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Design of a Scalable Content-based Publish-subscribe Model for Efficient Information Dissemination in Obstetrics and Gynaecology

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Publish-subscribe models provide a scalable solution for exchanging information in the distributed environment of public health care. However, existing health information systems that have adopted the publish-subscribe models in the literature to alleviate the problem of delay in information delivery and retrieval are limited to Windows-based mobile platforms which are no longer popular

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with the availability of competing platforms such as Android operating System (OS) and iOS. Hence, this research aims to design model of a content-based publish-subscribe information system to represent the functional and non-functional requirements of the domain knowledge within the field using Microsoft Visio and Unified Modeling Language (UML). This research addresses the challenge of delayed information delivery in obstetrics and gynecological healthcare by developing a content-based publish-subscribe information system. The system utilizes a modern, platform-independent approach and deliver relevant health information to women of reproductive age. The evaluation findings showed average SUS score of 74.35, indicating the system is acceptable for use, with a good adjective and marginal acceptability scale. The initial findings suggest the system improves user knowledge about reproductive women's health issues. This has the potential to improve maternal health outcomes and reduce child and maternal mortality rates.

Keywords: Maternal health services; publish-subscribe; information system; obstetrics and gynecology; reproductive health.

1. INTRODUCTION

In today's world, computers and information systems are constantly changing the way organizations conduct their day-to-day business practices. According to Correia et al. [1] information systems can be defined as a set of interrelated components that can be used to collect, manipulate, and disseminate data and information for planning, control, coordination, analysis, and decision-making by an organization. Nowadays, the widespread use of information systems has permeated almost all aspects of life including the healthcare sector. Haux et al. [2] described systems that process data and provide information Health information systems (HIS) refers to the interaction between people, processes, and technology needed to support operations, and management in delivering essential information to improve the quality of healthcare services [3]. Telemedicine helps eliminate distance barriers and can provide access to medical services that would often not be consistently available in distant rural communities [4]. Thus, to facilitate the effective dissemination of information between public health experts, specifically obstetricians and gynecologists (OB/GYN) and patients (women of reproductive age), a publish-subscribe system is usually recommended. Obstetrics is a branch of medicine that specializes in the care of women during pregnancy and childbirth while Gynecology is the branch that deals with the diagnosis and treatment of diseases of the female reproductive organs [5]. A specialist in obstetrics is called an obstetrician, while a specialist in gynecology is a gynecologist. Women of reproductive age are referred to as women within the child-bearing years of life between menarche and menopause, roughly from ages 15 years to 49 years [6]. The term 'content' refers to information obtained from medical experts, which are available but not formatted in certain ways easily accessible to the users upon request, thus there is need to facilitate the effective dissemination of information between public health experts and patients, hence the need for a user defined or content-based publish-subscribe system whereby the subscribers have more flexible and control of subscription by allowing him/her to express his/her interest as an arbitrary query over the contents of the events [7]. Thus, subscriber is now able to define and describe the subscriptions based on content of the information such as symptoms of illness, causes, complications and possible treatment to mention a few. This study presents a model of a content-based publish-subscribe information system to represent the functional and non-functional requirements of the domain knowledge within the field using Microsoft Visio and Unified Modeling Language (UML), that can be applied in the health sector for improving maternal health, and reducing child and maternal death rate to the barest minimum. The patient privacy and confidentiality are ensured using a pub-sub data store for facilitating the process of the encryption and for ensuring the anonymity of published resources between the publisher and the subscribers

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2. RELATED WORKS

Awokola et al. [8] worked on the development of a context-aware publish-subscribe information system for the public health service delivery. The study adopted a hybrid of implicit and broker models of publish-subscribe systems and the information filter combined both topic-based and content-based filtering. The architectural design was specified using UML diagrams such as flowcharts, use-case, and activity diagrams. The model was implemented as a mobile application in order to serve mobile users. The study was limited to the development of a publish-subscribe system which serves mobile users within the public health service.

Wadhwa et al. [9] developed a publish-subscribe architecture required for supporting public healthcare data exchange. The study developed a system which facilitated a real-time exchange of healthcare related data among various interested stakeholders, such as: doctors, researchers, and policy makers. The architecture was suitable for handling privacy and security requirements and provided interoperability support for data exchange. The study adopted a role-based access control mechanism for handling topic creation, publication of data for a specific topic and subscription to existing topics. The study was limited to the implementation of topic-based publish-subscribe system.

Roffia et al. [10] worked on the development of a semantic publish-subscribe architecture for the Internet of Things (IoT). The architecture was designed in order to support information level interoperability in smart space applications in the IoT. The architecture was built on top of a generic SPARQL endpoint for subscribers and publishers alongside an event detection algorithm for heterogeneous events. The study implemented the architecture for a smart city lightning system. The study was limited to the implementation of a publish-subscribe architecture for the Internet of Things (IoT).

Narus et al. [11] developed an event-based publish-subscribe architecture for supporting event processing workflows for an electronic medical records (EMS) system. The study developed a workflow for various events within a health care center's information system based on the publish-subscribe model. The results of the study showed that the event-based publish-subscribe model proved to be reliable, flexible and high scalability to heterogeneous devices.

Belguith et al. [12] developed an efficient revocation technique for content-based publish-subscribe systems. The revocation technique developed could efficiently remove compromised subscribers without requiring regeneration and redistribution of new keys as well as re-encryption of existing data with those keys. The technique required ensuring that subscriber's interest was not revealed to curious brokers and published data could only be accessed by the authorized subscribers. The study was limited to the modeling of an improved service delivery process for publish-subscribe systems required for ensuring confidentiality and privacy.

Peral et al. [13] an ontology-oriented architecture required for dealing with big data from heterogeneous sources for telemedicine systems. The ontology-oriented architecture consists of a core ontology used as a knowledge base which allows the integration of data from different heterogeneous sources. The study also applied natural language processing and artificial intelligence methods for process and mining data in the health sector for extracting hidden knowledge from diverse data sources. The study was limited to the development of an ontology-architecture required for implementing a personalized telemedicine system for diabetes patients.

Eken [14], developed a topic-based publish-subscribe messaging scheme for supporting the detection of COVID-19 in X-ray image. The study adopted the use of a topic-based publish-subscribe model for the transfer of information between communication nodes over a distributed scalable network of collaborative computational nodes. The study showed that using the topic-based publish-subscribe model architecture as a middleware, information transfer is delivered within a shorter time thereby facilitating the development of an early warning system.

Rodrigues et al. [15]. The study developed Publish-subscribe Digital Imaging and Communications in Medicine (PS2DICOM) model. The study adopted the combination of a cloud-based PubSub infrastructure with high-level topics, including multilevel cloud elasticity and adaptive data compression features to facilitate the contribution and collaboration capacity of distant medical specialists who are engaged in a particular study by sharing access to medical images and correlated metadata The study achieved the transmission of high quality, storage capabilities, querying, and retrieval of DICOM images was. However, in the study, the security measure to mitigate intrusion by cyber attackers wasn't considered. Also, the system was not tested to validate the veracity of the data sent and received. The packaged might have been damaged during compression, and transmission.

