UNIVERSITY OF NAIROBI

FACULTY OF SCIENCE AND TECHNOLOGY

(Department Of Computing and Informatics)

PROJECT PROPOSAL

ON

Microservice based architecture referral for health information exchange with patient authorization for HMIS – Kenya

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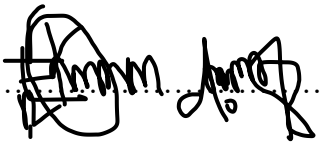
A research project proposal submitted to the department of computing and informatics in partial fulfillment of the Degree of Master of Science in Distributed Computing Technology of University of Nairobi.

March 2023

Declaration

This research proposal is my original work and has not been presented for any award in any University.

Signature  Date 03-Aug-2023

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ABSTRACT

In this current century, health care in organizations can be improved among other factors with proper health care information systems. According to Yasser (2017), health care across the world has been greatly impacted by speedy development and automation of health information systems. Further, Tavakoli (2020) agrees by stating that COVID 19 did the least disruption in areas where automation had been fully implemented. Tavakoli cites that companies like Amazon that had already heavily invested in automated robotics in its centers had a great positive impact in providing robust shipment of medical supplies that rescued the situation earlier enough before it worsened.

Lack of a system to automate Patients' Referral in referral hospitals in Kenya is the driving force towards designing and testing a Microservice systems which has the capabilities of scalability, resilience and most importantly which is faulty tolerant. Bob (2015) defines a Microservice as an agile approach of service-oriented architecture that structures a software as combination of loosely coupled and autonomous services whose communication is dependent on the lightweight communication protocol. Descriptive research design was used to establish the status of the current patients' referral system where questionnaires were used to collect data from sampled population that was identified and analyzed by simple tabulation where results were obtained.

To tackle the problems and gaps that were identified from the respondents' feedback, a microservice based system to automate the referral process, patients' vital transmission from IoT devices from patients and access to patients' medical history with the patients' consent was presented using an agile methodology. In this system the latest technologies were used, and they include: Microservices, IoT and REST APIs integration, interoperability technologies and web programming. In evaluating the system over the existing manual system using 100 real users from each group as test case 100 results were obtained in the test scenarios using the software protype developed as part of this work. It was realized that 99 percent of the users carried out the referral process with a positive impact in reduced time in the referral process as compared to the manual process.

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List of Abbreviations

SOA -	Service Oriented Architecture
API -	Application Programming Interface
SaaS -	Software as a Service
ESB -	Enterprise Service Bus
JSON -	JavaScript Object Notation
SOAP -	Simple Object Access Protocol
XML -	Extensible Markup Language
WSDL -	Web Service Definition Language
REST -	Representative State Transfer
IoT -	Internet of Things

Definition of Terms

Microservice: This is software component which has only one responsibility which can be designed, developed, and executed separately but still can interact with other components through network communication mechanisms.

SaaS: A software designed and deployed on the cloud utilizing cloud computing for its delivery to users over the internet.

Scalability: This is an ability for a software, software component or device to adjust according to changing environment to meet the changing needs of its resources.

Load Test: This is a technique by which simulated virtual users are meant to access a web-based application to check of the system is retaining stable operations.

SOA: This is a term used where the software development uses a logic of small modules that are loosely coupled together to form a big one system.

Model: This is a sample, or prototype product used to experiment with an idea through simulation of main functions.

Grafana K6: This is a load testing tool which is open source that is used for software development performance testing for software development teams.

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Each day there is new technology, frameworks and policies emerging from researchers and institutions across the world which brings about a ripple effect on how players in the industry would operate and embrace the changes while designing and implementing software systems. The continuous change of customer needs and competition from other competitors are compelling institutions to adopt systems or rather software that are not only highly available and cost effective but also are quick to deploy and has ability to scale vertically as their needs changes. The traditional architectures have been designed to handle this but over time they have been facing various challenges paused by the software code size grow which calls for more scalable and dynamic style of software development. According to Jeremy (2021) suggest that Microservice architecture approach best suits this.

1.2 Problem Statement

According to (Barboy J., 2019) in the current trends the Microservice Architecture model seems to be greatly embraced and adopted across the software hemisphere as opposed to Service Oriented Architecture Model and Monolith Architecture Models. Familiar, 2015 observes that the majority of the organizations using technology are still using the older monolith architecture models in the systems which is giving them a run for their investments against the competitors who are embracing the new technology, which is more resilient, dynamic, highly scalable and easily implemented across almost all platform because of its heterogeneity in nature. Gifu B., 2019 notes that monolith architecture-based applications are compounded by large problems spanning from software complexity, difficulty in scaling, non-fault tolerance and continuous downtimes which forces the systems to be redesigned to embrace the microservice architecture approach. The complexity and slowness of SOA caused by multiple sub systems accelerated the uses to run to microservices (Familiar K., 2018). Pachjare, 2016 praises the technology being used by service-oriented architecture, smart endpoints in conjunction with dump pipes, as opposed to what SOA is embracing, Enterprise Service Bus.

Abdullah, 2021 in their research paper notes that the patients' referral systems across the world have not fully adopted proper technologies to enhance service delivery. Further he notes that regardless of the health facilities lacking the specific automation in patients' referral the facilities have their independent heterogeneous systems used for other purposes like patients' billing, outpatient and inpatient management system, pharmaceutical management system and supply chain management systems or inventory among others. Therefore, the referral process heavily relies on manual documentation and reports like patient's referral report, patients' history while receiving the patients for referral. This is uneconomical viable because the patients are compelled to repeat tests that were done in the previous facility within 24 hours. Arban H., 2020 cites that due to lack of integrated systems and proper way of patients authorizing sharing of their information, has created a huge communication gap amongst the stakeholders. Moreover, following the data protection act in Kenya, Kenya Government Act: Data protection Act No.24 published in Kenya Gazette Notice No. 181 makes it difficult for the stake holders to share patients information without express authority from them or their next of kin.Therefore in order to improve the patients delivery service in the referring processes, the gap in the data sharing through integration automation with right technology and authorization from patients should be handled.

1.3 Study Objectives

The main objective in this study was to evaluate, investigate and test the use of secure microservice architecture in the integration of patient's referral information system with the capability of express authority from patients to share their data.

The specific study objective were;

i.) To find out the existing patients referral system and what could be required in the proposed model for patients' referral automation in the health facilities in Kenya.
ii.) To find out the simple, easier, and reliable way the patient can authorize sharing of their records between the hospitals.
iii.) To provide a scalable means of monitoring available resources in various referral hospitals in Kenya using the proposed Microservice model.

iv.) Finally, the study proposed and came up with a design that incorporated patients' authorization in information sharing, patients' vitals IoT that was tested and validated its performance against the existing systems.

1.4 Research Questions

The research tried to answer the following questions;

i.) What are the existing referral systems used in Kenya and what challenges do the face?
ii.) What would be the easiest simple and reliable way patients can authorize access to their medical history records?
iii.) Can technology be used to enhance the process of monitoring medical services required in referral process?
iv.) Can technology be used to enhance the process of monitoring medical services required in referral process?

1.5 Significance of the study

The study's findings formed part of other scholarly works that already have been done and documented in this domain of microservices, thus, provided some more insights and knowledge more especially in using two factor authentication approach in data exchange authorization. This became a point of reference and acted as a literature review foundation for those intending to pursue their research in the microservice architecture sub-domain, more especially in patients' data exchange between healthcare facilities.

Through the study going forward it was easier for the health facility stakeholders to have an informed opinion in adopting the new technology which would handle the issue of patient's referral process and data protection.

The new proposed system provided a secure platform to share patients' medical history by the referring facility through patients' authorization that will be done by OTP tokens. This will in turn reduce misplacement and tampering with the medical records that are usually printed for the patient and improve patients service delivery.

The research and system prototype justified the model as a better method and practice compared to the existing one which will be applicable in medical data exchange to the current Kenyan population.

1.6 Scope of this Study

The scope of this study was limited to the use of microservices architecture and 2 factor authentication within the Kenyan health facilities by handling the following.

- Help hospital administrators to locate available facilities and resources for prospective patients.
- Will monitor and help in referring patients to available facilities.
- To link referral hospitals for the purpose of sharing patients' medical history with patients' authorization.
- Enable patients to authorize sharing of their information to other health facilities.

1.7 The Assumption of the study.

It was assumed that the source of literature review was from legit platforms like Google scholar and the owners of the referenced work did not plagiarize other people's work. It was further assumed that the studies provided in the literature review had done thorough research and met the threshold standards to be published.

An assumption was made that the sampled population answered the questions in good faith without prejudice and bias. The tools used in data collection had no or minimal ambiguity for the users to give clear and genuine feedback. Further, there was an assumption that the tools to be used in data analysis had proper precision and handled the nature of data collected and the person interpreted the results did it professionally, accurately and in good faith.

During the process of data collection all ethical issues were observed.

The study observed ethical issues before, during and after data collection. All the information gathered from the respondents had been treated with the confidentiality it deserved. The sample hospitals were notified of the exercise during data collection.

The researcher complied with the ethical issues in the field. Confidential information was not disclosed subjecting the respondents to risk. That the facilities that were sampled received an earlier communication on the visit and data collection.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter shall have a broad discussion on patients' referral system and the available technologies to be adopted. A cross check on the available technologies was done in reference to the scholarly study that has been made by other researchers. A comparison in terms of stability, scalability and efficiency was also discussed. The chapter will be able to bring about the advantages of embracing microservice architecture as opposed to the Service Oriented Architecture and the Monolith models.

2.2 Patients Referral system in Kenyan Hospitals

Patients' referral system is advisable and thus becoming a requirement for every hospital facility that must refer and admit referred patients to promote high quality patients care in the country.

2.2.1 Referral process in Kenyan Hospitals

According to Kenya Health Sector Referral Strategy (2014-2018), the formation of Kenyan health care systems has been structured in a hierarchical manner into 6 levels. Their levels are based on the proximity to the patients, nature disease to treat and level and experience of personnel and also magnitude of medical equipment installed. However, in some instance this might not be through and is not based on laid policies and procedures (Angela K., 2021)

2.2.2 Challenges of Patients Referral systems in Kenya

Over time patients' referral process has been affected by many challenges that has been affecting the main players in the system. Hospitals, Patients, patients' relative and next of kins are the major victims of this challenges. The process of referring patients from health facility to another is not easy (MOH, 2022). About 15% of the patients get proper referrals with their discharge or referral summary notes clearly shared to the receiving facilities (Aineah, 2019).

Most of the patients' referral notes and medical summary are manually shared or handled in the process of patients' referral process. (Hasti, Lesari and Gustiana, 2019). This includes patients' lab tests, patients X-ray reports, patients' treatment plans and patients'

medication drugs. Additionally, patients' referral request and patients' information are shared through SMS and WhatsApp applications which might compromise the confidentiality of patients' data. Further in reference to Kenya Government Act: Data protection Act No.24 published in Kenya Gazette Notice No. 181 makes it difficult for the stake holders to share patients' information without express authority from them or their next of kin. Due to this kind of systems that are not automated and integrated the entire process is marred with a lot of difficulties that prompts the whole process to be manual from getting patients medical files to sharing patients' medical summary by both the referring and receiving facility. Communication between the referring and receiving health facilities is mostly unstructured (e.g., through phone calls, letters, text messages, emails) which is a manual way of doing things and limits the patients from having control to their information being shared.

2.3 Microservice Architecture

Gifu B., (2019) notes that it's the challenges that users experience from the old methods i.e., monolith and service-oriented architecture that has pushed them to embrace the approach of microservices architecture. Further the researcher notes that, with the high competition in the market every player is running to the best technology for their service delivery.

Implementation of the proposed model using microservices will be of great benefit as opposed to using technologies like monolith and SOA Chen L. (2015). He lists the following advantages: (1) when some of the systems modules are being updated they do not affect other team members working on the other modules

2.3.1 Comparison between Monolith and Microservices Applications

According to Kanjilal, J. (2020) monolith applications are designed to have one code base that is tightly coupled and installed as single unit. Monolith applications are designed with the user interface, controller and database model as shown below.

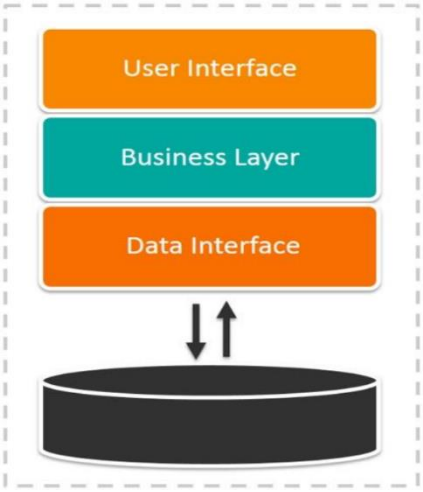


Figure 1: Monolith Architectural Design View, (Kanjilal, J. (2020).)

Ken J, 2022, agrees with BMC, 2021 publication on how the monolith arch is modeled. He further gives a definition to microservices that these are applications that whose units are loosely coupled. The units work independently to deliver specific functions. They run on their own database and are linked to each other to form the main system.

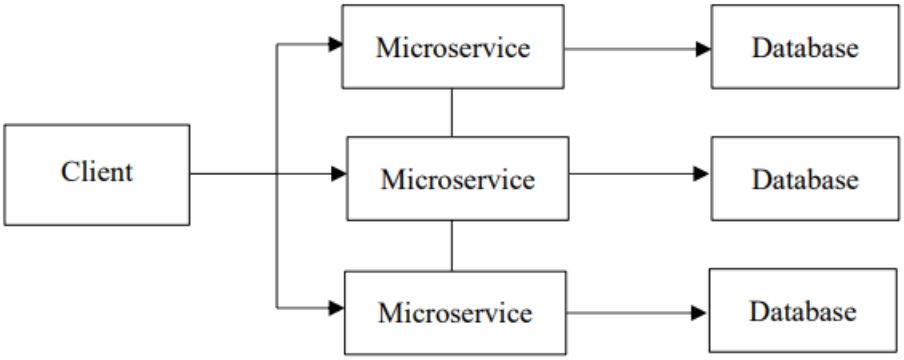


Figure 2: Microservices Architectural Design View, (Kanjilal, J. (2020).)

Gifu, Baboi ., 2019 suggests that the way microservices work and operate and executed independently makes it better than monolith applications which allows the modules to be tightly joined together. The separation of services in microservices makes it better in fault tolerance and becomes more resilient to downtimes. The fact that monolith systems have intertwined units that depend on one another, they are always subject to single point of failure once a unit fails. And if failure happens it becomes very difficult to trace down the

issue as opposed to microservice where a unit can be isolated to establish and work on the bag without bringing the whole system down.

According to Yadav (2019) it is easy to understand and maintain microservice systems compared to monolith. The development team can easily work independently in separate units before bringing them together. On the other hand, the development team will find it difficult to quickly work on single systems thus microservices emerging with high agility.

Using different technologies to implement systems is a plus in the current error (Chandramoul K., 2020). Microservices applications tops in allowing various technologies to implement heterogeneity in application integration. For example, the independent subunits in microservices can be developed by various technologies and programming languages as opposed to monolith that depends on single technology stack.

In database storage design, Rashm S., (2022) explains how microservices can operate with independent databases in each unit as opposed to monolith that uses one database for the whole system. With the capability of developing independent databases to multiple units in microservices it allows quick system development which forms the case of microservice being scalable and high agility.

The mode of communication in microservices greatly differs from that of monolith applications. The monolith technology embraces procedures and function calls (Chandramoul K., 2020). On the other hand, microservices applications communicate using Application Program Interfaces, APIs. According to Pachghare, 2017) the majority of microservice applications use REST for both asynchronous and synchronous as opposed to using Hypertext Transfer Protocol, HTTP. For the integration of system using different languages both the JSON and XML are used to support the process.

