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# Towards Developing an Interoperability Framework for Healthcare Community of Practice

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## *Abstract*

*The Healthcare Industry is one of the world's largest and fastest growing industries, consuming over 10 percent of gross domestic product (GDP) of most developed nations, and has a major impact on any country's economy. One of the biggest issues the healthcare industry struggles with is Interoperability of Health Information. Central to interoperability is the ability of one healthcare organization task to be "visible" in another healthcare organization. Healthcare tasks usually expressed in an acceptable some standard like HL7 CDA or FHIR. However, it all ends into how one can mobilize interoperability within the fabric of healthcare organizations. In particular how one can implant interoperability within healthcare tasks workflows and their communities of practice.*

*A Community of Practice is a group of people who share a craft, a profession, passion, or a concern and deepen their knowledge and expertise in the area by interacting on an ongoing basis. Each Community is a unique combination of three fundamental elements: a "Domain" of knowledge, which defines a set of issues and can vary from basic know-how to technical expertise; a "Community" of People that care about this domain; and a shared "Practice" that they are developing to be effective in their domain, and is made up of set of frameworks, ideas, tools, styles, languages, stories, and documents that the community members share.*

*We introduce a Community of Practice model for healthcare that we call "Intersecting Communities of Practice", where the medical practitioners can collaborate and form individual communities to share and exchange discharge summaries between them providing their individual input and contribution, while discussing issues via a "messaging subsystem", thereby fostering knowledge growth and facilitating better patient-care. We provide an interoperability environment by implementing HL7's Clinical Document Architecture (CDA) standards.*

***Keywords**: Healthcare, Electronic Healthcare Record (EHR), Community of Practice (CoP), Interoperability, Heath Level Seven (HL7), Clinical Document Architecture (CDA)*

## 1. Introduction

The Healthcare Industry is one of the world's largest and fastest growing industries, consuming over 10 percent of gross domestic product (GDP) of most developed nations and has a major impact on any country's economy. The delivery of healthcare services fundamentally comprises of three visible forms. *Primary Care,* which is the day-today-care given by a healthcare provider, and acts as the first contact and the principal point of continuing care of patients. *Secondary Care* is the health care services, such as acute care, provided by health professionals who generally do not have first contact with patients, Cardiologists and Urologists for example. Tertiary Care is a specialized consultative health care, usually for inpatients and on referral from primary and secondary health professional for advanced medical investigation and treatment. The rapid emergence of

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the Information Technology Solutions has benefited the healthcare industry. Today Healthcare organizations are expected to deliver faster, more secured and continuous patient-care. IT-enabled healthcare applications simplify the various healthcare processes including but not limited to administration, management of healthcare records and billing. Such applications are referred to as Electronic Healthcare Record's (EHR's). In order to provide a seamless, on-time and efficient patient care, it is so important to have proper thread of communication between all three levels of healthcare, especially for countries like Canada, where healthcare is one of the top priorities. Though moving from use of paper based documents to EHR systems has improved the patient-care radically, this industry still has its challenges ranging from medical errors to health insurance. One of the biggest issues the healthcare industry struggles with is ***Interoperability*** of Health Information. It is estimated that more than 30% of healthcare spending is wasted on costly, ineffective and redundant care, as patients switch between hospitals, doctors and healthcare system. Quite often this is because of the disparity in following up the patient data. Most of the patient data is in form of *patient-story* or *patient-narratives* and most EHR systems don't work well with other EHR systems. In other words they lack platform interoperability.

One of the ways to tackle this problem is by standardization of the medical data. Organizations like Health Level Seven (HL7) International and American Society of the International Association for Testing and Materials (ASTM) International provide wide range of standards and vocabulary for integrating, exchanging, management and retrieval of electronic healthcare data. The Clinical Document Architecture (CDA) by HL7 is one of the most widely used medical document standards. It is an XML-based specification and uses HL7's Reference Inference Model (RIM) to represent health concepts and takes advantages of coding systems such as Systemized Nomenclature of Medicine—Clinical Terms (SNOMED CT) and ( LOINC). A CDA Document is a well-defined and complete information object that can include text, images, sounds, and other multimedia content and provides Persistence, Stewardship, Potential for authentication, Context, Wholeness, and Human Readability to a clinical document. A Community of Practice is a group of people who share a craft, a profession, passion, or a concern and deepen their knowledge and expertise in the area by interacting on an ongoing basis. Each Community is a unique combination of three fundamental elements: a ***Domain*** of knowledge, which defines a set of issues and can vary from basic know-how to technical expertise; a ***Community*** of People that care about this domain; and a shared ***Practice*** that they are developing to be effective in their domain, and is made up of set of frameworks, ideas, tools, styles, languages, stories, and documents that the community members share.

Providing an efficient, timely and cost-effective patient-care is a team effort. These days it is a common practice to involve the patient in the process of care. Injecting the idea of a community of practice into healthcare enables medical professionals to read, submit and receive advice and feedback from the community to the extent that they wish. Even less active members who chose to participate in a strictly receptive manner can still gain knowledge from the communal resources. The result is an atmosphere of mentorship for novices. As new practitioners gain understanding and expertise, they become more comfortable with sharing their own backgrounds and perspectives with the community further expanding the field of knowledge. The communities maintain a record of ideas, discourse and resources, creating an archive of expertise for a field of practice that can be accessed at any time from nearly anywhere.

Our prototype is essentially a framework for Community of Practice in Healthcare where the members can collaborate and form individual communities to share and exchange discharge summaries between them providing their individual input and contribution, while discussing issues via messaging a subsystem, thereby fostering knowledge growth and facilitating better patient care. We provide an interoperability environment by implementing HL7's Clinical Document Architecture (CDA) standards.

