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Data Center Strategy to Increase Medical Information Sharing in Hospital Information Systems

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Abstract — The sharing of medical information among healthcare providers is a key factor in improving any health care system. By providing opportunities for sharing and exchanging information and knowledge, data center, agent and ontology play a very important role in the field of medical informatics. In this paper, we propose a design of architecture and data center for the development of a Hospital information system (HIS) based on agents and ontology.

Index Terms — Hospital information system, Data center, Agent, Profile ontology

I. INTRODUCTION

The field of medical informatics is one of the largest areas of research currently being undertaken mainly in Artificial Intelligence and Information Systems (IS). Health networks in general, are supported by IS. These IS are structured particularly around medical record to support the storage, access, dissemination and sharing of patient information [1].

To be more effective and to make the right decisions at the right time, Hospital information systems (HIS) need to have high quality of information: relevant, reliable, accurate and actual. In addition, this information must be stored, updated and made available to the different actors involved in the care system whenever is necessary. For care providers, information is a strategic resource that is essential to be mastered because it contributes to the quality of decision. It is the role of HIS to disseminate information, regardless its nature, to relevant stakeholders.

The HIS is a typical collaborative information system in which people such as physicians, nurses, professors, researchers, health insurance personnel, etc. share patient information (including text, images, and multimedia data). It makes data available for the following uses: patient care, administrative and business management, monitoring and evaluating medical care services, epidemiological and clinical research, and planning of medical care resources [2].

Important functionalities of HIS include: fast, easy and ubiquitous access to patient information. So, this access must be: (i) effective and as complete as possible (ii) ubiquitous independently of the geographical and/or equipment available to the healthcare professional [3],[4].

1.1. Problems

The increasing use of digital medical information leads the need for information storage capacities that must be accessible in real time. This requirement forces most hospitals to continually expand their databases. Unfortunately, most hospitals are not able to expand their databases because of poor planning as explained by Shawn [5]. According to Low et al., [6] in the coming information boom, data will be stored in large data centers around the world and will serve as access to hospital information records for doctors, pharmacies, insurers, patients, and institutions. Missing medical information may lead to late or wrong decisions. For Lejiang et al. [7] there are some problems in traditional medical data management: (i) the storage capacity and

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quality of electronic files is limited to hardware devices (ii) with quantity of data increase, the speed of the system will slow down, because of channel access mode and the bandwidth (iii) since the current backup mode is simple, it does not fit the security and long-term storage needs of medical files (iv) traditional data storage mode is not conducive to the sharing of resources. Therefore, there cannot be information sharing among all the stakeholders of the medical system throughout the course of a patient's care. It is really difficult and very costly if we adopt the architectures based on mediation [8]. Thus, the healthcare domain is facing a crucial problem: it is the design of HIS.

1.2. Objective

Data center has recently emerged as a topic of great interest [9],[10],[11]. Choosing a data center is based on: used the platform, the ability to deliver advanced storage solutions and bandwidth. So, any information included in a data center must be available quickly with high-speed internet connections, whatever the circumstances are.

In literature, the term data center is a place where we store servers [12],[13]. In our research context, the data center is where the majority of a hospital servers and storage are located. Our data center is classified as CDC (Corporate and Institutionnal DataCenter) [14].

The main objective of this study is to design architecture and data center for the development of a HIS. It aims at improving the sharing and exchange of information in a controlled manner in HIS.

The rest of the paper is organized as follows. The section 2 highlights the types of information in HIS. The section 3 shows the requirements of the proposed architecture. The section 4 presents a generic architecture based data center, agent and ontology. The Section 5 recapitulates the synthesis of this paper and indicates orientations for the future works.

