Chapter 2

2. Literature Review

The main objective of literature review is to understand the generic concepts of interoperability and interoperable environments specific to health data exchange. It is a collection of approaches, standards, mechanisms, vocabularies in context with the EHR exchange between independent silos. Significant problems prevail that need to be addressed minutely. This chapter highlights the challenges or obstacles to interoperable health data exchange and tries to identify some of the enormous approaches used in designing disparate healthcare models. It brings forward certain rampant security issues hindering the seamless sharing of EHRs. Many industries, including telecommunications, securities trading, and retail merchandising, invested heavily in Information Technology (IT) in the 1990s and have moved far ahead of healthcare in their ability to electronically capture, store, and send data.

An explorative literature review identifies various architectures designed over a period of two decades. The research papers listed in Appendix A (Table A1) were selected focusing on health data exchange between different organization and departments of healthcare domain. The table includes architectures both-generic as well as related to healthcare interoperability. The study conducted is in perspective of identifying interoperability and security dimensions in exchange of health data. Applying Electronic Health Records and Interoperability as narrative search terms yielded 130 articles (N=130) further restricted to 70 relevant articles (i.e. 60 papers irrelevant) most commonly related to information technology, interoperability, healthcare data-exchange standards, vocabularies and security issues in sharing of health data. Articles selected extended to such areas as electricity grid, smart homes, where interoperability exploitation is utmost. Selection of papers from both renowned journals and conference proceedings helped in broadening the vision and analyzing current requirements in healthcare domain. The data sources provided information on EHR topics, such as EHR implementation issues, challenges to integration of hospital information systems, standards, messaging formats and vocabularies, and privacy and security issues.
The observations from various papers show that the challenges to EHR (50%) gains maximum weightage. Among these challenges, the prime concern is security (N=28) of EHR concerning confidentiality, integrity and privacy issues in accessing EHR from different systems.
2.1 Dimensions of Interoperability

Interoperability of EHR [7] defined in ISO (ISO TC 215, ISO/TR 20514, 2005) is “the ability of two or more applications being able to communicate in an effective manner without compromising the content of transmitted EHR.”

![Figure](Error! No text of specified style in document.)

**Figure** 2: Parameters for Interoperable Sharing

Interoperability can only be achieved with active engagement of the users ensuring that the systems, procedures and culture of an organization are managed in a way as to maximize opportunities for exchange and re-use of information, whether internally or externally. Figure 2.2 lists the parameters identified to understand interoperability in health data exchange. It represents the major aspects that relates to sharing or exchange of EHRs of patients between healthcare stakeholders.

EHR-systems need to be compatible with each other. Integration generally considers going beyond mere interoperability to involve some degree of functional dependence also. The range of discrepancies and diversities across all aspects [8][9] characterizes the interoperability on following dimensions:

- **Technical interoperability** means the ability of two or more disparate applications, to exchange data from each other and perform the required task appropriately and satisfactorily without the need for added operator intervention.

- **Network interoperability** enables message exchange between systems across a variety of networks. Data travels between various links on the network. Network interoperability is the arrangement of these links agreed for data exchange. It
encompasses various issues rising from information transfer between heterogeneous systems across multiple communication links.

- **Semantic interoperability** refers to the meaning of information delivered to users, as opposed to the simple physical transfer of data. Failure to achieve interoperability may be caused if different users, or groups of users, use different terms for the similar concepts, or use similar terms to mean different things. Full semantic interoperability [9][10] is required across heterogeneous EHR systems in order to gain the benefits of computerized support for decision support, workflow management and evidence based healthcare.

- **Syntactic interoperability**[10] [11] refers to ability of two or more components to work together with data and messages passed between them by each component. The order in which the data and messages are passed needs to be same across components. It is fundamental to follow specified data formats and communication protocols. In general, eXtensible Markup Language (XML) or SQL standards provide syntactic interoperability.

- **Legal interoperability** covers the issues dealing with laws, policies, procedures and cooperation agreements requiring seamless flow of information between different organizations, regions and countries.

### 2.2 Need of Interoperability in EHR

Interoperability enables better workflows [12]and reduces ambiguity. It improves the performance of any organization by making the right data available at the right time to the right people. With respect to healthcare, interoperability would result in the following key benefits.

- **Enhanced quality of care**: Coordination of semantic and syntactic interoperability would assure a common understanding of medical information and subsequently lead to more meaningful representation of data. The healthcare users would be able to correctly infer the data in spite of being associated with different healthcare organizations. It would presumably reduce medical and prescription errors and enhance the quality and continuity of care related to communication of the patient’s health status, performed procedures, family history and personal history.
• **Ready available information:** It ensures that, patients treated by a variety of health care providers, can access his medical history and treatment details any time anywhere.

• **Improved cost efficiency:** Interoperability improves decision making by providing a common platform or an interface where the disparate systems can communicate. If functional, it can certainly benefit the patients by preventing duplicate and medically unnecessary tests and imaging procedures.