Abdul and Hasan. [16]. The study developed an Enhanced MQTT (Message Queue Telemetry

Transport) Protocol by Smart Gateway a software/hardware between sensors and IoT platform for sharing healthcare information. The study adopted IoT application protocols based on publishing/subscribing patterns and uses a broker to manage the communications between the publishers and subscribers over the internet. The study was limited to simulated environment with small number of users which would lead to delay in traffic if large number of users considered.

Xu et al. [17]. The study presented a decentralized and expressive novel Publish-Subscribe scheme for secure and flexible data sharing. Publish-Subscribe scheme achieves a good balance between security goals and practical efficiency.

Agrawal et al. [18]. The study presented a decentralized pub–sub-based framework which addresses data sharing issues among multiple subscribers. Publish-Subscribe model allows sharing of data but yet to be deployed in real world application for scalability and veracity.

Lohitha and Pounambal [19]. The study presented a framework for publishing and subscribing data to the cloud in the real time. Facilitate data exchange and reduces computing overhead but could not handle media requiring seamless synchronous streaming between pub-sub like audio and videos.

2.1 Research Gaps

The research gaps identified from the review of the related works are as follows:

a. Publish-subscribe model has been adopted in the area of facilitating information exchange within medical information systems however the potential benefits of content-based publish-subscribe models in ensuring confidentiality has not been explored.
b. Related literature identified the content-based publish-subscribe model as one of the most effective methods for facilitating communication. However, there were limitations facing the support of heterogeneous devices exchanging information on a communication network.
c. Related literature in the area of public health considered the deployment of publish-subscribe model on mobile communication devices that are no longer popular (windows mobile app) thereby making them unsuitable for use of contemporary mobile operating systems such as the android and iOS platforms.
d. Related literature successfully adopted publish subscribe model and smart gate application for sharing of healthcare information. However, the model was limited to simulated environment with small number of users, which upon introduction to large number of users would lead to delay in traffic.

3. REVIEW OF EXISTING ARCHITECTURE

3.1 Existing System Architecture

The following paragraphs describe the two existing publish-subscribe architecture that are most relevant, out of which some features are adapted in the system. Among the literature that were reviewed in this study, the relevant work was conducted by Awokola et al. (2014). The study considered the development of a context-aware publish-subscribe information system for the exchange of information required for the delivery of public health service. Fig. 1, shows the architecture of the context-aware publish-subscribe model in the study. According to the Fig. 1, the publish-subscribe model is composed of three (3) main parts, namely: publisher, subscriber and the context-awareness module.

The context-awareness module acts as the mediator between the publisher and the subscriber. The context-awareness module is composed of the request filter which is used to filter information provided by the publisher based on five (5) information, namely: disease, symptoms, treatment, occurrence statistics and previous measures. This request filter is connected to a device called the eGranary which matches published content with user profiles of subscribers. On the other end of the context-awareness module, the subscribers communicate with the notification broker which saves received subscriptions in user profiles. The Mediator is a controller which checks the published contents and matches them to the user profile of the subscriber thus making information available based on the context of the data to the respective subscriber.

3.2 Existing E-Health IOT Network Architecture

Among the literature that were reviewed in this study, the most relevant and recent work was conducted by Abdul and Hasan, [16]. The study considered enhanced MQTT Protocol by Smart Gateway. Fig. 2 shows the architecture of E-Health IOT Network model of the system in the study was to measure and monitor the ECG signal by using a lightweight MQTT protocol. The system structure of design frame is divided into four main parts: the sensor node (publishers), which is a set of sensors attached to the body of the individual or patient. The sensor part of the ECG sensor is used to detect heart rate in people using pulse sensors even when the individual or patient is at home / hospital. The sensor is then connected to the gateway.

The smart gateway is a device which matches published content with user profiles of subscribers, it sends the signal from the publisher (sensor) to the local broker, where the local broker sends the data to the Pub-sub model. When the signal arrives at the Pub-sub model, it performs the necessary processing for data and then publish it to the cloud broker. The internet cloud (MQTT) is part of cloud, that receives the signal from the publisher and sends it to the subscriber, and can be more than one subscriber on the same signal and one subscriber can take more than one patient. In propose design, eight subscribers were used. The Client (subscribers), waits for any signal sensor to be automatically sent from the publisher when the signal is attached by the broker. The client is either a doctor or a nurse, each with the authority to enter and disclose the patient's specific information through MQTT protocol security by password and user name. The customer has one or more subscribers.

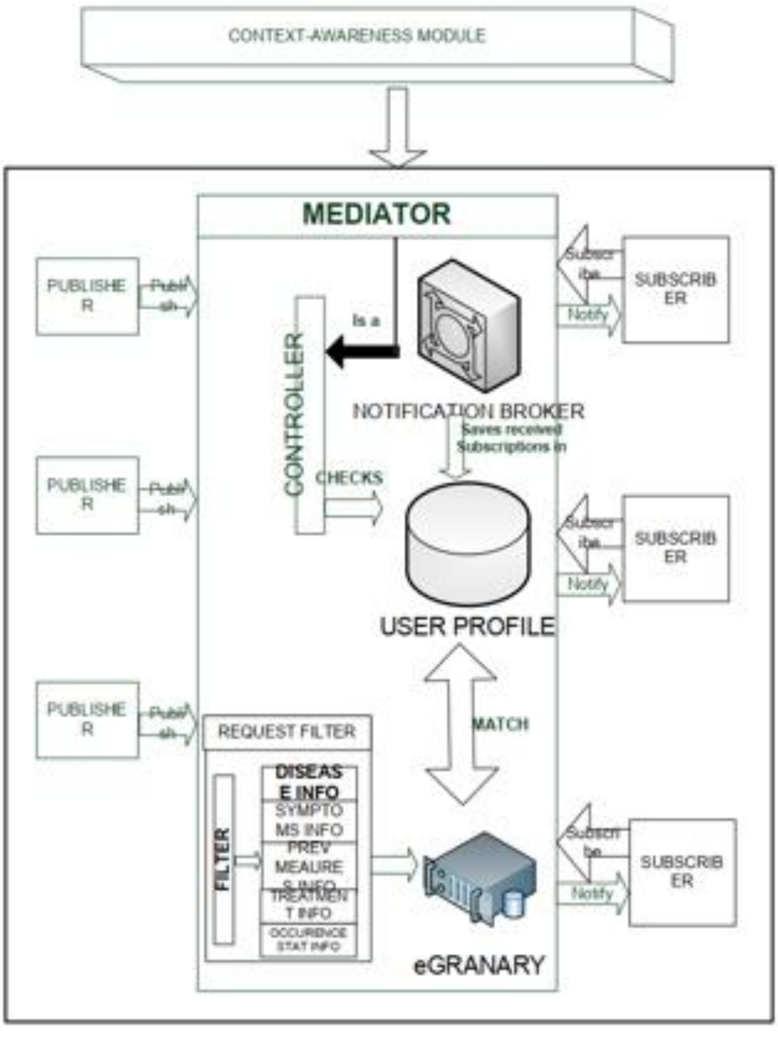

Fig. 1. Existing publish-subscribe architecture
(Source: Awokola et al., [8])

