CHAPTER 4
EXPERIMENTATION

4.1 A CASE STUDY ON AUTONOMOUS HOSPITAL DATABASES

In order to illustrate and evaluate our approach, GIE System is proposed and experimented on distinct healthcare systems for standardizing the healthcare data and also this GIE System may be experimented on various domains for e.g. Bibliographical Databases, E-Business and Self-Service Banking.

The purpose of the case study is not to give a solution to the problems associated with the field of medical informatics in particular interoperability of HIS Rather; the case study aims to show the feasibility and applicability of current approach and provides the basis for an evaluation of the current work [121]. The need for interoperability amongst a large number of independent database systems is required in many different areas. One example is found in the health care industry, where each hospital, or even each department in a hospital, keeps its own database system.

4.2 HEALTHCARE SYSTEMS

Healthcare experts whenever they require all the relevant patient medical data in an appropriate format must be available to them. They moved from isolated software systems in primary health centers towards
solutions which support a continuous medical process. Healthcare systems have grown rapidly in the last decade. It includes multiple healthcare professionals, institutions; utilize ubiquitous computing healthcare environments with technological advances. It means that the structure of EHR and the procedures used for exchanging their data may differ.

In any hospital, the electronic health record (EHR) is unique and it is generated for every citizen. This improves the quality of the healthcare. In an interactive environment, there is a need to look at the information sharing amongst healthcare systems. This becomes an obstacle for sharing health data or health records between healthcare systems.

4.2.1 Organizational System Components

The Organizational component includes key data for patient identification and measurement

Personal data: e.g. name, address, date of birth, sex and age

    //Primary data of a patient //

Administrative data: e.g. health insurance data, general practitioner and case number. // Secondary data of a patient //

Medical history: e.g. ailment, severity of symptoms.

    // Patient medical history//

Diagnosis: e.g. admission diagnose, main diagnose and secondary diagnosis

    Diagnosis   // Diagnosis done for a patient//
4.2.2 Laboratory System Components

The complete laboratory data is integrated with the EHR seldom only. The Laboratory Information System (LIS) can be used as center to incorporate orders, results from laboratory devices, schedules, billing, and other administrative data.

Example:

Medical findings: e.g. laboratory values

// Medical findings of a patient//

Therapies: e.g. medication, surgeries // Patient undergone different

Surgeries//

4.2.3 Clinical Documentation

It captures medical notes and medical reports of a patient. The electronic clinical documentation systems enhance the value of EHR. The examples of clinical documentation that can be automated include:

i. Physician, nurse, and other clinician notes.

ii. Flow sheets (vital signs, input/output, problem lists).

iii. Discharge summaries.

iv. Document recording management.
Example:

Course of treatment: e.g. chronological illustration of a patient’s Condition // Treatments given for a patient//

Discharge note: e.g. recapitulating review and interpretation of medical history // Patient medical history interpreted in discharge note//

Based on these components of the EHR its creation is described in the following subsection.

4.3 CREATION OF ELECTRONIC HEALTH RECORD

The next sub-section describes the accessing of an EHR. The creation of EHR requires the components as shown in Figure 4.1. Creating these components is based on standards such as HL7 that allow disparate healthcare systems to communicate as well as Digital Imaging and communication in medicine (DICOM) that allow images to transfer between imaging systems. In this process the records need to be retrieved from multiple sites that are part of the patient's healthcare continuum using the above mentioned standards. The retrieved information should be presented in a consistent user interface which will not only elicit required information but also support the decision making
process in delivery of healthcare effectively. The information may vary from historical to recent care pertinent to a patient.

The key capability of electronic health record (EHR) is to create a single patient-centric view of entire health data captured for his lifetime. The objective is to enhance the quality and safety of health care.

The EHR components with examples and standards are described in Table 4.1.
Table 4.1: EHR components with examples and standards

<table>
<thead>
<tr>
<th>Components</th>
<th>Examples</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal &amp; Administrative data</td>
<td>name, address, date of birth, sex, age, insurance data, general practitioner and case number</td>
<td>HL7</td>
</tr>
<tr>
<td>Medical findings</td>
<td>laboratory values</td>
<td>HL7</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>admission diagnose, main diagnose, secondary diagnosis</td>
<td>HL7</td>
</tr>
<tr>
<td>Therapies</td>
<td>medication, surgeries</td>
<td>HL7</td>
</tr>
<tr>
<td>Discharge Summary</td>
<td>recapitulating review and interpretation of medical history</td>
<td>HL7 CDA</td>
</tr>
<tr>
<td>Radiology</td>
<td>MRI, CT Scan and Ultrasound Images</td>
<td>DICOM</td>
</tr>
</tbody>
</table>

The Table 4.1 consists of three columns. The first column describes various components. The second column describes the components with examples. The third column describes standards for the components. The personal and administrative data component describes the name, address, date of birth, sex, age, insurance data, general practitioner and case number of a patient.