• **Enhanced choice for healthcare providers:** Distributors of EHR-systems have a huge responsibility enabling interoperability. Today, healthcare organizations have loads of vendor-specific systems to choose from. If the solutions are interoperable, providers have more choice in buying without the constraint of maintaining duplicate copies of data specific to each system. Also, the vendors can introduce their products to more markets, thus helping in global integration of health data and speeding the timely care extended to the patient.

• **Mobile and ubiquitous access to medical information** [13]: With the advent of mobile apps and its increasing popularity in today’s generation, interoperability is a necessary feature to achieve. Semantic and technical interoperability if achieved can enable access and correct interpretation of medical information across countries, regions and nations.

To achieve effective, efficient and coordinated care, data must be shared between health care organizations, physicians, pharmacists and other nurses, patients etc. seamlessly. Although all interoperability dimensions listed above have their own significance, the major contribution of this work focuses on semantic and syntactic interoperability of EHR.

### 2.3 Challenges to EHR sharing in Interoperable Environment

The need of interoperability is clearly visible but achieving interoperability in health data exchange has many constraints. These are the collective views from the research papers and articles searched on the following categories- Storage, Non-integration, Communication Barrier, Schema, Administration, Confidentiality and Privacy, IT and Legal Issues.
Figure 2.3 lists the count of papers read and reviewed under each category. Diversity or non-uniformity in various technical and administrative services like the mode of accessing the data, powers and authorities available to IT team, data storage schemas, security rules and policies, generate lots of complexities deterring uninterrupted sharing between independent organizations.

- **Every system has its own way of representing data:** In this case, records referring to the same entity can represent it differently due to any of the following factors: - different keys (key-conflicts), errors in the values of the record attributes (attribute-conflicts) [14], schema-level inconsistencies [15], different models, and structural representations. Hospitals may share the data but without the ability to transform into local formats leads to partial semantic interoperability.

- **One term has multiple meanings:** Different vocabulary lead to different interpretation of similar terms. Two or more terms refer to the same concept but not easily recognized as synonyms. Without contextual information the full meaning in health data, remain ambiguous. A single standard vocabulary is unlikely to meet all the EHR requirements of an organization.

- **Translation Limitations:** No two-metadata schemes are equivalent. The schema of one application differs [16] from other resulting in incomplete or unsuitable mapping. Mapping of fields or attributes encompass many difficulties due to unrelated schemas. Data requiring translation usually comes from platform-specific applications [17]. The incompatibilities result in loss of information during conversion. The same is left undiscovered until the occurrence of any undesired incidence.
• **Lack of Standard rules for Data Sharing:** Who will decide as to how much data should be available to the health providers especially in referral cases? The cost and benefits of data sharing should be viewed in ethical [18], institutional, legal [19], and professional dimensions. Sharing of data requires further clarity: can share or not, under what circumstances, by and with whom, and for what purposes.

• **Data Exchange Constraint:** Due to a lack of shared infrastructure among hospital IT and EHR systems, the healthcare industry has not reached the widespread interoperability. Lack of centralized storage of health records results in manual transfer of records from one hospital to another. This forfeits the aim of continuous availability of patient’s records for efficient and timely treatment extended to the patients irrespective of time and place.

• **Lack of integration**[20]: Data integration is a critical issue as a lot of heterogeneous data is collected over the lifetime of the patient. Interoperability can be achieved [7]if the network and infrastructure becomes capable to collect, aggregate and manage each data type. True interoperability involves intelligent bridging, not just connecting information. Incomplete or incompatible EHRs raises scalability issues [21], which further lead to redundancy [22] causing repetition of lab-tests and expenditure overhead to the patient.

• **Confidentiality, Availability and Integrity of EHR:** Medically, it is mandatory for a hospital to maintain the confidentiality and privacy of patient undergoing treatment. The code of conduct prohibits any kind of patient-doctor conversation disclosed to third person without patient’s consent. It is taken as breach to confidentiality [23][24][25] and privacy [26] of patient’s identity and health information. Every hospital employs security rules and policies [27]for protecting the data. It may not experience any security threat during internal transactions but while coordinating with other hospitals in interoperable environment, the rules and policies may contradict thus making the data vulnerable to threats [28] [29] and breaches. Security gaps in existing techniques [30], network security conflicts [27] and plenty of security issues exist in storage [14] and usage of EHR between independent systems. Distributed databases [31] on multiple and disjoint servers exacerbate ACID properties. Healthcare trends in Asia Pacific [32] face similar challenges and inefficiencies resulting from the need of sharing the information across borders.
- **EHR Linkage Problem:** Existence of multiple versions of EHR due to treatment availed at various independent and non-integrated systems are a major problem. At many places, patient’s identity remains unknown due to no single unique identifier [15] allocated to them. Such linkage problem [21] is not only external but is experienced in intra-departments as well. Correctness and completeness of data is at stake when a single unique identifier cannot recognize data across the systems.

