Using Web Services to support the interoperability between healthcare information systems and CDS systems

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Abstract: This paper presents a solution for improving communication between medical information systems using Web Services. A Web Service is used as a supporting technology to improve the interoperability between different medical informatics systems and CDS (Clinical Decision Support) systems. A demonstration is made for the communication between an Obstetrics-Gynecology Department Information System, a Pediatrics Department Information System, a General Practitioner Information System and a Clinical Decision Support System. All the applications are web-based and can be accessed using a browser. HL7 CDA (Clinical Document Architecture) and CCD (Continuity of Care Document) standards are used in order to support the entire system's interoperability. Flexibility and ubiquity in accessing vital information are the main benefits of the presented solution.

Keywords: Web Service, interoperability, Obstetrics-Gynecology Department Information System, Pediatrics Department Information System, guidelines, protocols, HL7 CDA, CCD.

1. INTRODUCTION

In healthcare, in many cases it is vitally important for the user to have the possibility to access medical information in real time. This can be achieved with web-based applications supporting any user who has rights to access the patient data through a browser.

Web Services enable flexible communication between different applications that exchange information using different hardware, different operating systems and different programming languages. Using Web Services results in automate connection and human support is reduced to minimum (Toader, 2010).

Web Services send public functions or messages of a Web-application to the rest of the world. The basic Web Services platform is XML and HTTP (w3, 2012).

The healthcare information systems and Clinical Decision Support systems are very important for hospitals and other medical units (e.g. laboratory, general practitioner, and radiography) supporting clinicians in their activity, presenting patient data, reducing medical errors, reducing the data storage space, facilitating the possibility of data analysis, and sharing the data with other specialists or medical units.

Shared information is the foundation for seamless care and the patient involvement, and its main strategic target is: high professional quality of care, shorter waiting time, high level of user satisfaction, better information about service and quality, efficient use of resources, and freedom of choice.

Communication between the information systems under study is critical and a high interoperability degree has real benefits for the clinical process. Based on related information from the discussed systems, Clinical Decision Support Systems can be improved during the real process and better medical recommendations may be issued.

Communication between different systems and their components in a complex and highly dynamic environment must fulfill several requirements (Blobel, 2006; Lopez *et al.,* 2009): openness, scalability, flexibility, portability; distribution at Internet level; standard conformance; business process orientation; consideration of timing aspects of data and information exchanged; user acceptance; lawfulness; appropriate security and privacy services.

All these actions are important to fill in the Electronic Health Record, defined (Atherton, 2011) as "a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports".

The paper presents a technical solution supporting the interoperability between different medical information systems using Web Services, particularly using Windows Communication Foundation (WCF).

The paper is structured as in the followings. Section 2 describes the importance of using the web services in healthcare. Section 3 describes the Web Service, in this case Windows Communication Foundation. Section 4 describes a healthcare system architecture using the Web Services for communication. Section 5 describes the implementation aspects. Section 6 presents the results using Web Services in healthcare. Section 7 presents several conclusions and future work.

2. WEB SERVICES IN HEALTHCARE

In Romania, to increase life expectancy and rise the quality of clinical act there is a need for a better care for the patient that can be reached supporting the medical staff with more proper and updated information about the patient health status, and providing doctors smart tools that improve efficiency. In case of an emergency it is important for the medical staff to have access in real time to the information about the patient. In time, this will reduce medical errors and raise the quality of the patient care.

A solution for a better communication between healthcare information systems and CDS systems consists in using Web Services and using standards (ensuring interoperability). Two known standards in medical informatics are: HL7 Clinical Document (HL7 CDA) and Continuity of Care Document (CCD). These two standards are used to create XML files which can be sent over the Internet using Web Services.

The benefits of sending XML files using Web Services are: ensures platform independence, makes communication between the applications flexible, collaborative, and compatible, avoids overlapping investment of the ICT utilization and development, and enables sharing different applications (Hori *et al.*, 2005).

(Maojo *et al.,* 2007) presents several languages and standards that support the Web service-based workflow definition and executions, and medical information systems which use Web Services for communication.

