Designing and developing a standard electronic healthcare system for the Telemedicine in Bangladesh.

[A research project report submitted to the Research and Extension Center of Jatiya Kabi Kazi Nazrul Islam University for the partial fulfillment of the research 2022-23]

জাতীয় কবি কাজী নজরুল ইসলাম বিশ্ববিদ্যালয়
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ত্রিশাল, ময়মনসিংহ

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DECLARATION

I declare that this research work is my own work and has not been submitted in any other form for another degree or diploma at any university of other institute of tertiary education. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given.

Signature and Date

Prof. Dr. Uzzal Kumar Prodhan

Dept. of Computer Science and Engineering

Dedicated to

My Respective Teachers

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ABSTRACT

Designing and developing a standard electronic healthcare system for the Telemedicine in Bangladesh is an innovation which helps to constitute an easiest and low-cost system for Electronic Health Record (EHR) for developing countries. The adoption of electronic health (e-Health) services in developing nations has been hindered by the interoperability issue with health data. Interoperability in healthcare systems is made possible by loosely linked distributed systems, which can also be utilized to design flexible architecture. The interoperability issue with health data is the main barrier to the adoption of electronic health (e-Health) services in developing nations. To address this challenge, this thesis proposes a convenient and low-cost distributed electronic health system for healthcare services in developing countries. The system is designed with a flexible architecture using loosely linked distributed systems, which enables interoperability in healthcare systems. The proposed system is based on health level 7 (HL7) compliant e-Health standards and utilizes distributed memory and heterogeneous data handling algorithms with loose coupling. The system is capable of storing data easily in less space and for an indefinite time. It can provide a summary report of a patient's clinical encounters throughout their lifetime, improve diagnosis accuracy and speed, and reduce unnecessary tests, thereby reducing costs. The open-source, secure PostgreSQL database is used to securely store health data in the server's database. Security threats are handled using HL7 standards, and regular backups of diverse health data are stored using the Message Passing Interface (MPI). Cronjob is used to make the backup operation automatic. Using loosely linked technologies, the distributed database has been made reachable from a remote server. Additionally, it offered e-Health data recovery tools and managed a sizable database in a remote setting. The study found that the established system is capable of successfully providing a low-cost service to the targeted group in a developing country.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The innovation of creating a Distributed Electronic Health System for healthcare services in developing countries aims to provide an affordable and convenient solution for Electronic Health Records (EHR) management. This system utilizes distributed computing, which refers to a network of interconnected components that function together to present a unified system to the user. The system is composed of separate equipment that is connected to form a cohesive unit. While desktop computers are commonly associated with this type of system, media tablets and mobile phones are also part of this technology[1].

A distributed system is a group of independently operating computing components that presents to its users as a single, seamless system. Two distinguishing characteristics of distributed systems are mentioned in this definition. The first is that a distributed system is made up of various computer components that can all act independently of one another. A computer element, or "node," can be either a piece of hardware or a running software program. Another factor is that users (whether they be individuals or software programs) think they are interacting with a single system. This implies that the autonomous nodes must cooperate in some capacity [2].

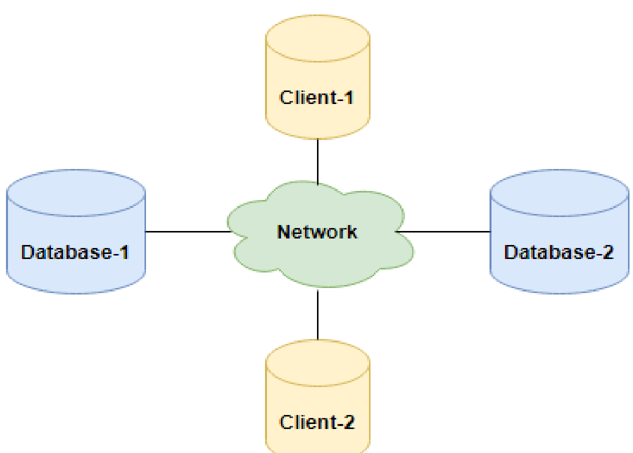


Figure 1.1: Distributed Database[2].

In above figure, there are two clients and databases are the server. All are connected each other over the communication network. Two servers, Database-01 and Database-02 also connect over the network to control the data consistency. If the client uses different operating systems, they will be able to distribute their information over network.

All organizations, institutions, and resources (components) dedicated to generating health actions are together referred to as a health system. A health system's primary objective is to safeguard and enhance the well being of the population in question. Along with patients, families, and communities, health ministries, healthcare organizations, pharmaceutical firms, health financing agencies, and other organizations play crucial roles in monitoring, the provision of healthcare services, finance, and resource management [3].

To rephrase the definition of health systems provided by the World Health Organization (WHO):

A health system, according to the WHO, refers to all the organizations, institutions, resources, and people involved in the delivery of health care services to meet the health needs of a given population. This includes health care providers, health facilities, financing mechanisms, information systems, and governance structures that work together to promote, maintain, and improve health outcomes. For instance, a mother tending to a sick kid at home, private providers, behavior modification programs, vector-control efforts, health insurance companies, and laws governing workplace health and safety are all included. It also entails cross-bencher action by health professionals, such as urging the ministry of education to support female education, a recognized factor in improved health [4].

To guarantee healthcare quality, accessibility, and cost in emerging nations, electronic health has immense promise. The creation of the nation's electronic health infrastructure has involved both the public and commercial sectors. For that, we must guarantee that Bangladeshi citizens, particularly those who live in rural areas, have access to adequate electronic healthcare facilities through a distributed electronic public health record system. So, Proposed distribute based system will make the electronic health record more flexible.

A distributed e-Health system is created to ensure remote monitoring of patients with chronic conditions and to enhance the responsiveness and quality of medical treatments. This study's major goal is to establish a distributed electronic health record (EHR) system that is simple and affordable for developing nations. It is designed to create healthcare systems that guarantee developing nations have access to high-quality, safe, cheap, and accessible healthcare services. It guarantees that patient records are readily available at all times and from any location. It is simple, takes up little room, and can be done forever to save data. It will provide an overview of all of the clinical contacts a person has ever had. It will increase diagnostic accuracy and speed and save needless test repetition. In impoverished nations like Bangladesh, this approach to healthcare is not used by the general public. In this study, we provide a distributed system-based paradigm for the healthcare industry.

1.2 Background of the Research

A distributed database system is composed of multiple interconnected databases that are physically separated and linked through a computer network. Such a system is often required when there is a need for users from diverse locations to access the same database simultaneously. Distributed databases come in two different varieties. Both are diverse, but one is homogeneous. The database is referred to as homogeneous if all servers and clients utilize the same software. so that it is simple to control. A heterogeneous distributed database utilizes two or more databases that are stored on one or more computers and employ several DBMS programs.

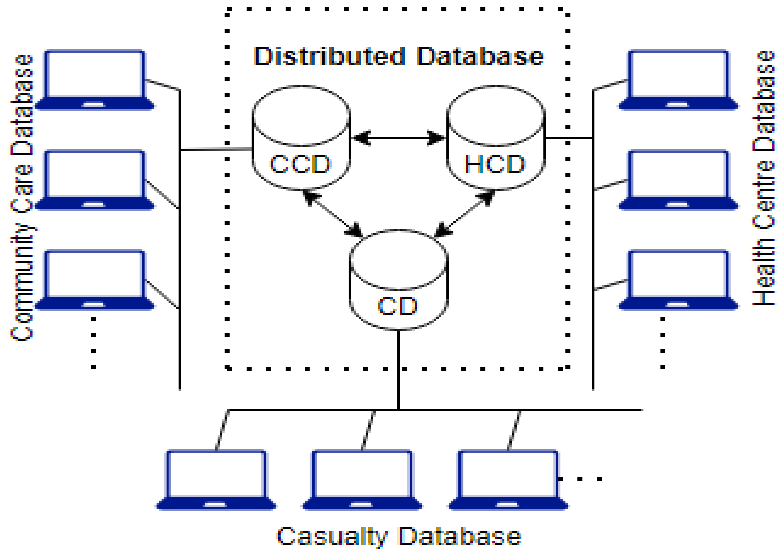


Figure 1.2: Distributed Database with three database [3].

The Figure-1.2 describes a distributed system that connects three databases: 1)COMMUNITY CARE DATABASE, 2) HEALTH CENTRE DATABASE and 3)CASUALTY.

The data in several databases in a single distributed environment can simultaneously access or modify by an application. For example, a single query from a COMMUNITY CARE DATABASE client on local database can retrieve joined data from the PATIENT table on the local database and the DOCTOR table on the remote HEALTH CENTRE database. In the context of a client application, the databases' location and platform are not apparent to the users. Additionally, it's possible to establish synonyms for remote objects within the distributed system, allowing users to access them using the same syntax as for local objects. For example, if we are connected to database COMMUNITY CARE DATABASE yet want to access data on database HEALTH CENTRE DATABASE, creating a synonym on COMMUNITY CARE DATABASE for the remote PATIENT table allows us to issue this query: SELECT * FROM PATIENT;

A distributed system can provide the illusion of local data access by concealing from users the fact that the data they are accessing is distributed across remote databases. In the case of the COMMUNITY CARE DATABASE, users can access the data without being aware of its physical location.

Healthcare interoperability refers to the timely and safe integration and use of electronic health data to improve individual and community health outcomes [6].

Currently, the latest available statistics for the population-health workforce situation of Bangladesh are from the Bangladesh Bureau of Statistics (BBS) in 2019 [7]. According to the BBS, the population of Bangladesh was estimated at 165.91 million in 2019.

Here are the latest available ratios for the population-health workforce of Bangladesh based on the BBS statistics [7]:

- Number of doctors per 10,000 population: 1.45
- Number of registered nurses per 10,000 population: 2.97
- Number of registered physicians per 10,000 population: 4.73
- Number of nurses per 10,000 population: 1.07
- Number of medical technologists per 10,000 population: 0.49
- Number of community and domiciliary health workers per 10,000 people: 4.01
- Hospital bed for 1528 population: 0.68

These ratios show a slight improvement in the number of doctors and nurses per 10,000 population compared to the statistics in the original text, but there is still a shortage of healthcare professionals in Bangladesh, particularly in rural areas.

The low density of physicians in Bangladesh indicates a significant need for improved healthcare facilities, particularly in rural areas. Telemedicine has the potential to play a crucial role in enhancing healthcare access and services for these undeserved populations. Figure 1.3 illustrates the various types of health facilities operating under the Directorate General of Health Services (DGHS) in Bangladesh.

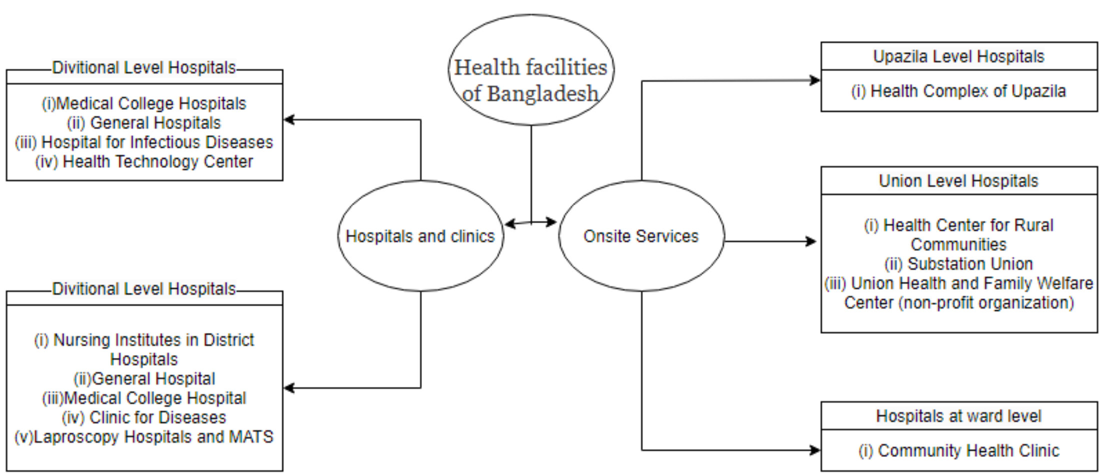


Figure 1.3: The various types of health facilities operating under the Directorate General of Health Services (DGHS) in Bangladesh [8].

Primary healthcare facilities are provided to rural areas through ward, union, and upazila level hospitals, while secondary and tertiary care facilities are limited in number and primarily cater to urban populations. To address this disparity, telemedicine has emerged as a potential solution to enhance healthcare facilities in rural areas.In Bangladesh, remarkable progress has been made in the development and deployment of countrywide telemedicine services in government hospitals. The first telemedicine service was initiated in 1999 by the Centre for the Rehabilitation of Paralyzed in Savar, Dhaka, using a store-and-forward-based telemedicine system. Since then, various government and non-government organizations have taken initiatives to advance telemedicine services.

As the number of secondary and tertiary care facilities is limited in Bangladesh, the use of telemedicine has become a viable option to provide expert healthcare services to rural areas through primary healthcare centers. With the development of a low-cost DEHS, healthcare services in developing countries can become more accessible and cost-effective for rural populations.The healthcare sector is facing a significant issue in creating interoperability among apps offered by various manufacturers. To transfer clinical and administrative data among-st apps, any hospital department or medical clinic may employ different tools. It makes it easier for medical providers to access health record data and information at any time, anywhere. By enhancing data interchange, data quality, and health professionals' access to patient information, quality and safety of treatment for patients are enhanced. Data gathering is enhanced for health management, and statistical and economic analysis is made easier. Medical data are more readily available to health researchers. In order to manage remote patient records, distributed systems are crucial. Each client computer has a local database, and the patient record has a distributed architecture.

In a distributed database design, data is dispersed throughout a network of computers connected by communication links rather than being wholly kept at one physical place. Because of this, our database is trustworthy, accessible, and versatile. The main benefit is that a distributed database can provide quicker local searches and thus lessen network traffic [9].

In impoverished nations like Bangladesh, this approach to healthcare is not used by the general public. In this study, we provide a distributed system-based paradigm for the healthcare industry.

1.3 Motivations of the Research

The motivation behind this research is to address the lack of adequate healthcare facilities, particularly in rural areas of developing countries like Bangladesh. With approximately 75% of the population living in rural areas, access to quality healthcare services is a major challenge. Expert doctors and healthcare centers are primarily concentrated in urban areas, leaving rural areas under served. Additionally, there is a shortage of expert doctors in Bangladesh, resulting in limited access to quality healthcare services for the majority of the population.E-health can provide an effective solution to bridge this gap and provide healthcare services to rural communities through local health centers. As a first step, a primary survey was conducted among expert doctors, local doctors, pharmacy owners, and patients to understand the current state of telemedicine in Bangladesh. The survey results serve as the main motivation behind this research. The goal is to develop a convenient and low-cost distributed electronic health system that can be deployed in developing countries to improve healthcare services.

1.3.1 Survey Questionnaires for Data Preparation

All patient, physician, and healthcare professional health-related information is stored as part of the data preparation process. The demo datasets of the GNU Health system, an open-source and cost-free hospital information management system, is used here to evaluate the e-Health system (HIS). Utilizing the interchangeable demo data is made simpler by the GNU Health demo database. The collection contains a variety of information from 40 different health system components. For our investigation, we used data from 100 patients who were treated by 100 healthcare professionals such as doctors,Medical assistants, lab assistant, nurse at five different healthcare facilities such as Private hospitals, clinics, Health complex, Diagnostics centre(see figure 1.3.1) etc.

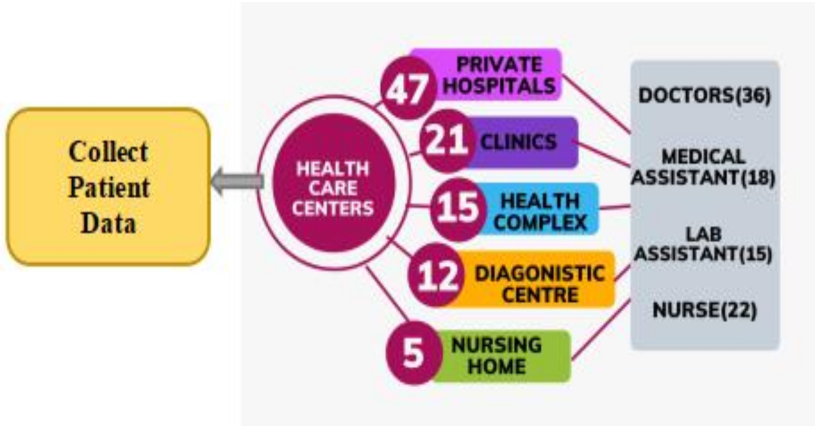


Figure 1.3.1: Primary survey data collection for data preparation

The data processed in Excel were converted to CSV file format and analyzed in R, a versatile and widely-used open source programming language for statistics and data science. Various plot functions in R were used to analyze the processed data, and the resulting outputs were used to derive the research results. Bangladesh, being one of the most populous countries in the world, faces numerous challenges in delivering quality healthcare to its citizens, particularly those living in rural areas. Electronic healthcare services can bridge this gap by providing access to quality healthcare to all citizens, regardless of their location. Electronic health is being increasingly used in Bangladesh to improve healthcare access and services, despite inadequate infrastructure. But the current e-health systems in Bangladesh face challenges related to interoperability and patient data management become difficult in healthcare services. This emphasizes the significance of enhancing the national healthcare system for fast, accessible, and affordable healthcare. The aim of this survey was to evaluate the current state of e-health systems in Bangladesh and to explore the future prospects of these systems, finding we are still in early stages with limited impact on patient outcomes due to inadequate infrastructure and standardization. It investigates the consequences of existing systems and their impact on healthcare services, patient care, and overall health outcomes. The study also identifies key challenges and opportunities that need to be addressed for the successful implementation and sustainability of electronic healthcare systems in Bangladesh. Investment and standard protocols are needed for efficient data management and access to healthcare. Survey highlights current challenges and future opportunities for healthcare providers, policymakers, and tech companies to improve e-health services in Bangladesh.

A final set of 23 survey questions was developed after taking into account the involvement, goals, responsibilities, and financial issues of medical officers, nurses, physicians, intern doctors, and data management officers.We distributed the questionnaires in zila, upazila, thana, union,and district.The area of conducting the survey is shown in Figure 1.3.2. 44 copies of questionnaires on paper were distributed to the concerned person and all the results were collected from the respondents. And 65 copies of Questionnaires were distributed over online to the concerned person and around 58 sets were collected from the respondents.Table 1 summarizes the data collecting scenario. From the table we can see that the average acceptance rate of the questionnaires are 91.74%.

Summary of survey data collection				
Targeted person	**Types of Questions**	**Numbers of Questions**	**Collected response**	**Percentage**
Doctors	Online	28	26	92.85%
	Offline	11	11	100%
Medical/Lab assistant	Online	13	11	85%
	Offline	23	23	100%
Database Management Officer	Online	16	15	93.75%
	Offline	8	8	100%
Others	Online	8	6	75%
	Offline	2	2	100%

Table 1: Summary of survey data collection

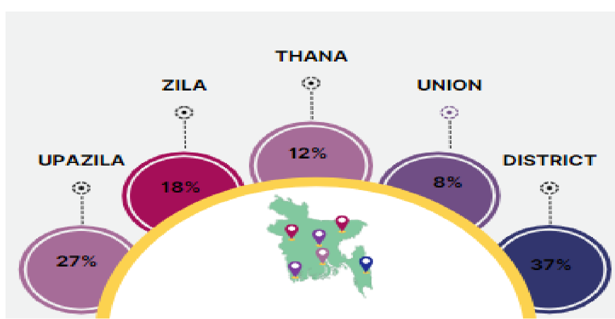


Figure 1.3.2: Area of data collection for data preparation

1.3.2 Findings of survey for data preparation

The current status of electronic healthcare services (EHS) in Bangladesh has been surveyed to examine the consequences and future prospects. Based on the survey, there are varying levels of familiarity and necessity in rural areas (10.57% unions, 17.30% thanas, 46.15% upazilas, and 25.96% zilas)(figure 1.3.2, which will guide future EHS initiatives to ensure accessibility and usefulness.

Data was collected from 100 diverse healthcare facilities (47 private hospitals, 21 clinics, 15 health complexes, 12 diagnostic centers, and 5 nursing homes) surveyed with 100 professionals (36 doctors, 18 medical assistants, 15 lab assistants, 22 nurses, and others). 74 facilities collect data electronically, 53 use centralized databases, 12 use distributed databases, and 9 use other technologies , leading to improved patient care and outcomes. 51% store data on databases, 10% on Excel, 3% on the cloud, 17% on paper, and 19% do not store data(Figure 1.3.4).