- **Different requirements when exchanging data:** Each facility in the healthcare may have different requirements with respect to network design and deployment. For example, the radiology department requires significantly more bandwidth because of the high volume of image files passed between modalities such as Computed Tomography (CT). As more and more critical patient information migrates to the network, the network must provide adequate bandwidth, security, and data availability to the end user.

- **Medical Aid during Accident and Emergencies:** Patient needs and demand of services increase in emergencies. This requires controlled coordination between each independent HIS enabling accessibility and timely availability of patient’s data. System like GPS, RFID tags or sensors can be of great help in such situations, but are not practically possible.

- **Data Ownership:** The question of who owns the health data of a patient is a challenging problem. Complete understanding of issues related to data ownership is must. These issues include archetype of ownership, policies, balance of obligations, handling of constraints and technology. It requires clearly-laid specification of who is permitted to do what with the data. The complexities of processes processing diversified data makes it impossible to generalize rules that could cover even routine situations and preferences under ownership model.

### 2.4 Architectures and Models achieving interoperability

There is high demand to generate interoperability standards [13] that would allow smooth data flow between different users. Evolution of new metadata techniques and standards describing semantics requires rigorous brainstorming sessions to select the most viable and appropriate approach for designing a system applicable in single and integrated healthcare environments. Comparisons of the available architectures [3] and their limitations aroused
our interest in identifying currently applied models, languages, message formats and vocabularies enabling EHR transmission between different organizations.

![Bar Chart](image)

**Figure**: Error! No text of specified style in document. 4: Parameters for Interoperability Architectures

Key terms depicted in Figure 2.4 gained considerable weight age while going through each research paper. Each of the listed parameter plays a vital role in enabling/disabling health data exchange and interoperability. These key parameters formed the basis of broadening our vision in understanding available set of models and well-known approaches. Approaches considered are those that confer to international standards for designing interoperable systems. This search encompasses the desired set of health vocabularies by each facility, data-exchange standards specific to EHR exchange and technical standards for EHR interoperability.

**Table**: Error! No text of specified style in document. 1: Generic Architectures to Interoperability Modeled on Healthcare Systems

<p>| Architecture/Model | Models designed for Healthcare                                                                 | Features                                                                                                                                                    | Limitations                                                                                           |
|--------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| CORBA ver. 2 [33]  | Synapses approach [14]: Synapses’ is designed around the work of CEN TC/251/PT1- 011, providing generic and open means (GEHR Standards) to combine healthcare records consistently and securely in single healthcare institution or between institution. | Define interfaces between components, and specifies standard services such as “persistent object services, directory and naming services and transaction services”. Simplifies establishing the communication formats, mapping applications to one another and maintaining the links. Any modification of legacy systems could be costly and time consuming. Defined by consensus and compromise and is not perfect. Conflicts [30] experienced with the reality of corporate security policies. Advancements of new languages and formats [30] depleted the use of CORBA making it incompatible with... |</p>
<table>
<thead>
<tr>
<th>Architecture/Model</th>
<th>Models designed for Healthcare</th>
<th>Features</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGOBT architecture for HL7 version 2.2</td>
<td>Uses a combination of emerging techniques like C#, .NET.</td>
<td>SIGOBT architecture for HL7 version 2.2 with ORB simplifying messaging and exploring how to share HL7 data in the environments of two object brokering environments i.e. Microsoft OLE and CORBA.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
</tr>
<tr>
<td>COM/DCOM [33] Developed in 1994 by Microsoft</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
</tr>
<tr>
<td>PACMEDNET [36] focuses on prototyping solutions for solving interoperability problems. Presents a structured view of data collected from medical treatment facilities around the world.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
</tr>
<tr>
<td>Hybrid Models based on Object Oriented Programming Language (OOPL) [37] CitusTech Healthcare Software Engineering using .NET, Java/J2EE [19], WPF smartData Offshore Health Care application Development using .NET, ASP, AJAX The Brazilian National Healthcare System developed in Eclipse based on EJB 2.1 + Struts.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
</tr>
<tr>
<td>GUMO (General User Model Ontology)[39] and OWL (Semantic Web language) extension of Resource Description Framework (RDF)</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
</tr>
<tr>
<td>Clinical E-Science Framework (CLEF, Patient Chronicle Model (PCM)<a href="Puleston">40</a> based OOPs concepts provided by OWL ontology</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
</tr>
<tr>
<td>Web Service-Based[42] Integrated HIS (WSIHIS) addresses system and language interoperability issues. GeSMO[8], uses XML standards, provides a unified way of identifying diverse kinds of services, facilitating interoperability and enabling integration in industrial environments. Fullmoon XML Processing Framework [16] enables smooth integration with OGC web feature services using GML-set of XML. XML based protocols that provide fundamental blocks for creating distributed applications Allows any piece of software to communicate with each other in a standardized XML Messaging system</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
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</tr>
<tr>
<td>Open Systems</td>
<td>Requires information of the remote systems before functioning and eventually leads into modifying the legacy systems that are not complied with COM standards.</td>
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<td>Architecture/Model</td>
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</tr>
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<tr>
<td>data warehouse (license: BSD license)</td>
<td>HRHIS Open-source human resource for health information system developed [23] by University of Dares Salaam for Ministry of Health and Social Welfare (Tanzania) (license: GPLv3)</td>
<td>hierarchical structure [43] from which software and hardware are built that ensure passing of information in an integrated and interoperable manner</td>
<td>problem when dealing with very large terminologies</td>
</tr>
<tr>
<td>Service-Oriented Architectures [38] Standards: JSR 168 and 286 Portlet Security: As per HIPAA</td>
<td>Carefx SOA[17] facilitates transitions without adding complexity and removing duplicacy of data. CONNECT [44] provides a SOA based “Platform for Participation” for Health Information Exchange HL7 System Design Reference Model (EHR-SD RM) Built on Healthcare SOA Reference Architecture Oracle SOA Suite [17] for Health Care Integration enables advanced capabilities, which allows health care organizations to simplify and jump-start their integration initiatives. Carefx allows users to select a patient in one application in such a way that its records are automatically available even when entering other applications. Provides a uniform means to offer, discover, interact with, and use capabilities to produce desired effects consistent with measurable preconditions and expectations. It provides a means to make services interoperable regardless of the programming language used, location, or platform of a simulation or model.</td>
<td>Transformations become unmanageable and extensions and the complexity of writing the eXtensible Stylesheet Language Transformation (XSLT) code reduce the interoperability and portability of these transforms</td>
<td></td>
</tr>
<tr>
<td>ISO/EN 13606 Part 1, openEHR [41] and HL7 Clinical Document Architecture (Generic reference models for representing clinical (EHR) data)</td>
<td>smartData Offshore Health Care application Development using PHP, Joomla, Drupal, Java JAnaemia[19] based on the EHCR architecture proposed in the ENV 13606:1999 standard, published by the CEN/TC251 committee Multi-agent Brokering Architecture[45] is set of services in which the brokering role is further classified into several sub-roles each with a specific architecture and interaction protocol that is appropriate to support required privacy level ITIH [46] is a framework proposed by DIIT(INDIA) stating standards, interfaces and formats for openEHR systems. These standards developed by ISO (Standardization Organization) and CEN (Committee for Standardization) helps in achieving semantic interoperability in the healthcare domain to fulfil the shared and secured healthcare scenario</td>
<td>The need to represent the context of sharing clinical information is essential in healthcare domain and remains a challenge in existing models. Developing large-scale application based on the standards proposed by the OpenEHR needs a greater contribution of the community and means to implement them.</td>
<td></td>
</tr>
</tbody>
</table>

