A Petri Nets-based Conceptual Framework for Web Service Composition in a Healthcare Service Platform

Sabri MTIBAA
LI3 Laboratory / University of Manouba
National School of Computer Sciences
2010 Manouba, Tunisia

Moncef TAGINA
LI3 Laboratory / University of Manouba
National School of Computer Sciences
2010 Manouba, Tunisia

***Abstract*—Healthcare industry must ultimately redefine the way they do business and deliver care for patients to deal with requirements changes and benefit from modern technologies and telecom capabilities. In this paper, we present a newly architecture of healthcare platform towards a service-oriented architecture using the enterprise system bus middleware and cloud computing technology. Our efforts concentrate on proposing a conceptual framework to conspicuously help designer in the optimizing the healthcare process through a robust comprehension of collaboration relationship between healthcare objects. Thanks to Hierarchical Petri-Net based conceptual framework, desirable properties such as deadlock free and safe satisfiability can be easily checked by designer.**

***Keywords*— Healthcare; evolution; information technology; conceptual framework; service-oriented architecture; enterprise system bus; cloud computing; Hierarchical Petri-Net**

I. INTRODUCTION

The healthcare industry is complex and experiencing many challenges regardless of region, country or system. In fact, healthcare systems around the world are being impacted in many different ways: providers and payers are facing increasing pressure to deliver higher quality of care and service whilst at the same time healthcare costs are increasing drastically and funding is being reduced [1].

What's more, the lack of effective information exchange between a healthcare organization's facilities, departments and staff – or the means for quicker and more convenient patent/physician consultations and discussions – reduces the ability to deliver patient services and treatment.

In the face of all these challenges, there is one overall reality: a key element of the healthcare industry's ability to thrive and succeed into the future rests on the strengthening and assurances of effective communication and collaboration between patients and healthcare providers.

The focus on the climbing cost to deliver and maintain quality healthcare is no longer in the peripheral view, but a clear line of sight for the patients, healthcare providers, regulators, and payers. This brings new requirements for healthcare professionals to share information, communicate and collaborate in real time from multiple locations, because medicine is a collaborative science. Communications become a strategic asset for a strongly needed healthcare transformation technology. It must be deployed to this field in order to ensure better context for medical decisions, reduce administrative costs and improve patient safety by reducing errors. In our previous work [2], a distributed telemedicine environment was exposed to accelerate service innovation for personalized and blended medicine services. In this paper, our efforts concentrate on the modeling of healthcare system to allow properties analysis and verification at the design before deployment. This model will allow designers to detect erroneous properties and formally verify whether the service process design does have certain desired properties.

Nowadays, the need to transform from the current hospital centralized treatment-based mode to prevention-oriented comprehensive healthcare mode in which hospitals, communities, families and individuals are closely involved become on the top of professional's agenda. This work is the extension of the distributed telemedicine environment to enable monitoring of patients outside hospitals or medical centers thanks to telecommunication technologies.

The advancement of information technology (IT) brings more opportunities for innovations in the healthcare area [3]. The use of service oriented technologies such as SOA, Web Services allows service providers to reduce and simplify integration process, to abstract network capabilities (e.g., call control, presence, location, etc.), and create personalized and blended services (both internally and with 3rd party partners). These technologies facilitate the construction of service systems with higher reusability, flexibility, extensibility, and robustness.

Cloud computing is evolving as an important IT service platform with its benefits of cost effectiveness and global access. To become a widely adopted IT infrastructure and service platform, cloud computing has to be integrated with other systems in organizations. In academia, there is very limited study of cloud computing integration. In practice, the industry lacks comprehensive systems integration architecture or tools that can integrate any system universally [3]. Built upon Enterprise Service Bus (ESB) as an integration backbone, this paper presents a novel citizen-centric healthcare service platform. We propose also a graphical conceptual framework which helps to design healthcare system based on a traditional healthcare scenario. The concepts of healthcare process net and hierarchical web service net are defined by Hierarchical Petri-Nets (HPN).

