Mapping CDA Documents for Health Information Exchange from Multiple Hospitals using Cloud Computing System

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Abstract - *Maintenance of Electronic Health Record helps improve patient safety and quality of care, but to do that we need the operation of interoperability between Health Information Exchange at different hospitals. The Clinical Document Architecture (CDA) established by HL7 is a core document standard to ensure such interoperability. Unfortunately, hospitals refuses to adopt interoperable HIS due to its deployment cost. More problem arises when all hospitals start using the CDA document format because the data scattered in many documents are difficult to manage. In this paper, we describe our CDA document generation and integration which is an Open API service based on cloud computing, through which hospitals are enabled to conveniently generate CDA documents without having to purchase software. Our CDA document integration system integrates multiple CDA documents per patient into a single CDA and physicians and patients can browse the clinical data in chronological order. Our system of CDA document generation and integration is based on cloud computing and the service is offered through Open API. Developers using different platforms thus can use our system to enhance interoperability.*

Key Words: **Electronic Health Record, health information exchange, HL7, CDA, cloud computing, SaaS**

1.INTRODUCTION

The health information that consists health of the patient, health care provided to that patient as well as the reaction of the patient to the provided healthcare can be stored as electronic health information in the form of longitudinal collection, thus forming an Electronic Health Record (EHR) [1]. Therefore, the implementation of HIE system is made to ensure successful maintenance of EHR [2]. But there is also a problem of incompatibility between systems and also there are different characteristics involved in HIS [3], [4]. Thus, there is a need to standardize the health information exchange between hospitals ensuring interoperability over health information. Therefore, the core of guaranteeing interoperability is to standardize the clinical document.

The major standard for clinical documents is CDA which was established by Health Level Seven (HL7). CDA is the core document standard, an XML document which holds the structure and semantics of clinical documents for health information exchange. The first version of CDA was released on 2001 and it's second version was released on 2005. Many countries have done many successful projects adopting CDA [7], [8], [9]. To improve semantic interoperability, many active works are done based on openEHR and CEN3606 [10], [11].

More HIE system has to support CDA to establish confidence in interoperable Health Information Exchange. Moreover, the structure of CDA is too complex and the correct CDA Document production is difficult without the good understanding of the CDA standard and enough experience with it. Also, the HIS development platforms for hospitals differ so greatly in such a way that generation of CDA documents in every hospital invariably requires a separate CDA generation system. In addition to that, hospitals refuses to adopt a new system unless it is perfectly necessary for delivery of care. As a result, except for only few handful countries like New Zealand or Australia, the adoption rate of EHR is too low [12]. To promote EHR adoption among hospitals, the USA government had implemented an incentive program called the Meaningful Use Program [13].

A CDA document which has the record for the diagnosis is generated, when a patient is diagnosed at a clinic. This CDA document will be shared with other hospitals if the patient agrees. A person or an patient may shift his location from one place to another hence it is common for a that patient to visit a number of different hospitals for check-in or treatment. The exchange of CDA document is invoked in the following cases: when a medical personnel needs to study a patient's medical history; when referral and reply letters are drafted for a patient cared by multiple hospitals; when a patient is in emergency and the medical history needs to be reviewed.

It takes a huge amount of time for the medical personnel because the amount of exchanged CDA document increases because more documents means that data are distributed in different documents. This definitely delays the medical personnel in making decisions. Therefore, when all the CDA documents are integrated into a single document, the medical personnel is motivated to view the patient's medical history conveniently in chronological order per clinical section and the corresponding care service can be provided more effectively. Sadly for now, a solution that integrates multiple CDA documents into one do not exist yet to the best of our knowledge and there is a practical limitation for individual hospitals to develop and implement a CDA document integration interface.

In this paper we show (1) a CDA document generation system that generates CDA documents on different developing platforms for the interface to be platform independent and (2) a CDA document integration system that integrates multiple CDA documents scattered in different hospitals for each patient.

The benefits of implementing this system are as follows. First, the system can be accessed through an Open API and developers can continue working on their developer platforms they are specialized for example Java, .NET, or C/C++. Hospital systems can simply extend their existing system instead of completely replacing it with a new system. Second, the hospitals do not have to train their personnel to generate, integrate, and view standard-compliant CDA documents. The cloud based CDA generation service produces documents in the CDA format approved by the National Institute of Standards and Technology (NIST) [14]. Third, as these services are provided free of cost at low price to hospitals, existing Electronic Health Record are more likely to consider adoption of CDA in their practices.

This paper is organized as follows. In Section 2, we have provided with a detailed explanations on the format of CDA document, cloud computing, and the overall architecture of our proposed system. Section 3 describes the effectivity of the proposed system and contrasts it to different HIE systems in various countries to improve the strength of our system.