2.3.2 Comparison between Service Oriented and Microservice Architecture Applications.

According to Witthner (2020), the service-oriented architecture and microservice architecture share several similarities in system implementation. Both technologies are structured in way their services have been designed in a smaller scope meant to perform a unique business process. The two architecture models allow interoperability but use

different approaches in implementation of the services. Enterprise Service Bus will heavily be used for SOA whereas remote procedure call will be used for microservices.

The SOA services will be exchanged using Enterprise Service BUS (ESB) while microservices will be exchanged using Remote Procedure Call (RPC) over the network.

While the two architectures converge at some point, on the other hand they equally diverge at a given point. Liang M., 2021in his article agrees that both microservice and SOA have different aspects when it comes to sharing components and granularity. For example, SOA is designed by bigger services which are stable in nature while microservices have relatively granular services that have various versions. As can be seen from the figure below the microservices services are autonomous and do not share same runtime.

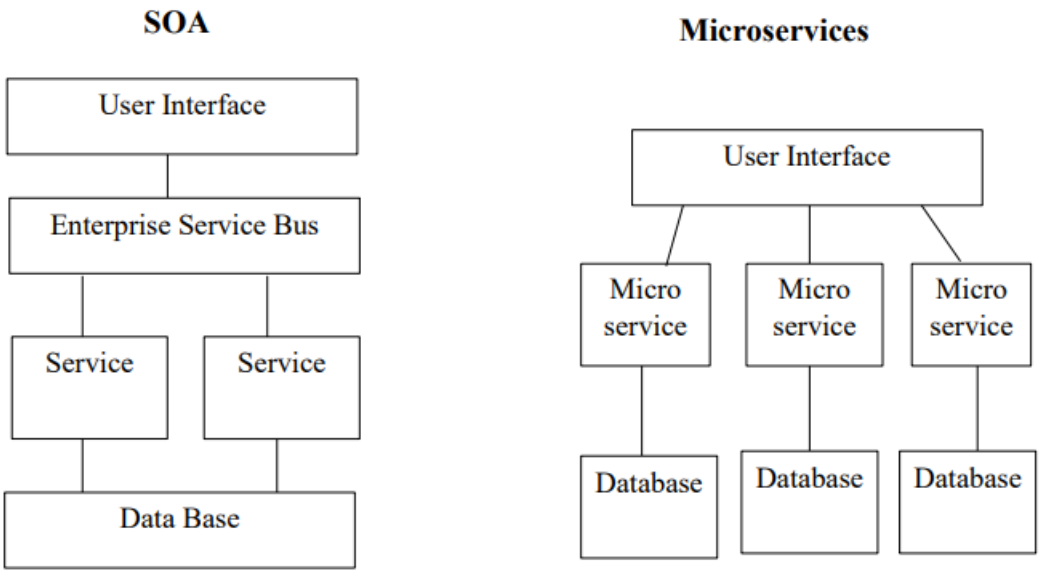


Figure 3: Service Oriented Architecture vs Microservice (Wittner, 2020)

Wittmer (2021) in his publication argues that SOA and microservices don't have common mode of communications among their services. The microservice architecture models empower the endpoints by shifting the business and communication logic from the communication bus to smart endpoints. Whereas SOA uses communication bus by empowering the communication bus instead of the endpoints and it's at this point the system might face a single point of failure.

2.3.3 Design Principles in Microservices

Newman P., 2015 tries to explain the various numbers of available design principles of microservices as follows; a) each single microservice can upgrade and scale. Its deployment doesn't depend on other services b) they only handle one business process c) the individual single should be stateless and resilient to tough conditions d) it works on the policy of one service single business functionality e) communication between the client and server logic is stateless f) the communication is done via smart endpoints majorly REST as opposed to Hypertext Transfer Protocol.

2.3.4 The Decomposition of Microservices Patterns.

Shivakum R, (2020) notes that to decompose microservices they should have such properties as low level granularity and lose coupling. The following are ways microservices patterns can be decomposed.

Decomposition by business capability: The business capability is a concept based on the business architecture design. In business capability a service is decomposed in terms of the specific work it does like in online business we have the order service and payment services. They can be decomposed differently.

Decomposition based on transaction: This is done by developing microservices considering the main transactions on the system e.g., on online systems for e-commerce the main transaction would be login, add to the cart and payment. Microservice for these transactions can be created. Siriwardena, (2020).

Decomposition of microservices by resources: The operation of specific resources can be defined and attached to a specific microservice. For example, a specific product on e-commerce can have insert delete and query operations Siriwardena, (2020).

2.3.5 Patterns used in Microservices Integration

According to Newman (2018), microservices have various patterns in which they can take through the process of integration. He recommends using choreography instead of orchestration and using REST instead of RPC for requests made and responses given. The following are sample integration available for microservices.

API gateway pattern: Shivakumar K.S., (2020) describes an Application Program Interface as a center point for executing microservices where functions like authentication and authorization and monitoring of the activities takes place. Multiple services can make requests to other services through API if it's configured to do so.

Aggregation pattern: This happens when one service for some reason might require responses from more than one microservice within or outside the main system.

User Interface composition pattern: every user interface from the end user is designed in a way that it handles specific business process once it's invoked by the user.

2.3.6 Security in Microservices

A study done by Shaik M., Zaide R., (2017) suggests that Oauth 2.0 is preferred protocol commonly used in microservices when approving and verifying a process. The Oauth 2.0 uses a centralized technique of authenticating the requester and granting access by providing tokens that can either be used by the users or a service to access resources.

2.4 Review of Related Systems

2.4.1 E-health Croatia

In Croatia health is real regarded seriously and they have taken great steps in automating their health management systems. The country has a very comprehensive solution that has integrated almost all health facilities in providing better services to their citizens. Their systems is developed in modularity with proper security features and it enables almost all services like patients' information management and service delivery to be automated. It's worth noting that in Croatia over 2400 primary health care facilities in over 18 counties including the city have been integrated and they are able to automate the process of patients' information management system. The system in Croatia enables e-booking of patients and e-reporting.

Regardless of their effort to automate the health services process they have not implemented a better referral system that is able to (1) monitor the available resource in other facilities, (2) to integrate the referral system with IoTs and (3) provide a module for patients' to authorize the sharing of their information.

2.4.2 EHealth system in Rwanda

A study review done Frasier K., (2017) Rwanda has adopted six important units in health information technology , they are Open Source Medical record system that is able to track the level of patients data and also monitors monthly infectious diseases like COVID-19, drug and medical supply information management system, EHealth called telemedicine , drug inventory and management systems and Health Management Information System that is used to record patients data and can be utilized by the management in evidence-based decision making.

Notwithstanding the many automated services in the country less lack the capability of integrating to one another because of the architecture that have been embraced i.e. Monolith Architecture. The current HMIS modules cannot be integrated to each other. The government of Rwanda could have wished to have all the systems integrated in the current and future set up. The access of patients' information is absolutely limited to single health centers and cannot be shared outside the facilities.

In Rwanda efforts to have a national patient's grid system has been at the fore front of their agenda but still this has not been achieved because of the slowness in embracing the new technology as opposed to old standalone systems.

2.4.3 Microservice Architecture in EHealth systems in Kenya.

Ouma J (2008) states that embracing the information communication in the country can positively impact the service delivery by the health facilities to the ailing Kenyan citizens. In Kenya various researchers / scholars have carried out various studies on the e-readiness of adoption of automated health systems, proposed and developed models to be used in health service delivery and even integrating hospitals across the country. Research done by Chogi B (2012) on integrating health management information systems in Nairobi metropolitan tried to solve the problem of referral systems but did not address and embrace a better technology as the system was designed with a monolith architecture where he proposed the main system to be hosted online with a single database and all services tightly coupled.

Further the ministry of health Kenya has come up with a blood bank management system and donor management systems. The systems are all designed using a monolith architecture. Therefore, it's through this gap that this study will try to address.

2.5 The Proposed Model

The model this study proposes will handle patients' referral process through automating the process of checking resources in facilities, patients' referral and sharing patients' medical summary report to the receiving facility upon patients authorizing. The health facilities will have an automated way of accessing available spaces in other medical facilities, booking, referring patients, and sharing the summary of their medical reports. The patients can authorize sharing of their medical reports through technology that will be found to be appropriate in terms of availability, reliability and easy to access to them.

The system therefore will have facility service, patients' service and patients' authorization service and patients' vital services.

2.6 Conceptual Model

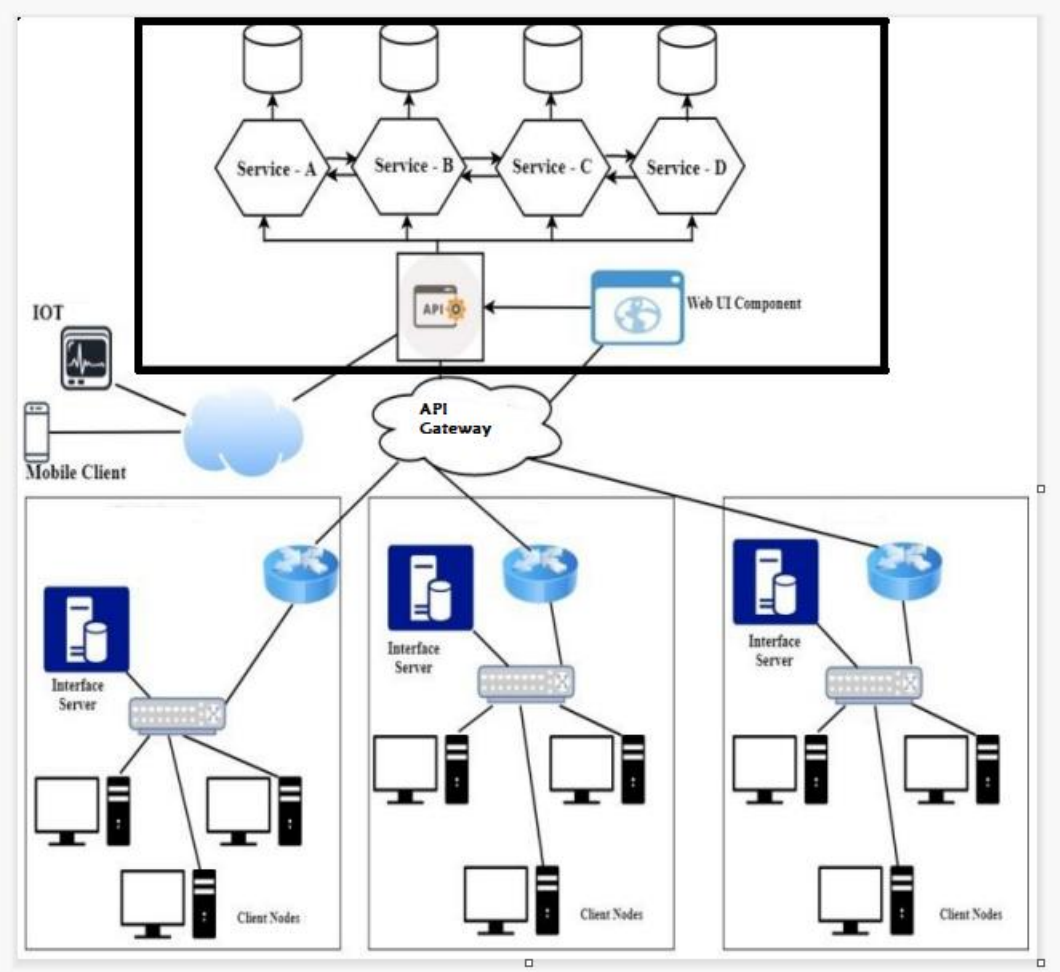


Figure 4: Proposed Patients Referring System

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

For the new system, the study embraced descriptive research design. The research heavily relied on Convenience Sampling Technique to select both the health facilities to represent the referring and receiving facilities and patients. To get sample data from the data that was collected, stratified sampling was used. The data that was used in the study was collected through questionnaires and reviewing archived documents and finally the data subjected to analysis through statistical methods. The study adopted the agile methodology in developing the microservice model as the agile methodology which had more advantages as opposed to the rest of other methodologies for this research. JavaScript libraries and Python frameworks were used. Further, the model was deployed and scaled by Docker containers and K6 load tester. For load balancing / reverse the Nginx was used while system performance was tested by Locust load balancing.

3.2 Research design

A sample model was created which was in line with the data that was collected, measured, and analyzed (Kothari, 1985). The state of the referral system being used was systematically described by descriptive research design. The design adopted in this study was able to answer the obvious questions on where, what, and when. While trying to establish and understand the status and preferences of the users a descriptive design method was employed to collect more data for the study.

With the numerical data that was collected in the research, the study heavily relied on quantitative research which is perceived to be the most convenient (Carly, 2022). Statistical methods that have been tested and verified shall be used to analyze the numerical data that will be collected.

3.3 Developing the Proposed Model

3.3.1 Software Development Methodology

The microservice model was developed using Agile Methodology. According to (Radha S., 2018) agile methodology is regarded as a software development approach that embraces continuous changes on working product delivery that is derived after many iterations based on user requirements. The agile method was considered because of the advantages it has

over other methods of software development. Ihor (2021) states that the agile methodology is flexible, faster, and mostly focuses on iteration that will allow flexibility in developing the software product. Agile makes it suitable for microservice development because of its nature of enabling collaboration amongst developers. The quality of the software product can be improved in the fact that this method allows continuous iteration changes. The agile methodology has seven stages (Nazar, 2021) which includes planning, analysis of the system requirements, system design, project implementation/ iteration stage, testing, deployment and lastly product maintenance.

Figure 5: Agile Software development lifecycle (Nazar, 2021).

The user requirements are transformed into a working software in line with the customer feedback at the iteration stage. Further, the quality of the software product improves based on the numerous iterations made as per the user demand. Within the iterations stage the following sequential steps were followed: definition of user requirement-implementation of the requirements- testing and user training-deliver a working product and integrating to the main system.

3.4 System Requirements Gathering

3.4.1 Target Population

Individuals, groups, and communities from which the research gets information is defined as a study population (Mumar, 2011). For this research the target population included hospital administrators, nurses, doctors, ICT experts, patients and patients' next of kin. The population included all that are involved in the process of patients' referral. The investigation drew a sample representation.

3.4.2 Sampling Procedure

The research used stratified sampling where the respondents were subdivided into groups of similar characteristics. Convenience sampling was used too in this study. In the convenience sampling, convenient respondents for the study were selected (Oates, 2006). Convenience sampling was relatively easy to apply as it has fewer rules and is faster in implementation with less costs. National referral hospital and County referral hospitals were selected to represent the referring and receiving health facilities.

Using stratified random sampling method, patients and hospital health workers from three health facilities who have handled referred patients were selected to represent two groups i) patients ii) health workers. This helped in avoiding biasness with better precisions (Alan, 2018).

3.4.3 Sample Size

The population that included health staff workers and the patients was infinite and therefore the study used the Cochran's formula as follows:

$n = (z)^2 t (1 – t) / d^2$

$n\text{-}1.96^2\ 0.5(1\text{-}0.5)/0.5^2$

n=384, the desired sample size

Where:

n: desired sample.

z: the standard normal deviate usually set at 1.96 (which corresponds to the 95% confidence level

t: the proportion in the target population to have specific characteristic. In this case 50% (or 0.50) was used there being no estimates of the target population.

d: was the absolute precision or accuracy, normally set at 0.05 on calculation:

$n\text{-}1.96^2\ 0.5(1\text{-}0.5)/0.5^2$

n=384, the desired sample size

3.5 Methods of Data Collection

3.5.1 Questionnaires

According to Oates (2006) a questionnaire can have both or one of the open and closed questions that is used to gather information from the respondents. Feedback which was in the questionnaires from the respondents provided information that was analyzed and interpreted as feedback. The conclusion was based on what the majority's view and understanding.

Kumar R., 2011 states that the choice of questionnaires would be more convenient to administer as it can be sent on email through the internet. This will be faster, and the cost will be relatively low.

To have humble time and convenience in data analysis the questionnaires were designed with closed questions. All respondents were well guided with no ambiguity in filling the questionnaires. Closed questions were clearly designed and easily presented to the respondents which enabled them to quickly fill in and save on time.

