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REPLICATION AS A WAY TO ACHIEVE INTEROPERABILITY IN HEALTHCARE

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ABBREVIATIONS

eHealth	- Electronic Health
WHO	- World Health Organization
EMR	- Electronic Medical Record
MoH	- Ministry of Health
ICT	- Information and Communication Technology
IT	- Information Technology
EHR	- Electronic Health Record
HIS	- Health Information System
PHR	- Patient Health Record
HL7	- Health Level Seven
iEHR	- Interoperable Electronic Health Record
NPfIT	- National Programme for IT
HIE	- Health Information Exchange

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CHAPTER 1

INTRODUCTION

1.1 Background

When Kenya gained independence a three-tier health system was adopted by the central government at all levels including the district, provincial, national levels, sub-district levels and local government in the urban areas. Kenya is a established and fairly well organized country in Africa and particularly found on the East African region, nevertheless, the obligation and need for improved sustainability, availability and improved quality care in the health system is quiet high.

Health is the state of complete physical, mental and social well-being which leads to better quality of life and reduces pressure on overburdened hospitals, clinics and medical professionals (The Boston Consulting Group, 2012). Health management is a crucial part of national priority to improve patients' health in the society. In the 19th and 20th Century, clinical care documentation was handwritten as progress notes that were paper-based patients' records. This consumed a lot of doctor's time in record taking rather than handling the patient and increased data redundancy (Free et al., 2013). Until now most healthcare facilities still use paper-based records for recording data such as identifying the patient, why the patient is visiting the healthcare facility, the patients' medical history and background, results of the physical and any other examination, existing symptoms, evaluation, treatment and the discharge letter (Dalianis & Dalianis, 2018).

Healthcare systems in developed and developing countries are faced with many tests which include high demand for quality and equitable distribution. But with these challenges governments globally are striving to develop and improve health systems and facilities in their countries by allocating huge chunks of their budgets to the health sector. For example in the USA the health sector is the second largest share of the total county's budget and in most industrialized and developed countries their governments provide healthcare services for their citizens at a subsidized rate (Kelton, 2007).

Health is very critical in building of a country's economy because a healthy nation is a healthy economy (Rono, 2016) . Kenya has not been left behind in the adoption and improvements in the healthcare sector this is seen in the government's continued efforts in providing services to its

citizens especially in adopting and focusing on electronic health (eHealth). WHO defines E-Health as the use of ICTs for health. This has been recognized by the constitution of Kenya 2010, Kenya Health Policy (2014-2030), Vision 2030, Kenya eHealth Strategy (2011-2017), ICT Master Plan, the Health Bill and the Big 4 Agenda (Ministry of Health Kenya, 2016). That there is fundamental need to develop strategies for the long term, guidelines on policies, and standard legislations that govern the adoption, deployment and utilization of eHealth services in Kenya so as to strengthen and fasten integration of use of ICTs into healthcare system.

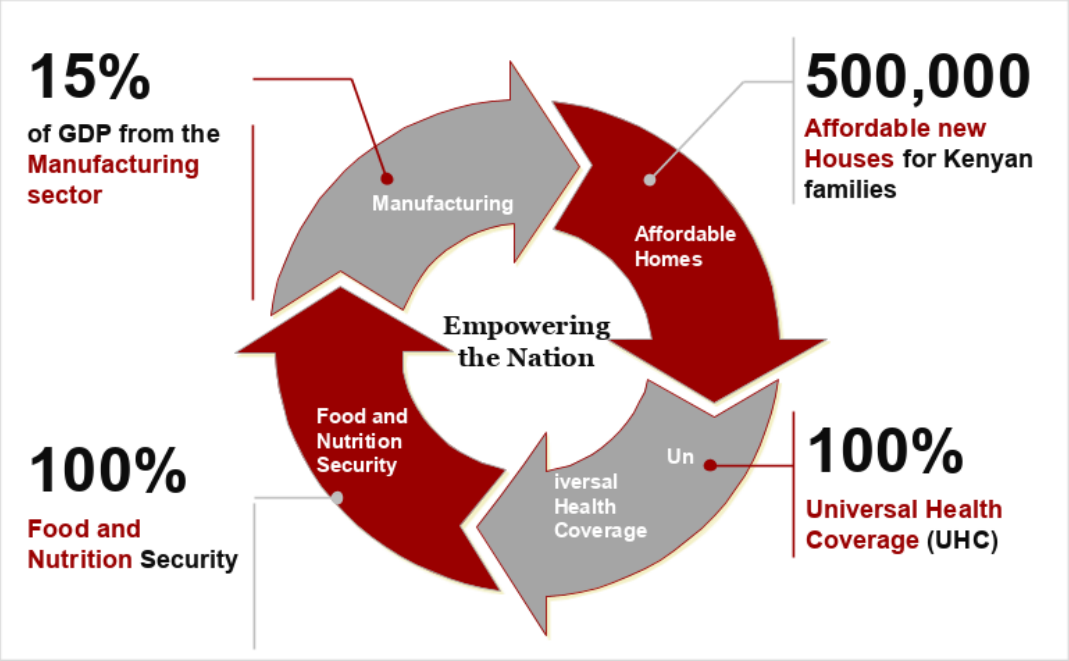


Figure 1: Kenya Big Four Agenda

Table 1: Global and Local Standards/Initiative relating to eHealth

ORGANIZATION	STANDARD/INITIATIVE
National Electrical Manufacturers Association (NEMA)	Digital Imaging and Communications in Medicine (DICOM)
Health Level Seven International (HL7)	HL7 family of standards relating to the exchange, storage, and use of electronic health information
World Health Organization (WHO)	Global Observatory for eHealth
Comite Europeen de Normalization (CEN)	CEN/TS 15699:2009: Health Informatics
International Telecommunication Union (ITU)	Multimedia Framework for eHealth Applications; and Emergency eHealth Services Standardization
International Organization for Standardization/ Institute of Electrical and Electronics Engineers (ISO/IEEE)	ISO/IEEE 11073 Medical/ Health Device Communication Standards
Ministry of medical Services, and Ministry of Public Health and Sanitation Kenya	Standards and Guidelines Electronic Medical Record (EMR) systems in Kenya, 2010
Ministry of Health (MoH), Kenya	Kenya Health Enterprise Architecture. 2015
Ministry of Health (MoH), Kenya	Kenya Standards for E-Health Systems Interoperability. 2015

The use of Information and Communication Technology (ICT) has facilitated in developing new ways of providing efficient, effective and secure health care. When developed and implemented successfully, ICT can improve access for rural and isolated communities, provide support for healthcare workers, aid in data sharing and it provides effective electronic mean for data capture, storage, interpretation and management especially in the Kenyan concept. ICT currently can simplify the patients' medical treatment process and spread medical services to the isolated

communities and also to other patients for example, digitization of medical records which reduce retrieval of data and maintenance cost of these records (Free et al., 2013).

Though many health facilities in Kenya in the last few years begun adopting IT for administrative purposes, medical record keeping in public health facilities is still done manually (Kimathi, 2017). Still there is use of offline mediums i.e. paperwork, tapes, compact tape etc. to store patient data and subsequent history can lead to damage/loss of the data and there is no transfer of data from one facility to the any other facility. Patients' medical record keeping in many public healthcare facilities is still mostly done manually a fact that is acknowledged due to the number of patients seen in these institutions. This is so because of the ease of accessibility and affordability to majority of Kenyans. A case is that of Kenyatta hospital which is oldest referral and teaching hospital which receives many patients and the number of records required to be maintained is enormous and requires a large work force consisting of medical records officers, assistants and clerical officers for efficient record keeping.

This is why there is a need for deployment of health information system. The role of the HIS will not only routinely collect health service data and convey it to higher levels of the healthcare system, but to facilitate evidence based decision making at all levels (Ministry of Health Kenya, 2016). Over the years the government has been taking great strides by developing policies which are put in place to promote delivery of healthcare services to its citizens. Just like other countries Kenya has a constitution that has a legal framework which includes all inclusive right to health approach in terms of health service delivery and ensures that each Kenyan citizen achieves the highest attainable standards of health (Kimathi, 2017).

This approach is a bit difficult to implement particularly when dealing with many facilities at the same time as seen in Kenya because of the public, private and even other institutions like home care etc., such that if failure occurs in the central server no operations will take place. Unfortunately, most healthcare facilities still use and rely on paper based records, making it difficult to coordinate care for the patient and perform routine quality measurements leading to medical errors. These paper-based records are expensive to maintain, easily destroyed, difficult to analyze, lack security and confidentiality, time consuming retrieval methods and medical errors caused by ineligible handwriting of physicians (Ayieko, 2016). According to (Chebole,

2015), migrating to EMR will be one among the many solutions for providing better access to healthcare facilities such as hospitals and clinics for patients and health professionals such as doctors, nurses, general practitioners among others, improve working together and collaboration between different government ministries across the globe and internally, increase quality care of the patients and exchange of health records.

The concept where there is the capability of two or more information systems or computers to communicate and exchange information and be able to use the data and information that has been exchanged is what is known as interoperability (Guedria & Lamine, 2015). In healthcare, interoperability can be defined as the ability of HIS and information technology systems to collaborate and work effortlessly within and across organizational boundaries so as to advance effective delivery of healthcare stakeholders such as communities and individuals. Interoperability is a key that will enable access to robust patient data and ensure that there are better healthcare outcomes and in the process enhance efficiency and cost saving (Juma et al., 2012).

Globally every year, over 22 million people die from ailments such as cardiovascular diseases, HIV, cancer, diabetes among others and a large chunk of these deaths occurs in developing countries. Time is one of the main crucial factors in all process of health services delivery to improve the safety of the patient. Provision of previous and recent medical records of the patients will help in limiting and preventing errors and deaths. EHealth has in its capacity the power and ability to lower healthcare costs while bringing and enhancing quality care closer to the citizen by even use of Personal Health Records (PHR) to enabling patients to participate in their own health (Chebole, 2015). Traditional methods include paper chart records which are not available when needed and patients have to pay additional cost due to their past data being inaccessible.

Most healthcare facilities in Kenya use either traditional mediums of data recording e.g. paper records and charts for storing patient information or most of them have standalone systems which keep data that is relevant to the clinic and the patients who visit them. These files/records remain stagnant and are not shared with the patient or any other facility unless there is a request to do so. When the patient visits a different clinic or hospital, a new file is opened and

progressive treatment is not possible since their previous records are located manually or in a different system elsewhere.

Doctors carry out new tests to know the state of the patient even if it is clear that the patient has some condition since the health facility does not have the records and compulsory examination has to be carried out. This can lead to delayed attention and worsening of the patient's condition and sometimes death of the patient. According to Emmanuel and Jamah (2013), medical lawyers and pathologist show that three out of ten patients are wrongly diagnosed and even given the wrong medication. Cases have been seen in Kenya where by patients are given the wrong diagnosis and medications leading to life threatening situations for example brain surgery being conducted on the wrong patient among other cases and this is due to poor records management. Patients also incur more costs because of repetition of examinations and referral to other high level facilities in cases where the facility lacks proper equipment or laboratories. Many facilities fear exchanging the patient's data due to the privacy and confidentiality of health records.

1.2 Problem Statement

Most health facilities in Kenya use either traditional mediums of data recording e.g. paper records and charts for storing patient information or most of them have standalone systems which keep data that is relevant to the clinic and the patients who visit them. These files/records remain stagnant and are not shared with the patient or any other facility unless there is a request to do so. When the patient visits a different clinic or hospital, a new file is opened and progressive treatment is not possible since their previous records are located manually or in a different system elsewhere.

E-health interoperability has the ability to improve individual health care and well-being and ensures greater quality in delivery of safer medical services. It will also ensure access to eHealth records of patient anywhere at any time by authorized personnel. Patient's healthcare will improve due to availability, synchronization and continuity of care, improved exchange and organization of information flowing and collaborating between stakeholders participating in this process and also conduct research and come up with better ways of delivering healthcare.