 

The rest of the paper is organized as follows. In Section 2, we discuss the Background and some of the Related Work done by other researchers in the field of standardization and interoperability of clinical data as well as discussing in brief, the idea of Community of Practice. In section 3 we discussed our Prototype Design, introducing our model for *Intersecting Communities of Practice* and how we achieved clinical data interoperability using CDA standards. We discuss the design architecture of our prototype. Section 4 gives an insight on our Implementation explaining in the project, the technologies involved, the software design and the functional specification. Finally in section 5 we draw the conclusion of our research and the future work that can be carried out on the platform we have set through our research.

## 2. Background and Related Work

In this section discussed Background and Related Work, explaining key concepts and previous approaches in the field of standardization and interoperability of clinical data as well as discussing in brief the idea of Community of Practice.

### 2.1. Electronic Healthcare Record (EHR) Interoperability

IT-enabled healthcare applications simplify the various healthcare processes including but not limited to administration, management of healthcare records and billing. Such applications are referred to as Electronic Healthcare Record's (EHR's)[1]. There are several factors that need to be considered for efficient implementation of an EHR system. These include significant changes in the workflow, privacy and security, handling duplication of records and interoperability. The Institute of Electrical and Electronics Engineers (IEEE) defines interoperability as *"ability of a system or a product to work with other systems or products without special effort on the part of the customer."* In the IT sector the term Interoperability refers to the extent to which two or more systems can exchange, interpret and subsequently use the shared data. *."* In healthcare it would refer to the effective sharing of clinical data within and across organizations including clinicians, lab, hospitals, pharmacy and the patient itself, regardless of the application or the vendor. Due to the presence of a large variety of EHR systems, the healthcare sector faces a lot of challenges providing continuity in patient care. Each year we face tremendous losses in terms of time, money and most importantly patient's health due to absence of a common platform. An interoperable platform allows practitioners and healthcare organizations to provide continuity in patient-care while fostering administration and researches. It decreases inefficiencies and efficacies improving overall patient's health and care quality. As we are dealing with extremely sensitive data, it becomes really important to preserve both the structure and the semantic meaning of the exchange information without compromising with the privacy.

Health Level Seven International (HL7)[1], founded in 1987, is *"a non-profit, ANSI-accredited standards developing organization dedicated to providing a comprehensive framework and related standards for exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation pf health services."* Level Seven refers to the seventh level of Open Systems Interconnection (OSI) model by the International Organization for Standardization (ISO) –the application layer. It provides flexible specifications, guidelines and standards that enable healthcare systems to communicate with each other ensuring the interoperability of clinical data. It consists of collection of message formats and related clinical standards that loosely define an ideal presentation of a clinical information and provide an interoperability framework [2]. As the complexity of clinical information grew and the need to address these issues became more important than ever, the growing HL7

[1] http://www.hl7.org/

community came up with HL7 V.3 Messaging standards in the late 1990's. Though the first normative edition of HL7 V3 Messaging Standards was released in 2005, which is a suite of specifications based on HL7's Reference Information Model (RIM) with full set of messages, data types, and terminologies. HL7 V3 messages are based on XML encoding system due to well-formedness, error-handling and schema validation mechanisms.

Down the years many attempts were made to achieve interoperability using the HL7 version 3 standards. In 2011, [3] Mustafa Yuksel and Asuman Dogac, used ISO/IEEE 11073 Domain Information Model (DIM) to derive an HL7 v3 Refined Message Information Model (RMIM) of the medical device domain from the HL7 v3 Reference Information Model (RIM). They were able to trace the medical device data back to a standard common denominator, that is, RIM, further transforming them into HL7-based standard interfaces through XML transformations. They demonstrated the proposed method by mapping the developed RMIM to some widely used HL7 v3-based standard interfaces. Another attempt was made in the same year by [4] Teeradache Viangteeravat et.al., where the authors proposed a prototype implementation of HL7 V3-RIM mapping for information integration between distributed data sources to promote collaborative healthcare and translational research. The prototype ensured the accuracy of the information and knowledge extraction systems that were integrated.

## 2.2. Clinical Document Architecture (CDA)

The HL7 Version 3 Clinical Document Architecture or CDA is *"a document markup standard that specifies the structure and semantics of clinical documents for the purpose of exchange between healthcare providers and patients."* It aims to provide Persistence, Stewardship, Potential for authentication, Context, Wholeness, and Human Readability to a clinical document. A CDA document is usually a Discharge Summary, Imaging Report, Admission & Physical, and Pathology Report *etc*. It is an XML-based specification and uses HL7's Reference Inference Model (RIM) to represent health concepts. It also takes advantage of coding systems such as SNOMED CT (Systemized Nomenclature of Medicine—Clinical Terms) and LOINC (Logical Observation Identifiers Names and Codes). The normative edition of CDA (Release 2) was published by HL7 in 2006. A CDA Document is a well-defined and complete information object that can include text, images, sounds, and other multimedia content. It can be transferred within a message, and can exist independently, outside the transferring message.

Since CDA is widely used in exchanging medical information in the international community, we can find a lot of implementation based on CDA. In 2010, [5] Che-Ju Lin and Der-Ming Liou achieved interoperability using CDA Standards. They implemented a tool to generate and edit CDA documents. The tool provided interfaces to generate and edit a CDA template depending on the type of clinical document in play and a mapping engine that essentially mapped CDA elements from a legacy information table. The output CDA was save as XML. Another big implementation was observed in the same year when [6] Huang, Ean-Wen et.al., came with a Web-based system called Standardized Clinical Document Generation System tapping the power of the HL7 CDA Standards. The system converted the fields in more than 100 paper-based forms that were collected from hospitals in Taiwan to standardized format of CDA, as a reference for inter-hospital information exchange. It was set up to create numerous different types of document samples.

In the year 2010, [7] Sabah Mohammed et.al., presented an article outlining a distributed Web Interactive System for sharing health records on cloud using distributed OSGi services and consumers, called HCX (Health Cloud Exchange). The system was aimed at allowing different heath records and related healthcare services to be dynamically discovered and interactively used by client programs. These client programs run on a private cloud. The authors used Eucalyptus for providing private cloud infrastructure as a service. Apache CXF DOsGi was used for building distributed OSGI based services. The system allowed adaptors and bridges to be created for existing EHR systems and repositories in order to exchange health records in CCR format.