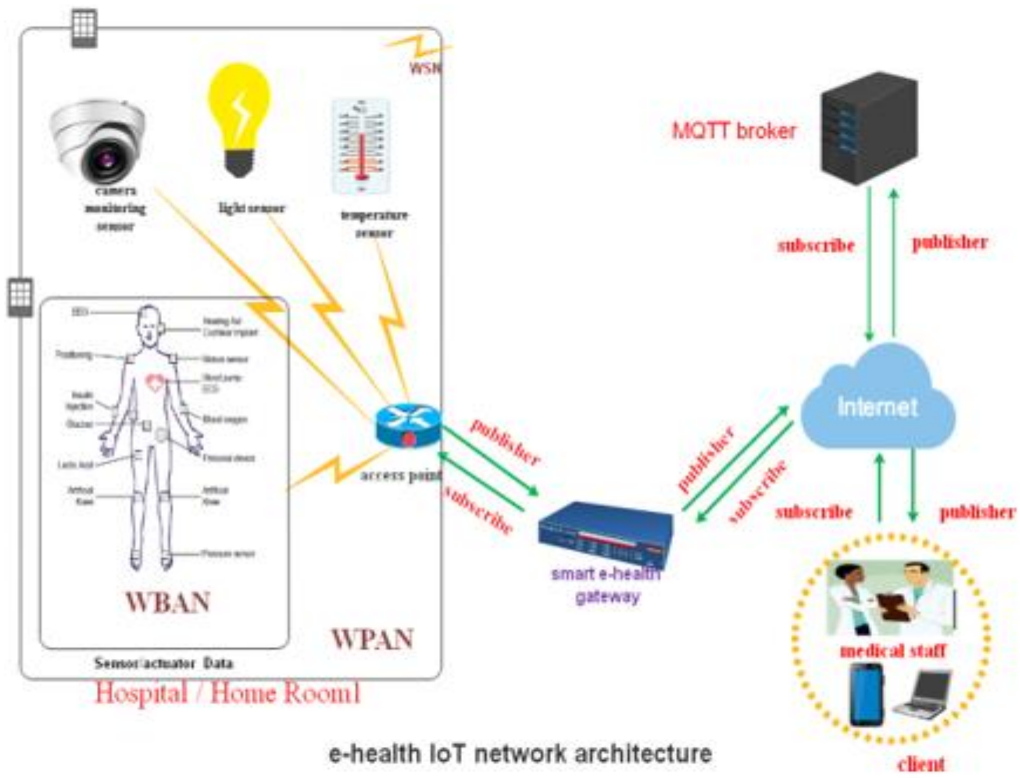

Fig. 2. The E-health IOT network architecture of the existing system
(Source: Abdul and Hasan, [16])

4. ARCHITECTURAL DESIGN OF THE SYSTEM

4.1 Content-Based Publish-subscribe Model

This section presents the formulation of the publish-subscribe model for the health information system using the content-based approach. First part of this section was used to present the formulation of the publish-subscribe model in terms of the various components of the system, namely: publishers, subscribers, published contents, subscribed contents and respective notifications. The second part of this section was used to present the formulation of the content-based approach which was used to filter the published information by the system for the subscriber.

4.2 Assumption of the Publish-subscribe Model

The following assumptions were made about the publish-subscribe model:

(1) The system hosts represent the set of publishers and subscribers;
(2) A host is unique hence a host cannot be a publisher and at the same time a subscriber;
(3) There is a unique set of subscribers and publishers of the system hence a single host cannot be represented by two or more subscribers or publishers; namely
(4) Published notifications are unique hence they can only by published once by the publisher;
(5) A subscriber host can subscribe to a published notification using a search filter;
(6) A subscriber can subscribe to two or more published notifications.

4.3 Elements of the Publish-subscribe Model

This section presents the elements which represents the building blocks of the publish-subscribe model of the health information system in this study.

(1) Let Γ represent the space of host within the publish-subscribe system who are composed of the set of publishers P and subscribers S.

(2) Let N represent the set of notifications that are posted by publishers while Q is the set of queries that are used to filter notifications by the subscribers.
(3) Let φ represent a one-to-many mapping of the set of publishers P to the set of published notifications N according to equation (3.1), such that $\varphi(p) = n_p$.

$$\varphi: \quad P \quad \rightarrow \quad N \qquad 1.1$$

where:

n_p is a set of notifications published by publisher; $p \in P \text{ and } n_p \in N$

(4) Let ψ represent a one-to-many mapping of the cartesian product of the set of subscribers S and matching query S to the set of subscribed notifications N according to equation (3.2), such that $\psi(s, q) = n_{(s,q)}$.

$$\psi: \quad S \times Q \quad \rightarrow \quad N \qquad 1.2$$

where:

$n_{(s,q)}$ is a set of active subscriptions by subscriber; $s \in S, q \in Q \text{ and } n_{(s,q)} \in N$

4.4 Content-based Filter

In this study, the content-based filter was chosen as the approach that was required for the retrieval of published notifications based on a query containing keywords posted by the subscriber. Using this approach, the content-based filter was used to measure the similarity between the keywords in the query provided by the subscriber with the contents of the notifications that were published by the publishers. A similarity measure was used to assess the level of similarities between the various notifications and the query terms provided by the subscriber thus adopted as a means of ranking the notifications which were presented to the subscriber in order to subscribe for the most appropriate request.

In this study, the vector space model was chosen as the representation model for the various documents/resource posted by the publisher on the system. Such that each document/resource D is represented as an *m*-dimensional vector, where each dimension corresponds to a distinct term, t_i and *m* is the total number of terms used in the collection of the document/resource as shown in equation (1.3).

$$D^m = \{t_1, t_2, t_3, t_4, \ldots.. t_m\} \qquad 1.3$$

For each published notification, each term t_i is allocated a weight w_i which is used to define the importance of the term in each published notification collection in the system. However, if a published notification does not contain the query term t_i then, a weight of 0 is allocated. The term frequency-inverse document frequency (*tf-idf*) scheme was used a basis of estimating the weights of terms in this study for each published notification as a function of all published notifications in the system's collection.

$$TF(t, n) = \frac{frequency\ of\ term\ t\ in\ notifications\ n}{total\ frequency\ of\ terms\ in\ n} \qquad 1\ 4$$

$$DF(t) = log\ log\ \left(\frac{number\ of\ all\ notifications}{number\ of\ notifications\ containing\ term\ t}\right) \qquad 1.5$$

$$TF - IDF(t, n) = TF(t, n) \cdot IDF(t) \qquad 1.6$$

Thus, the terms were assigned a weight based on how often the term appeared in a particular published notification and how frequently it occurred in the entire published notification collection. The assumptions behind this approach includes the fact that:

The more times a term appears in a published notification, the more relevant it is to the query term; and

The more times a term occurs in all published notifications in the collection, the more poorly it discriminates between the notifications.