Interoperability is important in E-Health domain because it increases the quality of healthcare and decreases costs of treatment and data exchange. It also allows unrestricted access to EHRs of a patient anywhere at any time by authorized personnel. The purpose of this study was to come up with a solution that will be integrated into the different EMR systems to ensure that there is exchange of data among the systems

1.3 Research Objectives

i. To evaluate the challenges facing patients and health facilities in the adoption of eHealth interoperability
ii. To identify a model for health information systems interoperability for exchange of health records
iii. To develop a prototype that will support exchange of health records based on the identified interoperability frame work

1.4 Justification of the Study

For many years due to the adoption of ICT, most organizations have been migrating from manual recording of data to electronic way of storing this data. Most organizations have developed their own systems or others prefer to buy ready -made off-the-shelf software. This has steered to the mushrooming of many EMRs in the country and all of them have different ways of handling and storing this data. The issue comes when there is need to exchange this data or share it when the need arises; this is where the issue of interoperability comes in.

The study will aim at coming up with way of providing an easier way of exchanging the patients' health records between and among the health facilities. This means more precise and up to date decisions will be made concerning the patients in any hospital in the country as health practitioners are able to preview the patient medical history. Is there a need to have interoperability of paper records?

CHAPTER TWO

LITERATURE REVIEW

2.1 Electronic-Health Records

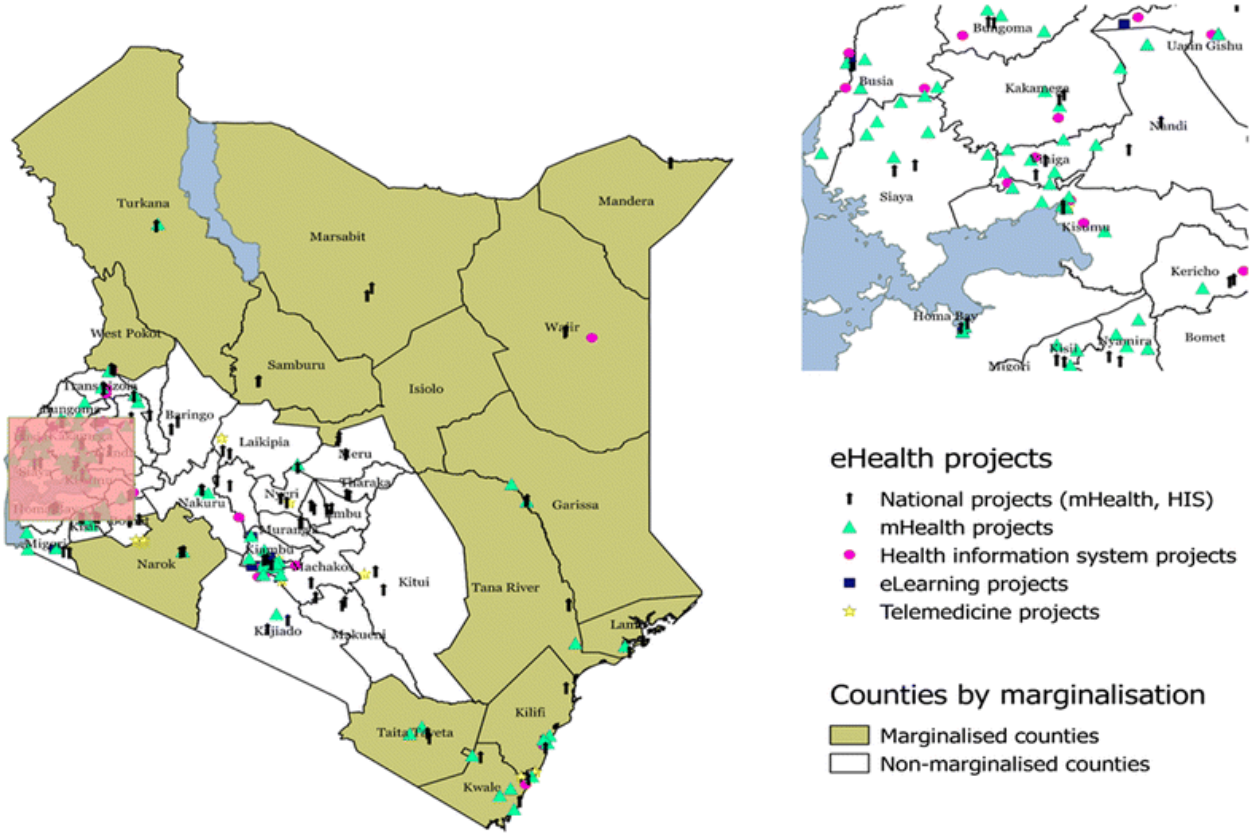
EMRs were first used as electronic sources used to digitize patient information due to the additional benefits that are available and not mostly present in paper-based charts. These benefits include the ability to easily order and keep track of sets of information, monitor changes in patient outcomes after application of new procedures, and identify which patients are due for physical exams, surgical procedures and immunizations among others. However, EMRs are practice-specific, and they are inept to transfer information to outside healthcare providers, other healthcare systems and facilities and also to patients. This is why EHRs were developed as they have additional modules such as information sharing among various types of healthcare providers located in different locales and between providers and patients (McMullen et al., 2014).

Information Technology (IT) has transformed every feature of our lives and it has drastically changed very industry in the world healthcare system being not left behind. IT has and is being used in many countries in terms of individual HIS, electronic medical record (EMR), telemedicine among other areas (Noraziani et al., 2013). Electronic-Health Records (EHRs) is an automated version of patients' historical health record that was previously generated, recorded for use and kept in paper based-charts (Melis, 2011). The American Journal of Health Sciences defines EHR as an electronic record of patient health information that is created and produced by one or more encounters in any healthcare delivery setting and can used even in the long-term. The information that is found in these records provides the patient bio and a lot of information on a particular patient. Some of the information that may be included include but is not limited to patient age, name, gender, , improvement records, complications, the medicine given to the patient, any changing signs like drop in blood pressure among other vital medical signs, history of the patient in terms of any medical conditions, lab information and imaging and x-ray reports. EHR is capable of generating complete record of all information when a patient visits a healthcare facility and any care activities that the patient has gone through and also shows the

kind of decision the healthcare professional has undertaken while enhancing quality and reporting on the progress.

EMR systems have been used since 1972 but their acceptance and use in digitization of medical records has only begun to be accepted and encouraged by governments recently. MoH in Kenya is vigorously promoting the implementation of EMR systems aiming at improving healthcare delivery, management of health information systems and patient medical results (Waithera et al., 2017). Kenya is not been left behind in adopting and implementing eHealth.

Figure 2: eHealth and mHealth adoption in Kenya (Njoroge et al., 2017)



EHRs documents clinical care and also perform other additional functions in supporting good quality care. Some common functions of EHRs include (Knox & Brach, 2015):

- Recording patient name, age and other crucial information in terms the care they are given on each visit.
- Use of EHRs for making decisions.
- Approvals, consent and directions
- APIs and interoperability essential to exchange health information with other facilities
- Prescribing of medications
- Reminders and warnings
- Understanding the medications
- Screening tools and checklists
- Educating the patients

EMRs have the capability on hoe improvements in patient care can be achieved by managing patients' medical and personal information efficiently and effectively. The EMR has some benefits which include but not limited to human errors reduction, securing of medical information is improved, easier access to medical information, minimizing duplication of labor and records, enhancing the documentation of health data, costs reduction of ICT, decision making activities support, quality care being improved, data repository and reduction of papers (CHERONO, 2015).

2.1.1 EHRs At The County Level Hospitals

Over the last two decades, EHRs and other forms of IT systems in healthcare facilities have been accepted swiftly in developed countries. Countries like Kenya are now embracing this development and commencing in replacing paper based systems with digital systems. This has been made possible due to the ever changing technology infrastructure such as cloud-hosting, smart phones, tablets, and the internet (Powell & Paton, 2019). Kenya's hospitals are devolved at a county level to the 47 counties. The government through the MoH, is supporting these counties especially in use of ICTs, by establishing an e-Health departments, to the District Health Information Software (DHIS2).

Machakos County in Kenya was the first to implement and use AfyaEHMS which was later adapted to other healthcare facilities within other counties. Machakos County hospital earlier on used existing IT systems but was encouraged by MoH to use their back up system so as to lower costs, have better performance of the systems and be supported technically. The county plans to digitize all the 320 facilities so as to increase collection of its revenue, retrieval and exchange of patients records and using the information for research. However, like many county hospitals in Kenya, its highest level of digitization is at the revenue collection points, administrative services and the Comprehensive Care Clinics (CCC) that offer services to HIV patients.

The referral hospital is using a system for billing the patients and they are working to automate the paper-based records.. Despite all this the process is facing some problems such as; having budgets that are low especially in ICT, and no training for the users.

2.1.2 Challenges of Implementation of EHRs at the County level

Some of the challenges identified were (Paton & Muinga, 2018) (Muinga et al., 2020):

1. The manual paper file system ran in parallel with the new system making making the users use the older way of doing things use of paper charts due making assumptions that that EHR is complex to use and lack of adequate training.
2. Work flow difficulties due to incompatibility with how their work flows
3. Fearing that the computers that would be used would be stolen
4. Different levels of interoperability where the systems although in the same hospital cannot communicate and exchange medical records.
5. Not having the necessary skills to operate the systems and not willing to learn to do so resisting the changes.
6. Nor having PIs due to the terms that are in use in the different healthcare
7. Infrastructure challenges like low number of computers.
8. Managerial issues at the different levels of county and national government

2.2 interoperability Concept

The healthcare IT environment is developing and progressing in recent years and healthcare administrations are becoming more interested in improving the care of patients through systems

that are well-organized, information availability has become greater, use of advanced technology and new value-added ways of data and analysis of data plus the risk. Therefor this shows that healthcare facilities worldwide need to become more adept to new ways of echange, process and being able to interpret this exchanged information between the devices and heath information systems.

Interoperability is where systems or different applications are able to exchange data and have the ability to use this information. In healthcare context globally, interoperability enables health information systems to work across the administrative and healthcare facilities to effectively deliver healthcare services to private and public individuals (Juma et al., 2012). It is therefore achieving and using the different technologies that are there such as computers, OS, applications connected to form different LANs and WANs.

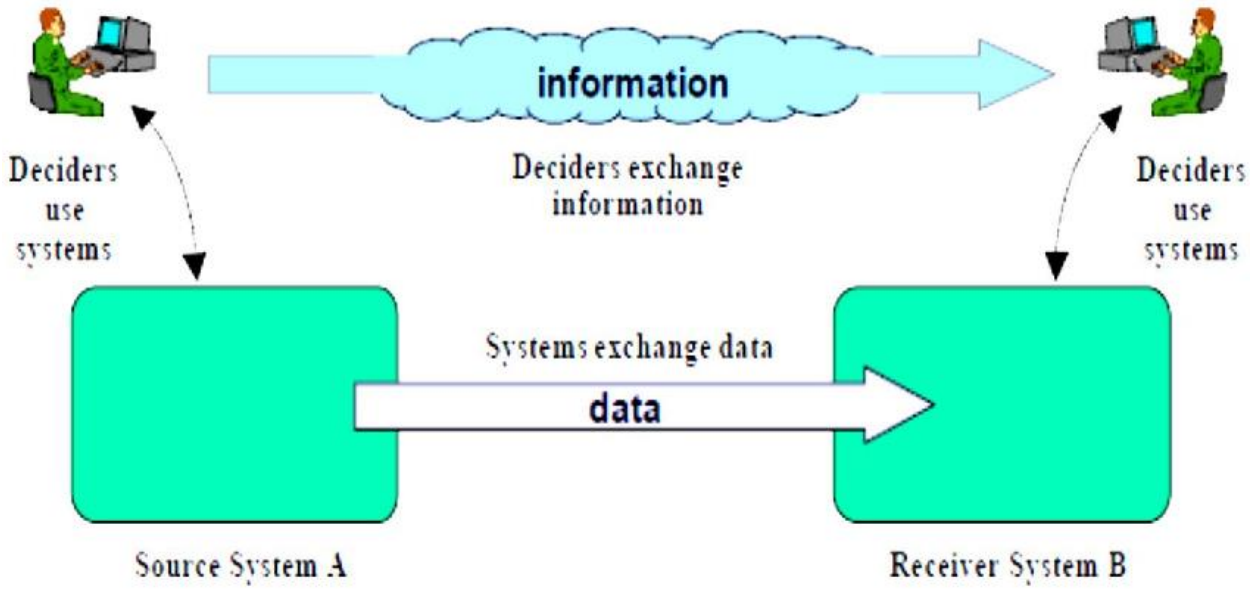


Figure 3: interoperability concept

2.2.1 Types of interoperability related to health

(Studeny & Coustasse, 2014), interoperability issues can be looked at from three different viewpoints:

Foundational interoperability exchanges data between HISs but the recipient system is unable to interpret the received data. For example, user is able to read the medical record and write in their device and the receiving device.