II. INFORMATION CATEGORY

Hospital information systems are characterized by their ability to record and transmit information and medical knowledge. The objectives of this information are various; they include patient care, quality assessment, research, epidemiology, planning, management and training. Information flows are manifold. They concern health functions, logistical and administrative management functions. The nature of the exchanged information is wide. It depends on the actor and his field of activity and the taken action. We classify it into three categories:

- Medical: related to medical information
- Organizational: activities of all actors
- Common: hierarchical roles and functions among all actors

HIS can be characterized by their functions, their types of processed information and their types of the offered services. In order to support patient care and the associated administration, the tasks of HIS are to provide [15]:

- Information, primarily about patients, in a way that it is correct, pertinent and up to date, accessible to the right persons at the right location in a usable format, and must be correct
- collected, stored, processed, and documented; Knowledge, primarily about diseases but also for example about drug actions and adverse effects-to support diagnosis and therapy;
- Information about the quality of patient care and about hospital performance and costs.

We distinguish between data, information and knowledge. Studnicki et al. [16] give the following distinctions:

- Data are raw facts and statistics that are collected as part of the normal functioning of a business, clinical encounter, or research experiment.
- Information is data that has been processed in a structured, intelligent way to obtain results that are directly useful to managers and analysts. This is often the case once data has been organized in a database management system.
- Knowledge is obtained by IS Architectures using information to explain the context of a problem or situation.

III. REQUIREMENTS

Medical actors often focus heavily on medical history during consultation of a patient. Indeed, the need for medical data in terms of quantity and quality evolves more. Function key to our approach is to facilitate the

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sharing of medical information by allowing different actors belonging to the hospital to access medical data. In this respect, our approach should allow:

- Availability, confidentiality and integrity of medical information at any time, in any situation, and anywhere
- Information flow must be controlled
- Providing the right information and knowledge to the right medical actors, in the right form, at the right point in time, in the right location (where actors can use the information to support their tasks), in a form which is comprehensible could greatly enhance taking care of patients.

IV. THE PROPOSED APPROACH

Our approach consists of proposing a generic architecture to support HIS. It is an architecture-independent platform. This architecture allows the development of a HIS based on data center, agent and ontology. It is capable of making information belonging to each of agents available to other agents. This is also a new manner to fulfill requirements, more adapted to the today's reality through the simplicity of its structure.

In our approach, the mechanism that allows an agent to recognize the actions of other members of his team is based on the message sending.

The behavior of the agent is more organizational in the sense that it knows how to take into account the other members of the hospital's organization and to update its organizational knowledge.

This approach allows providing access to full data useful for providing medical information and for medical care decision-making. It fulfills the following requirements:

- Find data normally recorded about each patient and store it in the appropriate database (e.g. Laboratory Information System database)
- Make available any appropriate part or all of these data, on demand, to medical care providers for patient care and to administration and business offices.
- Make available useful databases for clinical decision making, epidemiological and planning and evaluation of medical care.

In the following, we give a description of the architecture components which is illustrated in fig. 1.

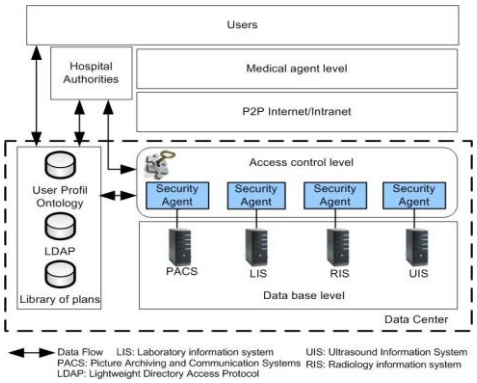

Figure 1: Components of the proposed architecture

4.1 Hospital authorities

They act on behalf of the hospital. These authorities have a number of powers: recommendation, decision, regulation and sanction. They also ensure some form of control over different actors.

4.2 User level

Each user (actor) belongs to an IS of Hospital. So, the Actors of HIS (doctor, nurse, etc.) are different in terms of forming, competence or task to be carried out. It is necessary to take into account this variety, to offer to the actors the adapted and efficient interaction modes, better diffusion, and data acquisition to interoperate.

4.3 Medical agent level

An agent represents an actor of a HIS that takes care of the patient. It cooperates with other agents of the system to achieve its goals. Agents are linked among them by an inter-professional collaboration. Every agent consults only the information that concerns them according to the access rights, example: only the doctor agent can write a prescription and that the patient agent can have access, the nurse agent can make reports, etc. Every agent (doctor or nurse) has to up to date on all new information, and a part of their function is to inform on every new situation and pathological state of the patient agent. Accordingly, each agent of HIS keeps all information relative to its interventions and activities.