The remainder of this paper is organized as follows. In Section II, we present the healthcare service platform architecture. A scenario using the novel healthcare is introduced in Section III. In Section IV, we describe our conceptual framework for healthcare system design. Section V provides the model of the conceptual framework using Hierarchical Petri nets. Finally, we conclude in section VI.

II. HEATHCARE SERVICE PLATFORM ARCHITECTURE

In this section, we present the global context of our work and an overview about service oriented architecture, cloud computing and enterprise service bus. Then, the healthcare services platform architecture is exposed and some basic concepts and definitions are explained.

A. *Context and Background*

Below we have summarized a few key notions and technologies that should be of significant value to the design of healthcare architecture.

1) Service Oriented Architecture (SOA): In this IT architecture, applications and more discrete software functions are network-based, loosely coupled and available on demand to authorized users or to other applications or services. Although SOA is not a new concept, the emergence of Web services as a standard way to expose, describe, access and combine services has given new life to this approach to computing.
The key idea of SOA is the following: a service provider publishes services in a service registry [2]. The service requester searches for a service in the registry. He finds one or more by browsing or querying the registry. The service requester uses the service description to bind service. These ideas are shown in Fig. 1.

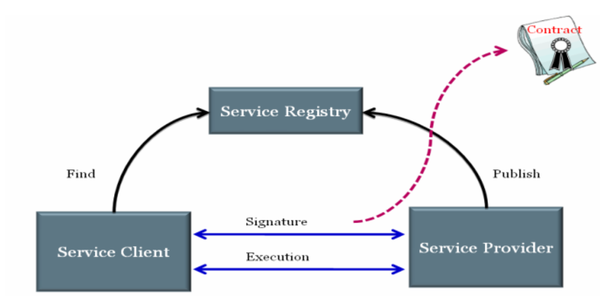

Fig. 1. Reference architecture of web services- SOA

2) Cloud Computing: Cloud computing called also *utility computing* refers to an IT service model and platform that provides on-demand based IT services over the internet (see Fig. 2). The five essential characteristics are: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service [3]. The three services models include:

- SaaS (Software as a Service) which delivers software service on demand, such as, salesforce.com – Customer Relationship Management (CRM) service and Google Gmail;
- PaaS (Platform as a Service) which provides the computing platform for companies to deploy and customize business applications on demand, such as, Google App Engine and Microsoft's Azure;
- IaaS (Infrastructure as a Service) which offers data center, infrastructure hardware and software resources on demand, such as, Amazon Elastic Compute Cloud (EC2) and VMware vCloud Datacenter. Both of these resources provide virtual computers for renters to run their business applications.

The four major deployment models include: private cloud, public cloud, community cloud, and hybrid cloud. Companies normally adopt different service models and deployment models depending on their unique business processes and demands on IT services.

Cloud computing today is an evolution and application of modern ICT including server virtualization, autonomic computing, grid computing, server farm, network storage, and web service.

2) *Enterprise Service Bus:*

ESB is one piece of an infrastructure that might help facilitating the implementation of a SOA, but it is not a perquisite. There are many aspects of an ESB that fit well with the SOA model, and denying its possible usefulness would be counterproductive, but the two are not completely inter-dependent [4].

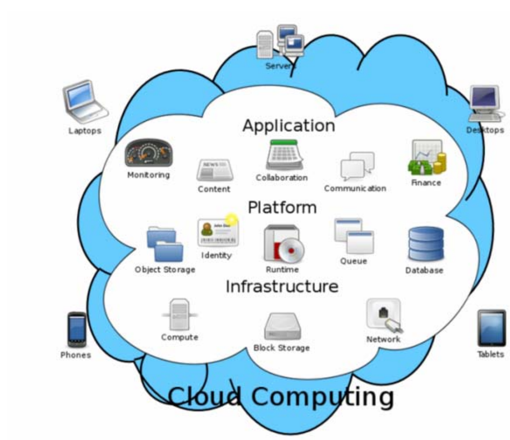

Fig. 2. Cloud computing architecture

Fig. 3. depicts the base functional elements within an ESB. It includes: data transformation, Application adapters, Automation of processes, Transformation, Routing, Messaging and Event triggering.