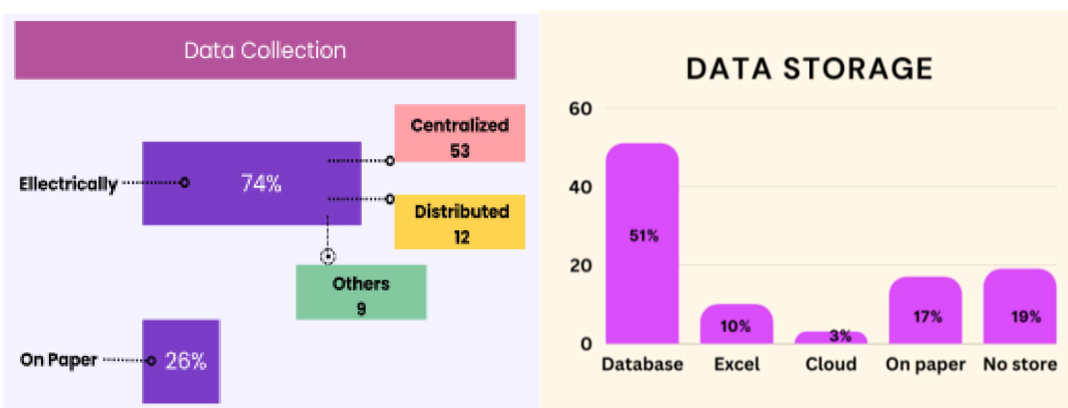


Figure 1.3.4: Data collection types and data stored technology

Among surveyed healthcare systems, 29% keep no backup of health records and 11% use paper for data collection and backup. 74% collect data electronically, but only 4% use Excel for storage and 2% use other technologies for backup. 54% use centralized databases without proper backup and interoperability, risking loss of patient information and increased costs (Figure 1.3.5(a)).

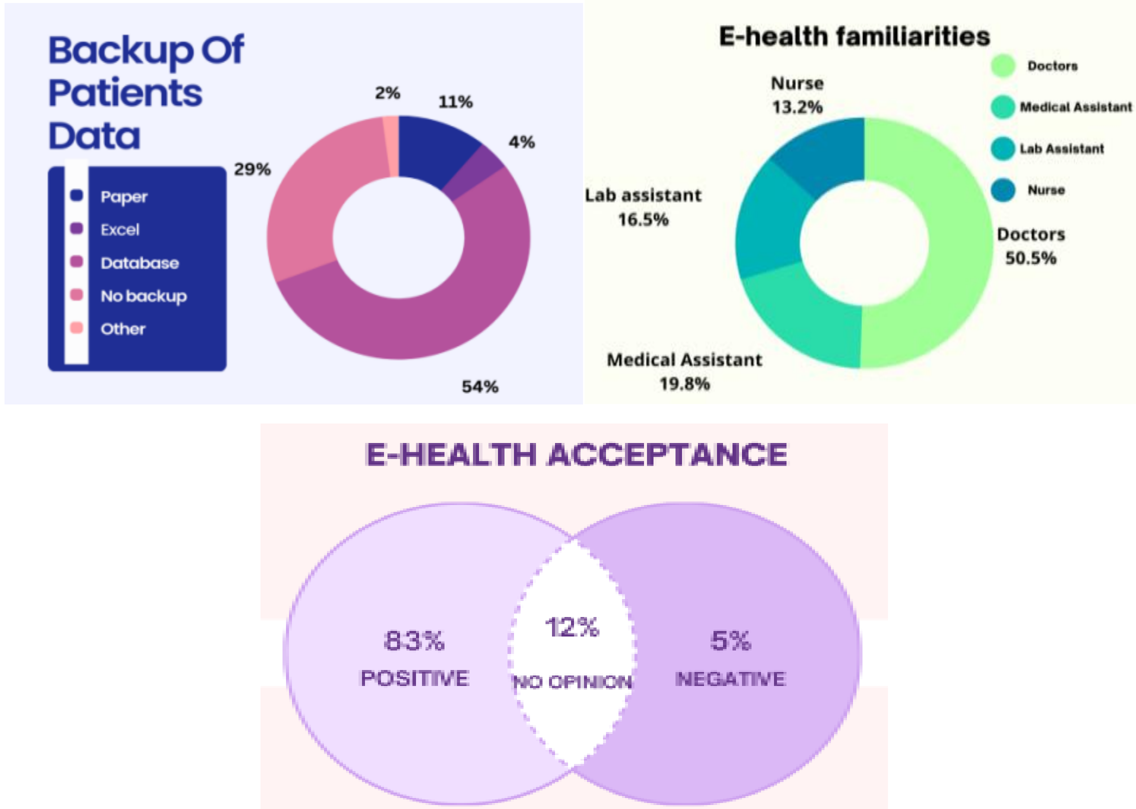


Figure 1.3.5:(a) Availability of Data backup technology (b)Familiarity of e-health(c)Acceptance of e-health

Familiarity with e-Health among healthcare professionals in Bangladesh varies, as shown by the survey. 50.5% of doctors are familiar with e-Health, compared to 19.8% of medical assistants, 16.5% of laboratory assistants, and 13.2% of nurses(In figure 1.3.5(b)). However, it is encouraging to note that currently, 83% of responses to the distributed e-health system are favorable, 5% are negative, and 12% are neutral(figure 1.3.5(c)). The survey of electronic healthcare services in Bangladesh shows challenges due to centralized systems, lack of infrastructure, and trained personnel, but growing adoption of distributed EHS to save time and money. Collaboration is needed to address rural community access issues and develop sustainable solutions.Proper data backup and interoperability are crucial. Investment and development are needed for EHS to improve patient outcomes and healthcare efficiency. Distributed e-health systems can improve healthcare services by addressing the challenges posed by centralized systems.

1.3.3 Conclusion of survey

The survey on electronic healthcare services (EHS) in Bangladesh reveals that there are varying levels of familiarity and necessity for EHS in different areas, with rural areas showing less familiarity and necessity. Among surveyed healthcare facilities, the majority collect data electronically, but there are different ways of storing data, with some using centralized databases without proper backup and interoperability, risking loss of patient information and increased costs. The survey also shows that there is a need for investment and development in EHS to improve patient outcomes and healthcare efficiency.One of the major challenges facing EHS in Bangladesh is the centralized system, which hinders data exchange. The survey suggests that distributed e-health systems can be a solution to this problem by saving time and costs. The survey also highlights the need for proper data backup and interoperability to ensure that patient information is not lost and that the different healthcare facilities can exchange data seamlessly.Familiarity with EHS among healthcare professionals in Bangladesh varies, with doctors showing higher familiarity compared to medical assistants, laboratory assistants, and nurses. However, it is encouraging to note that currently, there is growing adoption of distributed EHS, with 83% of responses being favorable. This suggests that there is potential for EHS to improve healthcare outcomes in Bangladesh, but it requires further development and investment.The survey results offer insights for healthcare providers, policymakers, and technology companies in Bangladesh. Collaboration is needed to address rural community access issues and develop sustainable solutions. Investment and standardization are necessary to fully realize the benefits of EHS in Bangladesh. By addressing the challenges posed by centralized systems and investing in distributed e-health systems, healthcare services in Bangladesh can be improved, leading to better patient outcomes and increased efficiency.

1.4 Problem statement

Currently, telemedicine and electronic health can benefit from the use of mobile technology and cloud computing to provide the appropriate level of virtualization and service aggregation (e-Health). However, security, trust, user-friendliness, and the implementation of creative E-Health initiatives all face technological obstacles. The main challenges are-

- A lack of e-Record system governance and legality.
- A lack of ICT assistance.
- Inadequate support budget.

• Inability to use e-Record systems effectively.

• Variable, unique patient identification numbers (UPI).

• The absence of interoperability standards enforcement.

We suggested a low-cost Distributed Electronic Health System for underdeveloped nations as a solution to all the problems.

1.5 Objectives

Every thesis has a few distinct goals. Additionally, my research has a few straightforward and focused goals. I mentioned things in the following order:

- The major goal is to create an Electronic Health Record (EHR) distributed system that is simple and affordable for developing nations.
- To create healthcare systems that offer developing nations a network of healthcare facilities and services that are easily accessible, reasonably priced, of the highest quality, and safe.
- To guarantee that patient records are quickly and easily available at all times and from any location.
- Data may be kept for a long time, conveniently, and with little storage capacity.
- To provide a summary of all clinical experiences a person has ever had.
- To increase the speed and accuracy of diagnosis and prevent repeating pointless tests.
- To make a resource available for usage by several people at once.
- To inexpensively backup patient records.
- Resource sharing, openness, concurrency, share ability, local autonomy, enhanced performance, improved dependability, and availability are among the characteristics of the system.

To develop a system that enables the interconnection between heterogeneous data resources.

1.6 Organizations of the report

The development of a convenient and low-cost Distributed Electronic Health System (DEHS) in healthcare services for developing countries is a crucial need of the current time. In developing countries, there is a lack of proper healthcare services due to limited resources and insufficient funds. To overcome these challenges, the use of technology in healthcare services has become increasingly important. The DEHS system provides an efficient way to manage healthcare services in developing countries.

The research report is divided into five chapters, each covering different aspects related to the development of the DEHS system.

The first chapter is introduction which describes the idea behind the thesis and introduces the DEHS system. It highlights the need for such a system in developing countries and how it can improve healthcare services. It outlines the purpose of the study and provides a clear direction for the research. The chapter also discusses the research questions that the study aims to answer. The second chapter name is Literature review which provides a literature review of the existing system in healthcare services for developing countries. It analyzes the strengths and weaknesses of the current system and discusses the challenges faced by the healthcare industry in developing countries. The chapter also highlights the importance of the DEHS system in overcoming these challenges. This chapter provides a model review related to the DEHS system. It analyzes different models that can be used for the development of the system and identifies the most appropriate model based on the requirements of the system. The third chapter name is Methodology which presents the methodology for the DEHS system. It provides the model for the DEHS system. It outlines the system architecture, its components, and the functionalities that it provides. The chapter also discusses the design and implementation of the system. This chapter discusses the software requirements for the DEHS system. It identifies the software tools and technologies that are required for the development of the system. The chapter also discusses the testing and validation of the system. The fourth chapter name is Result and Discussion which provides the result and discussion related to the DEHS system. It summarizes the key findings of the study and provides recommendations for future research. The fifth chapter name is Conclusion which provides the conclusion of this research. This chapter summarizes the main findings of the study, restates the research questions and objectives, and discusses the implications of the study for practice, policy, and theory. It may also highlight the limitations of the study and suggest avenues for future research. The chapter also includes a list of references used in the thesis.

In conclusion, the development of a convenient and low-cost DEHS system in healthcare services for developing countries is crucial for improving healthcare services in these regions. The thesis report provides a comprehensive analysis of the existing system and highlights the importance of the DEHS system. The report also presents a model for the development of the system, discusses the software requirements, and provides recommendations for future research. Overall, the DEHS system has the potential to revolutionize healthcare services in developing countries, providing access to high-quality healthcare services to those who need it most.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The development of electronic health systems (EHS) has the potential to revolutionize healthcare services, particularly in developing countries where access to quality healthcare is often limited. However, the implementation of EHS in these settings can be challenging due to factors such as lack of infrastructure and resources. To address these challenges, there has been increasing interest in the development of convenient and low-cost distributed EHS for healthcare services in developing countries. This literature review aims to explore the current state of research on the development of such systems and their potential to improve healthcare outcomes in developing countries. Through an analysis of existing literature, this review will examine the challenges and opportunities associated with the development of distributed EHS, as well as the factors that contribute to their success or failure. The findings of this review will inform future research and development efforts aimed at improving healthcare services in developing countries through the use of distributed EHS. This section shows some of the recent related literature and concepts published by the different authors. This section helps us to find out the different approaches on the research and guides an advanced approach to solve the current problems. Major case studies involve big nations or wide regions. Among them we need to consider some e-health information integration strategies.

2.1.1 Literature Review

Developing nations face challenging decisions when allocating their limited healthcare resources. In light of the significant financial deficit in the healthcare system, the appropriate distribution of resources among low-income countries becomes even more crucial. The World Health Organization (WHO) estimates that the south-east Asian nations spend an average of 4.7% of their GDP on health. Bangladesh has a huge chance to enhance its healthcare system through the use of electronic health records, despite being a developing nation (EHR). In light of the government of Bangladesh's announcement that it will become "Digital Bangladesh" by 2021, digital healthcare is seen as a rapidly developing industry in Bangladesh. Many substantial problems still exist, despite interest in the EHR for researchers and health outcomes. Two significant issues are a lack of financing and a paucity of qualified employees. To establish EHR in Bangladesh, the public and private sectors must band together [10].

An electronic health record is a patient's digital medical file. It is occasionally maintained as well. The patient's whole clinical history is meticulously documented. It contains data, comments on progress, significant health concerns, a list of medications used to treat the particular patient, major health issues, past medical records, the likelihood of a cure, and the results of all tests. It decreases the need for the same test to be repeated and expedites therapy. As every material is thoroughly researched before use, it aids patients in making better decisions. It makes health information public, which has enhanced all medical records' accuracy and openness. Additionally, it improves the confidentiality and privacy of patient data. Despite the fact that it has numerous advantages, they believe that because there is no existing low-cost distributed database system, their maintenance costs will grow [11].

One of the key projects undertaken by the Government of Bangladesh (GoB) is to realize the vision and mission of establishing "Digital Bangladesh" by the year 2021 through the establishment of transparent, effective, and citizen-centric public services, referred to as "e-services" through ICT, "National Enterprise Architecture" and "e-Government Interoperability Framework (e-GIF)" (International Telecommunication Union (ITU) 2016). The project's goal was to create systems, structures, technologies, and strategies that would enable the government as a whole while also improving asset management, boosting interoperability, and lowering risks and procurement costs. The system's objective is to raise the standard of healthcare professionals' service delivery. The bulk (about 76%) of Bangladesh's population, who reside in rural areas, was first enrolled in the system (Zishan et al. 2019). 2014 saw the start of the project, which was finished in 2016. The Bangladesh Computer Council (BCC), the GoB's highest authority, carried it out. According to the Additional Director General and Director of Management Information System (MIS), DGHS (2015), the government of Bangladesh uses three different types of software: DHIS-2 for public health services provided by healthcare facilities across the nation; Open HRM for human resource management and

MRS for healthcare services. To facilitate data transmission via electronic health records (EHR), the government wants to create systems that combine DHIS-2, Open MRS, and HRM into a national level E-health enterprise architecture (eHEA) (electronic health record) [12].

The majority of research on e-Health adoption in LMICs concentrated on EHR deployment. Open-source EHRs have been widely employed by resource-constrained regions on all continents, Aminpour et al. noted, especially in Sub-Saharan Africa and South America. The authors concluded that HIS offer chances to enhance national health care, especially in emerging nations with limited financial resources [13].

After their experience in developing nations, Fraser and Blaya addressed the main barriers to OS EHR utilization in low-resource settings. The authors discussed their experiences and key learnings, emphasizing concepts like the necessity of clinical staff participation to provide qualitative data entry, the reuse of validated EHR implementations, and the planning of offline data entry, which is especially pertinent given an unstable power supply and Internet connection [14].

The study conducted in Ethiopia by Tilahun et al. was based on interviews with medical staff members at 5 hospitals. The results revealed healthcare staff discontent with, for instance, poor service quality and double-entering data (both on paper and electronic medical records [EMR]). To improve the usage of EMR systems by healthcare practitioners, the authors advise concentrating on training, user assistance, and supplying adequate PCs [15].

It was also discovered in an application of cutting-edge telemedicine services for Bangladesh's rural residents, which was reported in 2018 by Uzzal Kumar Prodhan and other academics. The telemedicine services in that study were provided through a centralized electronic health system. However, if the central system fails, the entire system would shut down and the overall level of service will suffer. Therefore, the ideal option in this situation could be a distributed database built on an other open source platform [16].

Distributed e-Health system with Smart Self-care Units is the title of Mircea Rusu's study. A distributed e-health system was created in order to guarantee remote monitoring of patients with chronic conditions as well as to enhance the responsiveness and quality of medical treatments. The smart self-care unit (SSCU), which enables remote capture of medical data from patients treated or monitored at home, is a crucial component of this system. A wireless network connects a collection of intelligent medical sensors and gadgets that make up this unit. The technology guarantees patient mobility while under supervision and smooth medical data transfer to healthcare facilities (hospitals, clinics, general practitioners, etc). Through a distributed, multiserver-based application, patients may obtain medical services and communicate with medical staff remotely [17].

Kostyantyn Kolisnyk talked about the use of contemporary internet technologies in telemedicine screening of patient conditions. The authors set out to examine the current state of use of cutting-edge Internet technologies in relation to the tasks of telemedicine patient condition screening and to investigate the potential for figuring out how to improve the quality of telemedicine services by building contemporary telemedicine complexes. The writers are working to advance telemedicine in Ukraine. The implementation of telemedicine screening complicated on the use of regional telemedicine tools MedStar Solusion LLS is taking particular recommendations into consideration [18].

Victor A. Gorelov proposed a sophisticated methodological approach for integrating contemporary telemedicine technologies into the national, regional, and local healthcare systems. In order to create a scalable telemedicine system, the paper recommends a complicated methodological approach that addresses the following issues: resolving implementation-related challenges; selecting the best plan for building a worldwide telemedicine network at the federal, regional, and municipal levels while taking into account the unique characteristics of each medical facility [19] .

As a Case Study, Kelvin K.F. Tsoi from the Chinese University of Hong Kong utilized artificial intelligence to a platform for diagnosing symptoms via telemedicine. Exploring the potential of digital health as a tool for medical consultation would be a decision given the society's rising desire for higher-quality healthcare. In this case study, the author introduces an AI diagnostic platform and shows how its characteristics may be used to identify illnesses based on patient self-reported symptoms and a doctor's physical examination. He performed a pilot research with 36 patients who had used the platform, and 22 genuine data were examined. When compared to human doctors, its differential diagnoses revealed complete coverage of each and every patient's diagnosis in each circumstance. It has been demonstrated that the Envive AI Diagnosis system correctly identified patients based on their symptoms and physical examinations. The results demonstrated the possibility for implementing digital analytics in consultation in the future, particularly in primary care settings [20].

Comparative Analysis of e-Health Care Telemedicine System Based on Internet of Medical Things and Artificial Intelligence is represented by Ankush Kadu and Manwinder Singh. Experts in the field of medicine have started to realize their abilities in processing and analyzing data for telemedicine as a result of the development and widespread usage of artificial intelligence (AI) in a range of sectors. Telemedicine platforms, which provide distinctive and innovative options, may be helpful for outpatients who need medical care but are unable to get it because of a lack of funds or restricted access. Because telemedicine might be challenging to use, it is essential to increase its capabilities and adaptability in order to solve telemedicine issues. The expansion of the ability to handle information has opened up more substantial opportunities for the global health industry, particularly telemedicine, thanks to the Internet of Things (IoT), a continual advancement in technology that enables the extension of interactions over the internet. The benefits of telemedicine and AI in combination offered countless opportunities for improvement, and this paper reviewed the literature on current projects [21].

In a study that was published, Harry Fulgencio discussed the societal issue of using eHealth to manage health. There have already been some potential applications of leveraging information and communication technology to deliver healthcare in both developed and developing nations. The principal difficulties in establishing eHealth solutions for Developing Countries, however, have not received enough investigation. He listed the difficulties developing nations will face in implementing eHealth, along with a comparable list of solutions. Six themes of obstacles emerged from the systematic evaluation of 46 publications in the literature: 1) a lack of trained stakeholders, 2) weak infrastructures, 3) resistance, 4) scarce resources, 5) poor information sharing, and 6) weak process direction. We founded our suggested theoretical model to concentrate on three aspects: 1) guiding, 2) acceptance, and 3) creating basis, based on the facts. We hypothesized that this approach would enhance or assist Developing Country deployments of eHealth. eHealth, systematic literature review, theoretical model, stakeholders, developing nations [22].

With his study, Iftikhar Ahmad discusses the adoption of and state of the e-health system in Pakistan (2012). He claimed that while both traditional and modern models are being used by communities all over the world, the majority of people in developing nations like Pakistan are still unfamiliar with the idea of e-Health. Health information systems powered by computers are increasingly common. A successful e-Health, it is believed, requires more than just purchasing hardware and software; rather, it necessitates social treatment by addressing all of the challenges of a technological, organizational, human, and social nature [23].

The author used a descriptive survey approach for his study, "The Effects of Information and Communication Technology on Health Service Delivery at Tafo Government Hospital," which Kennedy Addo conducted. 50 respondents were given a semi-structured questionnaire to complete, and data were gathered using a stratified random sampling approach with each respondent's ranking position serving as a stratum. Utilizing descriptive statistics, data were examined. The author discovered that 56% of respondents overwhelmingly agreed that ICT applications speed up medical diagnoses, reduce user workload, improve patient wait times, and make information more accessible. However, 72% of respondents bemoaned a lack of ICT infrastructure, poor ICT network concerns, and a lack of knowledge about ICT use, all of which could limit the impact of ICT on the delivery of high-quality services. The findings showing ICT enhances cooperation and clinical decision support in improving clinical work flow integration among nurses and other medical professionals, according to the author, suggest that this may be inferred. The data above also support the idea that it is impossible to properly integrate ICT into health care delivery without adequate electrical infrastructure, ICT skills, and technical expertise. Because they regarded their expertise as being quite good, the majority of healthcare professionals had a favorable view regarding the potential of ICT [24].