Structural interoperability is when data is exchanged among the medical systems is read and understood by the recipient up to a certain level. For example a hospital directing a Health Level Seven (HL7) interface message with patients' collective past to a home based healthcare facility. The information is read and is added to that facilities record.

Semantic interoperability data exchange allows interpretation of data. This happens when patients visit different facilities and this data is pulled from all the facilities visited by the patient giving the most current and up to date data on the patient.

Many benefits of Interoperability can be identified for all the stakeholders involved in healthcare delivery:

i. i. Providing an easy access to patients records that is stored in heterogeneous warehouses in an easy and timely manner and thus improving the healthcare process

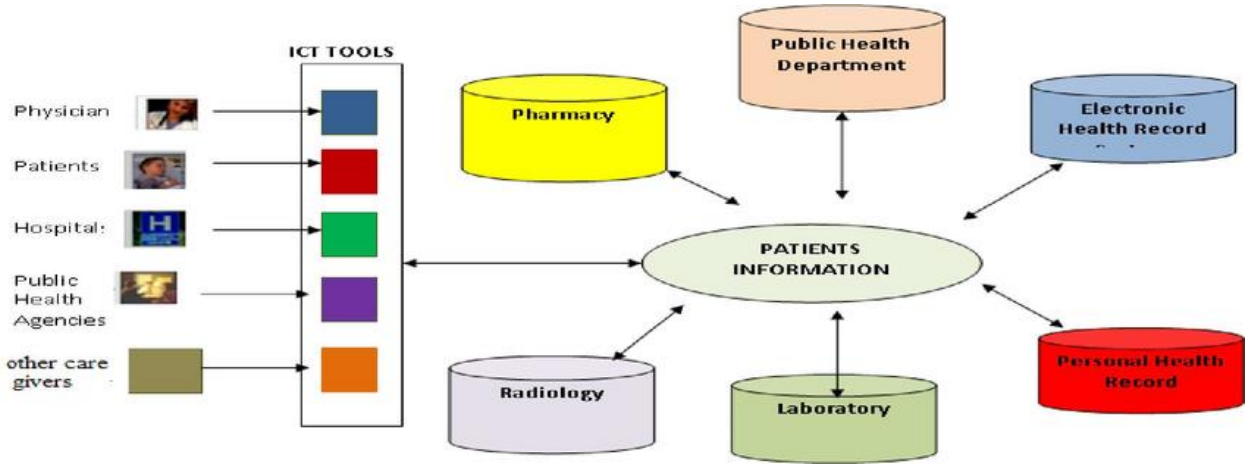


Figure 4: Access to patient information

i. ii. The care givers to understand the languages and models that are transmitted between and among the systems and the meaning is known and understood
ii. iii. Implementing interoperability can help reduce medical errors.
iii. iv. Stakeholders can benefit efficiency gains due to reduction in duplication of data entry that is individual and healthcare professionals.
iv. v. Faster access to care, diagnosis and treatment of disease while reducing costs.

2.2.2 Barriers to Interoperability in Healthcare

Interoperability has major positive impacts on healthcare when it will be successfully adopted, however there are some factors that are hindering the adoption of interoperability in healthcare systems (Iroju et al., 2013), (The Health Information Technology Policy Committee, 2015):

a) Universal adoption of standards- based EHR systems is lacking
   HIE cannot happen until vendors develop EHRs that exchange patient records with other systems.
b) Privacy and security challenges associated with wide spread health information exchange complexity
c) Use of incompatible clinical terminologies
d) Legacy systems prevent interoperability with other vendor's applications and systems so as to protect their identities and brands.
e) Resistance to change because of the perception that paper-based records are secure.

2.3 Interoperability Frameworks/Models

These are some of the main interoperability models and frame works relevant to the health sector

2.3.1 eHealth European Interoperability Framework (eHealth EIF)

The e-Health EIF framework (European Commission, 2013) was developed by the European commission for the development of interoperability. This framework provides endorsements and conditions to link e-Health systems. The model identifies four stages of interoperability which are: legal, organizational, semantic and technical.

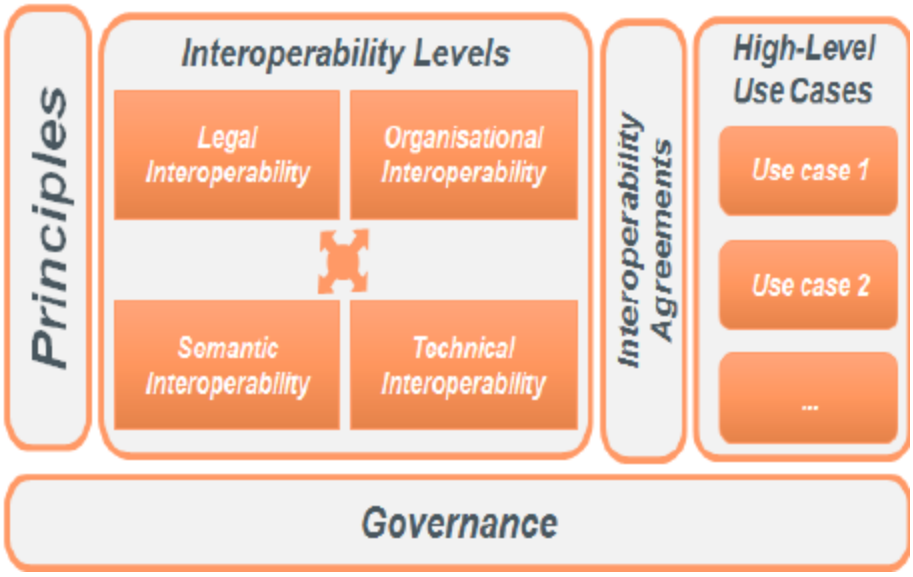


Figure 5: eHealth EIF Framework

Legal interoperability aligns legislature so that the exchanged data is given appropriate legal weight.

Organizational interoperability synchronizes the procedures for the organizations to achieve an agreed and common value added objective.

Semantic interoperability enables the same meaning in the data that has been exchange by the systems.

Technical interoperability discusses these issues that are raised when the computers, applications and services are connected

For individual level, the organization involved should authenticates collaboration measures in the interoperability contracts, interoperability authority covering the owner of the data , meaning, repairs, observing and executing interoperability among the organizations .

EIF has 6 principles: security and privacy, transparency, preservation of information, reusability, technological neutrality and adaptability and openness and two additional principles patient centricity and an use case approachability.

2.3.2 Health Information Systems Interoperability Framework (HIS)

This is framework developed by ASIP Sante (Agence nationale des Systemes d'Information Partages de Sante) which aims at:

- Inspiring expansion of services for the electronic sharing of PHI.
- Permitting creation of interoperability conditions between HIS systems which have been able to give and stipulate privacy and security requirements.

The model stipulates the principles which are used for e-sharing of individual health records by use of HIS systems. The model also stipulates the implementation of the standards for facilitation of distribution of communicating HISs who have agreed privacy and secured requirements.

This framework is divided into components across 3 interoperability layers:

- Content layer (semantic and syntactic content): specifies the exchanged or shared data in view of terms and vocabularies used;
- Service layer: specifies the content shared , services, the rules and up to what restriction
- Transport layer: specifies the rules used to exchange the services

The two layers of service and transport technical as they developed with vendors participating. The other layer which is content depends on the users input and it is developed independently.

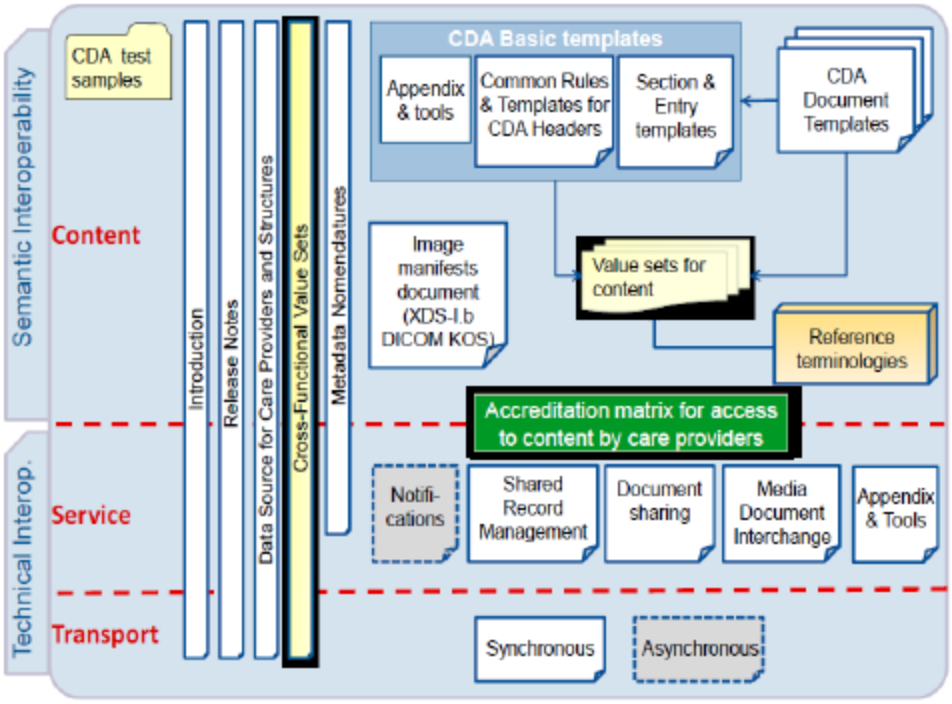


Figure 6: How HIS Interoperability framework is Organized(ASIP, 2010)

2.3.3 eHealth Interoperability Framework (eHealth IF)

This interoperability framework (NEHTA, 2007) was established by the National eHealth Transition Authority (NEHTA) initiatives in Australia and it summaries three levels of interoperability across health organizations:

Organizational layer provides sharing of policy and processes across the shared policy and e-Health interoperability agenda found in NEHTA initiative. It includes business processes, standards plan, security polices and privacy.

Information layer provides the common development blocks for sematic interchange including established components, important domains, structures, mutual assemblies, relations and metadata.

Technical layer deals with connecting the systems to enable exchange of information and services. Results are seen depending on the set standards and having an equal base for competition in providing solutions for technicality.