Another collaboration of Cloud services and CDA standards was evident when in 2012, [8] M. Vida et.al, proposed a method to improve interoperability of healthcare information systems by presenting a control that displayed fields from different databases and its cloud integration. They demonstrated the use of this control in a Pediatrics Application on Azure Cloud.

Later in 2012, [9] Lu Xiaoqi et.al. , demonstrated an Electronic Medical Records (EMR) Editing Subsystem using the CDA standards. It was a model-driven approach and unlike other researches mentioned above, a third party API called Open-Health Tools Model-Driven Health Tools (MDHT) was used for CDA generation. The subsystem was able to effectively produce, parse, validate and view clinical documents in a recursive manner.

Another interoperability approach was taken in the Italian healthcare in the November of this year. [10] Renato Calamai and Laura Gierre presented a localization experience for Patient summaries and e-Prescriptions Clinical Document Architecture Release 2. They implemented a Chronic Care Model (CCM) for sharing Patient Clinical Data among healthcare providers in the management of diagnostics and therapeutic pathways for chronic diseases. The research aimed General Practitioners (GP) and Health Specialists (HS). In 2014, [11] Sung-Hyun Lee et.al., took advantages of both cloud services and the CDA standards by implementing a CDA document generation and integration Open API service based on cloud computing. The system integrated multiple CDA documents per patient into single CDA document and physicians and patients could browse the clinical data in chronological order. For this Amazon Cloud was used as the cloud service provider and the CDA integration system was provide as a Software as a Service (SaaS).

Further in 2015, [12] Giovanni Vizzini et.al. , presented the case study of an interoperability system aimed at producing HL7/CDA2 documents to be sent to a centralized EHR. The case study dealt with the standardization of an analysis laboratory encoding system based on LOINC, focusing on a software tool for semi-automatic mapping of internal analysis laboratory codes into LOINC codes.

### 2.3. Community of Practice

A Community of Practice is a group of people who share a craft, a profession, passion, or a concern and deepen their knowledge and expertise in the area by interacting on an ongoing basis. Wenger, McDermott and & Synder are known to be written the first book that lays a common foundation of this area, though Community of practice is not a new concept and dates back to pre-historic era. Many examples of CoPs can be found in ancient Roman Empire and even throughout the Middle-Ages. Cultivating CoPs in strategic areas is a practical way to manage knowledge as an asset, while creating value for its members and organization. A Community can be small or big, long-lived or short lived, co-located or distributed. Spontaneous or intentional *etc*. and can provide tangible or intangible values, strategy-making or strategy-implementing value and many other. Each Community is a unique combination of three fundamental elements: a ***Domain*** of knowledge, which defines a set of issues and can vary from basic know-how to technical expertise; a ***Community*** of People that care about this domain; and a shared ***Practice*** that they are developing to be effective in their domain, and is made up of set of frameworks, ideas, tools, styles, languages, stories, and documents that the community members share. In 2008, [13] Emrah Orhun and James Hopple, published a paper discussing four theoretical frameworks derived from the theories of social capital and social exchange with aim of developing an integrative conceptual framework for knowledge sharing.

Virtual Community of Practice or VCoP, sometimes also called Online Community of Practice or OCoP is a CoP that is developed on and maintained on the internet. VCoPs provide a virtual space in which people who normally never meet can come together, share experiences, and solve problems pertaining to the domain interest. This idea mushroomed since the advent Web 2.0, a term coined by O'Reilly media in 2004, to refer to a new trend in websites and other Internet mediated services of encouraging and fostering online collaboration, sharing, and user feedback. Virtual COPs range from forums, blogs, and email servers to social networks.

In the year 2009, [14] Daniel Firpo et.al. , implemented a project at the school of Information Systems and Technology (SISAT) at Claremont Graduate University (CGU), U.S. The artifact developed was an online community for the purpose of improving sense-of-community amongst students, faculty, and the alumni. In the following year, [15] Paul Penfold publish a paper, exploring the potential use of Virtual CoPs to help the development, sharing and management of knowledge. It reviewed the development and nature of VCoPs and how new technologies can be introduced to help communication and collaboration, comparing the tools that can be used to build such communities.

CoPs have received increasing attention in the healthcare sector in the recent decade. CoP was originally developed to provide a template for examining the learning that happens among practitioners in a social environment, but over the years there have been important divergences in the focus of the concept. In 2009, [16] Linda C Li et.al. , published a research examining and evaluating the presence and effectiveness of CoPs in healthcare sector, reviewing literature, databases and journals published between 1991 and 2005. The research concluded that the structure of CoP groups varied greatly, ranging from voluntary informal networks to work-supported forma education sessions, and from apprentice training to multidisciplinary, multi-site project teams.

Another research by [17] Philip Candy in the same year, explored several major aspects of how technology is being used to deliver work-based e-learning, to provide electronic performance support, to allow access to information resources and communities of practice, and even to allow for the collection and sharing of data in real-time for both diagnostic and research purposes. As the field of healthcare accelerates into the digital age, patient care is increasingly mediated and enabled by ICT systems. With the wide adoption of large-scale information infrastructure, such as Electronic Health Records (EHR), in healthcare organizations, and the use of various patients care technologies deployed in homes and communities settings, health practitioners and consumers are able to make informed decisions based on readily available patient care information. Despite having been originally designed as record-keeping tools, many health IT systems have now become central infrastructures hosting collaboration and communication activity – an essential part of health practices. Patient care work is highly distributed among multiple stakeholders across different locations, such as the home, community and various clinics, over different periods of time. These stakeholders, on one hand, jointly document and use patient care information; and, on the other, constantly articulate and communicate patient-specific information in achieving collaborative work. In 2013, [18] Yunan Chen described the challenges and opportunities identified in designing medical records systems that are aligned with collaborative-nature of work practices.