ICT Implementation in the Nigerian Healthcare System is represented in this article by Ishaya Gambo and Abimbola Hettie Soriyan. According to the author, Nigeria's healthcare sector reform has considerably contributed to a decrease in medical mistakes and healthcare delivery costs. Additionally, it has increased productivity for medical personnel including doctors, nurses, radiologists, lab scientists, and others, and it has significantly enhanced the doctor-patient interaction. Thus, we may conclude that Nigeria is consciously working to achieve the Sustainable Development Goals (SDG) far in advance of the 2030 deadline [25].

Wahid B. Hamad describes the state of e-health in Tanzania and the difficulties it faces. It is a master's thesis in information system literature review. According to the author, several initiatives and developments have been made in the adoption and use of e-health systems as a means of enhancing the health sector nationwide. However, the health industry continues to face a variety of obstacles, such as a lack of infrastructure, inadequate ICT-related knowledge and skills, governance structures, e-Health standard compliance, and system interoperability [26].

Elham Monaghesh and Alireza Hajizadeh conducted a systematic assessment based on recent data to examine the effect of telehealth during the COVID-19 epidemic. An international public health emergency, coronavirus disease-19 (COVID-19), is now raging. The COVID-19 epidemic can be controlled with the use of telehealth. This systematic review's author set out to determine how telehealth services may be used to prevent, diagnose, treat, and manage illnesses during the COVID-19 epidemic. Five databases, including PubMed, Scopus, Embase, Web of Science, and Science Direct, were searched for this systematic review. Currently, telemedicine is unquestionably acceptable in reducing the risk of COVID-19 transmission among healthcare workers and patients who isolate themselves. This approach may be used to avoid any kind of direct physical contact, offer ongoing care to the neighborhood, and eventually lower morbidity and fatality rates during the COVID-19 epidemic [27].

Toyeeb Olamilekan Abolade gives a presentation on The Benefits and Challenges of E-Health Applications in Developing Nations. ICT may be used to improve healthcare quality or maintain standards with fewer workers and at a cheaper cost. As we all know, the goal of information and communication technologies (ICT) for health (also known as eHealth) is to greatly enhance the quality, accessibility, and efficacy of healthcare for all individuals. As a result, many businesses are now working on fantastic eHealth innovations. ICT for Health refers to the use of information and communication technology for a wide variety of purposes that have an impact on the health sector [28].

The writers Examine the performance and accessibility of a cloud, fog, and edge-integrated e-health system. The authors provide a sensor-based architecture for electronic health monitoring that uses cloud and fog infrastructures to manage and store patient data. Additionally, they suggest stochastic models to examine the performance and availability of such systems, including models to comprehend how failures along the Cloud-to-Thing continuum affect the availability of e-health systems and to spot possible bottlenecks. They plan, create, and build a prototype and conduct performance trials to provide their models with actual data. According to their findings, the sensors and fog devices are the elements that, in the scenarios examined, have the most influence on the overall availability of the e-health monitoring system. Their findings imply that there is a trade-off between performance and delays that has to be handled in order to determine the appropriate architecture to house the e-health monitoring system [29].

The authors created a generic E-healthcare unit that can accommodate a range of demands in a variety of deployment circumstances. The suggested deployments demonstrate how a tailored E-healthcare solution for individuals or groups may be established with ease by utilizing the current selection of telemedicine equipment and the telecommunication link [30].

Tsion H. Tebeje and Jorn Klein's book Applications of e-Health to Support Person-Centered Health Care at the Time of COVID-19 Pandemic. They claimed that the majority of the research made use of e-health technology to streamline team care and clinical decision support. Telehealth and mobile health were used to improve patient participation and access to healthcare from the comfort of their homes. The databases utilized were PubMed, ScienceDirect, CINAHL, MedRxiv, and Web of Science. Each record that was obtained was evaluated for eligibility by two researchers separately. The researchers then rescreened each of the included studies. The suggested reporting items for systematic reviews and meta-analyses were followed when conducting the systematic review [31].

ICT infrastructure, e-health technologies already in use, participant understanding of ICT advantages, and difficulties preventing ICT adoption in these facilities are all taken into consideration. The findings show that the existing ICT infrastructure is insufficient for implementing e-health due to a number of issues. As a result, recommendations for how to approach the various difficulties have been made in S. Ouma's study [32].

Although health informatics has varying effects in developed and developing nations, it has the ability to enhance patient security and care quality. Government-sponsored educational or training initiatives in the field, issues with cultural or educational barriers to eHealth implementation, policies governing terminology or messaging standards, and policies regarding eHealth status for extended periods of time are all problems in developing countries. The percentage of respondents that responded positively was as follows: 1. Policies for economic assistance (58%), 2. Policies for training (25%), 3. Issues with culture and education (95%), 4. Policies for standards (38%), and 5. Policies for long-term (50%) The authors' study revealed that cultural and educational issues, economic resource constraints, and long-term policies are the three key issues that need to be resolved before e-Health can be implemented in developing nations [33].

A Low-Cost IoT and UAV-Based Platform for Environmental Smart Farming Monitoring. By deploying airborne IoT, the scientists want to create a cheap platform for thorough environmental parameter monitoring. Between March 2020 and March 2021, this platform is set up and tested in a real-world setting on a farm near Medenine, Tunisia. By employing both above- and below-ground sensors, the experimental work satisfies the criteria for automated and real-time monitoring of the environmental parameters. These IoT sensors are located on a farm and are gathering enormous quantities of environmental data, which is relayed to ground gateways every hour and then gathered and transported by a drone to the cloud every twelve hours for archival and analysis. This low-cost platform may assist manufacturers, governments, and farmers in forecasting environmental data over a geographically expansive farm field, which improves crop yield and farm management in a timely, cost-effective manner. This kind of inexpensive IOT device may carry out an important function in an e-health system by monitoring [34].

Data interchange architecture for the creation of mobile apps that promote the interoperability of eHealth systems: Author Frederick Chali represents a Tanzanian instance. Both urban and rural health care systems have found use for electronic health (eHealth), particularly in the form of electronic health records (eHRs). But many of the systems are dispersed and operate separately. Therefore, despite their advantages, these stand-alone systems have certain operating difficulties. Interoperability amongst eHRs is one of them. One mobile application that can access various integrated eHRs is among the potential alternatives on the road to eHR interoperability, according to early efforts to interoperate eHealth systems. The suggested data exchange strategy provides a way to mitigate the interoperability issue while integrating a single mobile application with several eHRs. The design work draws on the findings of a survey that was conducted in the past to gather the system's basic needs for data interchange. This system was created using system design methodologies. This study presents an architectural system design of an electronic health data exchange that might lessen the interoperability problem [35].

The eHealth system has been plagued by what is frequently referred to as "pilotitis" since a number of eHealth pilot programs in poor nations were unable to advance to full-scale adoption. The frameworks for implementing sustainable eHealth systems described in the literature are linearly modelled and do not adequately capture the dynamic and nonlinear complexity of eHealth system implementation. In order to assist the long-term sustainability of eHealth systems in underdeveloped nations, this study suggests a paradigm for sustainable eHealth deployment. The framework uses a system dynamics approach to handle the nonlinear and dynamic linkages among ecosystem components in the implementation of eHealth through feedback systems. According to the report, eHealth's long-term viability is dependent on economic, social, and organizational elements in addition to technological ones [36].

According to the conversation, we see that cloud computing and mobile technologies can be crucial in helping telemedicine and electronic health attain the required degree of virtualization and service aggregation (e-Health). However, security, trust, user-friendliness, and the implementation of creative E-Health initiatives all face technological obstacles. We suggested a low-cost Distributed Electronic Health System for underdeveloped nations as a solution to all the problem.

2.2 Existing Systems

Telemedicine and Electronic health (e-Health) platforms are the use of high-speed telecommunications systems that facilitate information and communication technology (ICT). Electronic medical records (EMR) are also helping to enhance health care facilities with other health information systems (HIS). It provides faster treatment by reducing the repeat of the same test. It also improves the privacy and security of patient information. But ICT infrastructure has various challenges which make it inadequate for e-health implementations. To improve the security and quality of patient care Health informatics has the potential, but its impact of it has varied between developed and developing countries.

Developing countries face difficult decisions in distributing limited health care resources. Lack of funding and shortage of experienced personnel are two major problems. Although World Health Organization (WHO) says that the countries of south-east Asian regions spend 4.7% of their gross domestic product (GDP) on health on average. While novel models are advancing societies worldwide, e-Health remains an unfamiliar concept to many people in developing nations like Pakistan. Although some developing countries try to improve their health care services. On the other hand, the vision and mission of establishing “Digital Bangladesh” by the year 2021 are to improve the quality of service delivery by health care providers and to develop systems, structures, technologies, and strategies. The urban citizens, who form a majority (around 76%) of the Bangladesh population are the first to be included in the system. Nigeria is also making deliberate efforts to attain the UN’s Sustainable Development Goals (SDG) well ahead of 2030 deadly.

A case in Tanzania suggests that a single mobile application can access multiple integrated EHR among the viable solutions on the way to EHR interoperability. OS EHR utilization in low-resource settings provides reuse of validated EHR implementations, qualitative data entry, and planning of offline data entry. Smart Self-care Units(SSCU) in distributed e-Health systems are used to assure remote monitoring which can interact remotely with medical personnel. In Telemedicine Modern Internet Technologies Screening Patient Conditions are used. Victor A. Gorelov Introduce Complex Methodological Approach of Modern Telemedicine Technologies into the Healthcare

System on Regional, Federal and Municipal Levels. Artificial Intelligence was also applied on 36 patients at the University of Hong Kong in Chinese that provide physical examination and self-reported symptoms by physicians. Internet of Things (IoT) has created more significant chances for the global health sector, usually telemedicine. Numerous initiatives and advancements have been made to promote and implement e-health systems in various countries as a means of enhancing healthcare services.

Telehealth is an implicit option to fight the outbreak of COVID-19. A systematic review was directed by searching five databases including PubMed, Scopus, Embase, Web of Science, and Science direct currently, for healthcare providers and patients who are self-isolating, telehealth is undoubtedly suitable for minimizing the risk of COVID-19 transmission. During the COVID-19 pandemic, an evaluation was considered outlining activities in judging the satisfaction of helpless people with telemedicine, like e-Health assistance provided by healthcare professionals in their areas. A proposed architecture for e-health monitoring leverages sensors that utilize cloud and fog infrastructures for the processing and storage of patient data. An E-healthcare solution can easily be developed which is customized for individuals or groups benefiting from the existing array of telemedicine devices. Patient engagement and access to health care from their homes were enhanced using telehealth and mobile health.PubMed, ScienceDirect, CINAHL, MedRxiv, and Web of Science were used. Telehealth and mobile health have improved patients' ability to engage with and access healthcare services from the comfort of their own homes. Developing a low-cost IoT system can perform a vital role in e-health system by monitoring as A Low-Cost Platform for Environmental Smart Farming Monitoring System Based on IoT and UAVs in Medenine, Tunisia, the period of March 2020 to 2021. There are some description of few existing systems:

Analyzing the availability and performance of an e-health system integrated with edge, fog and cloud infrastructures (2018)

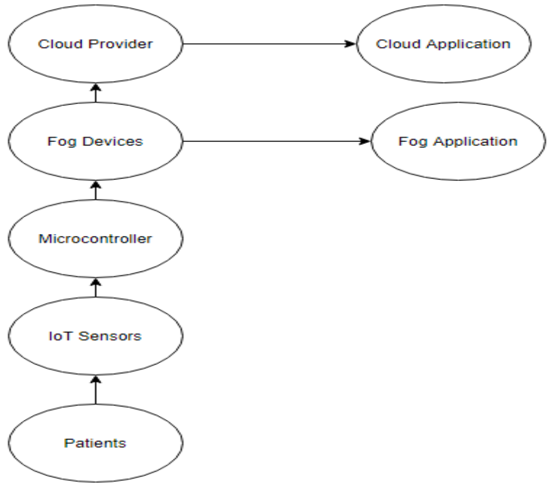


Figure 2.1: E-health monitoring system model [37].

Guto Leoni Santos, Patricia Takako Endo, and Matheus Felipe Ferreira da Silva's e-health monitoring system is represented in Figure 1 by a Structured Process Notation (SPN) model. Lisboa Tigre, Theo Lynn, Judith Kelner, Djamel Sadok, and Leylane Graziele Ferreira da Silva. The sensor, microcontroller, fog device, and cloud data center are used in this application[37]. They employ two-place construction bricks to represent these elements.The central focus of this paper is to introduce a new e-health monitoring architecture that employs sensors and utilizes cloud and fog infrastructures for the storage and management of patient data. The paper also proposes stochastic models to analyze the availability and performance of such systems, including how failures across the Cloud-to-Thing continuum impact on e-health system availability and potential bottlenecks. The paper discusses the results of performance experiments and highlights the trade-off between performance and delays that must be resolved to identify the best architecture to host the e-health monitoring system. In contrast, this strategy is expensive for developing nations like Bangladesh. Theo Lynn, Patricia Takako Endo, Matheus Felipe Ferreira da Silva Lisboa Tigre, Leylane Graziele Ferreira da Silva, Djamel Sadok, Judith Kelner, and Guto Leoni Santos all suggested this approach.

An integrated holistic model for an eHealth system: A national implementation approach and a new cloud-based security model (2019, Canada)

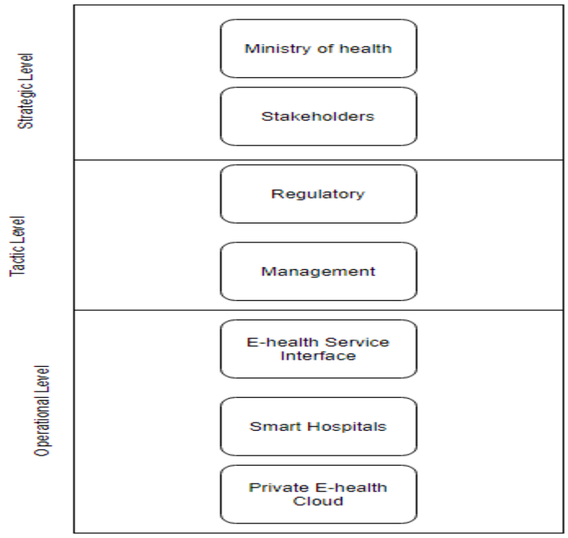


Figure 2.2: The holistic E-health model[38].

The suggested framework in Figure 2.2[38] is organized according to a general layered architecture made up of various integrated layers, including an infrastructure layer, an e-health cloud layer, a layer for smart hospitals, a layer for healthcare solutions, a layer for portals, and a layer for decision-making. Here, they make use of a central cloud-based program known as Software as a Service (SaaS), which is linked to users' PCs through networks. All hospitals, primary clinics, and other healthcare facilities are linked to the cloud through these networks. The cloud will make a variety of healthcare systems, including the Health Information System (HIS) and Radiology Information System, available to hospitals and other stakeholders (RIS). No matter where they are physically located, patients and doctors may access these services online. They utilize Infrastructure as a Service (IaaS), which offers all hospitals and clinics on-demand virtual computing resources like servers, and Platform as a Service (PaaS), a cloud-based environment. But emerging nations must pay a high price for this kind of paradigm. Salah Al-Sharhana, Esraa Omrana, and Kamran Lari suggested this approach.

Design and implementation of an advanced telemedicine model for the rural people of Bangladesh (2017, Bangladesh)

Figure 2.3: Business process diagram of telemedicine model [39].

There are several parts to the model in Figure 2.3. The following elements were used to construct the model.

1. A portable telemedicine tool kit will be used by distant local doctors to gather nine vital signs from patients and transmit the information for professional judgment.

2. Remote client log-in module: Using a Raspberry Pi, they created a client log-in module. This module will be used by a local pharmacy administration and a qualified doctor to provide telemedicine services.

3. An android mobile device with an android app has been created for preprocessing and real-time data visualization. Additionally, this module is used to submit patient information for telemedicine services.

4. Staging server module: For the telemedicine service, patient-specific test data are kept in the staging server module, and a message is also sent to the expert doctor for prompt assistance.

5. Health Level Seven (HL7) based health system: In this study, an open source health system built on the Health Level Seven International (HL7) standard is employed as the model. This module processes and maintains telemedicine-related records.

6. Data collection: Sensors and a toolkit are used to gather data that is then sent for professional judgment. Data on ECG, blood pressure, SPO2, blood glucose concentration, airflow, temperature, body posture, height, and weight are effectively obtained.

7. Data analysis: After gathering the raw data from the sensors, they examined the information to be used for telemedicine.

On the raw data, filtering techniques based on both hardware and software are used to eliminate undesirable signals. They utilized such data for healthcare applications after per-processing. Although it lacks a database system, this strategy was created primarily to help poor nations' rural health services.Although this strategy is less expensive and simpler to adopt in underdeveloped nations like Bangladesh, it has database issues because it relies on a centralized database. This model was proposed by Uzzal Kumar Prodhana, Department of Computer Science and Engineering, Jatiya Kabi Kazi Nazrul Islam University, Trishal, Mymensingh, Bangladesh, Mohammad

Zahidur Rahmanb and Israt Jahan, Department of Computer Science and Engineering, Jahangirnagar University, Savar, Dhaka, 89 Bangladesh[39].

Enhancing User Privacy in IoT: Integration of GDPR and Blockchain (2020,United Kingdom)

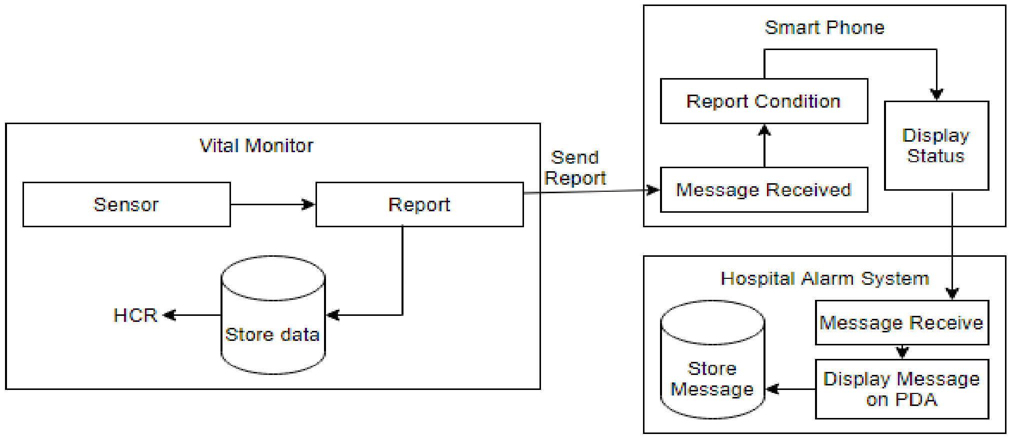


Figure 2.4: The process model of IoT-based e-health monitoring system [40].

In order to safeguard the personal information of IoT users, this research suggested a blockchain-based method that supports GDPR. Through a few common activities, they explained the goals of IoT devices' data processing. Each operation was given a set of GDPR regulations in the form of legal queries. Blockchain and GDPR integration in their strategy improved privacy across the board, not only in the IoT arena. Additionally, it might be prescribed for any environment based on services, including SOA and cloud computing.

Their suggested smart contracts were implemented in the Ropsten test network, and the findings showed a clear correlation between the volume of operations carried out on personal data and the expense incurred for confirming that those activities were carried out in line with GDPR regulations. However, the length of the mining process was unrelated to how complicated the suggested smart contracts were.

Though this model is IoT base advance model it is not suitable for the developing countries as it will need a huge cost.So we can say that it is not most satisfying model for developing countries like Bangladesh.The model was proposed by Masoud Barati from NewCastle University and Omer F. Rana from Cardiff university at 2020 in United Kingdom[40].

A Taxonomy on Smart Healthcare Technologies: Security Framework, Case Study, and Future Directions (2021)

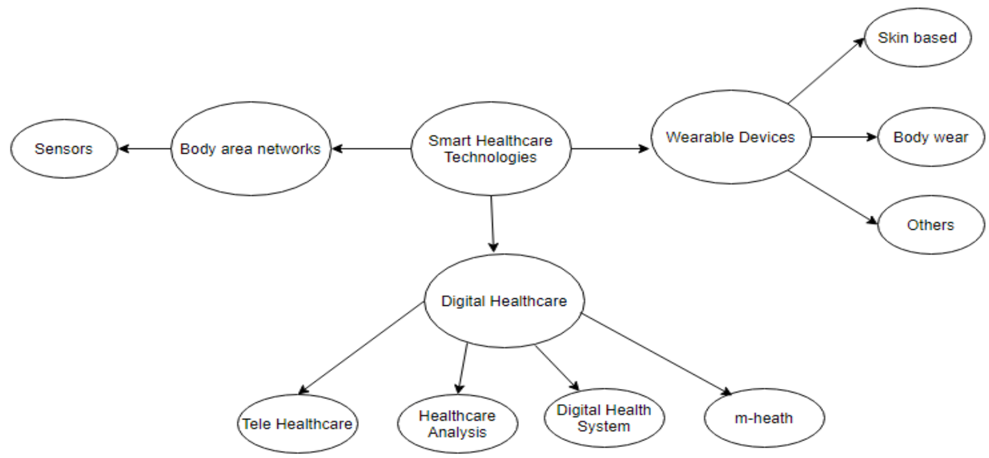


Figure 2.5: Taxonomy on smart healthcare technologies [41].