4.3.1. Organization of actors

The organization is the structuring factor that allows each actor (agent) to know with which other agent it is

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likely to interact. It follows a certain simple functional distribution and actors' responsibilities (see fig. 2). Which we find by nature in a medical information system, and which depends on the type of service to be supplied. This functional structure presents certain advantages:

- Respect of the functional hierarchy.
- Cost and reduced number of messages exchanged between various intervenients.
- Easy information exchange.
- Easier cooperative work.

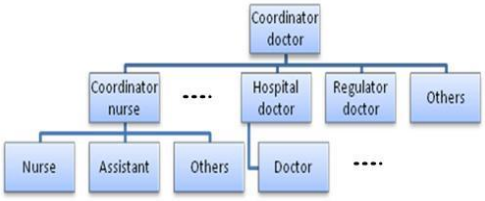

Figure 2: organizational hierarchy

4.3.2 Team work

Group work is by nature in hospitals. A team is a group of medical actors working together to achieve a common goal, putting in synergies their competencies. They were complementary. We followed a model inspired from [17]. The team is an organization. The members of this organization are agents. These agents have a collaborative behavior that takes into account the other team members according to the roles that they play. The team is hierarchical. There is a relationship of subordination among roles. This allows an agent to know his superiors and subordinates. A team may reach several common goals. Each team member intervenes to reach a common purpose.

4.4. Network structure

On the cost and performance side, Peer to Peer (P2P) decentralized networks have several advantages over traditional client-server platforms. P2P networks have advantages on redundancy, robustness, performance and scalability. In our architecture each agent belonging to the HIS is a peer of the P2P network. Each peer controls and maintains its own data. This data can be solicited by other peers. On the other hand, data center represents a common model of sharing data and information. We know that the strength of P2P technology is that it allows the addition or deletion of a peer without degrading the whole system. This is a facility of our system too, during operation agents can be added or removed. Furthermore, the agents do more than file sharing, but rather they interact with each other. Another essential point is to facilitate collaborative work. The use of these tools (groupware, calendaring, etc.) allows geographically-distant actors to work as a team.

In the context of our research, the sharing of information is the basis for the care organization. For each agent (doctor, nurse, lab technician, etc.) the role is foremost to circulate information.

4.5. Data center

In order to make optimal use of medical data, hospitals require well-designed IS. Now a growing collection of technological resources exists for developing effective IS for hospitals. The data center is one of these technologies.

The main advantage of using a data center resides in the consistency of data in the proposed system. These data can be secured during the exchange process, well as in the rapidity of access to information from the appropriate data, independently of the source system. In addition, this solution allows overcoming our first difficulties, exchange and sharing of medical information, to avoid that each peer of the network has to manage too many proprietary interfaces. The benefits of using a data center for HIS are:

- A variety of data sources can be integrated within a HIS
- Reducing medical errors and time saving
- Reducing redundancy of tests and patient mobility
- Collaboration between medical actors and between them and their patients, since information sharing is easy
- It makes backups of data easier to maintain, so catastrophic data loss is more easily remedied

Among reasons that have pushed us towards data center:

- Shared databases very numerous quickly become too complex to manage and access
- Modify its contents in a collaborative way
- Network bandwidth is usually high
- Communicate and broadcast information quickly

4.5.1. Access control level

Each actor has his own credential key automatically

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generated and delivered by the hospital authorities to access the web portal. On the other hand, they supply a username and password to different actors from the hospital to access data. Database must be associated with access control for designated agents (actors) or groups of agents having the right to read the content of the folder and to add information in a systematic way or using some conditions. Here we mean by group of actors the team that will take care of a patient. Any other agent that does not have these rights must not have access to information. It should be noted that direct access to medical records is simple in principle, but sometimes complex when it is applied in real life.