3.5.2 Secondary Data

According to (Oates, 2006) archived information from other research scholars can provide sources of information or data. The interviews results and questionnaire feedback documents can form a basis for referencing so has to get the required data for a study. For the case of this study the hospital documentation like patient's referral forms, patients' summary medical records, discharge summaries, consent forms provided data that was used in this study.

All research publications made from scholarly literature, journals, conferences on implementing microservices played an important role in this research. Oates (2006) clearly states that document-based data has many advantages in the fact that they are cheap, easily obtained and convenient to access.

3.5.3 Validity

Meddleton, 2020 defines validity as how precise a technique measures. If the results have high precision with close to 100% similarity it is regarded as high validity. Whereas the consistency procedures or methods measure something is regarded as Reliability. The research subjected the questionnaires to a pre-test and errors corrected. This was done by my fellow students, colleagues and 20 medical health workers before proceeding to data collection exercise.

3.6.0 Data Collection

3.6.1 Questionnaires for the Administration

This study considered giving each of 384 respondents a questionnaire. Health facilities were issued with 192 questionnaires while patients received 192. This was done from the sampled hospital and patients.

3.6.2 Document review

The institutional archived documents like sample patient's referral forms, patient's summary medical record, discharge summaries, consent forms were obtained from 4 health facilities for the purpose of data collection.

3.7 Data Analysis.

The numerical data that will be collected shall be analyzed using mathematical and statistical methods.

384 questionnaires were administered in this study where the ratio of equitability was used for the three categories at a ratio of 7:7:5 equivalent to 35%:35%:30% for medical health workers, patients, and ICT staff respectively. This translated to 134, 134, 116 respondents for the medical health workers, patients, and ICT staff respectively. The responses were 120, 110, and 98 for medical health workers, patients, and ICT staff respectively.

3.7.1 Responses from Referring and Receiving Facility Medical Staff

The study sampled medical health workers who were on duty during the sampling period and who had previous experience in referring and receiving referred patients in their facility stations. 134 responses were from this category and were analyzed with the following output.

i) The following were listed as one of the main challenges faced by patients while seeking alternative referral medication.

Item	Frequency	Percentage
Lack of space in the receiving facility	114	95%
Lack of centralized system to quickly process the referral requests	110	91%
Technological challenges in sharing patient's medical summary	108	90%
Providing incomplete medical report on the patient's status occasioned by lack of centralized patients medical records.	102	85%

Table 1: Main Challenges faced by patients during referral process.

ii) Documents issued to the patients to be presented to the receiving facility.

Item	Frequency	Percentage
Referral note	120	100%
Investigation Report (Like; Imaging, Lab test, etc.)	114	95%
Request for test not available in referring facility	116	97%

Table 2: Documents Issued to Patients to be used in receiving facility.

iii) Response on whether patients are referred to other medical facilities.

Item	Frequency	Percentage
Referring patients to other medical facilities	120	100%

Table 3: Checking whether patients get referred.

iv) Responses on the common referral system used by the medical health workers in their facilities.

Item	Frequency	Percentage
Automated System (Using Patients management system – No paperwork)	0	0%
Manual System (Use of paper as referral note)	120	100%

Table 4: referral system used by the medical health workers.

v) Responses on some of the key requirements medical health workers think should be included in the proposed automated patient referral system.

Item	Frequency	Percentage
Patients consent to share their data to other facilities	116	97%
Function to allow referring facility to share patients' data	119	99%
Unique patients' identifier across all the facilities for referring purpose	108	90%
Technological devices like smart watch to capture patients' vitals in advance for example within 30 minutes of patients' arrival for normal diseases	101	84%

Table 5: Proposed functionalities to be included in the proposed system.

vi) Responses on the average time taken to process patients' referral to the receiving facility.

Item	Frequency	Percentage
0-2 HRS	12	10%
2-4 HRS	60	50%
4-6 HRS	36	30%
More than 6HRS	12	10%

Table 6: Average time taken to process patients' referral in admission.

vii) Responses to challenges faced while receiving referred patients to health facility.

Item	Frequency	Percentage
Patients lack proper documentation	90	75%
Patients with distorted medical reports	72	60%
Patients having wrong diagnosis	60	50%
Lack of space for admission translating to long queues and waiting hours	78	65%

Table 7: Challenges faced while admitting referral patients.

viii) Responses on common technologies used in the patients' referral process.

Item	Frequency	Percentage
Email	74	62%
SMS/ WhatsApp	110	92%
Printed word document	115	96%

Table 8: Common Technologies used by patients.

ix) Responses on proposed measures to improve the process of referrals system in Kenyan health facilities.

Item	Frequency	Percentage
Introduction of a stable, interactive, and reliable web-based system	119	99%
Introduction of a sharing patients summary report system	113	94%

Table 9: Proposed measures to improve the process of referral system.

x) Response on the average time taken for patients to be processed in receiving facility from referring hospital.

Item	Frequency	Percentage
0-3 HRS	46	38%
3-6 HRS	71	59%
6-9 HRS	2	2%
More than 9HRS	1	1%

Table 10: Average time taken for patients to be processed during admission

3.7.2 Responses from Patients

Of the 134 questionnaires administered 110 responses were received from the patients so us incorporate their views in the proposed model for patient's referral system. The patients interviewed are those who had already been referred or were in the process of referral.

1. Patients' response on the major requirements before they are referred to another health facility.

Item	Frequency	Percentage
Patients Consent	90	82%
Patients Medical Summary	108	98%

Table 11: Patients' requirements before referral

2. Response by patients on the medium in which their medical summary report is shared to the receiving facility.

Item	Response	Percentage
WhatsApp	68	62%
Message	64	58%
Email	66	60%
Print out report	79	72%

Table 12: Medium for patients' medical summary exchange

3. Response on the convenient methods patients should use to authorize access of their medical records shared by the referring facility.

Item	Response	Percentage
Email	8	7%
One Time Password (OTP) through SMS	92	84%
Digital Signature	9	8%
Thump	1	1%

Table 13: Convenient patients to authorize sharing of their medical reports

4. Response on the view of patients on automation of patients' referral process against referral efficiency improvement.

Item	Response	Percentage
Strongly Agree		93%
Agree		4%
Disagree		2%
Strongly disagree		1%

Table 14: Patients views on the introduction of referral automation

3.7.3 Responses from ICT Staff

A total of 116 questionnaires were administered to ICT health workers and there a was 98 responses received as follows:

i) Response on internet connectivity to the health facilities?

Item	Response	Percentage
Connected to internet	97	99%

Table 15: Internet connectivity in health facilities

ii.) Response on the availability of Hospital Management System

Item	Response	Percentage
Internet Connection	90	92%

Table 16: Availability of Hospital Management System

iii.) Response on the sufficiency of infrastructure to support the proposed patients' referral system.

Item	Response	Percentage
Stable Internet Connection	88	90%
Availability of enough working computers	96	98%
ICT personnels	94	96%

Table 17: Nature of infrastructure to support proposed referral system

iv.) Response on the quality of GSM network coverage in the hospital building to support One Time Password (OTP) messages.

Item	Response	Percentage
Excellent	90	92%
Good	4	4%
Fair	2	2%
Poor	2	2%

Table 18:Quality of GSM network coverage in Sampled Kenyan Health Facilities

3.7.4 Document Reviews

In the process of trying to establish and complete system requirement the study gathered more information from the main documents used in the process of referring and receiving patients, they included, medical reports, investigation report and referral request notes.

3.8.0 Proposed System Requirements

3.8.1 System Feasibility

To evaluate the possible benefit of the system to the health facilities and the patients a proper visibility was done.

i. Operational Feasibility

The study found out the challenges users faced with the existing systems and further established the user's ability and willingness to use the proposed system. It also established the availability and ability of ICT personnel to support the proposed system.

ii. Technical Feasibility

This was geared towards establishing if the respondents had the minimum requirement to adopt or implement the new proposed mode. Of importance was the hardware such as computers and the availability of stable internet connection. With this information the study was justified in its adoption and implementation. It is well known that some of the software that was used during the study were open source.

iii. Economic Feasibility

The cost-benefit analysis and the return on investment were important factors. Both the capital investment and operation investment were taken into consideration. The result benefit to the consumer in terms of wellbeing versus the cost were put into a balance.

3.8.2 System Analysis

The data that was corrected from the respondents' proper functional features was established for the proposed system. It formed the basis of the functional requirement of the proposed system. This was achieved by the study considering both the functional and non-functional requirements.

i.) Functional Requirements

At this point various system units were identified. It's from these units that the study formed larger units called subsystems that worked in flow manner to for the main system. The users' functions were identified e.g., health facility supper admin user , patient's user,

referring health staff user, receiving facility health staff user, medical records staffs among others that were identified.

Supper Admin

- Add other users.
- Provide privileges to other users.

Health Records Staff

- Add patients records.
- Modify Patients records.

Medical staffs (Nurses & Doctors)

- Write patients' notes.
- Write Patients' Referral notes.
- Refer Patients.
- Review Patients medical history.

ii.) Non-functional Requirements.

For better function of the proposed system the study focused further on the non-function requirements.

The study considered the following non-functional requirements among others that the study established from the respondents.

Security

- The system must maintain a high level of security as this is expected to handle patients' data which is very sensitive. The system was designed to allow only the authorized users or persons to access it.
- The system should be able to segregate the user's roles and permissions.

Efficiency

- The system should, in the minimal time possible, be able to allow execution of its functions and give out proper output.

Reliability

- The system should be able to synchronize with other subsystems to provide real-time or up to date information.

Usability

- The user should be able to use the system with a lot of easiness, it should clear and have consistency to the users. Should be easy to know the obvious with minimal rain.

Scalability.

- As proposed earlier in the proposal satge on one of the key components of microservices on scalability. It is therefore envisaged to have a system that is highly scalable with minimal downtimes and resilience to severe environment.

3.8.3 Patient's Referral System Use Case Diagram

According to Wixon and Roth, 2012 the use case diagrams are designed to represent the user behavior which contains personas and activities which are further contained in systems boundary. They helped in listing and separating system functionality. Personas represent the fictional users who will interact with the system.

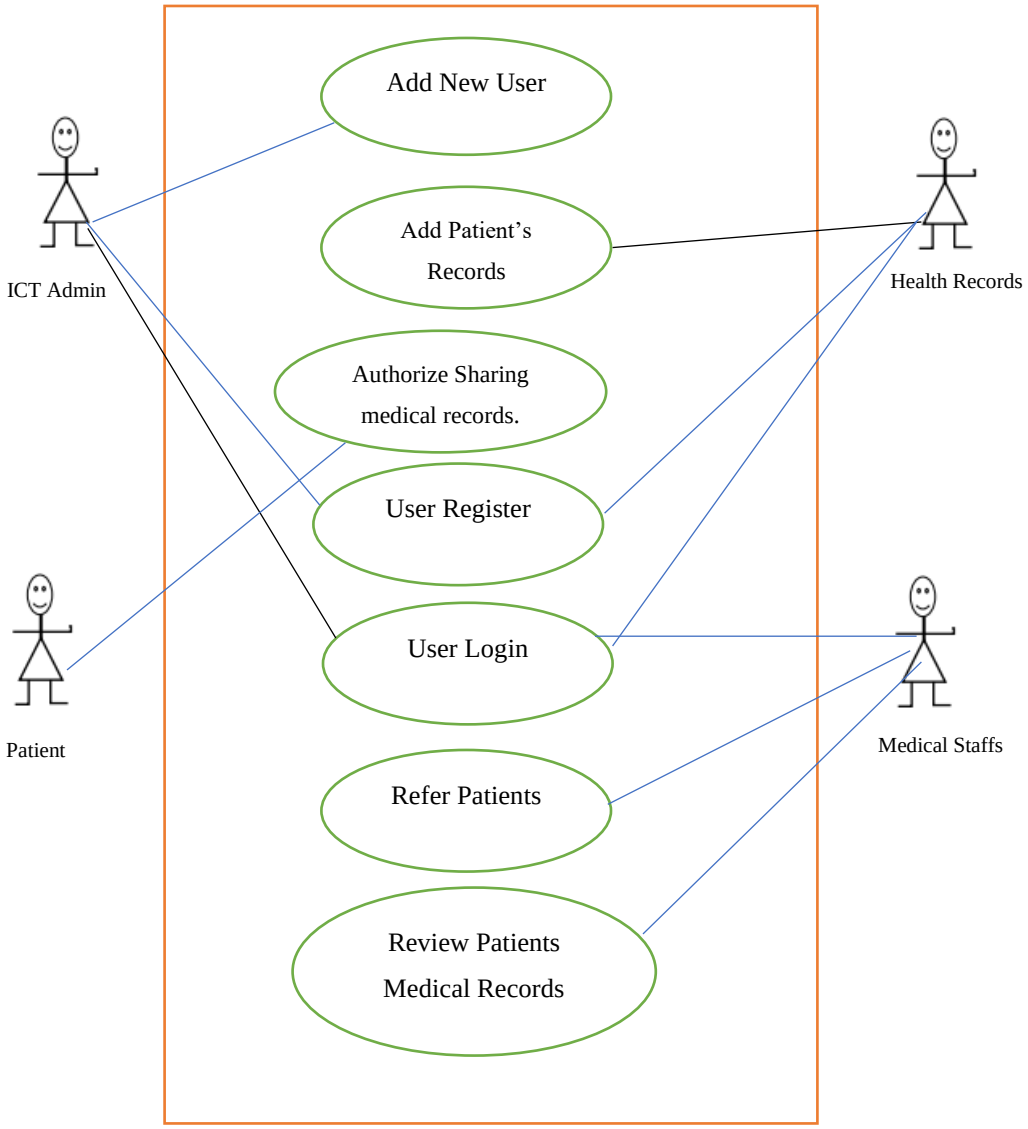


Figure 6: Use Case Diagram

3.8.4 Patient's Referral System Data Flow Diagram

a) Patient's Referral System Context Diagram

The patients' referral system context diagram shows data flowing into and out of the system using external personas in order to establish of the scope of the system is achieved with its objectives.

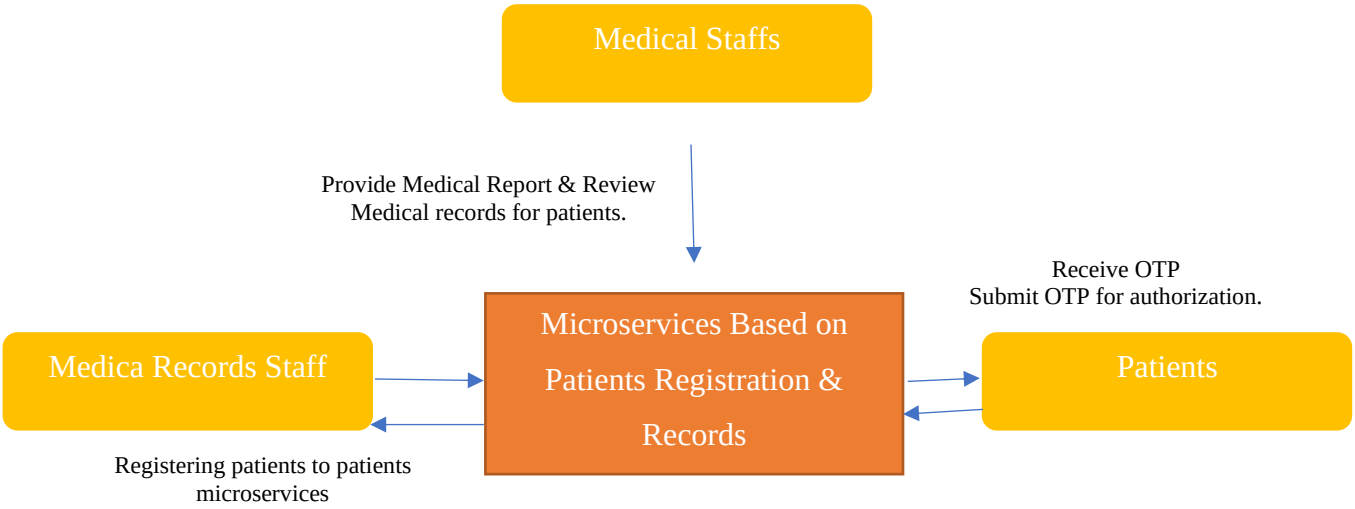


Figure 7: Context Diagram

b) Patient's Referral System Level 1 Data Flow Diagram

Level 1 data flow diagram

3.9 System Design

The system design for this project entailed all the components that led to the system development and operationalization, and they all span from software development kits, frameworks, hardware and the network architecture (Wixxon and Ruth, 2018). Through the process all the interfaces that enable users to interact with the system were well designed with incorporation of the databases for each microservice that is used to accomplish the main objectives of the system. During the design process the following

activities were critical, process design, user interface design, database design, network architecture and system architecture.