(Mykkanen *et al.,* 2005) proposes a model to define services and solutions for healthcare applications starting from the requirements in the healthcare processes. A comparison between three services scenarios is presented using 11 phases for design.

In (Dogac et al, 2006) the Artemis project is described where the messages or documents are exchanged using Web Services. Also, presents several advantages introducing Web Services into healthcare domain.

(Marcheschi *et al.,* 2004) presents a healthcare information system developed by CNR Institute of Clinical Physiology sending information using the HL7 CDA standard through Web Services.

In (Spyropoulos *et al.,* 2010) is presented an integrated system. The system consists of a prototype laptop-based portable monitoring system with fuzzy-rules-based software, and implementing two standards: Continuity of Care Record (CCR) and HL7 CDA. The communication is using Web Services and the two standards that enable the system to exchange homecare information.

To ensure interoperability between different healthcare information systems and CDS systems a possible solution is the HL7 version 3 messaging standard. In Figure 1 are presented the abstraction layers for message transmission (after Grieve *et al.,* 2006).

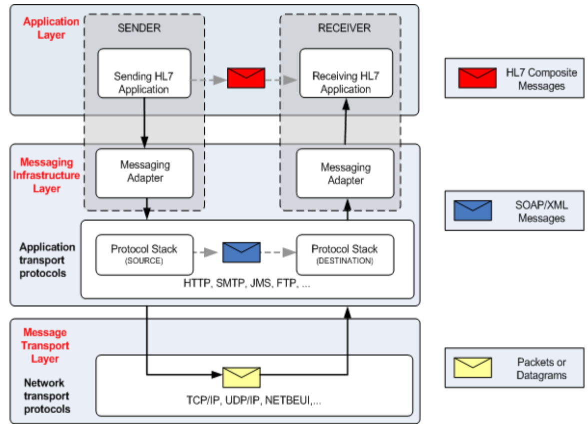

Fig. 1. Abstraction Layers for message transmission.

The HL7 CDA XML is encapsulated in the body of a SOAP message. The SOAP message is directed to the application which receives the message using the network protocol.

Communication systems are subdivided into layers. The seventh level is the application layer. HL7 is the application layer in which work is done and interaction takes place in the delivery of patient care. For the current application the HL7 version 3 messages are presented as HL7 CDA messages created by the CDA Component. The Sending HL7 Application is the CDA Component which extracts the requested data, converts it into a CDA in XML format and sends it to the Receiving HL7 Application. The Messaging Infrastructure Layer is responsible for the HL7 messages transfer following the rules specified by the HL7 applications. For the presented process the Message Transport Layer is built on TCP/IP, the communication protocol for the Internet, and defines the rules for computer communication on Internet (Grieve *et al.,* 2006; Vida *et al.,* 2011).

A scenario that shows how the XML in standard format (HL7 CDA or CCD) is sent from one application to another application using Web Services is presented in the following.

The Component HL7 CDA or CCD sends the XML file which is passed to a Web Service that works as the Messaging Adapter (Figure 1) that answers to specific application calls (Data Manger, etc.). For the Messaging Infrastructure Layer it is important to configure correctly the message by adding the appropriate metadata to properly guide it to the calling application. The configuration will contain some of the following elements: Messaging Protocol's Source, Destination, definition of the delivery conditions required for particular interaction, security characteristics. The Web Services Messaging Adapter attaches a SOAP envelope to the XML file, sending it to the Source using the Messaging Protocol, which results in easier control and message transfer. After delivering the HL7 message, the Web Services Messaging Adapter will remove the SOAP envelope and headers as well as the appropriate metadata (adapted after Grieve *et al.,* 2006).

3. WINDOWS COMMUNICATION FOUNDATION CHARACTERISTICS

The present application uses as Web Services for communication between different healthcare information systems the Windows Communication Foundation (WCF) technology. WCF is a Microsoft technology and is designed using service oriented architecture (SOA) principles, which can support distributed computing where services have remote consumers. Messages sent using WCF are asynchronous messages from one service endpoint to another (WCF, 2012). Based on this technology, different Microsoft applications can communicate, but, furthermore, it is possible to communicate with other applications which are not Microsoft applications (e.g. Java applications). The applications described in this paper are developed using Visual Studio .NET 2010, ASP.Net pages and C# language.

