Cloud Computing and Interoperability in Healthcare Information Systems

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***Abstract*—One of the areas with greatest needs having available information at the right moment and with high accuracy is healthcare. Right information at right time saves lives. This work proposes a solution based on cloud computing implemented for hospital systems having as a result a better management, high speed for the medical process, and increased quality of the medical services. Cloud computing technology is still new but promises a revolution in the entire connected areas. At national level, hospital information systems are somewhat rare and not very well managed. Cloud computing allows using the latest technologies at low prices (pay-per-use) and with minimum resources necessary for clients. The paper suggests a model for the architecture of the information systems in two key departments of a hospital: Pediatrics and Obstetrics, and Gynecology using interoperability for better access to information and preparing the system for future connectivity.**

Keywords-cloud computing; HL7 CDA; interoperability; Pediatrics; Obstetrics and Gynecology

I. INTRODUCTION

The most critical area that requires a lot of information, a lot of data and computing power is the healthcare domain. Doctors need, in critical moments, the medical history of patients in real time. Patients are sent to various investigations, supposing a high rate exchange of data between departments of medical units. Doctors need complete medical information of the patients to provide a complete and accurate treatment.

The technology that we chose to solve these problems is cloud computing because the resources are dynamically scaled (doctors can store a lot of medical data when they need) and is used over the Internet as services (doctors can access the medical data when and where they need it). To access this technology one can use a variety of Internet-connected devices which can access programs and development environments offered by cloud computing [1]. The information available at the right moment and location can save lives and significantly decreases the sources of medical errors increasing the quality of life of a patient. Another element used in our proposal to solve the problem of data exchange between medical units is ensuring the interoperability of the developed systems through HL7 CDA Standard [2].

This solution can be improved having a better security system for the medical data and creating a longitudinal data sheet of the patient (medical records for entire life span).

Cloud computing is a technology that could help a vitally important area because it offers a complex infrastructure at low cost and also provides greater computing power to achieve comprehensive health care operations.

In section two, the architecture and characteristics of cloud computing are described. Section three presents cloud computing applied in healthcare. Section four deals with interoperability in Pediatrics, and Obstetrics and Gynecology systems. Section five discusses cloud computing as a solution supporting information systems in a hospital, and Section six concludes the suggested solution.

II. ARCHITECTURE AND CHARACTERISTICS OF CLOUD COMPUTING

Cloud computing, defined by NIST (National Institute of Standards and Technology) [3] is a technology that supports ubiquity, it is convenient, supplies on demand access to the network for sharing computing resources (e.g., networks, servers, storage, applications and services), can be launched and developed quickly with minimal management and without service provider interaction.

The cloud model consists in five essential characteristics, three service models and four models of development (Figure 1).

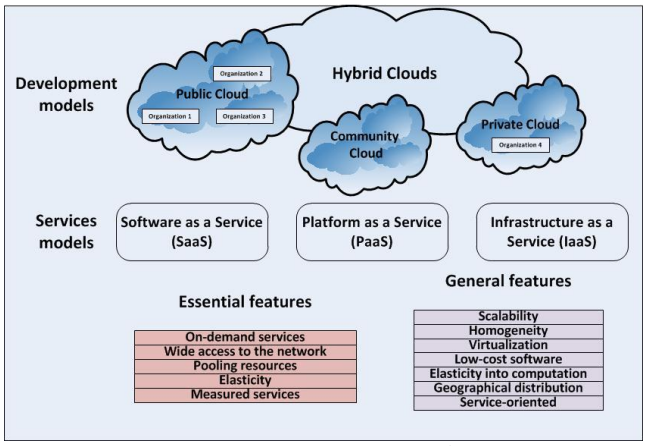

Figure 1. Elements and characteristics of the clouds

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A. Essential characteristics

The essential five characteristics of cloud computing are: **On-demand services**: consumers can connect to a website and can use web services to access additional computing resources whenever they need; **Wide access to the network**: web services are based on cloud computing and for this reason can be accessed from any device connected to the Internet; **Pooling resources**: customers can share computing resources with other clients, so these resources can be reallocated dynamically and can be hosted anywhere; **Elasticity**: cloud computing allows users great flexibility that customers can scale systems (and costs) up or down as required; and **Measured services**: cloud computing monitors and records resources usage, which enables customers as payment for use (pay-per-use), a fundamental paradigm for cloud computing [3].