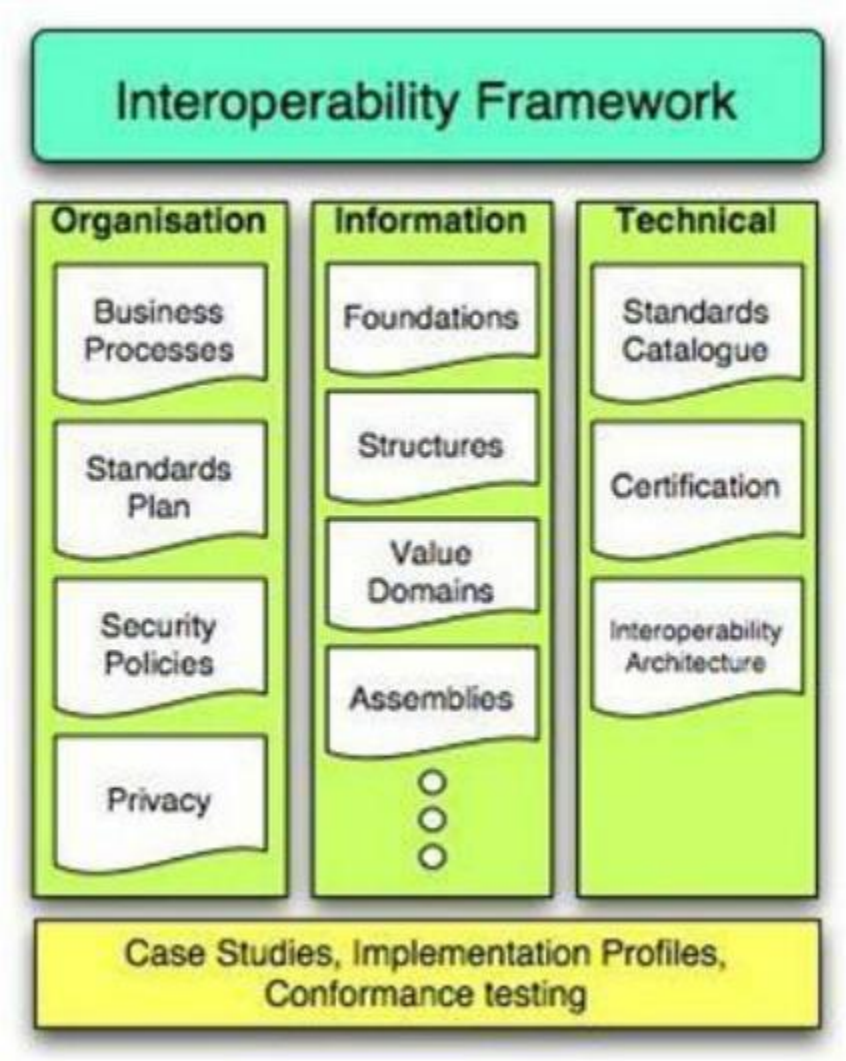


Figure 7: eHealth Interoperability Framework (NEHTA, 2007)

2.5 Summary of Literature Review

From the literature review, to successfully adopt interoperability in healthcare, the following points need to be looked at:

i. Patient data exchange does not occur unless on a demand basis by the patient when this data is required by another healthcare facility which may take a lot of time for it to be made available. Data exchange is occurring but not through EHRs. There is no single unified system that has been put in place in the country to help in achieving this.

ii. E-interoperability can only be successfully adopted if ICT is improved and introduced in all parts of the country which is not the current case as most counties in Kenya lack even the basic amenities like hospitals, schools among others.

iii. Most healthcare providers globally fear adopting interoperability because of the privacy and security challenges. Patients are afraid of their data being put out there and exchanged and stored among these EHRs because of privacy concerns. The main challenge is not technical but societal as to what degree a patient wants their data to be shared among the different healthcare facilities.

iv. For interoperability to work there is need of adopting and introducing universal standards of exchanging patient data among the different EHRs. This can be acquired by having certified EHR vendors who can build these systems for the different healthcare facilities and they are known to them. We have very many EHR vendors who are competing with each other and their main goal is to get money from their systems and some hospitals only support selected ERH vendors.

v. E-interoperability will and can work but healthcare providers need to be taught the use of ICT tools in healthcare so as to avoid resistance when adoption is needed.

Some countries have been able to adopt interoperability in healthcare and a good example is seen in Canada. Canada works to develop interoperable electronic health record (iEHR) for many years. An iEHR is a protected, assimilated view of patient's medical records from all the healthcare systems that are in the network, providing a view of patients' medical history. The system incorporates data from the different areas such as diagnostic imaging systems, laboratory information systems (LIS) as well as drug information system (DIS), to provide a long range view of a patient's clinical history. One of the metrics used is availability of iEHR data that has been electronically held in data warehouses and is only accessible to authorized healthcare users. This access to the patient data is made available through linking CIS and EMR via web- based APIs for extraction of important patient medical data from different healthcare facilities databases in a easy and understandable way.

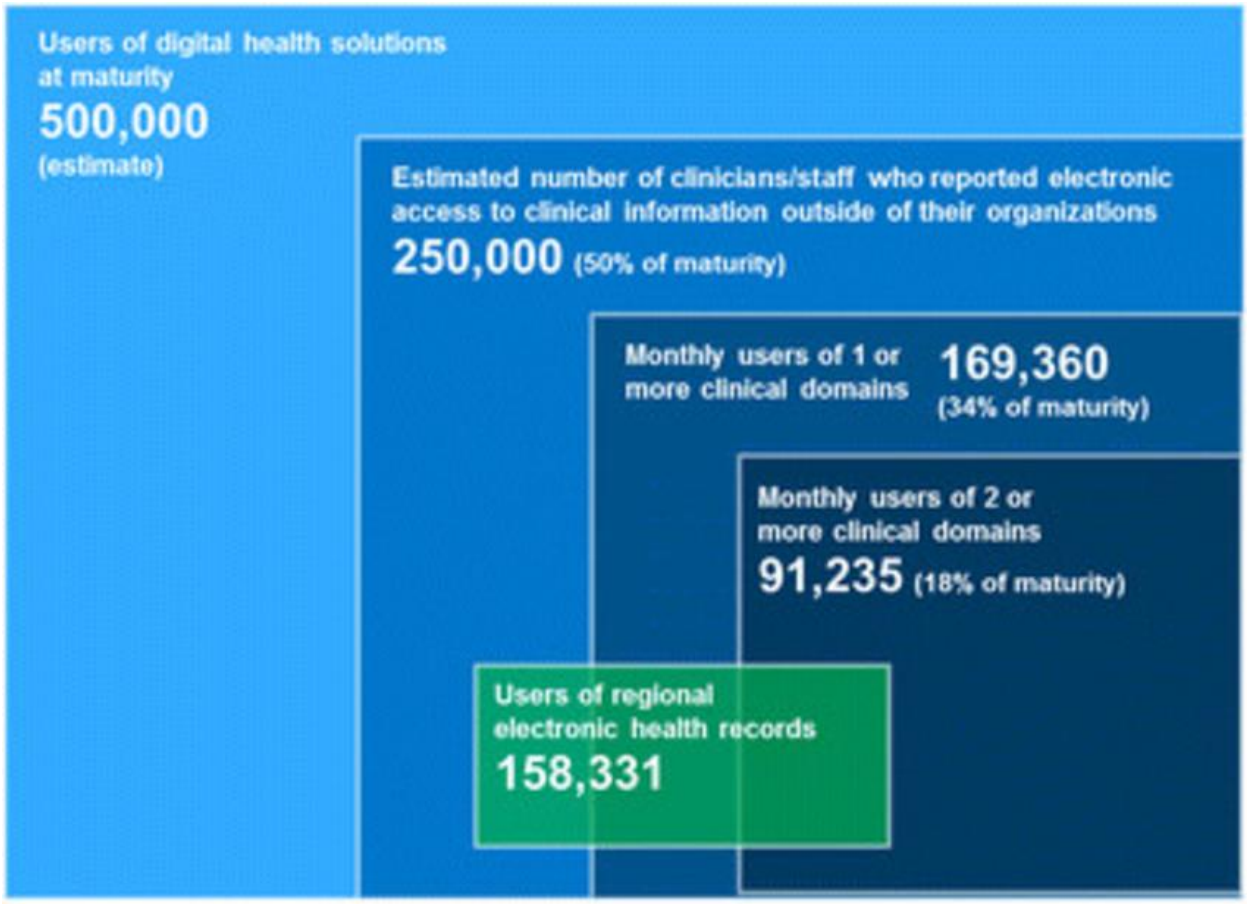


Figure 9: Canadian iEHR user landscape (Gheorghiu & Hagens, 2016)

50% plus of doctors, nurses and pharmacists have the patient information available to the even outside their healthcare facilities

Another country where this has been made possible is England, the English National Health Service (NHS) was created in 1948 to provide health care free at the point of delivery. In 2003, the UK government created the National Programme for IT (NPfIT) whose aim was to fully computerize the NHS over 10 years. The NPfIT uses a framework to connect Local Health Care Record Exemplar programme (LHCRE). LHCRE focuses on use of the patient data and who owns this data. This health data is exchanged across health economies and transforming service that is gained from the data and interoperability of systems in the programme. The London LHCRE provides HIE and transformation of service to the entire London by including local

HIEs, and exchange of data and even images. In transferring of a patient, the patient registers with NHS care provider and a message confirming the patient identity is confirmed and sent to the user requesting this EHR. As seen from the literature review, interoperability and HIE can work very well if the barriers are addressed especially the data exchange standards for health systems and also the privacy concern on the part of the patient as it has worked and it is working very well in other countries. In Kenya what needs to be addressed is access of ICT infrastructure and connectivity in most parts of the country. This will be a very big step that will make adoption of interoperability in healthcare in Kenya successful.

2.6 Conceptual Model

For ICT- a based project to be successful or become a failure depends vastly on users approaches to application and implementation (Status, n.d.).This research was guided by the federated data exchange model which is also known as distributed model and the query based data exchange model, where each participating organization or healthcare facility maintains distinct controls of its data, especially in special superior servers at their individual setting and sharing patient-specific data that is requested by another HIE that is part of it. The federation model is a tiered model in nature containing a collection of areas signifying federation entities, where by each region is individually organized and can be able to function autonomously. Each healthcare facility is able to join or leave the federation as the model has use of interconnected networks connected via the internet, allowing the participants to submit the clinical data to warehouse databanks that are managed centrally by the HIE. This model accentuates on restricted, well-ordered sharing amongst autonomous databases. Modules the federated data exchange model has and includes some stakeholders such as users of the system, Apps, terminals, servers among other components (Just & Durkin, 2008). Patient data is retrieved by member organizations sending query messages to the HIE's patient registry which has a cybernetic identifier of where the patients' medical records are located. These medical records are searched by use of unique patient identifiers such as name; system generated patient ID number, national ID number that is given by the government among others.

Query-based exchange enables users to discover and pull information on a patient from other healthcare providers or users via a HIE, and this mostly happens when not much is known about the patient or when the healthcare providers expects to find new information in the patients

records from other providers. Query-based exchange may include one click access to a web-based portal, exchange on application programming interfaces (API) for easier pulling of information into an EHR (Mandl & Kohane, 2015).

The participating healthcare facilities, use a master patient index (MPI) or a patient identifier which enables the HIE to link and share the records. A record in the registry is transmitted to the requesting health facility through the state central authority (McCarthy et al., 2014). This data is or can be transmitted through secure e-mail, web services or VPN upon request by a healthcare facility. Individual sources of data are able to control their data and only giving them out to other healthcare facilities only when requested to do so, this is one of the advantages of this model (Longitudinal et al., 2012). With the federation model individual healthcare facilities are able to maintain their legislation and decision making support capability while participating in information sharing (Duan, 2009).

