KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

A PROPOSED FRAMEWORK FOR INTEROPERABILITY OF ELECTRONIC HEALTH RECORD SYSTEMS IN GHANA

BY

ANTHONY KOBINA EMIL JNR

(BSc. INFORMATION TECHNOLOGY)

PG8962913

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DECLARATION

I hereby declare that, with the exception of references to other people's works and publications which have been duly acknowledged, this thesis is the result of my own independent work. I also declare that, this work has not been presented, either wholly or in part for any degree or other academic honors anywhere else.

SIGNATURE …………………………… DATE ………………………………

ANTHONY KOBINA EMIL JNR

PG8962913

SIGNATURE…………………………… DATE ………………………………

DR J. B. HAYFRON-ACQUAH (SUPERVISOR)

SIGNATURE…………………………… DATE …………………………..

DR. MICHAEL ASANTE
(HEAD OF DEPARTMENT)

DEDICATION

I dedicate this work to the almighty God for his guidance, protection and wisdom throughout the period of this work. I also dedicate this work to my parents Mr. and Mrs. Emil, my siblings Anita, Ernest and Paa Kwesi and friends for their enormous support throughout my life. I also dedicate it to Mr. Kofi Boakye Owusu-Kwarteng for his maximum support; sleepless nights and passion to support me in making this work a success. I specially dedicate this work to my lovely, caring and supportive wife Mrs. Joyceline Odamea Emil for her massive encouragement, guidance, fasting, prayers and constant reminders to finish this work on time. I also dedicate this work to Rev. Francis K. Arhin, and members of Praise Baptist Church for their prayers and spiritual support. Lastly to all loved ones who through their encouragement and guidance made this work a success.

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ABSTRACT

Electronic Health Record Systems (EHR's) plays a major role in today's health care delivery. Problems associated with patients' records scattered across many different health facilities have become enormous. It has therefore become very necessary that these Electronic Health Records systemsare interoperable. This would enable health care providers to have comprehensive records about their patients in order to provide them with better care. This work proposes a framework that would enable interoperability of Electronic Health Records from different health facilities across Ghana. The framework underlines certain key requirements

such as reliable internet connectivity, biometric finger print scanner and mapping of various tables of the individual databases from different EHRs to the adapter of the framework for interoperability to take place. A simulation and virtualization test about the framework was conducted based on connectivity,search for patients who has visited many facilities and those who don't have their records in any of the facilities to examine how it would perform if used in the real world. The simulation results from the virtualized framework revealed that it does not require many resources such as high internet speed, one programming language platform for the EHRs, computer servers with high memory and CPU to allow interoperability of patients' records. Therefore, the framework would highly help health care providers to care for their patients well, due to the vast amount of information they would have on their patients. As part of the recommendations, each EHR in the health facility needs a backup internet, electricityand standby sever for the framework in order to function effectively.

Finally, further works could also be done on this study to generate trends reports.

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LIST OF ABBREVIATIONS

EHR..Electronic Health Records

EMR...................................... Electronic Medical Records

MRS……………………….. Medical Records System

ICT.. Information and Communication Technology

KBTH.................................... Kore-le Bu Teaching Hospital

KATH.................................... Komfo Anokye Teaching Hospital

TTH....................................... Tamale Teaching Hospital

ENRH.................................... Effia Nkwanta Regional Hospital

CCTH.................................... Cape Coast Teaching Hospital

MoH....................................... Ministry of Health

API... Application Programme Interface

HL7....................................... Health Level 7

CIEHR.................................. Centre for Interoperable Electronic Healthcare Record

MIES.................................... Medical Information Exchange System

CDA...................................... Clinical Document Architecture

EHR-PH................................ Electronic Health Record - Public Health

NHIN.....................................National Health Information Network

RHIO / E................................ Regional health information organizations / Exchanges

DHHS................................... Department of Health and Human Services

HIT.. Health Information Technology

HCPs......................................Healthcare Providers

MLLP.................................... Minimal Lower Level Protocol

COTS.....................................Commercially-available Off the Shelf

HTB.......................................Healthcare Transaction Base

XML......................................Extensible Mark-up Language

CCD………………………... Continuity of Care Document

SPL………………………… Structured Product Labeling

CCOW………………………Clinical Context Object Workgroup

FHIR……………………….. Fast Healthcare Interoperability Resources

SAIF………………………... Services-Aware Interoperability Framework

MLLP……………………. Minimal Lower Layer Protocol

TCP /IP…………………… Transmission Control Protocol / Internet Protocol

WbEHR………………….. Web-Based Electronic Health Records

PHCP……………………. Primary Health Care Provider

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CHAPTER ONE

INTRODUCTION

1.1 Background Study

Health information is one of the most important factors that contribute to the strengthening of health care delivery in every country. Health information which is reliable brings about timely health policies and planning, which leads to the improvement of the general health status of a country, as well as, serving as a vital element for individual health facilities in managing and improving healthcare delivery (Teviu et al., 2012).The contributions that Information Technology plays in enhancing the quality of health information cannot be overlooked. This is proved by using IT to record, store, retrieve, analyze and transmit huge amount of health information across many locations (Norman et al, 2012).

Research undertaken in a number of developing countries show that the usage of IT in providing the delivery of healthcare has lead to proficient access of healthcare facilities for both patients and healthcare professionals and improve the quality of healthcare delivery.This has therefore resulted in productive labour and development of the country at large (Khan et al 2010; Cecchini and Scott, 2003; Oyeyemi and Wynn, 2014). The use of Information Technology (IT) in health also referred as Ehealth,has not only been marked as eminent in improving the effectiveness and reliability of health information, but also strengthening the healthcare delivery system. This is done through numerous customized applications and programmes such as electronic health records(Yusif and Soar, 2014). E-health is defined by the World Health Organization (WHO) asthe use of digital health data that has been transmitted, stored and retrieved electronically, which supports healthcare delivery at local or distant location(WHO, 2006). E-Health provides the means which ensures that the correct health information is provided to the exact person at the precise place and time in a secured electronic form in order to optimize the quality and efficiency of healthcare delivery, research, education and knowledge (Mohan and Jacob 2004).

In a national healthcare system, the exchange of information through Electronic Health Records (EHRs), patient registries and shared knowledge resources is very critical (Wolmarans et al., 2014).

Presently, patient's health records are either being documented electronically, on paper, or a combination of both, and then stored in special locations. This practice has made it cumbersome for healthcare professionals to get a detailed image of the patient's healthcare journey. In addition, division of services such as primary, secondary and tertiary within hospitals in combination with different clinical information systems at certain periods can make it hard tocommunicate safely about clinical information (Begoyan, 2007). This could result inwrong communication about patient information,ultimately compromising on the safety of the patient. The adoption of Information Technology within the healthcare setting can improve such limitations.The sharing of clinical information among healthcare providers at the right time can be facilitated by IT, which will allow health information systems to communicate or interoperate, therebymaking it easy for health information to be shared within and outside organizational boundaries.

Advancements made in IT over the past 2 decades or more, especially within the healthcare industry has become the backbone for which different types of electronic health records (EHR) have been planned, designed, and put into operation (WHO, 2006). Eventhough some countries have worked on various forms of a computerized patient healthcare information system, not many health facilities have successfully introduced EHR which has entry of clinical data at the point of care (WHO, 2006).

The storage and retrieval of detailed patient information is done by an EHR system, which is being used by healthcare providers, during the hospitalization of a patient and across care settings(Silow-Carroll et al., 2012). In today's world, record entries made by healthcare providers on various locations where treatment is provided has become a norm which is generally accepted(WHO, 2006). One of the most significant feature of an EHR is its ability to share health information among diverse authorized users and across different health facilities (Dobrev et al., 2008). The main obstacle to realizing the potential benefits of IT in healthcare delivery in many countries is the lack of interoperability between varied systems (Wolmarans et al., 2014). The exchange and sharing of information and knowledge between two or more computer systems, components and business systems is referred to as interoperability (Vernadat, 2010). In order for systems to be interoperable, there has to be a defined architecture or structure that describes the way in which the systems can communicate with each other and provide standards that allows for the exchange of data (GhanaMinistry of Health, 2010).

Standardization is the only way by which interoperability in EHR systems can be achieved (Begoyan, 2007). An acceptable and repeatable way of doing something is termed as standards. From a perspective of standards, EHR has one of the most complex and demanding areas of standardization (Foster, 2013). The benefits derived from the development of any IT systems, based on an approved set of standards include integration, alignment, reusability, portability and flexibility. Therefore, the baseline for any healthcare system development are marked by standards, whether electronic or manual (Wolmarans et al., 2014).

In Ghana, E-Health is at the infant stages (Achampong, 2012). As a result, lots of EHealth projects are running separately without any coordination between them. More than 22 projects in Health Management Information Systems (HIMS), being piloted in certain health facilities have been identified. Many health facilities in the Ghana are partly using electronic system in one way or another and efforts to institute an adequate management information system throughout the health industry is ongoing (Achampong, 2012; Afarikumah, 2014).

The usage of health information management system within the country is not extensive (Achampong, 2012). Two major applications are currently implemented for information management. The first one is used for the management of clinical business process, whilst the other supports the collection and aggregation of data, and is mainly used for reporting (Achampong, 2012).

The Ghana Ministry of Health, (MoH) recently developed the Ghana E-Health strategy which makes emphatic statement about interoperability of Patients Health Information among different health care facilities as one of the key strategy for the country's growth in the health industry (Ghana Ministry of Health, 2010).

1.2 Statement of the problem

The current trend for keeping patient information in healthcare is done on Electronic health records (EHRs) system and many physicians, allied health professionals, pharmacists and hospitals uses some form of EHRs. These software applications comes in a modular form and hence does not support the full processes in health facilities (Achampong, 2012). Despite the advantages EHRs has, health facilities do not have access to the health information of a patient outside their facility. As a result of this, each health facility has different health information about a patient. Hence, patient records are scattered across different health facilities within the country. As a result of this issue there are several challenges. These challenges are:

a. Healthcare providers do not have complete and comprehensible health information about their patients to give them the best treatment they require.

b. Not readily accessiblehealthinformation on patients during emergencies to facilities they have never visited for healthcare provision.

1.3 Motivation of research

It is very sad to note that in this day and age of information technology where things have become rapid and instant, Ghana is still lagging behind in taking advantage of the huge benefit IT has to offer in the health industry. It is quite worrying when words like ―I didn't know he was a diabetic‖ are being iterated from health care providers after a serious medical error has occurred. This occurs as a result to the fact that every health facility has a different health records about their patient. A hospital record of a patient in facility A is different in facility B of the same patient. This leads to serious problem within the healthcare industry and needs to be addressed.

1.4 Aim of Study

The purpose of this study is topropose a conceptual framework on how to interoperate EHRs across all levels in the health care industry in Ghana.

1.5 Research Objectives

The specific objectives of this study are to:

a. Propose a framework that would facilitate the technical integration of EHRs from different health facilities to allow for the exchange of health information.

b. Simulate the framework with two popular and widely used open source EHRs (OpenMRS and OpenEMR) to establish its benefits to healthcare providers.

c. Suggest standard guidelines or key requirements that would allow for interoperability between EHRs using this framework.

1.6 Research Questions

a. How are EHRs going to be interconnected to exchange health information on patients?

b. What will be the benefits of the proposed framework to healthcare providers?

c. What standard guidelines or key requirements would be used for the implementation of interoperability?

1.7 Justification of the study

As one of the few studies on a proposed framework for the interoperability of EHR in health facilities in the Ghanaian context; if not the first of its kind, this study is expected to reveal the challenges, benefits and the process of allowing interoperability of EHRs. This study also serves as an enormous contribution as it explores Electronic Health Record keeping in Ghana and the use of IT in various health facilities. It also contributes to knowledge on the deployment and implementation of electronic health records in developing countries, which is noted to be limited. The study is expected to guide hospital managers, health professionals, health information officers or managers and developers of information system who are interested and are part of the implementation of electronic health records in the assessment, design, and implementation of EHR systems within various health institutions. The study's findings may also be relevant for the formulation of policies, implementation and implication for EHRs and other electronic health systems in the Ghanaian health sector.

1.8 Organization of Thesis

The study is presented in five chapters. The first chapter introduces the study by detailing some background information to the study, which elaborates on the need for the study. It also presents the statement of research problem, the objectives of the study, the research questions, the motivation for the study and the expected contributions of the study. Chapter two elaborates on the theories underpinning the study and some relevant literature in the field of study. Chapter three presents the methodology used in the conduct of the study as well as the detailed description of the framework being proposed and a simulation and virtualization of the proposed framework with other existing EHRs. Chapter four provides information on the analysis of the result of the simulation conducted on the proposed framework. Chapter five provides information on the conclusions and recommendations on the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This section is divided into two parts. Firstly, it brings to bear a review of paper based record keeping and electronic based record keeping in health facilities, the state of IT in Ghanaian healthcare industry, Electronic Health Records System in Ghana, the meaning of interoperability, types and standard guidelines used in the healthcare industry for interoperability. Finally, this chapter would enumerate related works conducted by other people on interoperability of EHR. It would also highlights the benefits and challenges associated with interoperability of EHR as accounted for by other studies. And then conclude with a summary and the rationale for the present study.

2.1 Record Keeping in Healthcare Delivery

There are two main ways of keeping health records of patients in any healthcare facility. These are paper-based record keeping systems and Electronic Health Record keeping systems. Each of these record systems is targeted towards achieving two essential factors (Häyrinen and Saranto, 2004). Firstly, health record systems assist with the gathering of data on patients, which can be used in the future (Häyrinen and Saranto, 2004). Secondly, the coordination of activities and events at various departments and other geographical locations are being assisted by health record systems (Häyrinen and Saranto, 2004). The following sub-section further throws light on these categorizations.

2.2 Paper Based Record Keeping in Healthcare Delivery

In more than 200 decades, the healthcare industry has largely used paper based record system as a way of storing the medical information of patients (Scott, 2006). Even thoughthe paper based record system has aided the healthcare delivery system over this long period,research has shown that, it has created some informational and humandifficulties that makes it uneasy for it to be continually used as anappropriate means of keeping records within health facilities (Coiera, 2003). From the experience of healthcare providers, using papers to keeps records alone is not good enough for usage in health care delivery. The reasons are:

*Improper Organization of Patient Records:*There is a high risk of assigning wrong codes or symbols to medical files when using paper based records. This poses a challenge by making it very difficult to locate these same files in the future when there is a need for it to be reused. Also, theretrieval of a patient's medical file among a pile of other health records can overwhelming and time consuming (Warshawsky et al., 1994).

*Difficulty in accessing and sharing medical history of patients:*It is extremely difficult to make use of paper based record for healthcare providers at varied geographical locations to the means of getting previous patient's medical information for an appropriate diagnosis and better treatment. In as much as patient's medical information on paper can be sent through fax machine, telephone, and other means,these modes of transmission have the potential for the misreading or mishearing the data and even cause information delay or loss (Institute for Medication practices, ISMP, 2000). Even in cases where health professionals at various geographical locations get access to previous medical information of patients, sometimes reconciling the medical data could still be very challenging or even impossible Different interpretations are sometimes are given to the same medical records. This is because medical data interpretations mostly differ from one health professional to another due to illegibility of a medical terminology (Coeira, 2003).

Error in Prescriptions and Medications: With paper based record systems, prescriptions are usually written completely by hand. This could lead to a pharmacist making mistakes in filling prescriptions because of an illegible handwriting, or may have to spend extra time calling the doctor's office to get clarification about a prescription. The Institute for Safe Medication Practices in a report estimated that pharmacists make more than 150 million calls to physicians each year to clarify what was written on prescription forms in order to avoid error of medication (ISMP, 2000). Another report by the institute calculated approximately 39% of errors; which occurs at the time of prescribers order medications, occurring due to the illegibility of prescribers' handwritings which is often misinterpreted by pharmacists (ISMP, 2002). According to the report, handwritten prescriptions or paper-based prescriptions serve as a major source of medication error which occurs at the very beginning of the medication use process (ISMP, 2002).

Non-assurance for backup of health information: Health records kept on paper could be destroyed by flood, fire, stolen or even damaged totally. Unless a duplicates of every paper in the filing cabinet was made, that part of a patient's medical history would be missing forever and could be detrimental to the health progress of a recovering patient or an old patient of the facility (ISMP, 2000).

Breach of Patients' Privacy: With paper based records, easy accesscould be made to patient's medical recordswithout any traces of the person who had access to the records.There is difficulty in keeping track of who sees patient's records. This makes it sometimes impossible to completely prevent unauthorized people from getting access to the medical records of a patient, especially those who have confided compromising secrets to their doctors, risk irreparable damages like loss of job, embarrassment at home or work, bias, and the inability to even get insurance coverage (ISMP, 2000).

2.3 Electronic Health Records (EHRs) In Healthcare Delivery

EHR has been around for many years. It was mostly referred as a Computerized Patient Record (CPR), an Electronic Medical Record (EMR), and most currently as an EHR. The concept has evolved over time, and is viewed broadly as a record of a patient's health history, status and treatment that is owned or controlled in part by the patient, and used by the health care providers of the patient to provide adequate healthcare to the patient (DesRoches, 2008). EHRs provides a comprehensive view of all patient information (DesRoches, 2008). In addition EHR has information management tools that provide clinical alerts and reminders to the healthcare provider on the patient. It also has connections with knowledge sources for health care decision support, and aggregate data analysis for care management and research (Tang and McDonald, 2006). All personal and health information of a person is also entered into an EHR, which is accessed electronically by healthcare providers over the person's lifetime and extends beyond acute inpatient situations including all ambulatory care settings at which the patient receives care (WHO, 2006).

Many definitions have been ascribed by various in defining EHRs; the definition accepted internationally was however stated by the International Standard Organization (ISO). They defined EHR as ―a repository of information regarding the health of a subject of care, in computer processable form‖ (ISO, 2005). This definition narrowly focuses on only the structure of EHR systems; therefore Hayrinen et al (2008) sought to explain EHRs by broadening the ISO's definition of EHRs. According to Hayrinen et al. (2008), EHRs should be construed as comprising of retrospective, concurrent as well as prospective information which has the primary objective of supporting continuous, efficient and quality integrated healthcare delivery. Luo (2006) also asserts that EHRs go beyond just the electronic version of the paper based record to encompass the whole management of data required for patients' care. Thus Bernstein et al. (2005) agreed to the point that EHRs play a many-sided role in healthcare delivery than just being a computer system.

Components of an EHR

Tang (2003) has noted that an effective EHR system: should have the capacity of storing patient health information and data longitudinally; should enable results generated from the system to be managed proper; also enables the facilitation of electronic communication and connectivity; it should provide patient support and help in administrative processes and report. Nøhr (2006) also highlights the common components of EHR as:

Clinical Documentation: EHR should enables health professionals to better handle progress notes of their patients either as free text directly entered into the system or by predefined structured notes.

Physician Order Entry (POE): EHR should also allow for ordering diagnostic test and medication in a standardized and formalized way. Other EHR systems provides for checking drug interactions and alert for patient allergy.

Booking service: An EHR system allows for patients to book appointments with their medical professionals, either face to face or online.

Communication/Messaging: EHR systems should also enable the exchange communication between various hospitals, General Practitioners, pharmacies, and laboratories.

Results Management: EHR systems also facilitate the assaying of medical results. The system is should be able to show some warnings to abnormal results. The system should also depict trends of a particular result.

Charge Capture/Billing: EHR makes it easier to track expenses owed to the facility by virtue of the health service provided to the patient.

Disease Management: EHR also help in management of chronic diseases, by allowing health professionals to access data to assess whether or not disease is been managed properly.

Management of security issues: All EHR systems have special features that help manage authentication and authorization of users.