2.MATERIALS IMPLEMENTED

In this section, we present the necessary techniques in detail for the design, and explain the implementation of our CDA generation and integration system based on cloud computing.

2.1 The CDA Document

American Nation Standards Institute approved the HL7 Clinical Document Architecture Release 2 (CDA R2) in May 2005, where CDA is an XML-based document markup standard that specifies the structure and semantics of clinical documents, and its primary purpose is to facilitate clinical document exchanges between heterogeneous software systems.

A CDA document is divided into its header and body. The header has a defined structure and it includes information about the patient, hospital, physician, etc. The body part is flexible than the header and contains various clinical data. Each piece of clinical data is allocated a section and given a code as defined in the Logical Observation Identifiers Names and Codes (LOINC) [15]. Different subcategories are inserted in a CDA document depending on the purpose of the document, and we chose the Continuity of Care Document (CCD) [16] because it contains the health summary data for the patient and it is also widely used for interoperability. Types of data included in CCD are listed in Table 1.

We chose the Korean Standard for CDA Referral and Reply Letters (Preliminary Version) format for CDA integration system as the number of clinical documents generated when patients are referred and replies made, is large [17], [18]. It has the identical structure as the CCD and the types of data contained in the body are listed in Table 2.

2.2 Cloud Computing

Cloud computing is defined as using a network of remote servers, hosted in the Internet that helps to store, manage, and process data, rather than a local server or a personal computer. It refers to the applications delivered as services over the Internet and software in the data centers that provide those services [19]. The user pays fee depending on the amount of resources allocated, such as network, server, storage, applications and services. Currently, three major types of cloud computing services exist:

1. Software as a Service (SaaS): It is a software distributed model where the third-party provider hosts all the applications and makes them available to customers through the Internet.
2. Platform as a service (PaaS): It is a category of cloud computing services that provides a platform for allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure typically associated with developing and launching an app.
3. Infrastructure as a Service (IaaS): It is a form of cloud computing that provides virtualized computing resources over the Internet.

In this paper, we chose Amazon Cloud, a widely used cloud service [20], and provide the CDA generation and integration system as SaaS.

TABLE 2
Sections in the Korean Standard for CDA Referral and Reply Letters Body (Preliminary Version)

Sections in CDA body	CDA Referral letter	CDA Reply letter
Diagnosis	Yes	Yes
History of past illness	Yes	No
History of Medication Use	Yes	Yes
Laboratory studies	Yes	Yes
Radiology studies	Yes	Yes
Pathology studies	Yes	Yes
Function Status Assessment	Yes	Yes
Surgical Operation Note	Yes	Yes
Relevant Diagnostic Tests	Yes	Yes
Reason for referral	Yes	No
Special Treatments and Procedures	Yes	No
Subsequent Evaluation Note	No	Yes
Plan of Treatment	No	Yes

3.CURRENT METHODOLOGY

In the existing methodology, the CDA Documents generated in the cloud using the HIS system where the CDA Generation and Integration interface to connect with the APIs of both Generation and Integration residing in the cloud server.

3.1 CDA Generation System based on Cloud Computing

The overall architecture of how CDA documents are generated on the health information systems of different hospitals by using our cloud computing-based CDA generation system is shown in the Fig. 1. To show that it is easy to generate CDA documents on a variety of platforms if done via cloud we have demonstrated using two Hospitals - Hospital A and Hospital B. The purpose of each of the components is as follows:

- CDA Generation API generates CDA documents on cloud.
- CDA Generation Interface makes use of the API provided by the cloud and relays the input data and receives CDA documents generated in the cloud.
- Template Manager is responsible to manage the CDA documents generated in the cloud server. Our system uses CCD document templates.
- CDA Generator collects patient data from hospitals and generates CDA documents in the correct format which is been suggested by the Template Manager.
- CDA Validator inspects whether the generated CDA document complies with the CDA schema standard.

TABLE 1
Data Items in CCD Header and Sections in the CCD Body

CDA location	Data items
CDA Header	Document Information (creation time, template ID, language code, purpose) Patient's information (ID, name, gender, birth date) Author's information (ID, name, represented organization) Organization's information (name, address, phone number)
CDA Body	Payers Advance Directives Support Functional Status Problems Family History Social History Allergies Medications Medical Equipment Vital Signs Results Procedures Encounters Plan of Care

The DBMS maintained by each hospital and the HIS are linked as follows: Hospital A, using a .Net-based system is connected via ODBC to connect to the DBMS while Hospital B, which uses a JAVA-based system, is linked with Hibernate.

