EXPLOITING SERVICE ORIENTED ARCHITECTURES FOR THE DESIGN OF E-HEALTH SYSTEMS

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Abstract: The design of e-Health systems is a hard task since their requirements are complex and heterogeneous. These systems merge functional requirements with an important set of non–functional requirement like security, safety, standardization or technology related constraints concerning the hardware and software components to be used. The ICT research community has proposed recently architectural models for the development of open and dynamic distributed systems centered on the concept of "service". This approach has been followed by all the major actors of ICT for their frameworks due to its adaptation to the World-Wide-Web. This paper is a position paper where we analyze the current status and needs for e-Health systems and the limitation upon them. We present the main characteristics of middlewares that follow a service-oriented architecture and we explain how these frameworks could be exploited, as a vision to the future, to design e-health systems for a better insurance of their functional and non-functional requirements.

1 INTRODUCTION

Healthcare market is a typical example of service sector that has successfully increased its participation in the world's economy. Because of the importance of services market, in particular business and healthcare services, their development and their delivering have become the center of discussion in many levels of the society. Politicians and lowers have looking for adapted legislations and controls (Garner, 2004). Educators and industries search convenient methods to introduce *service science* (Chesbrough & Spohrer, 2006) into the continue education and to use it to prepare a new generation of healthcare professionals. A generation that needs interdisciplinary knowledge to increase the productivity and innovation of service delivering.

In a digital society, the concept of services evolves and words like e-service and web-service gains their place in the market. In health domain, these new kind of services have facing many difficulties (resistance to change habitudes, misinformation, technological phobias, etc.). However, caregivers are slowly getting used with the idea of adopting informatics devices to improve the quality of their services. Some countries are catalyzing this process forcing caregivers to use Information and Communication Technologies (ICT) to interact with public administrators (for example, social security administration and public hospitals administrations) (Currie & Guah, 2006),(GAO, 2005).

Clearly, the association of informatics with healthcare domains brings up many advantages. Healthcare industry is positioned to beneficiate of the advancements in technology and connectivity. High technological devices and software are available for healthcare services' providers and are adapted to the patient needs (patient-centered systems). Customers of these technologies can expect to achieve greater performance, reduce costs and improve patient care. Consequently, they are expanding marketshare and are pushing the transition to a digital era of *e-Health*. In this paper, the word e-Health expresses the association of e-technologies with healthcare services. Similar words have been used in the literature to express the association of specific informatics technology with healthcare, as well as telecare, telemedicine, telehealth, bioinformatics, etc. (Norris, 2002). The definition that we consider the most appropriated to our work was proposed by (Eysenbach, 2001).

"e-Health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical

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development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology"

The complexity associated with the design of e-Health systems and its application environment has driven developers to look for methodologies that can simplify their work. The service-oriented architecture (SOA) is a solution that is captivating many important industrials. SOA describes the practices and frameworks that enable the functionality and information of applications to be provided and consumed as service interfaces. In this formalism, services can be seen as network addressable entities with a well-defined, easy-to-use and standardized interface. From a technical viewpoint, SOA is essentially a collection of software services communicating with each other over a network to pass data or to coordinate activities. The software services can be implemented as gray boxes where implementation details (as well as the technologies used) are not necessarily accessible by the clients. The main expected benefit of SOA is their capacity of satisfying the requirements of complex and heterogeneous information systems domains such as healthcare. Further, services can be combined in different ways to support the evolution of processes and organizational models, for example towards virtual organizations.

The work developed at LASSY (Laboratory for Advanced Software Systems) aims to contribute to the improvement of the organizational structure of health systems proposing a SOA adapted to e-Health requirements. In this paper we identify the current status and needs for e-Health systems and the limitations upon them. Section 2 introduces some problems observed in the Healthcare structure. Section 3 presents the mains concepts of service oriented architecture (SOA) and a summary of TAPAS project. Section 4 describes the potential application of SOA for designing e-Health systems as the objectives and perspectives of RESIST project.

2 IDENTIFYING PROBLEMS IN HEALTHCARE SYSTEMS

The current situation of healthcare domain points to an excessive individualization of activities and a lack of communication inside of the institutions. Information generated to/by one caregiver is rarely shared and finishes in an archive (electronic records or not) often inaccessible by other caregivers and by the patient. The same problem had been faced in other professional activities, the most representative are the financial activities. Continuous investments on ICT solutions contribute to reduce the consequences of this problem. (Luftman et al., 1993) highlights that the effective and efficient utilization of information technology requires the alignment of IT strategies with the business ones, what was not successfully done in the past with traditional approaches. The same idea can be applied in healthcare systems waiting for attaining efficient and responsible use of ICT to solve the exigencies of healthcare centers' administrators, caregivers, patients and governments. This idea is not completely new, some hospitals use ICT in their organization from the lasts 25 years. But this initiatives are rare and do not represent the majority of the cases. According to the Department of Health and Human Service of USA (HHS), healthcare is the largest sector of the economy that has not fully embraced information technology. The Medical Group Management Association reported that only 31% of physician group practices use fully operational Electronic Health Records (EHRs). The Healthcare Information and Management Systems Society reported that 19% of hospitals use fully operational EHRs (GAO, 2005). The results of these initiatives were reported in (Currie & Guah, 2006), (Wears et al., 2006), (Keizer & Ammenwerth, 2007), but we are only at the beginning of great changes produced by the association of information technologies, network managed organizations and specialization with the healthcare domain. The current challenge is to define how to integrate the set of existing specific solutions?