Further, Coeira (2003) also provides various components of EHR, which could be illuminated, graphically from Fig 2.1 below:

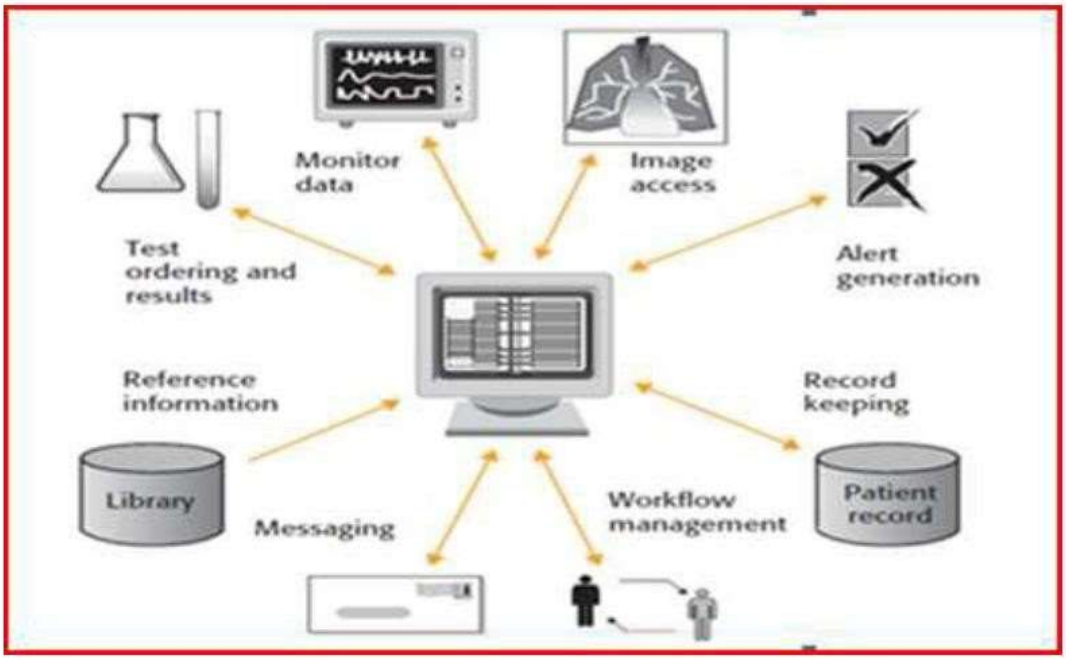


Figure 2.1: EHR and Its components (Source: Coeira, 2003)

2.4 Structure of an EHR

Three (3) structures or functions of EHR system was identified by Dickinson et al (2004). These structures were classified as; direct care functions, supportive requirement and Information Infrastructure. This could further be explained by the aid of Figure 2.2.

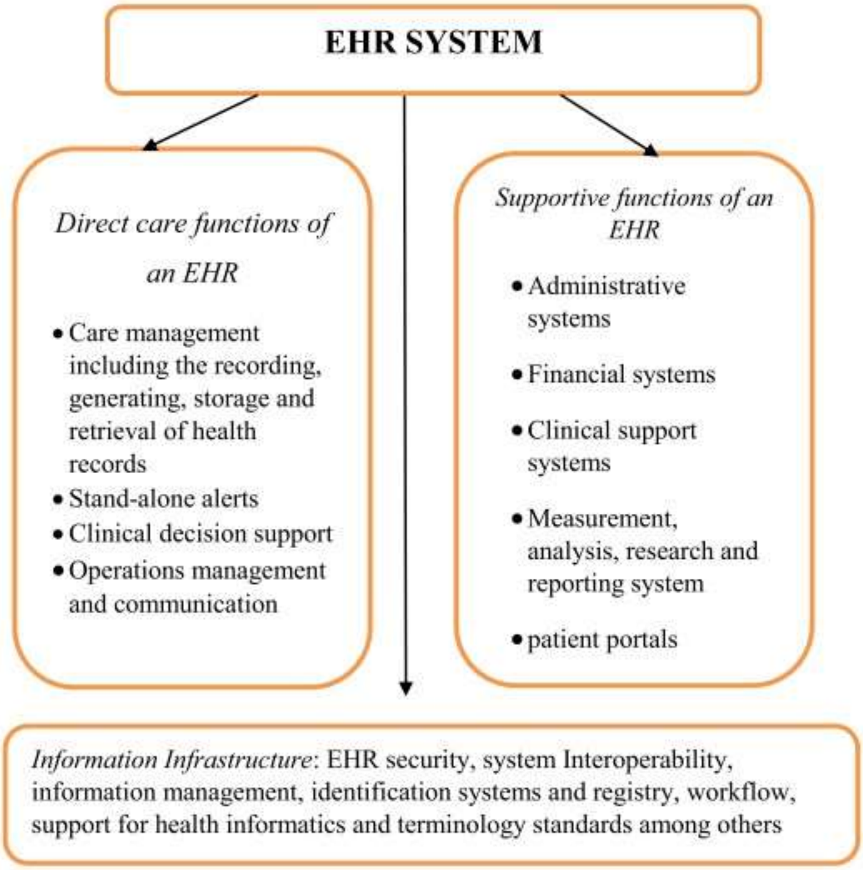


Figure 2.2: Structure of an EHR (Source: Dickinson et al. (2004))

The Direct care functions of an EHR

The direct care function of every EHR systemis involved with carrying out the functions associated with general clinical tasks. And it involves the capturing or generation, storage, management, retrieval and communication of health information that are strictly defined by the healthcare provision. Dickinson et al. (2004) stated that: ―The direct care function of EHR is to ensure the delivery of better healthcare to patients every day‖. These consist of functions such as diagnosis, goal setting on management of patient, planning and providing interventions, examination and assessment of results (Bernstein et al., 2005). Stand-alone alerts used as prompts for contraindications and mistaken prescription of medications to patients are also included in it (Veselý et al., 2006).

The direct care function of an EHR also provides task tracking to ensure timeliness in the provision of care (Dickinson et al., 2004). Hayrinen et al. (2008), however, were of the view that patient referral, past medical history, physical examination, diagnosis, tests, procedures; treatment, medication and discharge are some of the commonly known direct care functions of an EHR.

The supportive function

The supportive functions of EHR systems are those functions that are not directly related to the provision of healthcare but are subsidiary direct provision of healthcare though relevant for the overall delivery of health care (Dickinson et al., 2004). The supportive functions seek to improve quality healthcare delivery through the provision of inputs for medical researches and promotion of public health. It also provides assistance for general administrative and financial management (Dickinson et al., 2004). Examples of these supportive functions are optimizing patient bed assignments, provision of health guidelines and resources available, administrative and financial coding assignments as well as the provision of providers' location in the facility.

The Information Infrastructure Function

The function of EHR as an Information infrastructure, relates to the provision of technical groundwork for the successful achievement of the direct care functions and the supportive functions. EHR thus becomes the force which propels the wellfunctioning of both direct and supportive functions. According to Coeira and Clarke (2004), it involves security, which entails controlling access and privacy of data. It also involves the interoperability or exchange of clinical and administrative information through standard-based solutions as well as the sharing of information and records across management and various units (Dickinson et al., 2004).

2.5 Hybrid Health Record System

In an empirical study conducted in the US by Varga (2011), it was noted that although EHR is needed to aid in the automation of paper based health records, the complete migration to EHR system; and thus the consequent elimination of the cosmic majority of paper in the delivery of healthcare, will take at a minimum of 1015 years or potentially many years longer. The study again noted that high percentage of healthcare professionals will continue to receive health information from patients in the form of paper documents for some long time to come, even if healthcare professionals themselves convert to an EHR system.

Therefore many healthcare facilities are now combining the use of both EHR systems and the paper based records systems. This is nonetheless, not exclusive to Varga's study amongst US medical professionals but the same phenomenon of combing paper based health records with EHR has been observed by some writers in the implementation of EHR systems (Adjorlolo and Ellingsen, 2013). Kalra and Ingram (2006) sum it all up by instigating that; *"Healthcare professionals require access to patient health information that is scattered across many different locations, held in a variety of paper and electronics formats and represented in various forms of structure and multimedia entries to provide a better clinical care for their patients".*

2.6 The State of IT in Healthcare in Ghana

Since the first internet was setup in 1989,Ghana has been a regional principal and an advocate for ICT (Ghana Ministry of Health, 2010). Over the past twenty years or more, collaborations between the government and private industries have worked to ensure the stability of internet within the country. TheICT for Accelerated Development (ICT4AD) programme, which is on-going, has ended up with many improvements within the sector and the economy at large. Due to the rapid changes within the ICT sector, the plan is being modified to help improve ICT services in the country in the years to come. There has been a redesign of the plan to meet the present needs of the speedily changing sector of ICTand is expected to function effectively in the future (Achampong, 2012). All health facilities in Ghana have acomputer system, some form of device on multimedia, printing and imaging system, and a communication system in one form or another (Achampong, 2012). The current ICT infrastructure within the country have not been fully networked or interconnected to support the healthcare delivery system (Ghana Ministry of Health, 2010).

With the exception of some health facilities with complete local area network (LAN), many healthcare facilities have their LANs connected to the reception, records and pharmacy departments. They are used mostly tofacilitate in the automation of activities that goes on in these departments; such patient registration and records keeping (Ghana Ministry of Health, 2010). Many of the health facilities in the country are partly using electronic record system in one form or another. However, there are a number of works going on to establish a sufficient management information system throughout the country (Achampong, 2012).

After a thorough assessment of the present state of IT within the Health Sector, it can be concluded that, in order to setup a proper Health Information Management within the health sector, the following building blocks should be available: Health Information system tactical plan, Legal and policy framework for reporting health data, policy on medical records, central data repository framework, Computerized District Health Management Information System and Centre for Health Information establishment at a central level. The use of information system for health management is not extensive or well embraced by people within the country (Achampong, 2012). Presently, there are basically two applications that are used for information management within the health sector. These are: a version used for the management of clinical business processes. And another version that aids with the compilation and aggregation of data, which is also mostly used for data reporting. Sometimes, Personal Digital Assistants (PDAs) are used for collection of data at the district and community levels (Achampong, 2012).

District Health Management Information System (DHIMS)

The District Health Management Information System (DHIMS) is computer application software that is basically used in the capturing and aggregation of data and also the generation of management reports based on the data captured. Recently, the District Health Information System (DHIS2) has replaced DHIMS. The DHIS2 is an improvement over the DHIMS in terms of its functionality. Many types of software are being employed by various health facilities for various services. However, these software applications are compact in natureand do not said the entire hospital processes. With regards to how each and every health facility uses information systems vary from one facility to the other. Below are the characteristics of hospital some processes:

- Admissions documentation, taking of management regimen and summaries of discharge are all kept in folders and done manually.

- Important information of the records of patient within the health facilities are still kept on paper. Diagnostic and imaging results are not electronically available and also cannot be accessed from remote locations.
- History prescriptions done electronically are not available.
- Electronic logistics and supply chain management system for non-consumables and medicines are not available. Many activities are carried out manually.
- Unavailable systems in place for generating medical records electronically. This has a huge significant on referral arrangements.
- Patients waiting in queues for long
- Insufficient number of staffs, thus clinical and non-clinical issues with financial management reporting

National Health Insurance Scheme (NHIS)

The Government of Ghana's health insurance scheme plays an important function in the financing arrangements for the health care providers. An IT infrastructure which is being used for automation of the insurance services has been deployed by the National Health Insurance Authority (NHIA), the organization in charge of the NHIS. As a result, all accredited healthcare providers of the NHIS makes use of a popular IT platform with common protocols for management of authentication and claim of a patient. The government has also made plans to deploy an online claims management system which would improve the services. Currently, the IT platform for the insurance of health scheme does not aid in the support any shared services.

Rather, It is used for the business processes and needs of the insurance scheme (Achampong, 2012).

Human Resource

Clinical and non-clinical staff with some background in IT literacy has become very critical in projects of health informatics. According to the Ghana Ministry of Health (MoH) there are inadequate staffs with skills in health informatics. Because the current Human Resource positions does not have proper structure of IT professionals, the small number of staff who have undergone professional training in health informatics are not occupied in mainstream IT related activities (Achampong, 2012). The Ministry of Health (MoH) has no routine or laid down structured training for non-clinical and clinical health professionals in IT related courses such as systems administration, networking, computer security and ethical hacking, database administration and web-based systems.

2.7 Electronic Health Record Systems in Ghanaian Healthcare

In a research conducted by Achampong (2012)he indicated that most hospitals in Ghana are not using Electronic Health Records system for their operations despite the advancement in technology with regards to healthcare. The study focused on four (4) hospitals within the country, thus Korle-bu teaching hospital (KBTH), Komfo Anokye Teaching Hospital (KATH), Effia Nkwanta Regional Hospital (ENRH) and Tamale Teaching Hospital (TTH). According to him, since the inception of the National Health Insurance Scheme (NHIS), many health facilities within the country has at least one standalone computer for the purposes of the scheme. A number of health facilities are gradually putting into operation EHR's using an agile approach, while some health facilities are yet to begin implementing it. For instance, KATH already has an EHR system for keeping records of their patients. This is being used together with the paper based records until the paper records gradually phases out. In addition, the Komfo Anokye Teaching Hospital (KATH) has a well functional

Information Technology (IT) Unit, which is in charge of managing the EHR system. Korle-Bu Teaching Hospital also has some of their numerous departments using EHR. For instance, the cardiothoracic and surgery departments have some of their records in EHRs whiles some are still kept on paper. Because there is no space to keep the records, some patients are allowed to take their folders to the house and then bring it to the hospital during their next visit. Much has not being achieved with regards to EHRs even though the hospital has an IT department. As a result, the hospital is finding it difficult to fully implement the EHR system. The Effia Nkwanta Regional Hospital (ENRH) just had EHR software being installed on one of the computers for implementation. The Tamale Teaching Hospital (TTH) however didn't have any EHR system in place during the time of the study.

A more recent study shows that Ghana, unlike in the past, Ghana can now boast of nationwide electronic health management projects, including DHMIS (District Health Management Information System), which generates electronic information from all districts, based on the International Statistical Classification of Disease and Related Health problems (ICD10). Other EHRs include; Health Administrative Management system (HAMS), District Health Information System (DHIS), Healthfore and others (Darko-yawson and Ellingsen, 2016). Most health facilities in Ghana use the Health Administrative Management System (HAMS) which was developed by InfoTech Dot Net System Limited (IDNS), Ghana. Technically, the HAMS is a client server solution which was designed using a Microsoft Visual Studio and a Microsoft Dot Net framework which serves as the front-end portion of the system and Microsoft SQL Server as the database base portion. In generating reports from the HAMS, the developers used the Crystal Report Writer, an inherent part of Microsoft Visual Studio, in designing all HAMS reports which are being extracted from the Microsoft SQL Server. According to many users, they are happy with the system due to its user friendliness especially with people with differing computer background and its billing a management module implemented in a way that enhances easier claims with NHIS Scheme (Acquah-Swanzy, 2015; Darkoyawson and Ellingsen, 2016).

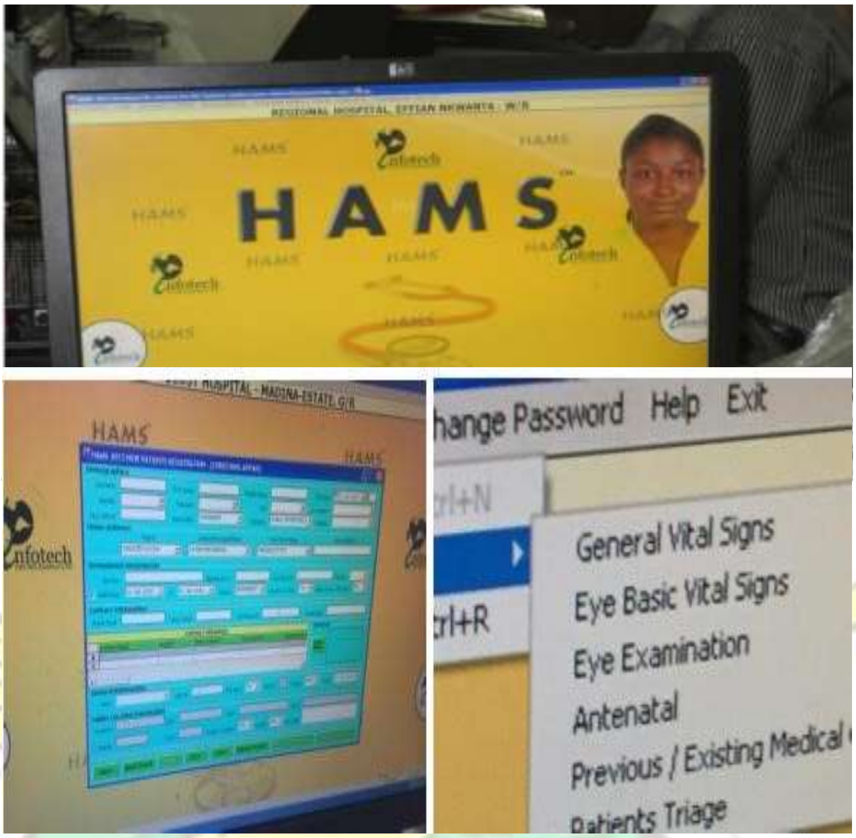


Figure 2.3: Interface for HAMS Solution (Source: Acquah-Swanzy, 2015; Darko-yawson and Ellingsen, 2016)

2.8 Defining Interoperability

Interoperability has been defined and explained by many researchers in varied ways, although they all sum up to the same meaning. Peristeras et al., (2007) Define interoperability as the exchange of data through IT and business processes of the systems they support, in order to enable information and knowledge sharing. Begoyan (2007) also defines Interoperability as the ability of two or more systems or components to exchange information and make use of the exchanged information. But amore simplified and appropriate definition given to interoperability in health care is the ability of diverse IT systems and computer applications to communicate and exchange data and make use of the information that has been exchanged (Begoyan, 2007). In a nutshell, Interoperability is the ability of health information systems to work collaboratively within and across organizational boundaries to provide effective healthcare delivery for individuals and communities in order to improve their health status. For systems to interoperate there is the need for communication, data exchange and usage of the information that has been exchanged.

There is growing realization that interoperability isa long term endeavor which requires a continuous change management in order for it to be successful and making use of permanent structures of institutions and organizations charged with this responsibility and organization of processes for consensus building among all stakeholders involved (Dobrev et al., 2008). Experience by many who have done some work on interoperability reveals that for interoperability to be effective and efficient there is the need to focus on a concrete application context, which requires much more than implementing specific standards. This usually involves comprehensive specifications and agreement between users and industry with regards to use cases and results to be derived, testing and certification, legal and regulatory compliance (Dobrev et al., 2008).

Interoperability standards in health care can be measured in three different angles to maximize business benefit (Begoyan, 2007).The view points are listed below.

Technical Interoperability

Technical interoperability refers to the exchange of data between two computer systems, thus computer A and computer B, where by both computer systems cannot interoperate or understand the meaning of the data that has being exchanged. For instance, when emails are transmitted from one computer to another, the content of the information is not understood by the sending or receiving computer.

Semantic Interoperability

Semantic interoperability is another type of interoperability in which the data exchanged between computer system A and B is understood and interpreted by both computer systems. Semantic interoperability is very central to interoperability of healthcare. For example, when a laboratory information system sends results to a practice management system, the practice management system is able to identify the structure, format, units and meaning of the result sent by the laboratory management system. This is achieved by both systems using a common terminology or language to communicate.

Process Interoperability

Process interoperability is the type of interoperability that adds business processes. It has become very necessary that businesses processes also interoperate and the people who are part of it have a collaborative view and understanding in order to enable computer system A and B to work together. Healthcare professionals for example, must standardize business rules and regulations so that health information is captured in a homogeneous and timely manner to enable consistent and complete transfer of information between systems (Begoyan,2007).

In order to make interoperability between systems more effective, the standards used in health information must address the syntax (structure) and the semantics (meaning) of data exchanged. Standards used in interoperability are not software or hardware, but rather guidelines that are used by technology developers for the development of health information systems which will essentially make it compatible with other systems following the same standards (Begoyan, 2007).

2.9 Interoperability standards

Interoperability of Electronic Health Record systems is very complex. However, there several standards that supports this interoperability (Mykkänen and Tuomainen, 2008). These standards are captured in three categories; Process Standards, Technical Standards and Semantic standards.

Process Standards

Process standards define how health data should be used within the workflow of the facility involved in interoperability. The actual data may not be understood correctly unless the facility involved in it understands the context within which data is being used. According to many people, this standard is the least tangible among them. Interoperability functionality is mostly expressed using stories, use cases and use narratives to explain the clinical or other healthcare related role being performed by the intended users. Examples include:

- American Health Information Community (AHIC) Use Cases (2006-9)
- Direct Project User Stories
- HIMSS Use Case Repository
- HL7 FHIR Common Example Scenarios
- Standards & Interoperability (S&I) Framework Use Cases ○ Laboratory Results Interface ○ Longitudinal Coordination of Care ○ Provider Directories Query for Electronic Service Information including Electronic Address and Query for Digital Certificate Use

Case for Direct Project Use

Cases ○ Public Health Reporting ○

Query Health ○ Transitions of Care

○ Structured Data Capture (SDC) ○

Data Access Framework (DAF)

Technical Standards

The structure, syntax and the reliability of transactions used in interoperability forms the technical standards. Structure and syntax mostly work together. The transport machinery used for transaction and the fundamental stability of the network in transporting it forms the reliability aspect of the technical standard. These standards are further sub-divided into specific areas which handle specific portions of interoperability. These areas are; Structure and Syntax, transport and privacy and security(Mykkänen and Tuomainen, 2008).