The healthcare models based on said standards and architectures listed in Table 2.1 allow data exchange among various institutions. The tabulated information covers the approaches, models, features and limitations of the models in context with the interoperability. The table represents the relationship of architectures with the approach or model designed for healthcare environment. The developers have incorporated various healthcare models on these approaches having unique and salient features. Many of these models have incorporated standards developed by ISO and CEN that can form as basis for future refinements of the systems allowing seamless but secured sharing of data.
2.5 Data Exchange Mechanisms

Data-exchange in interoperable environment may change the locally stored health information forfeiting the obligations and constraints set through well-crafted rules and policies of the organization. Interoperability must be enabled for distributed clinical environments [47] to communicate and share data even if different clinical sites have various ways of knowledge representation, e.g. different languages may be used to describe their resources, and database schemas may vary from one dataset to another.

2.5.1 Data Exchange Standards

This section deals with the data exchange mechanisms, languages and standards for exchanging information in interoperable environment. Previously data could be stored in fixed format text files, or as bits of information with standard delimiting characters, commonly called CSV for “Comma Separated Values”. Today, there is more dynamic format called XML. XML[42] allows for a more dynamic relationship with the data sets and less external programming. XML-based metadata standards developed for heterogeneous sharing are Encoded Archival Description (EAD), Metadata Object Description Schema (MODS), Metadata Authority Description Schema (MADS), Metadata Encoding and Transmission Standard (METS) [33], Metadata for Images in XML (MIX) and MPEG-21 [48].