3.9.1 Architectural Design

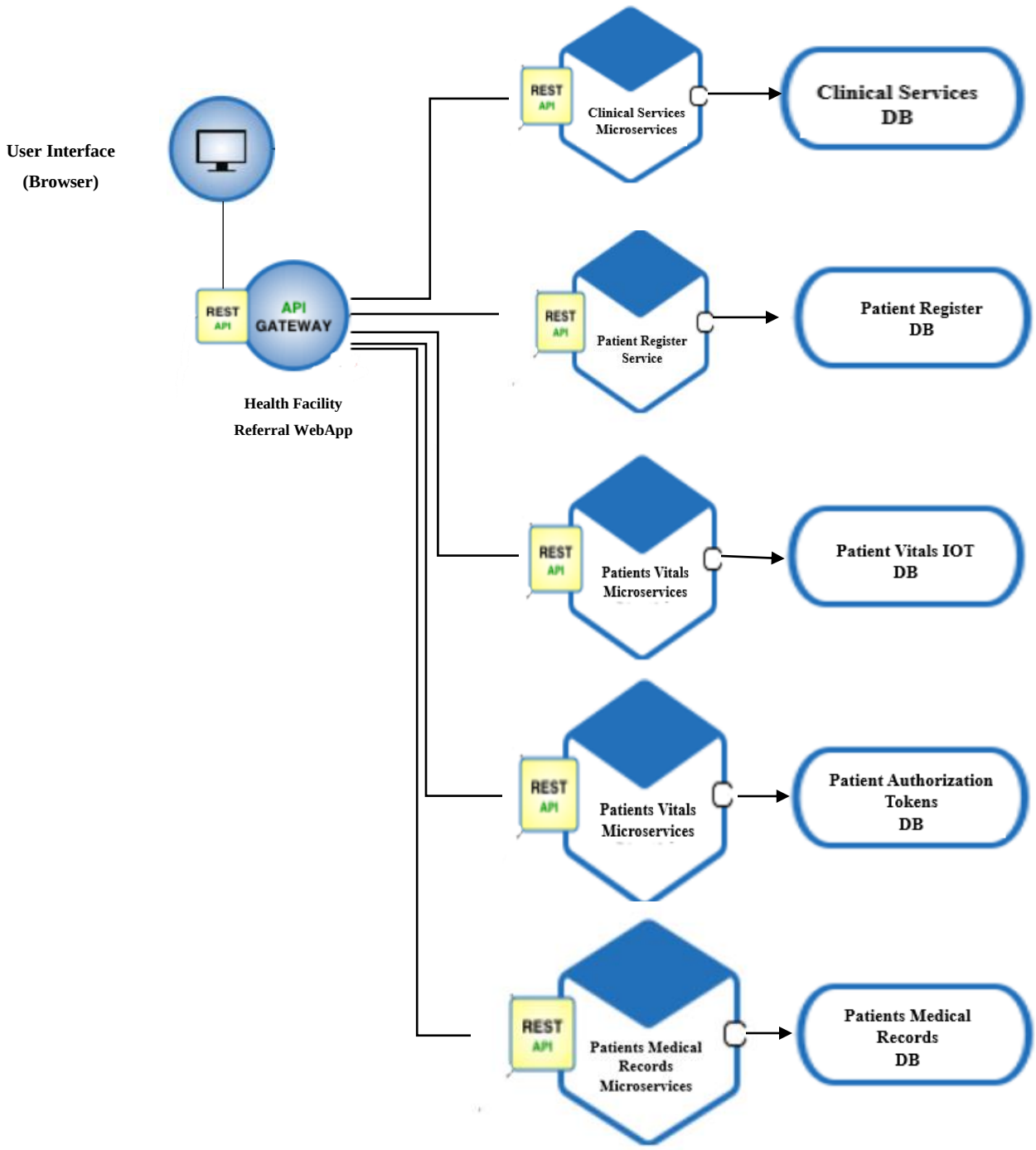


Figure 8: Architectural Design

3.9.2 Sequency Diagrams

i) Referral Microservices Sequence Diagram

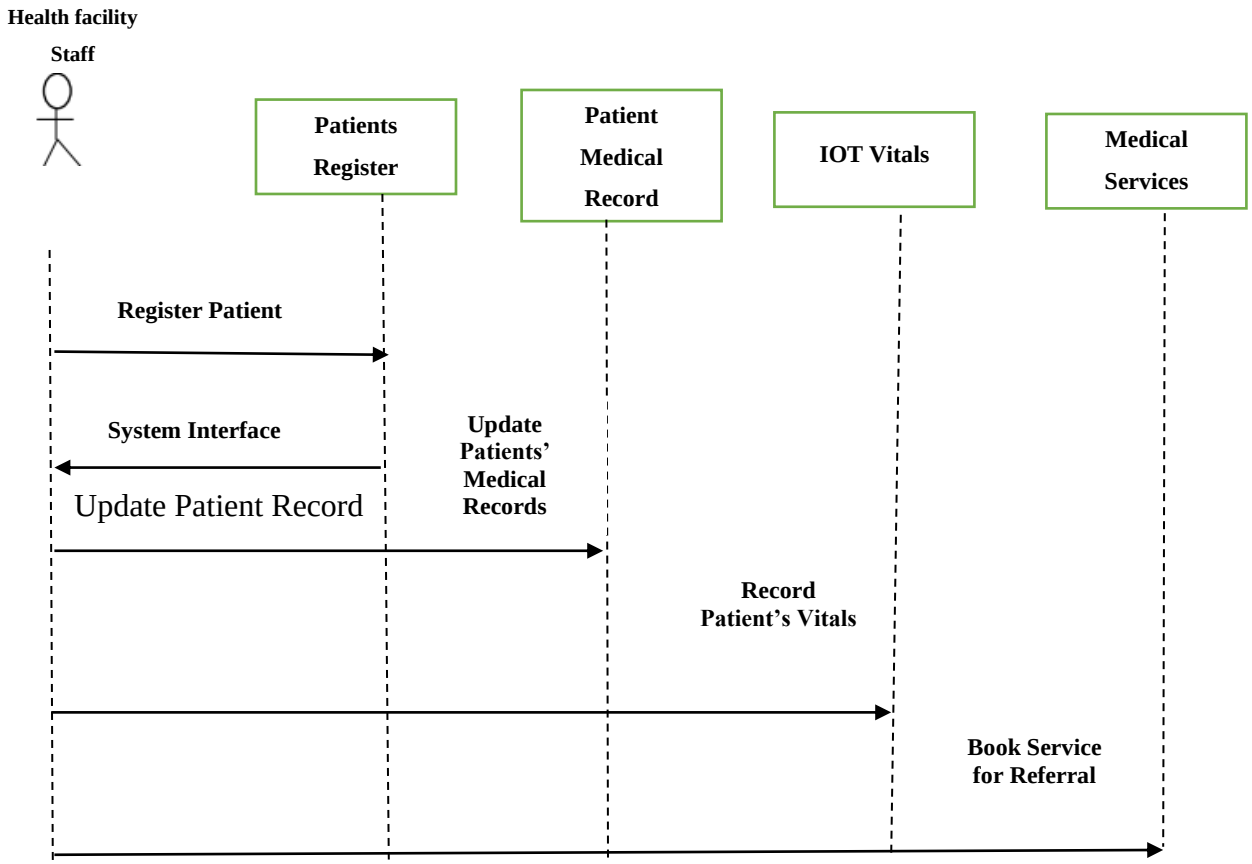


Figure 9: Proposed Referral Microservices Sequence Diagram

ii) Integration Sequence Diagram

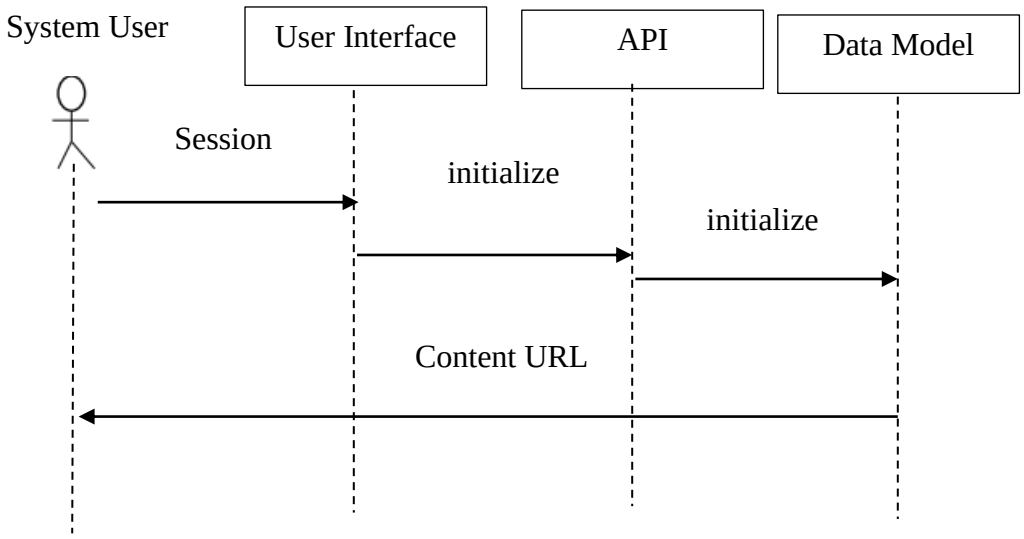


Figure 10: Integration Sequence Diagram

3.9.3 Database Design

According to Naeem, 2022 database design include all the process taken in creating and maintaining of database management system that contains the data. Through the database design logical schema and physical schema emerged as the products.

Using Object Relational Mapping technique, the physical schema produced functional management system. On the other hand, the database requirement was normalized through the logical schema.

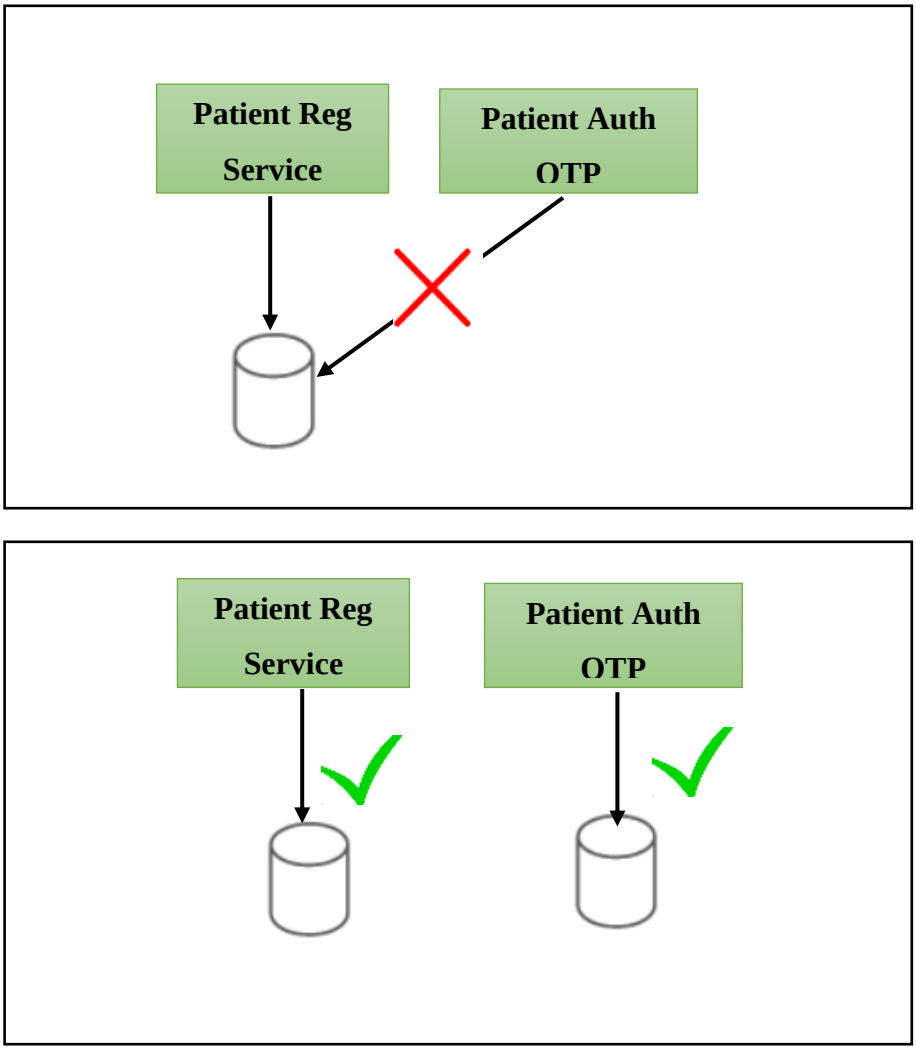
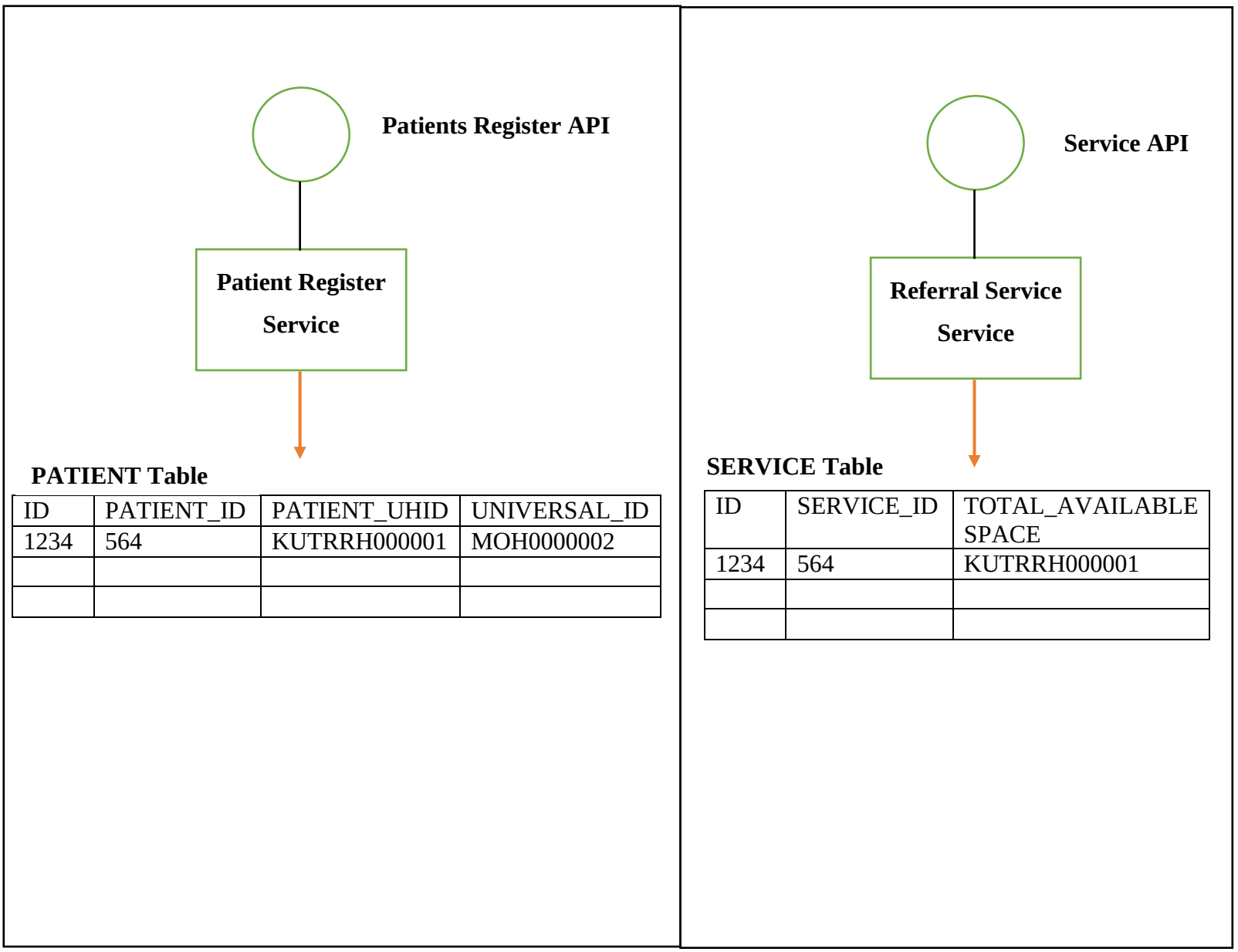