WCF implements a set of classes on the top of the .NET Framework's Common Language Runtime (CLR). This supports the developers to create easily service – oriented applications (WCF, 2012).

WCF has three important aspects (WCF, 2012):

- Unification of the original .NET Framework communication technologies
- Interoperability between applications based on diverse technologies
- Explicit support for service-oriented development.
- The WCF features described in (WCF, 2012) are:
- Service orientation
- Interoperability
- Multiple message patterns
- Service metadata
- Data contacts
- Security
- Multiple transports and encodings
- Reliable and queued messages
- Transactions
- Ajax and REST support
- Extensibility

4. WEB SERVICES ARCHITECTURE FOR HEALTHCARE INTEGRATED SYSTEMS

Figure 2 presents the architecture of a system that communicates based on Windows Communication Foundation as Web Services. The system includes the following information systems for different healthcare institutions: the Obstetrics-Gynecology Department Information System, the Pediatrics Department Information System, a General Practitioner Information System and a Clinical Decision Support system.

Using Web Services the messages will be transmitted automatically and in real time. If the Pediatrics Department Information System needs information from the Obstetrics-Gynecology Department Information System it will send an XML which contains the information about the patient. The Obstetrics-Gynecology Department Information System will read the XML and send the requested data as an XML file in HL7 CDA format.

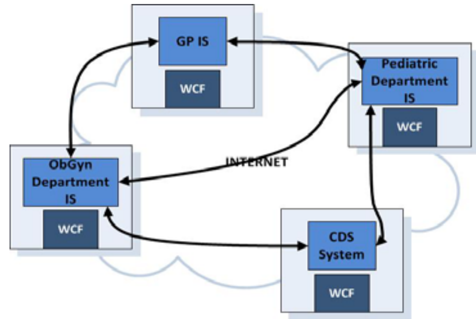

Fig. 2. System architecture using Web Services.

For example, a relevant scenario is:

A mother with her baby comes to the Pediatrics Department. The first time when she comes with the baby, the medical doctor will input the data of the baby into the Information System. The Pediatrics Department Information System will request data from the Obstetrics-Gynecology Department Information System of the hospital where the bay was born.

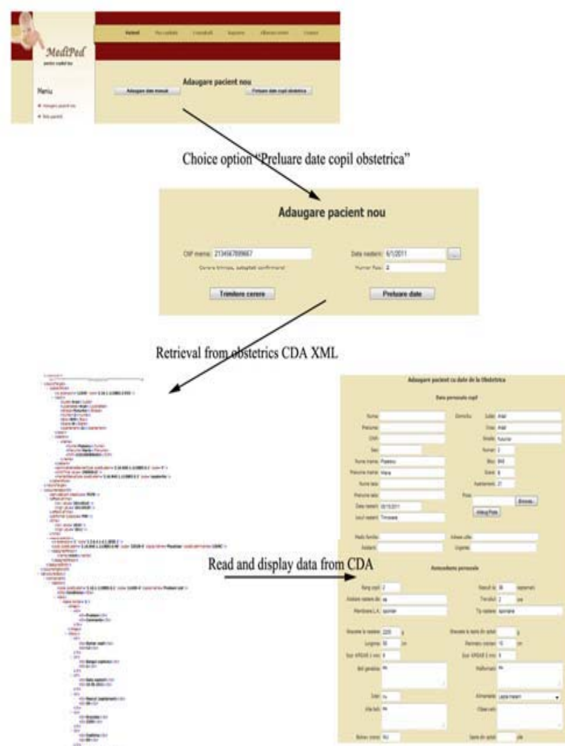

Fig. 3a. Requesting and receiving data from Obstetrics-Gynecology Department Information System.

