RFID Technology and Multi-Agent Approaches in Healthcare

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1. Introduction

Every year, thousands of people die because of medical errors. For example, in 2004 it was estimated that each year, more than 98,000 people die because of medical mistakes in the U.S., according to the Institute of Medicine, while in the United Kingdom the number is 40,000, according to the British Medical Journal. In 2005, according to a European Commission report, the number of deaths due to medical errors in the U.S. was higher than the total number of persons who died of breast cancer, AIDS or car accidents. A study conducted by the Institute for Safe Medication Practices in the United States indicated that approximately 25% of hospital patients had adverse reactions to medications; in many cases they could have been prevented or alleviated. Also, such side effects are registered in patients undergoing primary care, but there are not too many studies in this direction. In its 2008 annual report to Congress, the Agency for Healthcare Research and Quality reported that preventable medical injuries are growing each year by 1 percent (Crowley & Nalder, 2009). An investigation conducted by Hearst Media Corporation showed that nearly 200,000 people die each year from medical errors and hospital infections throughout the U.S (Hearst, 2009). Many of these errors can be avoided by using information technology. But in 2004 only 3% of the 64,000 U.S. hospitals had integrated a hospital information system (Hospital Information System - HIS) to allow the management of patient records.

The medical history of a patient is very important for his diagnosis and for setting an appropriate therapy. Unfortunately, for the moment, in many countries, keeping a patient's medical records is carried out at the general practitioner's level and healthcare units in which the patient has performed medical examinations. So, there is no complete data set comprising all the medical information about a patient and allowing quick access to the patient's complete medical history. In certain situations, for example, whether the patient has suffered an accident and he/she is unconscious, the emergency medical personnel do not have access to medical information concerning that patient. RFID technology provides a solution for enabling the access of medical personnel to the patient's medical history, by using a device (RFID tag) that allows storing relevant medical information related to its carrier, which provides a quick access to the actual health state of a patient and helps the medical staff to take the best decisions, especially in case of emergency. Thus, the risk of administrating wrong medication is highly reduced. Also, multi-agent systems offer the framework for the collection and integration of heterogeneous information distributed in different healthcare specific systems to get access to the patient's complete medical history.

This chapter provides a structured enumeration of the most notable recent attempts to use RFID technology and multi-agent systems for healthcare. Next, the authors propose an RFID-based system (named SIMOPAC) that integrates RFID and multi-agent technologies in health care in order to make patient emergency care as efficient and risk-free as possible, by providing doctors with as much information about a patient and as quickly as possible. 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 HL7 (Health Level Seven) and even non-HL7-based clinical applications already developed by other companies or organizations. All hospitals can use SIMOPAC with their existing system in order to promote patient safety and optimize hospital workflow. We 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.

2. Applying RFID technology in healthcare

Currently, RFID technology is successfully applied in many 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 (Figure 1) (Iosep, 2007).
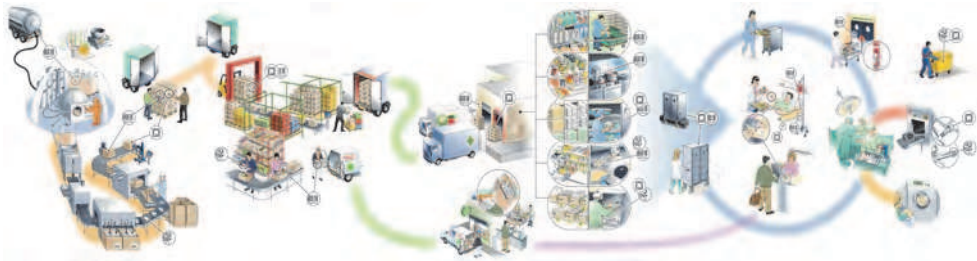

Fig. 1. RFID technology use for patient care (Iosep, 2007)

RFID tags can be used in the medical field in the following ways (BioHealth, 2007): identification of a patient in emergency situations; patient vital signs measurements (for example, for patients with chronic diseases); recording significant medical information and their transfer to an electronic monitoring device; monitoring the elderly, even at their home; monitoring of goods and equipment; controlling drugs administration and blood transfusions, thereby reducing medical errors in hospitals.