Many solutions use proprietary data exchange format and do not interact with the others. Interoperability becomes now fundamental to healthcare communities. Industries, research groups and governments are investing time and money to solve this problem. Many standards are emerging of these collaborations, but few of them are currently integrated in most commercial systems (HL7, 2007), (CEN, 2006), (DICOM, 2003). Unclear legislation, lucrative market, implementation costs, physicians' reluctance and disorganization contribute to prolong that reality. The way that IT solutions have been implemented in healthcare systems are not exactly what users expect and it will not solve all problems in this domain, but it is a beginning to improve the healthcare services' quality. The benefits that can be expected are:

- For the consumer: Higher quality care; Reduction in medical errors; Fewer duplicate treatments and tests; Decrease in paperwork; Lower healthcare costs; Constant access to

health information; Expansion of access to affordable care;
- For the public health sector: Early detection of infectious disease outbreaks around the country; Improved tracking of chronic disease management; Ability to gather de-identified data for research purposes; Evaluation of health care based on value, enabled by the collection of price and quality information that can be compared.

All these benefits contribute to improve the life quality of patients, but our main motivation is in reducing (or eliminating, if possible) the alarming number of deaths related to medical error that could be prevented if an efficient IT system was implemented.

The implementation of a good IT requires the selection of an architecture that can represent as real as possible the way of working of stakeholder in healthcare domain. The next section presents the main characteristics of the architecture that we consider as the most appropriated to e-Health systems.

3 SERVICE ORIENTED ARCHITECTURE

The concept of service-oriented architecture is not new, but with the advent of recent platform-independent programs and platform-neutral data models, this architecture took more attention. A unique formal definition of SOA does not exist, and discussion about it is out of the scope of this paper. However, we can highlight some important aspects (Gupta, 2007):

- The service-consumer needs must be specified independently of the service-provider component. A reasoning engine takes the responsibility of aligning the two specifications. This engine, often named Assembler component, bridges the gap between the two end-elements (consumer and provider). (Loose Coupling)
- The technology used by the service-consumer is completely independent of the one used by the service-provider and vice-versa. (Platform Independence)
- The communication between the two end-elements must not be dependent of the protocol. A variety of communication protocol must be available to request/offer a Service. The choice of protocol must not modify the quality of the service. Binding to a specific protocol must take place at run-time/deployment-time, and not at the design or development time. (Communication Protocol Independence)
- Each of the provider- and consumer-service components should be able to be implemented in their own time, according to their own life-cycle. (Life-cycle Independence)

Specially designed for flexibility and reuse, a SOA enables organizations to easily integrate systems, data, applications, and processes through the linking of services. SOA was first proposed to satisfy the necessities of business design and implementation that was not supplied by distributed-oriented architecture (DOA, e.g. CORBA, J2EE, etc.). It can be used as a complementary platform or to substitute DOA for providing intra and inter-business services. The general concept of SOA is close of the one of DOA, however there are small differences and the sum of these features leads to a radically different set of properties for enterprise-level system modeling and design (Baker & Dobson, 2005). SOA is a software architecture that uses loosely coupled software services to support the requirements of business processes and software users. It is technology neutral and has no standard specification of the components interface, what offers dynamism and flexibility to the system. The utilization of asynchronous message exchange instead of function calls allows services to be executed without share details about its implementation or platform. SOA enables uncomplicated connectivity by abstracting dependencies away from each application into an e-service (or other brokering service, e.g. web-service). Applications can then easily be connected to the broker through modular components. And each application can be modified whenever necessary to support flexible and dynamic business processes through platform-independent.

The design and development of a SOA implies a different way of organizing the system. Designers must to change the component oriented vision and think about services' "properties and attributes". It requires the application of a number of techniques – stemming from disciplines such as Enterprise Architecture, Business Process Modeling, Component-based development and Object-oriented methods – to produce modular, reusable and replaceable software applications.

It seems to be more complicated then DOA. In fact, it demands an extra effort on coordination and interface definition to understand information assets and link to business process. However, once created the basic structure, modifications in a service does not request the understanding of the whole model.