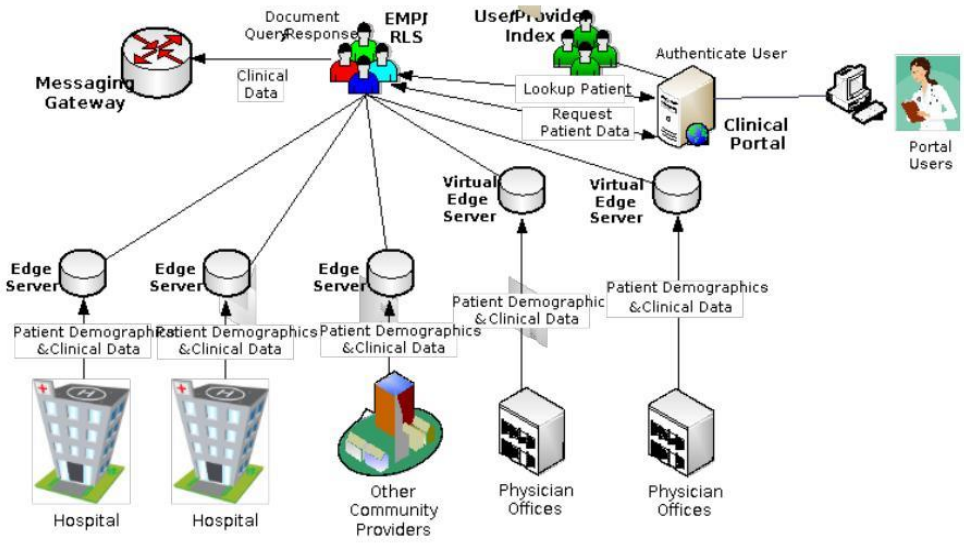


Figure 10: Federated and Query-Based Model (Longitudinal et al., 2012)

2.6.1 Advantages of the Federated Data Exchange Model

i. The federated model ensures that each healthcare facility is independent and can function separately.

ii. It also links the present organization and governance/legislative structure

iii. Because each healthcare facility is a federation entity, each health facility maintains its own self-governing legislation and decision making capability.

iv. The main aim is information sharing only other healthcare facility functions are done separately

v. Each healthcare facility/entity is able to maintain and maintain and control its own internal activities

2.7 Service Oriented Architecture

Service Oriented Architecture (SOA) is changing IT because it's an approach to software design that involves assembling systems from services that may be developed from different sources and different underlying technology. SOA is linked with web services and it recommends a fundamental shift on how an organization uses business systems with changes in technology, methodology and organizational structure (Duan, 2009). SOA requires a web services layer around existing systems while giving patients an active role in the EHR exchange. SOA presents an approach in which modular, accessible, self-describing, implementation-independent, interoperable, and reusable components are published as services which can be remotely invoked and consumed by other applications or combined with other services (Shah, 2016).

SOA has some advantages:

1. Interoperability where these services are more about interoperability and exchange.

2. SOA efficiently enables reusing of the applications that are in the healthcare facility instead of developing new applications.
3. Standardization where there is use of most industry leaders are involved in the internet and WWW whose underlying protocol is HTTP.

2.7.1 Challenges of SOA

A centralized model is followed by most SOAs which lacks elasticity and scalability which compromises the usability function. The healthcare facilities operate like governments with their own legislation, competency and leaders (Shaikh et al., 2009). The healthcare facilities are different entities with different policies, processes, mission and objectives. According to (Duan, 2009), Centralized model cannot work well for interoperability because if the main server fails then everything in that environment will also fail. The other challenge is that al legacy systems cannot be spontaneously incorporated into a SOA environment. Also, the use of principles does not necessarily warrant interoperability, interoperability needs agreement on both syntax and semantics. SOA is not all about change in technology but also changes in the organizational governance model.

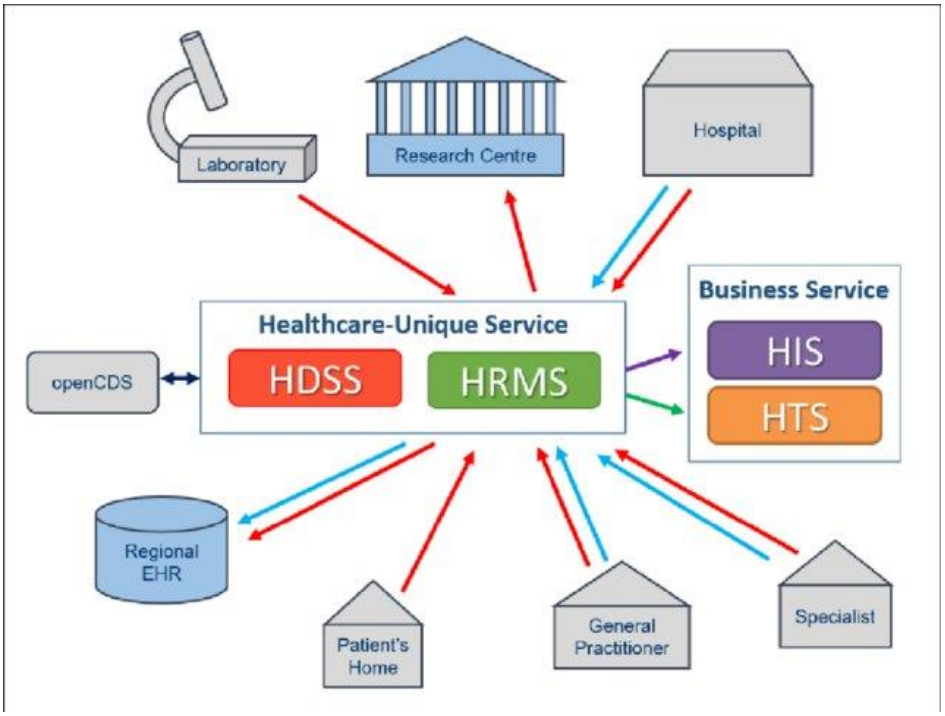


Figure 11: Service oriented Architecture (Trials et al., 2016)

Table 2: Comparison between SOA and Federated Data Exchange Model

SOA	Federated Data Exchange Model
Most SOAs are implemented using the centralized model	Implemented using the decentralized model
Does not match the existing organization and governance	Ties the current organization and governance
Governance in terms of ownership of the records is difficult to implement	Each healthcare facility preserves its own independent legislation and decision making ability
Tight coupling	Loosely coupled
The entities are tightly coupled and depend on one another.	Each object is capable to preserve control of its own in-house activities

2.8 Replication

Replication is when data is copied from a database to other computers so as to synchronize this data it entails the procedure of sharing information to warrant uniformity between redundant assets e.g hardware or software components so as to improve fault tolerance, accessibility and reliability.

2.8.1 Types of Replication

Replication is either synchronous or asynchronous mode (Oracle & White, 2011):

Synchronous Replication

Synchronous replication updates data at the central site ensuring that replication takes place in the secondary site due to this, the requesting health facility has an exact copy that is same as the

primary site at all times to void missing patient medical records. Because of this the data is not protected from corruption or data loss which maybe intentional or unintentional.

Asynchronous Replication

Asynchronous replication is where operations are written to where the data originally originates from and sent out to other remote storage systems. This data that is in the other system does not necessarily have the same data as the primary site and data may be lost when a communication error takes place due to downtime or a delay in replication.

2.9 Data Replication

Data replication is a data management technique that has been adopted by traditional systems like database management systems (DBMS), parallel and distributed systems, mobile systems and other systems like data grid systems is what is known as data replication (Tos, 2018). Data replication technology ensures that a copy and distributes data or objects from one database to another for them to run synchronically and have consistency. Data synchronization institutes uniformity enabling replication to occur in near real-time which is on a program such as planned updated transactions which can be transferred from parent to child on a specific interval (Kant, 2019).

Data replication creates instances of the same data, and these replicas are regularly updated and rapidly lose any historical state unlike backup which saves a copy of data which is unchanged for a long period of time (Kemme et al., 2010). In data replication, the same data is stored in numerous storage devices, this data is replicated to improve reliability and improve performance. Replicating data is important as it first, the replicated data increases the reliability of a system as it continuously works even after one replica crashed by swapping to other replicas this ensures that several copies are maintained and this becomes possible to provide improved protection on the ruined data (Arts, 2013). Data replication strategically places copies of data in order to increase availability, access performance, reliability, fault tolerance, bandwidth reduction and completing jobs on time.

Some schemes have been used to achieve the goals of data replication which address several challenges (Runceanu, 2008), (Tos, 2018):

What data should be replicated?- this entails creating a significant conditions on choosing how and what to replicate because it is unrealistic to replicate everything.

When should the replication take place?- this is entails choosing a best scenario on when to replicate so as to avoid wastage of resources.

How many replicas should be created?- this is so as to have a balance between benefits and costs when it comes to replicating.

Where should the replicas be placed?- this will assist so as to improve performance when accessing data by having the replicas nearer to the users.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research Design

The proposed model will be implemented by using the federated and query based data exchange model in a cloud based environment

This research was carried out to help in understanding how health data is stored, how patient data is stored in most healthcare facilities, how patient data is not readily available to other health professionals unless on demand basis, and how interoperable systems will solve this. This research design will help measure the occurrence of outcome before and again after adoption of interoperability in healthcare.

3.2 Target Population

In order to estimate the target population multistage sampling was used to identify the users of the system. The first stage is to identify the personnel to conduct the study including application developers, healthcare professionals and the patients.

The application developers helped in identifying the ease with which interoperability could be integrated into the existing systems. Healthcare professionals such as doctors, nurses, clinicians, general practioners and home care givers who work with EHRs systems. The healthcare professionals explained the challenges faced especially when sharing data between and among different healthcare facilities. Patients who visit these healthcare facilities were included because interoperability in healthcare aims at creating patient centric environment where the patients have access to their health records.

3.3 System Development Methodology

Agile development methodology offers prospects of assessing the direction of a project all the way through the development lifecycle. This can be achieved through iterations through which at the end of a potentially stable product increment is released.

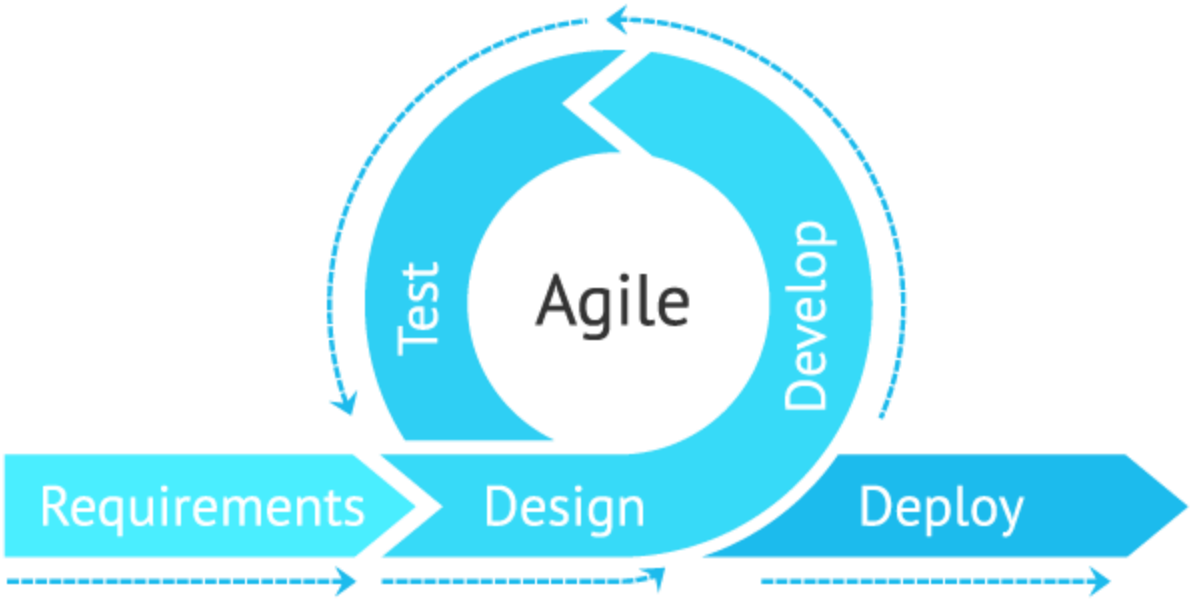


Figure 12: Agile Development Methodology

Figure 10 describes the stages that the development of the data replication platform went through. The first step was planning, where the research took the necessary steps to ensure the processes undertaken clearly outline the research objectives. This involved reviewing the problem and coming up with a new way of solving the problem. The second stage involved formulating the requirements for the system to be built and also creation of the system architecture. The design phase involved coming up with the application designs based on the gathered requirements , the nest step was implementation which involved the actualization of the designs into a working platform. Testing was the last stage and it involved testing the application to make sure that the needed functionalities were working as required and also discuss the platform with regards to the objectives and test to see that they were achieved.