The diagnosis component describes the main and secondary diagnosis done for a patient. The components are described with standards like HL7, HL7 CDA and DICOM. The medical findings component describes the laboratory values of a patient. The radiology component describes the medical images generated for a patient using MRI, CT scan and Ultrasound. The therapy component describes the
patient undergone different surgeries. The discharge summary component describes the patient medical history interpreted in the summary document.

### 4.4 ACCESS TO INTEROPERABLE ELECTRONIC HEALTH RECORD THROUGH GIE SYSTEM

The EHR of a patient is an important privileged actor with full access to his health data. The GIE System is experimented by relevant actors shown in Figure These actors are to be identified in the process of healthcare information exchange (HIE). The other actors comprise of General Practitioners (GP’s), physicians in hospitals, researchers and pharmacists who probably need different types of customized data relevant to their needs in catering healthcare.

![Diagram of actors identified as major stakeholders to access and exchange EHR.](image)
i. **Patient Requirements**

Actors are identified by the second capital letter. The U_Pat 3 describes the additional data entries into patient record. The U_Pat 1 describes the access of personal health record by patient. The U_Pat 2 describes the change of physician by patient choice. The user requirements for patients as the major actors are represented in Table 4.2. Requirement-IDs for user requirements start with a capital letter “U”, followed by an underscore.

Table 4.2: User requirements for Sharing EHR with GIE System.

<table>
<thead>
<tr>
<th>Requirement-ID</th>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>U_Pat 1</td>
<td>Access to personal health record</td>
<td>Patients want to access their personal health related data independent of location and time in an understandable representation.</td>
</tr>
<tr>
<td>U_Pat 2</td>
<td>Support for change of physician</td>
<td>Patients should be able to consult a physician of their choice.</td>
</tr>
<tr>
<td>U_Pat 3</td>
<td>Adding personal entries to record</td>
<td>Patients would like to add entries such as pain, blood pressure</td>
</tr>
</tbody>
</table>

ii. **Medical Expert Requirements**

The GIE System when experimented by different medical experts for his different requirements is shown in Table 4.3. The U_Med 1 requirement gives the description of physician access to patient record. The U_Med 2 requirement gives the description of emergency access by physicians. The U_Med 3 requirement describes the direct communication with a specialist. The U_Med 4 requirement describes the electronic prescription given by the consultant.
Table 4.3: Expert requirements for Sharing EHR with GIE System.

<table>
<thead>
<tr>
<th>Requirement-ID</th>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>U_Med 1</td>
<td>Access to health record of a patient</td>
<td>Physicians expect access to relevant information of a patient's record.</td>
</tr>
<tr>
<td>U_Med 2</td>
<td>Emergency access</td>
<td>Physicians want to override access permissions in case of danger to life.</td>
</tr>
<tr>
<td>U_Med 3</td>
<td>Direct communication</td>
<td>Secure communication for consultation of a colleague/specialist.</td>
</tr>
<tr>
<td>U_Med 4</td>
<td>Electronic prescription</td>
<td>Drugs should be prescribed electronically.</td>
</tr>
</tbody>
</table>

The data content of EHR promote data quality through data consistency across the organization. The data dictionaries support data standardization, which is necessary for ensuring accurate interpretation and exchange of healthcare information.

i. Table Name

ii. Attribute(s)/Field name(s)

iii. Attribute description(s)

iv. Data type (text, number, date etc)

v. Format

vi. Range of values

The parsing process consists of some events when reading certain elements. The EHR data will be parsed in order to access.

Every EHR that is created must make a provision to give access to the data stored. They are message generation process,
transport process and receiving process as shown in Figure 4.3 and are proposed as a message exchange model. The processes required to provide access EHR are proposed as three. The events are checking well-formed syntax and searching useful piece of information. It allows exchanging EHR data as XML document and vice-versa.