In order to address security and privacy concerns in the smart healthcare system, they gave a thorough overview of smart healthcare technologies in this article, including wearable technology, BANs, and digital healthcare. Additionally, a comparison of several cutting-edge healthcare programs has been explored. They developed a taxonomical taxonomy of various smart healthcare technologies with regard to their security vulnerabilities based on it. Then they suggest a 6G network interface for a safe, dependable AI-based architecture for smart healthcare solutions. The AI model in use guarantees the safe transfer of medical data to medical specialists. Additionally, they used a case study on the COVID-19 pandemic to assess the suggested architecture and develop a UAV-assisted safe healthcare framework to guard against security breaches. Though this model is efficient for developing countries it has a problem of using a centralized database. For this it can not share the records of patients among different hospitals. The authors of this proposed e-health monitoring architecture are Sachi Chaudhary, Riya Kakkar, Nilesh Kumar Jadav, Anuja Nair, Rajesh Gupta, Sudeep Tanwar, Smita Agrawal, and Mohammad Dahman Alshehri from the Department of Computer Science and Engineering at the Institute of Technology, Nirma University, located in Ahmedabad, Gujarat, India. Ravi Sharma from the Department of Computer Science at the College of Computers and Information Technology, Taif University in Saudi Arabia, Gulshan Sharma from the Centre for Inter-Disciplinary Research and Innovation at the University of Petroleum and Energy Studies in India, and Innocent E. Davidson from the Department of Electrical Power Engineering at Durban

University of Technology in South Africa also contributed to this model [41].

A prospective interoperable distributed e-Health system with loose coupling in improving healthcare services for developing countries (2021, Bangladesh)

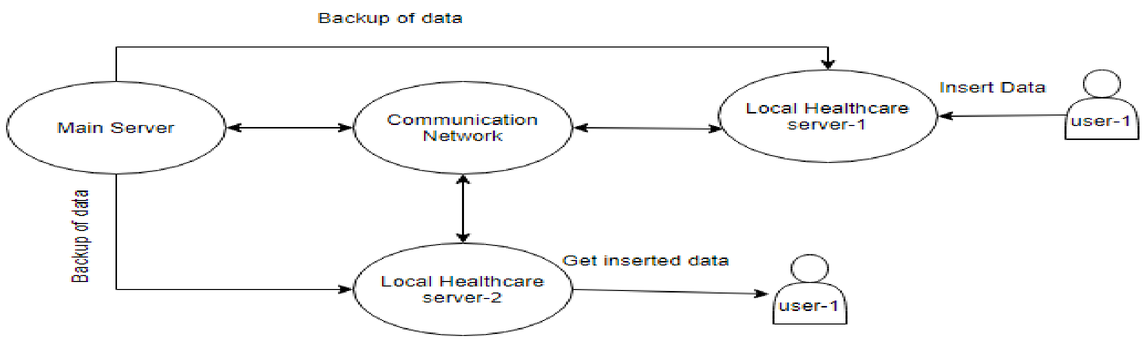


Figure 2.6: Distributed Electronic Health System [42].

Figure 2.6 of the system illustrates how PC-1 serves as the primary server and has access to any new data entered by any other healthcare facility linked to it. Using MPI, it sends frequent backups. Local healthcare facilities PC-2 and PC-3 are. Utilizing the communication network, these centers may access each other's data and provide services to patients in rural areas. However, the system can employ an IoT-based toolkit instead of a portable toolkit to monitor every patient's status in real time. Mahnuma Rahman Rinty, Dr. Uzzal Kumar Prodhan, and Dr. Md. Mijanur Rahman are the authors of this model, and they are from the Department of Computer Science and Engineering at Jatiya Kabi Kazi Nazrul Islam University in Trishal, Mymensingh, Bangladesh[42].

According to the report, e-long-term Health's viability depends on economic, social, and organizational variables in addition to technological ones. There are six difficulties: 1) Lack of stakeholders with the necessary skills, 2) a lack of infrastructure, 3) a lack of acceptability, 4) a lack of resources, 5) a lack of information transmission, and 6) a lack of process direction. To resolve the problems, attention should be given to: These percentages are: 1. Economic assistance policies (58%), 2. Training policies (25%), 3. Cultural and educational issues (95%), 4. Standards policies (38%), and 5. Long-term policies (50%) Many firms are currently coming out with amazing eHealth solutions. There are some existing system in Bangladesh-

SL .	E-Health system	Features	Technology	Limitations
1	A remote diagnostic center with four sensor[43]	primary health care: ECG, blood pressure, SPO2 and temperature	Centralized	Lack of interoperability with other health systems
2	A smartphone-based telemedicine system for remote patient monitoring[44]	Rural patient monitoring suffering from hypertension and hypotension	Centralized	System needs to include more sensors
3	Passive Wi-Fi sensing allows for wireless health monitoring[45]	As a conventional tool for health care, it replaces invasive medical instruments	Centralized	-
4	An Advanced Telemedicine Toolkit for Bangladesh[39]	primary health care services with nine sensors	Centralized	centralized system no data recovery
5	A prospective interoperable distributed e-Health system with loose coupling in improving healthcare services for developing countries[42]	A distributed e-health system withloose coupled database	Distributed	don't use any data security model or portable toolkit to collect data

Table 2: Related existing E-health system in Bangladesh

A centralized electronic health system was employed for telemedicine in the implementation of advanced telemedicine services for the rural population of Bangladesh, as reported by Dr. Uzzal Kumar Prodhan and other researchers in 2018. According to a poll done in Bangladesh, 80.32% of pharmacy owners, 94.80% of expert doctors, 74% of local doctors, 91.42% of patients, and 74% of local doctors all want to offer telemedicine services to Bangladesh's sizable urban population. In recent years, the e-Health system has been underused, cost-effective, and is currently confronting technological implementation challenges in underdeveloped nations. It also suggests that ICT facilitates clinical workflow integration among nurses and other medical professionals by enhancing clinical decision and cooperation support.All around the world's resource-constrained countries, especially in Sub-Saharan Africa and South America, have made extensive use of open-source EHRs. HIS presents potential to enhance national health care in underdeveloped nations with little in the way of financial resources. The health industry is still faced with a number of obstacles, such as a lack of infrastructure, poor ICT-related knowledge and skills, governance structures, e-Health standard compliance, and system interoperability.

According to the discussion, we notice that Mobile technology and cloud computing can play an important role to achieve the necessary level in Telemedicine and Electronic health (e-Health). However,challenges are present in security, trust, user-friendliness, and deployment of innovative E-Health strategies. To overcome all challenges we proposed a low-cost Distributed Electronic Health System for developing countries.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The development and implementation of electronic health systems (EHS) has brought about significant improvements in healthcare services worldwide. However, many developing countries are yet to fully adopt these systems due to various challenges such as cost, lack of infrastructure, and limited resources. As a result, the use of EHS in these countries remains low, leading to inadequate healthcare services for their populations. This thesis paper focuses on the development of a convenient and low-cost distributed electronic health system for healthcare services in developing countries. The aim of the study is to propose a system that is accessible, affordable, and scalable, taking into account the unique challenges of healthcare service delivery in developing countries.

The methodology of this research involves conducting an extensive literature review to gain insight into existing electronic health systems in developing countries.As a second step, a primary survey was conducted among expert doctors, local doctors, pharmacy owners, and patients to understand the current state of e-health in Bangladesh. The survey results serve as the important methodology behind this research. The study is also involve gathering requirements for the proposed electronic health system by involving stakeholders, including healthcare providers, patients, and other relevant parties. Based on the requirements gathered, the system design is developed, including the user interface, data storage, and security measures. The design is developed with a focus on ensuring that it is scalable, interoperable, and accessible to all stakeholders. Finally, the system is tested using appropriate software development methodologies.

The study is expected to contribute to the body of knowledge on the development and implementation of EHS in developing countries, and provide a basis for further research in this area. The proposed system has the potential to improve healthcare services in developing countries, reduce healthcare costs, and increase access to healthcare for under served populations.

It is hard to guarantee that rural residents in underdeveloped nations receive sufficient care. Because of some unique drawbacks, centralized electronic health systems. It is evident from the underlying research and analysis of literacy that the current healthcare system lacks an electronic healthcare system. Therefore, there are some special criteria that this investigation needs to uncover.

- Each patient needs immediate, independent access to their previous records in the system.
- Patients and healthcare professionals seek affordable data interoperability between healthcare organizations and medical services.
- The patient wants to get their essential and fundamental information accurately and remotely.
- Doctors desire access to information that is real time.
- Any kind of distant center may be linked to the system, and when necessary, centers can speak with one another and promptly obtain the needed data from the anticipated node.

The primary criteria of my suggested model are to create a system with three servers, one of which would act as the main server and have access to any new data added by any other healthcare facility linked to it. It ought to utilize MPI to store a backup. Using the communication network, the community hospital may access each other's data and provide care to patients in rural areas.

3.1.1 Design Specification

The initial phase in the development of any system is its design. System design involves the delineation of the system's architecture, components, modules, interfaces, and data to fulfill predetermined requirements. The application of systems theory to product development is often referred to as systems design. There are similarities between systems design and related fields such as systems analysis, systems architecture, and systems engineering.

The system has been designed with keeping in mind the following key requirements-

- The system should work properly in all the time.
- Clients should be able to quickly and seamlessly use the system
- Doctors should be aware of the present condition of the patients.
- A backup system should be available.
- Provide a simple and user-friendly interface to the client.

3.2 Methodological Steps

This section elaborates on the development and overall design of the e-Health paradigm aimed at improving medical services. Subsequent subsections delve into specific aspects of the system, including the system architecture, the data storage and EHR server module, the data backup system, and the implementation phase. There are some methodological steps in behind this thesis work. The methodology for developing a convenient and low-cost Distributed Electronic Health System for healthcare services in developing countries is given below: The proposed e-Health system's architecture is a distributed, loosely connected system that uses the HL7 standard structure to exchange health information and construct the framework. The architecture comprises multiple health care components, including full clinical workflow, patient records management, laboratory management, medical supply management, and more. The system's components include an HL7-based health system, an EHR server module, user login functionality, and server data backup. The system has two login modules, one for the clients and the other for the local physician. The login module for clients will serve as the distant health-care center for people in rural communities with the required resources. Rural patients will visit a pharmacy or a distant health care service facility for e-Health services. The pharmacy administrator will input the patient's medical history into the health system. The proposed e-Health system uses the CDA framework, created by HL7, as the main foundation for organizing electronic health records. The CDA framework is used to establish the semantics, structure, and how to categorize and arrange health records to communicate data in its many forms. The system's data flow demonstrates how each remote location has a unique e-Health system that is connected to the main or central server. The health care professionals or user here also utilize Tryton to log into the e-Health system. The system also has a backup system available in case of any sort of system failure, so that data may be retrieved from the main server. Overall, this methodology for a practical, convenient, and low-cost electronic health system indicates that the system can be successfully deployed in developing countries to improve healthcare delivery and outcomes.

3.3 Proposed system design

According to reference [46], systems design is the process of specifying the architecture, components, modules, interfaces, and data of a system to meet predefined requirements. Systems design could be seen as the application of systems theory to product development.The system has been designed with keeping in mind the following key requirements-

i. The system should work properly in all the time.
ii. Clients should be able to quickly and seamlessly use the system.
iii. Doctors should be aware of the present condition of the patients.
iv. A backup system should be available.
v. Provide a simple and user-friendly interface to the client.

This system employs the HL7 standard structure to exchange health information and construct the framework because HL7-based e-Health care is a new paradigm based on the usage of distributed computing and interoperability. The system architecture is shown in Fig. 3.1.

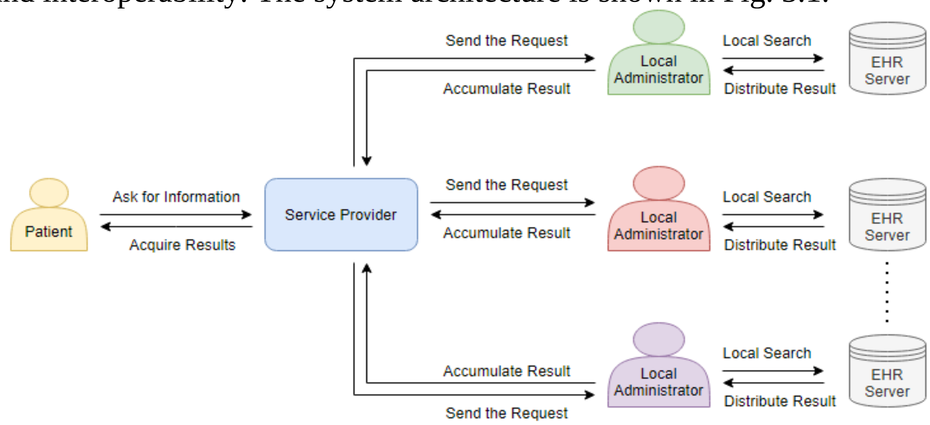


Figure 3.1: Conceptual Design Diagram

The architecture of the distributed e-Health system is loosely connected and isolates the implementation from the interface. Standard protocols are used to link the servers to one another. The "Tryton" client [47] is used to communicate with the GNU Health open source HL7-based e-Health system. Health care components including full clinical workflow, patient records management, laboratory management, medical supply management, and more are now available since Tryton supports hospitals.

3.3.1 Clinical document architecture based on HL7 (CDA)

The CDA framework, created by HL7, is the main foundation for organizing electronic health records. The HL7 CDA[48] is a mark - up framework for healthcare documents that establishes their semantics, structure, and how to categorize and arrange health records in order to communicate data in its many forms.

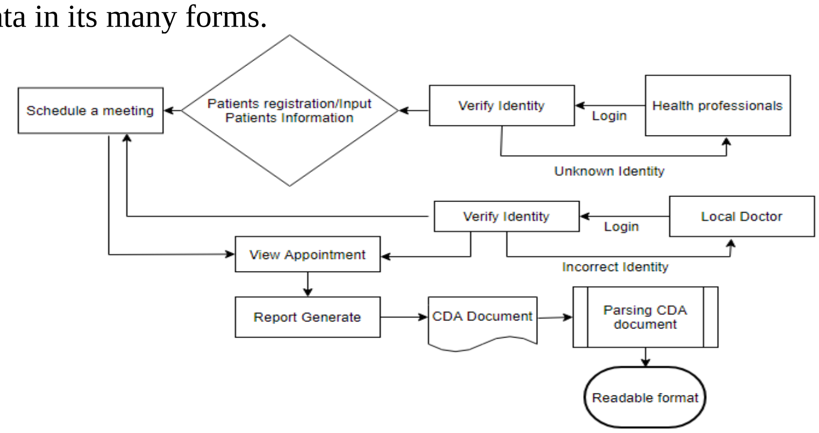


Figure 3.3.1: Conversion flow of XML based HL**7** CDA file to readable format.

The output of the CDA document appears to comprise an XML-based document. The designer can use the layout to create a legible document that provides details on the patient's health by transforming a CDA record to another format. In Figure 3.3.1, the conversion procedure is represented.

3.3.2 The e-Health system's functionality

We have taken into account the local EHR data sources and the search component's architecture, which focuses on the interactions between them. The e-Health system's end users can reach out to the system at any time and from any location for health-related information. The local administrator is then given the request, and the health system administrator organizes its execution. In order to prevent overloading, the health system administrator simultaneously regulates the maximum number of concurrent searches. The request is examined and converted into executable statements by the local administrator before being sent to the e-Health system's local EHR server. On the EHR server, the executable statements are eligible for use.

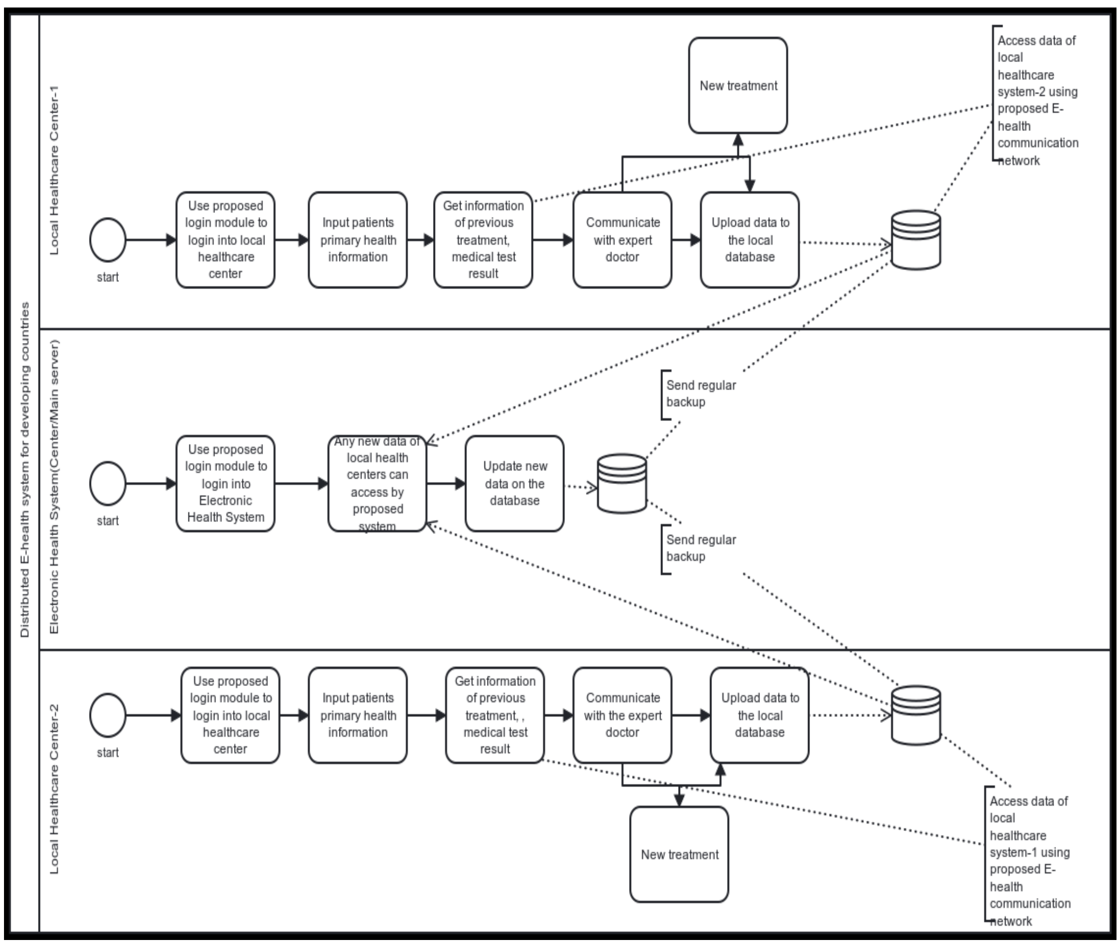


Figure 3.3.2: Functionality of developed e-health system with Business Process Model and Notation(BPMN) diagram

The research's recommended Business Process Model and Notation(BPMN) diagram is shown in figure 3.3.2 above. The local administrator of the EHR server communicates the findings to the healthcare system administrator. The administrator of the health system then compiles the individual findings and provides them to the users. The system's setup allows for loose connection and interoperability between the search interface and health data. Because of this flexibility, individual e-Health systems may be implemented.

Every healthcare facility has a unique health record system that is linked to its own system's database. A network connects each distant healthcare database for the public health record system. Remote populations are served by these healthcare facilities. Health data are interoperable across the board. The centers can exchange data with each other. An electronic health care system will adhere to a set of health system protocols so that data kept in any center may be reliably shared, transferred, and retrieved. The architecture of this method will simplify the data that is utilized in healthcare systems while also making them more adaptable.

3.4 Data flow diagram for the distributed, loosely connected EHR system

A data flow among communication modules is utilized in an architectural schematic to show how the decentralized EHR system was designed and developed. The data flow diagram for the network with n nodes is shown in Figure 3.4. This diagram demonstrates how each remote location has a unique e-Health system that is connected to the main or central server. The health care professionals or user here also utilize Tryton to log into the e-Health system. A center for the delivery of services is regarded to be where health professionals work. Patients may sign up online and submit and collect data from any location. Local doctors may access the system and view the patient's profile, and provide the appropriate prescription to the medical staff based on the patient's issue.