3.4 Limitations

Some limitations were encountered for example, patient data privacy especially how to share this health records without them being exposed to a third party. Patient health records are very private and for them to hear that their data is being shared across systems and stored somewhere else is a major problem since interoperability in health challenge is more social then technical. A written document to show that permission to carry out the research was needed in the healthcare facilities visited.

CHAPTER FOUR

4.1 Introduction

On this chapter a description of the system prototype is discussed in detail, the processes and mechanisms used in the prototype in order to achieve the functionalities.

4.2 Current Process

The current process uses manual ways of exchanging health records which are more paper based and where these records are electronically exchanged, it is more within the health centers than among the different health centers, and also even within these healthcare centers interoperability has not been fully implemented. The current process is not patient centric since most times the patient does not even have access to their records. Also, the healthcare centers end up carrying new tests when a patient visits their facilities. Other healthcare facilities have standalone systems where they able to retrieve patient records on it if the patient is registered in that facility and incase of system failure the records cannot be retrieved and used.

4.3 User Requirements

Functional requirements describe the processes carried out within the system and actions that can be undertaken by the actors within it. The proposed prototype is for enhancing interoperability between disparate health information systems will enable the users login into system and specify parameters of the health facility and information to be read or written. The proposed system will be used to extract data directly from heterogeneous information systems used by the health facilities or receive the data in form of e.g an excel worksheet

1. Provision of secure access to the system
2. The prototype will remotely login and gain access to the cloud server
3. It will enable the user to view and specify the required parameters in the cloud server for submitting and retrieving records of a health center
4. Period which the health information is required e.g month of January 2019
5. The user will harvest or pull information from remote host and map it to the cloud server

4.4 Software Tools Used for Development

Operating System- Windows

Relational Database Management- SQL

Programming Language- PHP

Running and Testing Environment- Standard Web browser e.g. Chrome, Mozilla Firefox or any other browser

Web Server- Apache

4.5 Results

4.5.1 Characteristics of Interoperability Achieved by the System

The prototype facilitates interoperability by providing a mechanism by which disparate EHRs systems communicate. Considers two healthcare facilities Hospital A and Hospital B that wish to communicate and exchange patients' records via the system. The system provides a communication platform where Hospital A is able to exchange the health records with Hospital B and vice versa. The doctor logs in and inputs the patient ID and is therefore able to extract data of a patient and also view a summary report of the patient from patient details, diagnosis, admission details to lab results if they are available.

4.5.2 Use Case Diagram

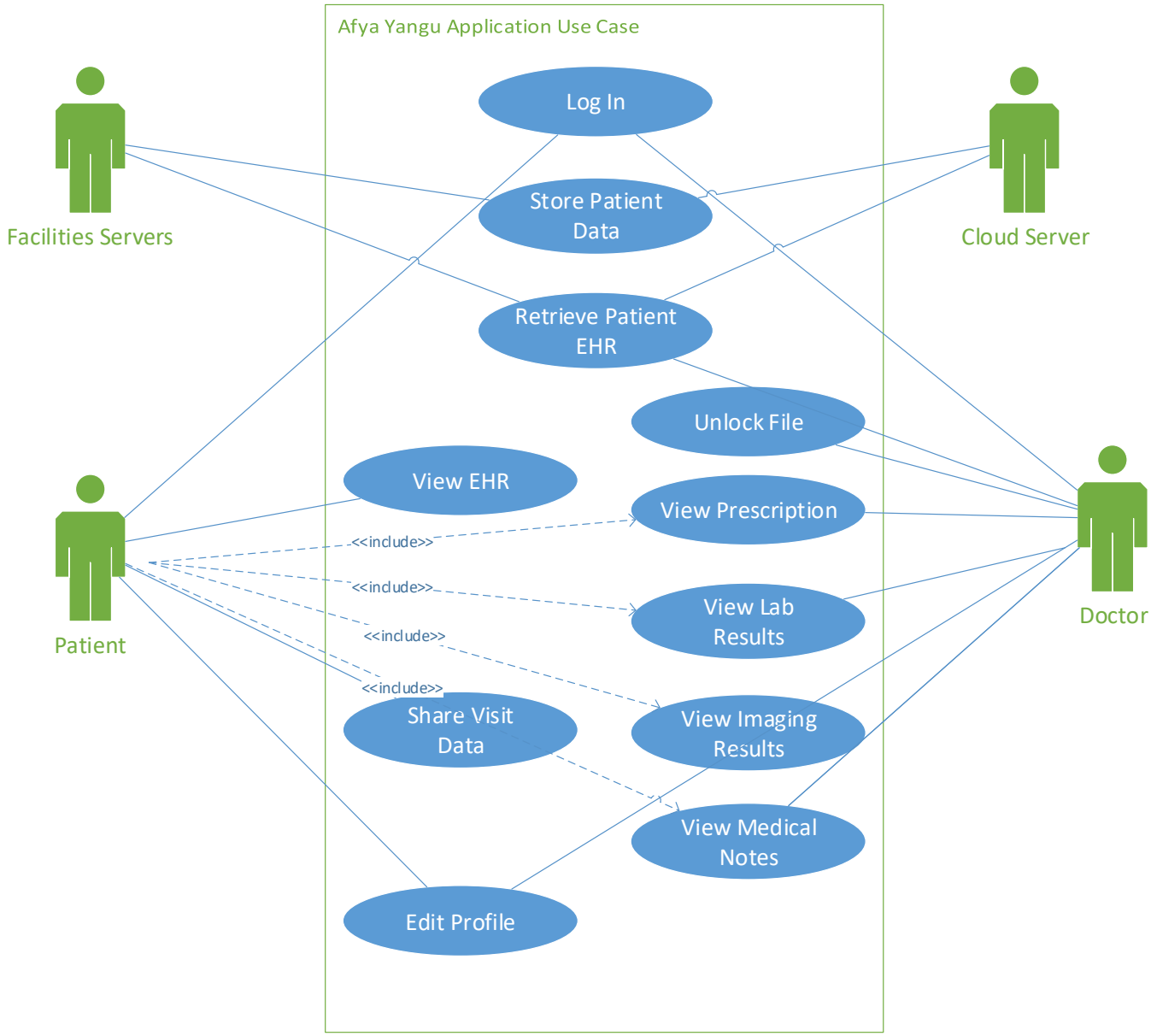


Figure 13: Use Case Diagram for Prototype

In this case the patient and doctor are the dominant users of the system. They should be able to view all EHRs and also be capable enough to share the same data with other healthcare providers and facilities the providing of services to patients. The doctors can only use the system to access the shared data. The system enables a function to all actors to be able to view the patient's profile. The application is a proof of concept that shows how systems can interact within the interoperability environment

4.5.3 Discussions

In this section, a discussion on how the set objectives of the study were achieved is given in detail. The first objective in section 1.3 was to evaluate the challenges facing patients and healthcare facilities in the adoption of ehealth interoperability. The study shows that there are several factors that contribute to the challenges of interoperability in the exchange of health record. The challenges discussed in section 2.2.2 eplain in detail these interoperability challenges and gives a comprehensive overview of the main factors that make exchange of EHRs difficult. One of the challenges is lacking in universal implementation of standards based on the EHR systems that are there and security and privacy challenges associated with wide spread HIE. These standards define a common language by which systems use to communicate.

The second objective was to identify a model for health information system interoperability for exchange of health records. Section 2.3 discusses some of the identified interoperability models used in the health sector. The models are used in developed countries where they have been able to come up with common policies for interoperability. Most use distributed databases. Data is stored in multiple locations and if there is a failure in one location , the system can still operate. Other models were discussed and their role in solving interoperability issues. Due to this, the federated/ distributed data exchange model was used.

The third objective was to develop a prototype that will support exchange of health records based on identified framework. Section 2.6 shows the conceptual model and give a detailed description of how the proposed solution works. The development methodology is explained in Section 3.3. This objective focused on the design and development and to establish a way to create a design and develop the health data exchange system. In Section 4.6 the study shows how the application was designed with regards to the requirements gathered.

4.6 System Architecture

AfyaYangu consists of:

Interface layer, which is the graphical user interface for system administrator to interact with the system web application

Input processing layer- used for input by the users in order to interact with the system

Database layer- used for storage of EHRs

The system consists of two main modules:

The administration side and user side which are both web based. System administration side consists of:

