8th International Conference on DEVELOPMENT AND APPLICATION SYSTEMS
Suceava, Romania, May 25 – 27, 2006

AN RFID AND AGENT TECHNOLOGIES BASED SYSTEM FOR THE IDENTIFICATION AND MONITORING OF PATIENTS

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Abstract.
The paper summarizes our preliminary findings regarding the development and implementation of SIMPAC – a newly proposed RFID (Radio Frequency IDentification) and agent technologies-based system for the identification and monitoring of patients. The brief evaluation of its relevance for the Romanian health care system and services is accompanied by a short review of the technologies involved in the development of the prototype. The paper focuses upon three main aspects: the architecture of the system, its benefits and its potential users.

Keywords: *ICT, RFID, agent technologies, healthcare.*

Introduction

In the last ten years, information and communication technologies (ICT) have progressed to such an extent that they have become accessible to worldwide organizations and even individuals. More recently, ICT have become increasingly common in most health care settings (home, residential facility or hospital).

The medical field, regarded on all its levels (local, regional, national and international) may be assimilated to an open environment characterized by a shared and distributed decisional process; this environment ultimately presupposes sharing and exchanging information among various participants (patients, physicians, laboratories, clinics, etc.).

Perhaps one should not forget to mention special events such as the three editions of the *eHealth Conference* debating the numerous contributions of ICT to health; the 2003, 2004 and 2005 participants reiterated the strategic importance of a full exploitation of new information technologies in the public administration of health for the benefit of the citizen as a consumer of both health care services and health information.

In the last few years, the whole medical world has shown a major preoccupation with ensuring and improving the quality standards of medical care and services. Software applications have particularly attracted the attention of medical professionals because their utility covers areas ranging from risk reduction in diagnosing patients and the establishment of treatment schemes to graduate and postgraduate medical training, health threats surveillance, the management of trans-border health challenges and crises or health literacy. Since the European citizens are increasingly mobile, it is imperative that people become aware of the pressing need for a more integrated and interoperable European health information space.

Most health systems in Europe face similar issues and the enlargement of the EU means that there are new opportunities and challenges for those involved in providing high quality health services and seeking to improve health in their communities. At the same time, it is expected that every national health care system should adopt its own long-term strategies in keeping with the *Action Plan for a European eHealth Area.*

The inefficient use of healthcare information is likely to be a major problem in large and complex health organizations. This is especially relevant when patient data, which is produced in heterogeneous environments, at various places and by different health professionals, should be

available for authorized individuals at any point of care. Consequently, the cost of non-automatic data collection, storage or integration is vast. On the other hand, the lack of an efficient information flow implies a delayed management of clinical report updates, mainly for some laboratory result and an increased length of stay or delays in outpatient consultation and surgeries.

In this paper we discuss some important aspects of SIMPAC – a proposed RFID and agent technologies-based system for the identification and monitoring of patients.

The declared goal of the SIMPAC system consists in activating in distributed medical environment and, in private, in solving the problems related to patients' identifying and monitoring in accordance with the latest technologies: radio-frequency identification, co-operative solving of problems within a distributed environment (intelligent multi-agent technologies) and a communication infrastructure ensuring the multi-point access to the medical information transmitted through the system.

ICT and Romanian Health Care

Although ICT has become an indispensable asset for most health care systems in the world, the Romanian health care system and services have been slow in nationally adopting ICT complex applications to improve the overall quality of medical care and assistance. It seems that there have been promoted mainly local applications designed to store and manage patient records. The major differences between the national and the international level of ICT implementation are presented in Table 1.

Table 1. ICT health care applications - the international versus the national agenda

Types of applications	International level	National level
Applications designed to assess the population's health status [3, 4]	Significant achievements, spread knowledge; research in different stages [11]; transnational research groups; information with limited character or on price	Research activities performed locally rather than nationally; most medical units do not benefit from the advances in information science
Applications designed to assist various medical services (telemedicine) and increase the overall quality of medical assistance	On-line medical applications; making efficient the medical act; reducing village-town disparities [18]	Idem

RFID and health care

While RFID is already widely used in the business world—for example, to locate packages or track inventory—its applications in health care are just emerging. The possibilities are as promising as they are varied, and include [8]:

- Tracking pharmaceuticals from the manufacturer, distributor, and pharmacy to the point of administering medication to the patient
- Tracking movable equipment, furniture, medical devices, and other valuable items both to provide ready access when needed and to reduce losses
- Identifying the location of caregivers in hospitals and other institutions to ensure the most efficient assignment in response to emergencies
- Ensuring the proper identification of laboratory specimens, including biopsy samples and containers of blood or urine to reduce medical errors
- Tracking patients—both for the purposes of redundant identification prior to the administration of medications or surgery and for protecting infants, Alzheimer's

patients, and others with special vulnerabilities
- Managing controlled substances, pathogens, and other materials that pose a public health risk

Our research team is involved in some projects where RFID technology is used for the identification and traceability of products and subsets in enterprises [19], products inventory or farm management.