- **Structure and Syntax:** This is basically handled by the Health Level 7 (HL7) which is a common messaging standard which represents the core of standards-based interoperability. HL7 has been in use in the health care industry for over 20 years(Czapski, 2013).HL7 is developed with a wide range of standards, thus HL7 Version 2, Version 3, CDA and FHIR.The most dominant in the industry is HL7Version 2 messaging standards. They have many sub-versions which are always not compatible with each other. Because of how complex they are, HL7 and other organizations provide guidelines to provide details and to characterize the level at which a particular message(s) could be used in specific setting. These messages are mostly used to exchange orders and results from laboratory, admissions of patients, transfers and discharges from in-patient facilities, immunizations, and many other types of information.

The third version of HL7standards have the aim of supporting all healthcare workflows based on a formal methodology and object-oriented principles. Reference Information Model (RIM) which is the corner stone of HL7 v3 provides the source which allows implementers to work with the full set of data types, messages and terminologies needed to build a complete implementation. It also includes standards for communications that provides documentation and manages the treatment and care of patients in a varied healthcare environment. RIM also forms the foundational part of the technologies that satisfies the global challenge of integrating healthcare information, in areas such as public health and patient care.

The Clinical Document Architecture (CDA) of the HL7 is a standard mark-up document which specifies the semantics and structure of clinical documents for the function of exchange. CDA specifies the syntax and provides a framework for indicating the full semantics of a healthcare document. A CDA could alsocontain any type of clinical content such as summary of discharge, report on imaging, admissions, Pathology Report and many more. CDA allows for non-XML format like PDF,Doc and Jpeg for simple implementations although CDA is XML based. The mandatory textual part, thus the human interpretation of document contents and optional structured part (for software processing) are all specified by the CDA. Coding systems such as SNOMED and LOINC which is used to represent concepts are relied upon by the structured part of the CDA.

The last of the HL7 standards discussed is the Fast Healthcare Interoperability Resources (FHIR). FHIR is a standard that describes data formats and elements known as resources and an Application Programming Interface (API) for exchanging Electronic health records. FHIR builds on previous data format standards such as the version 2 and 3 of the HL7. The implementation of FHIR is easier because it makes use of a modern webbased suite of API technology, which includes an HTTP-based RESTful protocol, HTML and CSS for integrating with user interface, andJSON or XML for representation of data, OAuth for authorization and ATOM for results. The assistance of interoperability between legacy health care systems is one of the goals of FHIR. This goal is to ensure the easiness of providing healthcare information to health care providers on a wide variety of devices such as computers, tablets and cell phones and to allow third-party application developers to provide medical applications that will make it easier to be integrated in to the already existing systems. FHIRprovides an option to document centered approaches by directly revealing distinct data elements as services. For instance, fundamental elements of healthcare such as patients, admissions, diagnostic reports and medications can each be retrieved and manipulated through their own resource URLs.

- **Transport:** It has become very necessary that all parties involved in an interoperability transaction must agree on the means that will be used to transport data reliably and securely. The IETF Transport Layer Security (TLS) Version 1.2 is the most common transport encryption protocol of the Internet and is sometimes only based on the web browser or Secure Socket Layer (SSL) Version 3.0. Many of the transport strategies identified below use TLS. In addition to the IETS Transport layer and the SSL, there are additional

transport layers that are also used. Some to these transport layers include direct, CONNECT, HTTP POST and VPN. Direct and CONNECT are open source projects that provides standards and tools for more interoperability, which can be used within the local, regional and country wide health information exchange. For Direct transport layer, involving parties must get a ―Direct address‖ (similar to an email address) from a Health Information Technology Service Provider (HISP) and be added to a
―trust domain‖ with the recipient the message is intended for so that it could be verified that the recipient is the intended one.

HTTP POST relies on the technique used by web-based type to transmit information entered from a browser to a web server. This is method is very simple and secure if encrypted with TLS or SSL method of data sending from one system to another. Virtual Private Network (VPN) is computer network in one organization that functions steadily as if it is part of secured network in another organization using an internet as a connection between the two computers. VPN is configured using either hardware or software-based solutions or both. Most often a VPN is used to create a point-to-point connection between two participants. However, VPNs can become complicated to manage when plenty of such connections are important. VPN is not a transport solution by itself. It requires a transport protocol such as HTTP or run inside its own connection.

- **Privacy and Security:** Privacy and Security cannot be taken for granted when it comes to the interoperability of healthcare systems**.**The primary guide for privacy and security of health information is in the US is being handled by the Health Insurance Portability and Accountability Act (HIPAA) of 1996, which takes into consideration care providers, payers, data processors, and their business associates. The standards provided by HIPAA are very detailed and concise. It is necessary that all participants involved in Health Information Exchange (HIE) understand the legal and policy framework within which they function. Stricter policies are therefore necessary for the exchange of health information between the participants involved so that healthcare providers who have access to such large pool of information would use it for the intended purpose. Technically, issues of security, authentication

and authorization, consent and transport should have stricter standards, protocols and guidelines to ensure the safety of patients.

Semantic Standards

Semantic standards are concerned with maintaining the meaning of data as it is sent from one organization or system to another. This is done by ensuring that consistent codes are used and translated correctly. In many instances, semantic standards are placed within the technical standards that make use of them. For example, many version 2 HL7 messaging implementation guides consist of code tables which are used in their messages. There are several semantic standards being used in the healthcare industry for the exchange of health information between heterogeneous healthcare systems (Mykkänen and Tuomainen, 2008). The table 1 shows the list of the common ones being used which is included in the Office of the National

Coordinator for Health information Technology in US (ONC) Interoperability Standards Advisory which is being updated annually.

Table 2.1: Some Key semantic standards commonly used (Adopted from Mykkänen and Tuomainen, 2008)

No	Standard	Description
1.	CMS' Healthcare Common Procedure Code System (HCPCS)/American Medical Association (AMA) Current Procedural Terminology (CPT®)	This is the standard coding for procedures widely used in the healthcare community
2.	Centers for Disease Control and Prevention (CDC) Vaccines Administered	These are widely used codes for vaccines and manufacturers
3.	College of American Pathologists Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT®)	This is the standard coding used for a wide variety of medical and health care terms.
4.	International Classification of Diseases, 10 revision, Related Health Problems	This revision to ICD9-CM contains a number of important improvements.
5.	Logical Observation Identifiers Names and Codes (http://loinc.org/) (LOINC®)	This is the standard coding for laboratory and clinical observations used by health care systems and messaging (like HL7).
6.	National Library of Medicine (NLM) Unified Medical Language System (UMLS) RxNorm	This is the standard for coding the names of drugs and dose forms.
7.	National Drug Code (NDC)	This is a universal product identifier for human drugs.

The use of standard vocabularies within the healthcare industry is much encouraged in order to ensure easy interoperability between healthcare systems (Begoyan,2007;

Mykkänen and Tuomainen, 2008).

2.10 Related Literature

A number of people have conductedseveralresearches on interoperability of Electronic Health Records (EHRs) across various health facilities using different approaches, methods and subjects. Some have even gone further to research on how interoperable EHRs impact positively or negatively on the life of a patient.

In a research conducted by Hwa et al, (2010) their focus was to develop efficient ways of sharing a patient's health information.There was a development of a Medical Information Exchange System (MIES) which was dependent on a registry server. This enabled them to exchange diverse types of data produced by various systems. In their methods, they adopted a standardized transfer of data methods instituted by the Centre for Interoperable Electronic Healthcare Record (CIEHR) of Korea to effectively exchange a patient's health information under different system environments.With regards to security, the Medical Information Exchange System (MIES) used the security guidelines provided by the CIEHR of Korea. The focus of this research was aimed at developing better security systems for the implementation of online services such of communication encryption, security of database, protection against hacking, network and content security. Their findings exhibited that information exchange was managed by their registry server in addition to the information registration within the Clinical Document Architecture (CDA) documents. Also, server of the CDA for transfer was used to locate and transmit the correct CDA document from the essential repository. The CDA viewer however displayed the CDA documents through a connection with the information systems of hospitals related.

In another study conducted,their mission was to develop a National Health Information Network (NHIN) of regional health information organizations (RHIO) and exchanges (RHIE). This was done to improve patient wellbeing and quality of health care delivery using HL7 messaging standard. This was because in 2004 of July,the Department of Health and Human Services (DHHS) announced 10 years of health information technology (HIT) for delivery of rich information and consumercentric healthcare within the country. As a result, there was the need to improve on their existing system. This study was used as a prototype by their health care systems on the areas of new born screening, birth defects, immunization, communicable disease surveillance, and lead poisoning prevention.Specific areas were taken into consideration with regards to this study. These areas included: Collaboration of architecture on surveillance of public health systems, reformation of health status quality monitoring,and speeding up research and dissemination of evidence. The reason was that inability to collaborate different public health programs lead to ineffective use of resource and brought lots of frustration within family members and the providers of healthcare since the family members we asked to provide the same information in different formats to various programs at varying periods. Aggregation of patient’s information of manycurrent public health systems was not easily allowed to provide real-time feedback information to the Health Care Provider (HCP).In their methodology, they designed a prototype of Electronic health record-public health system (EHR-PH). This system was made to track all reports from a Hospital of Birth on four public health programs. Thus, Newborn Metabolic Disorder Screening, Newborn Hearing Screening, Immunizations and Communicable Diseases.This is to symbolize the flow of information across public health reporting from a period of a child’s birth through to the first 48 hours of life before discharge. The prototype for the EHR-PH system illustrated a variety of clinical procedures that was significant to reporting of public health and vendors whose systems were currently in use by agencies of public health to support their programme of activities. There was a true representation of system interoperability as a result of their demonstration which could be achieved between clinical care and across public health programs within the agency.The integration engine which transforms HL7 messages from version to version 3 supported the data electronic data reporting. Data was stored at the systems source for newborn hearing, screening, hearing screening and immunization. The date of application for Communicable Diseases resided at Healthcare Transition Base (HTB). In their findings, Partners in the demonstration received or sent varied HL7 2 and HL7 3 messages transformed and transported by the engine for integration. The storage and collation of healthcare event information that was received from the HL7 3 messages was done by the HTB. This was done in real time. The partners for the prototype provided the applications to support the Public Health Surveillance portion. Apart from the Hearing Screening, there was a duplication of system behavior for clinical care components which had most of the partner components acting as registries for public health surveillance. With regards to Hearing Screening, there was a dual function of the application. Thus, patient management system at the hospital of birth and a tracking and surveillance registry at the state health department. Figure 2.4 shows the architecture for the prototype of interoperability.

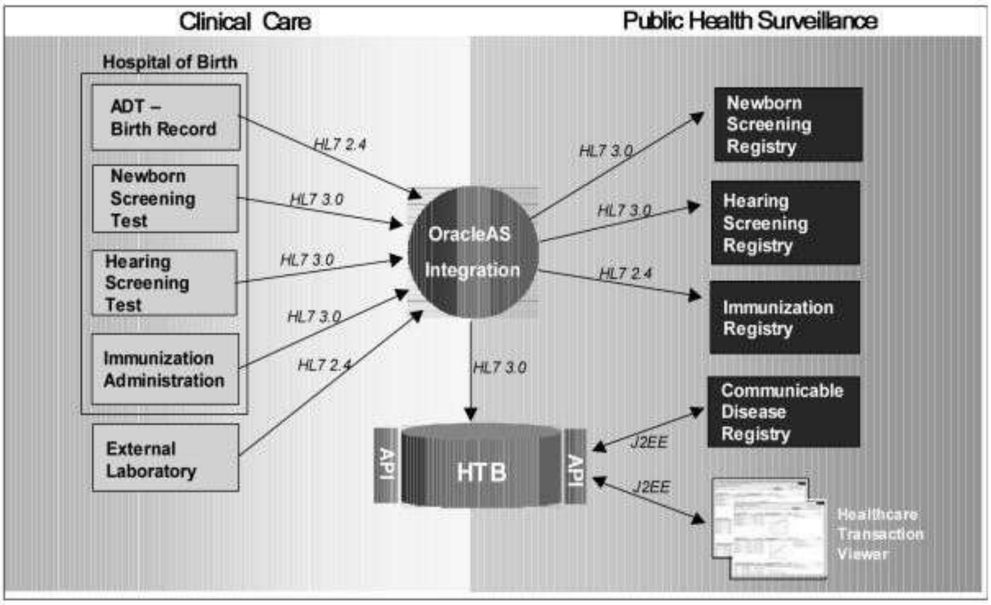


Figure 2.4: EHR-PH System Prototype Architecture (Source: Adopted from Orlova et al., 2005)

Katehakis et al, (2001) also conducted a study on interoperability. The purpose of the study was to provide accessible comprehensive medical information about a patient. This was done by integrating all the scattered and heterogeneous health record segments into an Integrated Electronic Health Record which available online through an integrated user interface and visualization environment. In their methodology, the technological approach they used for implementing the Integrated Electronic Health Record environment was based on the HYGEIAnet, which is a Regional Health Information Network of Crete Reference Architecture. It provides the essential structure for services reuse, interfaces, and components. A better information presentation was achieved by means of an Extensible Mark-up Language (XML), while its fundamental ability allow for dynamic navigation based on personalized end-user preferences and authorities. In their findings, the basis for reliable and authenticated access to primary information on the internet was provided by the Integrated Electronic Health Record environment developed, which supported decision making. The source of the primary information was used to keep the information. It was also maintained by the most suitable clinical information system, contrasting traditional store and forward techniques, or centralized clinical data repositories. Furthermore, because it is easy to access documents than data within a database, XML has the possibility of becoming a very cheap technology provided, that the fundamental Healthcare Information Infrastructure exists. XML can be introduced incrementally and its implementation is completely transparent to the end user.

In the research conducted by Hwa et al (2011), the standardization used was only based in Korea and no other country. No internet connection was used to send information to the other systems, hence making it more expensive to setup. The registry server had no backup sever to replace the existing one in case the main fails. The research by Orlova et al (2005) was focused only on Newborn babies. It however did not focus on the other patients. Their standardization was also based in the US environment and no other country. Katehakis et al's, (2001) research focused on only XML as their meansdataof exchange without considering the other data and their standardization was based only in their country.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This study proposed a framework and the EHRs systems.The study would implement the proposed framework using tools as PHP, MySQL, CSS, HTML, and JavaScript with EHRs (OpenEMR and OpenMRS) . This chapter contains two main parts. The first part talks about the description of the concepts, models and architecture for theproposedframework. The second part provides a virtualization and simulation test between the framework and OpenMRS and OpenEMR. These EHRs were chosen because of its popularity in the healthcare industry and how it replicate the ones used in Ghana (Aminpour et al, 2014).

3.1 The Proposed Framework (WbEHR)

Web-based EHR framework, dubbed WbEHR is the proposed framework for interoperability of different EHRs in health facilities in Ghana. It provides a solution for healthcare providers to be able to access a patient's health information beyond their own facility. If a health care provider is attending to a particular patient and would want to have more detailed information aboutthat patient beyond their facility, this framework provides a solution for that.

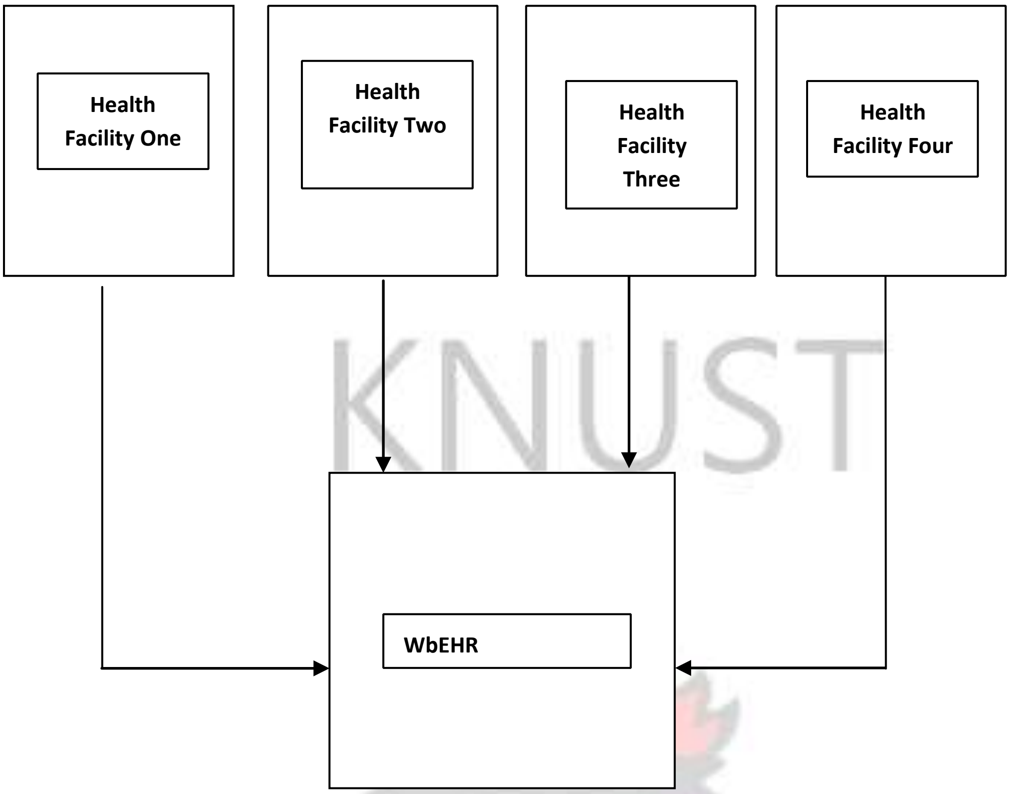


Figure 3.1: General Architecture of WbEHR Framework

Figure 3.1shows the general architecture of the WbEHR being interconnected to different health facilities to exchange health information. In the figure, each of the facility's EHR was developed with a different programming language. The significance of this is that, irrespective of the system used to develop the EHR in each of the health facility, they would still be able to exchange health information using this framework. The WbEHR connects to the databases of the other health facilities through the adapter by using the database URL, username, password and the database type of the EHR of the health facility. Hence in order for the connection to be done, the other health facility needs to make this information available. The search is done by using a fingerprint scanner to scan the patient's finger, NHIS Card or a national identification card.The framework uses an adapter that converts transmitted data from each of the health facility into a presentation format for the WbEHR. The adapter is used as a medium of interconnection between the various EHR's and the WbEHR.

Because each of the health facility's EHR uses different database system and structure, the adapter plays a vital role in ensuring interoperability.

The adapter follows the steps below to perform its operation:

1. The adapter connects to the other databases of the health facilities through the WbEHR using defined drivers for each database
2. The adapter picks the needed values from the databases based on the query made on the WbEHR
3. Using an algorithm, the adapter formats the data from the databases into an XML, JSon or message pack.
4. Finally, the adapter sends the requested data back to the WbEHR in XML or JSon for usage by the person who made the request.