Internationally, at present, the following main areas benefit from the application of RFID technology in healthcare (Table 1):

1. Management of medical articles – The fast tracking of mobile medical articles ensures a better use of them, which reduces losses and, consequently, new acquisitions, while considerably reducing the amount of time wasted by medical staff searching for equipment;

a)

2. Patient care – Correct identification of patients and their location at all times may lead to increased security (for example, in case of patients suffering from Alzheimer's disease), but also better management of hospital beds within a medical unit;

b)

3. Management of drugs and dangerous medical substances – Drug traceability is fundamental to eliminate counterfeit drugs. A significant decrease in the number of errors in patient medication administration can be achieved through quick and accurate drug identification, thus also ensuring the checking of prescribed dosage for a particular patient.
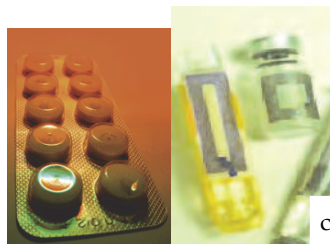
c)

4. Inventory Management – Early identification of inventory items and rapid inventory achievement may result in the elimination of '0 stock' situations and optimization of current inventory etc.

d)

Table 1. Examples of applying RFID technology in various areas of medical fields

But RFID is, also, an option for patients who are not hospitalized in a medical institution and who, for example, undergo medical treatment.

Various studies (e.g., BRIDGE project (BRIDGE, 2007)) estimate a significant increase in the coming years in the use of RFID technology in medical field (Table 2, Table 3).

Millions RFID tags items associated with	2007	2012	2017	2022
Medical equipment	2	98	190	320
Laboratory samples	1	8	30	40
Drugs	5	246	1500	6380
Total	8	352	1720	6740

Table 2. Estimating the use of RFID tags in the medical field

Use of RFID readers	2007	2012	2017	2022
Locations with RFID readers	110	2770	11900	40600
Total number of RFID readers	180	12600	70200	208000

Table 3. Estimating the use of RFID readers in the medical field

For example, in May 2008, an RFID-based system to be used in surgery rooms was implemented in San Jose, California. ClearCount Medical Solutions has chosen RFID technology to automate the process of tracking surgical dressing. The system uses passive tags, 13.56MHz, with a 2 Kb programmable memory (figure 2). Surgical dressings with RFID tags used in a surgery cost about $ 35-50. This system has been approved by U.S. organisation: FDA (Food and Drug Administration) and FCC (Federal Communications Commission).
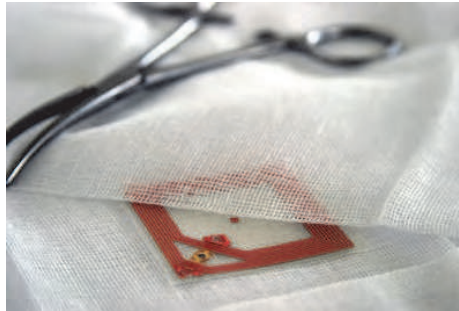

Fig. 2. RFID for tracking surgical dressing

Even if the labeling of hospital objects (such as surgical dressings, medical equipment etc.) submits a development potential for the RFID technology, patient labeling involves far more issues. Janz and others studied the impact of introducing RFID-based application in the emergency department of a hospital and found that the information collected from patient's tags has been particularly useful, especially in decision making process and resource management (Janz et al., 2005).