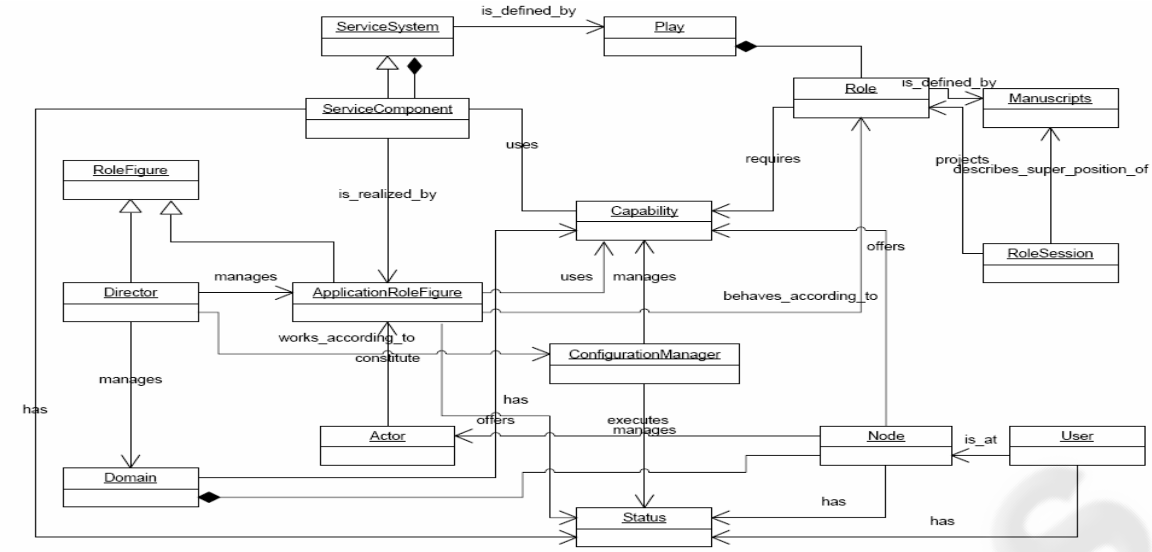

Figure 1: TAPAS basic architecture.

Services can be seen as gray boxes that have a description file each one (normally in XML) which specifies the interface and some other attributes of the service. Further, most gray boxes in a SOA are represented as legacy applications. However these will usually need re-engineering to provide access to their functionality and data from a wider population of consumers. The key of a good SOA implementation depends on the specification of the services' interface and the reasoning engine to mach requested services with offered ones. An usual way to solve this problem is to implement different layers of functionalities that see the services with different granularity. The approach described in TAPAS project (TAPAS, 2007), for example, proposes three layers: *Service, Play* and *Network*. The service layer consists of service components definition and the network layer consists of nodes specification (places where services can be executed). The play layer is used to connect consumers with providers and to identify the node to execute the service.

The next section presents more details about TAPAS' concepts, but a complete information about this approach can be found in the project website (TAPAS, 2007).

3.1 TAPAS' Main Concepts

The TAPAS project is a research project developed at NTNU which aims at developing and architecturing for network-based service systems with: a) flexibility and adaptability; b) robustness and survivability; and c) QoS awareness and resource control. The goal is to enhance the flexibility, efficiency and simplicity of system installation, deployment, operation, management and maintenance by enabling dynamic configuration of network components and network-based service functionality.

The TAPAS basic architecture, illustrated in Figure 1, is founded on generic *Actors* (software components) and on the *Nodes* of the network. The actors play *Roles* defined in a *Manuscript*, which consists of an EFSM (Extended Finite State Machine) extended with rule-based policies. The nodes may be servers, routers, switches, and user terminals, such as telephones, laptops, PCs, PDAs, etc. The idea is to associate the design model to a theatre organization. The Actors are coordinated by Director that also represents a Domain. Service System consists of a set of Service Components, which are units related to some well-defined functionality defined by a Play. A Play represents several Actors playing different Roles. The ability of Actors to play Roles depends on the defined required Capability and the matching offered Capability in a Node where they intend to execute.

Capability is an inherent property of a Node or user, it may be resources (e.g. CPU, hard disk, transmission channels), functions (e.g. printing, encryption devices), or data (e.g. user login, access rights) (Lühr, 2004). Where and how Actors are installed and roles executed are decided by the *Configuration Manager*. It is responsible for obtaining a snapshot of all system resources, and taking decisions about the configuration. This brief introduction to TAPAS gives an idea of the potentiality of this approach. The next section explains how TAPAS can be applied into healthcare domain.

4 EXPLOITING SOA IN E-HEALTH SYSTEMS

Analyzing the weaknesses of healthcare systems' organization described in section 2 and the features that can be expected from SOA, we can imagine that SOA is an interesting approach to supply many identified problems of health sector. In this architecture we can identify services associated with the specification: of different classes of users; of polices to increase the security and the reliability; of interfaces to allow communication between applications and between systems; of common terminologies to facilitate information exchange and information understanding; etc.