The Obstetrics-Gynecology Department Information System will search the baby information using the mother's ID, the number allocated at birth for the baby and date of baby's birth, then the information is sent to the Pediatrics Department Information System. The communication is realized using Web Services and a standardized communication based on HL7 Clinical Document

Architecture (CDA). The scenario is represented in Figure 3 and is described in more details in (Lupse *et al.,* 2011).

```
<maritalStatusCode codeSystem="2.16.840.1.113883.5.2" code="casatorita"/>
</patientRole>
</recordTarget>
- <documentationOf>
  <serviceEvent classCode="PCPR"/>
  - <effectiveTime>
      <low value="20110515"/>
      <high value="20110520"/>
    </effectiveTime>
    <performer typecode="PRF"/>
  - <time>
      <low value="2010"/>
      <high value="2011"/>
    </time>
  - <assignedEntity>
      <id extension="1" root="1.3.6.4.1.4.1.2835.1"/>
      <code codeSystem="2.16.840.1.113883.6.96" code="22028-5" displayName="Physician"
        codeSystemName="LOINC"/>
    - <assignedPerson>
        <name>mmm</name>
      </assignedPerson>
    </assignedEntity>
  </documentationOf>
- <structuredBody>
  - <component>
    - <section>
        <code codeSystem="2.16.1.113883.6.1" code="11450-4" displayName="Problem List"/>
        <title>Conditions</title>
      - <text>
        - <table border="1">
          - <thead>
            - <th>
                <th>Problem</th>
                <th>Comments</th>
              </th>
            </thead>
          - <tbody>
            - <tr>
                <td>Numar copil</td>
                <td>12</td>
              </tr>
            - <tr>
                <td>Rangul copilului</td>
                <td>2</td>
```

Fig. 3b. Example of a sequence of a CDA header related to Figure 3a.

5. SYSTEM IMPLEMENTATION

5.1 Describing the healthcare information systems

The **Obstetrics-Gynecology Department Information System** is an application developed in Visual Studio .NET 2010 using C#, for the Obstetrics-Gynecology Department. It is a web-based application developed using ASP.NET. The information system communicates using HL7 CDA and CCD standards. To send standardized information over the Internet it uses Web Services. This application uses WCF as a Web Service. The obstetric care is episodic, with frequent visits (monthly initially, increasing to weekly or even more frequently at term), the amount of information and the specificity of information to be captured and reviewed changes with the progression of the pregnancy. (Lupse, 2011; Vida, 2011).

The **Pediatrics Department Information System** is an application developed in Visual Studio .NET 2010, using C#, and ASP.NET pages. The system communicates based on two standards: HL7 CDA and CCD. Standardized information is sent over the Internet, based on Web Services (WCF). It is important to have this specialized application for pediatrics care, because an Electronic Health Record starts when a child is born and it is active as long as the person exists and for achieving this is important to have the patient information needed for clinical decisions and maintaining children's health which includes: coordinating maternal and newborn health information, tracking and reporting of immunization information, monitoring and documentation of growth and development, providing age-appropriate medication dosing and laboratory test result interpretation, protecting patient privacy appropriately, identifying patient data accurately and precisely (Lupse, 2011; Vida, 2011).

Figure 4 presents the data flow between the Obstetrics-Gynecology Department and Pediatrics Department.

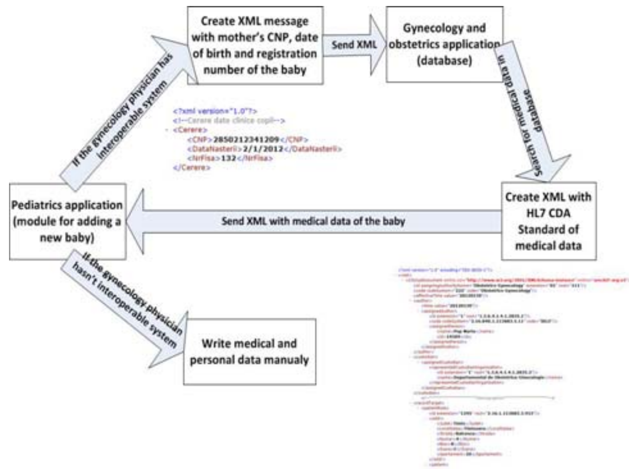

Fig. 4. Exchange of medical data between units.

When a new born data has to be filled in the Pediatrics the pediatrician will be asked if he wants to add the data manually or to retrieve it from the database of the Obstetrics-Gynecology Department of the hospital, which technically is located in the servers of the Obstetrics and Gynecology unit where the baby was born.