Many of these applications were not designed to exchange information. Hence their inefficiency. Furthermore, non-communicative applications generate redundant or contradictory data. The idea of the SIMPAC system could help the development of an electronic patient record and facilitate the communication process among health professionals. The types of applications to be included in the SIMPAC system and their initial development are presented in Table 2.

Table 2. Application types to be integrated into SIMPAC

Types of applications	International level	National level
Identifying applications based upon RFID technologies [3 ,4 , 8]	Especially implemented on goods production and access security [11]; research on increasing the reading range of FRID tags (HF, UHF) are carried out;	Electronic identification is not available for patients; little preoccupation for magnetic card/SMART card identification systems [5]
Applications based upon Web services [2]	Telemedicine – Vast proportions, especially on treatment at home, medicines supply field [18] etc.;	Developed locally, mainly in hospitals and only in certain medical divisions; the reluctance of the medical staff towards ICT prevents the implementation of various applications
Applications based upon multi-agent technologies [1, 6]	Early-stage achievements [17, 20]; international research networks; applications on critical medical fields (ex. transplants)	Do not exist nationally ; low collaborations with other research divisions
Holon-based Applications [7]	Extension from industrial environment towards the medical one; early-stage research; limited access to results.	Non-existent

Agent technologies and health care

The use of the agent/multi-agent system paradigm has increased sharply as an important field of research within the Artificial Intelligence area. This paradigm has been applied to different fields such as process control [9], mobile robots [16], air traffic management [14], industrial field [13], intelligent information retrieval [10] etc.
A lot of agent definitions can be found in the literature, yet there is no one to have been fully accepted by the scientific community. A definition that is seldom mentioned was proposed by Wooldridge and Jennings [21]. According to them, an agent is defined by its flexibility, which implies that an agent is:

- reactive: an agent must answer to its environment;
- proactive: an agent has to be able to try and fulfil his own plans or objectives;
- social: an agent has to be able to communicate with other agents by means of some kind of language.

The term *agent* selected as name for a tool implies that the latter should be able to meet the

above mentioned requirements. Nowadays, a small percentage of the existing software follows this definition.
Given their well-established properties, the agent technologies seem the most appropriate choice to solve most health care problems. This appropriateness results from the capabilities of the agents to provide solutions in a domain characterised by the distributed nature of data, the complexity of the software solution, the lack of centralised control, the need to ensure the independence of the health care entities, the need to communicate and coordinate in order to provide specific services to individuals, and the need to receive information and advice proactively [15].

The proposed system

The proposed system deals with immediate strategy of restructuring the national health system, ensuring the premises of offering medical and informing services, to the qualitative level imposed by EU standards. The architectures of the SIMPAC allow the collection, integration and availability of medical information at all point of care. The proposed system structure is presented in figure 1.