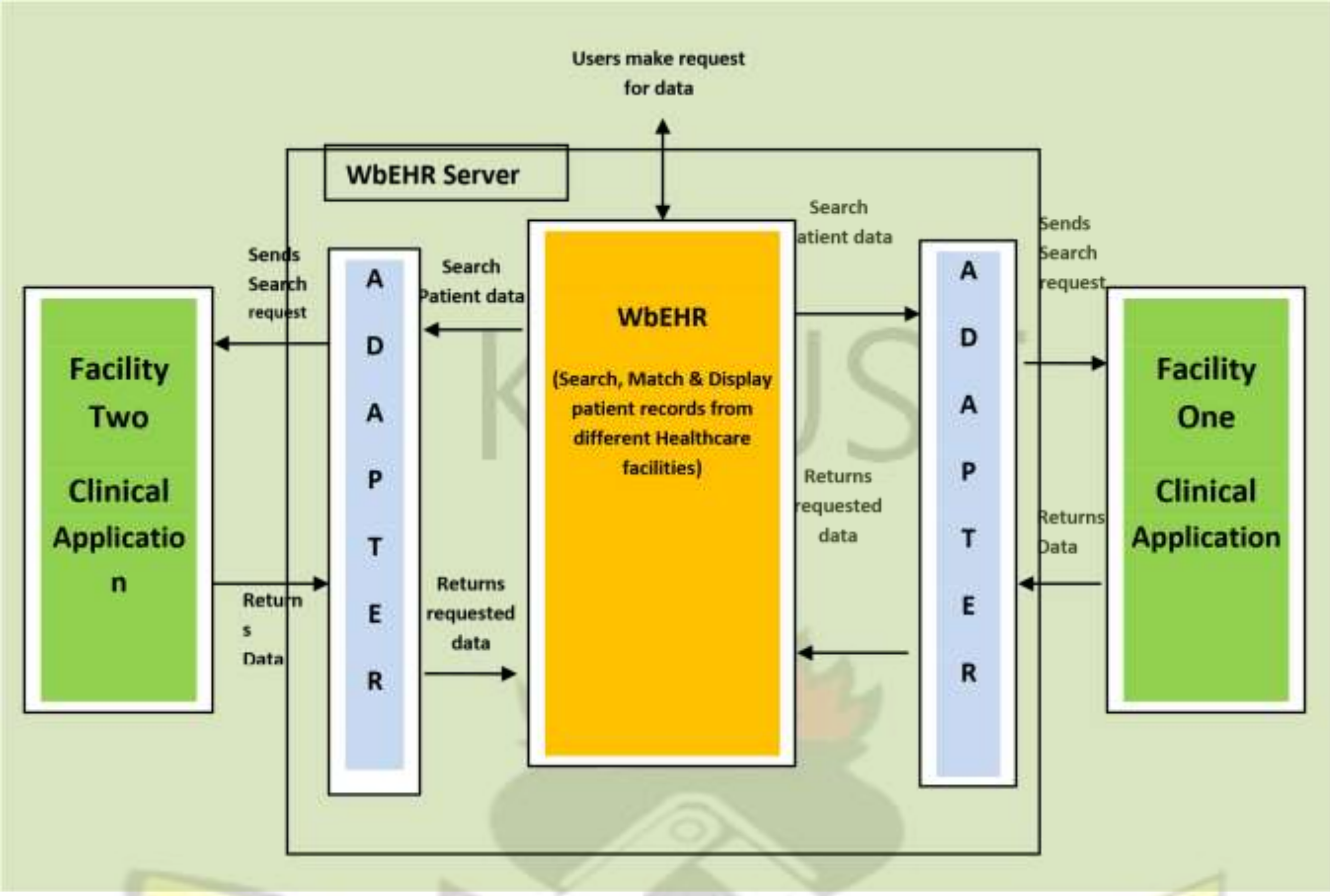


Figure 3.2: Detailed Architecture of the WbEHR Framework

From Figure 3.2, it shows a detailed architecture of the framework. From the architecture, when a user makes a request for data or information through the WbEHR framework, the request is sent to the adapter, which connects to the

databases of all the health facilities the user made request to (in this case facility one and facility two). The adapter then performs the search request from the databases of the other health facilities, the result of the request is returned back to the adapter and the adapter converts the results of the request to the WbEHR.

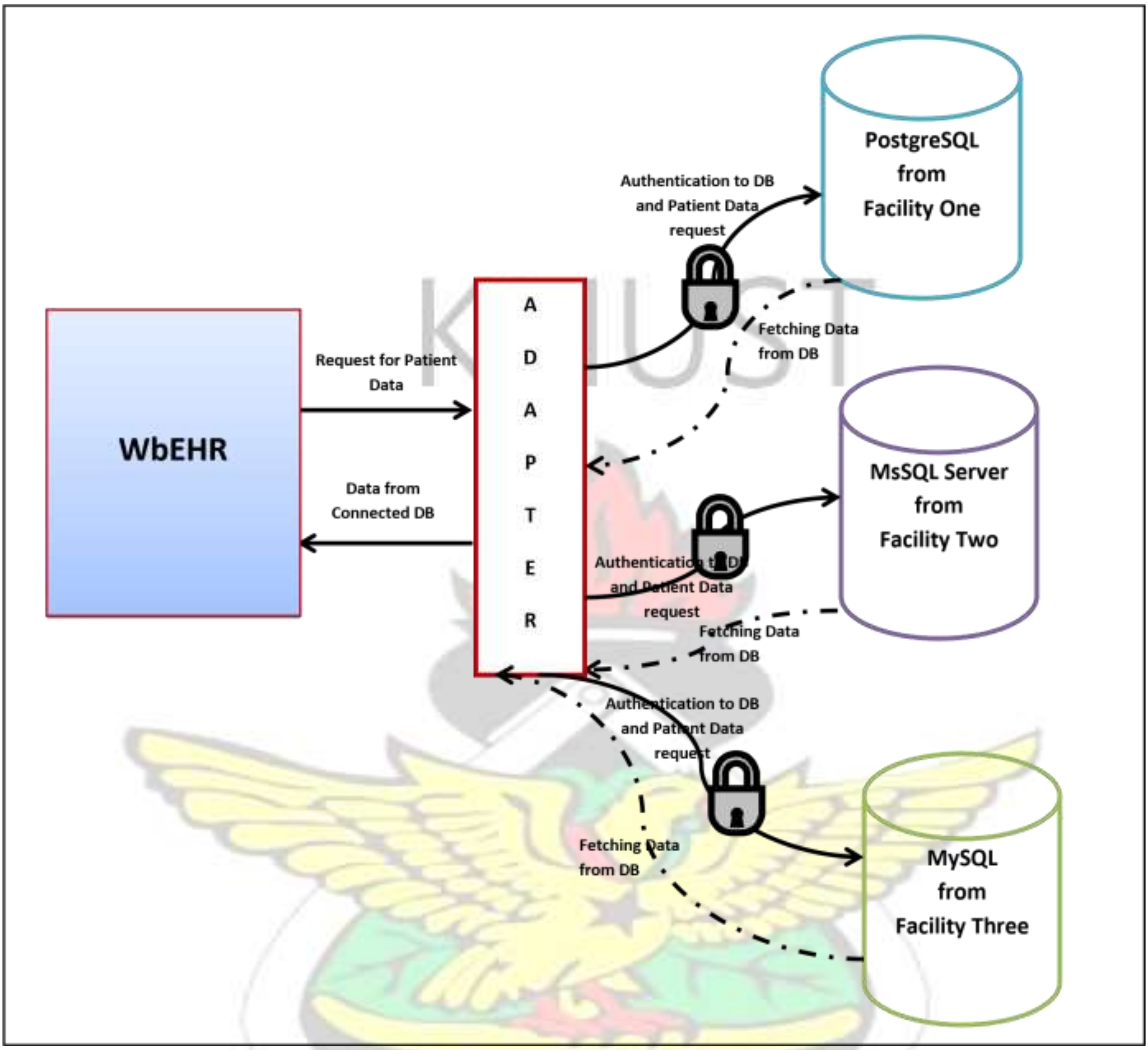


Figure 3.3: How the Adapter functions

Figure 3.3 above shows how the adapter works in the WbEHR framework. When the adapter receives a search query of patient data from the WbEHR framework, it authenticates to all the databases based on the credentials given during the facility configuration process. It the authentication is successful, the requested data is fetched and send back to the WbEHR.

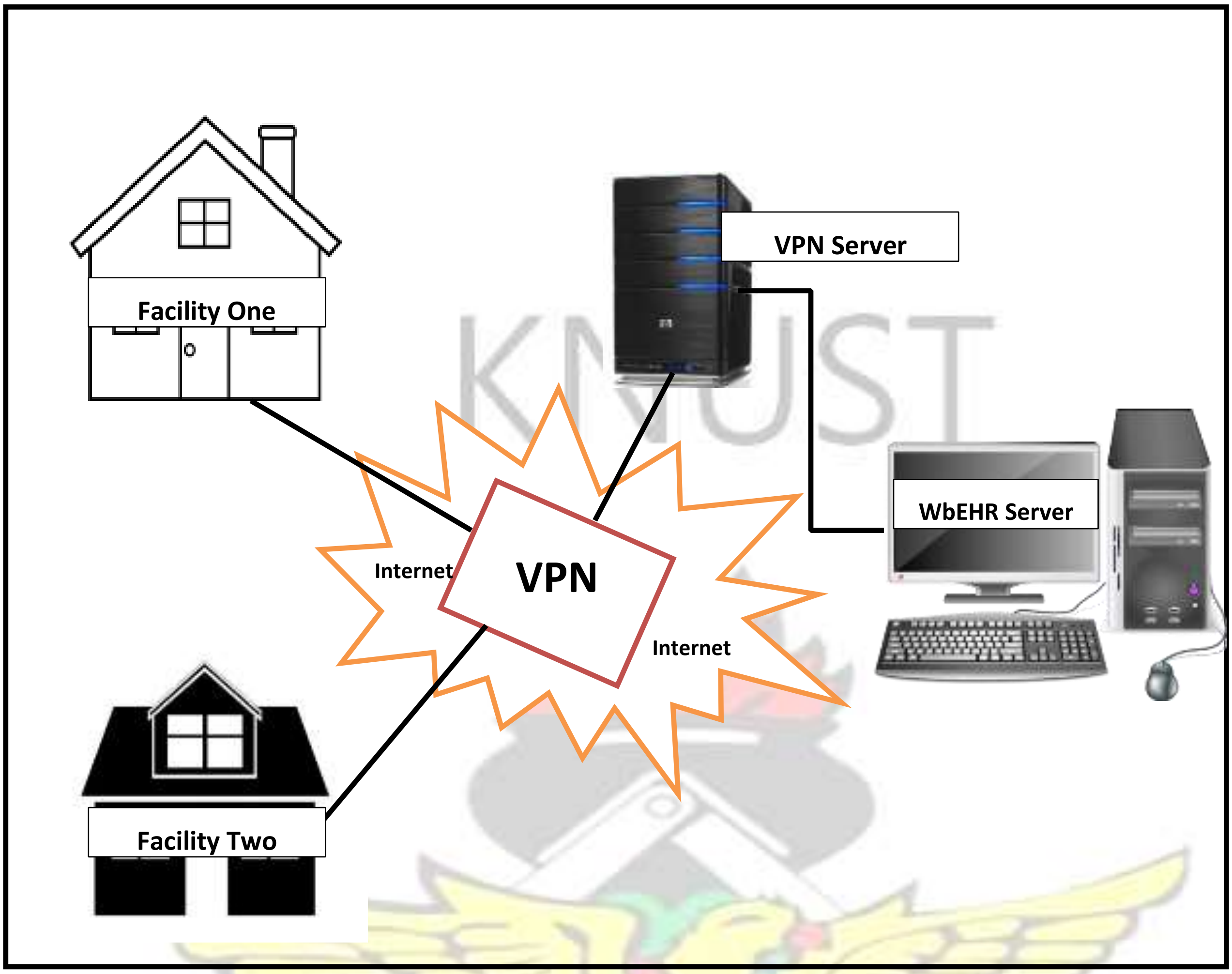


Figure 3.4: Network Architecture for WbEHR

Figure 3.4 above shows the network setup between the WbEHR and the other health facilities. The connection between the other health facilities and the WbEHR is done within the internet but through a Virtual Private Network. A Virtual Private Network (VPN) is a computer network technology that creates a secure a network connection over a public network such as the Internet. VPN technology enables remote users to securely connect to a private network.

A VPN can connect multiple sites over a large distance just like a Wide Area Network (WAN). VPNs are often used to extend intranets worldwide to disseminate information and news to a wide user base. Educational institutions use VPNs to connect campuses that can be distributed across the country or around the world. A VPN was used as part of the framework because it provides a secured, cheaper, and a more reliable connection between the various health facilities and the WbEHR. All connections routes through the VPN server to and from the WbEHR.

3.2 Search Algorithm

Binary search was used as the search algorithm for the framework. This is because it is much faster than a linear search. The best, a worse and average case scenario has proven to be the best compared with other search algorithms (Barnett and Tongo 2008, Dalal 2004). The idea behind binary search is that each time a comparison is made; half of the list is eliminated, until the search term is found or it is determined that the term is not on the list. This is done by looking at the middle item in the list, and determining if the search term is higher or lower than the middle item. If it’s lower, the upper half of the list is eliminated and the search is repeated starting at the point halfway between the first item and the middle item. If it’s higher, the lover half of the list and eliminated and the search is repeated starting at the point halfway between the middle item and the last item. This reduces the number of comparisons that is used for the search. The algorithm is shown below:

set first = 1, last = N, mid = N/2 ***while***

(item not found and first < last) {

compare search term to item at mid if

match

save index break else if search term is less

than item at mid, set last = mid-1 else set

first = mid+1 set mid = (first+last)/2

} return index of matching item, or -1 if not found

The algorithm was used in the adaptor to make the queries on the patient being searched for. Each database connected to the WbEHR was queried and the result was displayed.

3.3 Modules of the Framework

The Framework has been broken down into 5 modules which perform different operations. Figure3.5 shows the structure of all the modules in the framework.

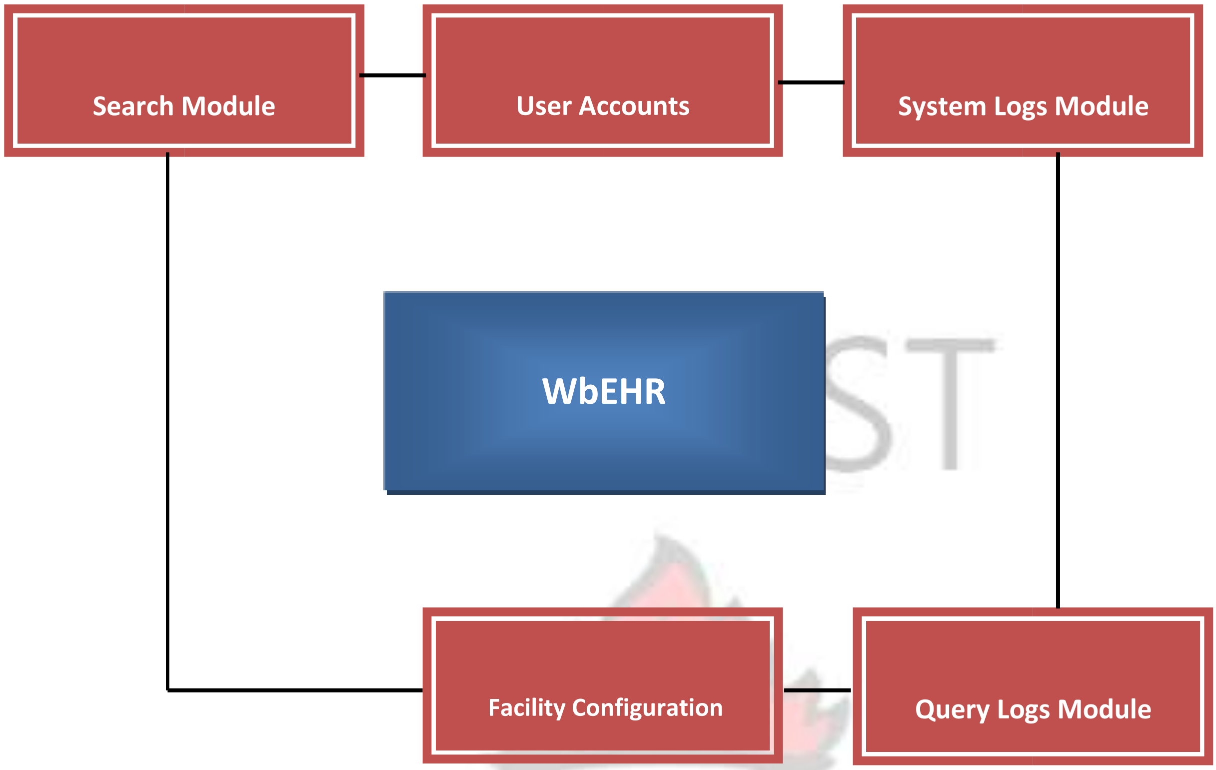


Figure 3.5: Various module of the Framework

Search Module

The search module allows Primary Healthcare Professionals to make search on the system with regards to a particular patient. The search is done by using a finger print scanner to scan a finger of a patient. This uniquely identifies the patient on the system. In addition, queries could also be made on a patient via NHIS ID card or a National ID card. However, it is recommended that the search should be done by using a fingerprint scanner.

User Accounts Module

The User Accounts Module allows users to be registered on the platform, blocked, change password and change account type from healthcare provider to administrator. The administrator of the system has the sole responsibility of performing these actions.

Facility configuration module

This is the module where all information from the other health facility is provided for connection to be made to the framework. The information provided includes the facility's name, facility ID, database name, database type, username, password, and the URL that connects to the database.

System Logs Module

This module keeps track of all events that take place on the system. It shows the time a user logs in, the activities the user performed on the system, the location of the user upon using the system, the IP address of the computer used to access the system and the time the user signed out of the system. The purpose of this module is to properly secure the system for auditing purposes. This allows for proper auditing when the need arises, hence guarding patients' records and protecting the users as well

Query Logs module

The module saves all the queries and searches about a patient made on the system from the other facilities. The saved searches allow for time saving and efforts in searching for records which has already been searched for over a period of time.

3.4 Users

The framework is made up of two (2) main categories of users. These are:

a. Administrator

b. Primary Healthcare Provider (PHCP)

Administrator

The administrator has the privilege of connecting the WbEHR to all health facilities, creatinguseraccounts for the Primary Healthcare Providers (PHCP), changing their passwords and disabling user accounts. In addition, the administrator also has the privilege of querying for a patient's data from the other health facilities.

Primary Healthcare Provider (PHCP)

The PHCP are basically the General Practitioners and nurses that a patient has the first interaction with during care giving in the health facility. The framework provides them with the privilege of searching for a patient within the other health facilities. The search or query is done by using a finger print scanner connected to the facility's computer to uniquely search for a patient's data.

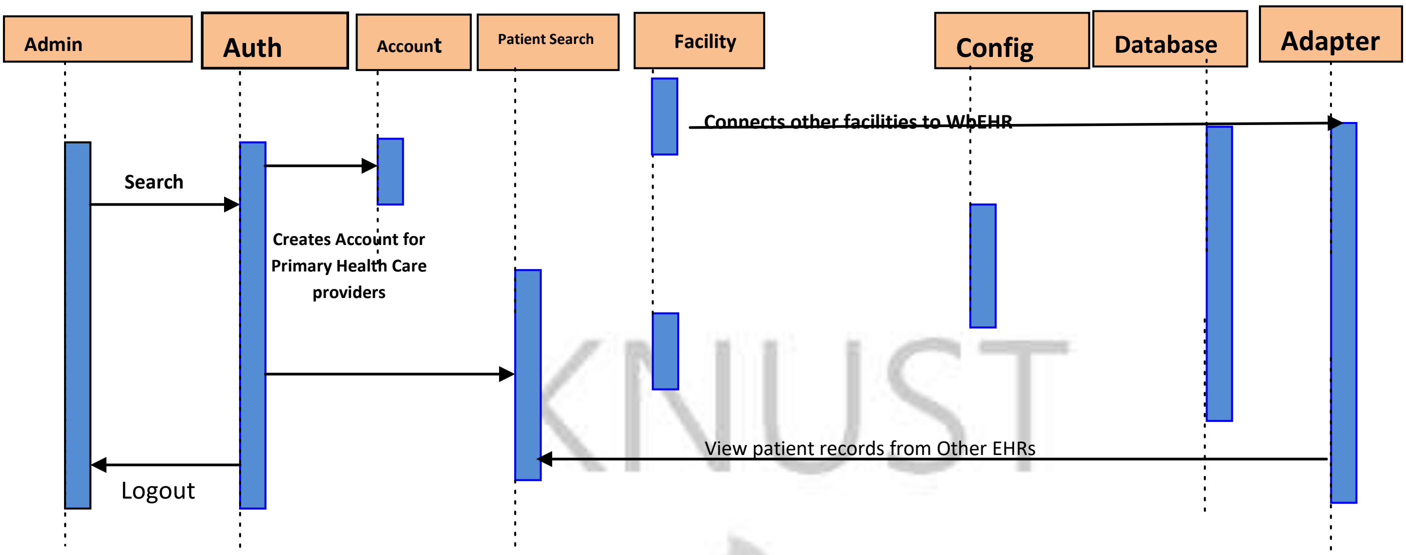


Figure 3.6: Sequence diagram of the administrator

Figure 3.6 shows the sequence diagram of how the administrator uses the system. When the administrator logs into the system and is being successfully verified, he or she has the responsibility of configuring and connecting the other health facilities to the WbEHR using the appropriate credentials such as the facility name, id, database URL or IP address, username, password and database type. In addition, the administrator also has the responsibility of creating user accounts for new administrators or for Primary Healthcare Providers (PHCP). Finally, from Figure 9, the administrator also has the responsibility of searching or querying the system for a patients' data within the other health facility that has been connected successfully to the WbEHR.