In 2003, at the Taipei Medical University Hospital (TMU) in Taiwan, a platform that exploited RFID technologies was implemented, due to the need to handle cases of bird flu that ravaged Taiwan that year. Thus, the implemented system used RFID technology to monitor the body temperature of medical staff and hospital patients, to allow the identification and monitoring of bird flu virus carriers. According to a report, in 2003, 94% of Taiwan's SARS victims were infected in hospitals. The implementation of this RFID-based system targeted a more rigorous control in hospitals, so that the danger of SARS disease or other transmissible diseases could be considerably reduced.

(Chung et al, 2009) proposed the Medicare-grid system (grid-based e-Health System) to facilitate the process of retrieving and exchanging patient's EHRs (Electronic Health Records) among hospitals and medical centers. Grid and peer-to-peer technologies were used to develop an EHR center as a decentralized database to store and share EHRs among participating hospitals and medical centers. In addition, they also integrate computing resources provided by hospitals, to form a computational grid for medical-related applications. Based on computing resources and a data grid platform, they developed medical related applications to improve the in-hospital medical services:

1. a data warehouse for medical decision support system; they use data mining techniques for analyzing patients' EHR information;
2. an RFID-based mobile monitoring system to identify people or items accurately;
3. an wearable physiological signal measurement system that monitors the health condition of a patient.

But it should be noted that some researchers warn that RFID technology in hospitals can influence the optimal operation of medical equipment. According to a study published in June 2008 in The Journal of the American Medical Association, RFID systems can cause random incidents over medical devices in hospitals. This study, however, is not confirmed by researcher around the globe and rather asserts that RFID technology can be used in hospitals and other patient care institutions. 25 common medical devices were tested in this study, 1,600 tests being considered. In all cases, the devices worked at standard parameters and no interference from passive RFID devices was observed. The report concluded that the RFID solutions can be applied to inventory monitoring, entities traceability etc. without adverse effects on the equipment. Therefore, passive RFID tags can be used safely in hospitals.

The price of integrating RFID technology in medical systems is the most important impediment to the adoption of this technology in the medical field. Currently, implementation and use cost of RFID systems is higher than the cost of any bar code system on the market. This is, mainly, due to the higher cost of tags production. But a decrease is foreseen over the next years in the price of tags because of the growing scope of RFID applications and, implicitly, because the number of these products is increasing.

3. Multi-agent system developed for the medical field

The medical field is characterized by information, data, knowledge and even distributed competence. Moreover, the three components (data, information, knowledge) may be of different types: natural language descriptions, images, measured signals, the results of various tests and measurements (usually lists of numbers). They are stored under different shapes: sheets of paper, photos, slides, electronic files, books (if we consider the "classical" knowledge) and sometimes private discussions. Usually they are not available in one place

at a time. Therefore, this distribution is a major problem when decisions must be made very quickly.

Modern medical systems include many specialists whose practice is limited to a particular branch of medicine or surgery. Complex examination of a single patient involves several consultations by medical specialists and, also, laboratory tests. Medical knowledge, examinations and treatments are distributed geographically and temporally. Therefore, there is a need for a consistent flow of information and trust among all involved subjects to meet the global target - a patient's enhanced health. But the necessary information flow is not predictable in content and structure, and it is evolving and changing over time due to new knowledge and reactions. To meet these demands and to provide appropriate decision support, intelligent software applications have to be used.

Generally, as shown in several studies on health system design for distributed heterogeneous environments (Laleci et al., 2008) the best-suited method of implementation is the use of multi-agent systems. Those systems include independent components that communicate in a reactive way, and some of these components should be instantiated and removed dynamically on demand.

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 that cooperate with one another. By using the multi-agent technology in the system implementation, the following advantages could be obtained (Bouzeghoub & Elbyed, 2006):

> *High performance*: agents can run in parallel. They can be cloned when their tasks and goals are very important;
> *High flexibility*: an agent can be developed for any context, providing the interface for different ontologies;
> *High modularity*: the number of connected sources can increase practically without limit.