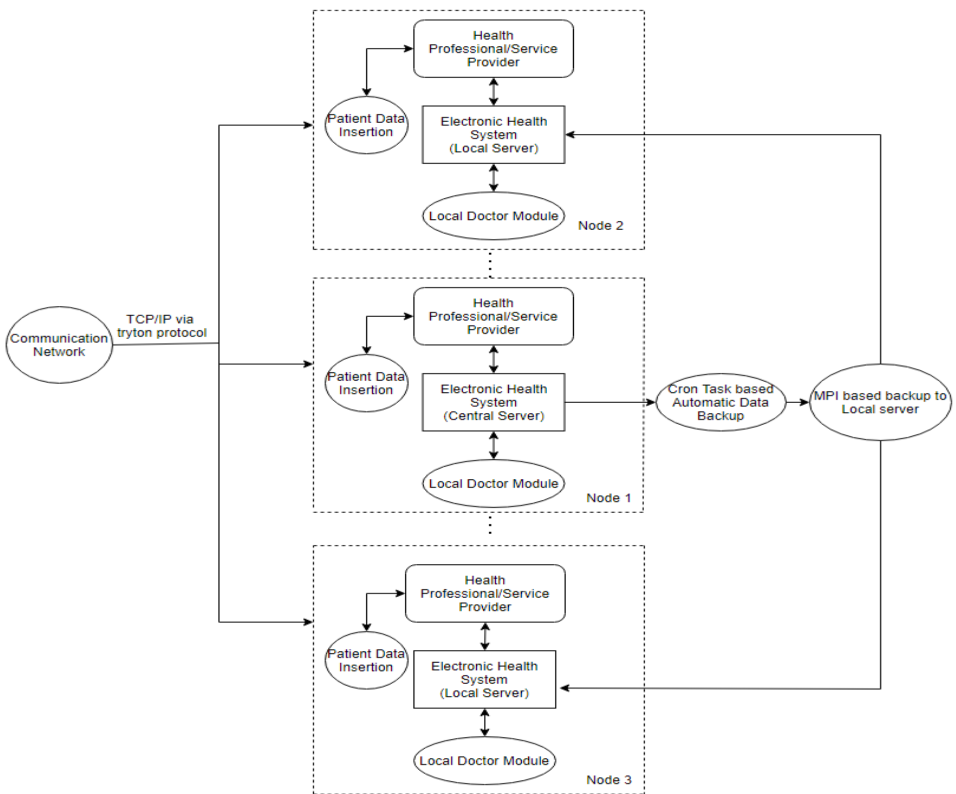


Figure 3.4: Data flow of distributed e-health system

After then, health experts tell the patients. Since the system is distributed, a data backup process is carried out in case of any sort of system failure so that data may be retrieved from the main server.

3.5 The system's components

A variety of components, including an HL7-based health system, an EHR server module, user login functionality, and server data backup, were used to construct the proposed e-Health system. The next subsections include descriptions of the main parts as well as the deployment diagram.

3.5.1 Login module

The system has two login modules, one for the clients and the other for the local physician; the client module will serve as the distant health-care center for the people in rural communities with the required resources. For e-Health services, rural patients will visit a pharmacy or a distant health care service facility. The pharmacy administrator will input the patient's medical history into the health system. We have implemented this module using the procedures below in the Figure 3.5.1 in order to link the service center with the electronic health system for patient identification and service delivery.

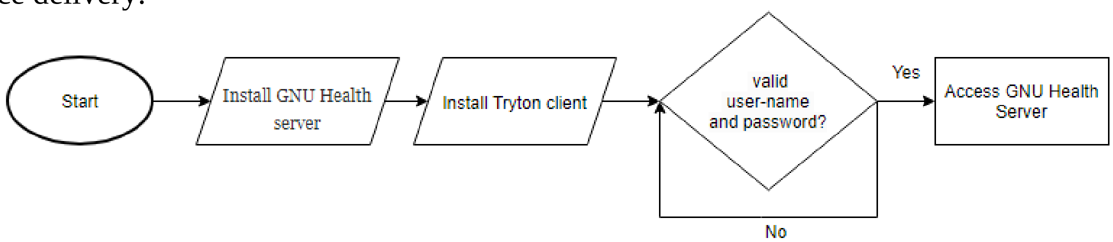


Figure 3.5.1: Login Module

First we need to Install the GNU Health server.Then we have to Install the Tryton client in Step 2. After that Use a legitimate user name and password to log in to the electronic health system. Patients in rural areas receive their primary medical treatment from local doctors. Local doctors will gather patient data after registration and double-check the information before uploading it to the server. Through the health system, local doctors may speak with expert doctors. The following actions were taken in order to implement this module:

Step 1: Sort the patient data in the HL7-based e-Health system logically.

Step 2: Grant patient profile access so that a medication plan may be created.

Step 3: Upload the medication or any further updates to the server.

3.5.2 Server module for electronic health records (EHR)

Each e-Health sub-system in this system has an EHR server module. Data importing techniques for the server are shown in Figure 3.5.2.Using unique patient IDs and test IDs, we are keeping separate fundamental patient data on each server. Each piece of data is distinct and may be utilized for remote EHR services with ease. Primarily, all patient data are kept in a local database, and all local database data are exported to the central server database. The local database is updated if the patient outcome is available. After the patient data on the server has been finalized, we export patient-specific information to the e-Health module for EHR services.

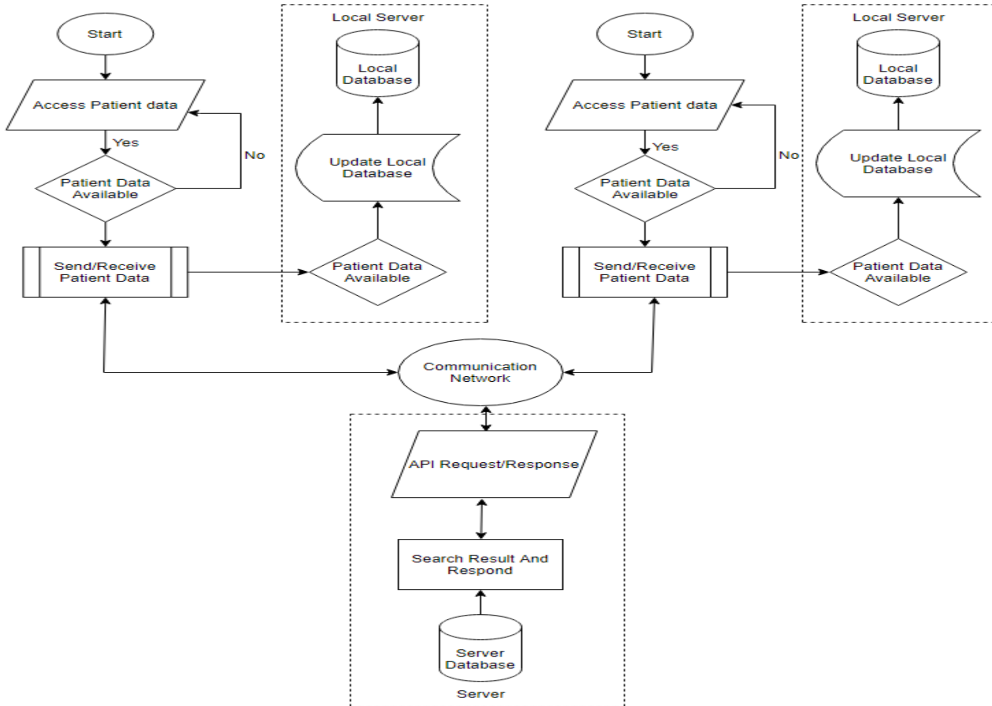


Figure 3.5.2: The ESR server module's flowchart of distributed e-health system.

In our setup, the patient is typically enrolled with a local server. If a patient relocates and still wishes to use our system, they can access the service through the local server at their new location inside the same system. The updated patient data will then be exported back to the primary server.

3.5.3 Proposed Healthcare system with Health Level 7 (HL7)

We used an open source healthcare system built on Health Level Seven International(HL7) to develop our system.The flowchart in Figure 3.5.3. shows the work of Health Level 7 (HL7) in our Healthcare system. In order to meet the needs of developing nations, we have customized the health system. The electronic health care system will contain every electronic health record. Other HL7-based health systems will be able to communicate with the created model.

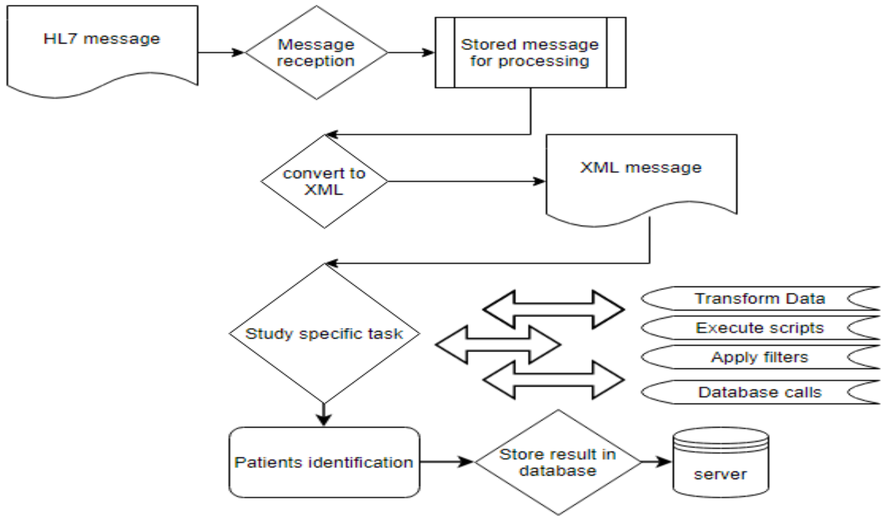


Figure 3.5.3: The flowchart of HL7 for open-source e-health system.

3.6. Security Model for server data storage operation

We utilized the open-source, secure PostgreSQL [49] database to store health data in the server's database securely. Data can be sent, received, and updated by each node.Advanced data types and performance-enhancing tools are only supported by pricey commercial databases like Oracle and SQL Server; however, PostgreSQL has these features built in.We use PostgreSQL because Write-ahead logging in PostgreSQL makes it a very fault-tolerant database.On the other hand, PostgreSQL is easy to maintain and gives a proper security of the stored data.Figure 3.6. shows the security layers in PostgreSQL.

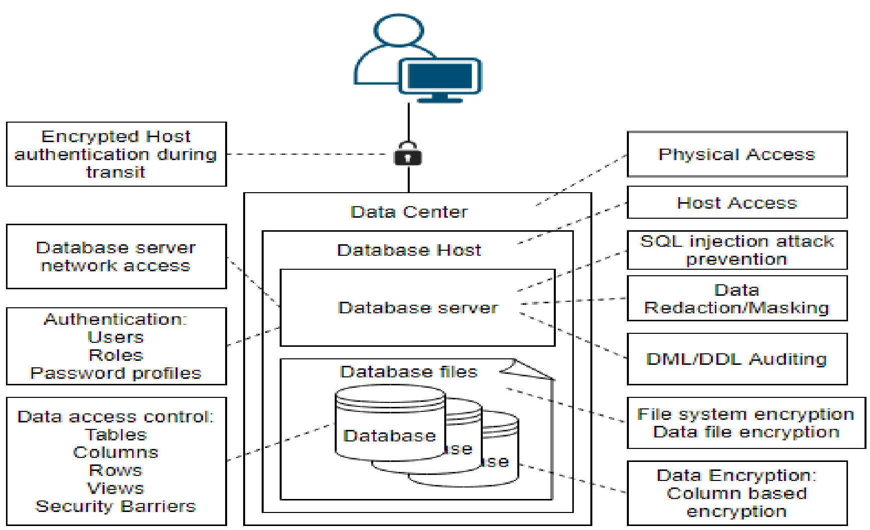


Figure 3.6: Security layers in PostgreSQL to store server data

To bolster security, PostgreSQL provides native support for leveraging SSL connections that encrypt client/server communications, as mentioned in the source referenced by [49]. This necessitates the installation of OpenSSL on client and server platforms, as well as the build-time activation of PostgreSQL support. When referring to a secure encrypted connection that makes use of the TLS protocol, the words SSL and TLS are frequently used synonymous. Although SSL protocols are no longer supported, the word SSL is still used for secure connections because they were TLS's forerunners. TLS and SSL are equivalent terms in PostgreSQL.Thus the security layers of PostgreSQL store, sent, received, and updated the server data by each node securely.

3.7. Backup operation of server data

If a local server of an EHR system fails, it must demand server data backup from the main server.For the backup operation of server data we use PostgreSQL with cron job, Secure Shell (SSH) and Message Passing Interface (MPI)[50].
It is important that we take regularly scheduled backups of our PostgreSQL data server and control how many backups we keep, this process referred to as "backup retention".We know that Replicas are not equivalent to backups. We may schedule routine backups and establish retention policies using the PostgreSQL Operator, which employs the aforementioned free and open-source pgBackRest backup and restore tool. We can make sure we are running a healthy production PostgreSQL server by automating backups and adjusting backup retention settings. In essence, the PostgreSQL Operator Scheduler is a cron[51] server that executes tasks that are provided. The cron syntax is used by schedule commands to create scheduled jobs.Figure 3.7 shows the data backup operation of server data using PostgreSQL.

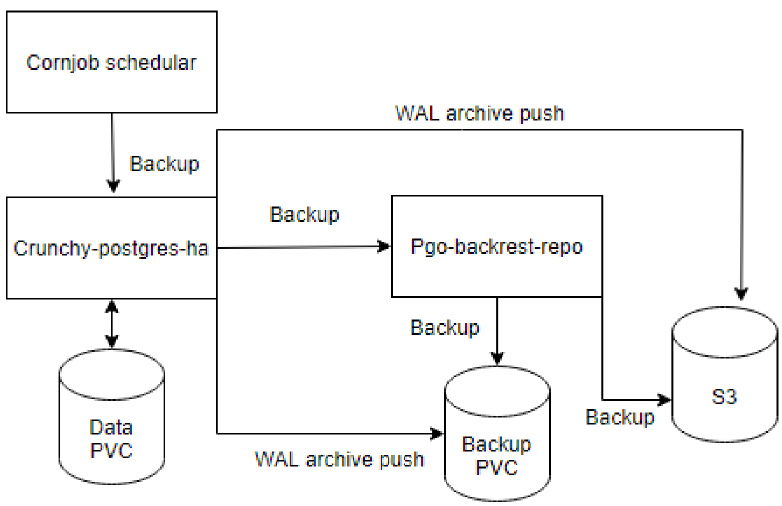


Figure 3.7: The data backup operation of server data using PostgreSQL.

PostgreSQL Operate with the help of the utility application Cron, users may provide instructions for repeating scheduling activities for a given period. Cron jobs are the tasks that are scheduled in cron. Users may choose the type of work they wish to automate and the best time for it to run.Users may automate system upkeep, disk space monitoring, and backup scheduling with cron tasks. Figure 3.8 shows the automatic backup operation of cronjob.

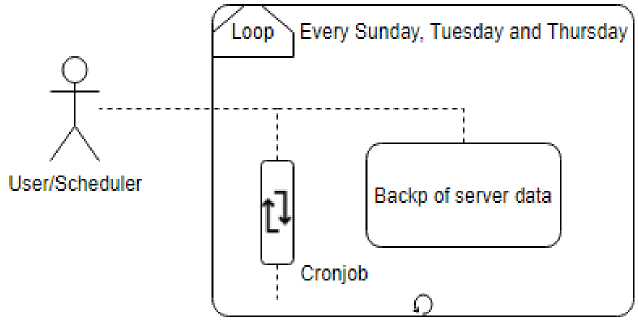


Figure 3.8: Cronjob as a Automatic backup scheduler.

To schedule the execution of their scripts, a root user can transfer the scripts into the following directories: 1. Execute each script once per hour, 2. Exercise every day, 3. Run once a week, 4. Run once a month.We use cron job to make the backup of the server automatic and it keep the backup of the server on Sunday, Tuesday and Thursday. We can make it daily or monthly according to the user demand.

3.8. Transferring Backup file to local servers

Although Secure Copy Protocol(SCP)[52] and Secure File Transfer Protocol (SFTP)[53] are available for file transfers, there is no method to transmit a file back and forth between local and remote hosts without opening a new program on the local system or signing in from the distant machine to the local machine.A well-liked technique of transferring data between servers is by utilizing SFTP or SCP to transfer files over an SSH connection[54].Installing SSH File system (SSHFS)[55] is required in order to mount a remote directory using only SSH. First we install the SSHFS and then mount the server backup data remotely from main server to the local healthcare server. In order to restore data for a system and assist in the creation of a new one, the "Message Passing Interface (MPI)" module executes server data backup procedures. The following stages represent a step-by-step summary of the complete MPI-based data backup process:
Initialize the MPI runtime environment in Step 1, which is the initial call that every MPI program may make using MPI Init (&argc,&argv).In Step 2 Use "sshpass -p "REMOTE USER PASSWORD" scpfile.sqlremote username@ remote ip:/remote/directory" to declare and set an integer variable r, and Print (r).The function MPI Comm size(MPI Commcomm, int *size), which returns the number of concurrent processes in the group that works with a communicator, returns the total number of processes in the group.Send a message to confirm backup.Then Send a message to confirm backup.MPI program is shut down by the MPI_Finalize().

3.9. Distribution diagram of the established e-Health System

Here, the created system is also represented by a deployment diagram. The implementation diagram for the created loosely connected distributed EHR system is shown in Fig. 3.9. Remote rural areas with internet connection will use the designed distributed EHR system. We have taken into account pharmacies as EHR service distribution hubs. The server component consists of an EHR server used as the primary repository for crucial medical data. Pharmacy administrators can interact with the healthcare system via Tryton. Through the pharmacy module, remote users will be able to interact with the e-Health system.

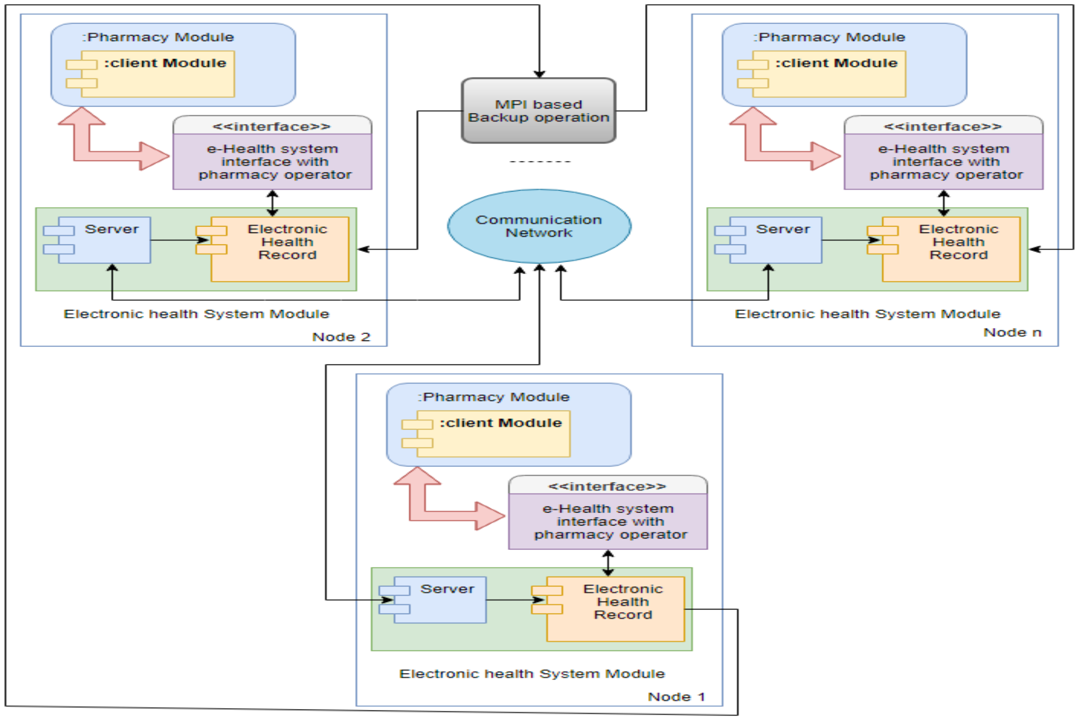


Figure 3.9: Distribution diagram of the established e-Health System.

3.10. Development of the system

We created the system using the methodology and system design. Three nodes (see Fig. 3.10.1) have been employed to provide a distributed environment for the system's actual implementation. Node 1 is regarded as the main server, while the other nodes are regarded as local servers. Every node has a separate e-Health system. For each node, we have set up an open source e-Health system based on HL7. Each node in this system has been viewed as a loosely connected distributed center for remote health care. The electronic health systems contain all of the electronic health records. In our architecture, the primary server houses all of the nodes' data.Data are recovered from the central server in the event that the local server's storage fails. On a centralized server that is dispersed and reachable from any place with a healthcare facility, the e-Health system is housed. A communication network connects the servers.