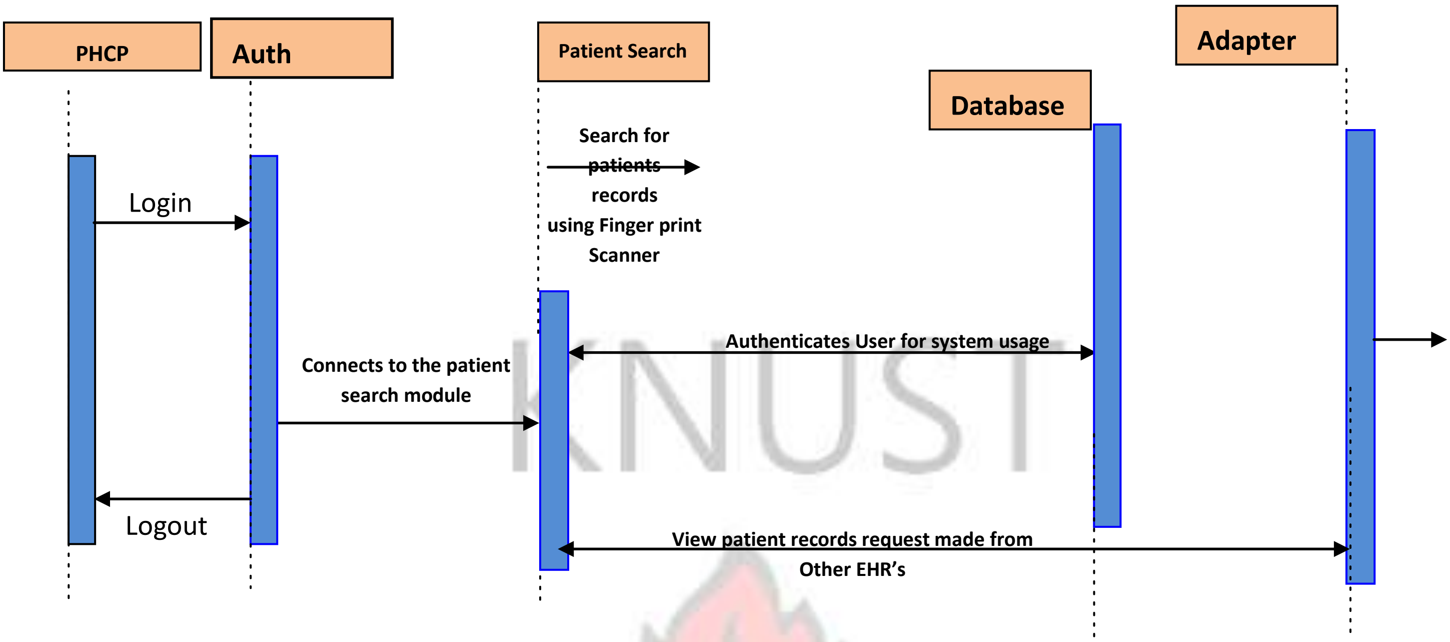


Figure 3.7: Sequence Diagram for Primary Healthcare Provider Figure 3.7 is a sequence diagram for the Primary Healthcare Providers (PHCP) on the system. The PHCP have the responsibility of searching for a patient's records in other health facilities within the WbEHR framework. Since the PHCP are the first point of call for patients to seek healthcare, it is very appropriate for them to use the search functionality on the framework more often. Figure 3.8 below shows the series of action the administrator undertakes within the use case diagram

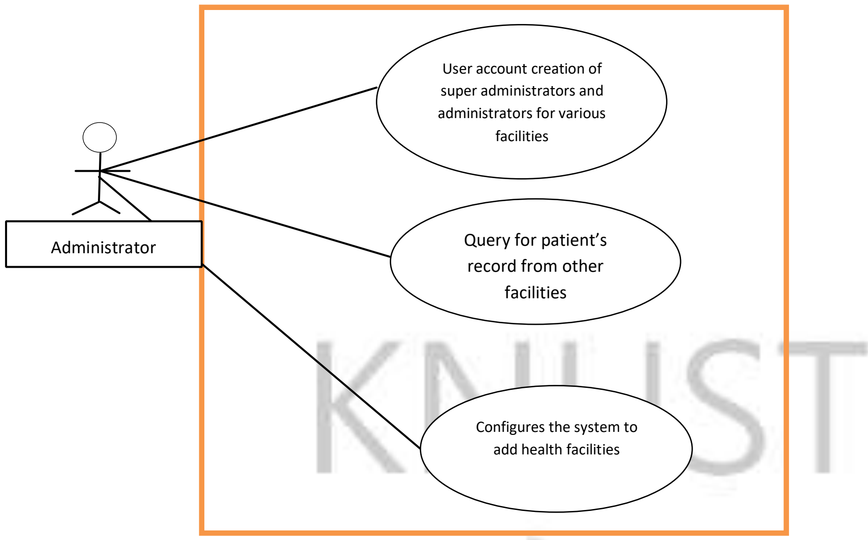


Figure 3.8: Use case Diagram for Administrator

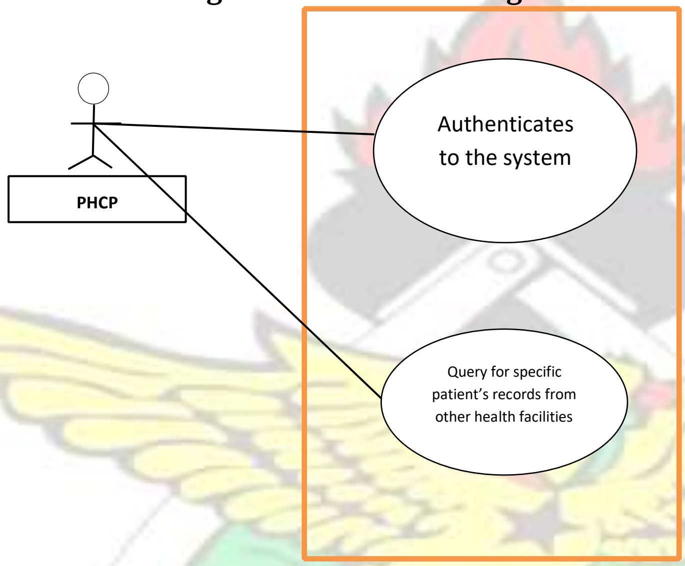


Figure 3.9: Use case Diagram for PHCP

Figure 3.9shows the series of action the PHCP undertakes within the use case diagram in the framework.

CHAPTER FOUR

IMPLEMENTATION AND RESULTS

4.0 Introduction

The aim of this study is to propose a framework that allows for interoperability of Electronic Health Record Systems in Ghana. This chapter provides information on the implementation of the framework design and results of the simulation and virtualization test conducted. In chapter three (3), there was a description of the concepts, models and architecture for the proposed (WbEHR) framework for interoperability.

For the purpose of simulation and virtualization, a prototype of the framework was developed using web development tools such as HTML, CSS, PHP, JavaScript and MySQL. The simulation test was conducted to take into consideration the performance of the system and how the system would interconnect with the other EHRs in the real world and to observe the amount of time it would take to output results when a patient is being searched for under a number of conditions. In the simulation test, three different scenarios were used. The first, second and third scenarios involved 2 EHRs, 5 EHRs and 20 EHRs respectively. Each of the scenarios had the following test parameters:

a. Connectivity Test
b. Database query response time for all systems online
c. Database query response time with some of the systems offline
d. Database query response time with patient not registered in any of the EHRs

4.1 Development of the WbEHR

For simulation purposes, the WbEHRframework was developed with laravel PHP framework, HTML, CSS, MySQL and JavaScript. Laravel was used as the backend server side script due to its flexibility, strong provision of security, faster integration with external web applications, simplification of authentication and authorization, fixation of most of the common technical vulnerabilities described by OWASP, making exception handling easy, separation of business logic from presentation and easy handling of message queue (Brazier, 2017). MySQL was used as the relational database management system to store all the data that would be used by the system. HTML,CSS and JavaScript were used at the client side for the user interface design and user validation. The WbEHR was designed to run inside a web browser in order to easily make it accessible to the other health facilities.

4.1.1 Database Design

The database was designed with four (4) different tables which would enable the efficiency and the effectiveness of the system. The tables include:

a. Users Table

The users table keeps data about the users of the system including their names, passwords, role, activation or non-activation and other relevant data about the user.

b. Facility Configuration Table

The facility configuration table contains data about the all facilities that are connected to the WbEHR system. It is with this information that the adapter uses to connect to the databases of the other EHRs in the other facilities. It contains the name and id of the facility; database URL or IP address, database username, password, mapped tables and columns based on the key requirement of the WbEHR framework.

c. Query Log Table

The Query Log Table keeps the data of all searches of patients made on the system. It contains data on the user who made query, the time the query or search was made, ip address of the machine used and an excerpt of the query made. This is to enable the users to verify the searches that have been done by them in order to make reference to. It also keeps track of the person who made the queries.

d. System Log Table

The System Log table keeps records of data about all activities that goes on in the system. This provides some form of security with regards to all activities by the users of the system. Table 5shows the details of System Logs table.

4.1.2 Interface Design

The system is made up simple and user friendly Graphical User interface (GUI) which is web based; hence the user interface was designed with HTML and CSS. JavaScript was used for user validation. The system is runs using a web browser such as Mozilla Firefox, Google Chrome and Internet Explorer.

4.1.2.1 Login Interface

This interface is the first point of call for all users of the application. This is where users enter their usernames and passwords in order to have access to the System. The role of the user will determine the menus he or she could view after logging into the system. Figure 4.1shows the login interface.

Figure 4.1: Login Interface for the WbEHR

4.1.2.2Main Dashboard Interface

The main dashboard interface is the next interface after login. This interface provides the user with the relevant menus to be used depending on the role or function of the user. For example, if the user is an administrator, he or she has access to all menus on the system. If the user is however a Primary HealthCare Provider (PHCP) such as a nurse or a doctor, he or she also has the relevant menus to their roles. Figure 4.2 shows the dashboard interface.

Figure Error! No text of specified style in document.**Figure 4.2: Dashboard Interface for the WbEHR.1: Dashboard interface for**

4.1.2.3 Patient Search Interface

This would be the most frequent interface used by users. It is the interface that provides the means of allowing users to search for health records of specific patient within different health facilities. Figure 4.3 shows the patient search interface.

Figure 4.3: Patient Search Interface

Figure Error! No text of specified style in document.**.2: Patient Search Interface**

4.1.2.4 Health Facilities Integration Interface

This interface allows users to add new health facilities to the system in order for patients' records to be queried from them. Figure 4.4 shows the interface for the Health Facilities integration interface.

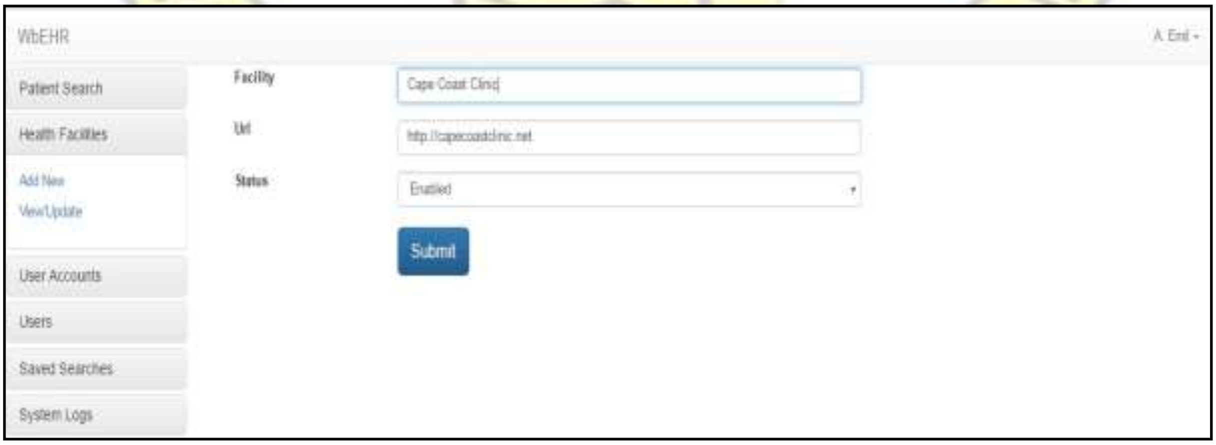


Figure Error! No text of specified style in document.**Figure 4.4: Health Facilities integration.3: Health facilities Interface Interface**

4.1.2.5 User Accounts Interface

The User Accounts Interface allows accounts to be created for users. The administrator is the only user who has access to this interface. Figure 4.5 shows the user accounts interface.

Figure 4.5: User Accounts Interface

4.2 Key requirements for Interoperability with the WbEHR

In order for any EHR system to interoperate with the WbEHR framework, the following key requirements should be met:

a. Each of the facility should have a biometric finger print scanner to take patient biometric data since this uniquely identifies the patient. In Ghana people are identified by NHIS Card, passport, voter ID card, drivers'license and SSNIT card. But not all Ghanaians have registered with some of these forms of identification. That is why the biometric finger print scanner would be more appropriate in uniquely identifying a patient. Secondly, it would also help to get information on patients even in times of emergency where no information would be provided on the patient.

b. Mapping of various tables in each of the EHR database to the adapter of the framework
c. Reliable Internet connectivity within the health facility

4.3 The Simulation test

The simulation test was conducted to verify that the WbEHR framework is feasible and interoperate with other EHRs based on the key requirements. The simulation test involves the simulation tools, design and performance test.

4.3.1 Simulation Tools

The following tools were used for the simulation test:

a. WbEHR System (The Proposed Framework being developed)
b. Oracle VM Virtual Box Version 5.16.1
c. OpenMRS and OpenEMR (Representing existing EHRs within the country)
d. HP Desktop Computer
e. OpenVPN

WbEHR System

Much has been discussed about this framework in this chapter. This system was developed as a web based application using HTML,CSS,MySQL and PHP. The system runs in any version of a web browser. This is the system that would be tested to find out if the interoperability works with the other EHRs within the healthfacility.

Oracle VM VirtualBox Version 5.16.1

Oracle VM VirtualBox is free and open sourcesoftware that is used for creating virtual computers on physical computers. It severs as a virtual computer that allows operating systems to be installed on it with hard disk and memory allocations for it. VirtualBox may be installed on a number of host operating systems, including: Linux, OS X, Windows, Solaris, andOpenSolaris. VirtualBox was used because it makes it easier to install multiple operating systems on one computer system. The version 5.16.1 is the most current released version.

OpenMRS

OpenMRS is a collaborative open source project to support the delivery of health care in developing countries. It actually started in Kenya. The system was Built on the MySQL database and written using the Java programming language. It also includes tools for data export and reporting and also Supports open standards for medical data exchange including HL7, Logical Observation Identifiers Names and Codes (LOINC).

Figure Error! No text of specified style in document.**Figure 4.6: User Interface of OpenMRS.4: User Interface of OpenMR (Adopted from: openmrs.org)**

Open EMR

OpenEMR is medical practice management software that highly supports Electronic Medical Records (EMR). It is ONC (Office of the National Coordinator for Health Information Technology, USA) Complete Ambulatory EHR certified and it features fully integrated electronic medical records, practice management for a medical practice, scheduling, and electronic billing. The server side is written in PHP programming language and uses MySQL as its database. OpenEMR is free and opensource software subject to the terms of the GNU General Public License (GPL). The software is subject to ongoing efforts of internationalization and localization in multiple languages, and there is free support available in various forums over the world (Aminpour et al., 2014).

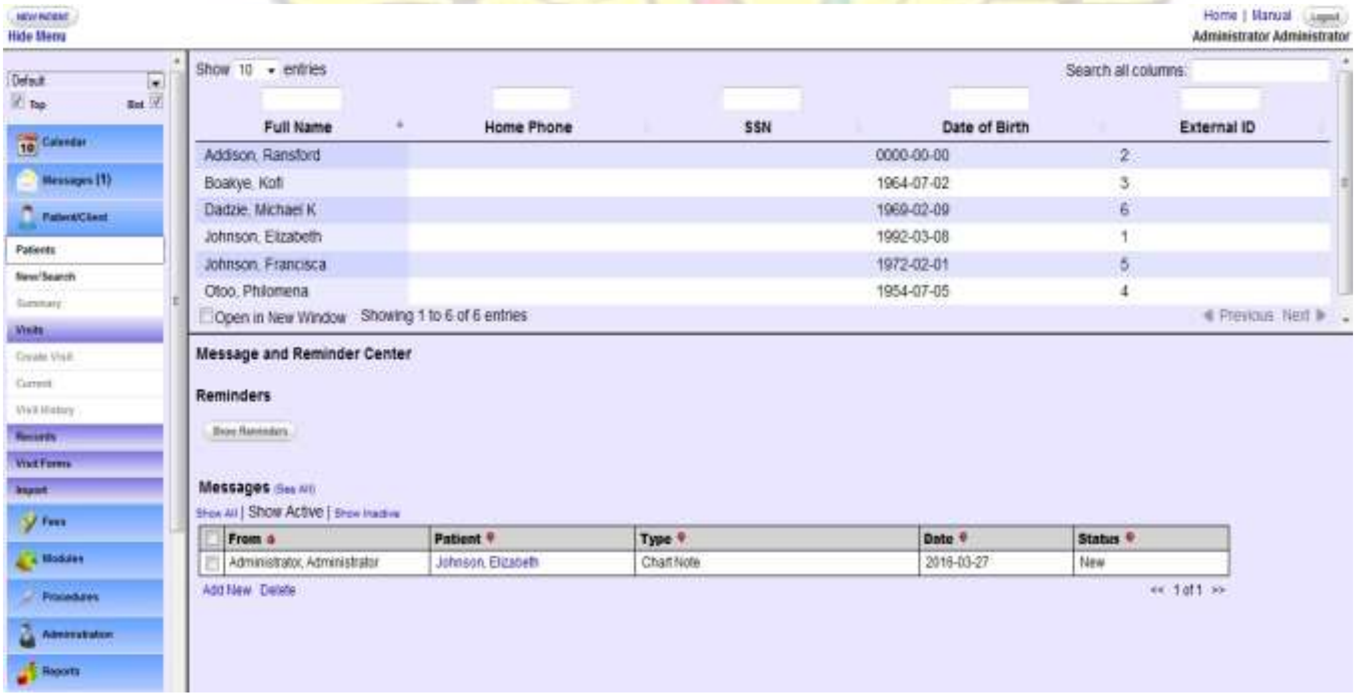


Figure 4.7: User Interface of OpenEMR (Adopted from: openemr.org)

In summary, these EHR systems were used because they are both open source, hence providing the means to modify the database and some parts of the code such as adding finger print scanner options during patient registration in order to suite the key requirement for interoperability as far as the framework is concerned.

HP desktop computer

The HP desktop computer was the computer available as at the time the simulation test was conducted. The computer had the following specifications:

a. Hard Disk Drive – 200GB
b. Random Access Memory (RAM) – 4GB
c. CPU Size –3.0GHZ
d. Operating System – Windows 8

OpenVPN

OpenVPN is an open source software application that implements virtual private network (VPN) techniques for creating secure point-to-point or site-to-site connections in routed or bridged configurations and remote access facilities. It uses a custom security protocol that utilizes SSL/TLS for key exchange. It is published under the GNU General Public License (GPL) (Titz and Olaf 2001). OpenVPN was used because it free and open source since there was financial constraints in buying VPN software.

4.3.2 Simulation Design

In this study, two EHRs were connected to the WbEHR via a VPN network in order to test for interoperability of patient records among these EHRs. These EHRs were OpenMRS and OpenEMR. In other for the objectives of this study to be achieved, the simulation was divided into two scenarios. The first scenario was that two (2) EHRs were used for the simulation test for interoperability. The second was that five (5) EHRs were used of the simulation test with three (3) copies of OpenMRS and two (2) copies of OpenEMR. These scenarios were simulated andresults were recorded accordingly. The performance of the interoperability test for all the EHRs used was based on the following parametersfor each scenario:

a. Connectivity
b. Database query response time for all systems online
c. Database query response time with some of the systems offline

4.3.3 Network Topology and Connections

Figure 4.8 and 4.9 shows the network topology and connections for the first and second scenarios which involves two (2) and five (5) EHRs respectively.The first scenario involves OpenMRSClinic 1 and OpenEMRClinic 1 whiles the second scenario involves Cape Coast Metro Hospital, Kwaprow Hospital, UCC Hospital, Amamoma Clinic and Adisadel Clinic, whichareallconnected to the WbEHR through a VPN network through a VPN Server (OpenVPN) on the internet. The VPN network allows a private, secure and an encrypted connection to be established within the internet (public network). This allows for cheaper, privacy and secured connection on the internet.