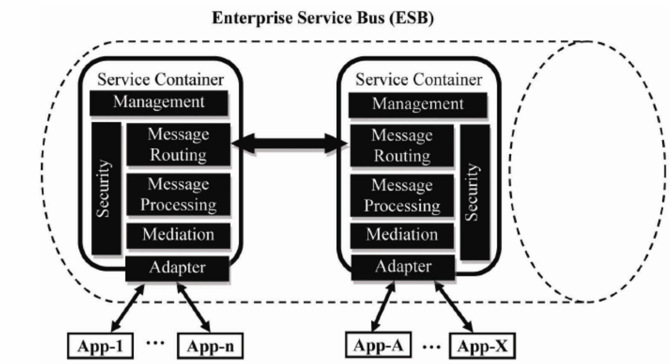

Fig. 3. ESB architecture

B. System Architecture

First, we present our Healthcare Service Platform (HSP). It intends to provide personalized healthcare services for the public. The healthcare value chain is complex. It consists not only of healthcare providers, but also of payers (government, employers and patients), fiscal intermediaries, distributors and producers of pharmaceuticals and devices. The HSP does not attempt to address this complete value chain. It focuses on the delivery of healthcare services. It is an end-to-end reference architecture that focuses on meeting the needs of citizens, patients and professionals. Its architectural diagram is given in Fig. 4.

We distinguish three main components, i.e. body sensor networks (BSN), IaaS cloud, healthcare delivery environment.

- *BSN*: according to circumstances and personalized needs, appropriate health information collection terminals (i.e. sensors) are configured for different individuals. BSN is used to provide long term and continuous monitoring of patients under their natural physiological states. It performs the multi-mode acquisition, integration and real-time transmission of personal heath information anywhere [5].

- *IaaS cloud*: modern healthcare is information driven. Healthcare providers are making progress in building an integrated profile of patients. This data sits in systems throughout the enterprise including the HER and many other electronic systems throughout the enterprise and community [6]. This component achieves the rapid storage, management, retrieval, and analysis of massive heath data. It mainly includes *Electronic Medical Record* (EMR) repository. It considers also personal health data acquired from BSN.

- Healthcare delivery environment: it includes a personal health information management system. It replaces expensive in-patient acute care with preventative, chronic care, offers disease management and remote patient monitoring.

III. HETAHCARE CASE STUDY SCENARIO

A way to motivate and illustrate this work, we presents an example of healthcare service scenario. We distinguish three main layers: service, business and HSP. The service layer consists of available web services, and the business layer represents the Web service like operations typically ordered in a particular application domain. We refer to the selected services as member services (see Fig. 5).

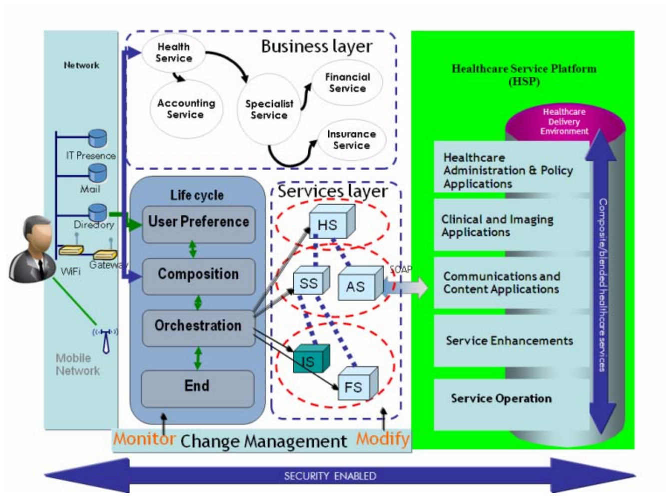

Fig. 5. Healthcare Service Scenario based on HSP

Let us assume that a *citizen* establishes a need for a business objective (healthcare service). Typically, he starts with formulating the business strategy (or goal). During the planning, some services can be identified: *HealthService*, *AccountingService*, *SpecialistService*, *FinancialServcie* and *InsuranceService*. Second, the *senior citizen* develops a specification listing the services to be composed through a graphical interface. We assume that *HS*, *AS*, *SS*, *FS* and *IS* are selected and orchestrated. The third step is the orchestration where member services that match the specified high level configuration are selected and invoked. We describe here the ideal scenario: the *senior citizen* subscribe to *HealthService*. Then all information regarding who contacts it and when are forwarded to *AccountingService*. *HealthService* forwards also the received data to *SpecialistService* in charge of checking the received values. After analyzing the received values, the team sends a confirmation or an adjustment of the medication doses. The *FinancialService* and *InsuranceService* are executed to finalize the process.