Table: 2: Data Exchange Mechanisms supporting Interoperability

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Mechanism</th>
<th>Data Exchange Standards</th>
<th>Format(s) and Language(s)</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORBA-based systems</td>
<td>Simple Object Access Protocol (SOAP), Remote Method Invocation (RMI) for Java-based platforms and Internet Inter-Orb Protocol (HOP)</td>
<td>OASIS (Web Services Security)[33]</td>
<td>XML-translation between two XML schemas done using XSLT for data encoding and the HyperText Transfer Protocol</td>
<td>Exchanges structured information in a distributed environment using SOAP messages [42]</td>
</tr>
<tr>
<td>COM/DCOM</td>
<td>Data Virtualization [41]</td>
<td>XML industry standards, data services and data virtualization middleware</td>
<td>XML including SQL, Xquery and Java, as well as graphical development techniques</td>
<td>data virtualization middleware results in operational transparency allowing easy transition into any existing IT environment [53]</td>
</tr>
<tr>
<td>System Type</td>
<td>Mechanism</td>
<td>Media and Format</td>
<td>Communication Method</td>
<td>Standardization Challenges</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Web-Based Systems [38]</td>
<td>Representational State Transfer (REST)</td>
<td>TCP/IP, HTTP, Java, HTML, and XML</td>
<td>XML, Distributed Transaction on XML[54]</td>
<td>Components communicate by transferring representations of the current or desired state of data elements.</td>
</tr>
<tr>
<td>OpenEHR Systems</td>
<td>An XDS Affinity Domain [51][52]</td>
<td>Cross-Enterprise Document Sharing (XDS) and Cross-Community Access (XCA)</td>
<td>HTTP/1.1 (IETF RFC2616) ISO/IEC 9075 Database Language SQL ebRIM OASIS/ebXML</td>
<td>XDS behaves in neutral manner while reading the clinical documents and supports any type of clinical information without regard to content and representation.</td>
</tr>
</tbody>
</table>

Standardization encompasses many issues [49] in sharing EHR. Web Services Description Language (WSDL) and XML Schema standards do not define how to move the documents between services, how to track the documents, or even how to interpret the documents. Survey [50] gives an insight to various realistic scenarios prevalent in healthcare industry forfeiting availability of sophisticated and robust techniques of designing HIS. Table 2.2 lists the data exchange mechanisms, data exchange standards, formats, languages, and methodology in each architecture. The compatibility of the stated architecture with the available standards and formats strengthens their relationship with each other. Efforts to exchange information employing XML incarnations of descriptive metadata standards such as Dublin Core [7] has fallen prey to a number of encoding and semantic inconsistencies. Thus, the presence of varsity of heterogeneous data-exchange standards and lack of coordination raises the need for designing a common platform that could access data diligently from such diversified sources.

### 2.5.2 Standardization of EHR

HIMSS [55] define the Electronic Health Record (EHR) as “A longitudinal electronic record of patient health information generated by one or more encounters in any care delivery
setting”. EHR includes information about patient’s demographics, medications, history, and laboratory reports. Disparate interpretations of the same information require standardized templates and use of generic terms while storing the values in EHR.

- **Vocabularies**: International classification of Disease (ISD) is considered as standard for billing from World Health Organization (WHO) and various country-specific versions. It is the standard diagnostic tool for epidemiology, health management and clinical purposes.

- **The National Drug Code (NDC)**: It is a standard used within US pharmacy industry. NDC is a universal number that identifies drug or related drug item. The complete NDC number consists of 11 digits with hyphens separating the number into three segments in a 5-4-2 format such as “12345-1234-12.”

- **Healthcare Data Dictionary (HDD)**: supports integration of coded data in the Clinical Data Repository (CDR) [49]. The content of HDD [56] is cross-referenced to standard vocabularies, e.g., SNOMED CT, UMLS, and classification schemes (ICD9CM). Each HDD concept is identified by a meaningless Numerical Concept identifier (NCID) used to encode the data in CDR.

- **Current Procedural Terminology (CPT)** [15]: CPT is a comprehensive list of descriptive terms and codes published by the American Medical Association (AMA) and used for reporting diagnostic and therapeutic procedures and other medical services performed by physicians.

- **RxNorm**: RxNorm [51] is a clinical drug nomenclature that provides standard names for clinical drugs (active ingredient, strength, and dose form) and for dose forms as administered.

- **Archetypes**: Archetypes play a fundamental role for achieving interoperability in healthcare. Archetypes are chunks of declarative medical knowledge designed to capture maximally expressive and internationally reusable clinical information units. These conceptual structures of medical knowledge provide standardized clinical contents. An archetype definition consists of three parts: descriptive data, constraint rules, and ontological definitions. The ISO EN 13606 and openEHR communities specify them using the Archetype Definition Language (ADL) [57]. Archetypes not linked a priority to any medical terminology [58], but can refer to multiple external medical classifications (e.g. SNOMED) from where controlled vocabularies are incorporated as labels of archetype elements.
2.5.3 EHR Exchange Standards

- **HL7**: HL7 is a Standards Developing Organization accredited by the American National Standards Institute (ANSI) to author consensus-based standards representing a board view from healthcare system stakeholders. HL7 has compiled a collection of message formats and related clinical standards like Fast Healthcare Interoperability Resources (FHIR) [66] that define an ideal presentation of clinical information exchange. FIHR promises a sound foundation in solving the real needs and demands of interoperable sharing of EHRs. The standard uses the concept of application-to-application message exchange. The central pillar of HL7 was the HL7 Reference Information Model or “RIM”, initially conceived by HL7 as a modelling language specific to the healthcare domain. Various versions of HL7 exists which unfortunately are incompatible with each other due to lack of well-defined mapping between them.