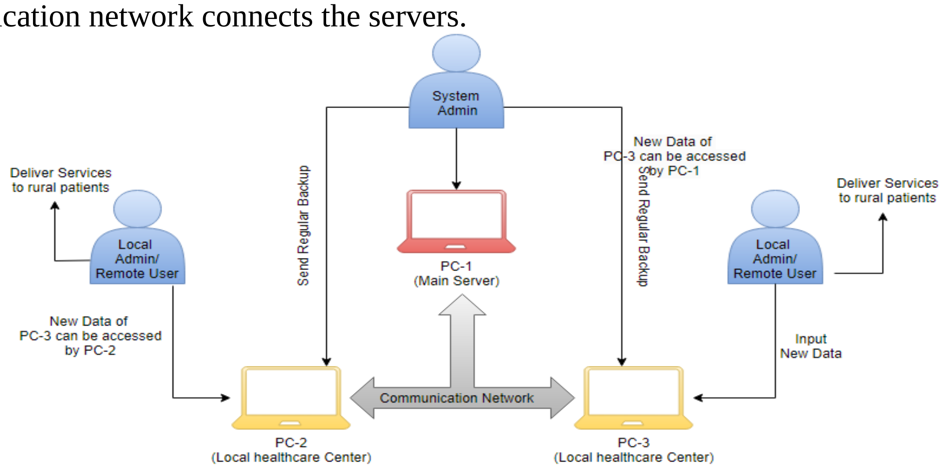


Figure 3.10.1: System Block diagram of the Results of the developed e-Health system.

The storing of frequent data backups is important for a distributed e-Health system. For the backup operation of server data we use PostgreSQL with cron job, Secure Shell (SSH) and Message Passing Interface (MPI). In this case, MPI is utilized for the backup process, which stores data on the primary server. The results of the system's implementation guarantee the distributed properties of the e-Health system, which are briefly discussed in the results and discussion section.

3.12 Work Flow:

To develop the proposed system we follow some steps. Those are given below:

First we have to install Gnu-health[56] in our nodes. Some of the key facilities and resources offered by GNU Health include:

Facilities:

1. Patient Registration: This feature allows healthcare institutions to efficiently capture and store patient demographic information, reducing the time and effort required to manage patient records.

2. Appointment Scheduling: The appointment scheduling feature enables healthcare institutions to manage patient appointments, reducing wait times and improving patient experience.

3. Medical History Tracking: This feature provides a comprehensive view of the patient's medical history, including past treatments, diagnoses, and medication information, which helps healthcare providers make informed treatment decisions.

4. Health Alerts: The health alerts feature informs healthcare providers of important health information, such as allergies, adverse reactions to medications, or chronic conditions, reducing the risk of adverse events.

5. Clinical Decision Support: The clinical decision support feature provides evidence-based treatment recommendations and drug interaction warnings, helping healthcare providers make informed decisions.

Resources:

1. Electronic Health Records: The system provides a secure and centralized repository for patient health information, enabling healthcare providers to access and update patient information from anywhere.

2. Reporting and Analytics: The reporting and analytics capabilities in GNU Health allow healthcare institutions to track patient outcomes, monitor the performance of the healthcare system, and identify areas for improvement.

3. Mobile Access: The system provides mobile access to patient information, enabling healthcare providers to access and update patient records from anywhere, at any time.

In conclusion, the facilities and resources provided by GNU Health help to improve the delivery of quality healthcare services and enhance the overall experience for both patients and healthcare providers.

3.13.1 GNU Health installation

Requirements:

The most recent stable GNU Health Federation ecosystem makes use of the following primary resources:

- Operating system: GNU/Linux for the server.
- PostgreSQL >= 10.x
- Python: >= 3.6
- Gunicorn : 19.9
- Flask : 1.0
- Tryton 6.0
- Bash shell
- PIP for Python 3

Creating the Operating System User

The GNU Health operating system user will be created by the subsequent procedures. Do it right now. As root, execute the following command:

adduser gnuhealth

Verify PostgreSQL authentication method

PostgreSQL employs a variety of authentication techniques (MD5, ident, trust ...). The mechanism used by the PostgreSQL server for authentication varies depending on the Operating System.

We must examine the setup of the postgreSQL authentication file because the default GNU Health installation use the trust authentication technique.

Find the pg hba.conf file and make sure the trust method is configured there. The location of this configuration file differs between operating systems; on UNIX/Linux, the following command, which must be run as root, will return the file's entire pathname:

su - postgres -c "psql -t -P format=unaligned -c 'show hba_file'"

Because this file could be produced on the first startup, we might need to start the Postgres server at least once. Typically, this file may be found at either */var/lib/pgsql/data* or */etc/postgresql/10/main*.

The following line provides an example configuration file entry that specifies usage of the trust method:

local all all trust

The example that follows in particular should help with connection problems that were reported when the Tryton client was used for the first time to create the GNU Health database (see below; Symptom: the "Create" button is not visible):

host all all 127.0.0.1/32 trust

host all all ::1/128 trust

To change the file, we must do it as the user "postgres," not root. If not, Postgres can encounter problems opening the modified file. The postgreSQL server has to be restarted whenever any modifications are made to the file.

sudo service postgresql restart

Creating the Database User

My freshly formed gnuhealth administrator is granted rights by the following command, which switches to the postgres administration user:
Activate as root:

su - postgres -c "createuser --createdb --no-createrole --no-superuser gnuhealth"

Downloading and Installing GNU Health

Launch the GNU Health Installer and log in as gnuhealth.

su - gnuhealthcd
$HOME

Download GNU Health from GNU.org

Afterward, use the matching version number for the most recent to validate the signature. For instance, download the detached signature if the most recent version of GNU Health is 4.0.4:

wget https://ftp.gnu.org/gnu/health/gnuhealth-4.0.4.tar.gz.sig

Use the detached signature to validate the package:

gpg --verify gnuhealth-4.0.4.tar.gz.sig gnuhealth-latest.tar.gz

Uncompress GNU Health HMIS package

tar xzf gnuhealth-latest.tar.gz

Change to the GNU Health installation directory matching our version

cd gnuhealth-4.0.4

Download the latest GNU Health installer

wget -qO- https://ftp.gnu.org/gnu/health/gnuhealth-setup-latest.tar.gz | tar -xzvf -

Run the GNU Health installer

bash ./gnuhealth-setup install

Enable the BASH environment for the GNU Health admin

The gnuhealth user should then have access to the BASH environment.

source ${HOME}/.gnuhealthrc

Activate Network Devices for the JSON-RPC Protocol

The Tryton GNU Health server blocks direct connections from other workstations and waits on localhost at port 8000.
To enable the network device so that workstations in our network may connect, we can update the parameter listen in the [web] section. For instance, the block of text after

[web]
*listen = *:8000*

will enable connections to the server in our system's various devices.

Initialize the database instance

Creating the database

createdb health

Switch to our recently set-up system (using the alias cdexe):*cdexe*

as well as creating the instance:

python3 ./trytond-admin --all --database=health

The "admin" account will require a password, which we must supply.
We are prepared to launch the GNU Health HMIS node server if all goes according to plan.

Creating a Systemd service for the GNU Health server

GNU Health service unit file

Create the GNU Health Unit file under /usr/lib/systemd/system/gnuhealth.service:

Starting and Stopping the GNU Health service

we can issue the commands:

systemctl start gnuhealth

or:

systemctl stop gnuhealth
then
systemctl enable gnuhealth

Installation of the GNU Health Client

Requirements

GNU Health Client installation with pip3

- Update PATH. To make changes permanent, add this line in $HOME/.bashrc

    $ export PATH=$HOME/.local/bin:$PATH

- Update pip3

    $ pip3 install --upgrade --user pip

- Install GNU Health client

    $ pip3 install --user --upgrade gnuhealth-client

The following command will boot our GNU Health client:

gnuhealth-client

Logging into the Application

We now fill out the login form after returning to the login screen:
Username: the one we previously used (usually admin)
• Password: the one you double-entered in the part before

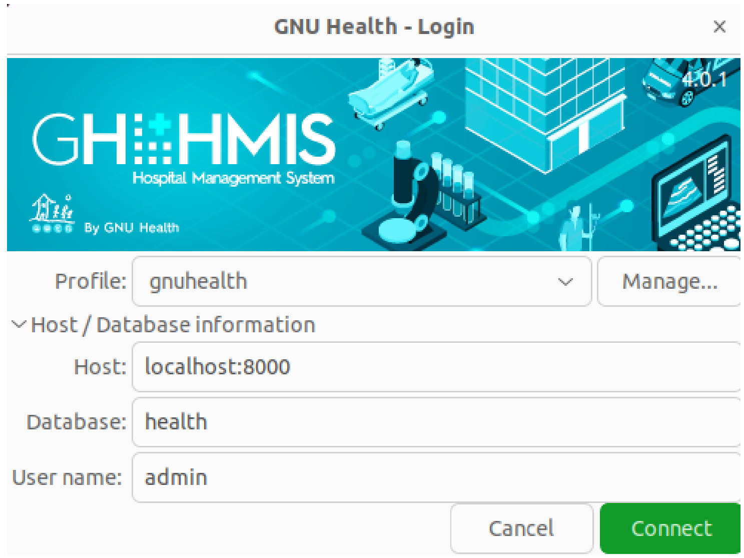


Figure 3.13.1: Login Screen

Installing the Default Modules

From this point on, practically every step will include the client. Install the foundational functionality first:

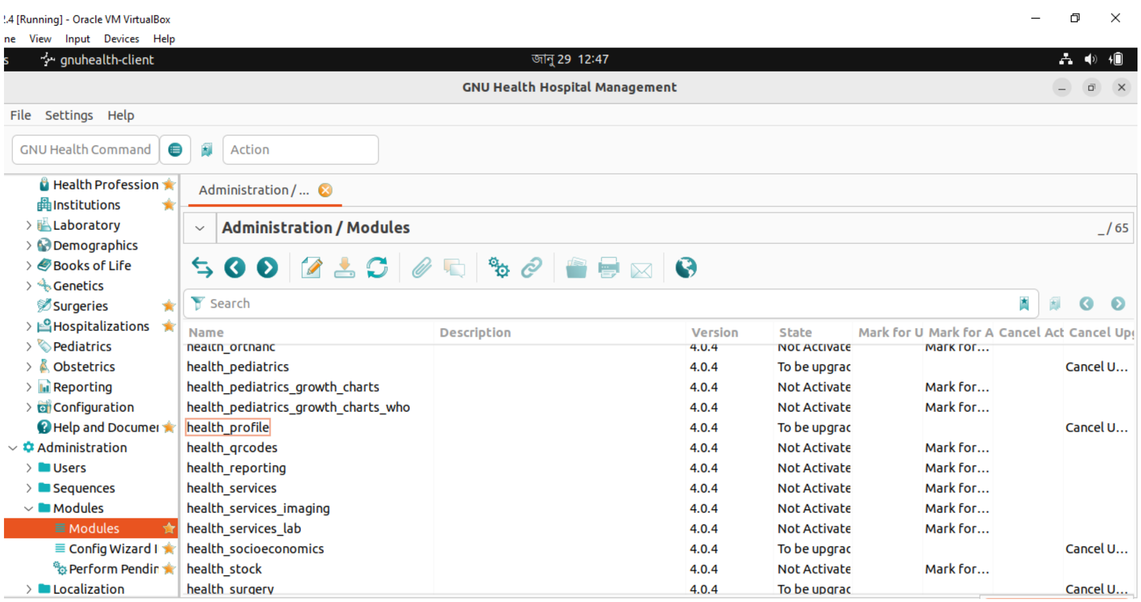


Figure 3.13.2: *Mark for installation* button for *health_profile*

The system will request the creation of new users when the database has been built.

All the modules of gnu health

GNU Health is a free and open source electronic health record (EHR) and hospital information system (HIS). It is designed to assist health professionals in providing quality health care services to their patients. The system is built on top of the Tryton application platform, which provides a robust and flexible framework for developing custom modules to meet specific needs.

The core modules of GNU Health include patient management, clinical encounters, appointments, laboratory, radiology, and pharmacy. These modules allow health professionals to easily manage patient information, track clinical encounters, schedule appointments, and manage lab and radiology results. Additionally, the pharmacy module allows for the management of medication prescriptions and dispensing.

One of the unique features of GNU Health is its integration with other systems. For example, it can be integrated with a hospital's existing laboratory information system (LIS) to automatically import lab results. This can greatly improve the efficiency and accuracy of patient care by reducing the need for manual data entry.

Another unique module of GNU Health is the health economics module, which allows health professionals to track the financial aspects of patient care. This can include tracking costs associated with medications, laboratory tests, and other treatments. This information can be used to improve the overall efficiency of the healthcare system and reduce costs for patients.

GNU Health also has a number of additional modules that can be added to the system to meet specific needs. For example, there is a module for managing epidemiological data, which can be used to track and analyze data on communicable diseases. Additionally, there is a module for managing mental health patients, which can help mental health professionals provide better care to their patients.

Overall, GNU Health is a powerful and flexible system that can be customized to meet the needs of any healthcare organization. Its core modules provide a strong foundation for managing patient care, while additional modules can be added to meet specific needs. The system's integration capabilities and ability to track the financial aspects of patient care make it a unique and valuable tool for healthcare professionals.

The Core Module

The Core Module of GNU Health is the foundation of the Health and Hospital Information System. It is the central component that manages the patient health records and provides a comprehensive view of the patient's medical history.

The Core Module includes features such as patient registration, demographic information management, appointment scheduling, medical history tracking, and health alerts. It also facilitates communication between healthcare providers by enabling the exchange of patient information and medical records between different departments and healthcare facilities.

The module has a user-friendly interface, making it easy for healthcare providers to access and update patient information. This helps to ensure that the latest and most accurate information is always available, leading to improved patient outcomes.

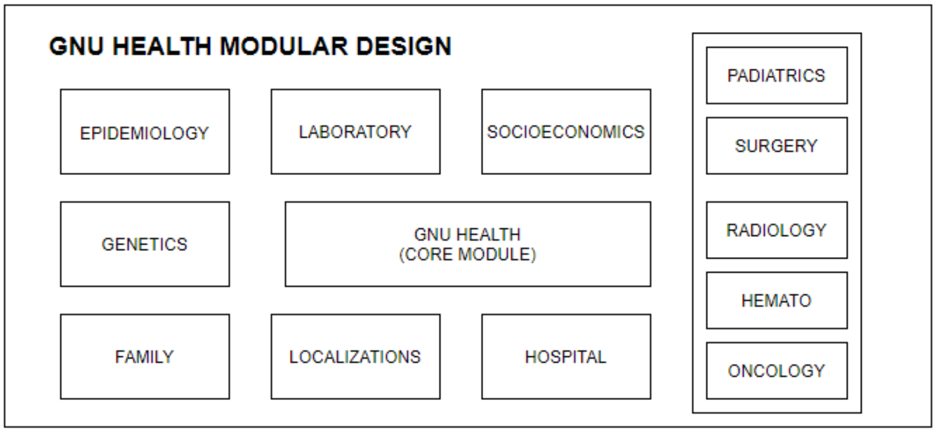


Figure 3.13.3: GNU Health modular design

Another important feature of the Core Module is its ability to integrate with other modules within the GNU Health system. This allows for seamless transfer of patient information between different departments, reducing the risk of errors and ensuring that the most up-to-date information is always available to healthcare providers.

Some of the models found in the core module are:

- Individuals
- Families
- Domiciliary Units
- Operational Sectors
- Health Centers
- Diseases
- Patient
- Patient Evaluation / Encounters
- Medicaments
- Treatments

In conclusion, the Core Module of GNU Health is a critical component of the Health and Hospital Information System, providing a comprehensive and centralized view of patient health records and facilitating communication between healthcare providers. Its user-friendly interface, ability to integrate with other modules, and ability to track patient medical history make it an essential tool for improving patient outcomes.

3.13.2 Creating and Updating Health Institutions

GNU Health provides the ability to manage and configure various facilities and resources within a health institution. The process involves creating records for each of the facilities, such as beds, buildings, wards, operating rooms, and units.

Beds : Beds are a fundamental facility in a health institution and can be managed in the Health → Configuration → Institutions → Beds section. To configure a bed, we need to create a product record for the bed category, a product variant record for each physical bed, and a bed record for each bed that stores additional information such as its status, and ward.

Buildings: Buildings have a name and a code, which must be unique within a health institution. Buildings can be managed in the Health → Configuration → Institutions section.

Wards: Wards belong to one building and one unit, and can be managed in the Health → Configuration → Institutions → Wards section. When configuring a ward, we will enter information such as its name, building, floor, unit, gender, capacity, and features such as telephone access, air conditioning, and private bathroom.

Operating Rooms: Operating rooms belong to a building and unit and can be managed in the Health → Configuration → Institutions → Operating Rooms section. To configure an operating room, we need to enter its name, building, and unit, and any additional information can be stored in the Extra Info field.

Units: Units have a name and a code, which must be unique within a health institution. Units can be managed in the Health → Configuration → Institutions section.

In conclusion, the facilities and resources within a health institution in GNU Health can be managed and configured with ease. Each facility or resource has its own form for managing its specific information, making it simple to keep track of all the information and minimize errors.

3.13.3 The Individual

In GNU Health, the core unit is the person. This entity represents a unique individual who is part of a family, interacts with the community, and contributes to society. Accurate information about individuals is crucial for effective public health programs and should not be overlooked, despite its apparent simplicity.

3.13.4 Patient Management

Introduction to Patient Management Patients are unique parties with specific characteristics that distinguish them from other parties.Within the context of GNU Health, it is possible for an individual to simultaneously act as both a health professional and a patient.

Creating a Patient Party Depending on the size of your healthcare center, patient creation may be handled by different teams. We'll go through the steps of creating a patient party using the example of "Ana Betz".

Step 1: Define the Party and Demographics

The health professionals enters information about Ana, such as her family, domiciliary unit, and contacts, to create a person. Ana may or may not become a patient at a later point, for example if she visits the primary care center for a health checkup.

Step 2: Enable the Patient Attribute

When Ana visits the primary care center, she provides her Social Security Number or other unique identifier. This enables the patient attribute in the party, making Ana a patient in the health system.

Accessing the Patient List The patient main menu can be accessed from Health → Patients → Patients. This menu displays all patients, or parties with the patient attribute and a patient record. we can search for patients using any field in the tree view and edit a patient record if we have permission.

Creating a Patient Record To create a patient record, click the new record icon or press Ctrl + N. The first and required field is the link to the party created in the previous step.

3.13.5 Patient Appointment and Admission Management

Revised: Patient Appointment and Admission Management Appointments Information The appointment form in GNU Health records the following information for each appointment:

- Appointment ID
- Patient
- Type of Appointment
- Level of Emergency
- Date
- Specialty
- Health Professional
- Health Center

Appointment Listing From the main menu in Health, we can access the Appointments section to view a list of all appointments in the system. The list is divided into two tabs:

- Free tab: shows available time slots for new appointments
- Confirmed tab: shows all confirmed appointments

Appointment Calendar The Appointments Calendar allows us to view all appointments in a calendar format.

Appointment Report The Appointments Report shows appointments by a specific health professional within a specified time period.

Patient Appointment Listing To view a list of appointments for a specific patient, go to the patient's record and click the "Relate" button, then select "Appointments."

3.13.6 Hospitalization Management in GNU Health

From the main menu, access the Hospitalization section to manage all actions related to patient admission and discharge. In a new Hospitalization record, there are tabs for collecting:

- Administrative Data: Enter administrative info about admission
- Nutrition: Input patient's diet and belief information
- Medication: Detail medication during admission
- Care Plan: Record nursing and discharge plans

3.13.7 Prescriptions in GNU Health

Prescriptions can be found in two places in GNU Health: the Health → Prescriptions section, or by opening a patient record and using the Relate button to switch to Prescriptions.

Information in each Prescription Each Prescription record holds general information, including:

- Patient (mandatory)
- Prescription ID
- Prescription Date
- Prescribed by (health professional)
- Pharmacy
- Pregnancy Warning
- Prescription Verified

Prescription Lines Information on medicaments can be found in the Prescription Lines section. Each line includes:

- Medicament
- Indication
- Allow Substitution
- Print
- Form
- Administration Route
- Start/End Date & Time
- Dose/Dose Unit
- Times/Frequency/Admin Hours
- Unit (Seconds, Minutes, Hours, Days, Weeks, or "When required")
- PRN
- Treatment Duration/Period (Minutes, Hours, Days, Weeks, Months, Years, or Indefinite)
- Review Date & Time
- Units
- Refills #
- Comment

3.13.8 Birth Certificates in GNU Health

- Part of Vital Record System in GNU Health
- Link person to official document with information used in most countries
- Date of birth taken from person or neonatology (if pediatric module installed)
- Access through people (party) model or Health → Demographics → Birth certificates
- Stores person name, date of birth, mother/father, institution, country/subdivision, and observations
- Default state is Draft, sign to switch to Signed state with certifier name, date/time

3.13.9 Death Certificates in GNU Health

- Key document with legal, administrative, demographic, and epidemiological significance
- Similar to birth certificates, but with more information on cause/circumstances of death
- Access through Party model or Health → Demographics → Birth certificates
- Stores person name, date of death, place of death, health institution, cause of death, type of death, autopsy, code, and observations
- Default state is Draft, sign to switch to Signed state with certifier name, date/time
- Digital signatures recommended for legal value and document verification
- Health cryptography module (health_crypto) verifies changes and allows signature with private key.