## 3. Prototype Design

In this section we discuss our Prototype Design, introducing our model for *Intersecting Communities of Practice* and how we achieved clinical data interoperability using CDA standards. We discuss the design architecture of our prototype.

### 3.1. Intersecting Communities of Practice

We propose a Healthcare Community of Practice model called ***"Intersecting Communities of Practice"***, where the members can collaborate and form individual communities to share and exchange discharge summaries between them providing their individual input and contribution, while discussing issues via messaging a subsystem, thereby fostering knowledge growth and facilitating better patient care.

These communities may be "*Symmetrical* "or "*Asymmetrical" in* terms of number and type of members associated and the term *"Intersecting"* refers to the fact these communities are allowed to have one or more than member common between them depending on the need. We call such members as *"ambassadors."*

Figure 1 depicts our notion of the intersecting Communities of Practice.

Clearly, the ***Domain*** of these communities fall into a subset of the Healthcare domain that is majorly concerned with discussing and exchanging information on Patient Discharge Summaries, and set of issues related to it.

Each ***Community*** consists of members who fall into essentially four kinds of member roles:

***Administrator:*** Administrators or Admin can be a domain expert, such as a doctor that identifies the need for and spawns the community. The Administrator is also responsible for deciding and bringing in the rest of the community members.

***Lab Technician:*** A Lab Technician would be responsible for providing updates to the community pertaining to laboratory test results concerning the Patient file associated with the community.

***Nurse:*** A Nurse can help the collaboration in terms of inputs and updates on Patient's Allergies, Hospital Course *etc*.

***Patient:*** Our model aims at involving the Patient into the collaboration making him/her a part of the community. A Patient can view the summary and update his personal information such as demographics.

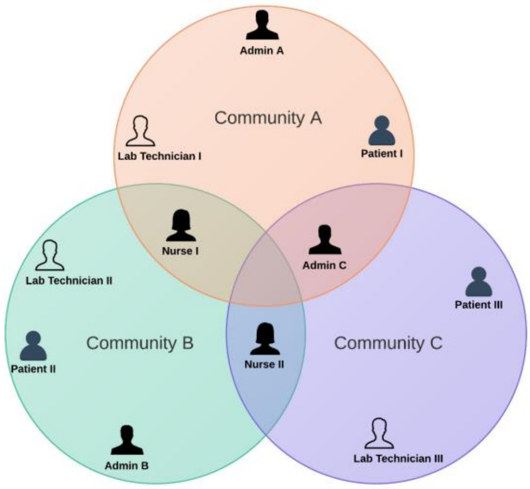


**Figure 1. Intersecting Communities of Practice**

The shared ***Practice*** here is made up of set of frameworks and documents that the community members share. The Practice incudes editing and sharing of the Patient Discharge Summary that community members share. The extent of editing the document varies from member to member depending on their privilege their level, which in turn, is determined by the role of the member in the community. Other than that, the community members can come together and share ideas by exchanging messages on a message board which will be community specific.

### 3.2. Achieving an Interoperability Environment

One of the most commonly used V3 specification is the Clinical Document Architecture (CDA), which is an XML-based specification that specifies the structure and semantics of clinical documents for the purpose of exchange between healthcare providers and patients. CDA standards provide Persistence, Stewardship, Potential for authentication, Context, Wholeness, and Human Readability to a clinical document. Based on XML encoding system, these documents easy to generate, parse and validate.

Due to its simplicity, completeness and its wide use in exchanging medical information in the international community, the *CDA standards* is our choice of documents format to be used in order to efficiently share medical information. We would like to focus on the exchange of *Discharge Summaries* so as to foster accurate and continuous patient care.

### 3.3. Application Architecture

Figure 2 shows an abstract view of the proposed architecture of our web based application. The entire application will be constructed around a Web Application Framework, which would be the central building block of our application. Users would interact to the web application via http requests sent through web browsers. The Web application would provide a *User View* to create and manage communities and exchange real time messages through the components *Community Manager* and the *Messaging Subsystem* that would interact with the *Database.* The users would be able edit patient discharge summaries from the local file system through the component *Editing Subsystem*, which, in turn would depend on the *Document Interoperability Module* that will have components to generate and parse patient records in form of XML based CDA documents.

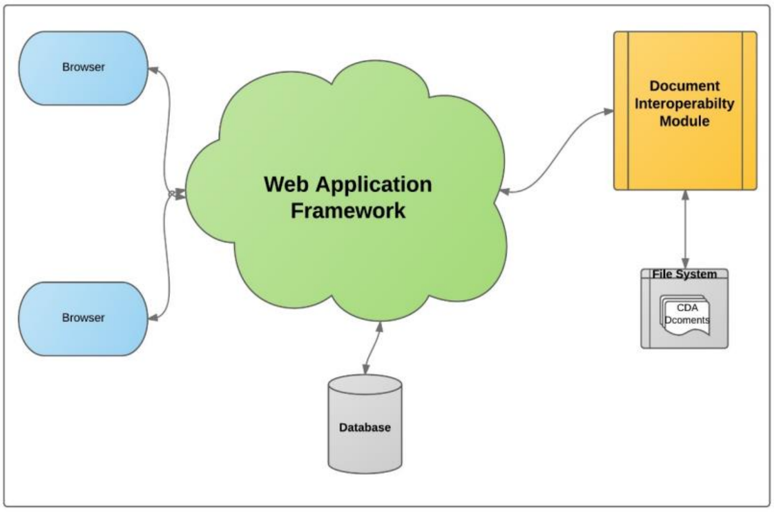


**Figure 2. Application Architecture**

### 3.4. Interoperability Module

The Interoperability Module will act as a broker between the Web Application Framework and the Patient Discharge Summaries stored as CDA documents. It will be responsible for accepting requests from and sending responses to the web framework and locating, generating and parsing the CDA records. The subcomponents of the Interoperability Module are shown in Figure 3.

***CDA Handler:*** This subcomponent will be the entry point for any incoming requests from the web application framework and will also be responsible to send responses back to it. It will talk to other subcomponents of the module.