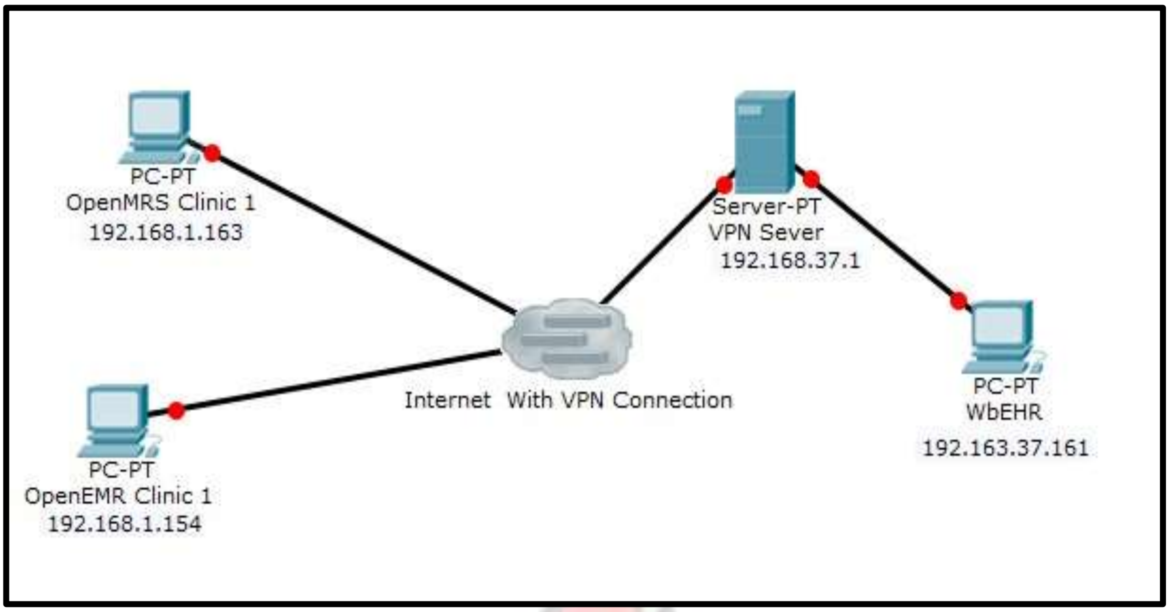


Figure 4.8: Network topology for First Scenarios of 2 EHRs

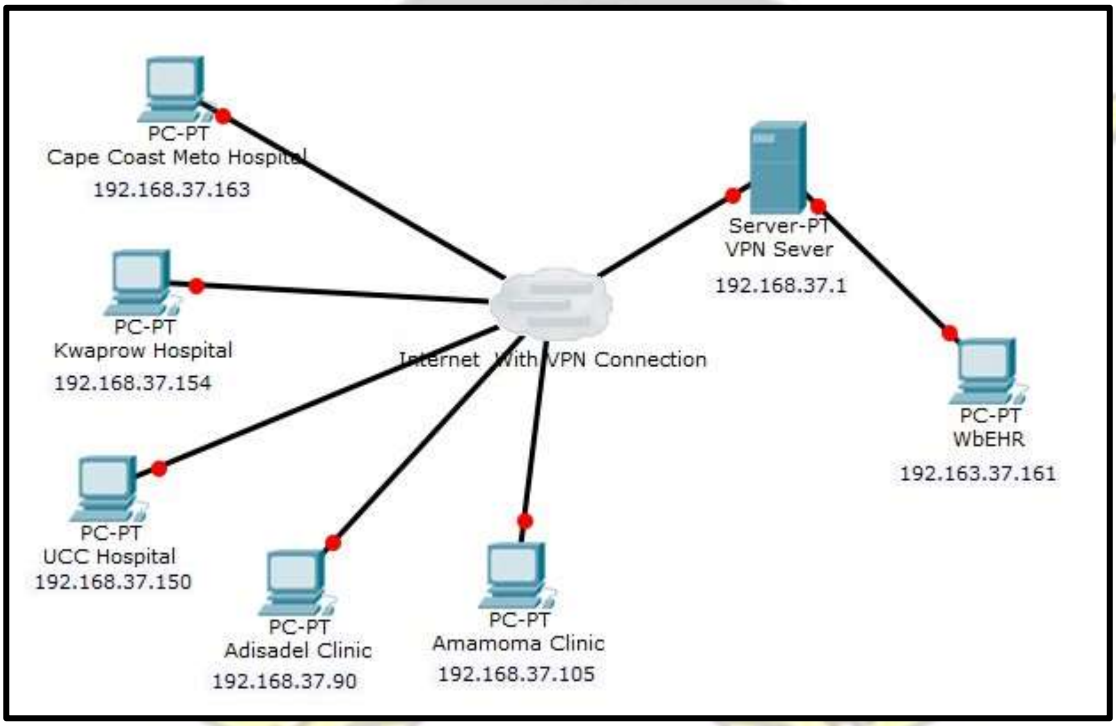


Figure 4.9: Network topology and connections for Second Scenario of 5 EHRs

4.3.4 Simulation Set Up and Configuration

In order to set up the simulation, the Oracle VM VirtualBox was installed on the HP

Desktop computer. Initially, three (3) different machines were created and Microsoft Windows 7 Operating system was installed on each of the machines. Packet tracer was used to simulate the network of the test. One of the machines was used to install the WbEHR and the OpenVPN server software. The other two machines had the OpenMRS and OpenEMR software installed on it. Figure 4.10 and 4.11 shows the installation of the virtual machines for the first and second scenarios. Figure 18 also shows the user interface of OpenMRS in the virtual box machine running inside the HP desktop computer.

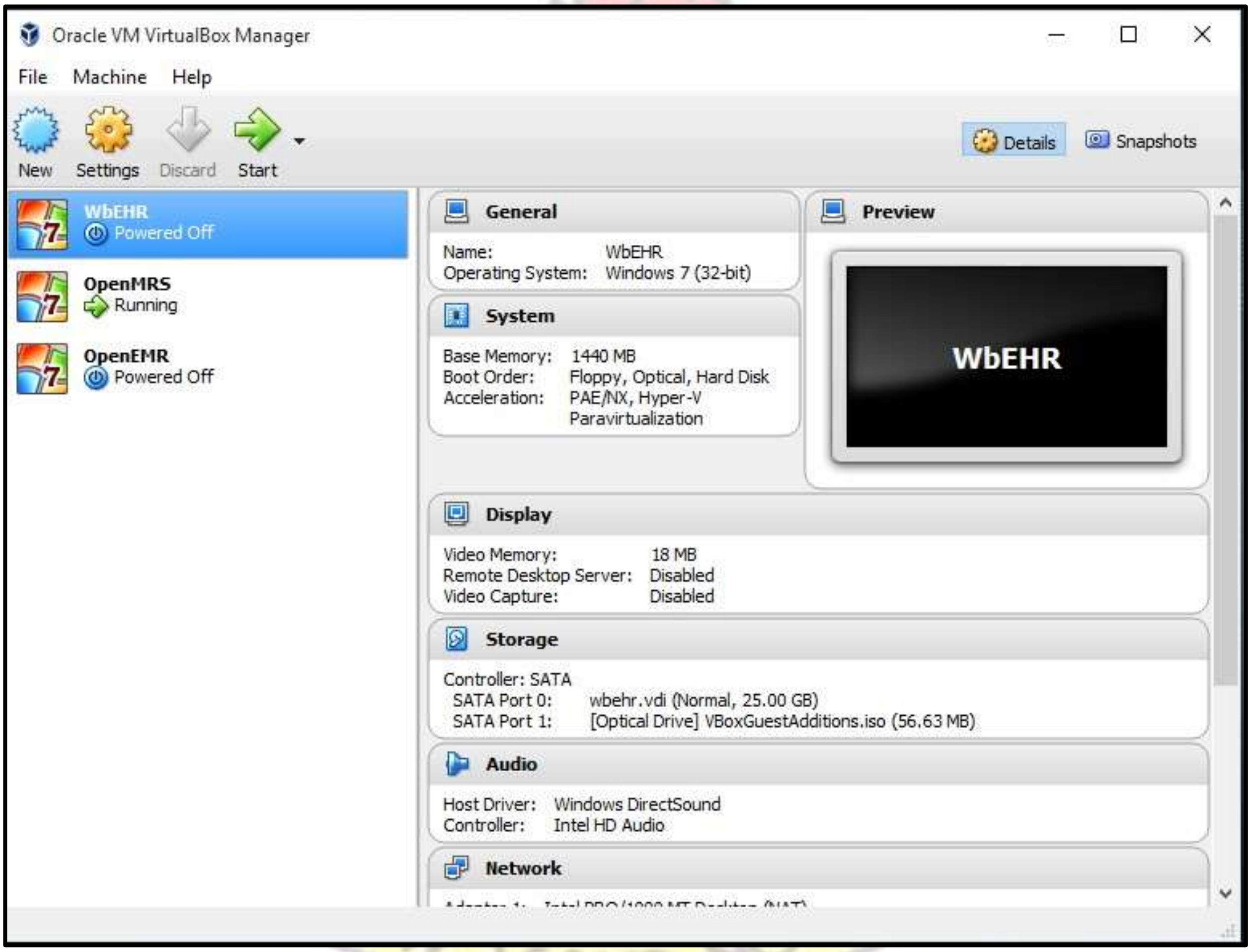


Figure Figure 4 Error!**.10: Ins**No text of specified style in document.**talled Virtual Machines with Windows 7 OS for first Scenario.5: Installed Virtual Machines**

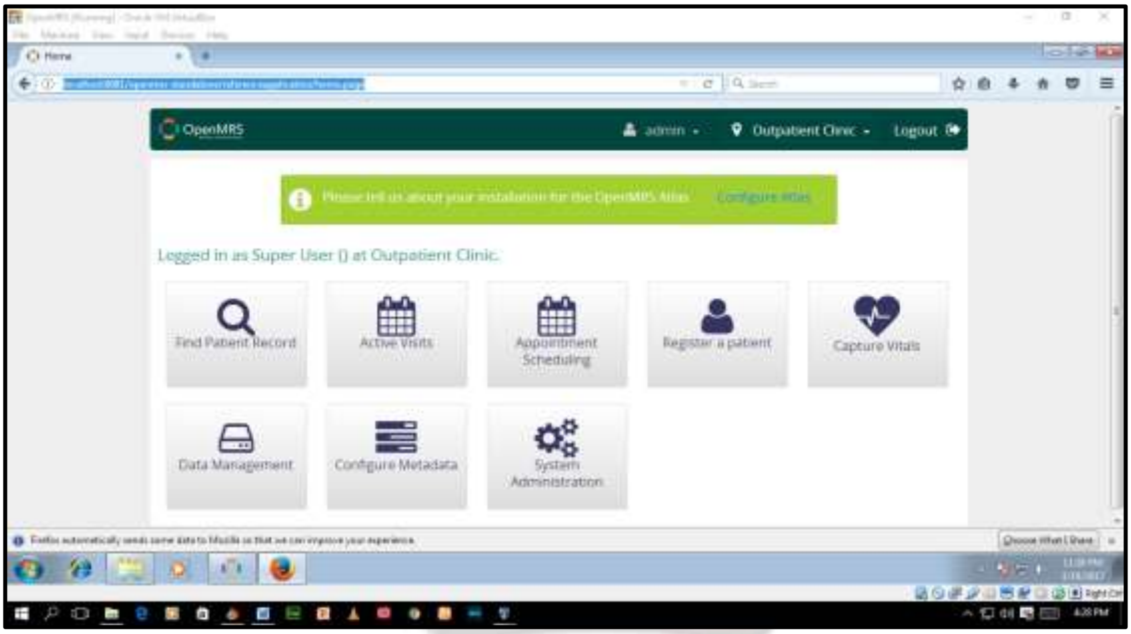


Figure Figure Error! No text of specified style in document.**4.11: Interface of OpenMRS in the Virtual Machine.6: Interface of OpenMR**

The second setup installation had six (6) virtual machines running on the virtual box for the second scenario of the simulation test. The setup involved five (5) EHRs in addition to the WbEHR. The initial installation and setup was however used for the first scenario which involved two (2) EHRs in addition to the WbEHR.

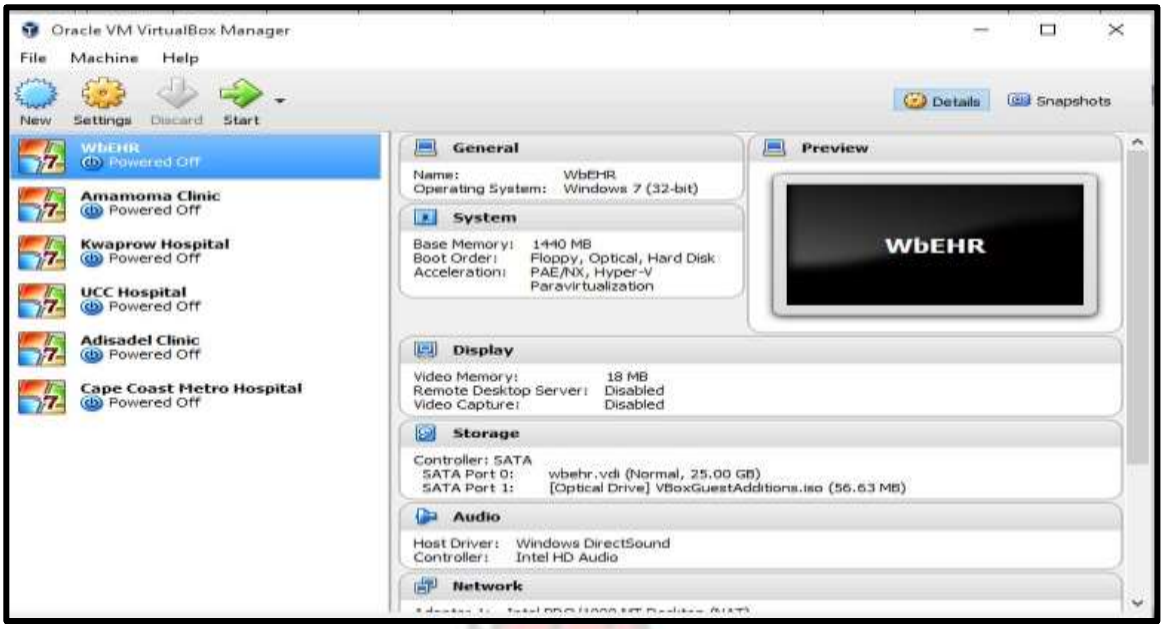


Figure 4.12: Installed virtual machine for second scenario

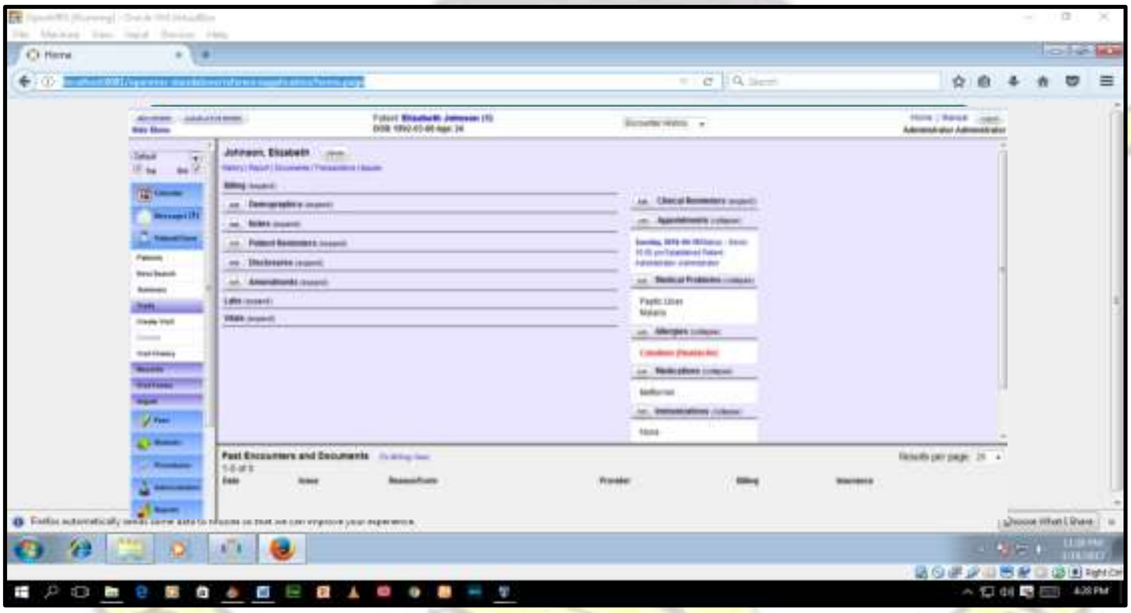


Figure 4.13: interface for OpenEMR in the virtual machine

The OpenVPN was installed on the same machine that the WbEHR system was installed. The OpenVPN was installed to setup the VPN network on the internet connectivity so that the other EHRs can route data through securely.

Figure 4.14 shows the installed OpenVPN on the WbEHR machine.

Figure Error! No text of sp**Figure 4**cified sty**.14: Inst**le in document.**alled OpenVPN.7: Installed OpenVPN**

IP addresses were given to each of the virtual machines and the OpenVPN. The following IP addresses were given:

a. WbEHR and VPN Server – 192.168.37.161

b. OpenEMR Clinic 1 – 192.168.37.154

c. OpenMRS Clinic 1- 192.168.37.163

4.4 First Scenario involving 2 EHRs

After the simulation had been setup and configured, the following test was conducted.

a. Connectivity Test

b. Database query response time for all systems online

c. Database query response time with some of the systems offline

d. Database query response time with patient not registered in any of the EHRs

4.4.1 Connectivity Test

After the IP addresses had been given, connectivity test was conducted on the WbEHR machine to ensure that there is communication from the WbEHR machine to the other connected machines through the VPN server. Connectivity test to the other machines was successful after pinging the IP addresses of the other machines in the command prompt.

As part of the connectivity, the WbEHR was connected to the OpenEMR and OpenMRS databases through the facility configuration interface of the WbEHR. Before the databases were connected to the WbEHR, the key requirements for interoperability were adhered to. During the connection of these two databases, the name of the facility, an optional facility ID, IP address or URL to the database, database username, password and the database type were provided on the facility configuration interface. In this case, the facility names used for the OpenMRS and OpenEMR were OpenMRS Clinic 1 and OpenEMR Clinic 1 respectively.

After these parameters were entered into the system,―Connect to Db‖ button was clicked to connect to the databases. After the button had been clicked, the system generates a ―Connection Successful‖ message prompt to inform the user that the connection has been successful. If the connection failed the system would generate ―Connection Failed‖ message prompt to the user. It should be noted that the use of the facility configuration interface of the WbEHR is always done by the administrator. Figure 4.15 shows the connection parameters being entered for the

OpenMRS Clinic 1 into the WbEHR system. In this case connections to both OpenMRS and OpenEMR databases were successful.

Figure 4.15: Database connection to OpenMRS from WbEHR

The next step after the connection to the database was the mapping of the various tables within the database(s) to the patient info, diagnosis, allergies and vitals on the system. The patient info, diagnosis, allergies and vitals are the information required by the WbEHR. Figure 4.16 shows the mapping of the various tables to the WbEHR. For instance, tbl_patientbio, tbl_diagnostics, tbl_vitals and tbl_allergies was tables mapped to the patient info data category in the WbEHR respectively.

Figure 4.16: Mapping of the DB tables to the data categories within the WbEHR

If the mapping of the various tables to the data categories in the WbEHR is successful then, the specific columns for each of the data categories are mapped to the WbEHR. In this case, the patient info for instance has specific columns that mapped to the first name, date of birth, other names and fingerprint of the WbEHR system. A similar action was taken for the diagnosis, allergies and vitals categories. Figure 4.17 shows the column mappings to the WbEHR.

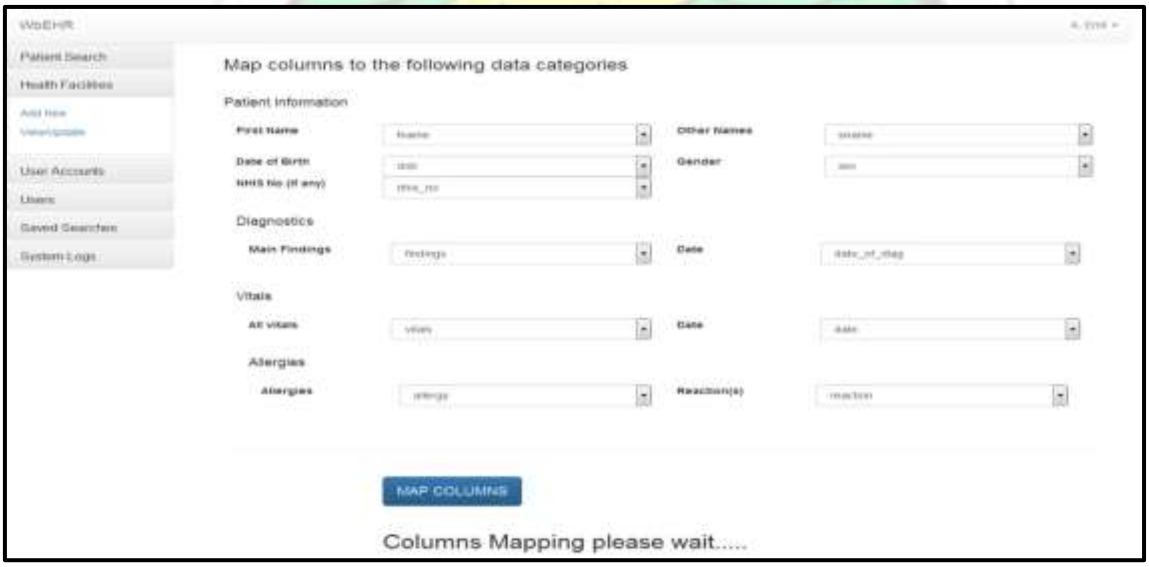


Figure 4.17: Column mappings from the data category tables to the WbEHR

The column mapping to the WbEHR completes the connection of the databases from the OpenMRS and OpenEMR to the WbEHR system.