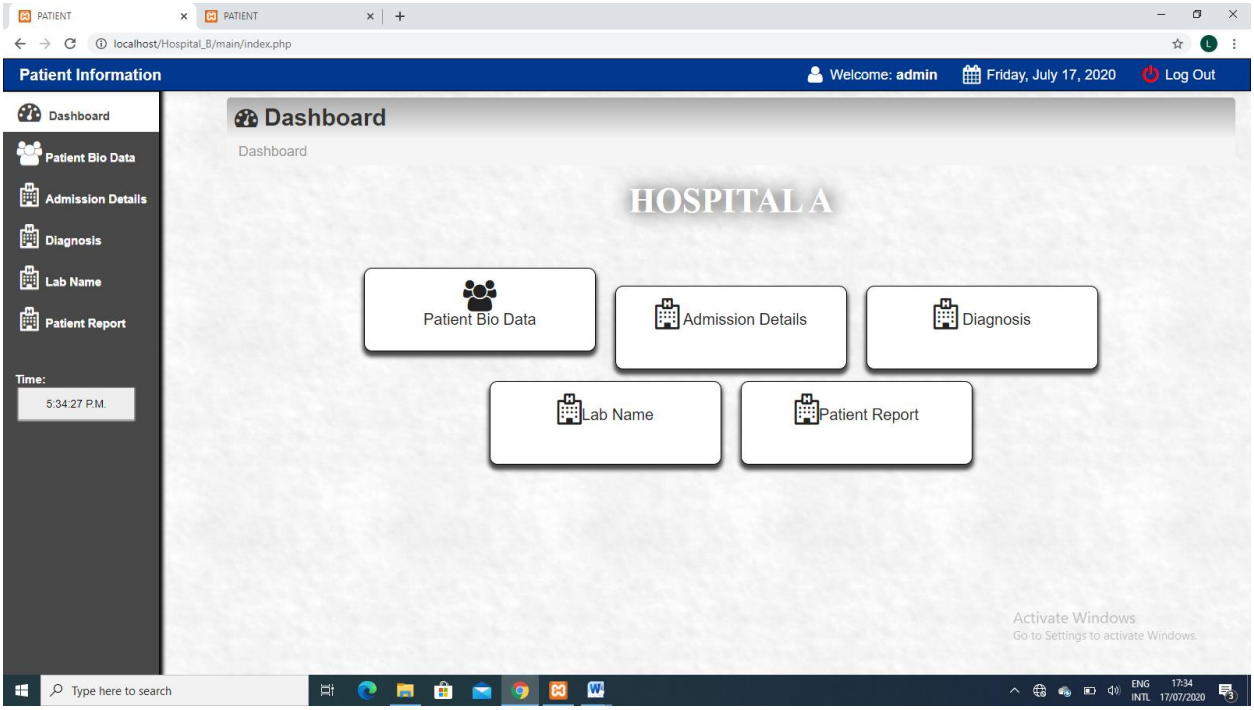
Creation and editing of patients

Creation and editing patient medical records

Creation and edit of new patients

Creation and edit of healthcare providers

Figure 14: Main page



The following menus are available

Patient Bio data- displays a summary of the patients' data

Admission Details: displays details of the patient admission

Diagnosis: provides a summary of the patient diagnosis

Lab Details: provides details of lab and any x-ray details

Patient Report: displays the full report of the patient

Figure 15: Patient Bio Data

To view the patient details the user must enter the patient ID

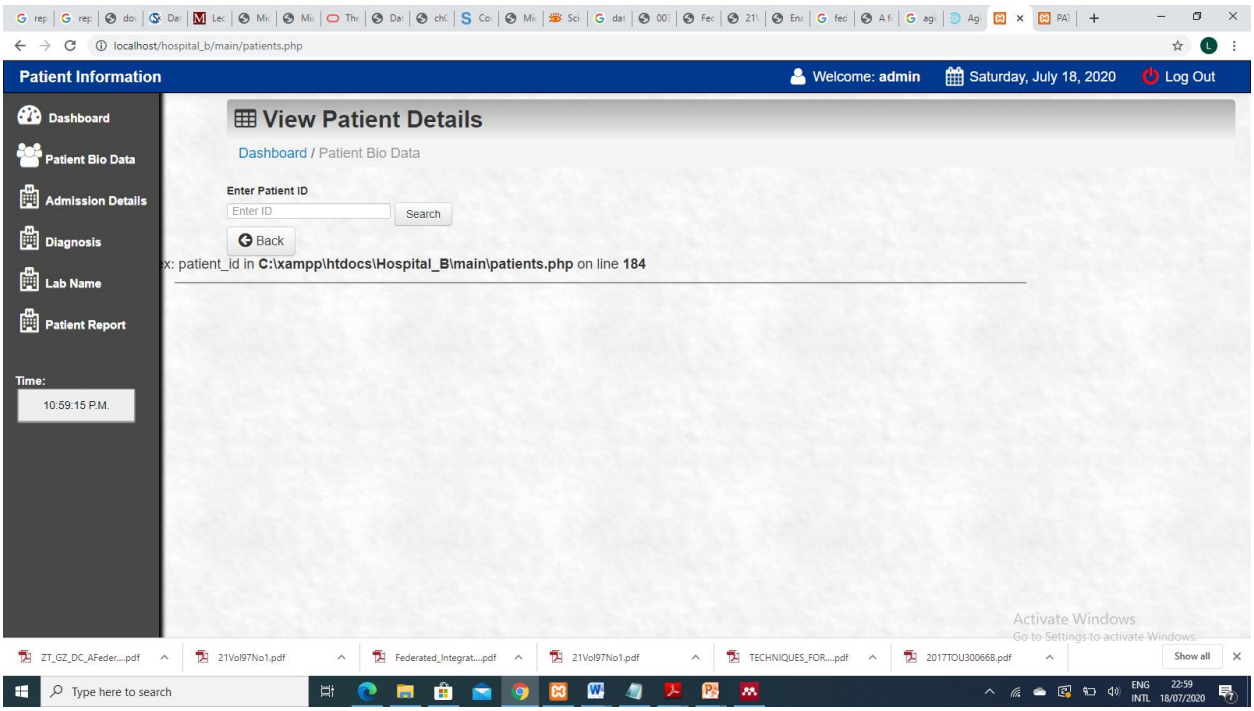
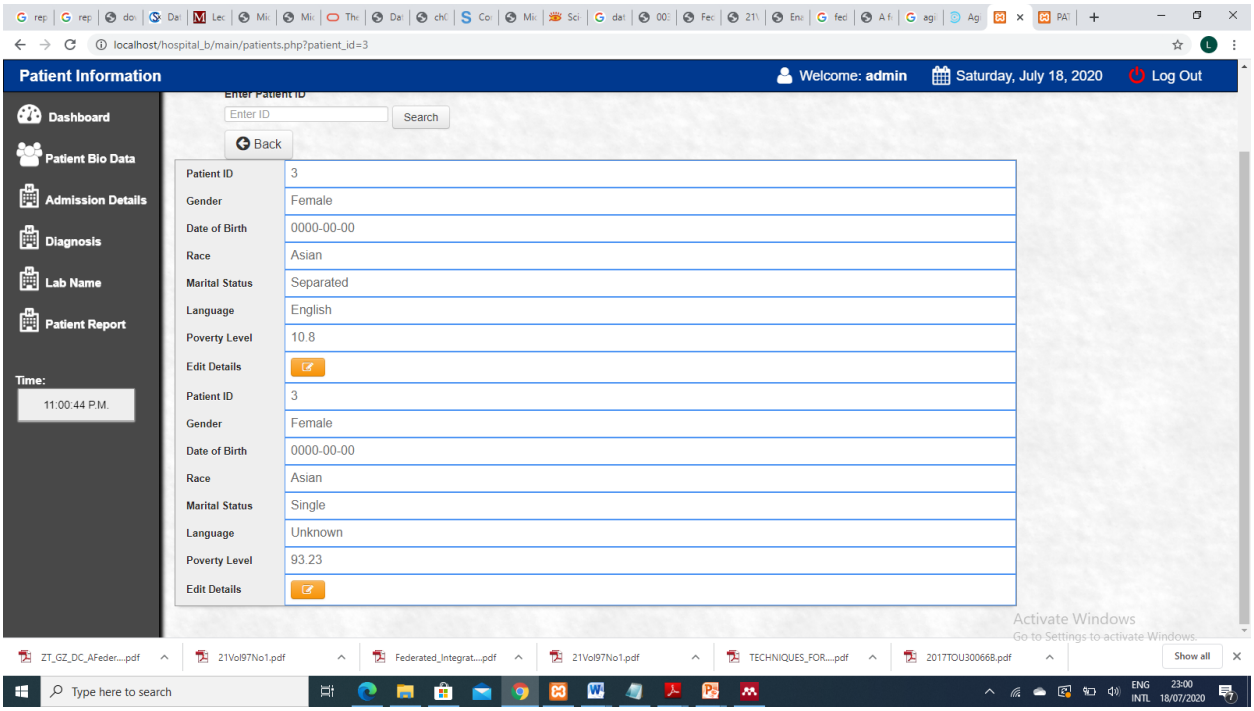


Figure 16: Patient Details



The patient details are retrieved after input of patient ID

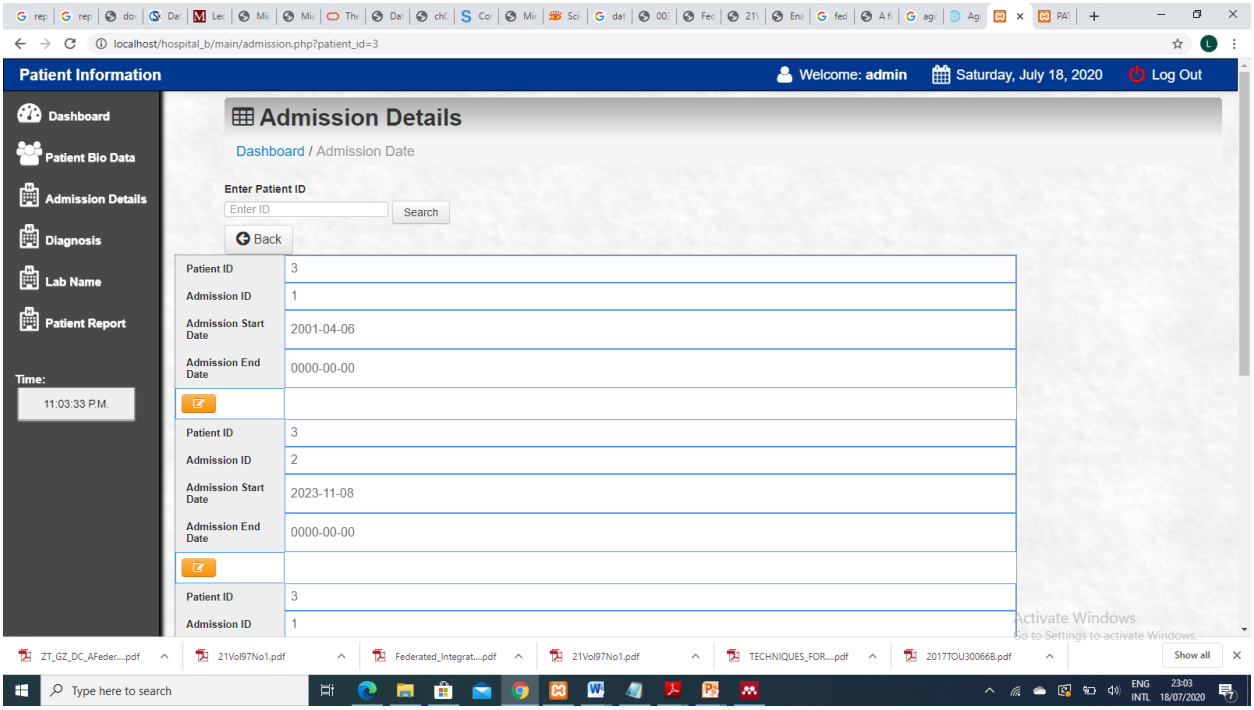


Figure 17: Admission Details

Provides all the records on the admission details of the patient inclusive of the number of times the patient has been admitted.