***CDA Producer:*** This subcomponent will receive request and data from the web framework through the CDA Handler will be generating CDA documents accordingly.

 

***CDA Consumer:*** This subcomponent will send responses and data to the web framework through the CDA Handler.

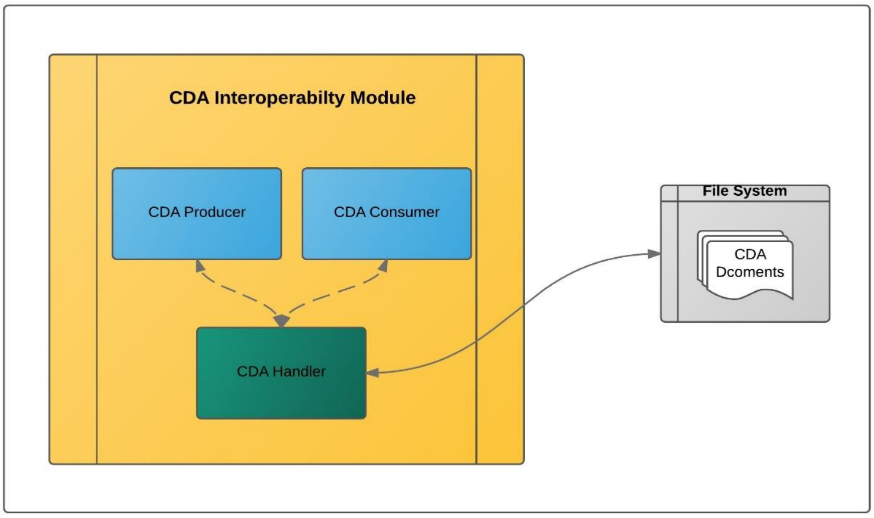


**Figure 3. Interoperability Module**

### 3.5. Data

The Data will be managed in essentially two dimensions:

***Database:*** This level will involve use of a database management system and will store data pertaining to the communities such as members and the patient file associated, and the data from the messages exchanged within the communities.

**File System:** This level will make use of the local file system to store and manage patient discharge summaries in form of XML based CDA documents.

## 4. Implementation

This chapter explains the project, the software design and its functional specification. The application is a prototype that simulates an intersecting healthcare community of practice environment that fosters a collaborative enhancement, sharing and exchange of patient health information, providing an interoperable platform.

### 4.1. Technologies Involved

**4.1.1. Play Framework:** The Play Framework is an open-source modern web framework for writing scalable web applications in Scala and Java. Built on Akka, Play provides predictable and minimal resource consumption (CPU, memory, threads) for highly-scalable applications. The architecture is lightweight, stateless and web-friendly and enables rapid productivity by automatically reloading the changes. A play application follows the *Model-View-Controller (MVC)* architecture, which splits the application into *Model Layer* and the *Presentation Layer*. The Presentation Layer is further divided into *View* and *Controller* Layers. The Play Application Lifecycle is depicted in Figure 4.

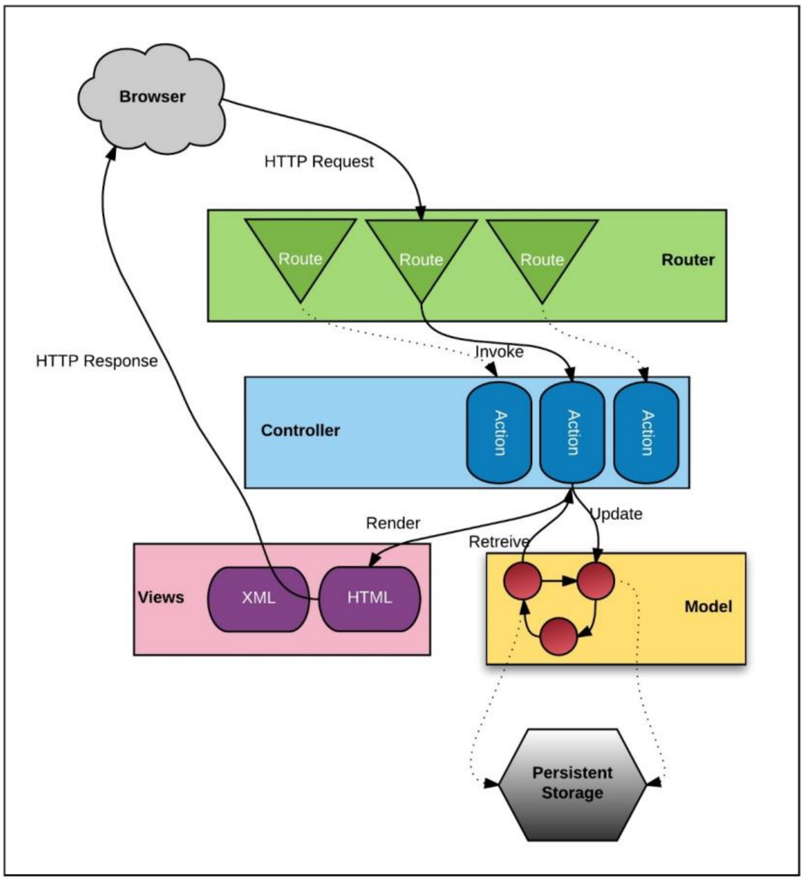


**Figure 4. Play Application Lifecycle**

**4.1.2. Scala Build Tools (SBT):** SBT is an open source build tool for Scala and Java Projects, similar to Maven or Ant. It provides native support for compiling Scala code and integrating with many Scala test frameworks, dependency management which supports Maven-format repositories. Its other features include continuous compilation, testing, and deployment and support for mixed Java/Scala projects. We used the Scala Build Tools to Generate, Build, Compile, and Test and Run our Interoperability module which is essentially a Scala Project. We used SBT's Publishing Tool to generate and publish libraries out of this project to the local maven repositories, which we used as dependency to the Play Web Application.