4.4.2 Database query response time for all systems online

Both the OpenMRS Clinic 1 and OpenEMR Clinic 1 were populated with 100 patient records with the same data content. After they had been populated, a search was conducted on the WbEHR patient search interface to get the health record of a specific patient. One of the patient's fingers was placed on the finger print scanner to search for her records among the two EHRs connected to the WbEHR. It took the system 0.009 seconds to finally output the patient's health information on the WbEHR.

4.4.3 Database query response time for one of the system offline

In this case, the OpenMRS Clinic 1 was disconnected from the WbEHR in order to test the query response time with only one system connected to the WbEHR, thus the OpenEMR Clinic 1.The OpenEMR Clinic 1 had the same records as was used in 4.3.2. The same patient was searched for on the WbEHR using the finger print scanner. It took the system 0.008 seconds to finally output the patient's health information on the WbEHR.

4.4.4 Search response time with patient not registered in any of the EHRs

In this case, a patient who didn't have his records on any of the EHRs was queried from the WbEHR system. The output of the result was empty but the system however used 0.003 seconds to complete the search to output the result as ―No Records Found For this patient‖.

4.5 Second Scenario involving 5 EHRs

In this scenario 5 EHRs were connected to the WbEHR to be used for the simulation test. Two instances of the OpenEMR and three instances of the OpenMRS were used to represent these 5 EHRs. The names given to the facilities, IP address and EHR used are shown below.

1. UCC Hospital (OpenMRS) – 192.168.37.150
2. Cape Coast Metro Hospital (OpenEMR) –192.168.37.163
3. Kwaprow Hospital (OpenEMR) –192.168.37.154
4. Amamoma Clinic(OpenMRS) – 192.168.37.105
5. Adisadel Clinic (OpenMRS) –192.168.37.90

The following test was also conducted for this scenario.

a. Connectivity Test
b. Database query response time for all systems online
c. Database query response time with some of the systems offline
d. Database query response time with patient not registered in any of the EHRs

4.5.1 Connectivity Test

Connectivity test to all the EHRs from the WbEHR was successful after pinging the IP addresses for each of the EHR in the command prompt. Figure 4.18 shows the result for the connectivity.

As part of the connectivity, the WbEHR was connected to each of the EHR representing the health facility. The database of each EHR was connected through the facility configuration interface of the WbEHR after following the key requirements for interoperability of WbEHR as done for the first scenarios with 2 EHRs. Connections for each of these EHRs were successful.

4.5.2 Database query response time for all systems online

Each of the 5 EHRs was populated with 100different patient records of the same data. A query search were conducted on the WbEHR patient search interface to get the health record of a specific patient. One of the patient's fingers was placed on the finger print scanner to search for her records among the 5 EHRs connected to the WbEHR just like it was done in the first scenario of 2 EHRs. It took the system 0.038 seconds to finally output the patient's health information on the WbEHR.

4.5.3 Database query response time for 2 of the system offline

Another test was conducted with 2 of the EHRs (Amamoma Clinic and UCC Hospital) being disconnected from the WbEHR. The same patient was searched for on the WbEHR using the finger print scanner. It took the system 0.032 seconds for the WbEHR to output the search result.

4.5.4 Database query response time for 1 of the system offline

A final test was conducted with one of the EHR (Cape Coast Metro Hospital) disconnected from the WbEHR. The same patient was searched for on the WbEHR using the finger print scanner. It took the system 0.036 seconds for the WbEHR to output the search result.

4.5.5 Database query response time with patient not registered in any of the EHRs

A test was conducted on the WbEHR. In this test, a patient who had not registered on any of the EHRs was searched for using the same search procedure. The output of the result was empty but the system however used 0.009 seconds to complete the search to output the result as ―No Records Found For this patient‖.

4.6 Third Scenario Involving 20 EHRs

In this scenario 20 EHRs were connected to the WbEHR to be used for the simulation test. 10 instances of the OpenEMR and 10 instances of the OpenMRS were used to represent these 20 EHRs. IP addresses and facility names were given to each of EHR just like it was done for the second scenario. The same test parameters used in the previous 2 scenarios was used in this scenario. The following are the test conducted.

a. Connectivity Test
b. Database query response time for all systems online
c. Database query response time with some of the systems offline
d. Database query response time with patient not registered in any of the EHRs

4.6.1 Connectivity Test

Connectivity test to all the 20 EHRs from the WbEHR was successful after pinging the IP addresses for each of the EHR in the command prompt. As part of the connectivity, each of the EHR was connected to the WbEHR by following the same procedure for the previous scenarios mentioned in this chapter. All database connections to the WbEHR were successful.

4.6.2 Database query response time for all systems online

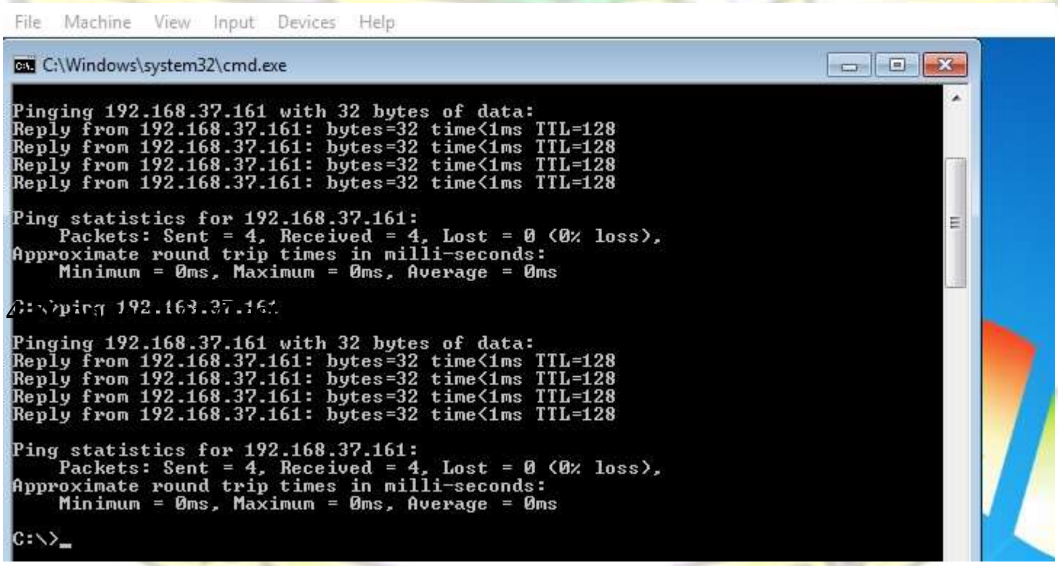
Each of the 20 EHRs was populated with 100 different patient records of the same data. A query search was conducted on the WbEHR patient search interface to get the health record of a specific patient. One of the patient's fingers was placed on the finger print scanner to search for her records among the 20 EHRs connected to the WbEHR just like it was done in the other scenarios. It took the system 0.096 seconds to finally output the patient's health information on the WbEHR.

4.6.3 Database query response time for 10 of the system offline

Another test was conducted with 10 of the EHRs disconnected from the WbEHR. The same patient was searched for on the WbEHR using the finger print scanner. It took the system 0.048 seconds for the WbEHR to output the search result.

4.6.4 Database query response time with patient not registered in any of the EHRs

A final test was conducted on the WbEHR. In this test, a patient who had not registered on any of the 20 EHRs was searched for using the same search procedure. The output of the result was empty but the system however used 0.014 seconds to complete the search to output the result as —No Records Found For this patient‖.



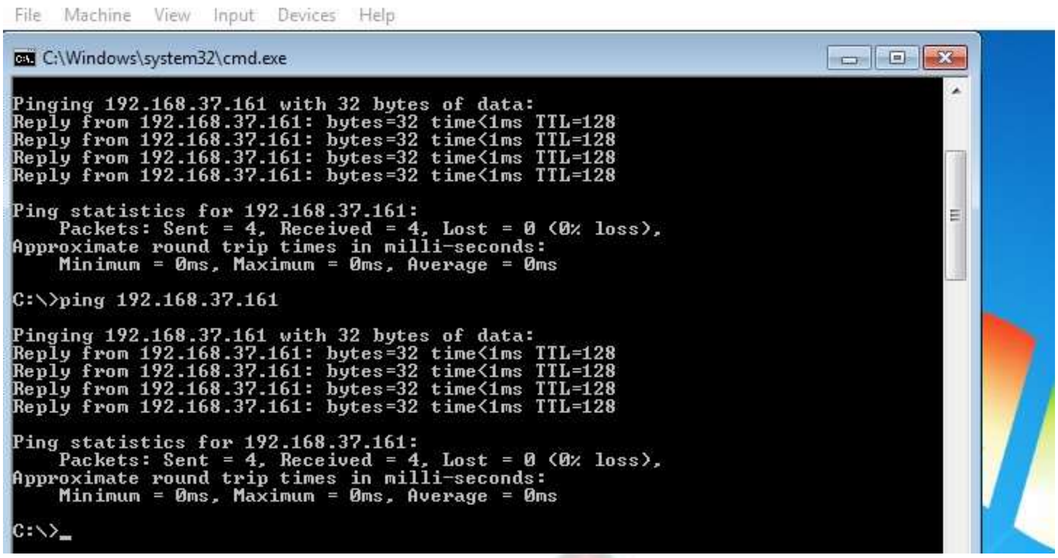


Figure 4.18: Output of the connectivity test

In order for interoperability to take place with the framework, the key requirements mentioned in the previous chapter should be adhered to before any other action is taken. The key requirements are:

a. Each of the facility should have a biometric finger print scanner to take patient biometric data since this uniquely identifies the patient. In Ghana people are identified by NHIS Card, passport, voter ID card, drivers' license and SSNIT card. But not all Ghanaians have registered with some of these forms of identification. That is why the biometric finger print scanner would be more appropriate in uniquely identifying a patient. Secondly, it would also help to get information on patients even in times of emergency where no information would be provided on the patient.
b. Mapping of various tables in each of the EHR database to the adapter of the framework
c. Reliable Internet connectivity within the health facility

These key requirements cannot be over looked when working with this framework. The reason for these requirements is to ensure conformity and standardization between the EHRs and the WbEHR framework.

For connectivity between the WbEHR and the other EHRs in all scenarios, the network connection and database connectivity was successful. Much time was not required to configure the database of the other EHRs to connect with the WbEHR since the interoperability format had already been created. Because a VPN network was created within the internet, security of the system was assured between the host and the client computers. In addition to the VPN connection, firewall and other security mechanisms could be added to increase the security.

This signifies that as many EHRs are interconnected with the WbEHR, much time is not required to ensure interoperability with the framework. Figure 4.18 shows the output of the connectivity test for the first scenario.

4.8 Search Response time for First Scenario

Figure 4.19: Output for 2 EHRs connected

Figure 4.19 shows the output for all the 2 EHRs online when a patient was being searched for.

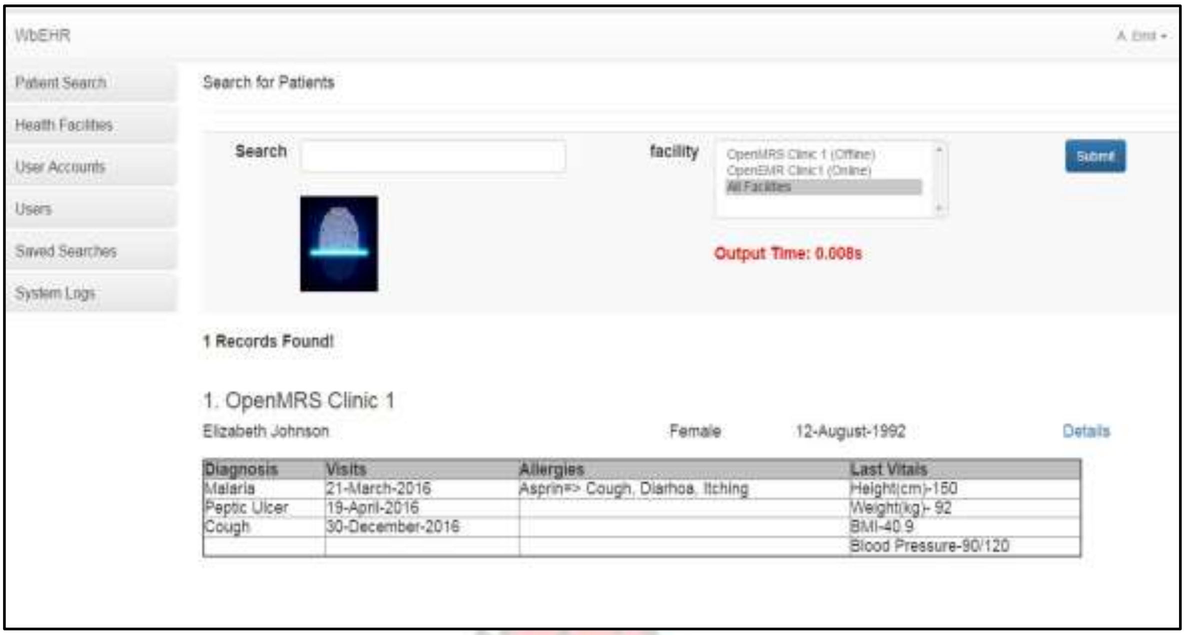


Figure 4.20: Output for only 1 EHR connected

Figure 4.20 shows the output for the system when only 1 EHR was connected to the WbEHR.

Figure 4.21: Search output for a patient without records in any of the EHRs

Figure 4.21 shows the search output for a patient who had no records in any of the EHRs being connected to the WbEHR.

Table 4.1. summary of results obtained in the simulation test for the first

Action	Time (seconds)

Database query response time for all systems online	**0.009**
Database query response time for one of the system offline	**0.008**
Database query response time with patient not registered in any of the EHRs	**0.003**

Table 4.1 shows the summary of results obtained in the simulation test for the first scenario involving 2 EHRs.

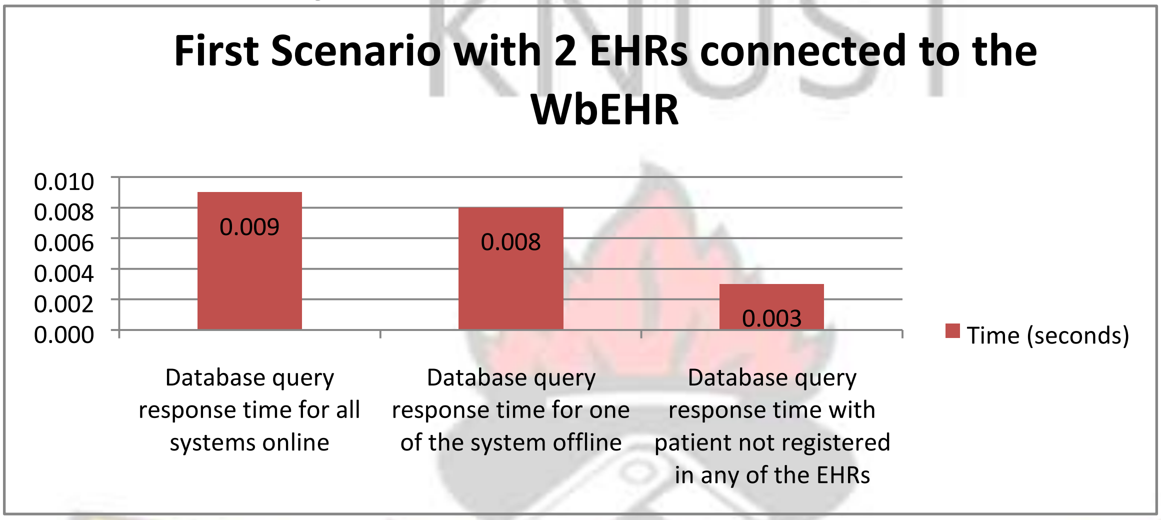


Figure 4.22: Search response time for first scenario

Figure 4.22 is a graph showing a search response time for the first scenario which involved 2 EHRs interconnected to the WbEHR system. From the graph, it is observed that it took 0.009 seconds, an equivalent of 9 milliseconds for the system to output the search results of a patient when all 2 EHRs were connected to the WbEHR. In the same graph, a second parameter which involved a search with one of the EHRs offline or disconnected from the WbEHR took 0.008 seconds for the search result to be displayed. The last parameter which involved a query not registered in any the EHRs took 0.003 seconds to display the result of ―No records found for this patient‖. This signifies the system search result increases with time as more EHRs are being connected to it. But in this case, the time would not be obvious for the user when the results are displayed after the search has been made. However, far less time was used when a patient without any information on any of these 2

EHRs was searched for.

4.9 Search response time for second scenario

Figure 4.23: Search output of 5 EHRs connected to the WbEHR

Figure 4.23 shows the search result of 5 EHRs connected to the WbEHR.

Figure 4.24: Search Results for 2 EHRs disconnected from the WbEHR

Figure 4.24 shows the search results for 3 EHRs connected to the WbEHR

Figure 4.25: Output result for 1 EHR disconnected from the WbEHR Figure

4.25 shows the output result for 4 EHRs connected to the WbEHR.

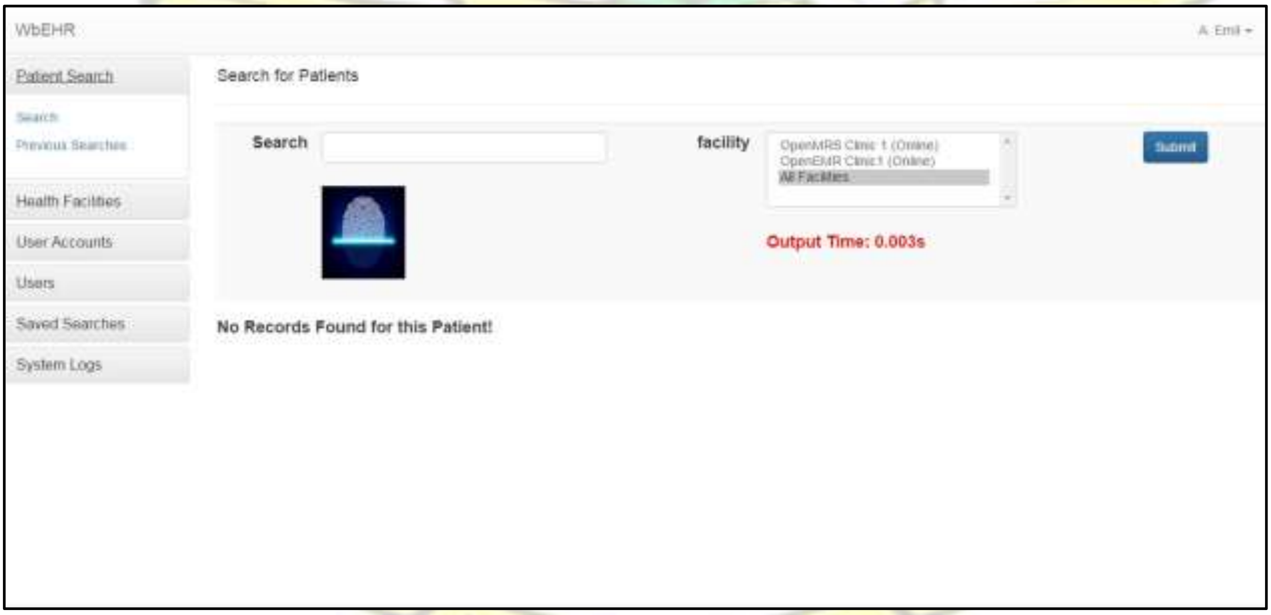


Figure 4.26: Output result for patient without records in any of the EHRs

Figure 4.26 shows the output result for patient without records in any of the EHRs.