B. Cloud computing architecture

Cloud computing architecture consists of: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS).

Infrastructure as a Service is delivering hardware (servers, network technologies, storage) as a service. It also includes the operating system and virtualization technology for resource management. Currently, the best job profile is Amazon's Elastic Compute Cloud (Amazon EC2) [3]. It provides a web interface that allows customers accessing virtual machines.

Platform as a Service offers an integrated set of software that provides everything that a software developer needs to build an application - an online environment for quick development of web applications using browser-based development tools.

Software as a Service – business applications hosted and delivered as a service via the web. These kinds of applications do not require installation of additional computer programs, the most popular being the e-mail in a web browser [3].

C. Models of development clouds

Cloud computing is offered in four different forms: **Public clouds** – are held by a company selling cloud services to the general public; **Private clouds** – are owned by a single organization and are being used only in that organization; **Community clouds** – belonging to several organizations and allowing access only to those concerned for certain actions; **Hybrid clouds** – a composition of two or more types of clouds (private, public or community) that remain unique entities but are linked by standard technologies that enable portability of applications [3].

For medical applications, the best choice of a model is the private one for reasons of security and data privacy. In a private cloud, medical data can be accessed only by the authorized medical staff.

D. Related elements of cloud computing

The cloud architecture includes as most popular principles virtualization and SOA (Service oriented architecture).

Virtualization is at the core of most cloud architectures. The concept of virtualization allows an abstract representation of logical and physical resources including servers, storage devices, networks and software. The basic idea is to pool all physical resources and their management as a whole meeting the individual demands from these shared resources. In addition to virtualization, service-oriented architectures and web services are considered important in cloud computing.

Service-oriented architectures have components implemented as independent services that can be linked together in a flexible way and can communicate through messages. In cloud computing virtualized IT infrastructures, platforms and developed applications are implemented as services and are made available for use in service-oriented architectures. In public clouds, services are offered over the Internet on standard web protocols and interfaces.

SOA offers positive benefits such as [4]:

- Language-neutral integration: uses XML (eXtensible Markup Language).
- Component reuse: after is creating a web service to achieve an application, it can be reused for other applications which have service like this, and no longer is needed to rewrite code.
- Organizational agility: after building blocks of software which respects the user specification, it is possible to recombine and integrate quickly.
- Using existing systems: enable integration between new and old systems components.

III. CLOUD COMPUTING IN HEALTHCARE

In the medical field, cloud computing offers great potential for quick access to medical information. Health IT infrastructure is very complex and for this reason organization has taken additional measures to protect the patient's private data under HIPAA (Health Insurance Portability and Accountability Act). Maintaining confidentiality and integrity of information stored in all forms, and providing data backup and recovery processes in extreme cases are extremely important in this field. Quick access to medical history of each person at any location can accelerate diagnosis and treatment quality, avoiding complications, increasing quality and saving lives. In addition, cloud computing can help patients to gain access to their medical history from anywhere in the world via the Internet contributing to personalization in healthcare. The healthcare domain needs increased security and privacy levels, meaning that cloud computing technology has to be

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more carefully managed in order to achieve this requirements. The matter is less technical and more ethical and legal. Before cloud computing technology can be fully adopted as a structure for health IT, providers must gain the trust of society and to demonstrate that they meet the HIPAA (Health Insurance Portability and Accountability Act) standard [5].

More than ever, healthcare services need cooperation between healthcare units due to high mobility of individuals for work or holidays. It is very important to ensure the availability of medical data to all the locations a patient is present in. Several scenarios and developments are already available in literature and presented in the following.

In [6], a scenario is presented to implement a cloud-based service for ePrescribing: the physician that uses the application is connected to the PHR (Personal Healthcare Record) system and reads a summary of medical history of each patient's records and selects a list of drugs. The application validates the selection of drugs based on their interaction with other drugs, patient allergies and medication history of the patient. If there are not incompatibility alerts, the prescription is stored in data centers of Insurance Organization waiting to be processed in Pharmacies. These systems are stored in a private cloud because in this way the information can be accessed only by authorized persons. Another proposal [6] is implementing a Semantic Wiki for User Training, based on the cloud technology available on demand and implemented on Amazon cloud infrastructure, a flexible, low-cost and scalable platform. Wiki users use the same database to store and read medical information. This solution offers support only for the ePrescribing system and for a cloud-based wiki.