Figure 11: Microservice Database Design Diagram



PATIENT Table

ID	PATIENT_ID	PATIENT_UHID	UNIVERSAL_ID
1234	564	KUTRRH000001	MOH0000002

SERVICE Table

ID	SERVICE_ID	TOTAL_AVAILABLE SPACE
1234	564	KUTRRH000001

Figure 12: API Microservice Integration Diagram

3.9.4 System Program Design

To achieve precise programming statements, the study had to utilize pseudocodes and flowcharts. According to Rai, 2021 the flowcharts in program development process show the algorithm pictorial representation.

i) Referral system overall flowchart

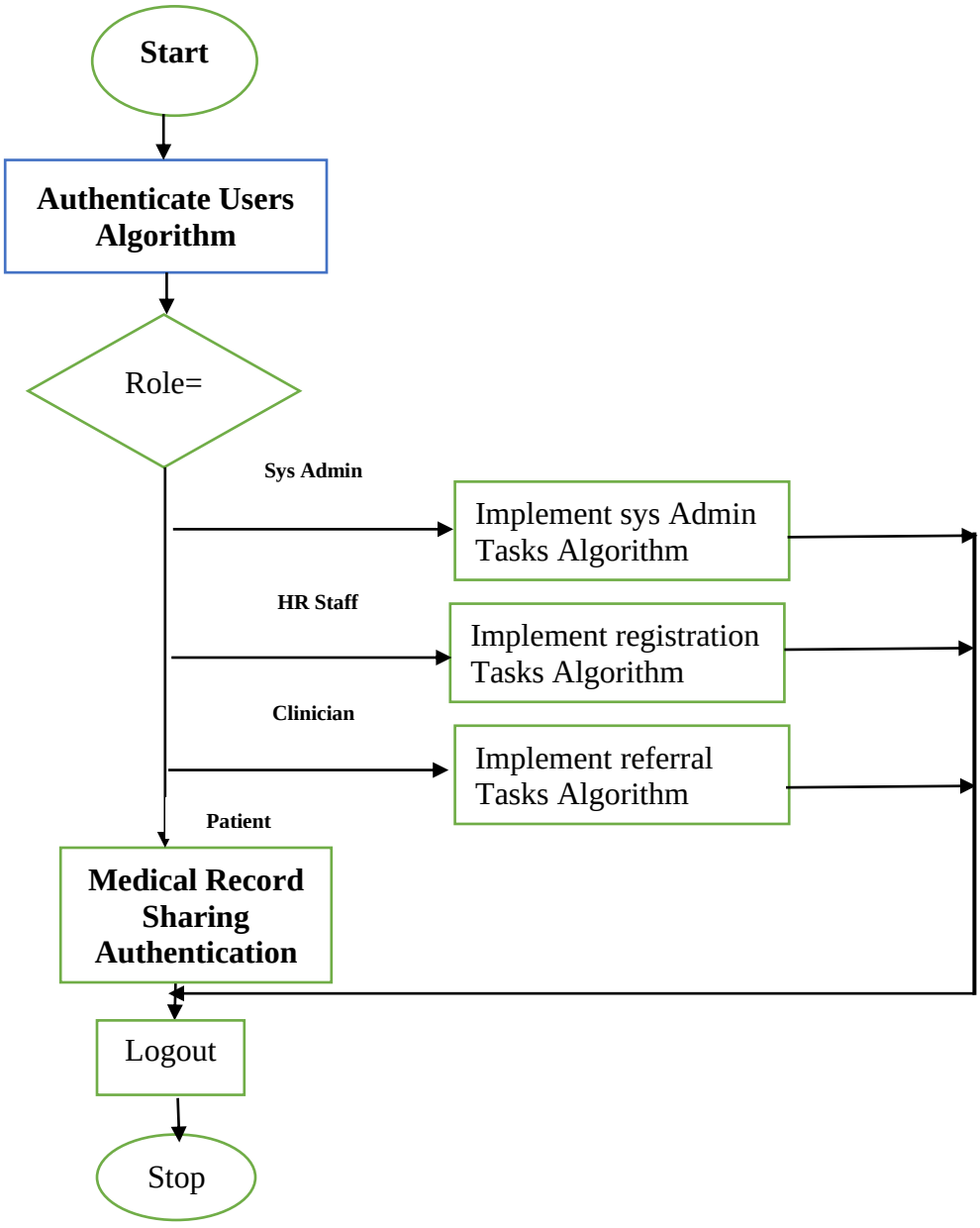


Figure 13: Referral system overall flowchart

ii) Validate and Authenticate Users Pseudocode

Begin

GET LoginID

GET Password

IF [LoginID == EnteredUsername && Password == EnteredPassword THEN

Login Successful

ELSE

Login Failed display wrong username and or password.

ENDIF

iii) System Admin Pseudocode

Begin

Display homepage admin

Display admindashboard

Display add and delete user

Display View User

Display Users Report

End

iv) Referral services Pseudocode

Begin

Display referral page

Display Referral Dashboard

Display available facilities.

Display cost per service per facility

Display referral button

Display patients' details

End

v) Logout Pseudocode

Begin

Display Logout

Confirm Logout

Exit page.

Display login home page

End

3.9.5 Referral Patients User Interface Design

The design shows the graphical user interface design used by users to interact with the referral system.

Admin's Page

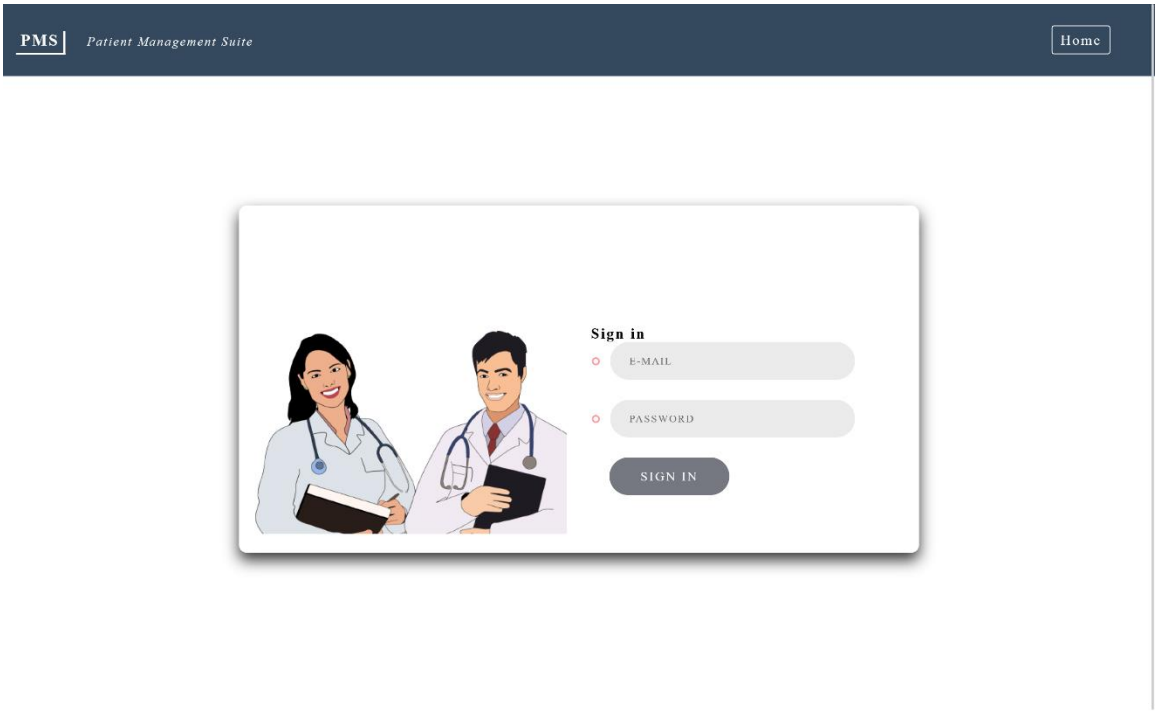


Figure 14: Referral Patients User Interface Design-Admin Page

Add User Page (Admin)