These generated RIM objects are represented over a DOM tree and then composed as XML message. All XML elements are involved and represents how they relate to one another to make a tree like model of XML document without any presumptions. The XML based EHR document ‘D’ is modeled as a DOM object. Document tree ‘T’, in which nodes represent XML elements and edges represent parent-child relationships between XML elements. The first process is to refer a
database, convert to RIM object, making document object model (DOM) tree and create a message. The DOM is an object model to represent XML documents. To start, it references database(s) and retrieves data to form a RIM object.

i. Elm.Name: the name of the XML element.

ii. Elm.Parent: the parent node of E, if root node NULL of T.

   Elm.Children: the set of child nodes of E denoted by: Elm.c1, .. , Elm.cm.

iii. Elm.Attributes: the set of XML attributes of Elm denoted by: Elm.a1, .. , Elm.an.

   The attribute names are denoted by Elm.ai.Name where i = 1.. n.

Elm.Value: the values of the set of XML attributes of E are denoted by Elm.ai.Value, if a non-leaf node value is NULL.

**Example 1:**

The Patient Data has children like Name, Age, and Ref_Hosp and Clinical_Test has children like Pat-Id, Type and Valuation. All these leaf nodes are represented by their respective values and all the values compose a XML message. An XML DOM tree for an instance of XML document is illustrated in Figure 4.4 & Figure 4.5. The PatientHealthRecord node at the top of the tree has two children such as (Patient_data, Clinical_test).
Figure 4.4: Tree representation for the patienthealthrecord.xml

Example 2:

Figure 4.5: Tree representation for the Patient Health Record

The patient with name ‘NARESH’ has components like laboratory results, surgical procedures, radiological images that create his EHR with
unique Patient-ID. In Figure 4.4 & Figure 4.5, the health data is parsed with proposed DBX algorithm and XML data is extracted as shown in Figure 4.10.

In another example, the patient with name ‘SURESH’ has components like radiological images that create his EHR with unique Patient-ID as shown in Figure 4.6. The health data is parsed with proposed DBX algorithm and XML data is extracted shown in Figure 4.10.

![Figure 4.6: Tree representation for the Patient Health Record with minimum XML data](image)

The aim is to send a message to receiver safely as shown in Figure 4.7. The XML message is sent by using some transport mechanisms such as e-mail, HTTP, TCP/IP & SOAP.
The final process is to receive the message which is shown in Figure 4.7. The receiving process is to parse, interpret the DOM tree and retrieve the data from a RIM object to store it into database.

To create and provide access to EHR a GIE System is proposed. It is both operating system and programming language independent. The interoperability is provided between different platforms regardless of the type of software or hardware used. It is simple and reliable method of distributing and synchronizing information among hospitals.
An automated interface that does not require users to handle information or be trained and supported.

A solution that is quickly installed, remotely configured, managed and supported.

It provides a standard way to support a wide variety of EHR’s that may be used by physicians.

It provides a remote application platform for future collaborative efforts with physicians and other across the community.

The Figure 4.9 illuminates the need of proposal and the algorithms to be employed. An interface is in need to integrate these two algorithms as a GIE System in order to support creation and access of EHR. The DBX algorithm is proposed to extract health data in XML format from database(s). To incorporate the EHR data into relational database a XDB algorithm is proposed.

![Diagram](image.png)

Figure 4.9: XDB and DBX algorithms are used independently or jointly.
4.4.1 DBX Algorithm

The DBX algorithm extracts health data from the database. It generates XML based EHR document and allows an exchange. The Pseudo-code for the DBX algorithm is given below:

**Input:** \{Attributes\} // set of attributes

**Output:** EHR document (XML format)

1. Begin
2. Create DatabaseConnection ()
3. Select Query (Connection)
4. Execute Query ()
5. Find Root Node ()
6. for (i = 0; i < table_n.Rows.Count; i++)
7. Begin
8. Add table tag in XML
9. Add child node for each Attribute
10. get attributeNames()
11. get attributeValues()
12. Create XML based EHR document
13. End
14. End
The DBX algorithm takes database attributes as input and produces EHR document. The DBX algorithm generates EHR documents like examples shown in Figure 4.10.

