PROGRESSIVE WEB APPLICATION FOR SEAMLESS PRIMARY HEALTHCARE DELIVERY IN NIGERIA.

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ABSTRACT
This project presents the development of a Progressive Web Application (PWA) aimed at enhancing access to primary healthcare in Nigeria, using the FUTO Medical Centre as a case study. Drawing on actor-network and socio-technical theories, as well as Object-Oriented Analysis and Design Methodology (OOADM) and Unified Modeling Language (UML), the architecture was designed to overcome technological barriers. The development process included rigorous testing and debugging to ensure functionality across website, mobile app, and desktop app platforms. Key features such as offline support and push notifications were implemented, leveraging a single code base to reduce costs and pave the way for technological advancements in Nigerian healthcare delivery.

Keywords: Progressive Web Application, Primary Healthcare, Healthcare Technological Barriers, FUTO Medical Centre, Actor-Network Theory, Socio-technical Theory.

1.0 INTRODUCTION

1.1 Background to the Study

Many countries have experienced ICT as an invaluable development tool. The use of ICT in Nigeria spans a wide range of applications with a physician-population ratio of about 1:83, as stated by the Nigerian Medical Association, data shows that this technology had a negligible effect on the health sector (Abolade & Durosimi, 2019). From a recent report by the World Health Organization (WHO), there are 4 doctors for every 10,000 people in Nigeria (Kareem, 2021). Apart from the doctors, the country also lacks the other health workers and medical facilities.

In Nigeria, there are three stages of healthcare delivery: The primary health care is a method of community-based management by local governments and private hospitals for providing health care services. The state government offers secondary health care. At the tertiary level of healthcare, the federal government with some private organisations provide healthcare services in all the states of the country such as FMCs, teaching hospitals, national orthopaedic hospitals, national eye center, psychiatric hospitals, and national ENT care center.

Tertiary Healthcare Centres are high-end care facilities that help people who cannot undergo diagnosis or treatment in primary or secondary care (Chukwuma, 2017). Even though the patients' lack of knowledge, the inefficiency of working procedures, and the inability of the other health care levels to meet the patients' medical needs bring the situation, the majority of the patients decide to bypass primary and secondary health care and go straight to the tertiary health care centres. Skipping primary and secondary healthcare centres means more patients at tertiary hospitals, more files to manage, and fewer doctors (Koce et al., 2019).

1.2 Nigerian Healthcare Operations

The Nigerian healthcare system is predominantly paper-based in the area of information management and service delivery. This system may slow down the delivery of information, store information inefficiently with the folders, perform a manual calculation that is fraught with errors, and prepare a report that may be wrong, which can be detrimental because people's health and lives are at stake.

The hospital management system which is manual and paper-based has many shortcomings which are life-threatening to patients and may even be the cause of Nigeria's substandard healthcare delivery (Chukwuma, 2017). In most hospitals in Nigeria, patients are required to spend much of their time in queues and pay registration fee before being allowed to see a doctor. They get frustrated by busy conditions, the crowded atmosphere as well as the slowness of the system.

The existing computerised hospital management systems, notwithstanding their benefits, have certain limitations. They are costly to implement and manage in government hospitals, which is one of the reasons why the number of private hospitals using them is still low (Alzahrani, 2021). In some hospitals that use computerised systems, adopting automated hospital management systems has enabled to enhance the healthcare system. Nonetheless, this calls for employee training specific to these systems, the provision of compatible systems, and the uninterrupted power supply to run on these platforms.

1.3 Progressive Web Applications

A progressive website application (PWA) is a software built using web technologies like HTML, CSS, and JavaScript (Koysawat et al., 2021). It works on the platforms that support standard-compliant browsers, including desktops and mobile devices. Hence, the upgrade of this computerised hospital management system from a desktop or native web application to a progressive web application will certainly improve working procedures in healthcare facilities, mainly the primary healthcare centers, which are a community-based approach to prioritize and strengthen national health systems through bringing health and wellness services closer to the communities.

The progressive web application allows the hospital management system to work on the Internet and becomes platform independent. It can be installed directly on desktop and mobile devices, or accessed via a web browser. They are more receptive, user-friendly and require no or little employee training to handle. The progressive web app, when installed, has shortcut on the user's device, and it can be opened by clicking an icon (Kiselev, 2020). Also, patients and staff do not need to remember the website address or the platform that was used to access the application.