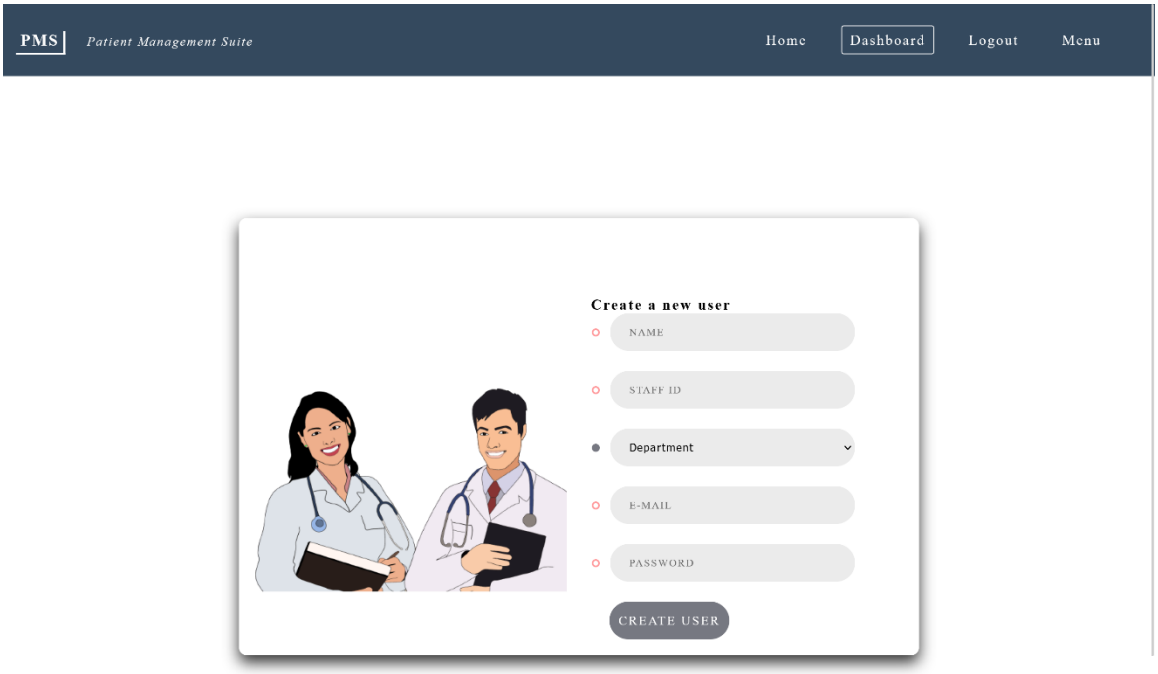


Figure 15: Referral Patients User Interface Design-Add User Page

Patients Referrals Page

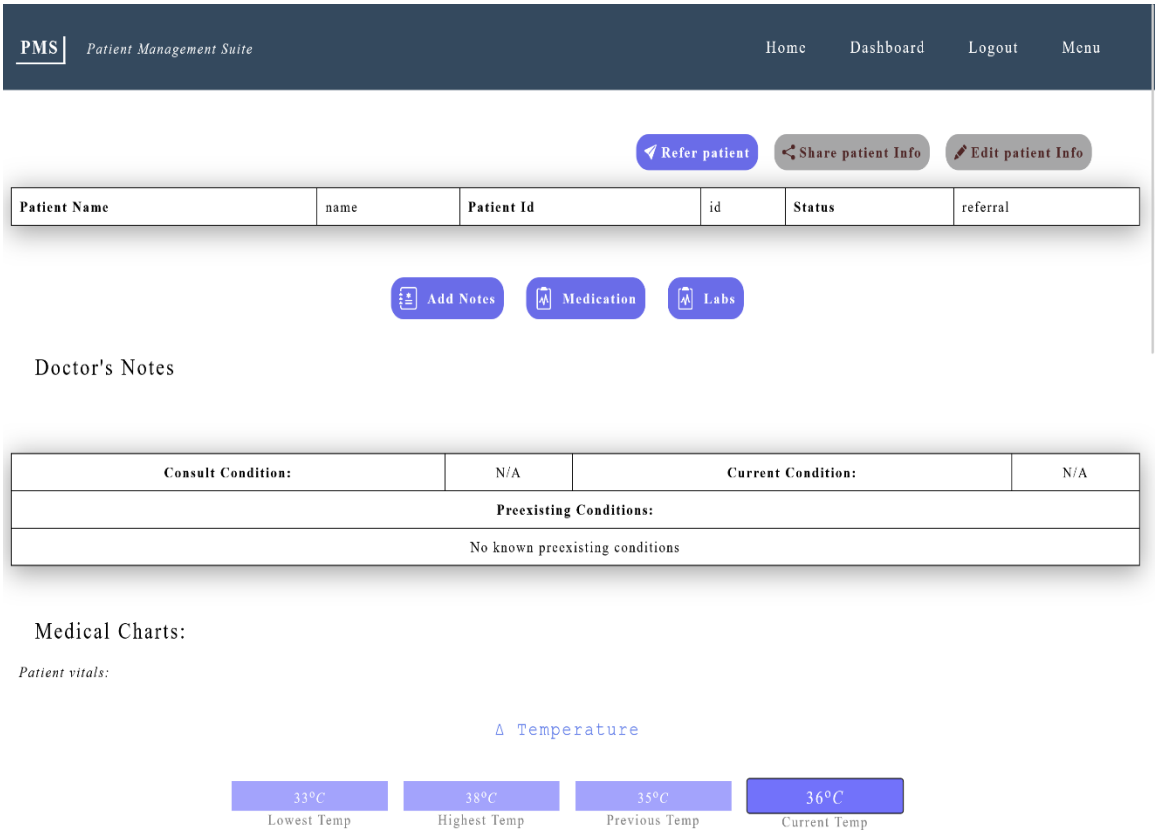


Figure 16: Referral Patients User Interface Design-Referral Page

Patient Authorization OTP

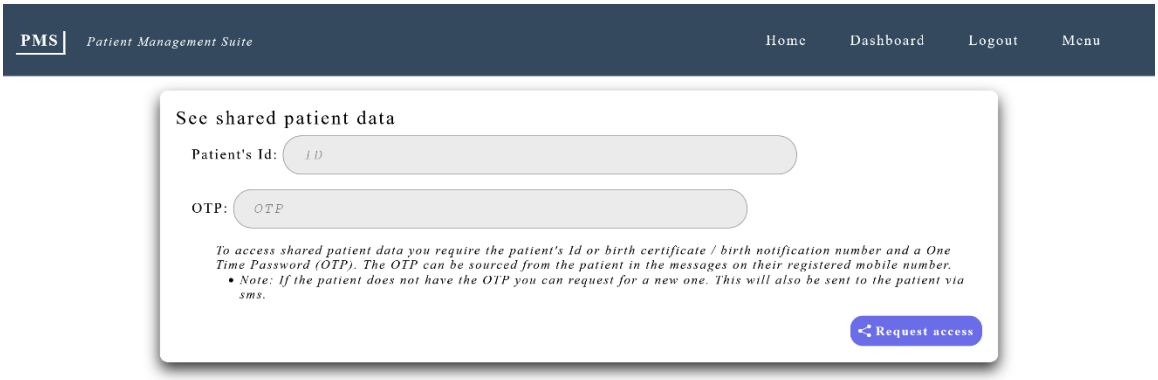


Figure 17:Referral Patients User Interface Design-Patient Auth. Page

IOT Patients Dashboard

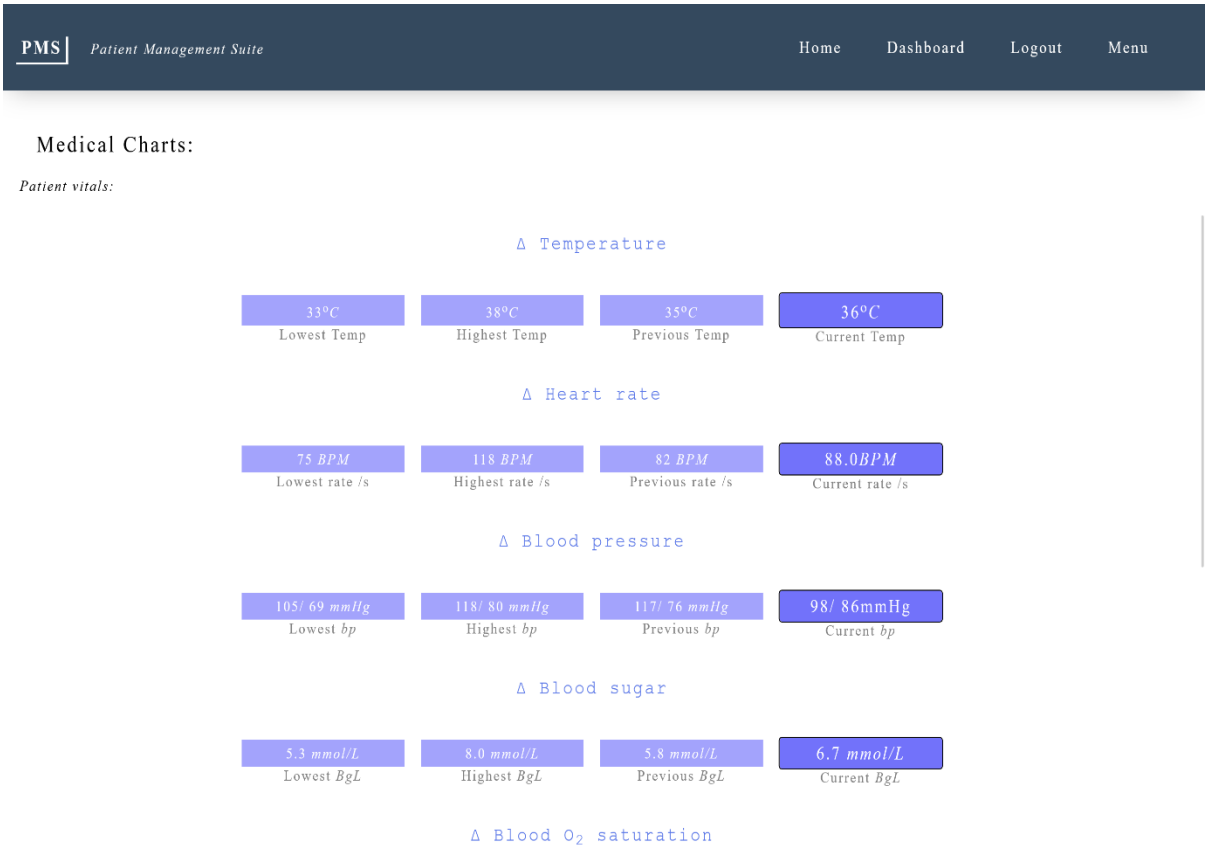


Figure 18: Referral Patients User Interface Design-IOT Patient Dashboard

3.10 System Implementation

3.10.1 Hardware Resources

The following hardware and software resources were utilized during the system implementation.

i) One computer 500GB and 8 GB RAM
ii) Internet Connection
iii) SMS subscription
iv) Windows OS
v) RDMS – SQLite (ORM)
vi) Visual Studio Code as an editor
vii) Python Flask Framework
viii) REST API
ix) JavaScript

CHAPTER 4: RESULTS AND DISCUSSIONS

The test plan was developed to establish that all the study objectives were achieved as per the expectation.

The plan focused on two areas: research part and system development part.

a) Research Area:

Conducted Reliability and validity testing of the questionnaires. Questionnaires were sent to five confidential friends.

For the collected data the study used SPSS V22 to test reliability and validity of the coded responses (Analyze-Scale-Reliability) on all the responses.

4.1 Responses from Referring and Receiving Facility Medical Staff

Reliability Statistics	
Cronbach's Alpha	N of Items
.827	120

Responses from Patients

Reliability Statistics	
Cronbach's Alpha	N of Items
.911	110

Responses from ICT Staff

Reliability Statistics	
Cronbach's Alpha	N of Items
.724	98

b) System Development Part

4.2 Referral System Model Scalability and Load Testing

The process of scalability and load testing began with using 2 instances through K6 scripting commands as follows:

```
import http from 'k6/http';
import { sleep } from 'k6';
export const options = {
  vus: 5, // 5 virtual users
  duration: '30s', //for 30 seconds
};
export default function () {
  http.get(' https://kutrrh-pms.onrender.com/');
  sleep(1);
}
```

After saving the above script file in the k6 directory the following command was run;

```
cd ..
cd ..
cd k6-test
```

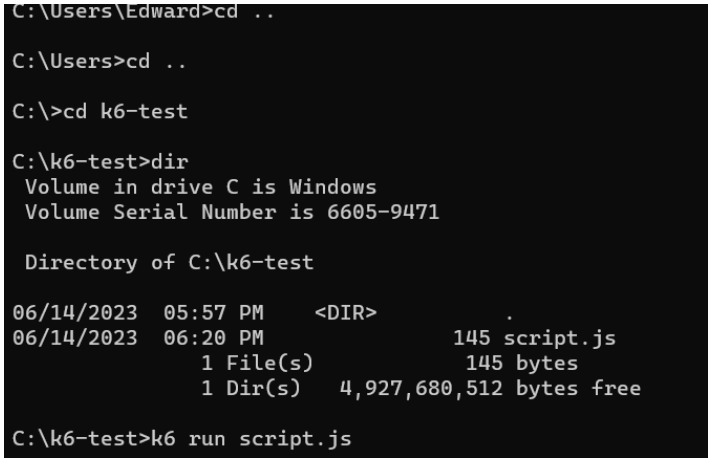


Figure 19: K6 Load testing script

```
k6 run script.js
```

The following contains the Test Plan, Test Data and results obtained during implementation testing.

The test was conducted on k6 testing tool with the aid of command line commands on windows operating system. Two parameters were used on testing the load and execution/response rate on the system and these were the virtual users against time taken.

The number of users was incremental against constant time and later adjustment on the time.

The results were as in the following figures.

4.2.1 Load Test 1

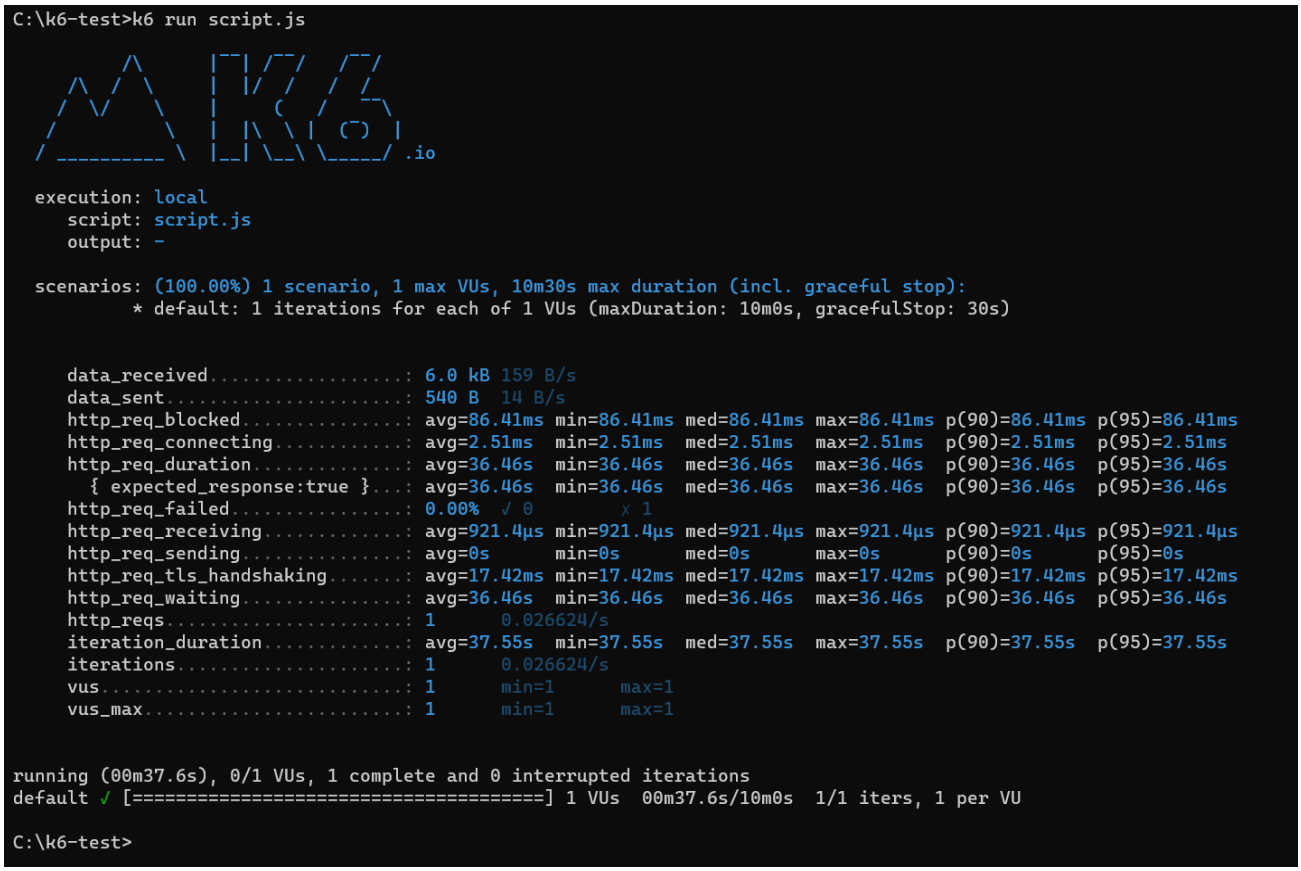


Figure 20: K6 Load Test 1

4.2.2 Load Test 2

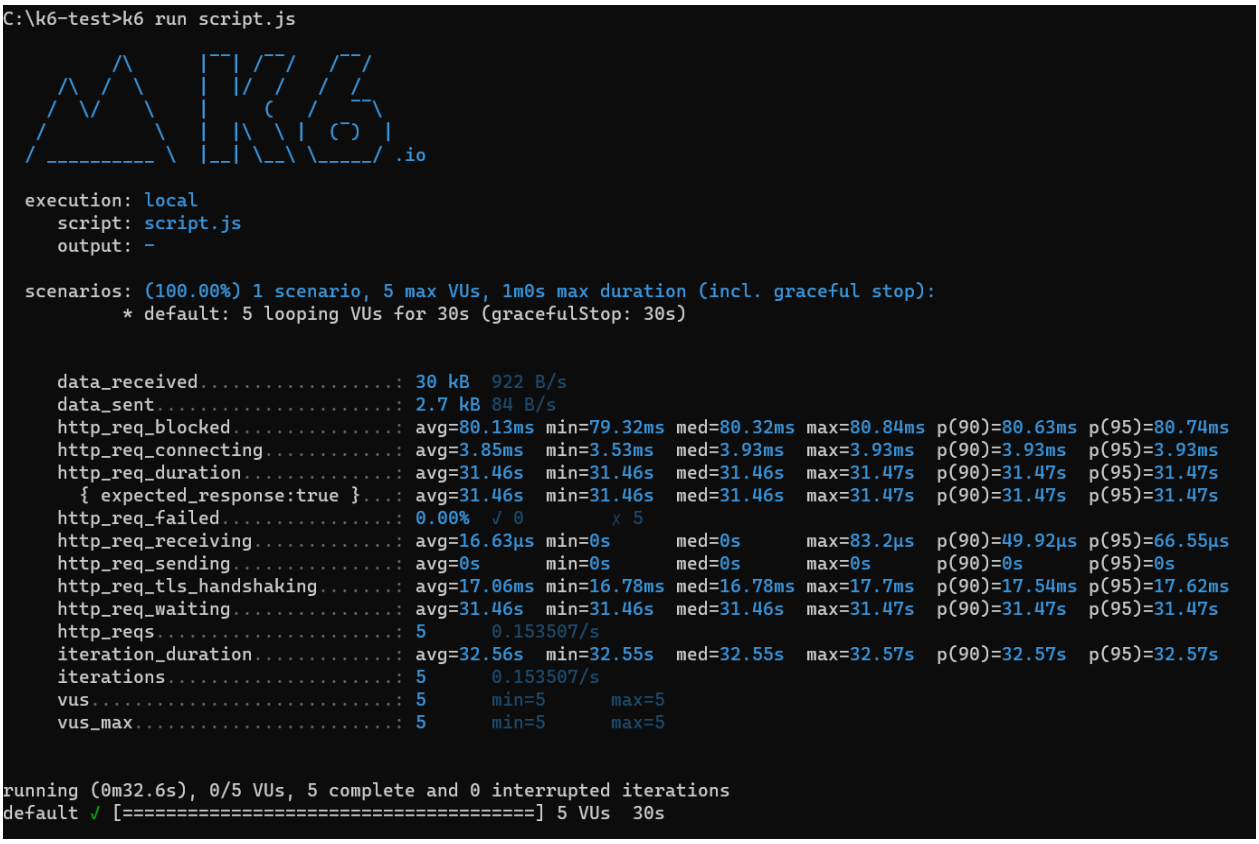


Figure 21: K6 Load Test 2

Discussion.

When running microservices the user load is usually distributed to a variety if instances accessed at a time in different environments which is in agreement with Iftene & Baboi (2019). The microservice will have reduced unnecessary processing tasks as they will be called only when needed as opposed to monolith. From the above results when the test was scaled to more users at the same time 30 seconds, still the system performed well and did not abort. The average response http waiting time was 31.46s as opposed to 36.46s of one instance less users and same time. Therefore, this indicates that the service failure rate or error occurrence is minimized by the increase of instances.

Performance Testing

Two Use Cases

Attached are two test cases with scenarios:

Case ID : 1

Scenario 1: Referring a patient who has not been registered in the system.

Activity	Login	Register Patient by Health Record Staff	Medical Consultation and notes writing	Checking available facility for referral	Referring patients	**TOTAL TIME (S)**
Time (s)	30	180	600	30	30	870

Table 19: Scenario 1 - Time taken for referring a new patient

Case ID : 1

Scenario 2: Referring a patient who has already been seen by the clinician.

Activity	Login	Register Patient by Health Record Staff	Medical Consultation and notes writing	Checking available facility for referral	Referring patients	**TOTAL TIME (S)**
Time (s)	0	0	0	30	30	60

Table 20: Time taken for referring a patient already registered

Response From Respondents

Responses on the average time taken to process patients' referral to the receiving facility.

