

# Healthcare Information Exchange System based on a Hybrid Central/Federated Model

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**Abstract**— The quality of care can be significantly enhanced and healthcare cost can be substantially reduced if healthcare providers can have access to patient records that are scattered among several paper and electronic based systems. Major challenges of Healthcare Information Exchange result from patient's medical records being kept in several healthcare provider offices, clinics and hospitals in different formats. There are two major problems with healthcare information retrieval. The first problem is lack of visibility and knowledge as to where patient's medical records reside. The second problem is lack of access to information and also incompatibility of data formats. A considerable coverage of Electronic Information Exchange among Electronic Health Record (EHR) systems remains to be implemented despite extensive standardization efforts toward providing solutions. The adoption pace of available standards and solutions has been slow with the exception of some public/government entities. This paper describes a comprehensive and practical solution based on a distributed system with independent subsystems that control and manage processes and data flow of information exchange. The Registrar Subsystem creates a directory of healthcare providers and patients. The Security Subsystem provides authentication and authorization services across all subsystems. The Locators address patient and medical location lookup. The Agents act on behalf of healthcare providers to communicate with other subsystems. The Mediators facilitate information retrieval. The Solution comprises of three levels of participation that allows healthcare providers to join the system easily by starting from basic semi-manual information exchange level and then migrating to a fully electronic and automated information exchange.

The Solution is modeled based on variety of standards and protocols used in Internet and other application fields as well as healthcare specific standards and proposals.

## I. INTRODUCTION

**I**NFORMATION Exchange among healthcare systems is one of the most complicated problems of Electronic Health Records. When patients move from one healthcare provider to another, their medical records are stored across several paper and electronic based systems and there is no lookup directory to find out where patients have medical records. The lack of visibility to patient's complete medical record can result in unnecessary procedures, duplicate tests and many other problems such as adverse drug interaction.

While several standards address medical record format and exchange protocols, adoption of the standards and interoperability among systems has been slow and limited. In addition to the government efforts for facilitating Healthcare

Information Exchange (HIE), private sector has tried to tackle the problem through solutions such as Personal Health Records. Such solutions that advocate patient to be central repository of health records have their own limitations by definition.

While this problem has been tackled in many papers and commercial implementations, coming up with a comprehensive and practical solution has been a challenge. Several architectures have been discussed such as architectures for Regional Health [1][2][3] or Agent Based architectures [4][5]. Some solutions have proposed Infrastructure for Public Health [6][7], or a Patient centric approach [8]. The specific aspects of the problems have been discussed separately as well, e.g. standards [9] or security [10]. Some solutions are specific to countries [11] or try to provide an international framework [12].

This paper introduces a comprehensive and practical system that addresses all HIE issues in one solution. It includes information registration through the Subsystem called Registrar, patient's medical record lookup through the Locator Subsystem, information retrieval through the Agents Subsystems, and then information exchange through the Mediator Subsystems. The Registrar subsystem is a distributed directory of all healthcare providers and patients nationwide. The Agents are subsystems made available to healthcare providers to import and submit information to the Mediator Subsystems. The Mediator Subsystems act as a Clearing House and transform the received records and submit them to recipient's Agent Subsystem to export it to the final destination. The Security Subsystem facilitates granting authorization by healthcare providers who have the custody of information and implements other security measures such as identity, authentication, authorization and encryption.

## II. SYSTEM DEFINITION

The Healthcare Information Consolidation System provides services to healthcare providers to register their patients, to submit requests for patients' medical records and to authorize submission of the requested medical records.

Healthcare providers are registered in the system by Registrar Subsystem and after registration they get access to the appropriate Agent Subsystem for their information exchange. The initial setup includes registration of healthcare provider's patients with the Registrar. Following the initial setup, all patient visit updates are submitted to the

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Registrar Subsystem that consolidates the directory of distributed patient records. Healthcare providers can access the Locator Subsystems to query the list of the locations that have records for a given patient. Healthcare providers can then request for authorization from the custodian healthcare provider. Upon approval, the requestor healthcare provider can access information through the Mediator Subsystem. The Mediator Subsystem is the authority for managing i.e. storing and verifying such authorizations.

### III. PARTICIPATION STAGES

The System offers three levels of participation to facilitate engagement of all healthcare providers even those with only a limited part of their patient information in the electronic format.

The Level 1 participation includes registration of patients with basic information that is available in electronic format. This level provides visibility to the location of patient records. Vast majority of healthcare providers can participate in this level as almost all healthcare providers have a computerized registration and billing system that has patients, visit dates and extensive information captured in their billing system.

The Level 2 participation comprises of the Level 1 engagement plus semi-automated participation in information exchange. The healthcare providers that do not have system with capability of providing structured data to the system, provide unstructured data (e.g. images of scanned records) or a subset of records that can be easily made available. At its minimum, information such as diagnostics and procedures will be available in electronic format through billing systems.