In the medical field, multi-agent systems can provide services that facilitate decision-making process for medical staff, providing a larger volume of information about certain situations and reducing the number of operations performed by the human operator. So far, worldwide, several multi-agent systems have been developed in the medical field. These systems provide:

- Patient monitoring and, in some cases, generation of automatic prescription;
- Automatic information extraction from medical databases and fast information analysis;
- Efficient patient scheduling in medical offices;
- Critical drugs scheduling;
- Doctors' access to patient's medical information, the information being distributed in heterogeneous databases;
- Medical images processing;
- Patient access to own medical information.

This chapter will describe a few examples of multi-agent systems developed to allow quick access to the complete medical information of a patient. The solution of developing some large centralized databases to store information about all patients is difficult to achieve. Currently, in most cases, medical information on a patient is stored in databases of the healthcare unit, where the patient resides or where the patient underwent medical

investigations. The heterogeneity of the information stored in different medical information systems used in healthcare units hinders easy access to comprehensive medical information of a patient.

For the integration of heterogeneous data from several health care units, (Schweiger et al, 2007) proposed the concept of Active Medical Document (AMD). These documents are compiled at runtime and can be prepared according to user's needs. The Active Medical Documents contain agents offering internal services (access control, appointments monitoring) as well as coordinative, administrative, and medical data (patient medical records). Their built-in agents offer additional services such as information retrieving and processing. The advantages of using such documents cover, among others, the possibilities for decentralized, adaptive and intelligent coordinating, ensuring, above all, availability of heterogeneous data sources.

In order to achieve full medical information about a patient several systems have been designed to provide advanced capabilities search for this kind of information in the medical information systems of different healthcare units. For example, agent-based systems, such as MAMIS (Multi-Agent Medical Information System), developed by Fonseca et al. (2005) and eMAGS (electronic Medical Agent System), implemented by Orgun et al. (Orgun et al, 2006), enable the competent 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. This database is a supplemental database, developed in addition to their existing private databases. 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 (2006) proposes a multi-agent architecture that uses an ontology based on the HL7 standard (Health Level Seven) to facilitate the flow of information about a patient 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.

Another solution allowing the access to complete medical information about a patient lies in placing the responsibility of sending the results of the medical test to the medical unit to which the patient belongs, in the hands of the staff from the medical unit where these tests are performed. To achieve this automatically, one should consider the multi-agent approach. Nguyen et al. (2008) made the first step in this direction, developing the MEDIMAS system, which is a multi-agent system for the transmission of test results carried out in laboratories within a medical unit to the healthcare professional who requested them. The considered medical unit already has a database and runs an application for recording and managing the performed analysis. The multi-agent system is designed and implemented in order to extract the necessary information from the existing database and to notify the appropriate medical staff within the unit.

Within a national project, Laleci et al. (2008) have developed the SAPHIRE multi-agent system, used for monitoring patients with chronic diseases both in hospital as well as at the place of residence. Based on the information provided by monitoring systems and that existing in the patient's electronic medical records, the system is able to deploy and execute clinical guidelines in a care environment that includes disparate medical units with heterogeneous information systems. As a result of conducted research, the team members have chosen to establish a semantic interoperability environment to enable communication with different heterogeneous health care systems; the considered solution is the adoption of a multi-agent system as the basic structure of SAPHIRE system.

4. Integrating RFID and multi-agent technologies

The research performed over the years has shown that RFID and multi-agent technologies can provide solutions for problems in various fields. Thus, for example, in the supply chain of companies, Dias et al. (2008) propose an intelligent transportation system that integrates both technologies. Lebrun et al. (2010) present a model of a multi-agent system dedicated to the management of objects identified by RFID tags that users shall move on a flat surface, with a first application for the study of road traffic.