In [7], a model is presented as an integrated EMR (Electronic Medical Record) sharing medical data between medical units. The application is developed on a cloud platform that keeps the EMR system on the form of Software as a Service and can be used by Government, Hospitals, Doctors, Patients, Pharmacies and Health Insurance Organizations, through the Internet. This system allows access to national data sharing; the data center is common to all units. Communication between the data center and the healthcare organizations is done via HL7 messages. All patient data are stored and accessed in the same location over the Internet from any healthcare organizations.

Using cloud computing in medicine results in benefits for the medical units and patients. Several benefits are:

- it is useful in storing medical data (cloud computing is scalable, increasing or decreasing resources, as needed),
- offers remote access (the data can be accessed via the Internet from anywhere),
- allows data sharing between authorized units
- the updates for the medical history of the patient - consultations, prescriptions, hospitalization - are made in real time and are useful for future treatment validation.

IV. INTEROPERABILITY IN PEDIATRICS AND OB-GYN SYSTEMS

4.1 General information about interoperability in cloud

Interoperability is the ability of two or more systems or components (for example two or more medical informatics systems) to exchange information and use the information that has been exchanged [8].

A web service is any service that is available over the Internet or an Intranet, uses standardized XML messaging system and is self-describing, discoverable and not tied to any operating system or programming language [9].

In eHealth is mandatory to use a standardized communication. In presenting the proposed system, one standard is used: HL7 CDA (Clinical Document Architecture).

Cloud computing technology supports interoperability, ensures high availability of resources, systems are "always ON", and available to communicate with other computing systems in the cloud.

4.2 Standard used in healthcare information systems

The HL7 CDA standard is a document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of data exchange [2].

CDA has three levels of document definition: Level 1 (the root hierarchy, and the most unconstrained version of document), Level 2 (additional constrains on the document via templates at the "Section" level), Level 3 (additional constrains on the document at the "Entry" level, and optional additional constrains at the "Section" level) [10].

In Figure 2, a CDA example for the pediatrics healthcare system developed in order to evaluate the proposed architecture is presented. The codes used in Romania are ICD-10-AM and LOINC (translated in Romanian) [11].

```
<section>
  <code code="101155-0" codeSystem="2.16.840.1.113883.6.1"
   codeSystemName="LOINC" />
  <title>Alergii si Reactii Adverse</title>
  <text>
    <list>
      <item>Penicilina - Urticarie</item>
    </list>
  </text>
  <entry>
    <observation classCode="OBS" moodCode="EVN">
      <code code="L50.0" codeSystem="2.16.840.1.113883.6.3"
       displayName="Urticarie" />
      <entryRelationship typecode="MFST">
        <observation classCode="OBS" moodCode="EVN">
          <code code="Z88.0" codeSystem="2.16.840.1.113883.6.3"
           codeSystemName="ICD10" displayName="Alergie la penicilina" />
        </observation>
      </entryRelationship>
    </observation>
  </entry>
</section>
```

Figure 2. CDA example

The CDA example presents that a patient has allergy to penicillin, and it is represented with ICD-10-AM (in allergy case is used L50.0).

CDA documents are encoded in XML. The process is derived from the HL7 RIM (Reference Information Model) and also uses HL7 version 3 data types [10].

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The information flow between the components of our model is this: The Pediatrics application sends an XML with the mother ID, baby's ID and the baby's birthdate, the ob-gyn application reads the XML request, identifies the needed data, and converts it to a XML in CDA format and sending it to the Pediatrics department where the data is read and filled in the baby's chart.

V. CLOUD COMPUTING AS A SOLUTION SUPPORTING INFORMATION SYSTEMS IN A HOSPITAL

As cloud computing can support different healthcare information systems by sharing information stored in diverse locations, a solution based on this technology was adopted for our case. A private cloud-based infrastructure was developed for each healthcare unit. To eliminate the drawback of cloud computing represented by weak security we have chosen the private cloud for each unit.

The architecture for the systems in the cloud is presented in Figure 3. All the medical data are stored in a private cloud and all the departments of the hospital can access medical patient data when is needed. In this case, the medical act is performed quickly, and the typing errors reduced, all of this driving to higher quality.