3.14. Automate PostgreSQL Backups using a Cron Task

1. Log in as the postgres user:

```
su - postgres
```

1. Create a directory to store the automatic backups:

```
bash
mkdir -p ~/backups
```

1. Edit the crontab to create a new cron task:

```
crontab -e
```

1. Add the following line to the end of the crontab:

```
0 0 * * 0 pg_dump -U postgres dbname > ~/backups/dbname.bak
```

The database will be backed up every Sunday at midnight. To adjust the schedule, refer to the guide "Schedule Tasks with Cron".

1. To check the status of your backups, you can set up error logging: a. Create a directory to store log files:

```
bash
mkdir -p ~/logs
```

b. Modify the cron task to append any backup errors to a log file:

```
0 0 * * 0 pg_dump -U postgres dbname > ~/backups/dbname.bak 2>>
~/logs/dbname.bak.log
```

c. To receive email alerts for errors, make sure mailx is installed and enabled for the postgres user. Then, add the following to the cron task:

```
0 0 * * 0 pg_dump -U postgres dbname > ~/backups/dbname.bak 2>>
~/logs/dbname.bak.log || tail -1 ~/logs/dbname.bak.log | mailx
'example@linode.com' -s "Postgresql backup failure!"
```

Now, if there are any errors during the backup process, you will receive an email with the error message.

3.15. Installing OpenMPI

Step 0: Create user and set ip address

Step 1: Install ssh (ssh server and ssh client for all machines)

Step 2: Install nfs (nfs server on master, nfs client on nodes)

Step 3: Install OpenMPI in all machines

Step 4: Test

Step 0

Create user account for MPI and work on it

sudo adduser mpiusersudo usermod -aG sudo mpiusersu mpiuser

Add all the hosts to server. Examples:

sudo nano /etc/hosts

Then add hostnames and ip addresses on Master machine.

Master machine is azcos1; others are worker nodes(azcos2, azcos3,azcos4,5,6)

127.0.0.1 localhost

10.1.20.1 pc1

10.1.20.2 pc2

Step 1 — Install ssh

Run update for all

sudo apt-get update

sudo apt-get upgrade

2. Check ip addr and run

sudo apt-get install net-toolsifconfig

3. Install ssh server and client for all machines

sudo apt-get install openssh-server openssh-client

4. Create directory .ssh for all machines, run

mkdir ~/.ssh

chmod 700 ~/.ssh

5. Generate ssh keys for passwordless ssh (on Master machine)

cd ~/.sshssh-keygen -t rsacp id_rsa.pub authorized_keyschmod 600 authorized_keysssh-copy-id azcos2 (hostnames of all node machines, azcos3, azcos4, azcos5, azcos6)

6. Node machines — do it all nodes

cat id_rsa (do it on master machine)vi id_rsa (paste it here)chmod 600 id_rsavi authorized_keyschmod 600 authorized_keys

7. Edit sshd_config file and restart ssh server

sudo nano /etc/ssh/sshd_config

Add this two lines.

PubkeyAuthentication yes

RSAAuthentication yes

Then restart ssh server.

sudo service ssh restart

8. Try to ssh the nodes without password

ssh azcos2 (and others)

Step 2 — Install nfs

Install NFS server on master machine

sudo apt-get install nfs-kernel-server

2. Create a directory and run:

sudo apt-get install nfs-kernel-serversudo chown nobody:nogroup /home/mpiuser/Desktop/sharedfoldersudo chmod 777 /home/mpiuser/Desktop/sharedfolder

3. Export files

sudo nano /etc/exports

then add these lines, save:

/home/mpiuser/Desktop/sharedfolder azcos2(rw,sync,no_subtree_check)

/home/mpiuser/Desktop/sharedfolder azcos3(rw,sync,no_subtree_check)

/home/mpiuser/Desktop/sharedfolder azcos4(rw,sync,no_subtree_check)

then

sudo exportfs -a

4. Restart NFS server, run

sudo systemctl restart nfs-kernel-server

5. Check firewall status(inactive), type:

sudo ufw status

6. We should install nfs client to all the nodes.

sudo apt-get install nfs-commonsudo mkdir -p /home/mpiuser/Desktop/sharedfoldersudo chown nobody:nogroup /home/mpiuser/Desktop/sharedfoldersudo chmod 777 /home/mpiuser/Desktop/sharedfoldersudo mount azcos1:/home/mpiuser/Desktop/sharedfolder /home/mpiuser/Desktop/sharedfolder

7. Then test nfs

You can create a file in /sharedfolder. You can see this file on all machines where /home/mpiuser/Desktop/sharedfolder.

Step 3 — Install OpenMPI

1. Install gcc for all machines, run:

sudo apt-get install gccsudo apt-get install openmpi-bin openmpi-common libopenmpi-dev libgtk2.0-dev

2. Download and decompress file openmpi for all machines:

sudo wget https://www.open-mpi.org/software/ompi/v4.1/downloads/openmpi-4.1.1.tar.gzsudo tar -xvzf /home/mpiuser/openmpi-4.1.1.tar.gz

3. install OpenMPI for all machines

cd /home/mpiuser/Desktop/openmpi-4.1.1sudo ./configure --prefix="/home/mpiuser/.openmpi"

sudo make

sudo make install

4. Export PATH, run:

export PATH=”$PATH:/home/mpiuser/.openmpi/bin”export LD_LIBRARY_PATH=”$LD_LIBRARY_PATH:/home/mpiuser/.openmpi/lib”

5. Test by running mpirun or mpircc

Step 4 — Test

Compile mpi program

Go to the link , copy the code and paste it here:

vi mpi-prime.c

Compile mpi file.

mpicc mpi-prime.c -o ./outputfile

copy outputfile to the sharedfolder & check the file in the nodes sharedfolder

2. Run cluster

Go to shared folder on master machine, run:

cd /home/mpiuser/Desktop/sharedfoldermpirun --hostfile /etc/hosts -np 5 ./outputfile

This is the proccess of installing SSH and MPI for autometic backup operation.

CHAPTER 4

RESULT AND DISCUSSION

4.1. Introduction

The main goal of this research is to develop a standard electronic health system that is both convenient and low-cost for healthcare services in developing countries. The system will be designed to address the challenges that developing countries face in implementing electronic health systems, such as limited resources and infrastructure. The system will also be tailored to meet the specific needs of healthcare providers and patients in these countries. In this section, we will discuss the results and findings of the research and development process, as well as the implications and potential impact of the developed system on healthcare services in developing countries.

4.2. Result and Discussion

Results measure how successful we are to reach our target. It's particularly important to measure results in research.

In this work, we have developed a suggested low-cost distributed EHR with loose coupling. In each healthcare facility, we have an electronic health system (EHS) that is HL7 compliant. Each center has an independent e-Health platform that is linked through a communication network. The Tryton client for databases allows users to do all administrative operations, including creating, deleting, backing up, and restoring data. Using personal computers at a healthcare facility, we set up a distributed environment for testing in which one computer serves as the main server and the others as local servers. The important results are listed below:

i. A complete free Hospital Management System including- Doctor module, Nurse module, patient module, laboratory module, Surgery module, Service Provider module etc.
ii. Easiest and low-cost HL7 based loosely coupled distributed system that ensures accessible from anywhere and at any time, interoperability(figure 4.1), affordable, high quality and safe health facilities with a strong security of data.
iii. Proper and secure backup of data(figure 4.3).
iv. To improve the accuracy and speed of diagnosis and avoid repeating unnecessary tests.
v. Patients may obtain any sort of update or recover their record from the local healthcare center of their area when necessary, thus it is not necessary for them to shift their geographic location. If a new record is uploaded or any information is modified in a neighborhood medical facility, the update will be accessible in every other medical facility linked to the e-Health network(figure 4.1).
vi. System will have the properties of resource sharing, openness, concurrency, local autonomy, improved performance, reliability and availability.

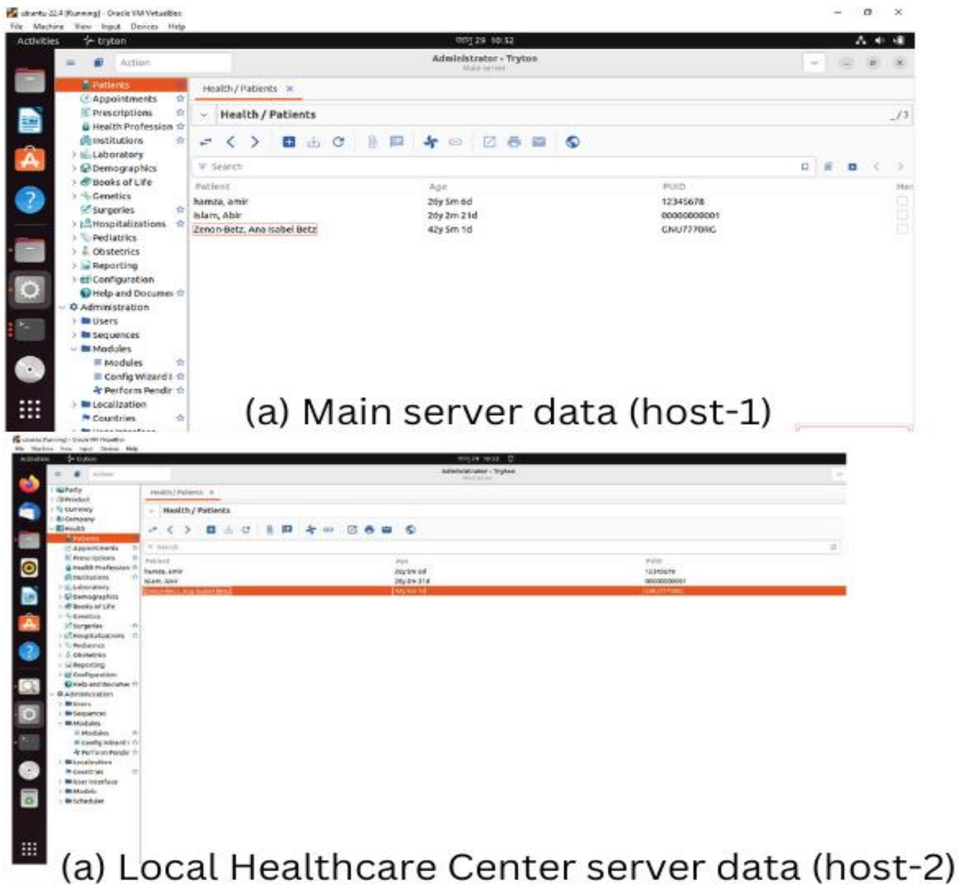


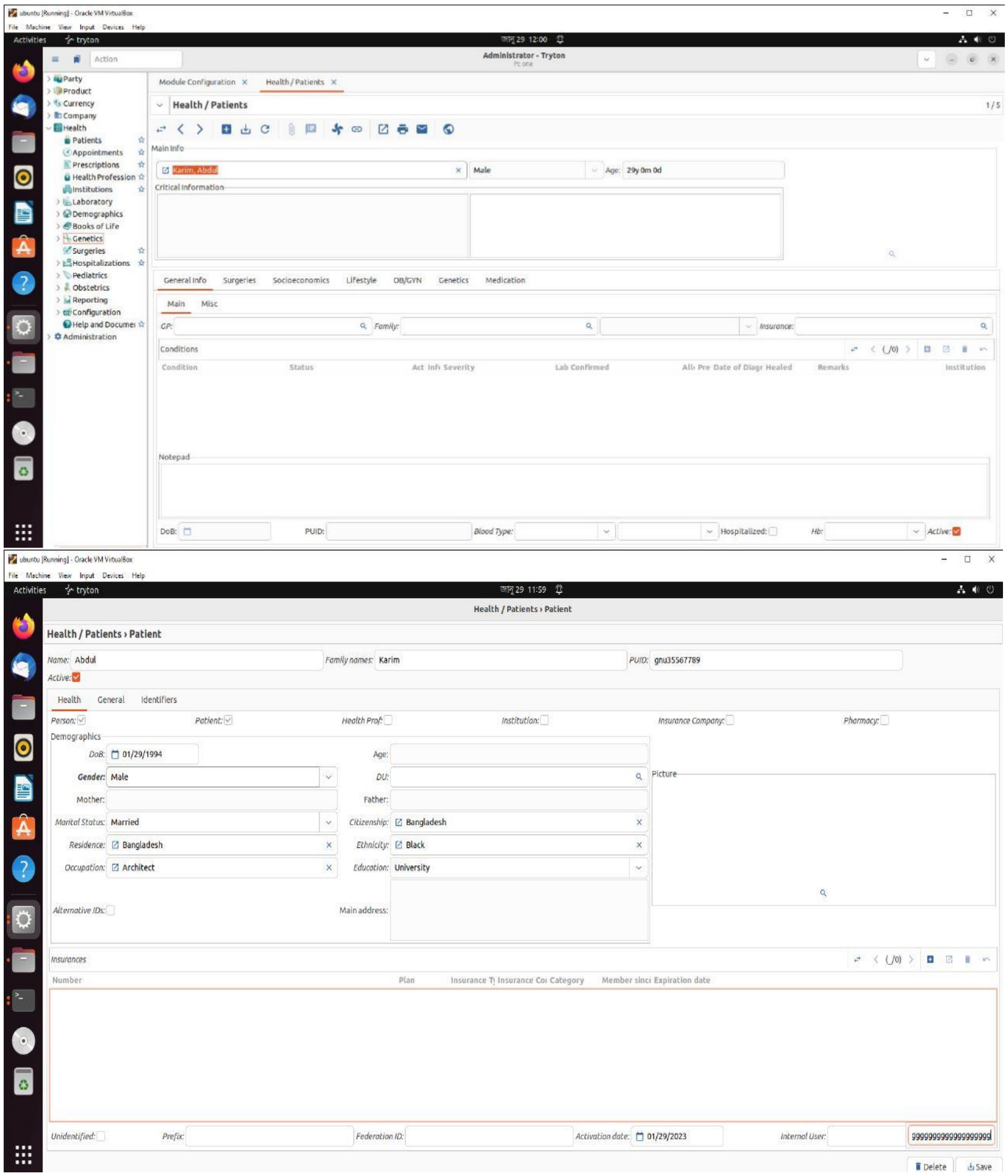
Figure 4.1: Data flow from one system to another illustrated.

4.2.1 Communication of health information between several hosts

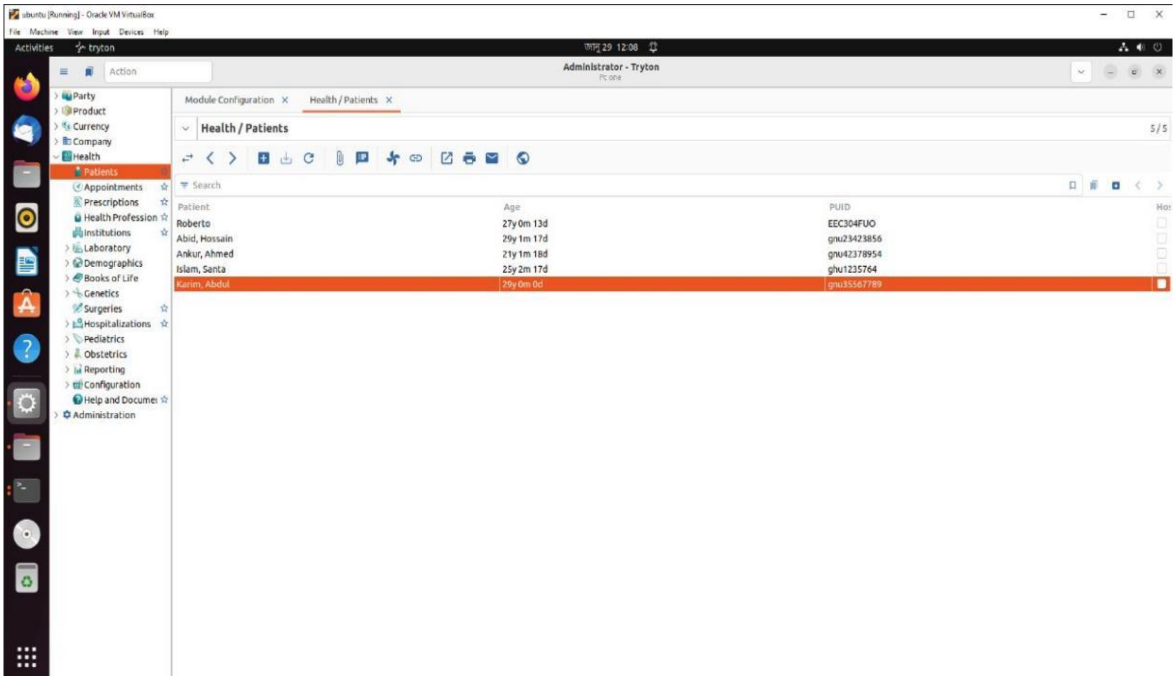
In this section we describe how any local user on any network can access the data they need at any time. Since both representations depict the same information, interoperability across all EHS has been accomplished. Health information is easily accessible, allowing for loose coupling as well. Health professionals have the option of adding new records or deleting some data, many of which require modification.Data interoperability between systems is shown in Fig. 4.1. Figure 4.1.(a) illustrates the main server data . By using a user ID and password, any locally connected user may effectively access the system. The identical data from the main server is displayed in the local administrator in Fig. 4.1.(b). By allowing access to the system from anywhere, all system users will be made aware of this alteration.

4.3. Activity to update or remove health data

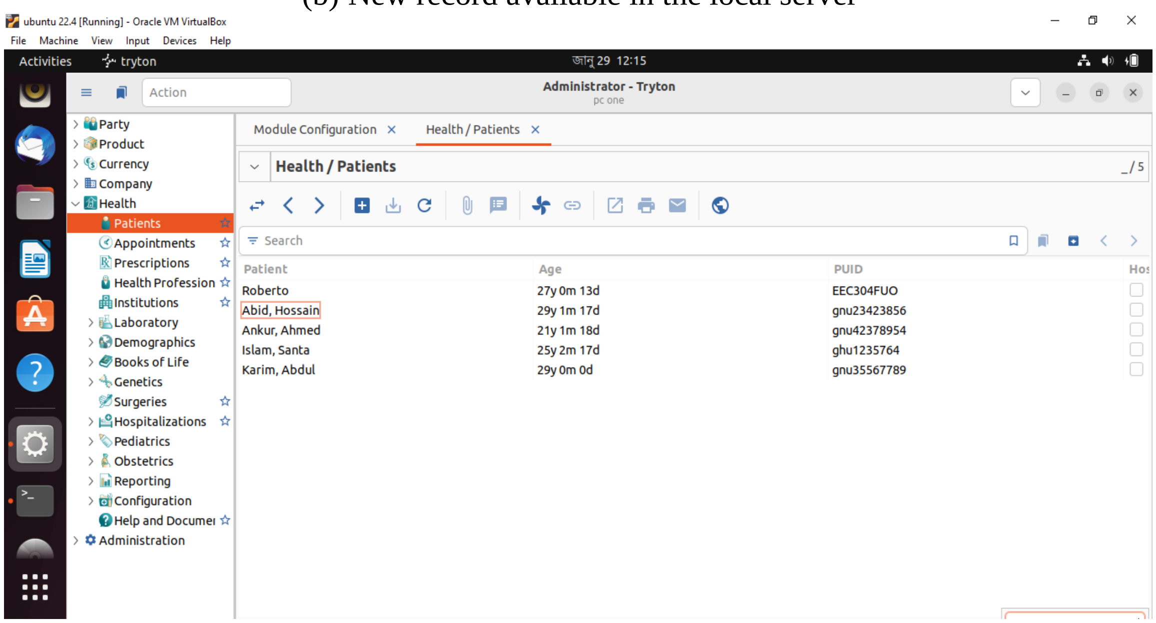
The suggested solution offers a loose connection that permits flexibility across e-Health systems, in contrast to prior work that offered dispersed components or client-server architecture but with closely tied technology. Additionally, it distributes the database to include underdeveloped countries. In our system, patients may register, new data can be added or deleted, and doctors can generate prescriptions. Fig. 4.3 depicts the local server's new record insertion procedure 4.3.(a). Additionally, Figures 4.3.(b) and 4.3.(c) show the database's state after a new patient record has been added to the local and main servers, respectively. All system users will be informed of any updates to the information by visiting the system from anywhere and viewing the changes to their records.