An RFID Identification System (IRS) commonly uses passive information about a particular entity, such as the identification and description of the information stored in the RFID tag, and chooses a set of actions based on already established rules stored in a database (Chen et al, 2010). Since this database is static, it cannot be updated in a timely manner for new types of objects or according to the dynamics of the environment, thus creating synchronization problems. Chen et al. (2010) propose an RFID system based on a code (CRS - Codecentric RFID System) as a solution to these problems. The RFID tag encodes a mobile agent that contains up-to-date service directives realizable by an intelligent handling of the dynamics of various networks.

In the medical field, Bajo et al. (2008) presents a multi-agent architecture, the Geriatric Residence Multi-agent System (GR-MAS), developed for facilitating health care 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. The core of GR-MAS architecture is a deliberative planning agent, aimed to optimize the visiting schedules for medical staff. This agent, which can learn and adapt to new circumstances, was designed to schedule the nurses' working time dynamically, so that patients receive proper care. Also, this agent will keep track of the standard working reports on medical staff activities. This multi-agent system used RFID technology to facilitate location and identification of patients and medical staff.

5. SIMOPAC solution for accessing full medical information about a patient

Diagnosing and setting proper medical treatment for a patient inevitably involves consulting the patient's medical history by medical specialists. Unfortunately, the access to the patient's medical history is not always possible, which may lead to errors in diagnosing or in setting a treatment, sometimes with adverse consequences for patients.

Currently, in Romania, the degree of computerization of the health system is relatively low; the information about patients is to be located in different healthcare units; patient medical records are neither consistent nor complete, and cannot be accessed online by the medical staff if necessary. In this context, our research team has designed and implemented an integrated information system for identifying and monitoring patients – SIMOPAC. The system aims to operate in the medical distributed environment and particularly, to solve the problems of identifying and monitoring patients based on the most recent technologies in the field: radio-frequency identification, collaborative problem solving in a distributed environment (intelligent multi-agent technology). Altogether, it aims to provide communications infrastructure in order to enable multi-point access to medical information conveyed in the system.

Our team designed the SIMOPAC system to use an RFID-based card (named CIP) for each patient. This card must contain patient personal information such as name, birth date, identification number and medical information considered critical, such as, 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 EHR server addresses used in the medical units where the patient was consulted. Then, through SIMOPAC, the patient's physician can use this card to get the results of the medical investigations suffered by the patient. This information will also be stored in the SIMOPAC database.

Some of the medical informatics systems of medical units implement HL7 standard, while others do not. In the first case, medical information may be retrieved based on the HL7 standard. For healthcare information systems that do not follow the HL7 standard (hereinafter referred to as non-HL7 servers), a partnership agreement shall be previously performed, with the details of communication protocol to be used in the SIMOPAC system to allow the retrieval from their database of the information relating to a patient.

To enable access to a patient's medical history, within the SIMOPAC project, a multi-agent system was designed and implemented to provide 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. Thus, existing software systems compliant HL7 can be integrated directly with the multi-agent system and healthcare information systems that do not meet this standard are interfaced through specific agents.

Figure 3 shows the flow of information within the multi-agent system which allows the update of the patients' medical records with information retrieved from HL7-compliant servers and non-HL7 partner servers, as well as the notification of the general practitioner where the patient is primarily registered.

Figure 4 shows the agents considered in the multi-agent system of the SIMOPAC platform (SMA-SIMOPAC):

Supervisor Agent – the core agent within the platform. It acts as 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 where a patient carried out medical investigation, in order to retrieve medical records;
- notification of family physicians on 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 that indicates the server address and the exact name of the DB-Server-type agent running on the server is set. To avoid overloading 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. Essentially, its task is confined to sending REQUEST messages to specific DB Agents of partner medical units and then to processing the responses.