The service worker of a PWA is in charge of caching resources and serving cached resources, which reduces loading time, allows the app to work offline, and allows advanced features such as notifications or push messages to be used, which improves overall user experience (Loretoa et. al., 2018).

2.0 RELATED WORKS

2.1 Literature Review

Matarlo and Oniot (2018) created a desktop hospital management system which was developed under Waterfall Methodology model in their study titled "Hospital Management System". The system contributed to the improvement of information management and staff efficiency by doing the work of patient registration, admission bills and pharmacy inventory. The system also produced reports, aided the receptionists, and lessened the workloads. On the other hand, improvements were recommended for the front-end design, laboratory and pharmacy modules, billing and discounts. The system's potential for enhancing management and performance was also emphasised.

In their study "Hospital Management System Using Web Technology", (Saimanoj et al., 2020) stated that today's web-based technology offers many online services in almost every field. According to them, online connectivity is now a requirement for all well-organized and well-managed establishments, one of which is healthcare, where information digitization should occur quickly and efficiently. Their research

paved the way for developing a web-based platform that eliminates the need for paper prescriptions in hospitals. It proposes E-Medical Management, which will improve the efficiency of patient management and doctor scheduling and provide universal access to patient data anywhere in the hospital.

Vijayasarveswari et al. (2021) were primarily concerned with building an E-healthcare management system for government and private institutes to schedule doctor appointments online. HTML, PHP, JavaScript, and CSS are the programming development technologies used. Patients could log in to schedule an appointment with the doctor, and all appointment details were processed and sent directly to a centralized database system. The doctor will then confirm the appointment via their website. Finally, after the confirmation, patients receive an alert from the doctor.

In 2019, Rêgo et al. examined the possibility of using PWA for m-Health solutions in the health sector, introducing a dietary evaluation app and comparing it to both the traditional dietary methods and the INTCare system.

2.2 Theoretical Framework

This healthcare system will be designed, developed, and implemented using two existing frameworks. The Sociotechnical Theory and the Actor Network Theory (ANT).

Sociotechnical Theory

The socio-technical system focuses on the interrelatedness of people, structure, technology, and processes in health care system management. People produce and use technology and software, and the structure refers to the organization's structure and information flow. As a whole, this process must be in line with the other components in order to be successful (Zia et al., 2011). The core of the socio-technical system is the people (users) who work as a team to make sure that the system will work properly (Hannah & Ball, 2004).

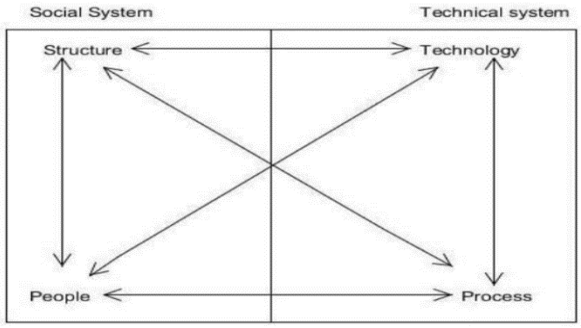

Figure 1: Components of a Socio-Technical System. (Zia et al., 2011)

Actor Network Theory

The actor-network theory (ANT) according to Cresswell and Creswellheikh (2010) claims that the social and natural world are dynamic networks of connections, and nothing exists isolated from these relations. It highlights the part played by nonliving things, including technology, in the shaping of social trends. An actor, regardless of its status, is able to act only in conjunction with other actors and in the constellations that allow them to act. ANT refutes the idea that technology has an external effect on humanity, according to the author, technology is an outcome of social interests, it can mold social interactions to the extent that they are allowed to (Wikipedia Contributors, 2022).

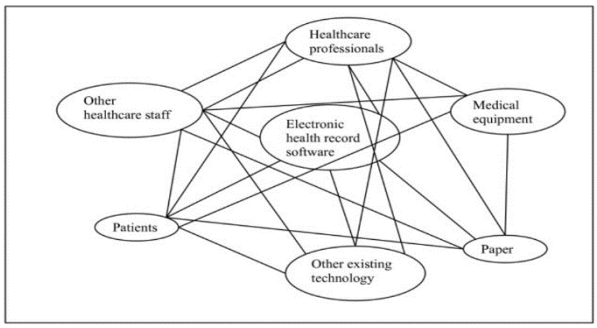

Figure 2: Sample Actor-Network in implementation of healthcare management system. (Cresswell et al., 2010).