The Level 3 participation includes electronic communication of structured data with minimal manual intervention that is mainly for authorization of record transfers.

Stage/Level	Scope	Participation
1	Basic	Location Information for Medical Records
2	Intermediate	Location and Health Record Information (Unstructured)
3	Full	Location Information and Electronic Health Record Exchange

Table 1 Healthcare Provider Participation Stages

### IV. SYSTEM ARCHITECTURE

The System is designed based on a distributed architecture in which all subsystems are geographically dispersed for load distribution and optimization for locality of data.

The Mediator Subsystem that acts as a clearing house is the center of the architecture. The Security, Registrar and Locator Subsystems are located in the inner bound of the architecture while the Agent Subsystems are on the edge of the architecture and perform import/export on the edge of network and in the healthcare provider premises.

All inner bound Subsystems are implemented as distributed systems to accommodate load balancing and

locality of data. The synchronization of data among distributed elements is modeled and borrowed from the well established Internet protocols.

### V. SYSTEM DATA FLOW

The dataflow in the system is initially originated by the registering healthcare providers in the system through the Registrar Subsystem. The directory data is built up through submission of lookup entries by participating healthcare providers. The participating healthcare providers use the Locator Subsystem to look up patients, locations of medical records and dates of visits. The request for authorization is submitted to the healthcare provider who has the custody of the data. Upon approval of access, data can be requested by the Agent Subsystem from Mediator clearing house which in turn submits the request to the Agent of healthcare provider that holds data. The Agent sends data to the Mediator Subsystem that in turn submits them to the Agent of healthcare provider that has requested the information.

### VI. SYSTEM MESSAGES

The System defines format for several message types that are exchanged in the system. The Agent Subsystems are responsible for encoding and decoding messages. The Categories of the System Messages are:

The Healthcare Provider Registration Message that carries initial registration information.

The Patient Basic Data Registration Message that carries patient's identification information for registration in the directory.

The Lookup Request Messages that carry search patterns for patient lookup.

The Data Access Request Messages that carry healthcare provider's request to access patient data in another healthcare provider's system.

The Approval Notification Message that notifies requesting healthcare provider that his request for access is approved and he can initiate the data transfer.

### VII. ACCESS CONTROL: SECURITY SUBSYSTEM

The Security subsystem provides security services such as Authentication and Authorization to all the other subsystems. It implements the Public Key Infrastructure (PKI) that uses Certificate Authority to bind users with their public keys.

The initial registration of healthcare providers is handled under human supervision while registration of patients by healthcare providers is handled by the software and use of the Security Subsystem only.

Providing unidentifiable data for clinical research is in future plans of the system in which case Simple public key infrastructure (SPKI) will be used for simplicity.

While the default settings of the Security Subsystem for allowing access to patient records require prior authorization, participating healthcare providers who obtain

release of information from their patients can grant access for those patients to all or certain healthcare providers such as Emergency Rooms as a pre-authorized system setting.

#### VIII. INFORMATION REGISTRATION: REGISTRAR SUBSYSTEM

The Registrar subsystem performs two major functions, the initial registration of healthcare providers and then the registration of patients by registered healthcare providers. The initial registration of healthcare providers - who intend to participate in the system - is done through the Registrar's Internet portal that enrolls healthcare providers. An application profile is created for the provider who applies for registration. The application is processed by a human actor to finalize the contract for the terms of use. The Registration and Contract is processed for both Group Healthcare Providers and Individual Healthcare Providers. Upon completion of the Registration phase, the Security Subsystem issues certificates for contracted healthcare providers. Such certificates are subject to renewal after the expiration date. The Registration certificate is used to submit the basic patient registration information and also to submit requests and queries.

Upon registration, healthcare providers are assigned an Agent Subsystem that conforms to their internal system for handling patient records. The patient information is categorized into the Basic Registration Data and the Medical Records. The Basic Registration Data for all patients on file is submitted to the Registrar Subsystem through the Agent Subsystem. The Registrar Subsystem continues to receive ongoing updates to the Basic Registration Data. The Basic Registration Data consists of patient identification information along with dates of visits and potentially some health record data.

The Registrar Subsystem is modeled based on the Internet Domain Name Services standard [14][15][16].

#### IX. LOOKUP: LOCATOR SUBSYSTEM

The Enrolled healthcare providers can query the system for medical record locations and dates of visit. Then they submit request to the Locator Subsystem to access/receive the medical records. The Locator Subsystem forwards the request to custodian healthcare providers for approval. If the custodian healthcare providers approve the request, they submit their approval to the Locator Subsystem (through the Agent Subsystem) which in turn grants access to the requestor. Upon notification that is sent by the Agent and initiation of the exchange, transfer request is handed over to the Mediator Subsystem.