IV. CONCEPTUAL FRAMEWORK FOR HEATHCARE SYSTEM DESIGN

In order to design the healthcare service scenario, we represent the three layers in hierarchical structure: customization layer, business layer and execution layer (Fig. 6).

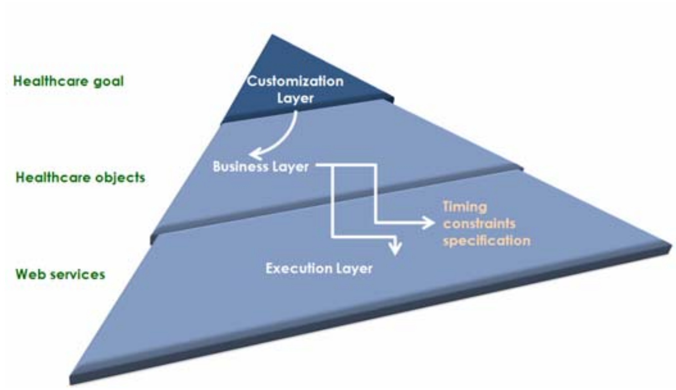

Fig. 6. Conceptual framework of healthcare system

- *Customization Layer*

This layer aims to adapt efficiently the system model to citizen needs.

- *Healthcare process layer*

Which includes a set of healthcare objects is designed based on instructional concepts such as activities and services to patients. This means that the layer reflects the pure healthcare perspective.

- *Execution layer*

Which integrates web services is designed upon the technological concepts such as web service or web service composition. It reflects the technology perspective. A variety of features and components can be realized as web services. A web service can be either simple or complex. Web services are mapped healthcare objects from healthcare process layer to web services layer in simple or complex healthcare scenarios. When using layered architecture, the design must adhere to the following design requirements:

- Aggregation - n healthcare objects (HO) 'a' in the healthcare process layer corresponds to a set of web service (a_1, a_2… a_n) in the execution process layer, where those activities jointly exchange the same messages as the HO 'a', thus achieving the same goal.
- Condition alteration – conditions must be designed such that the HO preconditions are the same or weaker than 'a_1' in the execution process layer. HO postcondition must be the same or stronger than 'a_n' in the execution process layer.

V. Modeling Conceptual Framework Using Hierarchical Petri Net

Petri-Nets are well-established process-modeling approach. Petri-Net represents communication patterns, control patterns, and information flows. They are used mainly for modeling and analyzing with formal semantics, powerful expressiveness and abundant analysis methods.

As Petri-nets find their way into different research and application areas, there are many extensions of the original Petri net definition. Hierarchical Petri-Nets were developed by Valette [7]. In this paper, we will be able to transform the operational semantics of conceptual framework discussed above into Hierarchical Petri-Nets (as described in TABLE I).

TABLE I. HPN-Conceptual framework mapping

Semantic Map	
HPN	***Conceptual framework***
Place	***condition of an action (pre-condition/post-action)***
Transition	***Action***
Token	***Process state***
Arc	***Process action flow***

From the above, the first part of hierarchical healthcare process net N with refinable transition named 'Health Service is shown in Fig. 7. This transition is refined with the attachment of web services net N'

The planned web service is the assembly of the set of web services presented previously (*PhysInfoWS*, *EnvInfoWS*, *SubjFeelWS*, *CoronaryDiagWS*, AssessmentWS, *EmrWS*, *GeoWS*, *EmerWS*, *GuideWS*).

