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Integrated Cloud-Based Services for Medical Workflow Systems

Nada Gharbi[1], Mārīte Kirikova[2], Lotfi Bouzguenda[3]
[1]*University of Sfax, Tunisia,* [2]*Riga Technical University, Latvia,* [3]*University of Sfax, Tunisia*

***Abstract* – Recent years have witnessed significant progress of workflow systems in different business areas. However, in the medical domain, the workflow systems are comparatively scarcely researched. In the medical domain, the workflows are as important as in other areas. In fact, the flow of information in the healthcare industry is even more critical than it is in other industries. Workflow can provide a new way of looking at how processes and procedures are completed in particular medical systems, and it can help improve the decision-making in these systems. Despite potential capabilities of workflow systems, medical systems still often perceive critical challenges in maintaining patient medical information that results in the difficulties in accessing patient data by different systems. In this paper, a new cloud-based service-oriented architecture is proposed. This architecture will support a medical workflow system integrated with cloud services aligned with medical standards to improve the healthcare system.**

***Keywords* – Cloud computing, cloud service oriented architecture, medical workflow systems, workflow.**

I. Introduction

The objective of the workflow is to automate processes in organisations. A process is a series of tasks coordinated according to a certain pattern and leading to a definite result. During the execution of a process, information, forms, or documents are shared or are sent from one workstation to another for processing. In our context, the workflow is designed to automate the medical process where different actors (doctors, technicians, nurses, etc.) must cooperate and synchronise their intervention process to act consistently and with the overall goal of supporting the patient. Typically, the workflow is executed by a known system, workflow management system (WFMS). In order to promote interoperability between WFMS and communication between the workflow process, the Workflow Management Coalition (WFMC: international standards organisation of operators in this sector) defined a reference architecture [1] for WFMS and exchange standards to connect to other computer systems. In our context, these systems are often the clinical decision support systems, computerised prescription systems, diagnostic support tools for medical images, etc. The main idea of the use of workflow technology in the medical field is taking care of daily operations and improving medical business process over time. What is well known about the workflow technology is the visibility that can be provided in a series of works so that they can be well managed. Further it makes the modification of business process much easier in order to respond to the healthcare setting. Workflow technology requires less training and testing in order to implement changes because it can incorporate and automate business rules that can be applied to the performance of different tasks over a process [2].

Through the use of workflow technology in medical systems, particular challenges appear. One of the challenges is that the clinical data to be entered are already gathered elsewhere in a digital format in local systems and other above-mentioned systems cannot access and use this information. In order to deal with this challenge, we have decided to benefit from the on-demand access and large storage facilities of the use of cloud computing services. As a starting point, we will design new cloud-based service architecture for medical workflow systems.

The goal of the paper is to use cloud services to specify architecture of a medical workflow management system to meet the above-mentioned challenge.

The rest of this paper is structured as follows. Section II gives a brief overview of cloud computing. Section III reviews the related research of the use of cloud computing in the workflow field and healthcare industry. Section IV explains in detail the new medical workflow system architecture with actual support of cloud computing services. In Section V, a proof of concept design is described. Section VI summarises the paper and discusses the future research.

II. Cloud Computing Overview

Several researchers have tried to provide a standard definition for cloud computing [3], [4]. However, those definitions are oriented to a specific field and are not universal. Nevertheless, it is possible to define cloud computing as a model for the on-demand network of a shared pool of resources in order to deliver services, data interchange, functions, and applications that can be accessed and used by any user and any system, anywhere.

A. Cloud Services

The main concept of cloud computing is to deliver a pool of resources and services from a virtual hardware infrastructure to software over the Internet [3]. All of those resources can be remotely accessed and configured by any user anytime through the Internet. According to the service provided, we can define three categories of cloud services:

- *Infrastructure as a Service*

It refers to the use of virtualisation technology, usually an infrastructure resource, which allows several virtual machines (VMs) to operate on the top of physical hardware in an isolated manner [5].