For increased security the suggested solution consists in a private cloud-based architecture where applications and data storage can be found within each private data center of the hospital (one in the Pediatrics hospital and one in the Ob-Gyn hospital). When individual patient data is needed from one department to another – both having different health information systems - it will be transmitted in real time to the proper location using an HL7 CDA message solution.

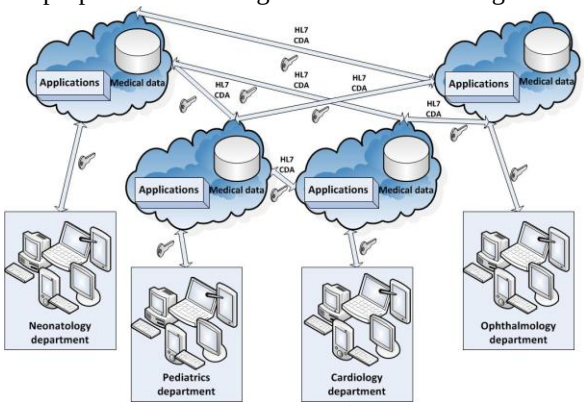

Figure 3. Architecture for hospital system

The solution ensures interoperability of the systems and a clear communication. Also the flexibility of the solution allows the connectivity in the cloud for new systems and devices.

The proposed solution is under development in ASP.NET environment for Windows Azure and the hospital database will be integrated into SQL Azure.

We started with two departments of the hospital: Pediatrics, and Obstetrics and Gynecology, because these are important starting points for the EHR (Electronic Health Record).

First contact with the medical world is starting at birth after which all the information about an individuals' health, immunizations, treatments, problems during pregnancy and all information of the child at birth are stored in the department of obstetrics and gynecology. After birth, the child is taken into care by a pediatrician for monitoring and treatment, if the case.

This is the reason why these two departments are the first departments of a hospital we wanted to give the opportunity to have a better communication and computing power and also more storage space using cloud computing and communications through HL7 CDA. The architecture of the solution is presented in Figure 4.

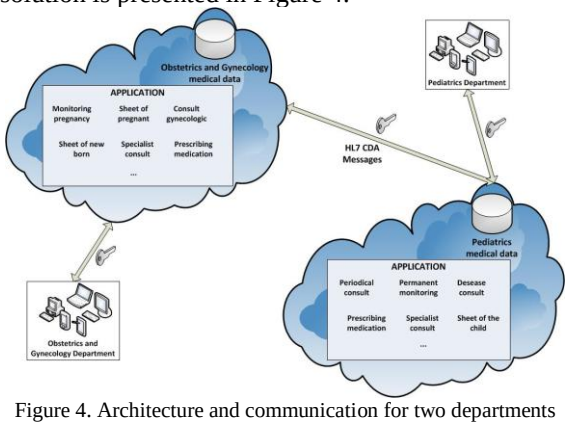

Figure 4. Architecture and communication for two departments

The applications were developed for each department separately (Pediatrics and Ob-Gyn) and also the support for communication in a local network. The next step is to upload the applications on the cloud and interconnect them.

To achieve interoperability we use XML files based on HL7 CDA standard. In Figure 5, the flow of data between the two medical units which exchange information is presented.

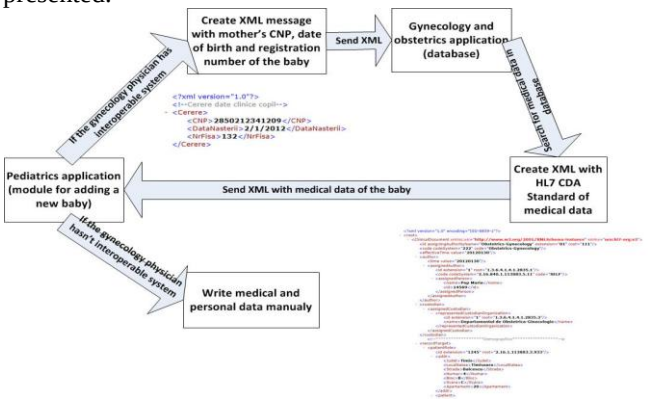

Figure 5. Exchange of medical data between units

The data of a new born child being added in the database of the pediatrician; the physician will be asked if wants to add the data manually or retrieve it from the database of the hospital, which technically is located in the private cloud of

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the Obstetrics and Gynecology unit, where the baby was born. When the data acquisition from the Obstetrics and Gynecology unit option is chosen, the Pediatrics application will create an XML file with the PIN (Personal Identification Number) of the mother, date of birth of the child and registration number of the child (every child is registered at birth with a unique identification number in the hospital). The XML file with these data will be sent to the data server from the private cloud of the unit of Obstetrics and Gynecology. When these dates are available in the server, via a specific application it will check the validity of the received message will analyze the request and if the data exists in the server the application will form another XML file which contains the medical data record of the baby from birth until to the day of discharge. These XML file is created in HL7 CDA standard format, and it will be sent to the unit who requested the data.