4.5 Design of an Architectural Framework of the System

In this study, the system design of the health information system was specified using the Unified Modeling Language (UML). In software engineering, the UML serve as a general-purpose modeling language for providing a standard way to visualize the design of a system. In this study, the two categories of UML diagrams to be adopted are: structural (or static) and behavioral (or dynamic) UML diagram models. Structural diagrams were used to describe the static structure of the system using entities such as objects (or classes), attributes, operations and their relationships. The UML diagram that was used to describe the structural nature of the system in this study was the class diagram. Behavioral diagrams were used to describe the dynamic activities that takes place within the system components alongside their changes in states as a result of such interactions. The behavioral diagrams include: use-case diagrams for the interactions between system users and sequence diagrams for the interaction between system components.

4.6 Identification of System Requirements

In this study, requirement elicitation was inferred regarding the functional and non-functional aspects of system behavior. The functional requirements covered areas which included the user requirements, software requirements and hardware requirements while the non-functional requirements covered areas which included system accessibility, user confidentiality, information security and access control. This section presents the functional requirements of the system followed by the non-functional requirements of the health information system.

4.7 Functional Requirements of Health Information System

In software engineering, functional requirements are important for the description of the services that a software must offer. The functional requirements in this study were used to describe the components of the health information system as a function of the various inputs, behaviors and the expected outputs. As a result of this, the functional requirements were identified with respect to the users, software and the hardware components of the health information system.

4.7.1 Description of user requirements of the system

In this study, there are two classes of system users of the health information system, namely: women of reproductive ages and the medical experts in obstetrics and gynecology.

Whenever a user logs into the system, their authentication is done.

In case of cyberattack, the whole system is shutdown.

Whenever a user registers on the system for the first time a verification email is sent to the user.

The information that was collected from the medical experts was related to the various types of obstetrics and gynecology-related information that are relevant to all groups of women of reproductive age. The information that was collected from the women was related to the ease of use of system alongside the functionalities that were supported by the system.

The medical experts are the providers of the various types of information that will be accessed by all women of reproductive ages using the system. As a result of this, the medical experts will serve as the publishers of information in the system while the women of reproductive ages will serve as the subscribers to information shared by publishers.

The system requires that every medical expert and women of reproductive ages who must use the system must be initially registered as an authorized user of the information system.

The registration of these users can be managed by the system administrator of the health information system and as long as registered users are logged into the system; they are able to perform their expected actions on the system.

The medical expert users must provide the information that needs to be accessed by the women users hence information that have not been provided will not be made available to the women users.

Every information provided by the medical expert users must be tagged using various keywords that capture the contents of the information provided.

The information provided by the medical experts can either be a document, a web resource, or a multi-media file contain audio, images or video content.

The women users can subscribe to the various information provided by the medical expert users using filters that searches through the contents of stored information. This way, any information related to the information subscribed for in addition to future contents can be easily recommended to the women users.

4.7.2 Description of the hardware requirements of the system

In this study, the health information system used by the medical experts and women of reproductive ages was deployed as a web-based application. As a result of this, the system hardware required for this system to be used will be based on a heterogeneous device with web browser.

This device is required to have the following specifications for optimal performance, namely:

32-bit ARM architecture
Minimum RAM size of 2 GB;
Minimum processing speed of 2 GHz;
Support 3 g or 4G Network communication; and
Minimum of 5000 mAh Battery.

4.7.3 Description of the software requirements of the system

The heterogeneous devices, for example mobile devices with a web browser is required to use the android OS and iOS which were developed by Google and Apple Inc. respectively, were considered in this study because they are the most commonly used mobile device by smartphone users in Nigeria. The mobile devices are required to have at least Android OS 8 or iOS 10 running on them as operating systems.

4.8 Non-Functional Requirements of Health Information System

In software engineering, non-functional requirements are required for describing the general properties of the system which are focused on expressing the quality attributes of the system. The system is required to be able to satisfy and meet up the following non-functional requirements, namely:

Authentication: The system must ensure that non-authorized users are not granted access to the system. This was guaranteed by ensuring that all medical experts who have access to the system are provided with username and passwords for accessing the system.

Confidentiality: The system must guarantee the confidentiality of the women whom are using the system. This was ensured to providing anonymity to all the women using the system by granting them a pseudo name which can be used to identify them on the system.

Integrity: The system must guarantee that information transferred across the system between users have not been modified in any manner. This can be guaranteed by the encryption of information stored by and transferred between users of the system.

Accessibility: The system must be available to every user of the system upon successful log into the system. Once a user has logged into the system, the various activities must be made available to the user without restraint.

Timely response: The system must provide a quick and prompt response to every request made by every user irrespective of the number of users that are logged into the system.

Concurrency: The system must ensure that more than one user is able to access the same atomic information at the same time without any conflict arising between the users accessing the information.

4.9 Architectural Framework of the System

The system architecture design of the information system required for use by women of reproductive ages and medical experts is presented in this section. Fig. 3, shows the various components of the system architecture such as the client-side alongside the service-side components of the information system in this study.

On the client-side of the information system, the medical experts (publishers) alongside the female patients (subscribers) can access the information system using any mobile or desktop devices, namely: laptop/desktop computers, smartphones or tablets devices. As shown in the diagram, the various *publishers* of the system (far-left side) are required to publish their resources which are loaded into the *pub-sub server* via the *load balancers*. Also, the various *subscribers* of the system (far right) are required to subscribe to resources which match the search query that are provided by them onto the system. On the server-side, the load balancers are used by the information system to distribute the various publishing activities by the publishers onto various pub-sub server over the cloud so as to maximize the use of computing resources used. The information that are loaded into the pub-sub servers are in turn loaded into the *pub-sub data store* alongside the *notification server*. The pub-sub data store was required for