(a) Adding new records to the local server



(b) New record available in the local server

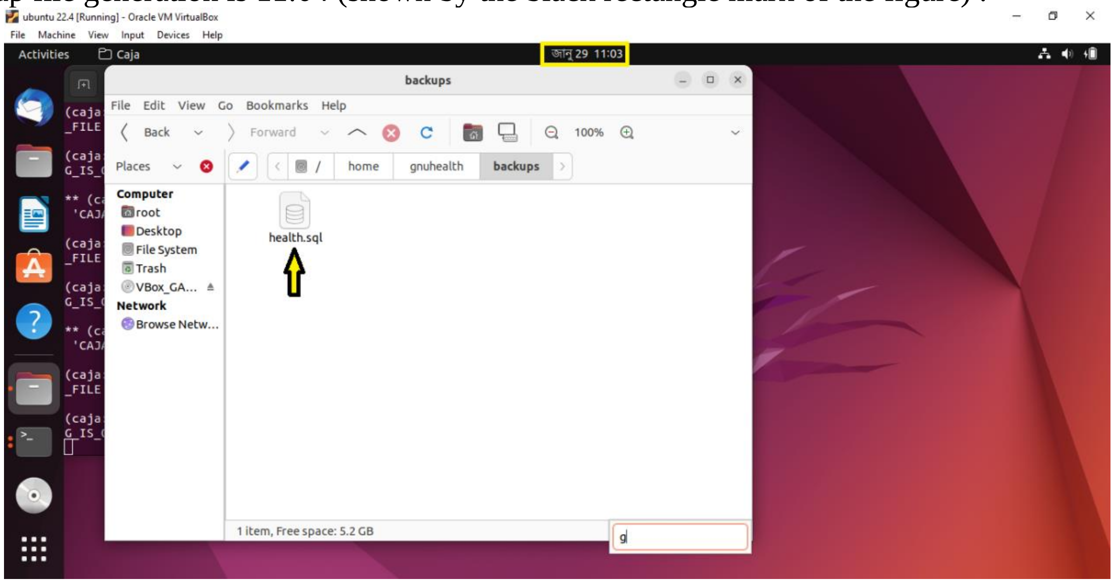


(c) New record available in the main server

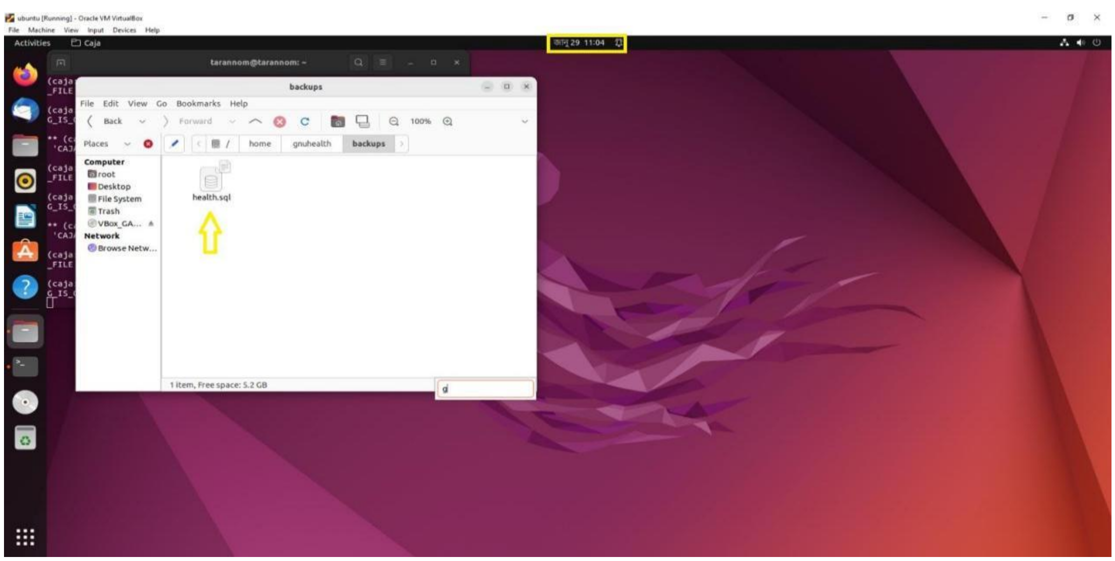
Figure 4.3. New record added or information updated in e-Health system.

4.4. The backup of health data

An EHR system's local server must request a server data backup from the main server if it fails. Secure Shell (SSH), Message Passing Interface(MPI), and PostgreSQL with cron jobs are used for server data backup operations .The PostgreSQL Operator makes use of the aforementioned open-source and free pgBackRest backup and restoration utility, allowing us to schedule routine backups and set retention settings.Figure 4.4 depicts the generation of the backup file. The "health.sql" file, the system's backup database, is shown by the black arrow in Fig. 4.4(a). Schedule commands generate scheduled jobs by using the cron syntax. We utilize a cron job to automate the server backup process, and it runs every Sunday, Tuesday, and Thursday. The graphic demonstrates how SSH and MPI are used to successfully provide the backup file to the neighborhood medical facilities. Figure 4.4(a) indicates that the "health.sql" file is received in a local EHS at a time of 11:03(in black rectangle mark of the figure), whereas Figure 4.4(b) indicates that the time of the backup file generation is 11:04 (shown by the black rectangle mark of the figure) .



(a) Pg_dump and Cronjob were used to build a backup file on the main server.



(b) Received backup file on the local server using SSH and MPI based backup operation

Figure 4.4. Backup file send and receive operation.

4.5. A comparison between the proposed and present systems

The suggested solution offers a loose connection that permits flexibility across e-Health systems, in contrast to prior work that offered dispersed components or client-server architecture but with tightly coupled technology. Additionally, it distributes the database to include underdeveloped countries. Although databases for comparable systems in developed nations are distributed, most methods in emerging and underdeveloped nations pretend that databases are centralized, which restricts the EHR's potential to scale. Additionally, while the suggested solution offers SSH and MPI-based data recovery, the majority of systems lack data recovery. In contrast to developed countries, adjusting with HL7 CDA to ensure interoperability for underdeveloped countries is an issue addressed in this work.Table 4 provides a summary of the comparative analysis of the planned work with comparable research.

The development of a convenient and low-cost Distributed Electronic Health System is a significant contribution to the healthcare services of developing countries. Compared to other available systems, this thesis paper offers several unique advantages.

Firstly, it emphasizes the use of low-cost technology to make the system more affordable for developing countries. Other available systems may use expensive technologies, which can be a barrier to implementation in countries with limited financial resources.

Secondly, the Distributed Electronic Health System proposed in this thesis paper is designed to be decentralized, which ensures that data is not dependent on a single central server. This makes the system more robust and less prone to data loss. In contrast, other systems may rely on central servers, which can be vulnerable to cyber attacks or system failures.

Thirdly, the system proposed in this thesis paper focuses on developing a user-friendly interface, which makes it easier for healthcare providers to use the system. Other available systems may have complex interfaces that require specialized training, which can be a challenge for healthcare providers in developing countries.

Finally, the Distributed Electronic Health System proposed in this thesis paper emphasizes the importance of data security and privacy. The system uses encryption to protect patient data from unauthorized access, ensuring that sensitive information is kept confidential. Other available systems may not prioritize data security to the same extent, leaving patient data vulnerable to misuse or theft.

In conclusion, the Development of a convenient and low-cost Distributed Electronic Health System in healthcare services for developing countries thesis paper offers a unique approach to addressing the healthcare needs of developing countries. Its emphasis on low-cost technology, decentralization, user-friendliness, and data security sets it apart from other available systems.

4.6. Comparative benefits of distributed loosely coupled electronic health records

As a result, e-Health services are ineffectual for rural residents in developing nations since they are unfamiliar with the system. However, the designed system is always accessible from any remote location. To use this service, people don't have to adjust their position. Both patients and physicians are free to use the system anyway they see fit. No matter how big the database gets, the term distribution in this case keeps it running smoothly. The potential benefits of the designed distributed e-Health system over existing systems are clearly present here:

i. provides HL7-based services to remote local health care facilities.
ii. Anytime accessibility
iii. Interoperability is made possible by e-Health systems based on HL7.
iv. Concentrating on rural health care
v. Comparatively low cost and affordable
vi. No posture modification is necessary for the patient.
vii. SSH and MPI-based distributed data recovery.
viii. Large databases are easily handled with the distributed capability.

Comparatively speaking, shared memory health systems have a lot of drawbacks. For instance, databases become larger every day, making it challenging to manage them. Additionally, if the central system fails, the entire system will be shut down, affecting the quality of all services. In this scenario, a distributed database is a suitable method for remotely maintaining e-Health care. Urban health care is the current emphasis of e-Health services. Since so many people reside in rural regions in developing nations, this research focuses on rural health care. For them, medical facilities are insufficient. As a result, the designed system will be advantageous and individuals won't have financial problems.

To improve public health and healthcare results while lowering costs, the government and healthcare organizations frequently construct distributed e-Health systems. A few advantages of distributed e-health, or the use of ICT technologies in the healthcare system, include remote patient contacts, quick access to medical care professionals, and remote monitoring capabilities. E-Health and medical information technology are expected to grow quickly in emerging nations as technological developments successfully compete in the third world.

4.7. Difficulties and prospective

The system's experimental findings highlight the existence of several difficulties. Organizational, cultural, and technological adjustments and supports are required for the transition from hospital-based to electronic health care services. We have difficulty creating a comprehensive health care system because of an insufficient health standard. Without more information, rural physicians, patients, and healthcare workers cannot manage this system.This program is designed using numerous hosts since it is distributed, simulating the testing environment. However, the simulation's outcome might not be indicative of actual healthcare services. Additionally, loose coupling has a cost since a closely connected system can reduce security attack, but free coupling may restrict security. A server database that houses the patient data makes up the data layer. Authenticating the data is a key issue for this system as well. PostgreSQL, an open source system with the greatest level of security, has been employed in this respect. First Healthcare Interoperability Resource, which is advised by Health Level Seven International, enhances the security of this database.We have spoken about the possible benefits of the distributed e-Health system that has been built. The following areas are possible future extensions of this study.

i. This technique may be implemented practically on a large scale in Bangladesh's rural districts.
ii. It may be used with a low-cost portable e-Health system tool set to gather patients' vital signs.
iii. A distributed healthcare system built on the Internet of Things will be created, connecting different medical resources through distributed databases and the IoT.
iv. In health care applications, machine learning (ML) techniques will try to identify patients uniquely or understand the potential effects of diseases.
v. To increase the effectiveness of healthcare, a distributed e-Healthcare system built on the cloud can be created.

However, the authors anticipate that the study's findings and the suggested technologies will provide a fresh perspective and expand the e-Health offerings in underdeveloped nations. The researchers' work on the standard loosely connected distributed e-Health system in underdeveloped nations will be aided by this study.

CHAPTER 5

CONCLUSION

5.1. Introduction

The development of a convenient and low-cost standard electronic health system is a critical step towards improving healthcare services in developing countries. Through this research paper, we have explored the various challenges faced by developing countries in providing quality healthcare services, including limited resources, inadequate infrastructure, and a shortage of healthcare professionals. We have also highlighted the benefits of electronic health systems, such as improved patient outcomes, increased efficiency, and cost savings.To design a successful electronic health system for developing countries, it is crucial to consider the technical aspects, including interoperability, security, and scalability. Additionally, engaging with local communities and stakeholders is essential to ensure that the system is designed to meet their specific needs and requirements. The development of a distributed electronic health system can provide a solution to the challenges faced by developing countries in providing healthcare services. This system can enable healthcare professionals to access patient data from anywhere, facilitate remote consultations, and enable effective disease surveillance and control. Moreover, it can increase patient engagement and improve health outcomes through enhanced communication and access to health information. In conclusion, the development of a convenient and low-cost distributed electronic health system can significantly enhance healthcare services in developing countries. It is crucial to continue to explore and develop innovative solutions that address the unique challenges faced by these countries in providing quality healthcare services to their populations. By collaborating and leveraging technological advancements, we can create a more accessible and equitable healthcare system that improves the quality of life for millions of people in developing countries.

5.2. Conclusion

Being the most populated nations, developing nations confront major difficulties in providing for the needs of their citizens in a variety of industries, including health care. The use of "information and communication technology (ICT)" in the healthcare sector is essential for improving productivity and service accessibility. The main issue with data interoperability is the ability to synchronize and integrate data from electronic health record (e-Health) systems with other heterogeneous platforms. This study's goal was to develop a framework for information sharing and data interoperability among e-health systems. The established e-Health system's interoperability enables collaboration across various information systems and organizations. Heterogeneous in data representation and care practices make it more difficult for e-Health systems to interact with one another (EHRs). The created system may independently track the health records of diverse companies and incorporate dispersed technologies into e-Health systems. According to the system design, each distant region's e-Health system is connected to the main server. The created system uses HL7 CDA to handle dispersed health data in rural healthcare. To avoid the difficulties of a central system, the intended system is dispersed among several hosts. The established system is made affordable to the general people in emerging nations since the majority of current healthcare services are hospital-based, ensuring the system's long-term viability. Regular backups of health data have been made in order to restore information from the backup server in the case of a malfunction. The use of the HL7 standard and SSH and MPI-based data recovery in the creation of a loosely connected distributed e-Health system, which is genuinely revolutionary in poor nations, is the study's main contribution, to sum up. It is determined that the constructed method aids in the advancement of e-Health in underdeveloped countries worldwide.

Even though the system architecture indicates a significant amount of privacy preservation potential, additional security and privacy tests are required. In the future, a security system based on block chain technology may be developed to guarantee that only approved informants have access to health data. A real-time e-Health system may be created using developed technology, and a large-scale practical implementation can be done for further development. We will do a follow-up investigation into the acceptability of integrating various healthcare systems. With the use of data mining and machine learning methods, we will be able to keep an eye on patient behavior.

5.3. Limitations

The system's experimental findings reveal that there are several challenges that need to be addressed, including organizational, cultural, and technological adjustments for the transition to electronic healthcare services. Insufficient health standards make it challenging to create a comprehensive healthcare system. The program is distributed and simulates the testing environment using numerous hosts, but the simulation's outcome may not accurately reflect actual healthcare services. Loose coupling has both benefits and drawbacks in terms of security. The data layer consists of a server database that stores patient data, and authenticating this data is a critical issue. PostgreSQL, an open-source system with high security, is used for this purpose. The possible benefits of the distributed e-Health system that has been developed are discussed, along with possible future extensions of the study.

1. The proposed technique can be feasibly deployed at a large scale in rural districts of Bangladesh.
2. A cost-effective, portable e-Health system tool set can be utilized to gather vital signs of patients.
3. A distributed healthcare system based on the Internet of Things (IoT) can be created, connecting diverse medical resources through distributed databases and the IoT.
4. Machine learning (ML) techniques can be employed in healthcare applications to uniquely identify patients or comprehend the potential impacts of diseases.
5. v. A cloud-based distributed e-Healthcare system can be constructed to enhance the efficiency of healthcare services.

5.4. Future Works

Based on the limitations identified in the study, there are several future directions for research and development of the distributed e-Health system. These include:

1. Feasibility testing and deployment of the proposed technique at a large scale in rural districts of Bangladesh.
2. Utilization of a cost-effective, portable e-Health system tool set to gather vital signs of patients.
3. Development of a distributed healthcare system based on the Internet of Things (IoT) that connects diverse medical resources through distributed databases and the IoT.

4. Employment of machine learning (ML) techniques in healthcare applications to uniquely identify patients or comprehend the potential impacts of diseases.
5. Construction of a cloud-based distributed e-Healthcare system to enhance the efficiency of healthcare services.

Addressing these areas of future work may help to overcome the limitations of the current system and enhance the quality and accessibility of healthcare services in underdeveloped nations.

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APPENDIX
QUSESTIONNARIES FOR PRIMARY SURVEY

Survey Questions

Name: ..…………………………………………………………

Designation: ……………………………………………………

Name of Institution: ……………………………………………

Phone number:…………………………………………………….

1. What type of database are you using to store patients information?

a.Centralized

b.Distributed

2. How do you collect information from patients?

a. On paper

b. Electrically

3. Do you have to go through the trouble of collecting information on paper?

a.Yes

b.No

4. If the same patient has multiple diseases, do you need to retrieve complete patient information repeatedly?

a.Yes

b.No

5. Have you saved any patient data as a backup for lost data?

a.Yes

b.No

6. How to store information after taken from patients?

a. On paper

b. In Excel

c. In Database

d. In the cloud

7. How do you keep track of patient appointment dates and times?

a.On paper

b.In Excel

c.In Database

8. Where do you think patient information can stored easily?

a. On paper

b. In Excel

c. In Database

9. In where data storing is more time-consuming?

a. On paper

b. In Excel

c. In Database

10. Which data storage do you think is more expensive?

a. On paper

b. Electrically

11. What problems have been faced in correcting patient information errors?

a. Couldn't fix it

b. It took a long time to fix

c. was able to fix it very easily

12. What problems have you encountered when using a centralized database?

a. Problems in data exchange

b.Problems in data storage

c.Time consuming

d. Others

13. Have you ever used distributed database for data storage and sharing?

a.Yes

b.No

14. How did you feel about using a distributed database?

a. Convenient

b. Inconvenient

c.Time consuming

d.Unnecessary

15. Do you share patient information with multiple institutions?

a.Yes

b.No

16. Will Distributed database be convenient for the patient?

a.Yes

b.No

17. Why do you think distributed database is more convenient than centralized database?

a.Easy to store and share information

b.One piece of information is destroyed but the other piece of information remains unaltered

c. Information changes are easy

d. All of them

18. Have you ever heard of telemedicine?

a.Yes

b.No

19. How important do you think telemedicine is during Corona-19?

a.Important

b. Not so important

20. Do you think it is appropriate to take health care with mobile?

a.Yes

b.No

21. How do you think about getting health care with mobile?

a. short time

b. Low cost

c.Both

d.None of these

22. In which sector/department of hospital management system are you performing this duty?

a.Clinical

b.Financial

c.Nursing

d.Pharmaceutical

e.Radiology

f. Pathology

g. Emergency

23. what is the area of Institution in which you work?

a.Union based

b. Thana based

c. Sub-district based

d. District based

EXAMPLE OF RESPONSES OF QUSESTIONNARIES FOR PRIMARY SURVEY

9/2/2022 22:09:28	Prof. Ainun Afroza	Child Specialist	Green Life Hospital	029612345-54	Centralized	On paper	Yes	Yes	Yes	On paper	On paper	On paper	On paper	On paper	Couldn't fix it	Problems in data exchange	Yes	Convenient	Yes	Yes	Easy to store and share information	Yes	Important	Yes	Short time	Clinical	Union based
9/16/2022 22:50:28	Omet kumar kundu	Data Collector	Nucaiba Health center	01737056565	Distributed	Electrically	Yes	Yes	Yes	In Excel	In Excel	In Excel	On paper	On paper	was able to fix it very easily	Problems in data exchange	Yes	Convenient	No	Yes	Information changes are easy	Yes	Important	Yes	Both	Financial	District based

List of Abbreviations of Technical Symbols and Terms with page number

Abbreviation	Full Form	Page Numbers
AI	Artificial Intelligence	10
BPMN	Business Process Model and Notation	31
CDA	Clinical Document Architecture	30
COVID-19	Coronavirus Disease 2019	13, 14
DBMS	Database Management System	3
DGHS	Directorate General of Health Services	8
DHIS	District Health Information Software	8
E-GIF	eGovernment Interoperability Framework	8
ECG	Electrocardiogram	22
EMR	Electronic Medical Record	9, 17
ehealth	Electronic Health	1, 2, 4, 5, 8, 12, 22
GDPR	General Data Protection Regulation	22
GNU	GNU's Not Unix	30
GoB	Government of Bangladesh	8
HIS	Health Information System	17
HL7	Health Level 7	21
IAAS	Infrastructure as a Service	20
IOT	Internet of Things	11, 15
LIS	Laboratory Information System	23
LMIC	Low and Low Middle Income Countries	8
mhealth	Mobile Health	8, 12, 22
MIS	Management Information Systems	8
ML	Machine Learning	53
MPI	Message Passing Interface	28
MTTF	Mean Time To Failure	19
NGO	Non-Governmental Organization	36
PAAS	Platform as a Service	20
RIS	Radiology Information System	20
SAAS	Software as a Service	20
SCP	Secure Copy Protocol	39
SDG	Sustainable Development Goals	12
SFTP	Secure File Transfer Protocol	39
SOA	Service Oriented Architecture	23
SOP	Standard Operating Procedures	55
SPO2	Blood Oxygen Saturation Level	22

Abbreviation	Full Form	Page Numbers
SPN	Service Principal Name	19
SSL	Secure Sockets Layer	38
SSH	Secure Shell	39
SSCU	Specialized Sensor Control Unit	9
TLS	Transport Layer Security	38
UAV BASED	Unmanned Aerial Vehicle Based	15, 24
WHO	World Health Organization	2, 7
XML	Extensible Markup Language	30