- **Digital Imaging and Communications in Medicine (DICOM)**: DICOM produced and managed by the DICOM standards committee consists of vendors, organizations, government agencies and business associations. It is a messaging standard for digital images. A DICOM image consists of attributes which contains a multitude of image related information. It incorporates client-server concept. A major disadvantage of the DICOM Standard is the possibility for entering probably too many optional fields. Image objects are often incomplete because of some fields left blank and some filled with incorrect data.

- **The US Health Information Technology for Economic and Clinical Health (HITECH) Act**: The HITECH Act is a part of the American Recovery and Reinvestment Act (ARRA) of 2009. The Act came into existence to promote meaningful use of health information technology. To ensure that it achieves its goals, Office of the National Coordinator for Health Information Technology (ONCHIT) [59], a staff division in U.S. Department of Health and Human Services, designed many programs with the mission to build and promote nationwide transparent interoperable healthcare system. It is constantly engaged in developing and harmonizing standards that could support diversified needs of interoperable health data exchange. The effort would definitely result in improving healthcare quality, reducing cost and redundancy, ensuring the security of EHR and interconnecting health information not only within America but also with other countries.
2.5.4 Technical Interoperability Standards for EHR

Data standardization [13] refers to the use of the same set of codes to encode data throughout the system. Organizations face the challenge of exchanging, comparing, aggregating or integrating data among multiple systems or facilities along with external organizations.

- **Systematized Nomenclature of Medicine, Clinical Terms (SNOMED CT):** It is a national standard for use in electronic health applications in many countries, including the U.S., U.K., Canada, Australia and Denmark. SNOMED CT aims to improve patient care through the development of systems that record health care transactions accurately. Scale is a major issue for SNOMED CT [35] and is activated during editing and development of such systems using most common tools available.

- **IEEE 1073 Point of Care Medical Device Communication:** Interoperability between medical instrumentation and computerized healthcare information systems is achieved through a family of medical device communications standards [40]. Hospitals and other healthcare providers can communicate effectively due to its compatibility with the acute care environment.

- **HIPAA ASC X12 and National Council for Prescription Drug Programs (NCPDP) Batch Transaction Standard:** HIPAA ASC X12 and NCPDP Batch Transaction Formats provide practical guidelines for file submission standard. It ensures consistent implementation of the standard used between pharmacies and processors, or pharmacies, switches, and processors. (www.ncpdp.org)

- **Logical Observation Identifiers Names and Codes (LOINC):** These identify test results or clinical observations uniquely. The observations consist of laboratories, clinical and administrative facilities. These codes are compatible with HL7 and SNOMED. (www.loinc.org)

- **Continuity of Care Document (CCD):** In June 2005, the American Society for Testing and Materials (ASTM) unveiled the CCR (Continuity of Care) [60], data content and document standard for relaying a patient’s core data set upon transfer. In 2000, Health Level 7 (HL7), worked with ASTM to harmonize the CCR with the CDA (Clinical Document Architecture). The CDA enables the electronic transfer of multiple types of medical data from one healthcare institution to another. Institutions that have successfully implemented the CDA aggregate the data sets defined in the CCR and share this information electronically with HL7 messaging. The CCD
(Continuity of Care Document) is part of ‘Integrating the Healthcare Enterprise’ (IHE) IT Infrastructure Cross Enterprise Document Sharing (XDS) profiles for 2006 and 2007.

2.6 Recommendations and Proposed Policy Decisions

Semantic is all about extracting information available in disparate formats, languages etc. by understanding its meaning and logic. Healthcare environment encounters numerous cases of such disparities where the same symptom diagnosed on two patients may have two different interpretation and magnitude depending on the kind of ailment. Automated data translation and storage developed by Kalgren [61] to support improved avionics health management through intelligent evidence streams and databases is a step towards achieving interoperability. The HealthAgents Prototype [62] provides an ideal platform to investigate the impacts and implications of experimenting with semantic-rich data management technologies in a distributed healthcare system.

Standardization

Systems with disparate formats and interfaces supported by wide range of vocabularies discourage interoperability. The high frequency of sharing data within organizations requires concentrating on designing and adopting some methodology that could allow seamless flow of data at both ends. The standardization and procedures [15] need a complete understanding while establishing communication mechanisms and policies for exchanging EHR, thus, eliminating all redundancies and inconsistencies.

Quality Control

Interoperability generates affiliations with multiple health plans and policies around the community. It demands maintainability, compatibility along with flexibility in sharing EHRs at the time of need. Generalizing the quality checks is a herculean task. The data passes through various nodes before reaching its destination. Ongoing monitoring [24], measuring [34] is also critical for quality control [60] and assurance [25] and can affect clinician liability risks. Conducting audits can trace any malicious intenders but cannot identify medical malpractices threatening the lives of the patient. Quality assessment [63] and controlling must be a dedicated department in every hospital. It must design dynamic rules for data sharing
considering associated parameters with every requirement. Submission of detailed reports made mandatory for reviewing the standards and quality of services.