- *Platform as a Service*

It refers to the platform layer that provides a resource of tools supported by the operating system (OS) and software frameworks to end users allowing them to develop their own system using different tools without the need to install and to configure these tools themselves.

- *Software as a Service*

It refers to providing on-demand applications over the Internet; it represents the highest level of abstraction on the cloud. By using this model, customers can use service provider's applications along with any required software, operating system, hardware, and network through a web portal or a program interface.

B. Cloud Services for Healthcare

According to the types of services provided above, we can mention some examples of the use of cloud services in the healthcare field. One of the recent examples based on the use of SaaS (Software as a Service) is CloudeMR that is a cloud-based electronic medical record system. This system was created in order to improve the delivery of healthcare system (specific for the healthcare industry in Nigeria) [6]. A similar example was mentioned in [7] for integrating model of cloud-based e-medical record for healthcare through the use of SaaS. Another example that implements the use of PaaS (Platform as a Service) is cloud services of medical imaging known as Cloud PACS (Picture Archiving and Communication System) [8].

III. Related Research

In this section, we present a brief description of the most relevant studies, which are related to our research, first, concerning the integration of workflow in the cloud, and, second, concerning healthcare.

A. Cloud Computing Related to Workflow

With the popularity of cloud and workflow systems, some researchers have proposed different approaches for deploying and executing the workflow management systems in the cloud using several techniques and providing several architectures. Well-known WMSs related to cloud computing are as follows:

- Taverna [9] in the field of bioinformatics, where workflows are designed and executed on the local desktop through other clients or web interfaces using the server mode.
- Other researchers have provided the Workflow as a Service (WFaaS) [10], which is a service model on top of other cloud services to support workflow publishing, query, and execution [11].
- There is also the study that shows how to deploy different layers of workflow management system on the cloud [12], [13].

B. Cloud Related to Healthcare Industry

Currently, many researchers have focused on the use of modern information technology in the delivery of healthcare. Recently, a handful of published studies in healthcare organisation have started moving their effort to cloud computing. Adapting the cloud technology to medical record management reduces the cost of healthcare delivery and tackles the problem of accessing patient's medical information [6], [7]. Meanwhile, some other researchers have focused on delivering a large spectrum of computer resources through cloud services to end users; these services are particularly useful in storage processing and sharing large databases of medical images. In order to improve manageability, they move onto the cloud the medical image archive such as PACS (Picture Archiving and Communication System), which is a medical imaging technology that provides economical storage and convenient access to images from multiple modalities [8].

IV. Architecture

The aim of this section is to describe the design of the proposed architecture. Figure 1 shows the architecture of the medical workflow system, which is based on the workflow reference model [1] and cloud-based service architecture. Our proposed architecture consists of a series of components described below.

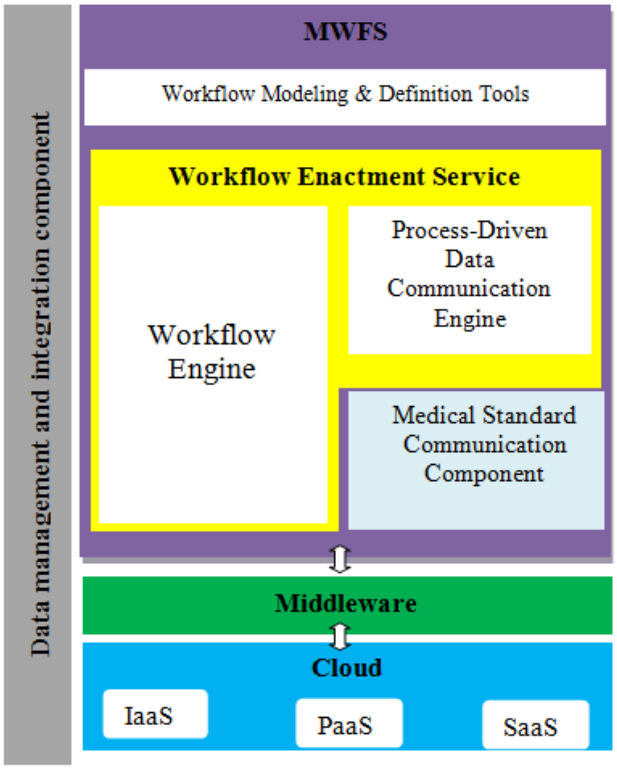

Fig. 1. Cloud-based medical workflow system architecture.