The verification of a healthcare system model is the key before deploying them into operation, especially when a mission critical service does not tolerate run-time failure due to design errors. The healthcare process that is represented using our hierarchical Petri-nets model can be analyzed using a variety of analysis techniques:

- Reachability: the outcome of this analysis method is the acknowledgement of the designer about possibility of healthcare process to achieve the desired results or not.
- Boundedness: healthcare process design is indicating an error each time the number of token in a given place is neither 0 nor 1.

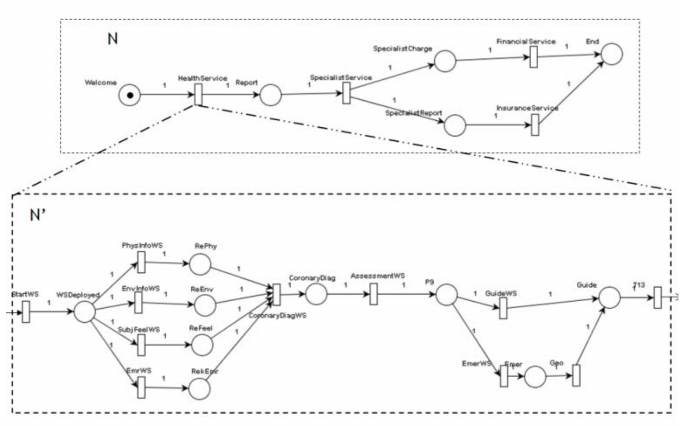

Fig. 7. Modeling conceptual framework of healthcare system using Hierarchical Petri Nets

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented a novel architecture of healthcare services platform. Using hierarchical Petri-nets as the basis for modeling, we demonstrate that complexity of healthcare process model can be reduced and we are able to check correspondence of the model to the specification of healthcare tiers specification.

Further research is needed for sure. Firstly, the customization layer should be an adapter module to capitalize from the past of citizen activity and formalize the evaluation process. Secondly, we will extend the Petri-Net based model to support dynamic QoS properties (timing constraints, reliability …).

REFERENCES

[1] S. Rey, and H. Sarrazin, “How telecoms can get more from Internet Protocol,” McKinsey on IT, 2006.

[2] S. Mtibaa, and M. Tagina “An Automated Petri-Net Based Approach for Change Management in Distributed Telemedicine Environment,” Journal of Telecommunications,Vol.15, No. 1, pp. 1-9, 2012.

[3] L. Chen,“ Integrating Cloud Computing Services Using Enterprise Service Bus (ESB),” Business and Management Research,Vol.1, No. 1, pp. 26-31, 2012.

[4] A. Azees,“ Challenges and Performance Enhancement in Could Computing,” IRACST - International Journal of Computer Science and Information Technology & Security (IJCSITS),Vol.1, No. 1, pp. 49-54, 2011.

[5] P. Wang, Z. Ding, C. Jiang, and M. Zhou, “Web Service Composition Techniques in a Health Care Service Platform,” IEEE International Conference on Web Services, pp. 355-362, 2011.

[6] V. .s. .Kondapall, J. Raju, K. R. Rao, and K. tanuja ,“ Patient-Centric-Integrated EHA OF Physician Pratice Portal Through Cloud Computing Technology,” International Journal of Computer Science & Communication Networks, ,Vol 2(2), pp. 172-18, 2012.

[7] E. Badouel, M. Llorens, and J. Olivier, “Modeling Concurrent Systems: Reconfigurable Nets,” Proc. Int. Conf. on Parallel and Distributed Processing Techniques and Applications, pp. 1568-1574, 2003.

AUTHORS PROFILE

Sabri Mtibaa is currently a Ph.D. student in the National School for Computer Sciences of Tunis, Tunisia (ENSI). He received the master degree from High School of Communication of Tunis, University of Carthage, Tunisia (Sup'Com) in 2008. His current research interest includes web service composition using Petri nets as well as system verification and QoS aware.

Moncef Tagina is a professor of Computer Science at the National School for Computer Sciences of Tunis, Tunisia (ENSI). He received the Ph.D. in Industrial Computer Science from Central School of Lille, France, in 1995. He heads research activities at LI3 Laboratory in Tunisia (Laboratoire d'Ingénierie Informatique Intelligente) on Metaheuristics, Diagnostic, Production, Scheduling and Robotics.