At a hospital, the medical information of patient, hospital, and physician is entered using CDA Generation Interface and it is sent to the cloud server using CDA Generation API. We use SOAP (Simple Object Access Protocol) as transmission protocol to enhance interoperability among multiple HIE systems when a hospital sends data to the cloud. CDA Generation API relays the data in the CDA Header/Body in the form of list.

The items included in CDA Header are: PatientID, BirthDate, Gender, Name, and FatherName. In CDA Body, the following items are included: Problem, Medication, Laboratory, Immunization, and so on. The data sent to the CDA Generation API are packaged in CDA Header Set and CDA Body Set and relayed to CDA Generator, which retrieves a CCD template from Template Manager and fills in the appropriate fields of the CCD template with the data from the CDA Header/Body sets.

The generated CDA document is inspected by the CDA Validator to check the CDA standards. After inspection, the CDA document is returned to the recipient hospital.

3.2 CDA Integration System based on Cloud Computing

The integration of multiple CDA documents are integrated into one in our CDA Document Integration System as shown in the Fig. 2. The standard for this is Korean Standard for CDA Referral and Reply Letters (Preliminary Version). Templates that generate a CDA use CCD part of Consolidated CDA was released by ONC and made by HL7. But, the actually generated CDA has a form of CDA Referral and Reply Letters.

The rationale for CDA document integration is given below [21]. When CDA-based HIE (Health Information Exchange) is perfectly used among hospitals, the number of CDA documents corresponding to each patient increases in time. Physicians need to spend a significant portion of their time on viewing these documents for making clinical decisions.

In Korea, physician's consultation time spent per patient is very less since the insurance model is fee-for-service. Chronic patients are mainly very likely to have been consulted by multiple doctors, in different hospitals. In this case, CDA documents will be scattered in many different locations. Therefore, multiple CDA documents needs to be integrated into single CDA document. If the clinical history of a patient is available in a single CDA document, the doctor's time can be more efficiently used. This is evident when a patient is being referred to a other hospitals or when a referral reply letter is forwarded. Our survey of doctors shows that displaying each section in chronological order helps improve the quality of care. The exisiting system shows how we integrate CDA documents on a cloud server so that any of existing systems can be easily extended to generate integrated CDA documents.

In the hospital, the CDA documents to be integrated are processed through our CDA Integration Interface. The CDA Integration API in cloud relays each CDA document sent to the cloud to the CDA Parser, that converts each input CDA document to an XML object and analyzes the CDA header and groups them by each patient ID. The CDA Document Integrator integrates the given multiple CDA documents into a single CDA document. In this process, the data in the same section of xml coded part in the document body are merged, using the LOINC values that differentiates each section in the CDA document.

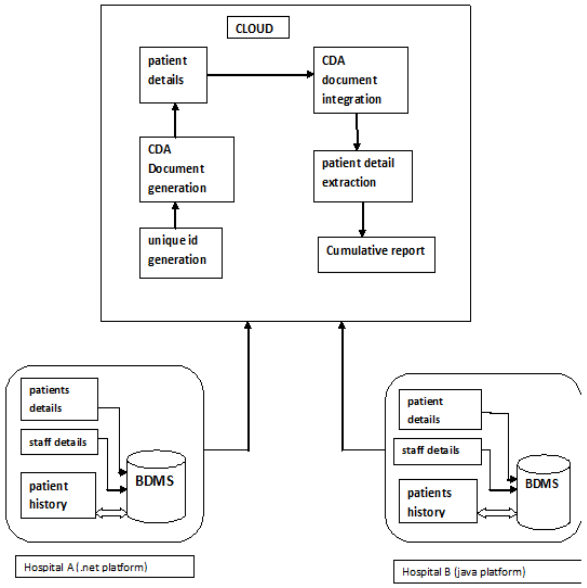

Fig -1: CDA Generation and Integration in Cloud

The integrated CDA document is checked for error in the CDA Validator, and the result is returned as string to

the hospital that requested CDA document integration. This is because the CDA Integration System and the CDA Generation System are separate different entities, and a new CDA document is made after document integration, hence it is mandatory to determine whether the new document complies with the CDA document integration, mainly whether there is any missing element, or the format is wrong. Error messages are returned when the missing element is found. And then the received string is converted to a CDA document file and saved. The validation process happening at the CDA Validator is based on the CDA schema. An error is returned when a required field has been left blank or the wrong data type has been used.

4.PROPOSED METHODOLOGY

The objective of our system is to generate the PDF format for the generated and integrated CDA Documents for the use of Patients. This conversion takes places in the CDA Generation and Integration Interface located in the HIS systems of the hospitals. Also, we have included an other attribute in the CDA Header like Aadhar number applicable in India to generate the unique ID in the cloud to create security of information residing in the cloud.