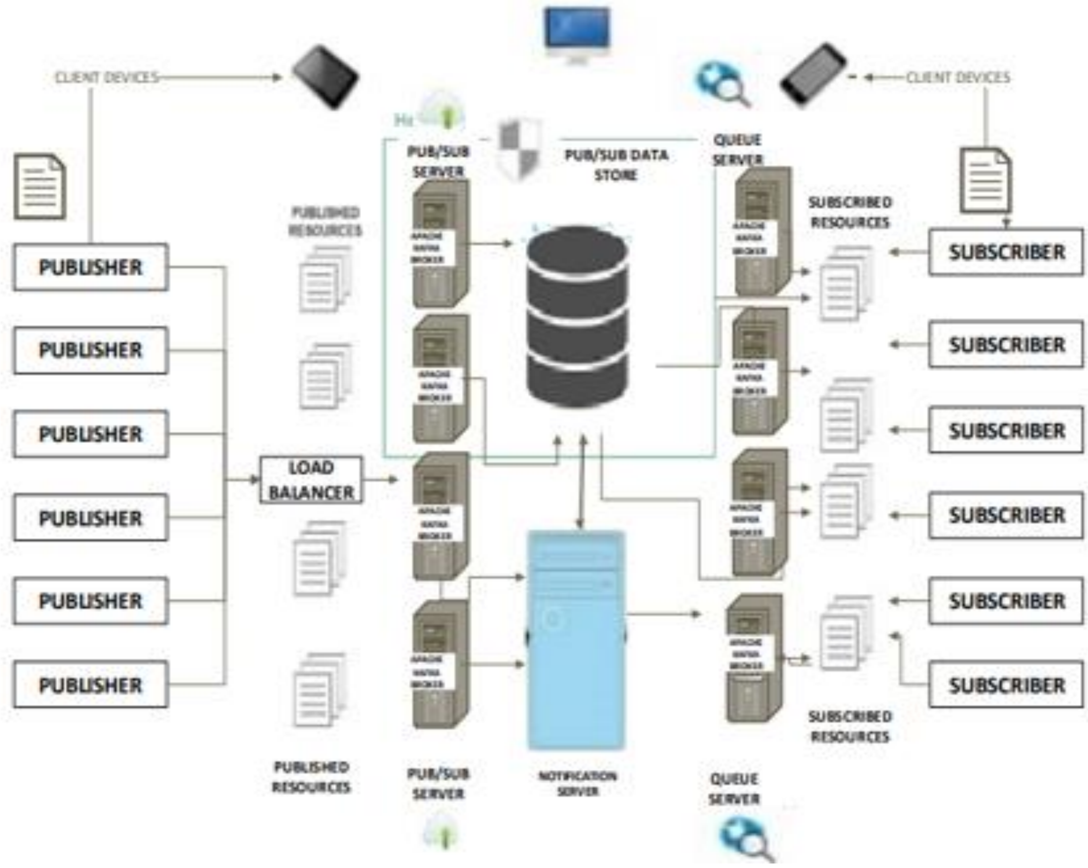

Fig. 3. Architecture of the system

facilitating the process of the encryption of the resources provided and for ensuring the anonymity of the publishers of the various resources on the system for use by subscribers. Once the search query sent by the potential subscriber has been used to successfully retrieve matching resources, then the information is passed to the *queue server*, from where the information is processed to their respective subscriber.

The notification server is used to notify the publisher of new subscriptions to published resources by subscribers and for the notification of new comments made by subscribers to resources. Also, the notification server is used to notify the subscriber of new response to their comments on subscribed resources.

The confidentiality of information transferred between publishers and subscribers are ensured using encryption before passing information through the pipeline and for guaranteeing the anonymity of system users providing and accessing information exchanged over the information system.

5. SYSTEM DESIGN USING UNIFIED MODELLING LANGUAGE (UML)

This section presents the results of the design of the system for providing access to information regarding reproductive health by women of reproductive ages. The design of the information system was specified using use-case diagrams for the identification of users and their respective actions; the data flow diagrams for describing the creation, storage and movement of data across the system; the sequence diagram for describing the order and timings of the activities of the female patient users; and the class diagram to describe the structure of the data model of the system, as shown in Fig. 4, Fig. 5, Fig. 6 and Fig. 7 respectively.

5.1 Use Case Diagram of System

Fig. 4 shows the diagram of the use-case diagram that was used to specify the identification of the users and their respective actions. As shown in the diagram, there are three (3) specific users, namely: system administrator, medical doctors and the female patient user. The system administrator has the sole responsibility of creating all the valid users of the system and the users can be able to perform their respective actions once created. The medical doctor is responsible for providing the information that is used by the system. It is the sole responsibility of the medical doctors to publish the resources containing information about various issues concerning reproductive health for other users of the system. The various use-cases of the medical doctor are described as follows:

a. Login - is used to give the doctor access to the system;
b. Doctor profile - is used to create the doctor's dashboard once logged into the system; from here basic actions are performed;
c. Publish resource - is used by the doctor to post the resource created; and
d. Published resource- is used to provide a list of all the resources that are published by each respective medical doctors ranked by time of update.
e. The female patient user is required to have access to the various resources that are provided by the medical doctor based on a search query that is provided. This search query contains a number of keywords that are used as a basis of filtering the resources in order to retrieve the most related to the search query based on its contents. The female patient user can only subscribe to resources that have been published by a medical doctor hence if none of the resources does not match the search query then no resource is found.