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's medical investigations and sends it to the Integration agent that
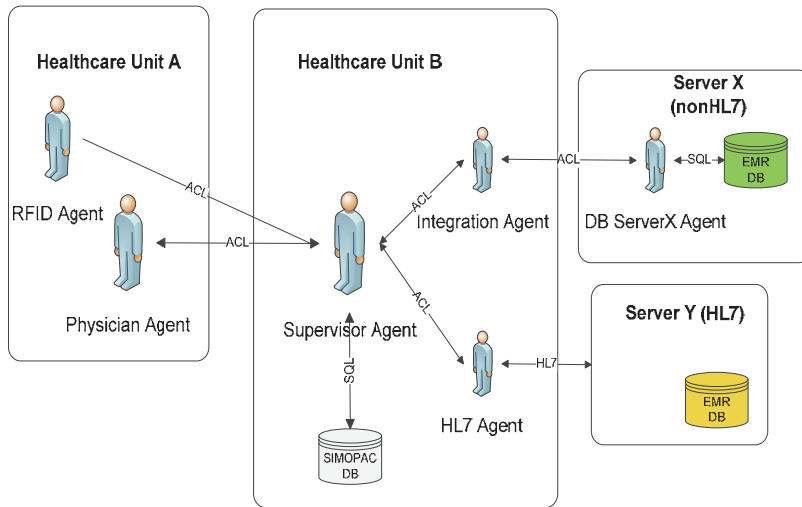
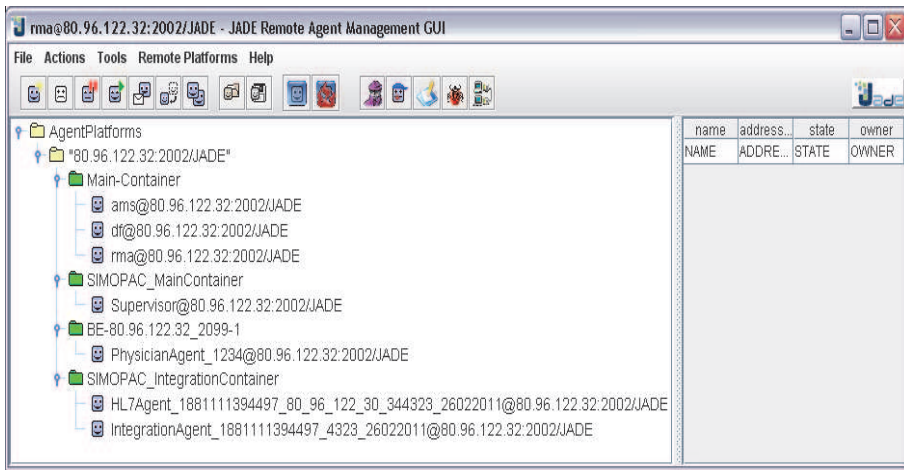Fig. 3. Updating patient's electronic records with information from HL7 and non-HL7 servers

Fig. 4. Agents considered in SMA-SIMOPAC

initiated the request. The DB-ServerX agent development is based on clear specifications regarding the response to requests from Integration Agents of various medical units. Thus, this agent receives the patient's identification number, extracts data from the database, transforms the data into a message expressed in the particular ontology developed within the project and then sends the message to the Integration agent.

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, viewing the notifications received from the Supervisor agent regarding the new results received.