If 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.

When data is available on the server, a specific application 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 record of the baby from birth until the day of discharge. The XML file is created using the HL7 CDA standard format, and it will be sent to the unit who requested the data.

Once received, the requested 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 processes the patient data. The received medical data will be saved in the database server of the Pediatrics unit. In this way the pediatrician will have access to the baby's medical history from birth and during pregnancy, information important for monitoring and treating the child (Lupşe, 2012).

The **General Practitioner Information System** is an application developed in Visual Studio .NET 2010, using C#, and ASP.NET pages. The information system communicates using a standardized communication based on CCD standard. The GP software covers all the informational needs in a general practitioner consulting room: consultation recording, including codification, generation and printing of documents, generation of reports for clearing house, and other reports at request, sending these via Internet, scheduling, etc. (Stoicu-Tivadar, 2006)

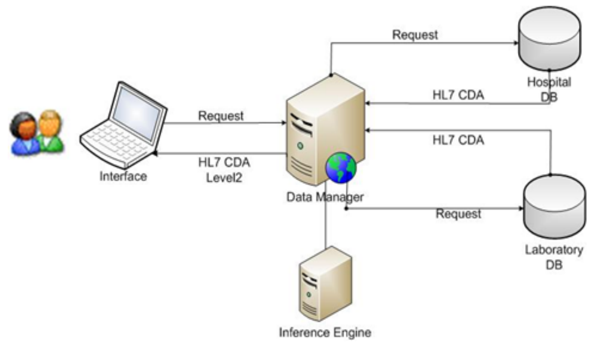

Fig. 5. CDS system arhitecure.

The **Clinical Decision System** is based on Web Services. The inferring engine is based on Egadss open source solution (Weber-Jahnke et al, 2008), (Bilykh *et al.,* 2006). For a standardized communication interface between databases and "recommendation generator" Egadss has as inputs HL7 CDA (Level 3) standard messages as XML files, containing the patient data (XML retrieved from the HL7 CDA Component). Egadss uses as standard for medical rules representation the Arden Syntax, as a clinical guideline formalism accepted as an official standard by the HL7 group. The result of the inference is a CDA Level 2 document, containing the medical recommendations (Weber-Jahnke *et al.,* 2008; Bilykh *et al.,* 2006). To manage the connection and the order in which different web services are called, a Data Manager was developed. The Data Manager responds to different requests from the main components of the system (interface, medical data source, inference engine). To achieve this, three communication channels are opened by the Data Manager, as presented in Figure 5: to the Interface, to the HL7 CDA Component and to the Inference Engine (Egadss). The Interface facilitates visualization of the protocols' steps, and medical information regarding a patient for the medical staff, alarms, and feedback concerning the recommendations. The interface is implemented using ASP.Net platform with C# (Gomoi *et al.,* 2011). Besides the use of an HL7 CDA document, other sources can be added to the system through the Data Manager (Gomoi, 2012).

5.2 Using the HL7 CDA standard

For the current system, data is sent between applications based on the HL7 CDA standard.

The HL7 CDA is a document mark-up standard that specifies the structure and semantics of "clinical documents" for the purpose of data exchange and it is a complete information object which can include text, images, sounds, and other multimedia data and could be any of the following: discharge summary, referral, clinical summary, history/physical examination, diagnostic report, prescription, or public health report (Healthcare, 2007; HL7, 2009).

The system architecture is presented in Figure 6, where the Obstetrics-Gynecology Department Information System communicates with the Pediatrics Department Information System and the Clinical Decision Support System based on HL7 CDA standard.

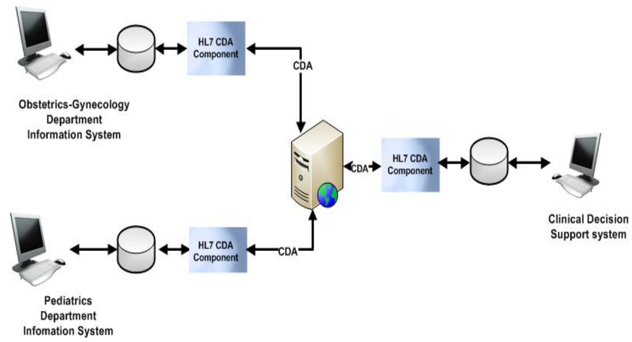

Fig. 6. Communication using HL7 CDA and Web Services.