**Scenario-Based Access Controls**

Controlling the access on data sometimes proves fatal in the healthcare domain. It may cause distress, social stigma to the patients if unauthorized access is gained by anyone unconcerned to receive that information. Technically, security tools such as encryption and access controls [64] are in place to protect patient’s health information. Accidental and emergency cases require immediate action where access controls might prove to be a hindrance. Scenario-based access controls and optimization would ensure confidentiality and integrity of patient’s data with its availability anywhere required.

**Patient’s Consent**

The Health Insurance Privacy and Accountability Act Rule (HIPAA) require health care providers to safeguard patient privacy in a variety of ways. Despite the regulatory mandates, a breach to patient’s EHRs is a frequent experience [23]. One of the attribute contributing to such a breach is patient’s consent on sharing his /her health records by the hospital. The hospitals and clinicians take the patient’s or their relative’s consent on every treatment but is hardly taken while sharing the same with their counterparts. It is easy to form rules of obtaining patient’s consent every time records before accessing his records. Such rules are not eligible in every scenario. Not every patient has the capacity to decide on this issue and hence requires doctor or family’s judgment on the same. Moreover, how much information should be shared with patients will vary, depends on their individual circumstances. This is an explorative issue requiring involvement of rational experts of every domain related to healthcare, including patients, finding an optimal solution.

**Encourage greater cooperation between Organizations**

Organizations that share a common strategy should be strongly encouraged to collaborate and design an interface where the health professionals can consult and study patient’s diagnostic data with each other. This collaboration can take the form of common investment in expensive tools (e.g. terminology server) resulting in minimization of cost in the longer run. Agreements can be formulated for exchange of methodology and resources between such collaborations. In order to make this possible, a common understanding of the strategies
chosen by all is an essential prerequisite. There is an increasing need to integrate existing data repositories into (apparently) homogeneous systems that allow queries involving several independent databases, enforce global integrity constraints, etc.

**Encourage greater cooperation between national authorities and standardization bodies**

Standardization is unachievable at local level. It requires strong participation and interference at national as well as at international level. Government at central and state level should set a common goal and encourage standardization of policies and mechanisms to enhance their strategic and operational cooperation in a coordinated approach.

**Monitoring and Training Users of Integrated Systems**

Each organization has one or other performance monitoring plan for its employees. However, while sharing health records between these organizations, number of issues like integrity, accountability and accessibility becomes a major concern. Monitoring and controlling data availability and access at granular level requires the organizations to develop and follow a common development plan i.e. develop high-quality monitoring guidelines concerning sharing of EHR systems. The actual EHR systems and reports of user problems should yield significant information about how clinicians typically use the technology.

Arranging periodic training-programs for EHR system experts, clinicians, government and others must be made mandatory for every healthcare organization. Framework must clearly state the methodology of usage, benefits, and penalties and the same circulated to each of the stakeholder of the system. Such guidance will educate health care providers in properly acquiring the EHR system, and adapting to its environment and behaviors. Positive acceptance of health providers would help in attaining standard of care extended to the patients.

**Global EHR**

Patient availing the healthcare services from any locality, city or country generates the need enabling the availability and accessibility of his EHR globally. A global enterprise EHR system developed by Gartner Healthcare Research [65] provides all the basic functionalities required for healthcare services in an integrated environment. However, their EHRS offerings come with a variety of challenges. Poor communication, coordination, clinical decision support and lack of adaptation between varied clinical needs of different countries are few
challenges to such systems. A white paper by HIMSS [55] explores the efforts and challenges in implementing EHR in various countries around the world. The paper identifies major components that must be tied together for global EHR implementation and its connection with everyone.

**Collaboration**

Many nations are joining hands and developing a common platform providing various health care services. Canada’s International Development Research Centre (IDRC) [67] supports eHealth projects in Africa, Asia, Latin America and the Caribbean (LAC). The Uganda Health Information Network (UHIN) is one such project with research funding from IDRC that has become a standard benchmark for anyone involved in electronic health data collection and transmission.

United States of America and the European Union are in collaboration, through MOU signed in Dec 2010, to accelerate and widespread the usability of interoperability in e-Health. Their joint effort focuses on identifying approaches and internationally recognized standards that would support transnational interoperability of EHR.

<table>
<thead>
<tr>
<th>Country</th>
<th>Program</th>
<th>Components</th>
<th>Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>The National Program for IT(NPfIT) [55]</td>
<td>Personal Demographic Service(PDS), Summary Care Record(SCR), Secondary Uses Service(SUS)</td>
<td>New network infrastructure, Electronic transfer of prescriptions, electronic outpatient scheduling.</td>
</tr>
<tr>
<td>Wales</td>
<td>Information Healthcare Program(IHC) [55]</td>
<td>-</td>
<td>Provides the broad vision and architecture in designing the interoperable interface compliant with the standards for privacy policy, security and interoperability</td>
</tr>
<tr>
<td>Canada</td>
<td>Canada Infoway -EHR Solution Blueprint- A National Framework [55]</td>
<td>Consist of many interoperable EHRs deployed across the country</td>
<td>Development of an interoperable EHR across all healthcare institutions, such that each institution can set up its own implementation strategy</td>
</tr>
<tr>
<td>Singapore</td>
<td>National Electronic Health Record (NEHR) system [32]</td>
<td>Key enabler of Singapore’s vision towards an integrated healthcare system</td>
<td>Enables information sharing across two or more groups and enhance community services</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Health Identity</td>
<td>Establishing logical</td>
<td>Ensure the sharing and exchange of data</td>
</tr>
</tbody>
</table>
The relationship between location, provider and patient is the key to accurate real-time information sharing. Health information within the health and disability sector accurately and safely.