Composed of a set of (reusable) services, this structure facilitates the management of the offered services and allows to measure more accurately the quality of those services (QoS). Improvement of QoS is an important requirement of e-health systems. Thus, in this structure the patients that can input data to accurate the QoS (having a proactive role) and consequently trust more on the (managers) selection of actors for the required services according to the level of QoS specified (feedback). Further, the healthcare administration centers can obtain all (or much more than today) necessary information to take decisions about the service. In a sense, the services-providers (caregivers, equipments and software's providers, pharmacies, etc.) are pushed to improve their QoS in order to keep their marketshare.

Following this trends, TAPAS proposes to create a plug-and-play environment where services and users can be dynamically included/logged on, excluded/logged off or modified (moving, changing of resources, changing the quality of services, etc.) without a big effort. Initially developed to general propositions, the current version of TAPAS is not completely adapted to healthcare systems. The conception and implementation of a TAPAS top level to include specific properties of healthcare sector is one of the objectives of RESIST research project, in development at University of Luxembourg, LASSY (Laboratory for Advanced Software SYstems) workgroup.

Evaluating TAPAS properties we highlight the well defined distributed management structure, separating the operational specification from the management specification. Where decisions are distributed and decision-makers can have different priorities and criteria. These elements together with the user-friendly description of the operational architecture (theatre metaphor) facilitate the complex definition of the architecture lifecycle of a healthcare organization. In other words, TAPAS assists the design and implementation of the following tasks: modeling, service composition, deployment and execution management.

TAPAS is structured clearly and formally. The description of the *Role* by means of *Manuscripts* in XML files follows the international trends to improve the syntactic interoperability and standardize business interface. RESIST project plan to use this facilities to benefit from ontological standards (SNOMED, 2007), when described in XML. The rule-based reasoning engine proposed into this architecture is an intelligent solution to associate dynamically services requests with services providers and to guarantee that the specified quality threshold will be respected if there is an *actor* that can satisfy it. In the specification of TAPAS we can observe that the authors also introduce tools to detect, diagnosis and recovering faults. These tools are in development, but it can become an interesting alternative to improve security, reliability and availability properties. This is an innovation that we can not be found in commercial tools whose base their security only on the communication/data access security policies.

5 DISCUSSION AND CONCLUSIONS

If the gap between public knowledge and academic curriculum isn't large enough, the gap between academia and professional practice is a gaping hole. While academic departments insists on doctor-centered teachings in an ideal organizational environment, medical industries have innovating proposing adapted solutions to specialized needs. Some existing medical equipments can be easily manipulate by ten-year-old boys and can give precise information about the health state of the patient. This is one of the contributions of e-Health. Moving away from classical methods to focus on delivering quality services that are in-line with the new context of modern medicine is the challenge of the next decades. Informatics came to give support to it in order by proposing tools to mange, integrate, disseminate and generate health information.

Proving its worth in different business domain, ICT solutions have been implemented on many hospitals, leading to reduce medical errors and to improve the quality of medical services. But the complexity of managing all needs of stakeholders in health domain had carried out many difficulties on e-Health implementations.

The solution proposed in this paper is the designing and implementation of e-Health systems based on SOA definitions. We remind that in this architecture, core business capabilities are encapsulated within independent software services, and these services are leveraged by various front-end applications to fulfill business requirements. The main properties of this approach are the use of business-oriented services; message-based interactions with "gray box" implementations; communication over a network; platform neutrality; service description and discovery; and loose coupling between system components (Kawamoto & Lobach, 2007). This set of properties leads to a simpler approach to software design and implementation and to enhancing re-use of existing IT resources. What gives to the system the ability to adapt to changing business requirements in a flexible, agile manner; and the potential for significant cost saving.

Lessons learned from countries' pioneer for the e-Health implementation shows that interoperability is a critical and crucial aspect for any national (and international) program. Many researches are contributing to develop it, but data exchange between softwares and between systems (respecting international directive for data control) still is a big challenge. These lessons had been taken into account during the development of RESIST project. The key idea is to improve the life quality of patients in Luxembourg, proposing a dynamic, flexible and standardized infrastructure to integrate healthcare application. The Plug-and-Play middleware developed in TAPAS project seams to be a good option to reach the RESIST aims. Our contribution in short term is the specification of an architectural framework to cover the stakeholders' necessities and the implementation of a top level in TAPAS middleware to adapt it to healthcare applications' needs. A case study has been specified to implement home monitoring in cardiology's departments. Current works targeting the identification of the requirements to create a Luxembourgish e-health environment. It deals with patient interests, caregivers' capabilities, healthcare centers' managements and governmental regulations and administration.

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