The HL7 CDA Component creates the XML file in HL7 CDA format and sends it to the applications connected using Web Services. The HL 7 CDA Component is developed in Visual Studio.NET using C# language. In Figure 6 is presented an XML file in HL7 CDA format.

```
<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 7. Example of an HL7 CDA

The HL7 CDA example presented in Figure 7 shows what type of allergy has a patient. It uses two medical codes: LOINC (Logical Observation Identifiers Names and Codes), a code which is used in this case to describe the type of section - in this case it is allergy and adverse reactions - and ICD-10-AM, describing which event happens when this allergy is enabled.

5.3 Using the Continuity of Care Document standard

CCD is an electronic document exchange standard for sharing patient summary information among providers and within personal health records. It summarizes the most commonly need pertinent information about current and past health status in a form that can be shared by all computer applications, from web browsers to electronic medical records (Ferranti, 2006).

CCD is a set of constrains on CDA that define how to use the HL7 CDA to communicate clinical summaries built using HL7 CDA elements (Healthcare, 2007).

CCD is compatible with any document or standard that uses RIM (Reference Information Model) – based specifications, including new versions of HL7, new types of public safety reports, IHE (Integrating the Healthcare Enterprise) specifications, HITSP (Healthcare Information Technology Standards Panel) specifications and CDISC (Clinical Data Interchange Standards Consortium) (Ferranti, 2006).

CCD templates include: header, purpose, problems, procedures, family history, social history, payers, advance directives, alerts, medications, immunizations, medical equipment, vital signs, functional states, results, encounters and plan of care (Ferranti, 2006).

The system architecture based on the CCD standard for communication is presented in Figure 8, where the Obstetrics-Gynecology Department Information System and Pediatrics Department Information System communicate with the General Practitioner Information System. The communication is realized using Web Services.

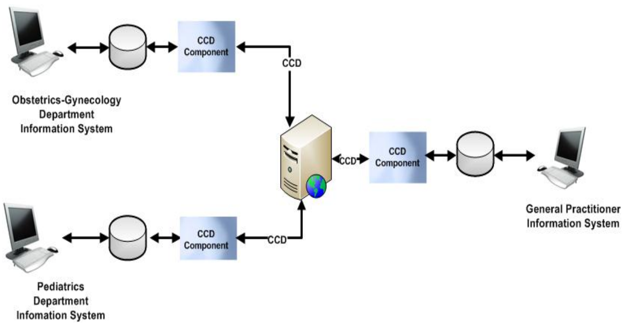

Fig. 8. Communication using CCD and Web Services.

The CCD Component creates an XML file in CCD format and sends it to other applications using Web Services. The CCD Component is developed in Visual Studio.NET using C# language. In Figure 8 is presented an XML file in CCD format.