The safety methods means proposed in the previous section are not sufficient. A better protection is possible when we consider the profiles of health actors defined in User Profile Ontology (UPO). This ontology plays the role of an access control model based on profiles. For each profile, we associate permissions represented by access rights.

4.5.2. Security agent

This agent must manage all associated databases in the data center to make their manipulation uniform. Also, the security agent manages data security and protection of privacy of patients and actors (confidentiality). Thus, it uses authentication and encryption mechanisms. It controls all the formulated queries to databases (radiology data, laboratory data, etc.). The solution of the security agent allows full control of agents, the voluntary or involuntary access to shared medical records which may contain sensitive data. The authentication system allows agents to prove easily their identities and get access to shared databases without threatening the security of HIS. Security agent has the advantage of supporting the adaptability, reuse and independence.

4.5.3. Database level

Each IS (radiology, laboratory, etc.) of the hospital is represented by a dedicated medical database. At this level, this is to ensure the entire life cycle of stored medical data of patients. Each database is not only a trace of information, but also a tool for communication, information and coordination between the different structures of the hospital to taking care of patients.

4.5.4. User Profile Ontology

The purpose of any health institution is to increase health quality and to decrease access errors of medical information. Our approach is to build a specific ontology. This ontology allows presenting necessary knowledge which guarantees the coherence of integrity of the health actors' profile. The purpose of UPO is to improve safety of medical data by reducing and controlling the access to database. UPO groups the terms relative to profile of the different actors of HIS in a formal way. This ontology allows the hospital authorities according to the profile of the appropriate actors to control access of hospitals databases. Their profiles are saved and continually updated by the hospital authorities.

4.5.5. LDAP directory

It is used to store identification data. This choice is based on: (i) quick access (ii) it is easy to maintain copies (iii) directory is designed to receive many more requests for reading as for writing.

4.5.6. Library of plans

It contains (i) a set of plans directed by the global purpose (taking care of patients) and sub-purposes (care of the sick, therapy, etc.) useful for the processes of planning and negotiation. These two concepts are the subject of our forthcoming article. (ii) A set of information necessary for actors to realize their tasks. Every plan is characterized by the actions to be executed and the resources to be used (see fig. 3).

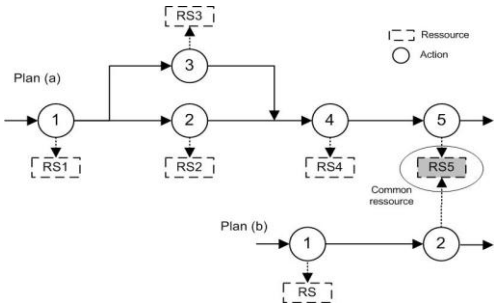

Figure 3: The action plans

4.6 Data exchanges

XML provides a freely available and widely transportable methodology for well-controlled data interchange in HIS. XML can be used to represent the information exchanged among agents (the possibility of using standards like HL7 v3 message (Health Level 7),

CDA (Clinical Document Architecture), DICOM (Digital Imaging and Communications in Medicine), etc. encoded in XML) via a standard communication language. The following example illustrates the use of XML.

```
<report>
<patient>
<firstNameP>Hamoud</firstNameP>
<lastNameP>Fares</lastNameP>
<sexP>Male</SexP>
…
</patient>
<clinicalExamination>
<weight>70kg</weight >
<pressure>14-9</pressure >
<fever>37</fever>
</clinicalExamination>
<conclusion>
<efr>EFR normal</efr>
<ecg>ECG normal</ecg>
</conclusion>
…
</report>
```

V. CONCLUSION AND FUTURE DIRECTIONS

In this paper, we have presented a new architecture for development of HIS based on data center, agent and ontology. This architecture improves access and sharing of medical information among medical actors. This approach allows: (i) being updated medical information from patients (ii) make data available to those trying to improve medical knowledge, the practice of medicine, and the education of healthcare providers (iii) accurate locating of data. Some HIS requirements such as interoperability have not been handled at this study stage.

The outline of the architecture can be seen as a basis for further research, in order to develop such implementation in the real environment. Subsequently, we intend to complete this work with a case study to evaluate our researches.

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