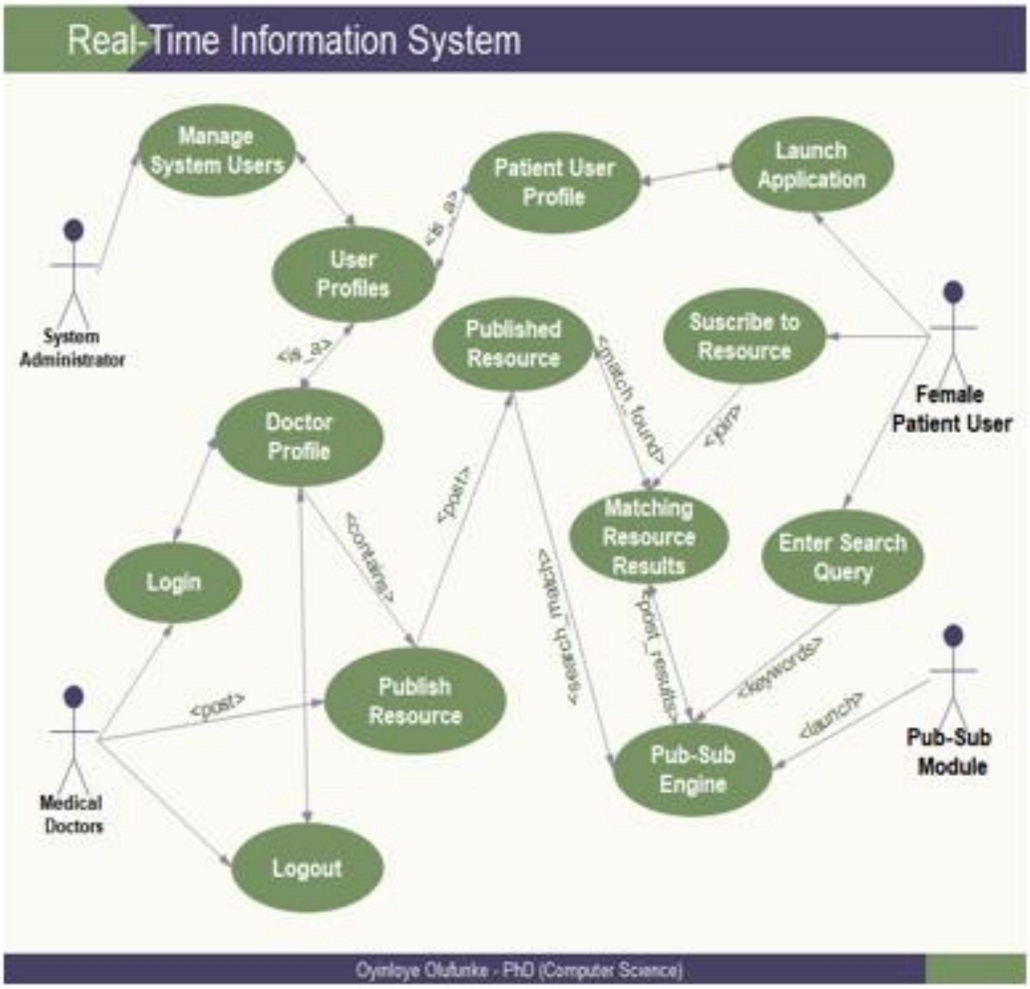

Fig. 4. Use case diagram of the system

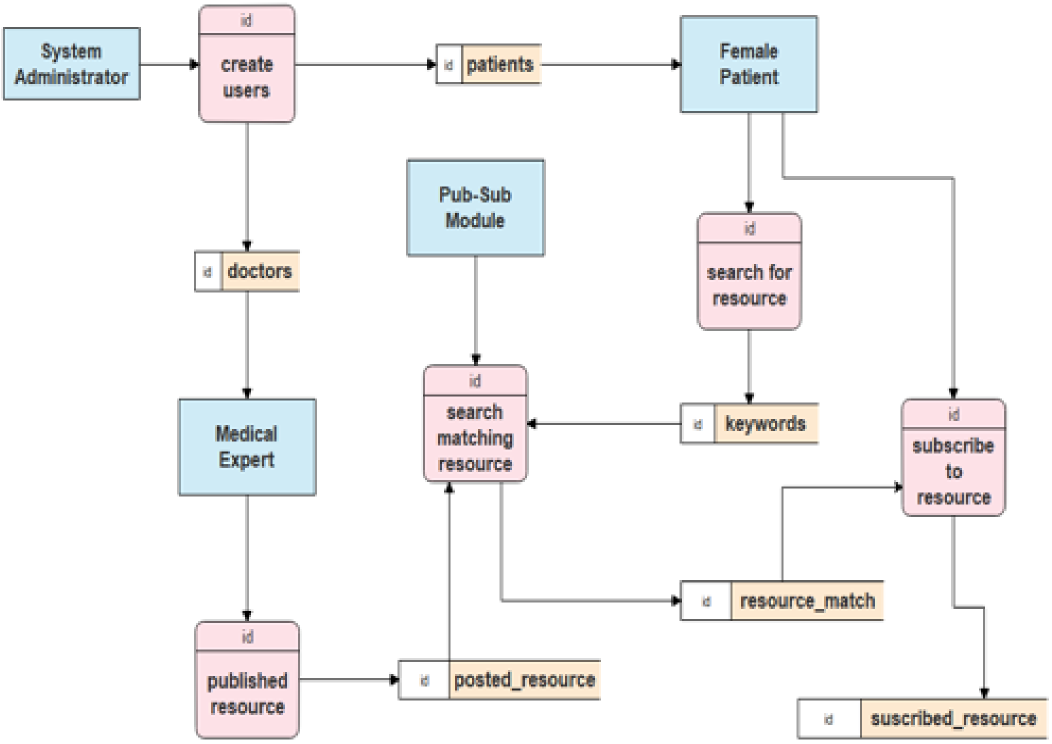

Fig. 5. Data flow diagram of the system

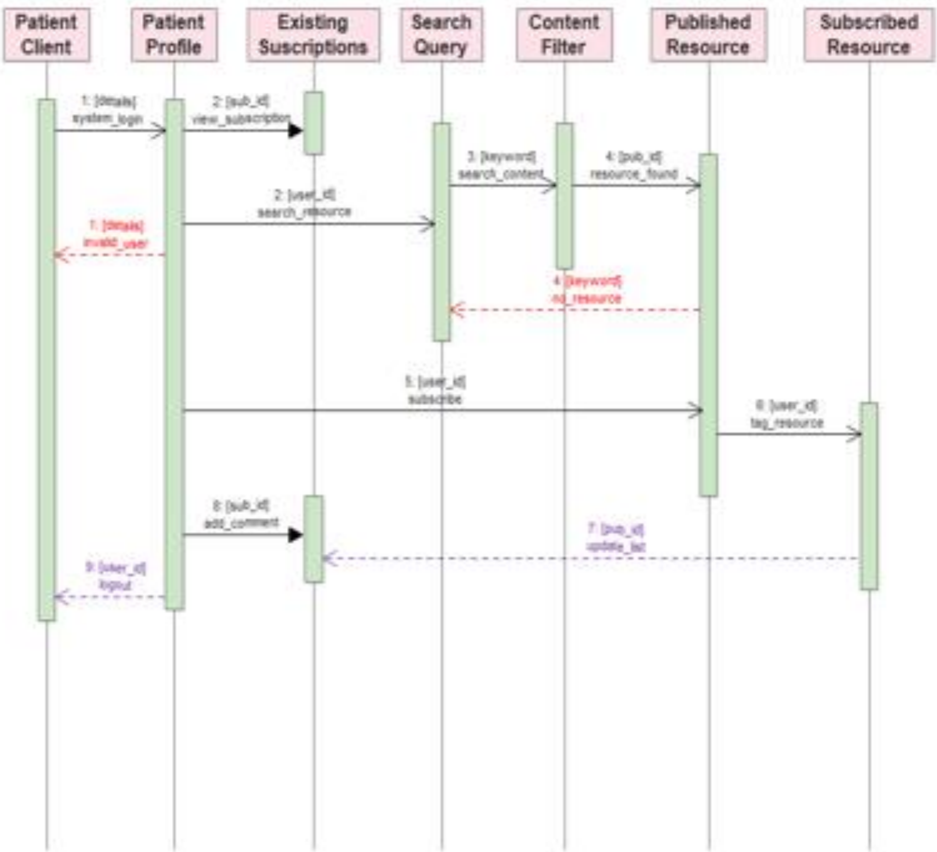

Fig. 6. Sequence diagram of the system

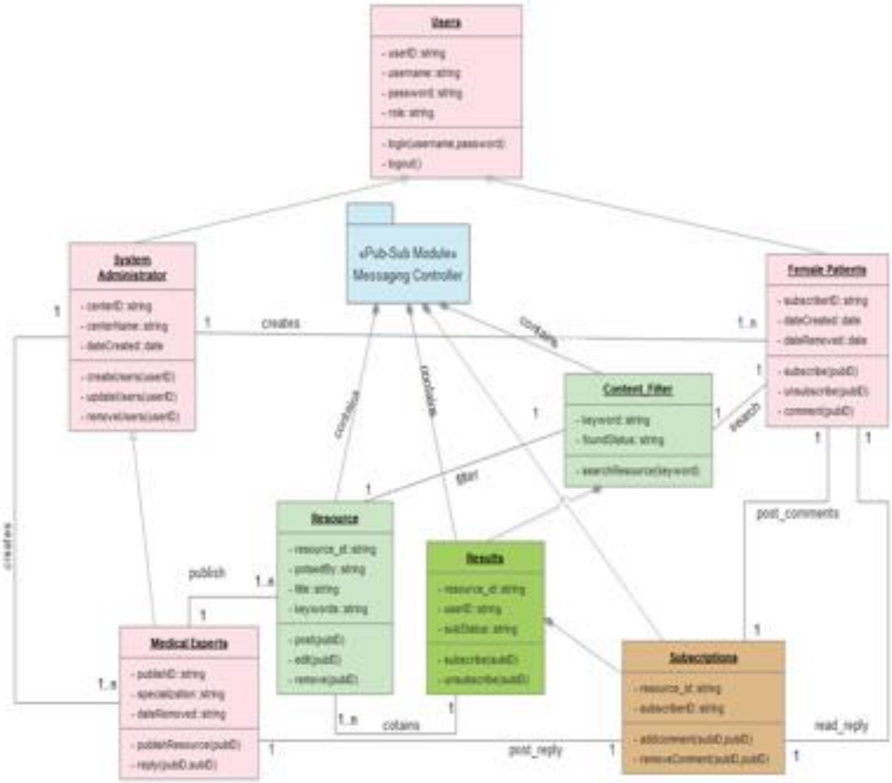

Fig. 7. Class diagram of the system

6. SYSTEM USABILITY SCORE AND EVALUATION RESULT

6.1 System Usability Score (SUS) Calculation for Usability

A questionnaire was designed on a scale of 1 (Strongly disagree) to 5 (Strongly agree) to estimate the System Usability Score (SUS). At first, SUS scores for each user were calculated following the standard process of Brooke's scoring system on a scale from 0 to 4. Odd-numbered statements are positive by subtracting from 5, and even-numbered statements are negative which were left unchanged. Each question's score contribution ranges from 0 to 4. For the positively worded items 1, 3, 5, 7, and 9, the score contribution is equal to the scale position minus 1 (i.e., Xi – 1, where i = 1, 3, 5, 7, 9). Negatively worded items 2, 4, 6, 8, and 10 each contribute 5 minus the scale position (i.e., 5 - Xi, where i = 2, 4, 6, 8, 10) (Brooke, 2013). For instance, if the system user answers question 9 with a score of 4 (i.e., disagree, positive meaning), the outcome score will be 3, and if respond for question 8 with a scale of 3 (i.e., Neutral, negative meaning). The adjusted scores were summed, and the result was multiplied by 2.5 to obtain the final SUS score for each user. The Individual User scores for all users was calculated, a dataset with individual user scores compiled. The average SUS score was estimated by summing all individual scores and dividing by the total number of users in our sample. In this survey, there are 477 respondents and for each of the respondents, their SUS score and the adjusted rating scale were calculated. Because SUS results are expressed as scores between 0 and 100 rather than percentages, some people occasionally find the findings confusing. To aid in the interpretation and comprehension of the results, Sauro and Lewis (2016) provides an adjective, acceptability, Net Promoter Score (NPS), grading scale for the SUS score, shown in the Fig. 8.

$$SUS\ Score = \sum_{User_i}^{N} Row\ SUS\ Scores = 35462.5$$

Where i = 1, 2, 3, …, 477

Therefore, the average SUS Score is;

$$\frac{SUS\ Score}{N} = \frac{35462.7}{477} = 74.35$$

The usability score of this study is 74.35, equals a grade of B.

The SUS score against acceptability scale classification and users' responses are shown in Fig. 9 and Fig. 10.