```
<component>
    <observation classCode="OBS" moodCode="EVN">
        <templateID root="11"/>
        <code displayName="Eritrocite" codeSystem="2.16.840.1.113883.6.1" code="11273-0"/>
        <statusCode code="completed"/>
        <effectiveTime>20110515</effectiveTime>
        <value value="5.36" unit="x10^6/uL" xsi:type="PQ"/>
        <methodeCode codeSystem="2.16.840.1.113883.5.84" code="460179">
            <referenceRange>
                <observationRange>
                    <text>4.00-5.80x10^6/uL</text>
                </observationRange>
            </referenceRange>
        </methodeCode>
    </observation>
</component>
```

Fig. 9. Example of CCD.

The CCD example in Figure 9 presents a laboratory result. In this case the erythrocytes volume is represented using a LOINC code. It also contains the result of the lab test and the measurement units.

6. RESULTS

The solution connecting 4 healthcare information systems - Obstetrics-Gynecology Department Information System, Pediatrics Department Information System, General Practitioner Information System and Clinical Decision Support System - making them interoperable has clear benefits increasing the quality of patient care through less medical errors, clinicians having the proper information available from anywhere and at any time. Using the suggested technology with Web Services and Windows Communication Foundation (WCF) the communication can be done without human help, and the data can be transmitted in real time. All the applications are web based, ensuring ubiquity, and the only restriction is for the user having an Internet connection.

The data transmitted between the healthcare information systems was provided by Bega Obstetric and Gynecology Clinic, Timisoara, Romania. In 2010, there were 2302 pregnant women which gave birth. The mother and children data were used for testing the communication between the Obstetrics-Gynecology Department Information System and Pediatrics Department Information System, and from the Obstetrics-Gynecology Department Information Systems to the General Practitioner, and from Obstetrics-Gynecology Department Information System to the Clinical Decision Support System. Based on this communication and the received data, the Clinical Decision Support System issued specific medical recommendations.

We used two sets of patient data which was transmitted between healthcare information systems. The first set is represented by data regarding the 2326 births that took place in 2010 at the Bega Obstetrics – Gynecology Hospital, Timişoara, Romania. Data regarding the mother, the fetus and the medical intervention performed on the mother or baby in order to help the birth were received as a Sheet in Microsoft Excel (there was no confidential data). For each birth the following data were retained: Age, The mother's background – rural or urban

- Gesta – the number of the current pregnancy
- Para – the number of the current birth
- The number of gestation weeks
- The month in which the birth took place
- The number of labour hours
- Presentation - the fetus position at birth, with the possible values, cephalic – the fetus has its spine parallel the mother's and its head down, its chin in the chest, pelvic – the fetus comes out feet or bottom first, facial – the fetus looks ahead, its face comes out first and transversal – the fetus is positioned sidelong in the belly
- Sex
- Weight
- Type of birth - natural birth or caesarean section,
- Videx – if a metal cap is used or not to help natural birth, the reason for a C-section,
- Episiotomy – indicates if a cut was made in the perineum in order to help the natural birth
- Emp – indicates if a manual extraction of the placenta was made
- The Apgar score - which is an estimate of the vital functions and of the capacity to adapt to the

conditions of the extra uterine environment, it is a whole score from 0 to 10

The second source is represented by data regarding the 217 births in 2011. Data regarding the mother, the fetus and the medical intervention performed on the mother or baby in order to help the birth were received as a Sheet in Microsoft Excel (there was no confidential data). In the next lines is presented which data contains the Excel file: birthday; type of studies; weight; body mass index; height; smoking; alcohol; number of pregnancy; number of births; hemoglobin; erythrocytes; maternal glucose; systolic blood pressure; diastolic blood pressure; uterine fundus height; abdominal circumference; weight gain; pregnancy evolution; gestational age; number of days late; type of delivery; newborn gender; newborn weight; newborn head circumference; newborn length; apgar score; primary diagnosis; diagnosis code.

The benefit of the solution is that the communication is automatically done. Any of the healthcare information systems or the CDS system needing information sends a request to the information systems involved. E.g., the Pediatrics Department Information System sends to the Obstetrics-Gynecology Department Information System a request in XML format which contains the mother ID, baby's number and the baby birth date, and this will be analyzed by the Obstetrics-Gynecology Department Information System which sends automatically the needed information.

7. CONCLUSIONS

The paper presents a technology applied to raise the interoperability degree between different medical information systems. Web Services ensure communication between medical units automatically with minimum human intervention, an essential requirement when designing applications for users of the medical domain. To support the solution, four web based information systems communicating using Web Services - in this case WCF, a Microsoft technology - were used as a case study: Obstetrics-Gynecology Department Information System, Pediatrics Department Information System, General Practitioner Information System and a Clinical Decision Support System.

The advantages considered using the Web Services are: the medical applications can send information about the patient to related applications, even ones using different technologies (e.g., Java), being platform independent and sending standardized information in an automatically way.

Using the same solution, future work will be done extending the communication to other related healthcare information systems: Neonatology Department, Cardiology Department.

Using Web Services to improve the interoperability between different applications will have benefits in increasing the quality of the medical care, reduce the variation in medical practice and errors, and provide real information in real time.

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