The DBX algorithm generates EHR documents like examples shown in Figure 4.10.

```
<?xml version="1.0"?>
<Root>
    <PatientHealthRecord>
        <Patient_data>
            <Name> Naresh </Name>
            <Age> 25 </Age>
            <Ref_Hosp> Apollo </Ref_Hosp>
        </Patient_data>
    </PatientHealthRecord>
</Root>
```

(a)

```
<?xml version="1.0"?>
<Root>
    <PatientHealthRecord>
        <Clinical_test>
            <Pat_Id> 10000 </Pat_Id>
            <Type> Blood Test </Type>
            <Valuation> 12.5 </Valuation>
        </Clinical_test>
    </PatientHealthRecord>
</Root>
```

(b)

```
<?xml version="1.0"?>
<Root>
    <PatientHealthRecord>
        <Surgery_Type>
            <Pat_Id> 10000 </Pat_Id>
            <Type> Skin </Type>
            <Srgn> Dr.Mohan </Srgn>
            <Date> 13/11/2005 </Date>
        </Surgery_Type>
    </PatientHealthRecord>
</Root>
```

(c)
The DBX algorithm generated XML based EHR documents shown in Figure 4.9 consists of patient primary data, secondary data, surgical and radiological data. The fields like Patient Id, Name, Age, Ref_Hosp and Clinical Test with type and valuation, Surgery Type, Surgeon Name, Date and CT scan are described. The EHR data are now ready to incorporate in any hospital domain for interoperability.

4.4.2 XDB Algorithm

The XDB algorithm takes EHR document as input and maps its contents to target relational database attributes. The XDB algorithm is illustrated below:

**Input:** EHR Document (XML Format)

**Output:** EHR Elements mapped to database attributes.
The pseudo-code of XDB algorithm is stated as below:

1. Begin
2. get EHR _Document()
3. Parse EHR _Document() // parse it
4. Find Root Node
5. Find children of Root Node
6. Element Count = 1
7. Read EHR Document(nodeCollection) // read EHR elements
8. {
9. For (i=0; i<size of (nodeCollection); i++)
10. {
11. Element Count++
12. Elm.Name = nodeCollection[i] -> attributeName
13. Elm.Value = nodeCollection[i] -> attributeValue
15. Create DatabaseConnection ()
17. Close (connection)
18. }
19. }
20. End
1. Begin
2. get EHR_Document()
3. Parse EHR_Document() // parse it
4. Find Root Node
5. Find children of Root Node
6. elementCount = 0
7. Read EHR Document() // read EHR elements
8. {  
9. For (i=0; i<=size Of (Mapping Table); i++)
10. {  
11. For (l=0; l<elementCount; l++)
12. {  
13. Read (a[l][0]);
14. For (n=0; n<=settingsCount; n++)
15. {  
16. Read (b[n][0])
17. If (strcmp (a[l][0], m[i][0]) && strcmp (b[n][0], m[i][1])
18. {  
19. b[n][1]=a[l][1];
20. i = i +1
21. Break
22. }
23. Else
24. \( n = n+1 \)
25. }
26. \( l = l+1 \)
27. }
28. Create DatabaseConnection ()
28. Insert into Table Values \( (b[0], b[1], \ldots, b[n]) \)
29. Close (connection)
30. }
31. }
32. End

The document is parsed to retrieve root node and corresponding children with values. The Element entity contains the following attributes: Elm-Id: A unique identifier for each element, Elm-Name: The name of this element, Elm-Value: The text or data of this element (NULL for none), Parent-ID: The element which is parent to this element (NULL for the root element).The GIE System maps EHR data into a relational database. The XDB algorithm takes EHR document (XML Format) as input and elements are mapped to the database. The proposed XDB schema incorporates EHR elements in to database as shown in Figure 4.11.
The XDB algorithm tries to map the EHR elements into database as shown in Table 4.4.

Table 4.4: Element Table constructed by XDB algorithm

<table>
<thead>
<tr>
<th>Elm-Id</th>
<th>Elm-Name</th>
<th>Elm-Value</th>
<th>Parent-Id</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>XML</td>
<td>Null</td>
<td>Null</td>
</tr>
<tr>
<td>2</td>
<td>PatientHealthRecord</td>
<td>Null</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Patient_data</td>
<td>Null</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Name</td>
<td>Naresh</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Age</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Ref_Hosp</td>
<td>Apollo</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Clinical_test</td>
<td>Null</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Pat-Id</td>
<td>10000</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>Type</td>
<td>MRI</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>Valuation</td>
<td>Metastasis</td>
<td>7</td>
</tr>
</tbody>
</table>