#### X. INFORMATION IMPORT/SUBMISSION/EXPORT: AGENT SUBSYSTEMS

The Agent Subsystems are the primary facilitator for message exchange among healthcare providers and all the other Subsystems. The messages that are handled by the

Agent Subsystems include Healthcare Provider Registration, Data Import, Patient Basic Data Registration, Lookup Requests, Data Access Requests, Approval Notifications, Data Submission, Data Retrieval, and Data Export.

#### XI. INFORMATION EXCHANGE FACILITATORS: MEDIATOR SUBSYSTEM

The Mediator Subsystem acts as a clearing house and facilitates format conversion and supports different communication protocols. This subsystem is modeled based on clearing houses that provide financial information exchange among healthcare providers and Payers (insurance companies.)

A wide range of standards is supported by the Mediator Subsystems to accommodate participation of the variety of systems used by healthcare providers. The healthcare providers who participate in the Level 3 information exchange go through a certification process that ensures smooth communication and data exchange between the Mediator Subsystem and the Electronic Health Record (EHR) systems used by the healthcare providers.

#### XII. MEDIATOR SUBSYSTEM SUPPORTED STANDARDS

Several standard bodies have been preparing standards for different aspects of the healthcare information data format and the communication protocols. With the recent emphasis on EHR some more initial steps have been taken. Federal advisory body Health IT Standards Committee that makes recommendations to the National Coordinator for Health IT on standards and electronic exchange of health information among many, has submitted recommendations for standards for healthcare information exchange to HIT Policy Committee. The recommended standards are Health Level 7 (HL7) v.3 CDA [13] for electronic documents, HL7 2.5.1 for messaging, HL7 v2.3.1 for Immunization and vaccination, NCPDP Script v10.x (ambulatory) and HL7 V2.5.1 (inpatient) for prescriptions, ASC X23 v4010A1, NCPDP Script v5.1 and CAQH CORE Phase I and Phase II for eligibility, benefits and referrals among others. Recommended vocabulary standards are SNOMED CT [21] for clinical problems and procedures; RxNorm for drugs and medication allergies; UNII for ingredient allergies; LOINC [20] for laboratory tests, UCUM for units of measure; and ASC X12 and NCPDP Script for administrative terminology.

These standards are primarily supported by the Mediator Subsystem to receive and submit information to the participating healthcare provider systems that support these standards. The Mediator Subsystems convert such information to other standards or to unstructured information for recipients that do not support the standards. The future plan for the Mediator Subsystem is to support proprietary format of some major EHR vendors to accelerate participation of healthcare provider systems.

## REFERENCES

Standard	Application
Health Level 7 (HL7) v.3 CDA	Documents
HL7 2.5.1	Messaging
HL7 v2.3.1	Immunization and vaccination
NCPDP Script v10.x (ambulatory)	Prescription
HL7 V2.5.1 (inpatient)	Prescriptions
ASC X23 v4010A1	Claims, etc.
NCPDP Script v5.1 and CAQH CORE Phase I and Phase II	Eligibility, benefits and referrals
SNOMED CT[21]	Clinical problems and procedures
RxNorm	Drugs and medication allergies
UNII	Ingredient allergies
LOINC[20]	Laboratory tests
UCUM	Units of measure
ASC X12 and NCPDP Script	Administrative terminology

Table 2 Standards for healthcare information format and exchange

### XIII. IMPLEMENTATION ARCHITECTURE

The prototype System is implemented in the Microsoft cloud (Azure) based on the Service Oriented Architecture (SOA.) Since compliance to Health Insurance Portability and Accountability ACT (HIPAA) is still a concern in public clouds, the live version of the system will be initially deployed in a private cloud to address the security compliance concerns.

A wide range of performance testing is performed to measure the system's scalability. The load testing is conducted from two angles of concurrent users and the number of transactions. The other planned testings are stress testing and endurance testing. The goal will be modeling the behavior of the system when it's pushed beyond the boundaries defined for each phase of the system launch.

The simulation of a Content Delivery Network is another testing activity that is planned to assess the required network for different stages of the system launch. Part of this experiment is intended to determine the configuration of a load balancing distributed network that is required for expansion of the system based on the growth of the system load.

### XIV. CONCLUSION

The described System addresses problems inherent to providing a comprehensive solution for healthcare information exchange. The support for three levels of operation facilitates participation of variety of existing systems from paper based healthcare providers to the paperless centers. The Locators, Agents, and Mediators implement Clearing House model that allows information collection, conversion and exchange. The level one - that can quickly accommodate a large number of participants - provides a valuable directory of scattered medical records.

The future work consists of supporting more standards to facilitate more participation in the Level 3 of the implementation. Collecting information for clinical research and providing anonymized and unidentifiable data is another service that will be built to extend the infrastructure services.

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