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 update of the patient's electronic health records with information from HL7-compliant or non-HL7 servers is performed automatically at a particular time set to the Supervisor Agent. To achieve this task, the Supervisor Agent extracts from the database the identification numbers of patients who have performed medical investigations outside the medical unit where they are registered and the list of server addresses of healthcare units where such medical examinations were performed. For each patient, the Supervisor Agent creates an Integration Agent, which receives, as parameters, his identification number and the list of non-HL7 servers corresponding to the medical units in question, along with the names of the DB Agents which they will communicate with for getting the necessary information. The Integration Agent sends REQUEST messages containing the patient's identification number to the DB agents of the partner medical units and then waits for answers from those agents. Each of these DB agents is familiar with the login details to the database from which information about the patient has to be retrieved (such as database type, address, user and password) and the database structure. Thus, based on the received identification number, the DB agent will extract data from the database tables containing the results of medical examinations undergone by the patient and will send them to the Integration Agent that requested it. The Integration Agent will mark in the database that it received the requested information from that server. In addition, it sends to Supervisor Agent the replies containing the requested information. The Integration Agent will end its execution when it has received responses to all performed requests or after a certain period of inactivity. With regard to getting necessary information from HL7- compliant servers, the Supervisor Agent will create one HL7 Agent for each HL7 server of the medical units of interest. An HL7 Agent receives as parameters the patient identification number along with details for connection to one of the considered servers. The HL7 agent initiates a communication channel with the appropriate server and attempts to obtain information from the patient's electronic medical record database through specific HL7 messages. The results received by the HL7 agent are also directed to the Supervisor Agent. As a result of the performed requests, the Supervisor Agent receives responses containing the results of patient's medical investigations from the Integration Agent or HL7 Agent. In this case, Supervisor Agent verifies that the information are not already stored in the system database and when there are no corresponding entries, adds them to the database and notifies the Physician Agent of the patient's family physician, with regard to newly received information. Moreover, when, for example, the family doctor/general practitioner recommended a specific medical investigation to a patient and got no answer, it can initiate the process of updating patient's electronic medical records, simply by selecting a command button in the user interface of Physician agent (*Refresh records* button in Figure 4). In this case, the Physician Agent will forward to the Supervisor Agent the request for updating medical records of the patient identified through identification number specified in the window.

Communications between agents comply with the FIPA interaction protocol. Interaction between agents is illustrated in Figure 6.

To develop the above-described multi-agent system, we selected the JADE platform. Jade is an open-source multi-agent platform that offers several advantages, such as the following: it is FIPA compliant (Foundation for Intelligent Physical Agents), allows the execution of

agents 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 also has a series of 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 will decrease the number of medical errors.
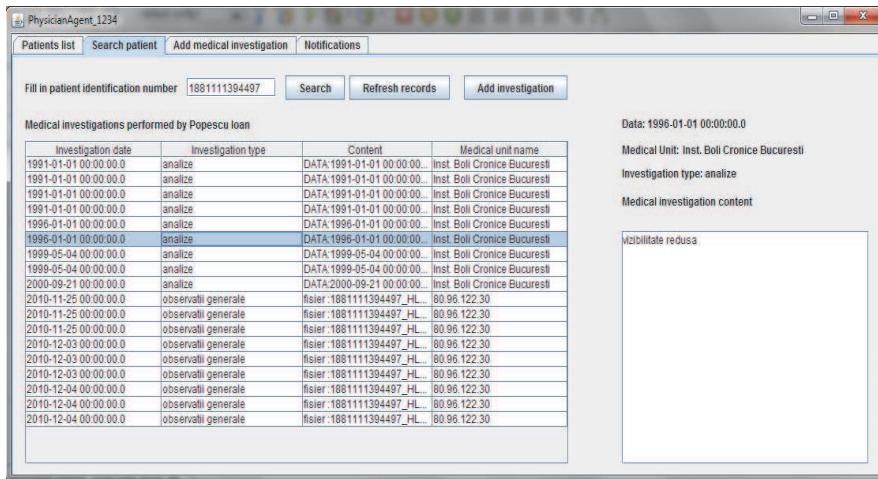
Fig. 5. The physician agent interface for displaying and updating patients' medical records

Regarding the information search performance, the eMAGS and MAMIS systems described above perform an exhaustive search for information related to a patient, 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 SIMOPAC approach, it is only in the servers of healthcare facilities where the patient has performed medical examinations that the system runs a query, resulting in a general improvement of system efficiency.