Table 4.2: Results of output time in 2nd Scenario

Action	Time (seconds)
Database query response time for all systems online	**0.038**

Database query response time for two of the system offline	**0.032**
Database query response time for one of the system offline	**0.036**
Database query response time with patient not registered in any of the EHRs	**0.009**

Table 4.2 is showing the results for the output time for the 2nd scenario

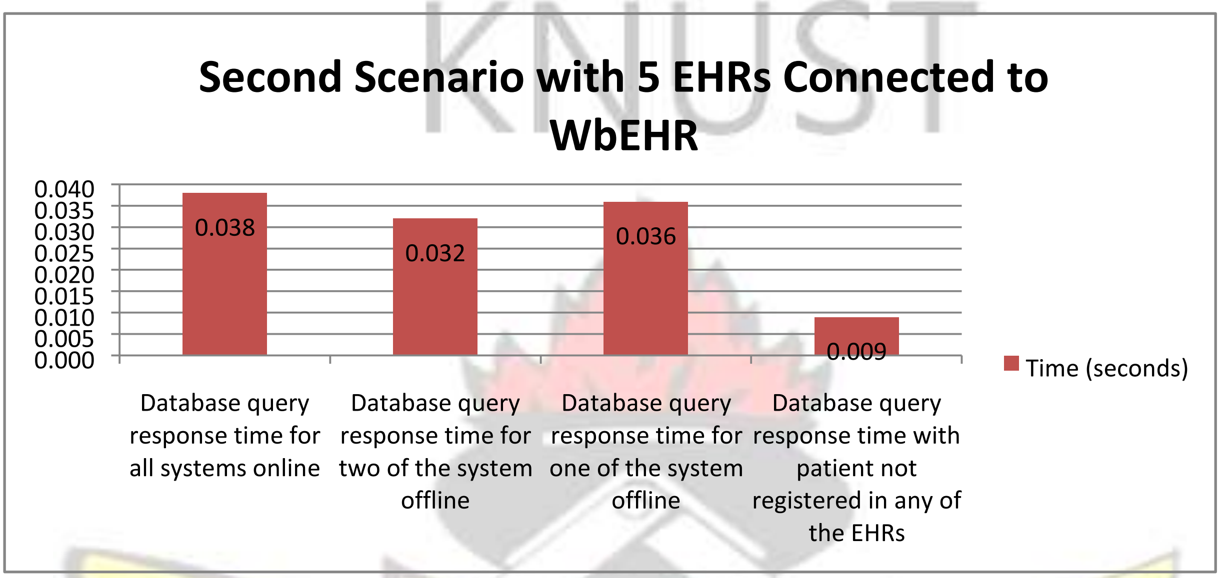


Figure 4.27: Response time for EHRs connected to the WbEHR

Figure 4.27 is a graph which shows the description of times for the second scenario which involved 5 EHRs. The graph illustrates that when a search was made with all the 5 EHRs connected, the system took 0.038 seconds to output the patient records. This is because the number of EHRs had increased in this scenario; therefore, more time was needed to query the databases to output the search results. As the number of EHRs was reduced it was observed that less time was needed to search for patient records within the database.Hence in the situation where, 2 EHRs were disconnected from the WbEHR, it took 0.032 seconds for the search results to be shown. But when an additional EHR was added, the time increased by 0.002 seconds for the search results to be seen. When a patient without any records in any of the EHRs was searched for, it took 0.009 seconds for the result output to be shown. Bearing in mind that each of the EHRs has 100 different records of patients.

4.10 Search Response Time for Third Scenario

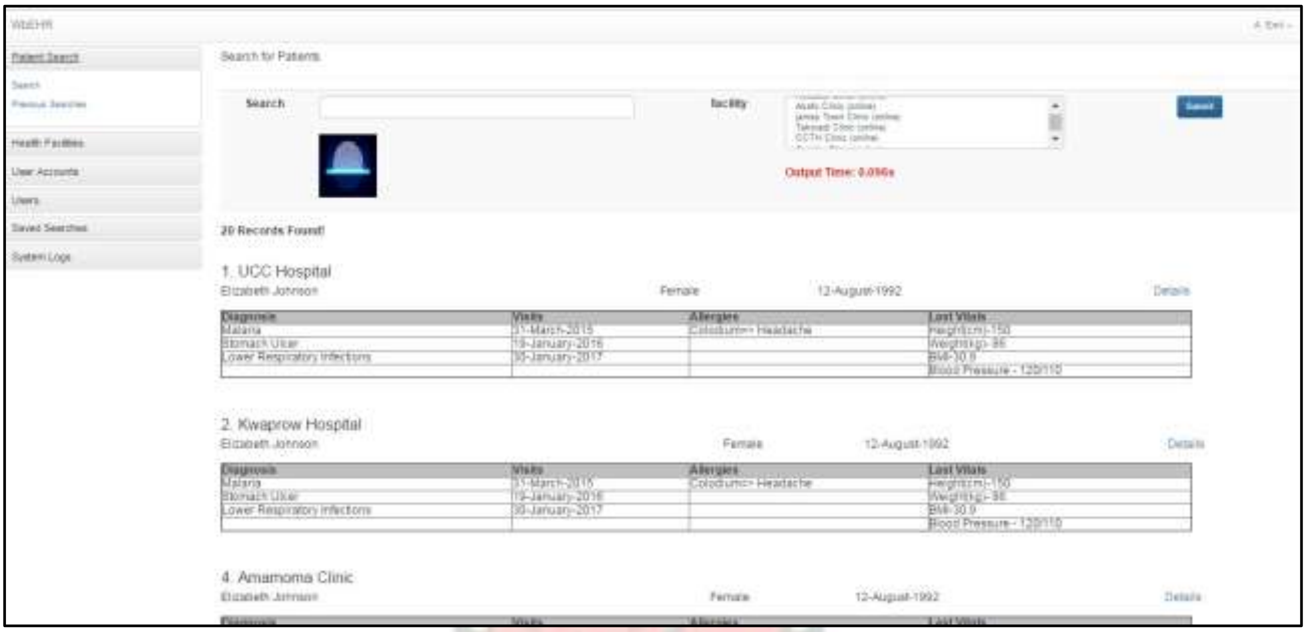


Figure 4.28: Output result for all 20 EHRs

Figure 4.28 shows the output results for all 20 EHRs connected to the WbEHR

Figure 4.29: Output result for 10 EHRs connected to WbEHR

Figure 4.29 show the output result for 10 EHRs connected to WbEHR

Figure 4.30: Output showing result of patient without records in the EHRs

Figure 4.30 is showing output result of patient without records in any of the EHRs

Table 4.3: Summary of results for response time of 3rd Scenario

Action	**Time (seconds)**
Database query response time for all systems online	**0.096**
Database query response time for one of the system offline	**0.044**
Database query response time with patient not registered in any of the EHRs	**0.014**

Table 4.3 is showing the results of all the output time in the third scenario of 20 EHRs connected to the WbEHR.

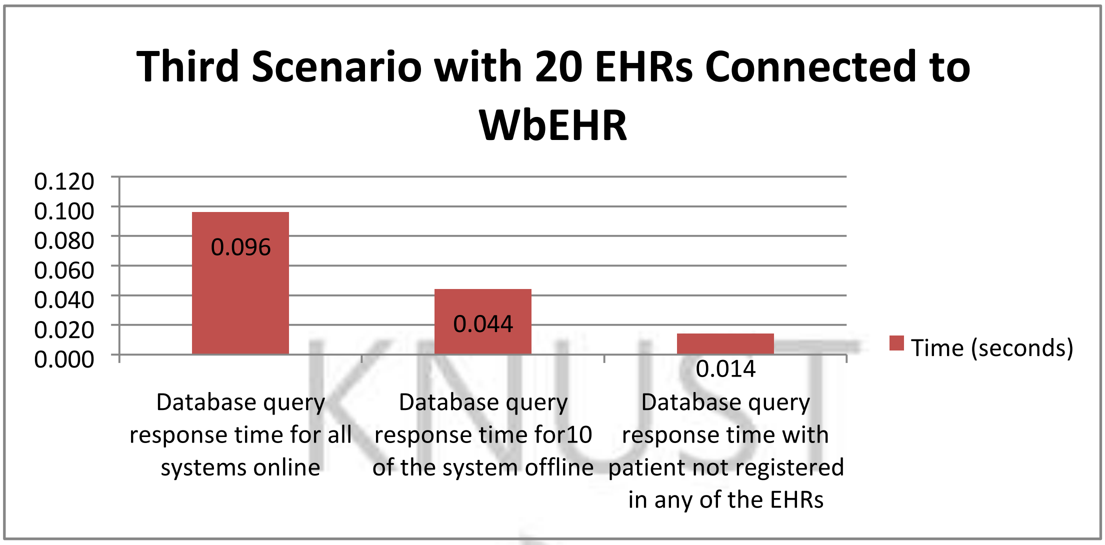


Figure 4.31: Search response time for 20 EHRs connected to the WbEHR

Figure 4.31 above is a graph representing the amount of time used in the 3rd scenario with 20 EHRs connected to the WbEHR with 100 records each. From the graph, it took the system 0.096 seconds to output the search result when a patient was searched for. It is observed from the graph that as the number of EHRs connected to the WbEHR was reduced by half; the system used 0.048 seconds to get the result of the patient. From the third graph, which represents a search of a user who had not registered on any of the EHRs, the system used 0.014 seconds to search for the patient. This implies that the system is very efficient and fast. This is because, even with 20 EHRs connected to the WbEHR with 100 records each, the output time for the search result is not even up to 1 second.

4.11 Comparative analysis of First, Second and Third Scenarios

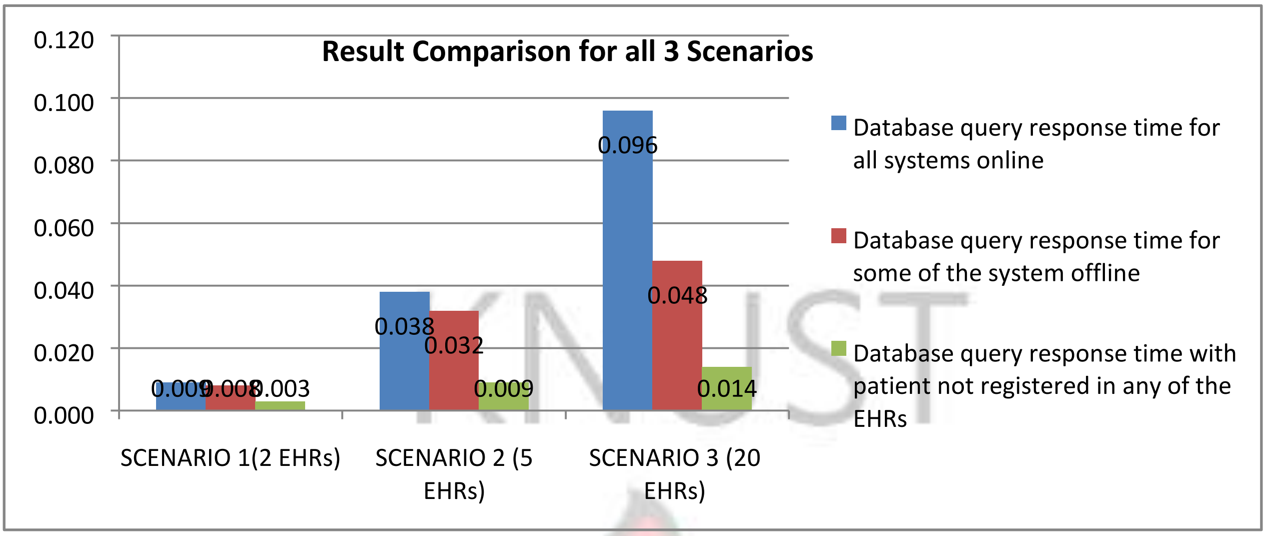


Figure 4.32: Search response time for all Scenarios

From all the test conducted using the simulation test, it can be identified from Figure 4.32 that, when more EHRs are connected to the WbEHR it takes more time to display the records of the patient being search for. However, even with 20 EHRs with 100 records each, the system did not use even up to 1 second to output the search result of a patient. There are several factors that contribute to efficiency of the query response time. These factors include memory, CPU size and speed of the network and the search algorithm used. The virtual machine hosting the WbEHR system has only 1GB of RAM allocated to it. This means that if the memory size is increased to 2GB of RAM or more, the search result time would be much impressive.

CHAPTER FIVE

CONCLUSION, FINDINGS AND RECOMMENDATIONS

5.0 Introduction

This chapter talks about research conclusions, findings and recommendations suitable to make this framework better, effective and more efficient. The objective of the research was to propose a framework that would facilitate the technical integration of

EHRs from different health facilities to allow for the exchange of health information in Ghana and to suggest standard guidelines that would allow for interoperability between EHRs using this framework.

5.1 Conclusion

This research work was purposed to propose a framework that would allow for interoperability of Electronic Health Records System in Ghana. To achieve this, the concepts, design, architecture, modules and description, of the framework was highly elaborated. Standard guidelines or key requirements for interoperability with the framework were highly emphasized. Based on the set objectives, the following conclusions were made.

The framework facilitated the integration of Electronic Health Record Systems from different health facilities for the exchange of health information. Since the framework is web based, it makes accessibility of the system easier in all the facilities that use the system. There is no need for special software to be installed in any of the client machines for the system to run. All what the clients need is the latest version of any web browsers such as Mozilla Firefox, Google chrome, Internet explorer and Safari.

More so, the suggested key requirements such as each health facility using a biometric fingerprint scanner to take a patient's biometric data, developers of EHRs for health facilities placing patients' bio it would become very easy for the EHRs to interoperate with the framework.

Finally, the framework used together with OpenMRS and OpenEMR for the simulation and virtualization test indicates that it does not require many resources to use this framework. With 1GB RAM and CPU of 3.0 as the server for the framework, an optimum performance should be expected ensuring patient search is very fast and requires less time. Hence during emergencies, patient's health information could be viewed faster.

5.2 Findings

In course of the research, it was found out that;

1. The WbEHR framework provides an easier way of interconnecting various EHRs regardless of the database management system used. This is because; the framework provides database drivers for most of the popular database management systems.
2. Health Care Providers (HCP) would be able to have comprehensive health information about their patients, since they have access to the health records in other health facilities.
3. Much training is not required for the usage of the system due to its simplicity and user friendliness.
4. Internet connectivity alone is enough for the EHRs to start connectivity with WbEHR. This makes connection easier and faster.
5. The key requirements provided by the framework for interoperability is simple enough to be adhered to without doing many changes to the existing EHRs.
6. The use of the fingerprint scanner to search for patient on the system provides a unique identity of patients. Hence, during emergency periods where the patient cannot even talk, the system would still be able to search for patient records. Additionally, much time is not wasted on searching for patient records.

7. Since the framework is web based, it makes accessibility of the system easier in all the facilities since it runs in a web browser. Hence, there is no need to install any special software on any of the client machines for the system to run. This saves cost, time and resources.

8. From the research findings and analysis, even with 20 EHRs connected to the system with 100 records each, it took a maximum of 0.096 seconds to generate the search result output. This means that the system is exceptionally fast since it searched through 2000 records and displayed the result in less than a second.

9. Considering the fact that the WbEHR system was allocated 1GB RAM was runned on a 3.0 GHz computer, the speed with which it worked would improve if installed on a higher specification computer.

10. The system is fast, efficient and reliable if and only if there is connectivity between the EHRs and the WbEHR.

11. Initial setup cost is quite expensive when it comes to purchasing the server, ensuring connectivity through the internet and ensuring constant supply of power. But the benefits are enormous.

5.3 Recommendations

The following recommendations were made:

1. Because the system is based on internet and electricity, the health facilities should have a backup internet and electricity so that if the main fails, they could fall on the backup for connectivity between their system and the WbEHR.

2. Provision should be made for a standby server for the WbEHR so that in case the main fails, the standby could be relied on.

3. Further works could also be done on this study with regards to generating trends in a patient's healthcare, families and an epidemic of diseases in specific facilities or areas.

4. Statistical modules could be added to the system to make it a research tool for studying patterns and trends in diseases and public health intervention for such diseases.

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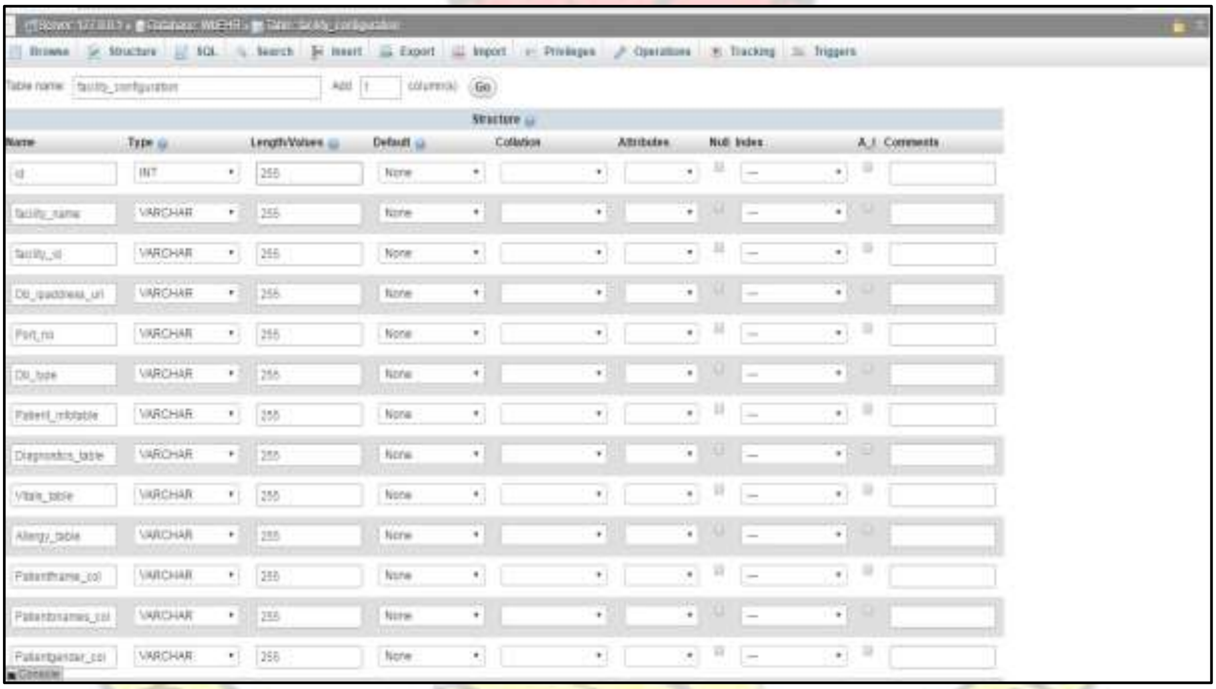
APPENDIX

Database Table for facility configuration



Laravel PHP Framework used for the development

```
<?php

/**
* Laravel - A PHP Framework For Web Artisans
```

```
 *
 * @package  Laravel
 * @author   Taylor Otwell<taylorotwell@gmail.com>
```

```
$uri = urldecode(
parse_url($_SERVER['REQUEST_URI'], PHP_URL_PATH)
);

// This file allows us to emulate Apache's "mod_rewrite" functionality from
the
// built-in PHP web server. This provides a convenient way to test a Laravel
// application without having installed a "real" web server software here.
if ($uri !== '/' and file_exists(__DIR__.'/public'.$uri)) {
return false;
}
require_once __DIR__.'/public/index.php';
```

Database Connection

```
'connections' => [

    'sqlite' => [
        'driver'   => 'sqlite',
        'database' =>storage_path('database.sqlite'),
        'prefix'   => '',
    ],

    'mysql' => [
        'driver'    => 'mysql',
        'host'      =>env('DB_HOST', 'localhost'),
```

```
    'database'  =>env('DB_DATABASE', 'WbEHR'),
    'username'  =>env('DB_USERNAME', 'root'),
    'password'  =>env('DB_PASSWORD', '*#passwbehrderiisı
    'charset'   => 'utf8',
    'collation' => 'utf8_unicode_ci',
    'prefix'    => '',
    'strict'    => false,
  ],

  'pgsql' => [
    'driver'   => 'pgsql',
    'host'     =>env('DB_HOST', 'localhost'),
    'database' =>env('DB_DATABASE', 'forge'),
    'username' =>env('DB_USERNAME', 'forge'),
    'password' =>env('DB_PASSWORD', ''),
    'charset'  => 'utf8',
    'prefix'   => '',
    'schema'   => 'public',
  ],

  'sqlsrv' => [
    'driver'   => 'sqlsrv',
    'host'     =>env('DB_HOST', 'localhost'),
    'database' =>env('DB_DATABASE', 'forge'),
    'username' =>env('DB_USERNAME', 'forge'),
```

'driver'   => 'sqlsrv',

```
        'host'      =>env('DB_HOST', 'localhost'),
        'database' =>env('DB_DATABASE', 'forge'),
        'username' =>env('DB_USERNAME', 'forge'),
        'password' =>env('DB_PASSWORD', "),
        'prefix'   => ",
    ],

],
```