3.0 Methodology

The project was conducted by applying the object-oriented analysis and design methodology (OOADM), and the system analysis and application design was done using the Unified Modelling Language (UML). OOADM studies and designs information systems in a systematic way by using formal approaches. This project used the object-oriented model as a software development lifecycle model.

3.1 Analysis of the existing system

Interviews and on-site observations were employed for data collection during the requirement analysis and system specification phases of the object-oriented development cycle for the project. Through conducting additional research, and review of the current paper-based documents and procedures, the design of the proposed system was obtained.

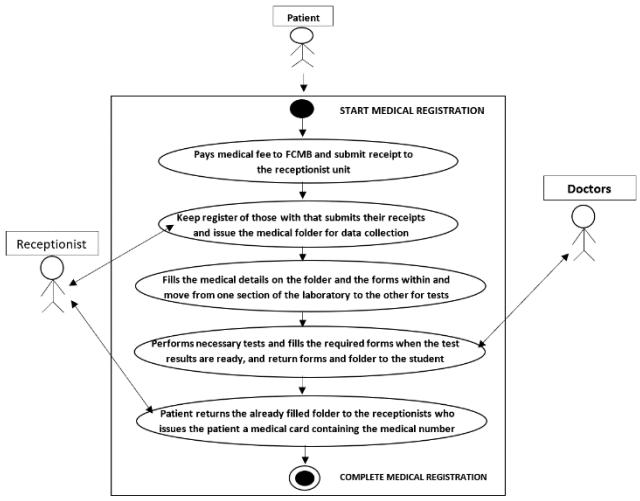

Figure 3: Workflow diagram for the patients' registration process in the existing system

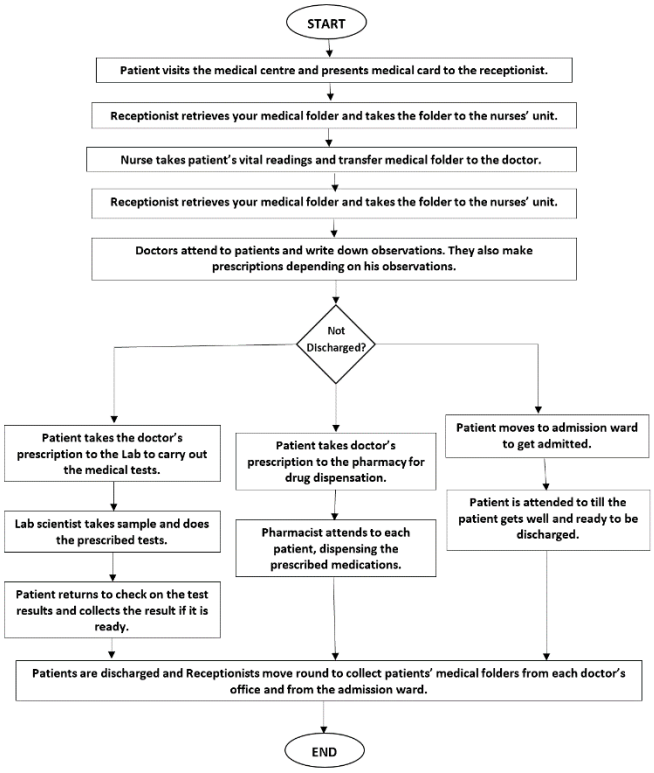

Figure 4: Workflow diagram for the patients' visitation to the medical facility in the existing system

3.2 Analysis of the proposed system

The progressive web-based Hospital Management System is the proposed system. It enables remote patient registration as well as the management of medical accounts details, viewing the medical visitation timeline and progress report. The admin module creates and maintains accounts for doctors, nurses, pharmacists, and lab scientists and track patients' activities. Doctors' module provides the access to the medical history of the patients, an assignment of the meetings, and the records of the patients. The module for nurses will help in checking patient visitation records, doctor assignments, and vital signs. The module of pharmacists includes the prescription of patients, the distribution of medication, and the reports of drugs. The laboratory scientist module tracks the patients' prescription lists, reports, and profiles. Admission modules are used by staff to receive patients, discharge patients and create their profiles. The receptionist module which deals with the patient registration details and the registration process monitoring.

3.3 Activity diagram of the proposed system

Below are the patient registration, and medical visitation activity diagrams of the proposed system showing the workflow of stepwise activities and actions, and the control flow.