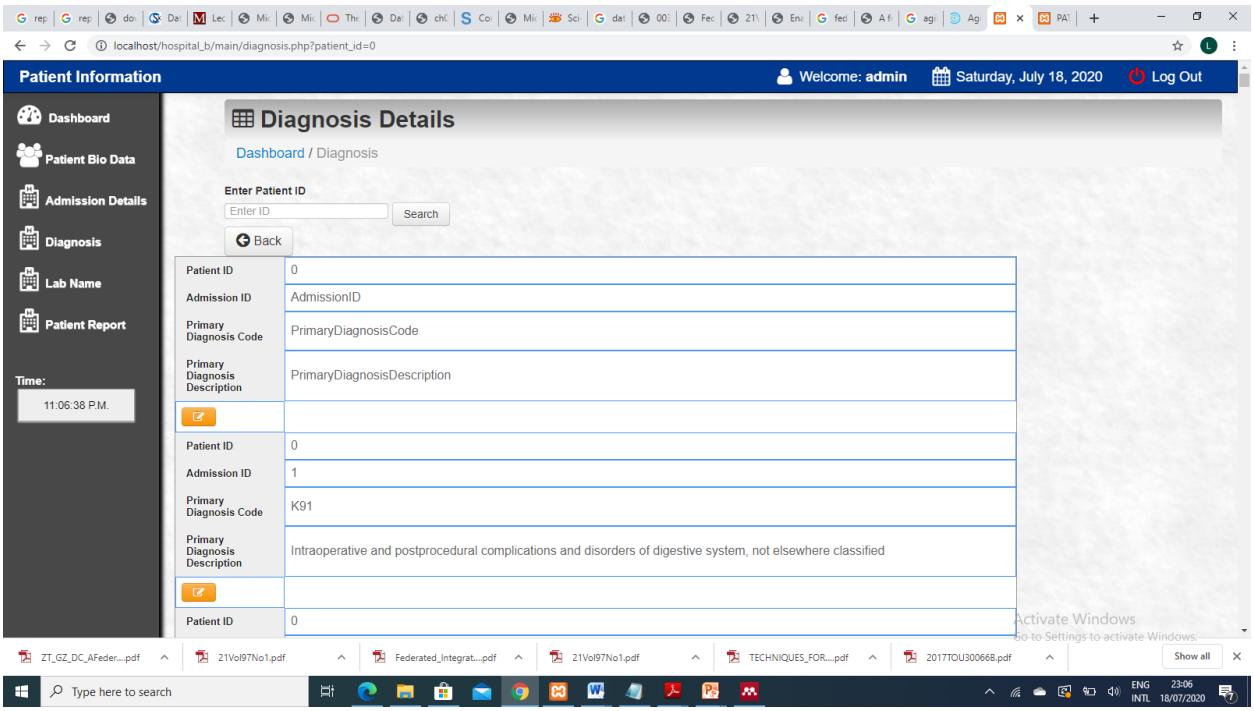
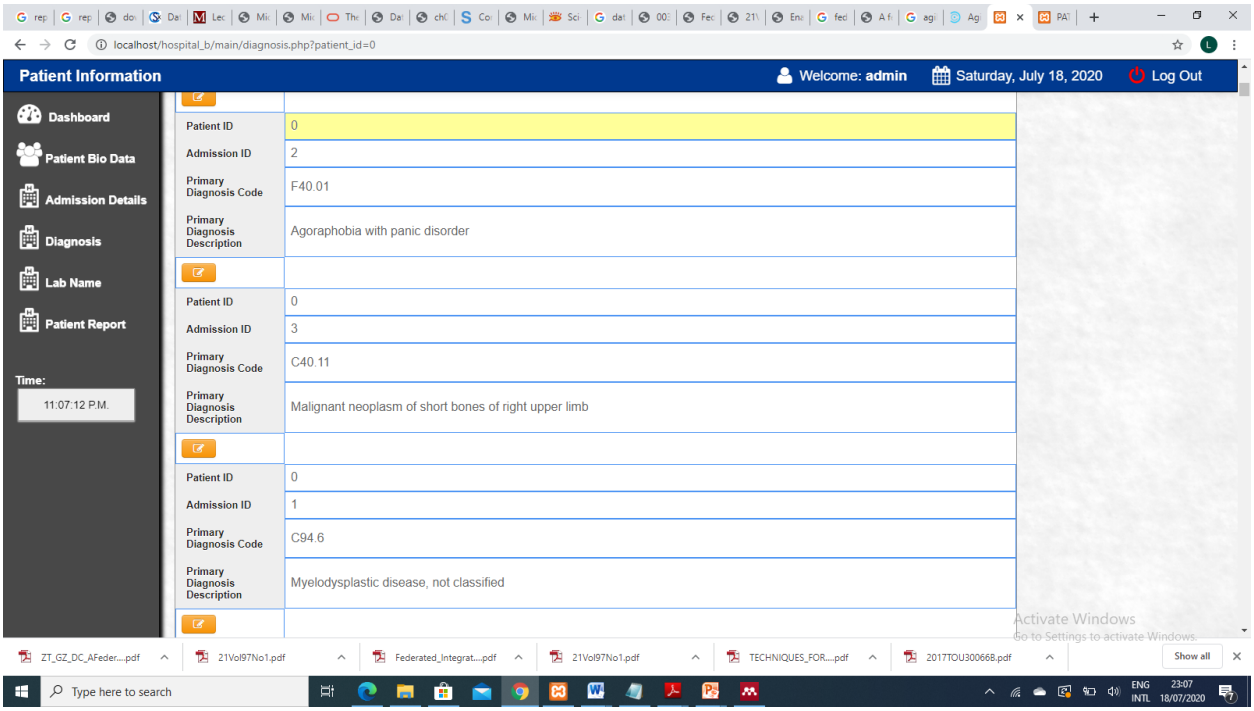
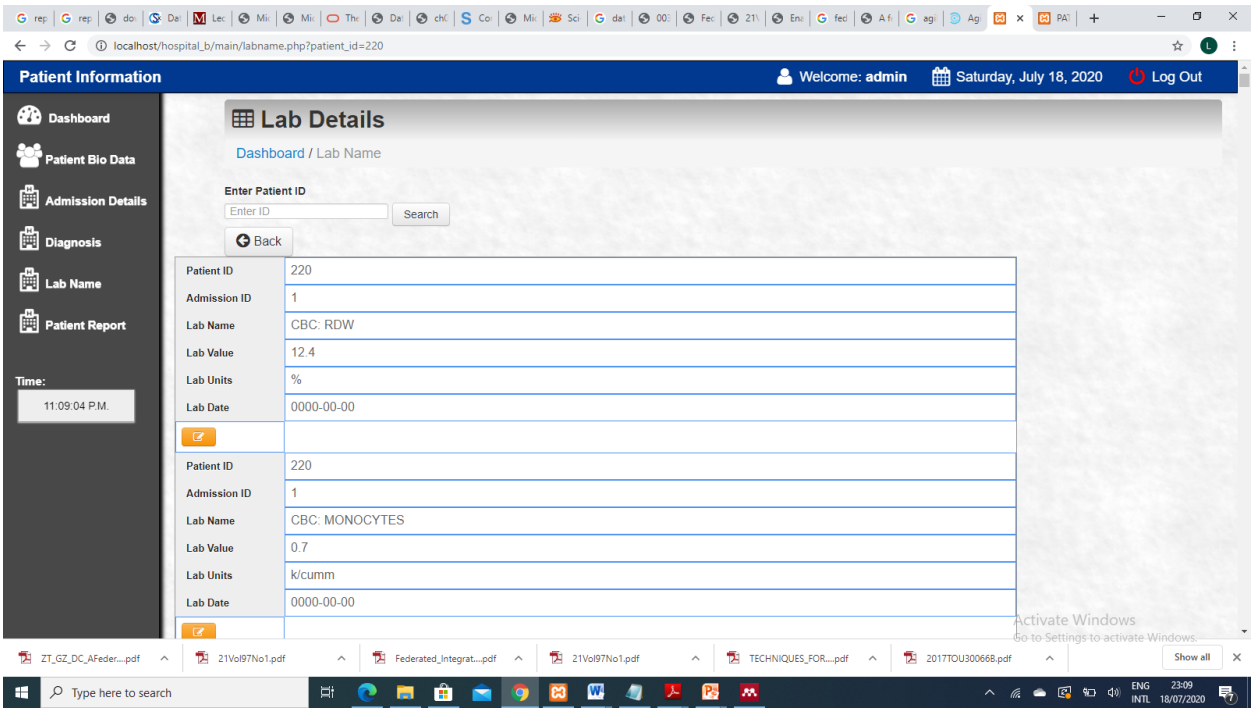


Figure 18: Diagnosis Details



Provides the diagnosis details of the patient based on the number of times the patient has visited the hospital



The lab details are displayed if they are available for that particular patient

Figure 19: Lab Details

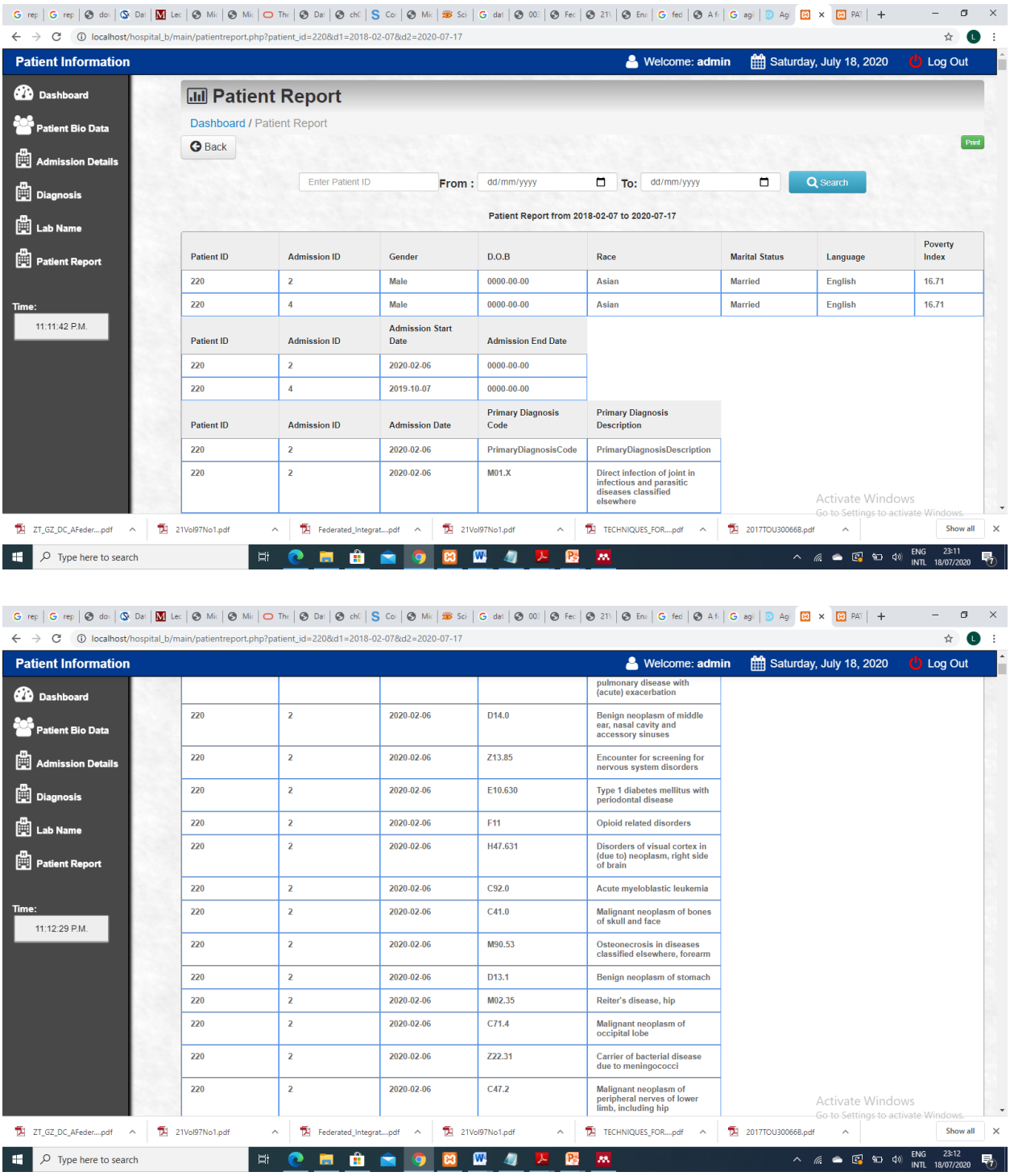


Figure 20: Patient Report

The doctor from hospital A will request or query a report from Hospital B for a particular patient and using the patient ID this information is made available to them through the concept f data replication. A cloud server is what provides the data replication ability as the hospitals each host their own data through the federated model.

CHAPTER FIVE

CONCLUSION

5.1 Introduction

Chapter five presents a comprehensive view in terms of research by providing a discussion on the results, the advantages of the system, suggestion for improvements and sought to see if the objectives were covered.

5.2 Conclusion

The study has revealed that a lot of effort has been put to ensure E-Health systems have interoperability. Several organizations have come up with standards and technologies to ensure data is exchanged seamlessly for example HL7. Doctors have insisted that patient data is very important in making crucial decisions about the patient and their health status. Some of the challenges that developers have are difficulty in integrating and interoperability due to the different systems used by the healthcare facilities and also their infrastructure. Also, most healthcare facilities are still using the manual way of data handling for their patients as the cost of automating is a barrier to them. To create interoperable systems, the study considered the use of distributed file systems that is the federated data exchange model.

Currently there is no standard system in the country for exchanging patient records, each healthcare facility uses its own system based n their requirements. For exchange of health records to take place, the patient has to give a history of what they can remember thereby omitting or forgetting useful information. Other times the patient has to pay an amount of money to get his/her records from a health facility and most of the times these records maybe handwritten.

If adopted this platform will enable healthcare facilities that own E-Health systems or are planning on developing new systems to have a common data exchange platform. By use of the platform the healthcare facilities are able to create an environment of interoperable systems.

5.3 Recommendations for Future Work

The findings of the study carried out were successful in an effort of evaluating the use of web technologies to enhance EHR interoperability for healthcare facilities. The system was able to stimulate a successful creation of sample EHRs which were replicated.

Future work will research on implementing interoperability where the different E-Health systems have the same data values and the same meaning in these applications that are exchanging data. To develop a secure platform which will boost the morale of healthcare providers and patients to want to use these systems for exchange of data. Also there should be open source data for which will easily allow testing of these systems since one of the challenges that is there is acquiring real patient data as it is protected by the law.