.

By using dedicated agents, SIMOPAC proves to be an easy-to-use tool, which allows automation of some of the operations performed frequently in healthcare units.

3. CONCLUSIONS

A patient's medical history is very important for doctors to make accurate diagnoses and provide appropriate medical treatment. In emergency cases, when these operations must be carried out against the clock, fast retrieval of information related to patient's medical history may be of vital importance for the patient's life.

The presented system, designed and implemented by our research team, used RFID technology to provide a solution for enabling the medical staff to access the patient medical history, by using an RFID tag that stores essential information about the patient, and acts as a gateway to the complete electronic healthcare records of the patient. The implemented multi-agent system allows the collecting and integrating heterogeneous information distributed in specific systems of various medical units, in order to retrieve the patient's electronic healthcare records as comprehensively as possible. Thus, it facilitates the integration of data from heterogeneous sources (HL7-compliant or non-HL7 servers) in order to achieve a complete electronic medical history.

The adoption of this system does not require major changes in terms of the software resources existing in the medical units. The proposed architecture is scalable, so that new sources of information can be added without amendment to the existing configuration. It also allows easy addition of new agents to provide other functionalities, without requiring changes of the existing

agents. When a data source does not follow the HL7 standard, a new agent is developed to interface with this data source and to provide communication with the appropriate agent from the SIMOPAC system. The developed system is robust, each agent acting independently and autonomously. The failure of an agent does not cause overall system failure; other agents may take over the task of that agent. Last but not least, we should mention that the system is secure, as the access to the information about a patient is permitted based on an RFID tag specific to the patient or the doctor who wants to access the patient's electronic medical records.

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