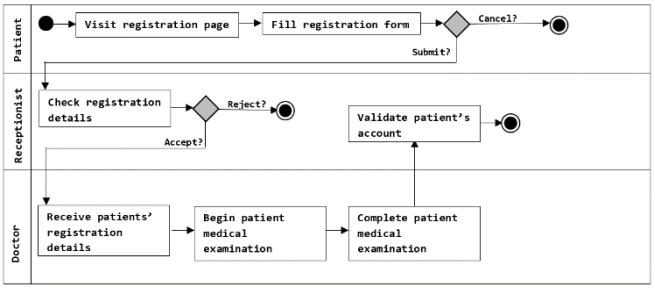

Figure 5: Patient registration activity diagram for the proposed system

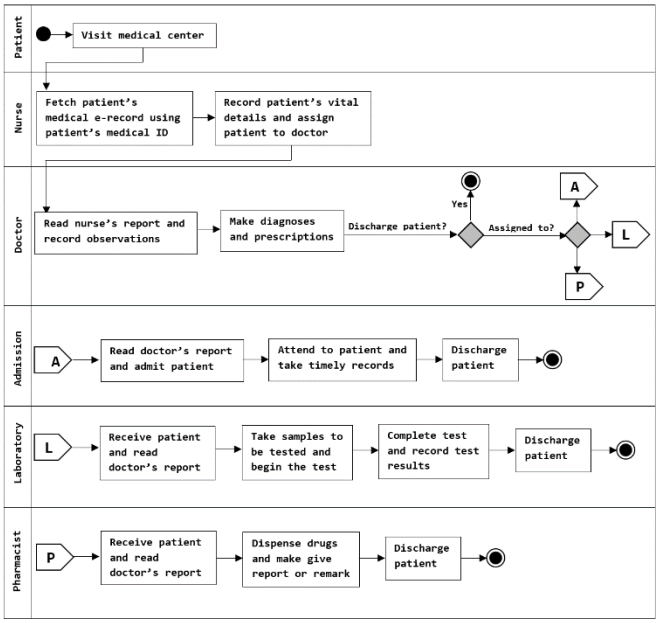

Figure 6: Patient medical visitation activity diagram for the proposed system

3.4 Use case diagram of the proposed system

Figure below illustrates the use case diagram of different roles and their interaction within the system. The following use cases demonstrates the key actors and processes of the new system.

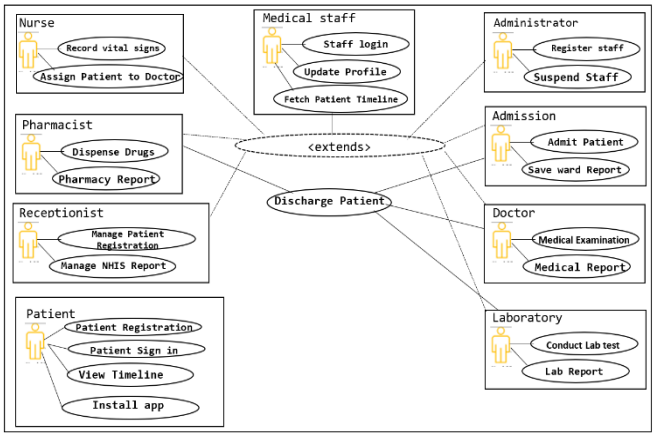

Figure 7: High level use case diagram for the proposed system

3.5 Sequence diagrams of the proposed system

The sequence diagrams hereunder show the structure of object interaction by time sequence. They illustrate how the

objects interact with each other in a specific situation, which is a use case example.

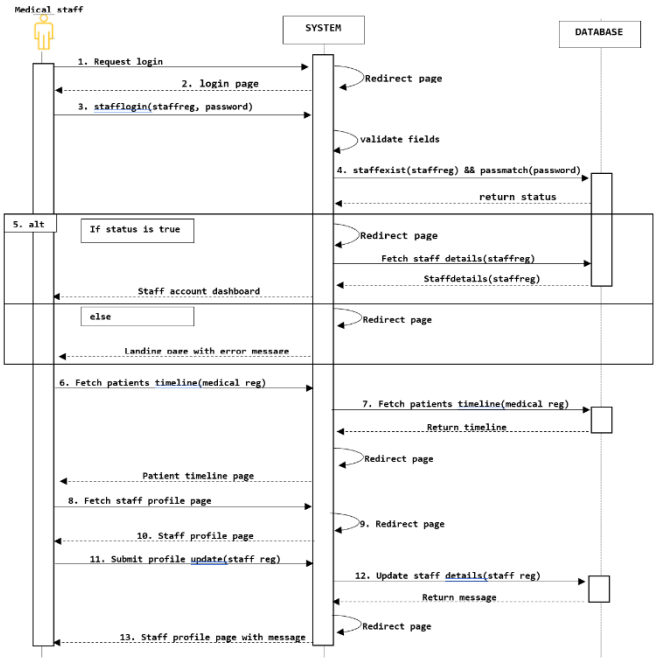

Figure 8: Medical staff login, profile update and fetch patient timeline sequence diagram