**4.1.3. Model Driven Health Tools (MDHT):** The Model-Driven Health Tools (MDHT) project was initiated by the Veterans Health Administration (VHA) in April 2008 in collaboration with IBM as the co-lead of this project. The MDHT project is an open source platform that promotes healthcare information exchange and interoperability. MDHT enables shared artifacts between related healthcare standards and Standards Development Organizations (SDO) by delivering a common modeling framework and tools to support consistent standards implementation. As parsing XML based CDA documents using traditional JAX or SAX parsers is a tedious and time consuming job, we used MDHT Runtime Java API to create and parse, and validate the CDA documents. By using an Adapter pattern, the transformations to / from the CDA can be accomplished, with minimal knowledge of the CDA standard, while cutting on the development cost and time significantly.

**4.1.3. MySQL Database:** MySQL is the world's most popular open source relational database (RDBMS). With its proven performance, reliability and ease-of-use, MySQL has become the leading database choice for web-based applications, used by high profile web properties including Facebook, Twitter, YouTube, Yahoo! and many more.

### 4.2. Message Board Architecture

The *Message Board* for this application is built using Play Framework with Html, JavaScript and Ajax, making use of Concurrent.Broadcast object as an Enumerator, a filtering Enumeratee and EventSource as Iteratee, together facilitating the message data flow within the application. Figure 5 depicts a typical flow of the messages in the message board.

The application uses Server Sent Events to deliver messages to the client and REST calls to send messages to the server. The messages flow from the POST to the **Server Sent Events (SSE)** stream through Concurrent.broadcast as the central information hub into the chatFeed controller which attaches an Enumeratee / Iteratee chain to the Enumerator provided by Concurrent.broadcast. Filtering for the correct Community is done with a filtering Enumeratee. Figure 6 shows the Filtering of Messages base on the community.

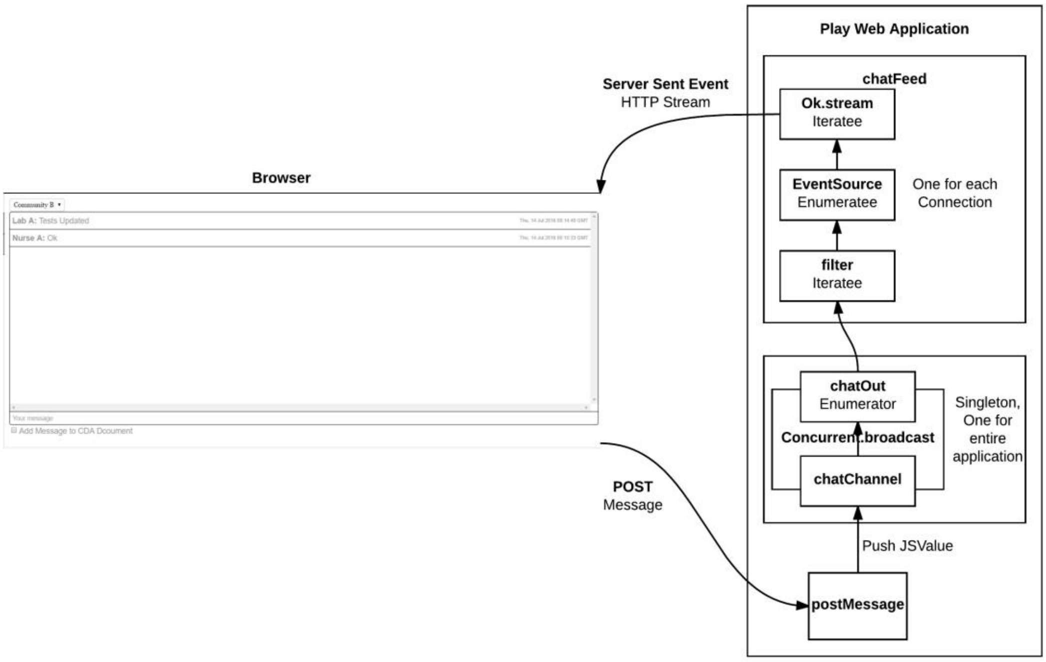


**Figure 5. Message Flow**

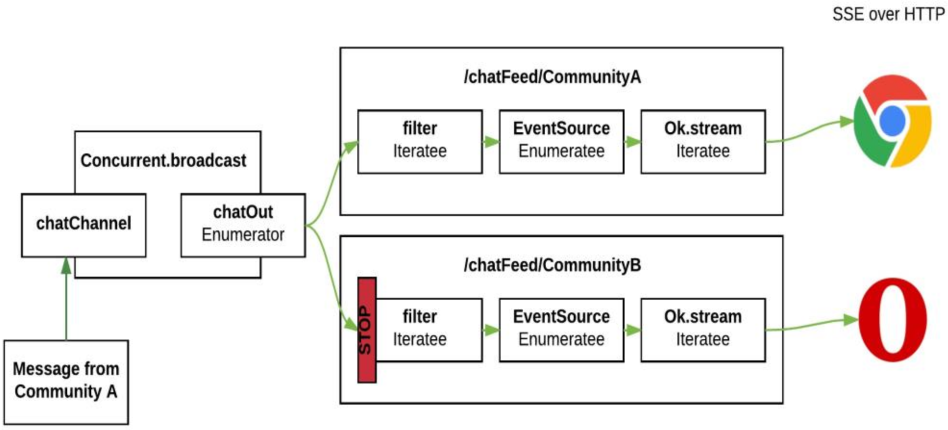


**Figure 6. Message Filtering**

The User Interface is essentially a Play Scala Html Template.

### 4.3. Handling CDA Documents

We use Model Driven Health Tools (MDHT) Runtime Java API to generate and parse the Patient Discharge Summaries CDA documents. Figure 7.1 shows the Dashboard Screen, while the Dashboard Screen for the Administrator is shown in Figure 7.2.