|----------------|-----------------------------|----------------------------------------|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------|

Table 2.3 summarizes the initiatives and efforts of various nations in designing national level programs with an objective of enabling availability and accessibility of patient’s EHR irrespective of time, place and location. National EHR success depends on proper and accurate identification of relevant attributes in spite of disparate notations and approaches. It is the time when each nation should put in similar efforts for the betterment of healthcare quality and services.

2.7 Security of EHR

As the health care industry becomes increasingly tech-driven, the privacy and security of data moving through electronic systems become important and simultaneously more difficult to achieve. Securing data exchange between two systems is a very difficult task, considering a possible intrusion on the flow of data when in transit. Health data is highly vulnerable to cyber threats and social engineering attacks. Access controls and authentication mechanisms, on a global level, are very difficult to maintain and verify. A deep understanding of heterogeneity issues in distributed EHR systems would possibly design appropriate security solutions enabling secured transition of EHRs between disparate hospitals.

2.7.1 Related Study

Currently, HIS deployed in individual healthcare organizations deploy individual security controls to protect EHRs from all possible attacks. Each organization assesses the risks to data disclosures as per their guidelines and strategies. Individual risk management can prove to fail when the systems integrate to achieve interoperability, thus enhancing exposure of data to various sorts of threats and disclosures. This requires significant system administration to reduce inherent risks in the data flow. A survey [68] shows a comparative study of the various security tools deployed in the hospitals and corporate organizations. The study finds firewall as the most sought after solution protecting network security and the biometric given the least importance when talked about safeguarding the internal threats.
Detailed literature survey [69] identifies various security models enabling EHR sharing between different systems. Accessing the data [44] bounded with policies and rules is one-step towards achieving security of EHR. A policy-driven framework [70] covers various security issues in ubiquitous e-health exchange of data. Privacy-preserving protocol [45] that performs record matching across two data sources claim to be more efficient than protocols based on cryptographic techniques [71]. Requirement of policy/mechanisms and multilevel technical framework [45] derive large numbers of longitudinal pseudonymised health records. The specific protection required at each point in a record’s transfer will depend upon many factors, including the system using the record and the data elements exposed.

2.7.2 Security Controls

Many safeguards are available to protect Electronic Health Records. Methods include identification and authentication (passwords, user ids) techniques, access control mechanisms (view/modify privileges of files), audit trails (record keeping of who is accessing what data), protection of electronic communication (encryption and biometric identification including fingerprints, retinal patterns and voice) and disaster recovery programs (backups and network redundancy). Other security controls include, multi-layer authentication, session-based data availability, patient-dependent data access etc. A detailed study of these and many other methods would certainly help in developing a privacy sustainable EHR model allowing efficient sharing between disparate EHR-systems.

2.7.3 Security Gaps

Local systems usually are autonomous, i.e. they enforce an independent access control policy. Interoperable health information systems are more vulnerable than proprietary products to bugs and security breaches. The data might be stolen or illegally sold to third parties. In order to cater for such a situation, the data rightly protected and documented allow such unauthorized party sued in a court of law. The protected health information involved in the breach includes full patient names, patient dates of birth, patient genders, patient clinic medical numbers, internal accession numbers, type of film and site locations, dates and times of image creation, physician or provider names, and internal provider numbers. Not only protecting the privacy of the patients is important but also the ownership (copyright) of the medical data shared with collaborative partners or third party vendors.
Well-defined security policies do not ensure a robust security plan. It is assumed that systems that simultaneously provide partition tolerance, availability and consistencies will prove to achieve the desired level of interoperability and fulfil the security requirements of EHR sharing. Applications that benefit from today's modern network technologies require the integration of existing data. In such environments, new systems can be built on top of existing ones.

2.8 Summarization

The work reviews the current healthcare environment with the perspective of designing the HIS in a manner that one can deploy the interoperability among them. The flow of information moves from understanding of basic interoperability needs in health data exchange to challenges faced during such exchange. Various models and standards are studied to identify the technical aspect of establishing interoperable healthcare environment. Availability of intelligent models supported by state-of-the-art mechanisms need to address various reality checks hindering the functionality in healthcare domain. Various functional challenges that are faced in providing interoperation and scalability among the sub system and external agencies are discussed. These challenges act as outliers while analyzing the suitability of approaches for building a completely viable interoperable healthcare environment. Due attention is given to identify various gaps and lacunae in achieving true interoperability between disparate systems used as a medium for health data exchange.