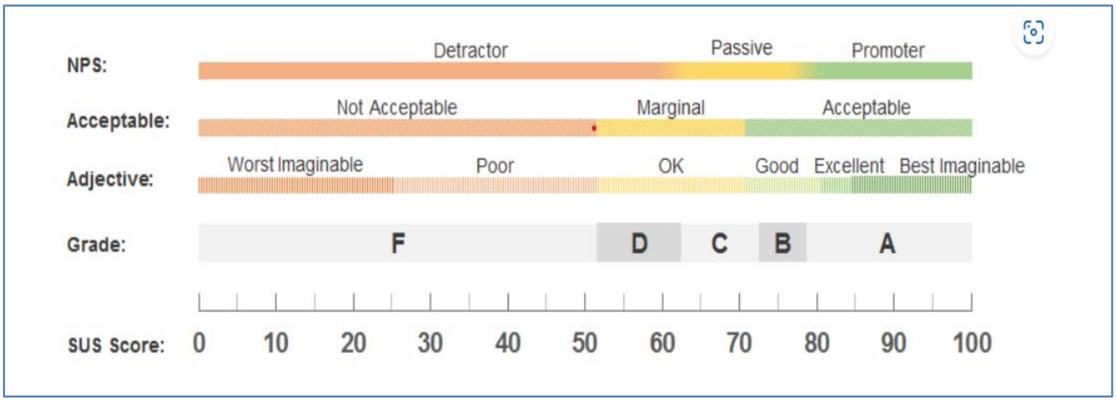

Fig. 8. Grading scale for the SUS score

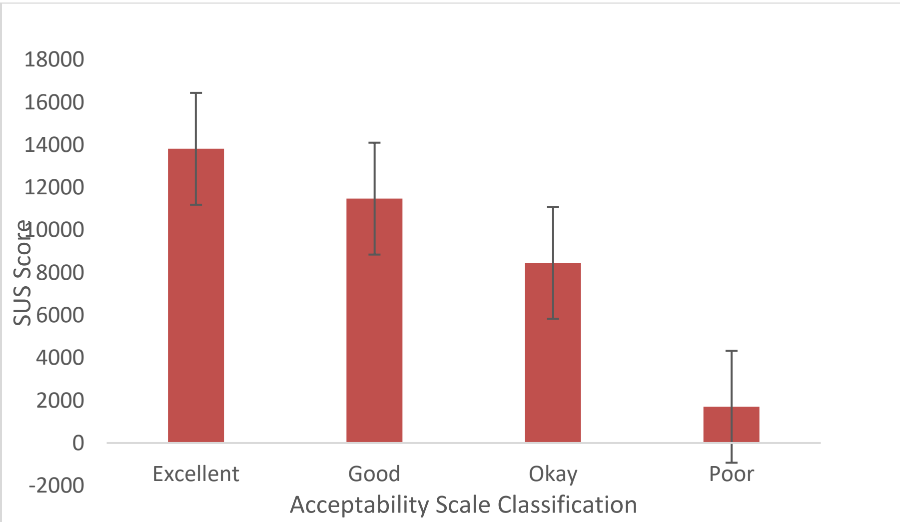

Fig. 9. SUS scores and acceptability scale classification

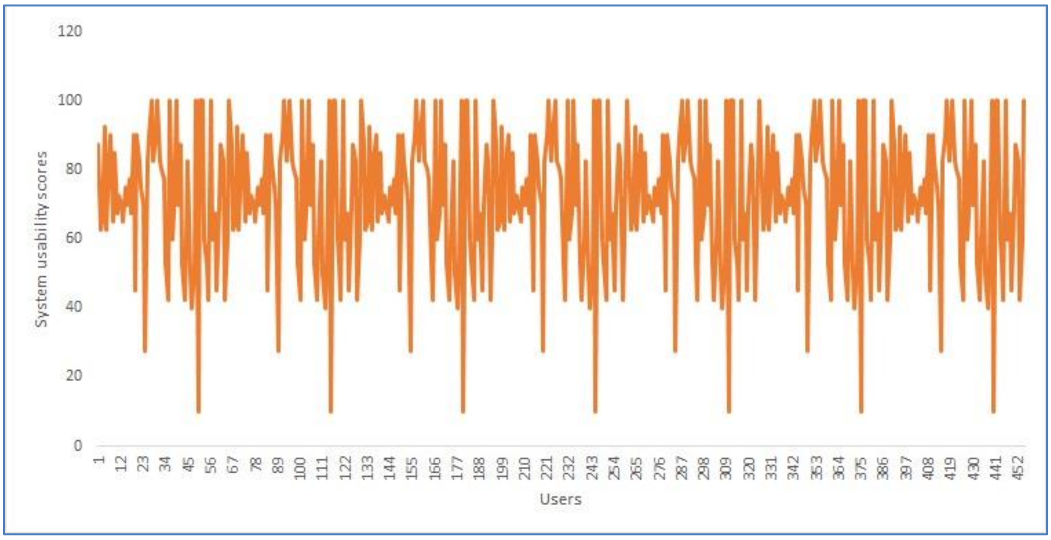

Fig. 10. Representation of SUS scores and the users

7. CONCLUSION AND DISCUSSION

The architecture of the model in this research is depicted in Fig. 3. This study presented the design of a content-based Publish Subscribe paradigm for asynchronous messaging that naturally fits the decoupled nature of real-time distributed systems, allowing simple and effective development of distributed applications. Publish-subscribe information systems, also known as pub-sub systems, are widely used in various applications to facilitate the dissemination and distribution of information among multiple participants. Content-management system has been adopted for solving issues related to maternal healthcare services. The existing system made use of Message Queuing Telemetry Transport (MQTT) underlying messaging protocol for facilitating information exchange in a publish subscribe model, while the proposed system uses a distributed streaming platform Apache Kafka, which has the ability to provide a more robust and scalable messaging infrastructure for efficient information exchange in a publish subscribe model. The usability score might not reflect the experience of a broader user base, the system's performance and scalability might not hold up in real-world scenarios with high user volumes. Security vulnerabilities could lead to data breaches, negatively impacting patient trust and system adoption. The reliance on specific technologies could limit the system's applicability in diverse healthcare settings. The focus on a specific demographic might restrict the generalizability of the findings to the broader healthcare context. Therefore, the study's conclusions about the system's potential benefits for communication, patient care, and research might be overly optimistic without addressing these limitations. Further research with a larger user pool, a more comprehensive user experience evaluation, and a focus on scalability and security would be necessary to strengthen the generalizability of the findings. The broader implications of content-based publish-subscribe systems for the healthcare sector and public health policy are significant and hold promise for improved communication, information access, and ultimately, better health outcomes. This study is useful to support research and education, and ultimately contribute to better health outcomes in these critical areas of healthcare.

8. RECOMMENDATION

The development of a content-based Publish-Subscribe Information System to handle a more scalable number of subscriptions, events, and users. Optimize performance to deliver real-time updates even in higher-demand scenarios, extended for mobile apps using more robust database service, for example, Postgre.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Correia B, Chiodini J, Dalfovo O, Silva L, Teske R. The use of information systems in health care facilities: A Brazilian case. Journal of Technology Management and Innovation. 2013;8:72-72.
2. Haux R, Ammenwerth E, Häber A, Hübner-Bloder G, Knaup-Gregori P, Lechleitner G, et al. Medical informatics education needs information system practicums in health care settings. Methods of Information in Medicine. 2006;45(03):294-299.
3. Tokayev KJ. The Role of Health Information Technology (HIT) in Healthcare Reform: Opportunities and Challenges. Reviews of Contemporary Business Analytics. 2023;6(1):72-87.
4. Achakzai A, Masood S, Khan J. Acceptance of Telemedicine: A Perspective from the Doctors Working in the Tertiary Care Hospitals of Quetta: Acceptance of Telemedicine. Pakistan Journal of Health Sciences. 2023;270-277.
5. World Health Organization (WHO). Maternal Health; 2023. Available:https://www.who.int/health-topics/maternal-health
6. Collin, J, Byström, E, Carnahan A, Ahrne, M. Public Health Agency of Sweden's brief report: pregnant and postpartum women with SARS-CoV-2 infection in intensive care in Sweden. Acta Obstet Gynecol Scand; 2020. Epub May 9 2020. DOI: 10.1111/aogs.13901 - DOI - PMC - PubMed.
7. González MD. Distributed Implementation of eXtended Reality Technologies over 5G Networks; 2023.
8. Awokola J, Emuoyibofarhe O, Awokola B, Alamu F, Awokola E, Akomolafe O. Development of a Context-Aware Publish-subscribe Information System for Public Health Service Delivery. Journal of Information Engineering and Applications. 2014;4(9):23-30.

9. Wadhwa R, Mehra A, Singh P, Singh M. A Pub-sub-Based Architecture to Support Public Healthcare Data Exchange. IEEE; 2015.
10. Roffia L, Morandi F, Kiljander J, D'Elia A, Vergari F, Viola F, Cinotti TS. A semantic publish-subscribe architecture for the Internet of Things. IEEE Internet of Things Journal. 2016;3(6):1274-1296.
11. Narus SP, Rahman N, Mann DK, He S, Haug PJ. Enhancing a commercial EMR with an open, standards-based publish-subscribe infrastructure. In AMIA Annual Symposium Proceedings. American Medical Informatics Association. 2018; 2018:799.
12. Belguith S, Cui S, Asghar MR, Russello G. Secure publish and subscribe systems with efficient revocation. In Proceedings of the 33rd Annual ACM Symposium on Applied Computing: 388-394.
13. Peral J, Ferrández A, Gil D, Munoz-Terol R, Mora H. An ontology-oriented architecture for dealing with heterogeneous data applied to telemedicine systems. IEEE Access. 2018; 6:41118-41138.
14. Eken S. A topic-based hierarchical publish-subscribe messaging middleware for COVID-19 detection in X-ray image and its metadata. Soft Computing. 2020;1-11.
15. Rodrigues VF, Paim EP, Kunst R, Antunes RS, Costa CA, da, Righi R, da R. Exploring publish-subscribe, multilevel cloud elasticity, data compression in telemedicine. Computer Methods and Programs in Biomedicine. 2020; 191.
Available:https://doi.org/10.1016/j.cmpb.2020.105403
16. Abdul HR, Hasan HM. Enhanced MQTT Protocol by Smart Gateway. Iraqi Journal of Computers, Communications, Control and Systems Engineering. 2020;20(1):53-67.
17. Xu Q, Zhang Q, Yu B, Shi N, Wang C, He W. Decentralized and expressive data publish-subscribe scheme in cloud based on attribute-based keyword search. Journal of Systems Architecture. 2021;119: 102274.
18. Agrawal A, Choudhary S, Bhatia A, Tiwari K. Pub-SubMCS: A Privacy-Preserving Publish–Subscribe and Blockchain-Based Mobile Crowdsensing Framework. Future Generation Computer Systems. 2023;146: 234-249.
19. Lohitha NS, Pounambal M. Integrated publish/subscribe and push-pull method for cloud based IoT framework for real time data processing. Measurement: Sensors. 2023;27:100699.

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