Item	Frequency	Percentage
0-2 HRS	12	10%
2-4 HRS	60	50%
4-6 HRS	36	30%
More than 6HRS	12	10%

Table 21: Average time taken to process patients' referral

From the above test carried on referring patients using the automation process verses the manual process, the study is justified that the automation process by use of microservices will reduce the time taken in processing patients for referral.

User Validation Test Case

Case ID: 3

User Interface: Login System

Action	Input	Expected Output	Status
Put in the right username and password	test-ict@test.test test	Authorized to access to the system.	Pass
Put in the wrong username with empty password	test-ict@test.test	The system to prompt error with "Invalid Username."	Pass
Put in wrong username with wright password	edward test	Show an error invalid username	Pass
Put in the right username with empty corresponding password	test-ict@test.test -	Prompt wrong password message	Pass

Type both wrong password and username	test-ict1@test.test GXT123	Error message for both password and username	Pass
username and password empty	- -	Error “ you must enter username”	Pass

Table 22: User Validation Test Case

Acceptance Testing

Using stratified and convenience sampling, 100 real system users were identified and allowed to access and use the system in order to test if the system meets the user expectations. The system model was hosted on onrender.com. Using the hospital computers all user categories were requested to log in to the system and start executing the tasks. All users successfully managed to log in to the system and all sampled patients were able to authorize the sharing of their medical records.

CHAPTER 5: CONCLUSION

5.1 Findings

This study was guided by four main objectives which whose end goal is to develop a prototype that uses microservices to automate the process of patient's referrals in Kenya. However, the first and second objective was to establish the preparedness and requirements of the new referral system in the health facilities in the country, Kenya. Further the first two objectives were to find out the most convenient way patients could participate in authorizing the access of their medical records. These objective goals were achieved, and their findings are summarized as follows.

5.1.1 Existing referral systems and their challenges in Kenya

Regarding research question number one on finding out the existing systems used or patients' referral in the country, the existing referral were identified from both the questionnaires and literature review to be manual referral system. It was established that most health facilities had an array of challenges while either trying to refer or receive referred patients using the manual system. The main including lack of space, lack of centralized system to quickly handle the referral process, technological challenges while sharing the patients' medical records and providing incomplete medical records to patients. Further, it was noted that over 95 percent of patients receive various printout documents like referral note , investigation reports like laboratory results and x-ray film printout and request notes which get distorted while being handled by the patients. The medical staff gave contributions on what they feel should be integrated into the new proposed system. The majority proposed that due to the data protection act, patients or their next of kin should be able to conveniently consent to access their medical records, they agreed that there should be a system that has one click to share patients' data. The responses on use of IoT devices on monitoring patients' vitals while on transit to the receiving facilities should be considered. Of concern to over 50% of the respondents was the time taken to process one patient for referral. 50% of the respondents agreed that patients would take an estimate of 2-4 hours to be processed for referral. During the process of referral, most respondents noted that patients present wrong diagnosis, distorted medical reports, lack of proper

documentation on medical history, and even after patients having travelled for long distance, they could still miss spaces for admission.

5.1.2 Easiest, Simple and Reliable way patients can authorize healthcare to access their medical history records.

Based on the 2019 Kenyan Data Protection Act no. 24 the patients' data would only be accessed with express authority from themselves or their next of kin. This informed the second research question finding out the easiest way the patients would be engaged in authorizing access of their medical history data. Use of right technology in patients consenting access of their medical records, the study provided questionnaires on the most preferred and accessible technology where it was established that at least 92 percentage of the patients were comfortable with SMS. This was backed by the positive response by the ICT category group who with 84% ascertained that the GSM network coverage was good to support the use of SMS.

5.1.3 Proposed a better technology and system model to facilitate the referral process in Kenya.

This will be able to answer the third research question on the best technology and development of system model that can be adopted to solve the challenges experienced by the current referral system. Through literature review, it was established that microservice architecture technologies have more advantages than monolith systems. Going by this, a system model was proposed, and a prototype designed using microservice technology with an agile software development methodology through Python & Flask Framework with REST API. The interface was designed using HTML 5, CSS and JavaScript. The prototype was tested and patients being at the epicenter of this research as they are the key customers and beneficiaries of the proposed system were selected to be part of the testing process where they participated in consenting the access of their medical history records. . In evaluating the system over the existing manual system using 100 real users from each group as test case 100 results were obtained in the test scenarios using the software protype developed as part of this work. It was realized that 99 percent of the users carried out the referral process with a positive impact in reduced time in the referral process as compared to the manual process.

5.2 Research Limitations.

The research being conducted in the health facilities which contains sensitive patient information, it took a lot of time to get approvals from the facilities to conduct the research. Some facilities were even denied access based on the past bad experiences they have had from researchers, even some allowing data collection to be conducted anonymously without disclosing their identity. This had a negative impact on the overall research in taking much time than envisaged before. This delayed development of some the whole system prototype has it depended on the response from the users.

As mentioned under the research methodology, descriptive research design was embraced which had its own disadvantages like limitation in answering such questions as "why". This type of design had to be embraced because of its ease to use and also its ability to narrate situations more especially in natural environment.

Though there was validation of the questionnaires, still they could not prevent the biasness of understanding of the referral concept from the respondents. The questionnaires could eliminate the excitement and bad experiences the respondents have had before and even managed the sincerity of the respondents. The ignorance of some respondents couldn't be managed by the reliability and validity testing of the questionnaires. While K6 load testing and response rate was successfully used, the environment used during connection could not meet the standard requirement as the researcher used the available item like personal computer.

5.3 Conclusion on the Research

From the research findings done from the sampled population, it established that the referral process in the health facilities in Kenya are largely manual and not automated, hence necessitate to embrace automation of referral process across all the health facilities in the country. The study further reveals that introducing a model that capitalizes on microservices will improve the process and reduce costs for the patients in the referral process. The use of microservices will improve the scalability of the system which has a positive ripple effect on the resilience and availability of the system when handling high demand of simultaneous operations. Further, through the testing process from the sampled population for testing it can be concluded that the system performed as expected. Users

managed to execute tasks in a timely manner with every functionality test passing. The proposed new system proved to be faster, easy to use and easy to understand.

5.4 Opportunities to Practitioners

Because microservices are deployed across different environments they increased risk and loss of control as much as visibility. Further studies are recommended to come up with a security framework that can be used by the microservices to cap such risks.

The process of decomposing the software application to microservices experienced a lot of complexity especially in determining each microservice component size with its database sharing model. Based on this, the study recommends further research to be done on the standards to the extent which decomposition should be done with respective database designs so as to manage the extent of microservice complexity and decoupling for better performance to be achieved

The study only used K6 technology for load testing of microservices with virtual user simulation. The study recommends that other load testing and scaling technologies be used, and the result be compared.

5.5 Recommendation for future work

5.5.1 To the Government of Kenya and Practitioners

It is recommended that the referral system be implemented by the Ministry of Health at the national level to facilitate the process of sharing patients' medical records and referral process.

The existing systems used by the Ministry of Health to be modified to microservices and have provision for integrating application program interface.

5.5.2 To Academician and Researchers

According to Bradley, (2021)microservices technology puts a lot of pressure on API. Research should be done on designing a strong API management technology model to be adopted by microservices technologies.

Researchers too should research on reducing the complexity of decomposing microservices by designing better, faster, and more efficient ways with guiding principles.

Researchers should establish best model or framework on service standardization to improve trust and confidence amongst healthcare providers both public and private sects.

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APPENDICES

a) Project Schedule

Activity	Months				
	March	**April**	**May**	**June**	**July**
Proposal Drafting	1 Month				
Data Collection and Analysis		1 Month			
Prototype Design			1 Month		
Prototype Implementation				1 Month	
System Testing					1 Month
Documentation	1 Month				

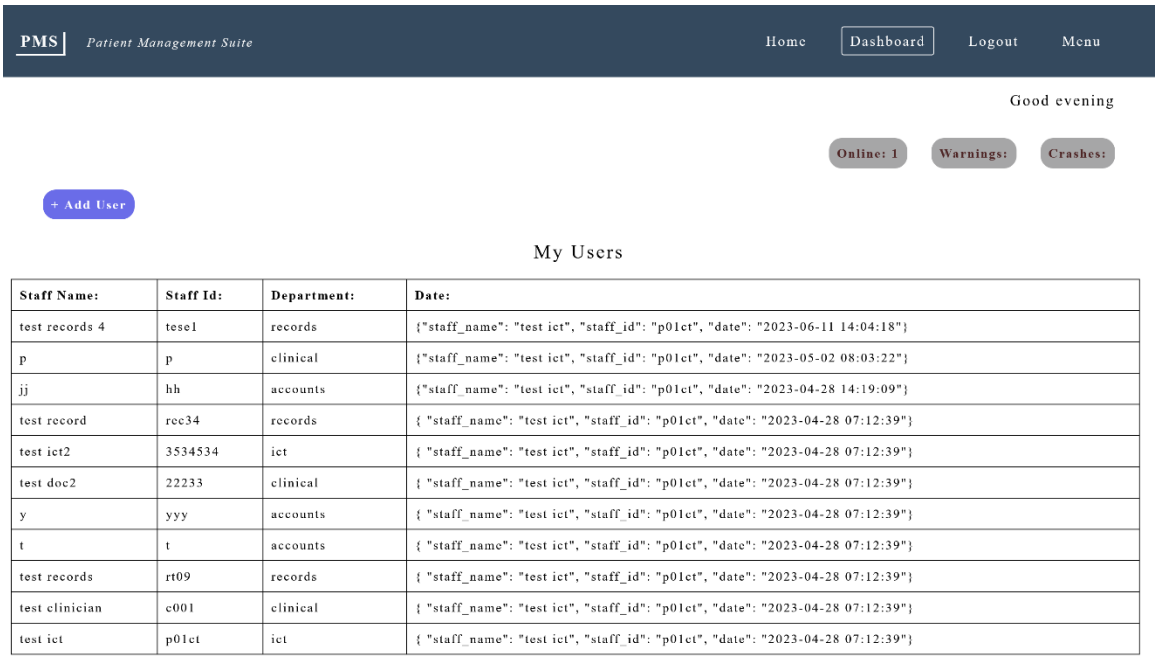
Table 23: Project Schedule

b) Project Budget

Description	Unit Price	Cost (Ksh)
Computer System	120,000	120,000
Other Accessories	10,000	10,000
Subscription fee to research Journals	22,000	22,000
NACOSTI Registration	1,000	1,000
Data Collection	30,000	30,000
Extraneous	15,000	15,000
Total		**198,000**

Table 24: Project Budget

c) Sample User Interface



Staff Name:	Staff Id:	Department:	Date:
test records 4	tese1	records	{"staff_name": "test ict", "staff_id": "p01ct", "date": "2023-06-11 14:04:18"}
p	p	clinical	{"staff_name": "test ict", "staff_id": "p01ct", "date": "2023-05-02 08:03:22"}
jj	hh	accounts	{"staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 14:19:09"}
test record	rec34	records	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
test ict2	3534534	ict	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
test doc2	22233	clinical	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
y	yyy	accounts	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
t	t	accounts	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
test records	rt09	records	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
test clinician	c001	clinical	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}
test ict	p01ct	ict	{ "staff_name": "test ict", "staff_id": "p01ct", "date": "2023-04-28 07:12:39"}