**Figure 7.1. Dashboard Screen**

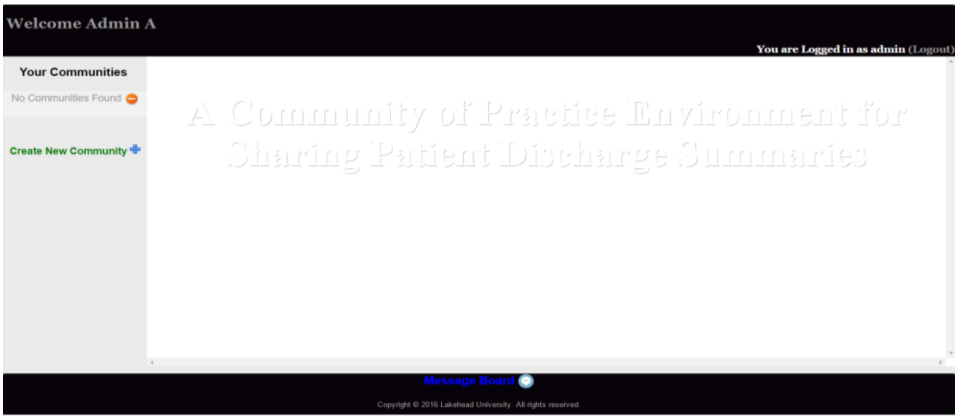


**Figure 7.2. Dashboard Screen: Administrator**

Next three figures show screens involved in creation of a community by the Administrator role. Figure 8.1 shows the Create Community Screen, while the Add

 

Members Screen and Add Patient File Screen are shown in Figure 8.2 and Figure 8.3 respectively. Figure 9.1 shows the View Community Screen. How patient discharge summaries are viewed and edited are shown in Figure 9.1 and Figure 9.2 respectively. Figure 9.3 is the Editing Screen for a Lab Technician, for example.