Our cloud computing based CDA generation and integration system has a few pronounced advantages over other existing projects. First, hospitals do not have to purchase propriety software to generate and integrate CDA documents and bear the cost as before. Second, our service is readily applicable to various developer platforms because an Open API is to drive our CDA document generation and integration system. Regardless of the type of the platform, CDA documents can be easily generated to support interoperability. Finally, the integrated CDA Documents is converted to PDF format.

4.1 Registration and Appointment

Users in the hospital environment will have an initial registration in the web end. The server in turn stores the information in its database. Now the patient login and fix appointment to the Doctor by mentioning time and date of the appointment, disease, specialist and name of the doctor. Each Doctor views their appointment in their appointment page.

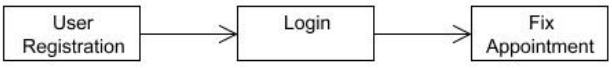

Fig -2: Registration and Appointment

4.2 Patient Report Generation

Doctor view the patient information such as disease, symptoms etc. If it necessary patient is advised to take lab test. Lab Technician provides test result to patient. Based on test result, Doctor suggests prescription to the patient, and also patient health history should be maintained in appropriate hospital database. Doctor can view patient health history before he suggests prescription to the patient.

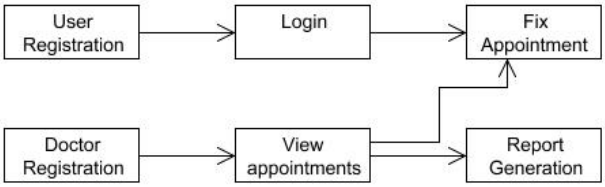

Fig -3: Patient Report Generation

4.3 CDA Generation

In this module patient health informations are send to the cloud server. Now the cloud server will generate unique id for every users based on patient name, father name, date of birth and additionally Aadhar card number using PJW Hash Algorithm. If already id exist then the patient details will be appended with patients clinical history else new CDA document will be generated.

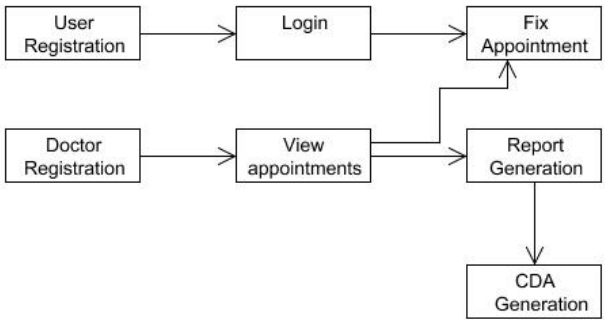

Fig -4: CDA Generation

4.4 Parsing CDA Document

In this module the new patient enter into hospital no need to give details about the disease and symptoms. The patient history already maintained in cloud server so we can get the patient histories by using key it is

retrieve from patient personal details. The patient histories maintained in document which is contains patient clinical histories (hospital name, disease, prescription).

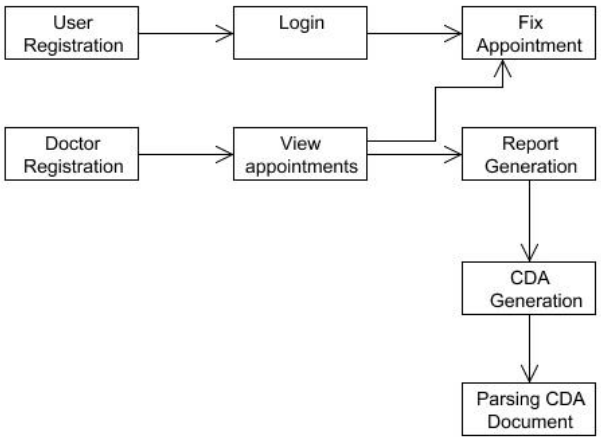

Fig -5: Parsing CDA Document.

4.5 Converting CDA Document to PDF

The parsed CDA Documents are received at the HIS system where the documents are converted into PDF for the personal use of the patient. To do this, we need to add an application called PDF conversion interface. This can be simply extended with the existing software where the entities like CDA Document Generation and Integration resides.

5. CONCLUSION

We establish an efficient way of generating the PDF format for the generated and integrated CDA Documents for the use of Patients. Our cloud computing based CDA generation and integration system has a few pronounced advantages over other existing projects. First, hospitals do not have to purchase propriety software to generate and integrate CDA documents and bear the cost as before. Second, our service is readily applicable to various developer platforms because an Open API is to drive our CDA document generation and integration system. Regardless of the type of the platform, CDA documents can be easily generated to support interoperability. Also, additionally the integrated CDA Documents of the patient is converted into the PDF format for the use by Patients. Thus, the time is saved for the doctors in taking medical decisions at emergency times and deliver the correct health care as the medical records are in chronological order.

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