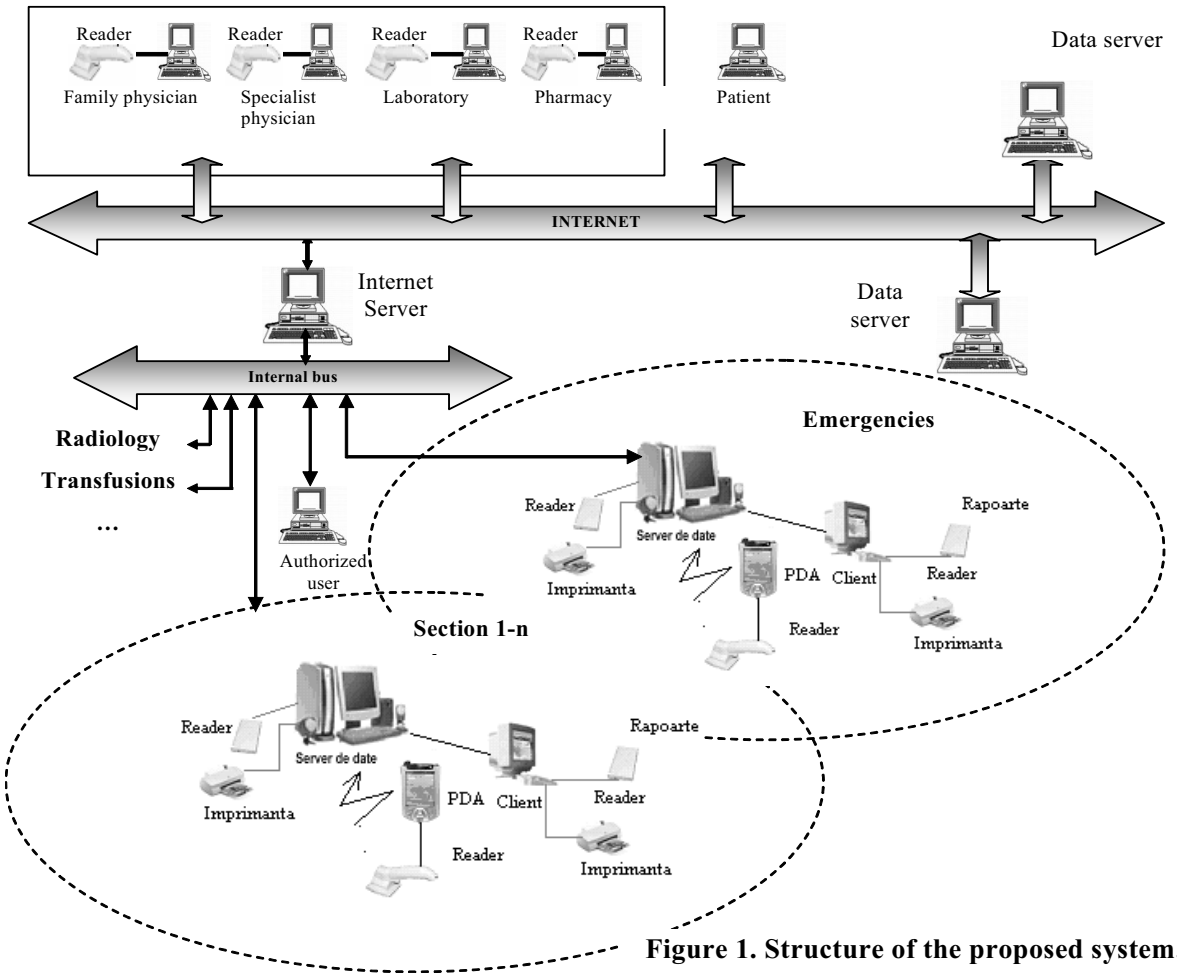

Figure 1. Structure of the proposed system.

The hospital structure comprises one or several modules, depending on the number of medical divisions taken into consideration, for example the emergency and the radiology division. The internal bus is designed to facilitate data sharing among the modules. The Internet server connects the medical divisions to the external environment. Represented at the top of figure 1, the component elements of the system corresponding to various group-participants such as family physicians, specialist physicians, laboratories, pharmacies, and patients, are provided access to the Internet network. More than one data server may be included in the system; these servers are designed to facilitate the storage of dynamic data, namely information about patients and medical imagery. The system is also endowed with an interactive interface for communication and reporting.

Among the novelties in this project, mention should be made about the *electronic personal identity card (PIC)* which ensures the identification of patients. Furthermore, our PIC has been developed using RFID technology: the information is stored in a transponder (tag) – an electronic chip with memory. Our preference for passive transponders has been dictated by their low costs. These transponders are written and read by equipments generically named *readers*, by an electromagnetic field emitted from their antenna, from which the transponders extract their necessary energy of functioning. In the absence of the field, the transponders do not function, but store information.

For the proposed system, PICs will memorize and store a whole range of valuable facts and details such as patient identification codes, personal health records, blood type, individualized emergency procedures, etc. The reader type to be selected depends upon the responsibilities and special needs of various health professionals such as family physicians, medical specialists, nurse practitioners, clinical biochemists, pharmacists, emergency doctors and nurses, etc. Wireless mobile devices (PDAs) have also been taken into consideration and represented in figure 1. These portable units can easily be used in ambulances and emergency situations when any delay or incorrect decision may endanger people's lives. Sometimes the patients in need of urgent medical assistance cannot provide vital information concerning their blood type, Rh factor, chronic diseases or allergenic substances; hence the usefulness of handheld readers which can provide paramedics or emergency doctors with vital information about their patients/victims and allow them to adopt and apply the most suitable medical procedures. Moreover, as no connection to a central server is required to retrieve information, especially in uncovered areas, these mobile readers have ruled out all time-consuming processes.