Figure 22: Sample User Interface 1: Add New User

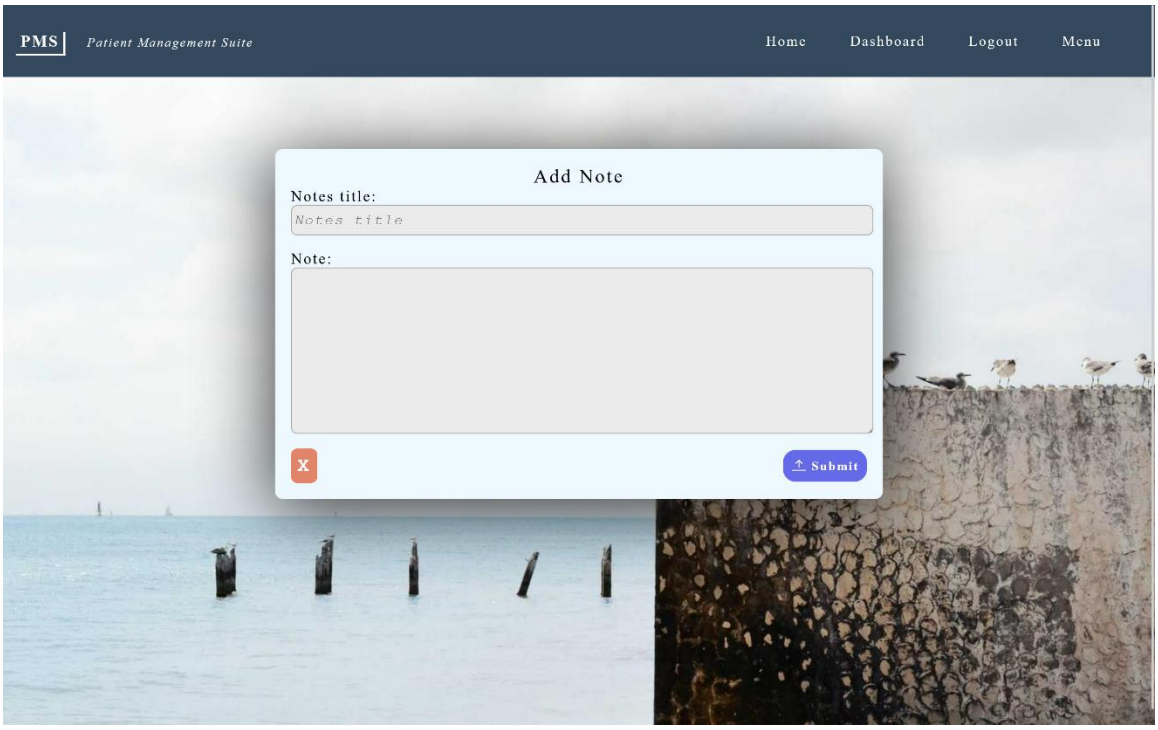


Figure 23: Sample User Interface 2: Add Patient Notes

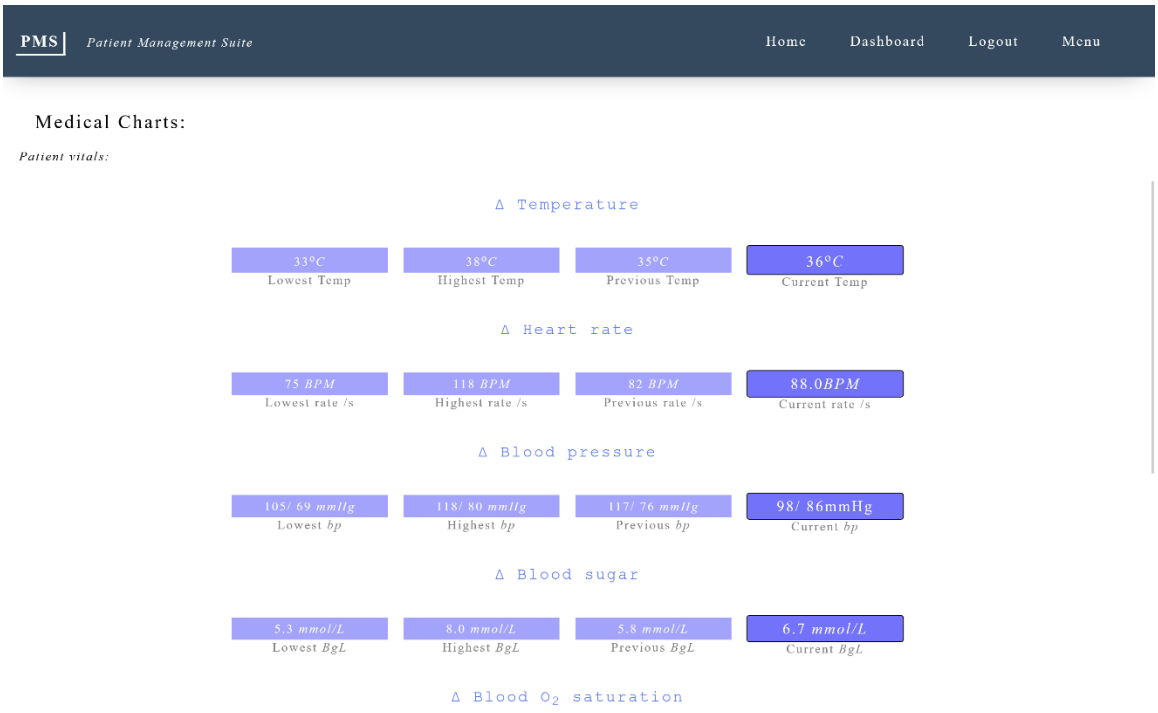


Figure 24:Sample User Interface 3: Patients Vitals from IOT

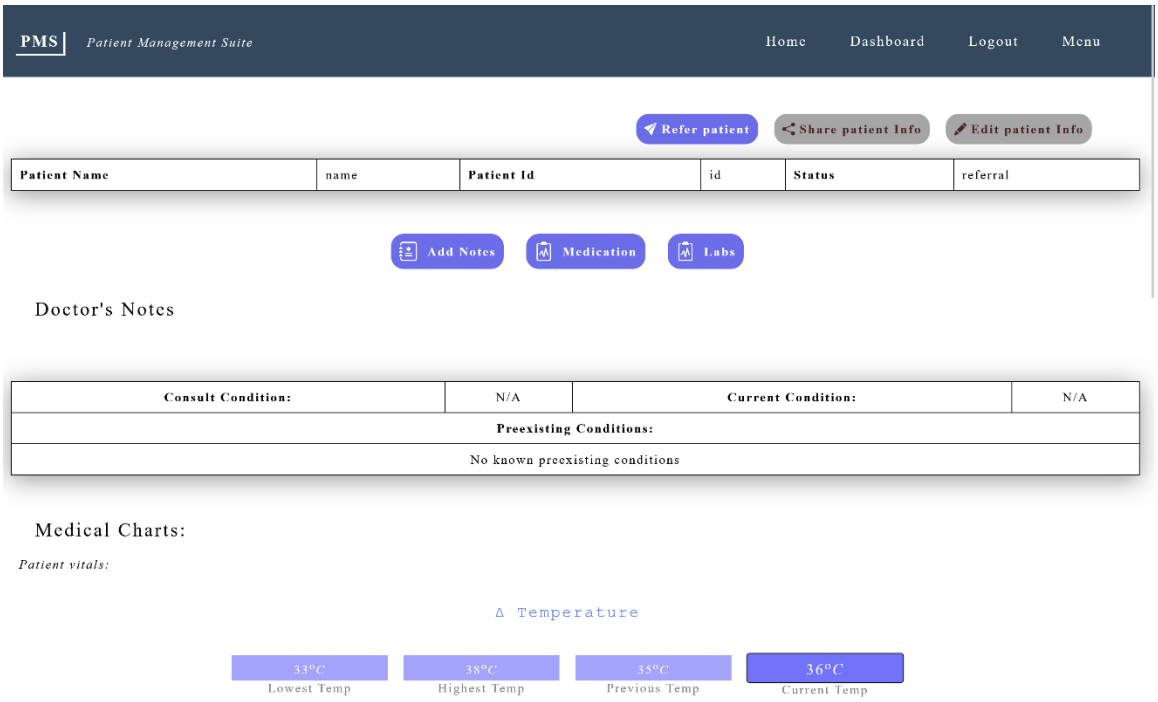


Figure 25: Sample User Interface 4: Doctor's Notes

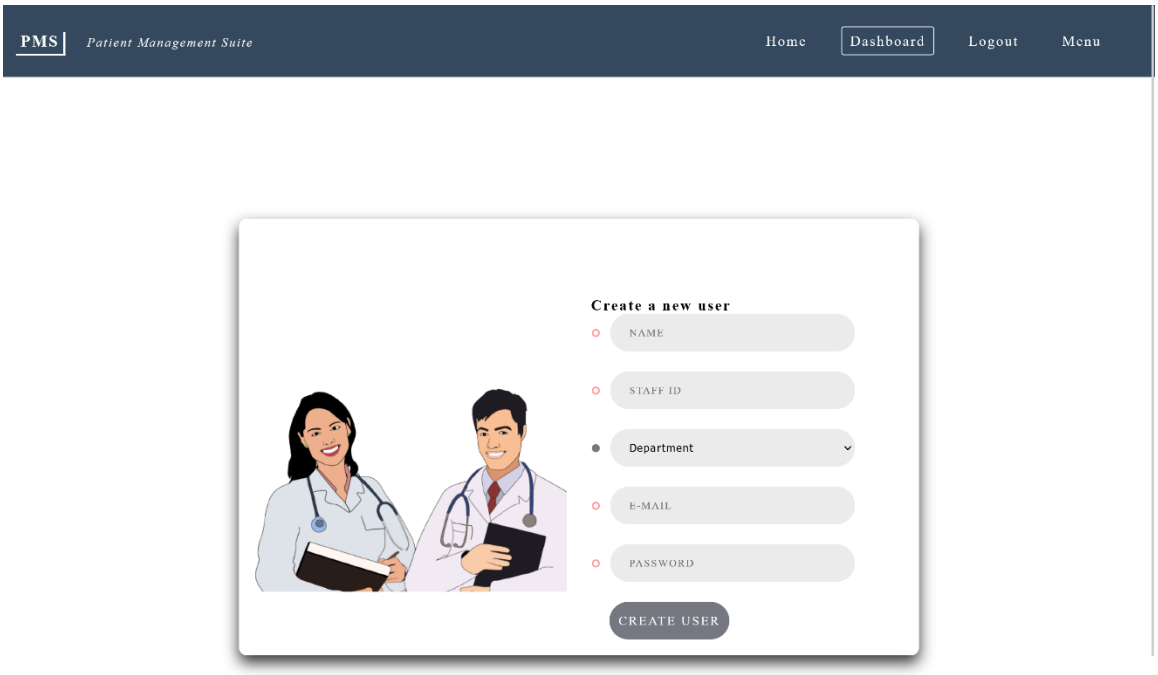


Figure 26: Sample User Interface 5: Add New User by Super Admin

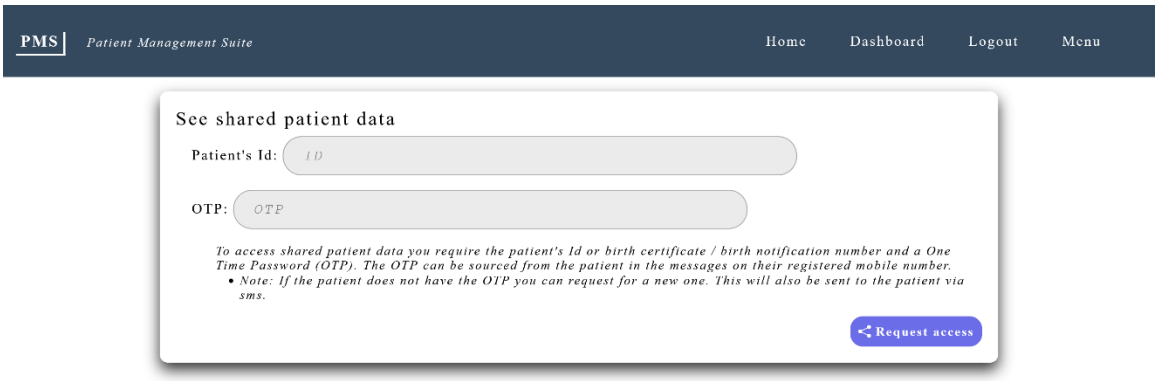


Figure 27: Sample User Interface 6:Patient Referral

d) Appendix I: Personal Research Introduction Letter

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To whom it may concern

Dear Prof./Dr./Sir/Madam

COLLECTION OF ACADEMIC RESEARCH DATA

My name is Edward Onkundi Ogendi a final year master's student pursuing Master of Science in Distributed Computing Technology in The University of Nairobi in the Faculty of Science and Technology, department of Computing and Informatics. Upon getting the approvals on my research proposal on "Use of Microservices in Integrating Hospitals' Health Management Information Systems for Patients' Referral in Kenya" and the **permit** from **National Commission for Science, Technology & Innovation,** I therefore wish to proceed with the research.

It is therefore in this regard, that I request your participation in this study that aims at finding the existing referral system in the Kenyan health facilities, the challenges with the current referral, and propose a better model that will be used to solve the challenges faced by the stakeholders i.e. the referring facility, receiving facility and patients during the referral process. My target population are Medical Officers, Clinical Officers, Nurses, Hospital Administrators, Health workers and Kenyan citizen who have been patients and referred at some point in their life. With honesty, kindly complete the questions attached.
I will accord confidentiality to your response and the feedback will solely be used for academic purposes.

Yours Sincerely.

Edward Onkundi Ogendi (master's student, UoN)

e) Research Questionnaires

Referring Facility Staff Questionnaires.

This research instrument on the use of microservices to design a patient referral information system for health facilities in Kenya will be used to find out i.) the current referral system in Kenyan hospitals and its efficiency, ii.) the status and nature of ICT infrastructure in the facilities, and iii.) most embraced communication mode by Kenyan patients. The data obtained will only be used for academic purposes and will be handled with confidentiality.

Check (✓) appropriately for the closed questions.

Please write your answers in the space provided for open-ended questions.

ii) ORGANIZATION NAME ……(OPTIONAL)

iii) Department……

iv) Facility Level

Level 1	{ }
Level 2	{ }
Level 3	{ }
Level 4	{ }
Level 5	{ }
Level 6	{ }

v) What are some of the challenges faced while sourcing for a referral facility?

Item	**Yes**	**No**
Lack of space in the receiving facility		
Lack of centralized system to quickly process the referral requests		
Financial constraints on ambulance hire		
Technological challenges in sharing patient's medical summary		
Providing incomplete medical report on the patient's status occasioned by lack of centralized patients medical records.		
Other		

vi) What are the documents given to the patients to be presented to the receiving facility?

Item	**Yes**	**No**
Referral note		
Investigation already done (Imaging, Lab test, etc.)		
Request for test not available in referring facility		
Other		

vii)

A) Does your facility refer patients to other facilities?

Item	**Yes**	**No**
Referring patients to other medical facilities		

B) If yes, what type of referral system does your facility use?

Item	**Yes**	**No**
Automated System (Using Patients management system –No paperwork)		
Manual System (Use of paper as referral note)		

viii)) What are some of the key requirements you think should be included in the proposed automated patient referral system?

Item	**Yes**	**No**
Patients consent to share their data to other facilities		
Function to allow referring facility to share patients' data		
Unique patients' identifier across all the facilities for referring purpose		
Technological devices like smart watch to capture patients' vitals in advance for example within 30 minutes of patients' arrival for normal diseases		

ix)) What is the average time taken to process patients' referral to the receiving facility?

Item	**Yes**
0-2 HRS	
2-4 HRS	
4-6 HRS	
More than 6HRS	

Receiving Facility Staff Questionnaire

This research instrument on the use of microservices to design a patient referral information system for health facilities in Kenya will be used to find out i.) the current referral system in Kenyan hospitals and its efficiency, ii.) the status and nature of ICT infrastructure in the facilities, and iii.) most embraced communication mode by Kenyan patients. The data obtained will only be used for academic purposes and will be handled with confidentiality.

Check (✓) appropriately for the closed questions.

Please write your answers in the space provided for open-ended questions.

x) ORGANIZATION NAME ……... (OPTIONAL)

xi) Department……

xii) Facility Level

Level 1 { }

Level 2 { }

Level 3 { }

Level 4 { }

Level 5 { }

Level 6 { }

xiii) What are the challenges faced while receiving referred patients to your facility?

Item	**Yes**	**No**
Patients lack proper documentation		
Patients with distorted medical reports		
Patients having wrong diagnosis		
Lack of space for patients translating to long queues		
Other		

xiv) What are some of the important documents used in receiving referred patients?

Item	**Yes**	**No**
Patients' Referral note		
Investigation already done (Imaging, Lab test, etc.)		
Patients personal ID		
Other		

xv) What technologies are used while the patients is being referred and while within your facility? What is the purpose of each technology used?

Item	**Yes**	**No**	**Purpose**
Email			
SMS/ WhatsApp			
Printed word document			
Other			

xvi) What are some of the measures you propose to improve the process of referrals system in Kenyan health facilities?

Item	**Yes**	**No**
Introduction of a stable, interactive and reliable web-based system		
Introduction of a sharing patients summary report system		
Other		

xvii)

A) Does your facility receive patients from other facilities?

Item	**Yes**	**No**
Referring patients to other medical facilities		

B) If yes, what type of system does your facility use to process patients received through the referral process?

Item	**Yes**	**No**
Automated System (Using Patients management system –No paperwork)		
Manual System (Use of paper as referral note)		

xviii) What are some of the key requirements you feel should be included in the proposed automated patient referral system?

Item	**Yes**	**No**
Patients consent to share their data to other facilities		
Function to allow referring facility to share patients' data		
Unique patients' identifier across all the facilities for referring purpose		
Technological devices like smart watch to capture patients' vitals in advance for example within 30 minutes of patients' arrival for normal diseases		

xix) What is the average time taken for patients to be processed to your facility from referring hospital?

Item	**Yes**	**No**
0-3 HRS		
3-6 HRS		
6-9 HRS		
More than 9HRS		

Thank you in advance.

ICT Staff Questionnaire

This research instrument on the use of microservices to design a patient referral information system for health facilities in Kenya will be used to find out i.) the current referral system in Kenyan hospitals and its efficiency, ii.) the status and nature of ICT infrastructure in the facilities, and iii.) most embraced communication mode by Kenyan patients. The data obtained will only be used for academic purposes and will be handled with confidentiality.

Check (✓) appropriately for the closed questions.

Please write your answers in the space provided for open-ended questions.

1. ORGANIZATION NAME ……. (OPTIONAL)
2. Department……
3. Facility Level

   Level 1 { }

   Level 2 { }

   Level 3 { }

   Level 4 { }

   Level 5 { }

   Level 6 { }

4. Is your facility connected to the internet?

Item	**Yes**	**No**
Connected to internet		

5. Do you have Hospital Management Information System (HMIS) in your facility?

Item	**Yes**	**No**
Connected to internet		

   If yes, does your HMIS have a patient's referral module?

6. Do you think the available infrastructure is sufficient to support the proposed patients' referral system?

Item	**Yes**	**No**
Stable Internet Connection		
Availability of computers		
ICT personnels		

7. How can you rate the quality of GSM network coverage in the hospital building to support One Time Password (OTP) messages?

Item	**Response**
Excellent	
Good	
Fair	
Poor	

Patients' Questionnaire

This research instrument on the use of microservices to design a patient referral information system for health facilities in Kenya will be used to find out i.) the current referral system in Kenyan hospitals and its efficiency, ii.) the status and nature of ICT infrastructure in the facilities, and iii.) most embraced communication mode by Kenyan patients. The data obtained will only be used for academic purposes and will be handled with confidentiality. Check (✓) appropriately for the closed questions.

Please write your answers in the space provided for open-ended questions.

1. COUNTY NAME …….. (OPTIONAL)

4 What are some of the requirements before being referred to another health facility?

Item	**Yes**	**No**
Patients Consent		
Patients Medical Summary		
Don't Know		

5 How is your medical summary report shared to the receiving facility?

Item	**Yes**	**No**
WhatsApp		
Message		
Email		
Print out report		
Don't Know		

6 Which methods do you think hospitals should use to allow you to authorize them to share your medical records for the purpose of referral process?

Item	**Yes**	**No**
Email		
One Time Password (OTP)		
Digital Signature		
Thump		

7 Do you think the process of automating patient's referral process will improve the efficiency of the process this improving medical care in the country.

Item	**Yes**	**No**
Strongly Agree		
Agree		
Disagree		
Strongly disagree		