A. Workflow Modelling & Definition Tools

Workflow modelling and definition tools are the foundation components of Workflow Management System. Workflow modelling and definition tools abstract the essential characteristics of a process and modify it in the form of being executed by the medical workflow system. The results of workflow modelling are descriptions and definitions of workflow [1].

B. Workflow Enactment Service

Workflow enactment service is composed of two main components, which are the Workflow Engine and the Process Driven Data Communication Engine.

Workflow Engine is the heart of WFMS [1]; it schedules the workflow tasks over the middleware services and manages the execution of tasks. The key components of the Workflow Engine are workflow submission, workflow language parser, resource discovery, dispatchers, data movement and workflow scheduler [14].

Process-Driven Data Communication Engine is the bridge between the Workflow Engine and Medical Standard Communication Component [15]. It contains many report communication models, and each responsibility in the idea corresponds with one DICOM (Digital Imaging and Communications in Medicine), which is the standard for handling, storing, printing, and transmitting information in medical imaging service or HL7 (Health Level Seven) that refers to a set of international standards for transfer of clinical and administrative data. When a function item is activated in the Workflow Engine, Process-Driven Data Communication Engine is invoked, and it will hit the exact data communication model through the item's task Then Process-Driven Data Communication Engine will guide the tasks according to the data communication model by invoking the communication initiator's Medical Standard Communication Component.

C. Medical Standard Communication Component

Medical standard communication component implements workflow-aware report communication over medical standard communication. For concrete illustration, the DICOM Services and HL7 messages can be mentioned. The Process-Driven Data Communication Engine controls which DICOM function is to be used or which HL7 message is to be sent to whom [15].

D. Middleware and Cloud Services

Medical workflow systems should be flexible, able to interact with many types of service-oriented architectures for effective use of computerised information and count facilities provided for optimised data delivery, storage, and distributed access [1].

E. Data Management and Integration Component

The data management and integration component ensure that processed outputs from one layer to another are contextually related and syntactically correct [1], [16].

V. Proof-of-Concept Design

The proof of concept is based on simple components deployed in a successive way to meet architecture demands. For the medical workflow system, many kinds of modelling tools have been presented and compared [17]. In our case, YAWL (Yet Another Workflow Language) system is preferred as a start point for its formal definition language, extensible service-oriented architecture, and its availability as an open source resource [18]. YAWL is an appropriate modelling specification tool also because of its ability to handle complex data transformations and web service integrations. It is used in some eHealth studies and designs of some healthcare processes; it supports XML Schema, XPath, XQuery, and Java.

We choose Aneka as middleware, which is a platform solution to cloud computing and provides a software platform for developing and deploying applications in the cloud. Aneka exposes Web services for service negotiation and reservation. It has to be taken into account that Aneka has limited resources to work with and no opportunities for provision of additional resources and task submission for executing jobs on Aneka. Based on the task programming model, this service allows remote clients to submit jobs and monitor their status [14]. One of the main reasons to choose Aneka is its flexible level of customisation design that helps the workflow to interact with cloud resources. The core component of any Aneka based cloud is Aneka container, which can be deployed into any computing resource connected to the Internet whether physically or virtually [19].

Thus, in additional to the Workflow Engine, our proposed architecture comprises the following components (see Fig. 2):

- Resource Broker for ensuring that the necessary resources are available at the right time to complete the objectives [20].
- Plug-in for communicating with Aneka platform.
- A storage service, known as FTP or Amazon S3, for short-lived files [15].