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

6. Conclusions

A patient's medical history is very important for doctors in the process of diagnose and determination of the appropriate treatment for the patient. 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. RFID technology provides a solution for enabling the medical staff to access a patient's medical history, by using a device (RFID tag) that stores essential information about the patient, and acts as a gateway to the complete electronic healthcare records of the patient. Multi-agent systems provide, among others, the framework for collecting and integrating heterogeneous information distributed in various medical units specific systems in order to retrieve the patient's electronic healthcare records as comprehensively as possible.
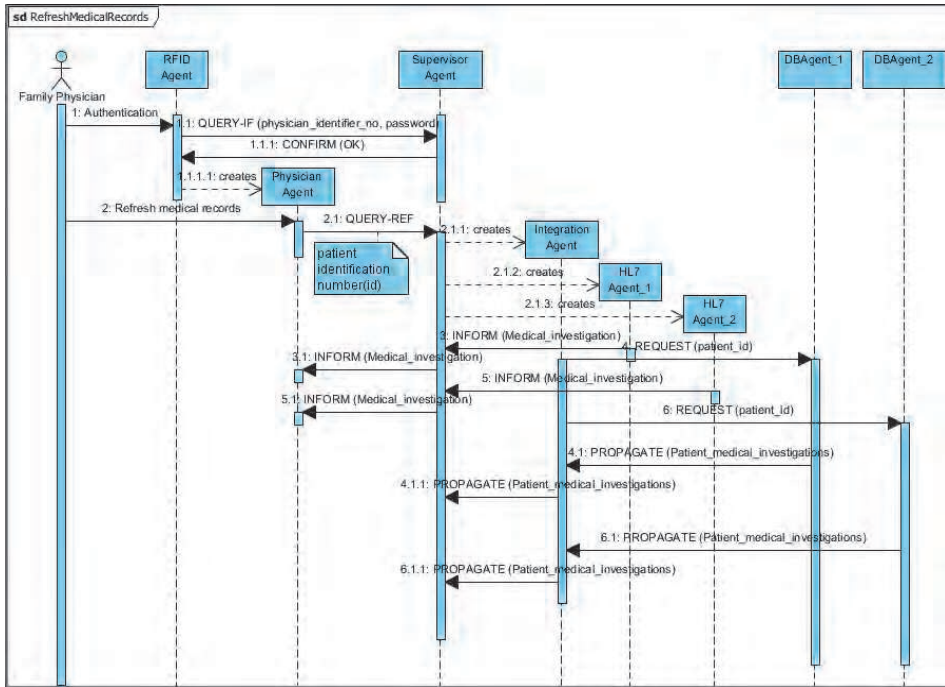
Fig. 6. Agent communication for updating electronic medical records for patients

The RFID-based multi-agent system, SMA-SIMOPAC, designed and implemented by our research team, facilitates the integration of data from heterogeneous sources (HL7-compliant or non-HL7 servers) in order to achieve a complete electronic medical record. 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 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 when they accomplished the received task or after a preset time interval from the moment of receiving the task. 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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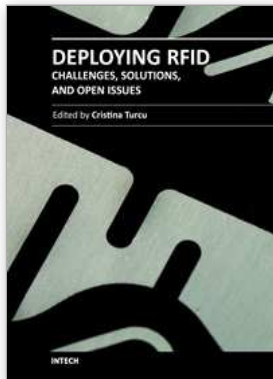
Deploying RFID - Challenges, Solutions, and Open Issues

Edited by Dr. Cristina Turcu

Radio frequency identification (RFID) is a technology that is rapidly gaining popularity due to its several benefits in a wide area of applications like inventory tracking, supply chain management, automated manufacturing, healthcare, etc. The benefits of implementing RFID technologies can be seen in terms of efficiency (increased speed in production, reduced shrinkage, lower error rates, improved asset tracking etc.) or effectiveness (services that companies provide to the customers). Leading to considerable operational and strategic benefits, RFID technology continues to bring new levels of intelligence and information, strengthening the experience of all participants in this research domain, and serving as a valuable authentication technology. We hope this book will be useful for engineers, researchers and industry personnel, and provide them with some new ideas to address current and future issues they might be facing.

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