Once received, the required medical data in XML format, the Pediatrics application will read the XML file and will display the medical records to the location point where the physician adds the patient. The received medical data will be saved in the database server of the private cloud of the Pediatrics unit. The pediatrician will have access to the medical history of the baby from birth and during pregnancy, information important for monitoring and treating the child.

For the applications to communicate better with each other and more effectively, we used the HL7 CDA standard, due to its features structuring the medical data on several levels and with certain codes that can be read by any application that uses these medical standards.

VI. CONCLUSION AND FUTURE WORKS

Using the cloud computing technology a medical act may considerably improve the access to information, which can be done be much easier. The scalability, that is the key of the cloud computing, can offer more resources needed for certain operation at any time.

The collaboration between medical units is an opportunity offered by cloud computing for healthcare staff. With this technology can be checked the availability of a physician, a medical specialist, a product or a service at different times and in different cases. Patients can be guided to appropriate persons or units where they can find what they need. This is a huge benefit for patients and health professionals, increasingly the quality of the medical service. The costs of the IT infrastructure will be cheaper because the medical units will only rent the infrastructure to store medical data as it need and will no longer need the latest equipment for the applications used, managed or maintained. They need only computers or devices with access to Internet.

The private cloud solution ensures the security of data and communication between departments, and messaging is done in a secure way. The application is equipped with a module that verifies the received and sent information.

Future work will improve the security solution (implement HIPAA requirements, using HTTPS) and will evaluate the results through measuring the interoperability degree achieved by the presented solution [12].

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REFERENCES

[1] Q. Zhang, L. Cheng, and R. Boutaba, "Cloud computing: state-of-the-art and research challenges," Journal of Internet Services and Applications, vol. 1, pp. 7-18, May 2010.

[2] "HL7 version 3 Interoperability Standards Normative Edition 2009, Based on HL7 v3 Data Types," Release 1, Disk 1 – Standards Publication

[3] P. Mell and T. Grance, "The NIST Definition of Cloud Computing," NIST Special Publication 800-145, September 2011

[4] G. Raines, "Cloud Computing and SOA," Systems Engineering at MITRE, Service-Oriented Architecture (SOA) Series, 2009

[5] P. K. Bollineni and K. Neupane, "Implications for adopting cloud computing in e-Health," Master's Thesis Computer Science, September 2011

[6] D. Papakonstantinou, M. Poulymenopoulou, F. Malamateniou, and G. Vassilacopoulos, "A cloud-based semantic wiki for user training in healthcare process management," XXIII Conference of the European Federation for Medical Informatics (MIE 2011), August 2011, vol. 169, pp. 93-97, doi: 10.3233/978-1-60750-806-9-93

[7] B. Pardamean, and R. R. Rumanda. „Integrated Model of Cloud-Based E-Medical Record for Health Care Organizations," 10th WSEAS International Conference on E-Activities, December 2011, pp. 157-162

[8] "IEEE Standard Glossary of Software Engineering Terminology," IEEE Std 610.12-1990.

[9] E. Cerami, "Web Services Essentials," Third Indian Reprint, O'Reilly Media, Inc., 2007

[10] CDA levels: http://www.corepointhealth.com, Accessed in 20.02.2012

[11] J. M. Ferranti, R. C. Musser, K. Kawamoto, and W. E. Hammond, "The Clinical Document Architecture and the Continuity of Care Record: A Critical Analysis," Journal of the American Medical Informatics Association, vol. 13, pp. 245-252, February 2006

[12] M. Vida, and L. Stoicu-Tivadar, "Measuring medical informatics systems interoperability using the LISI model," 9th IEEE International Symposium on Intelligent Systems and Informatics (SISY 2010), September 2010, pp. 33-36, doi: 10.1109/SISY.2010.5647396

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