The implementation of the systems raises several geographical implications as one and the same patient may be consulted by some specialist physician in another county. Hence the need to solve the problem of how the medical discount procedures will be effected by the National Health Insurance Systems. Therefore, a special attention has been given to the representation of data and communication methods; as a major novelty in this project, we have proposed the usage of *web services* and *multi agent technologies* to enable the efficient communication among various components within the system. Furthermore, the system proposed can assist health professionals in the management of most activities in the medical field. Thus, given the action method proposed, any health care agent can:

- preserve the autonomy of participant actors;
- integrate different operating backgrounds;
- coordinate all patient–related information (even when it is distributed at the level of more medical units, insurance companies or governmental bodies);
- can improve the overall management of medical information.

For instance, one or more health care agents can provide specialized services to one and the same patient, depending every patient's needs (eg laboratory tests, medication); moreover, every

patient's medical record can be updated and kept up-to-date.
The conceptual novelty of the system is based on its flexibility and adaptability. The agents' community has a dynamic evolution, depending on system's specific situations.

The possibility of integrating agents within holonic structures will be taken into account. The design-team will construct several system usage scenarios and provide alternative solutions for various situations occurring in cases such as the administration of medicines and food, transfusions, or transplants.

Various RFID applications will be employed to write the PICs and then easily retrieve data from the same PICs. Wired or wireless communication access will depend on specific technical conditions. The whole system will be designed in such a way as to allow the easy retrieval of information from all damaged PICs and its transfer to new PICs. Furthermore, the design team will look for innovative methods that will prevent any unauthorized users from changing or altering the data stored on the PIC. It is imperative that all project partners be involved in the joint development of both the electronic format of the information to be stored on the PIC and the user interfaces for the readers in accordance with enforced technical standards and specifications.

Both the design and the implementation of the system are complex issues; aspects such as the management of confidential information, the selection of the most appropriate certification and security procedures are to be carefully considered. Data encryption and certified and controlled database access have been chosen to protect and secure the confidentiality of the information on patients.

Moreover, the need to secure the information flow and to create the so-called *trust chain* represents another major concern. As long as various categories of health care actors, from medical staff to insurance agents, will gain access to people's medical files or records, it is of outmost importance that storage and retrieval information standards be employed. Already enforced at the international level, the E 1869-97 standard specifies the essential principals governing the confidentiality, access and security of medical information.

Potential users

The proposed system addresses the needs of many end users: a) various providers of medical services within the national health care system (family physicians, medical specialists, hospitals, medical testing laboratories etc.); the implementation of the solutions proposed will help the Romanian healthcare system meet the EU quality requirements in the medical field b) patients – as main beneficiaries of medical services; c) various units of medical, academic and scientific research; the research results will connect the Romanian research milieu to the European one (Strategic orientations and options towards Romania's informational technology and communications, chapter 4). d) educational and instructional units at the national level; the implementation of the solutions proposed will ensure the correlation between the quality of our national instructional process and the stresses and strains of human resources in the field of health care and medical assistance; e) various -public bodies in the medical field such as the National Health Insurance Body will have access to private information and yet never infringe on the confidentiality right governing the relationship between physicians and their patients; they are expected to employ the information in order to estimate the health status of certain communities or that of the whole national population, and only then prepare action plans or look for various types of resources to improve people's health.

Conclusions

The project addresses problems of outmost interest for the whole Romanian health care system and introduces novel approaches and technical methods:

- the whole system design follows new conceptual models which resonate with the latest advances in Informational Society; hence the reduction of subjectivism in monitoring processes, a more thorough evaluation of medical assistance and treatment, and the enhancement of quality in medical services;
- the usage of web services and multi-agent technologies for the implementation of complex distributed systems (e.g. functions of communication management);
- as an absolute novelty at the national level, RFID technologies are employed to identify patients;
- a secure system access ensuring the confidentiality, integrity and security of data;
- the implementation of RFID applications using transponders functioning on different frequencies (125 KHz, 13.56 MHz etc.) and readers observing the ISO15693 standard (approved in 2003);
- the suggestion to introduce a unique national identification code to be stored in the electronic identity cards;
- the participation of specialist members of the implementing team in the establishment of a new standard for the applications in the medical field;
- the establishment of some relevance indices for the information to be stored in the electronic identity cards; several European registration systems have been studied in order to see how the selection of relevance indices can be applied nationally;
- competitive access to medical records.

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