**Figure 8.1. Create Community Screen**


**Figure 8.2. Add Members Screen**

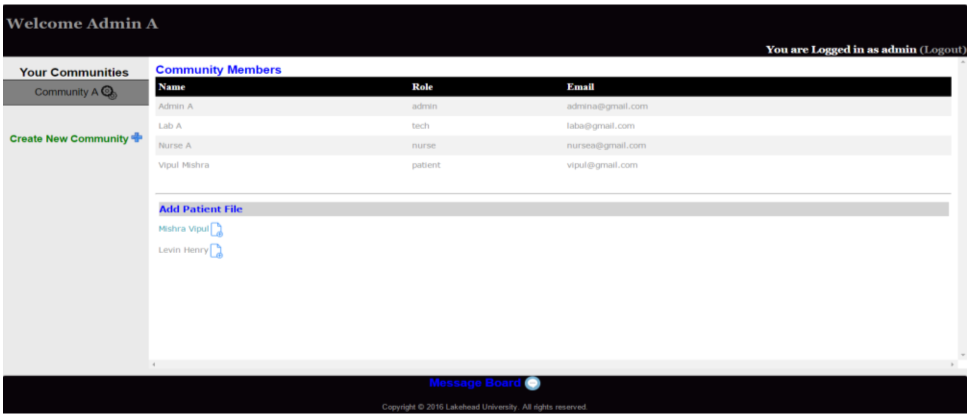


**Figure 8.3. Add Patient File Screen**

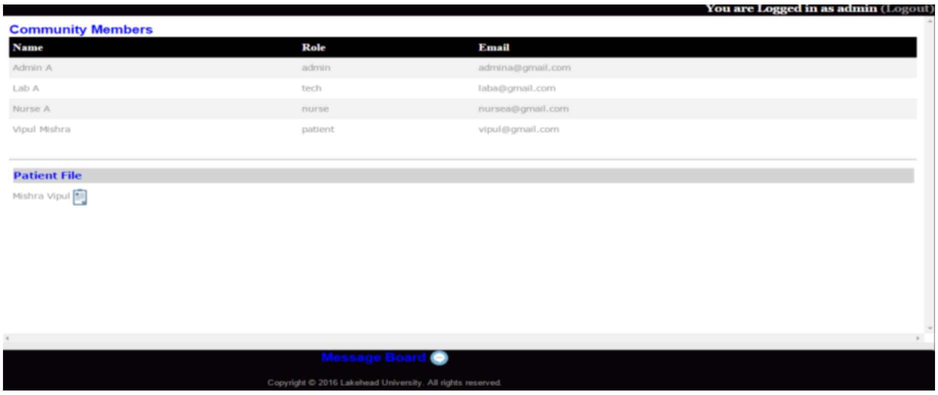


**Figure 9.1. View Community Screen**

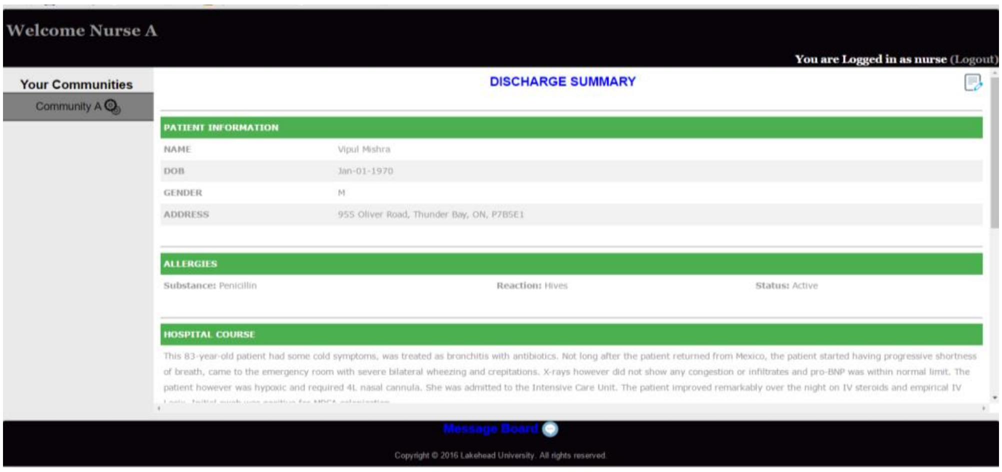


**Figure 9.2. View Patient File Screen**

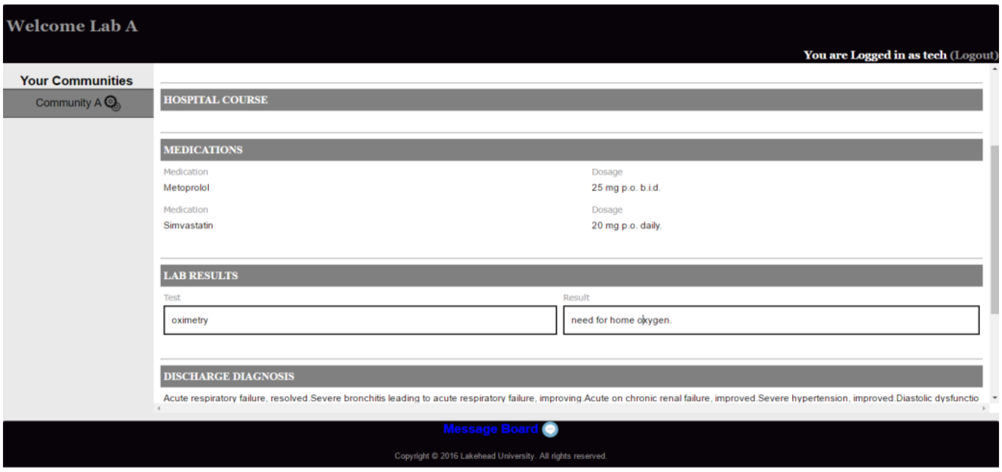


**Figure 9.3. Edit Patient File Screen for Lab Technician**

Figure 10.1 and 10.2 show the Message Board Screens with real-time exchange of messages between a Lab Technician and a Nurse who are members of a hypothetical community "Community A."


**Figure 10.1. Message Board Screen: Lab Technician (Community A)**


**Figure 10.2. Message Board Screen: Nurse (Community A)**

Figure 11 shows a snapshot of the Patient Discharge Summary as a CDA/CCD doucment that is generated and update within one such community in our Cop model.

```
</recordTarget>
<component>
  <structuredBody>
    <component>
      <section>
        <templateId root="2.16.840.1.113883.10.20.1.2"/>
        <code code="48765-2" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC" displayName="Allergies, adverse reactions, alerts"/>
        <title>ALLERGIES AND ADVERSE REACTIONS</title>
        <text><table><tr><td>Dilantin</td><td>Swollen glands</td><td>Active</td></tr></table></text>
      </section>
    </component>
    <component>
      <section>
        <templateId root="1.3.6.1.4.1.19376.1.5.3.1.3.5"/>
        <code code="8648-8" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC" displayName="HOSPITAL COURSE"/>
        <title>Hospital Course</title>
        <text>Mrs. Sherry is a 81-year-old lady, who was admitted to the hospital with chest pain and respiratory insufficiency.
              We discovered new T-wave abnormalities on her EKG.
              There was of course a four-vessel bypass surgery in 2001.
              We did a coronary angiogram. This demonstrated patent vein grafts and patent internal
              mammary vessel and so there was no obvious new disease.</text>
      </section>
    </component>
    <component>
```

**Figure 11. Generated CDA Document**

## 5. Conclusion and Results

This project was created as a proof of concept to demonstrate that building an *Intersecting Community of Practice* environment for healthcare industry, where we share Clinical Documents using by Health Level Seven's (HL7's) Clinical Document

Architecture (CDA) standards; results in an interoperability framework that fosters the knowledge sharing and expansion, catalyzing the overall patient-care process.

Creation and practice of such community models, improves the overall patient care quite significantly, as well as making the continuity of the patient care more efficient and streamlined, while bringing down the time and cost involved with it by a great deal. As a part of our project, we provided the medical practitioners and patients with a web based user interface, where they can sign up into one of the roles from *Administrator*, *Lab Technician, Nurse* and *Patient,* and then can logon to access their customized *Dashboards.* The *Administrator* could be a domain expert such as a doctor, who spawns a new community as and when required, and bring along other members to join that community. He will also be responsible for adding a patient file, which is the patient discharge summary in our case and is stored as an XML based CDA document in the file system, to the community and will be shared, viewed and edited by other members of the community depending on their privilege levels, which in turn is decided by the role they have in the community.

We also provide the users with an *Editing Subsystem*. After adding the members and the patient file, the administrator can view and edit the specific portions of the document such *as discharge medications*, *discharge diagnosis* and *plan of care*. Other roles won't be able to create new communities, but will be able to edit the shared discharge summary within the community. The updated patient file is transformed into CDA documents and stored in the file system.

Other important feature of our application is the *Message Board* to exchange and view real-time messages. This message board is accessible by all users, provide they are member of at least on community. The members will be able to post messages on the message board, which is constrained in terms of the community to provide privacy, as well as view existing message exchanges within the community. *Ambassadors,* who are basically members to multiple communities can exchange messages across different communities. An extension to the messaging functionality gives users an option to choose if they want to add their message to the discharge summary CDA document. This can boost the efficiency and continuity of the patient care.

### 5.1. Results

Our prototype generates Continuity of Care Documents (CCDs). The Continuity of Care Document (CCD) is a joint effort of HL7 International and American Society of the International Association for Testing in Materials (ASTM). CCD combines the benefits of CDA with Continuity of Care Record (CCR), which is a health summary standard by ASTM. The CCD specification is essentially a constraint on HL7 CDA Standard that usually contains sections of allergies, medications, problems, laboratory results, in addition to patient header information.

We use Model Driven Health Tools (MDHT) Runtime Java API validate these documents. The code snippet below shows how MDHT API is used to validate CDA/CCD documents in Scala.Our results show that using our prototype to edit different fields in the patient file at alteration step, as well as adding user comments to the CDA Document, preserves the validity of these documents. Hence, the generated CDA documents can be parsed by other systems while the semantic meaning and structure is still preserved. This is the proof of our interoperability approach.

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