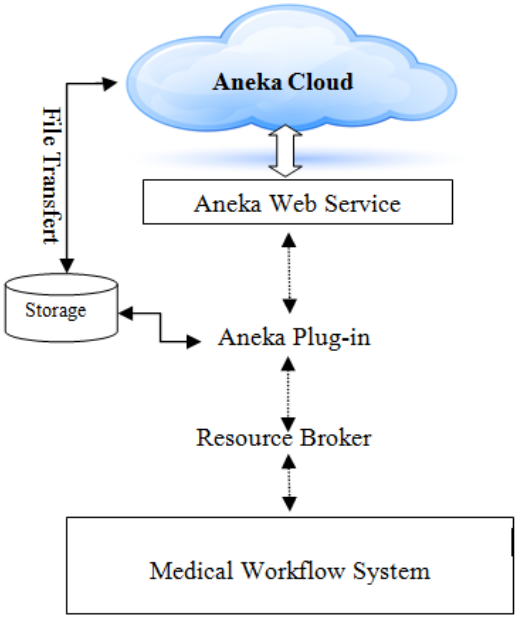

Fig. 2. Architecture implemented design shows that the growth of software use in healthcare increases the need for designing and developing the accurate system and requires finding particular tools for designing appropriate architectures of cloud-based medical workflow systems.

VI. Conclusion

In this paper, we aim at designing a new medical workflow system based on cloud services in order to deal with a particular challenge of using workflow technology in medical systems, namely, maintaining patient medical information in case of the difficulties in accessing patient data by different systems. To meet the challenge, we consider the middleware added to MWFS as the second core component of the proposed architecture. Therefore, we have implemented an abstract design, including Aneka Cloud Platform as a principal component, which provides a software platform for

developing and deploying distributed applications in the cloud. Since cloud computing as an innovate technology can face security and safety issues, the risks for a medical information system are tackled in advance through the use of Aneka platform.

In the future, we are currently planning to evaluate the proposed design to be adopted to develop our cloud medical care system, which is distributed software dedicated to the medical field that will help improve patient care in real life and provide it as an application, taking into consideration data privacy and security issue.

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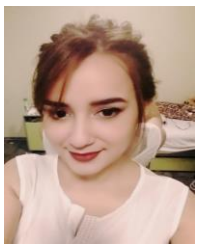

Nada Gharbi is a Master student majoring in Enterprise System Engineering at the Higher Institute of Computer Science and Multimedia of Sfax. She obtained her Bachelor degree in Computer Science and Multimedia at the University of Sfax in Tunisia. During her studies, she has participated in European exchange programmes. Her latest research interests include medical workflow systems, cloud computing, Internet of Things, and improvement of healthcare organisations.
E-mail: elgharbi.nada@gmail.com

Mārīte Kirikova, Dr. sc. ing., is a Professor in Information Systems Design at the Department of Artificial Intelligence and Systems Engineering, Faculty of Computer Science and Information Technology, Riga Technical University, Latvia. She has more than 150 publications on the topics of Requirements Engineering, Business Process Modelling, Knowledge Management, and Systems Development. She has done field work at Stockholm University and Royal Institute of Technology, Sweden, Copenhagen University, Denmark, and Boise State University, USA. Currently in her research she focuses on information systems design in the context of agile and viable systems paradigms.
E-mail: marite.kirikova@rtu.lv

Lotfi Bouzguenda is an Associate Professor in Computer Science at the Higher Institute of Computer Science and Multimedia as well as a Director of the MIRACL Laboratory, University of Sfax. He obtained his Doctoral degree at Toulouse University in France. During his career, he participates in different international projects and he was a member of the Reading Committee of more than 25 international conferences. His latest research interests include workflow mining, coordination in the inter-organisation workflow, web services, big data, and cloud computing.
E-mail: Lofti.Bouzguenda@gmail.com