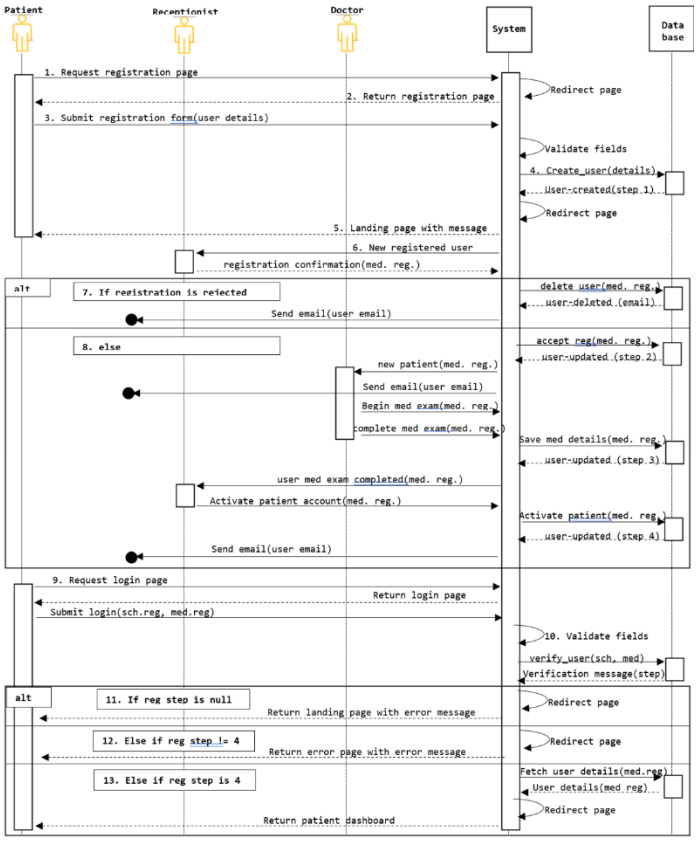

Figure 9: Patient registration and login sequence diagram.

3.6 Class diagram of the proposed system

The class diagram below depicts the proposed system's static structure, including the classes, attributes, operations (or methods), and object relationships.

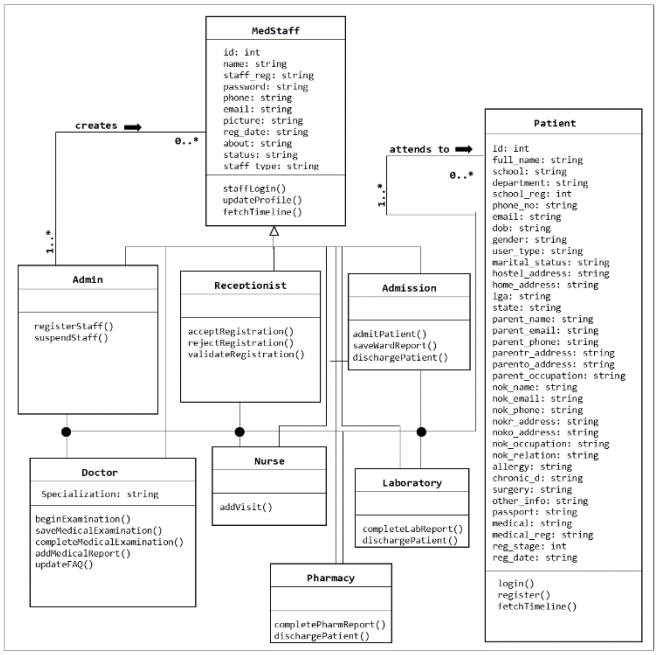

Figure 10: Class diagram of the proposed system.

3.7 Deployment diagram of the proposed system

The deployment diagram below illustrates a three-tier architecture with a client representing the user's device or web browser, an application server hosting the system software, and a database for data storage. The client communicates with the load balancer for processing requests and retrieving data and distributing traffic.

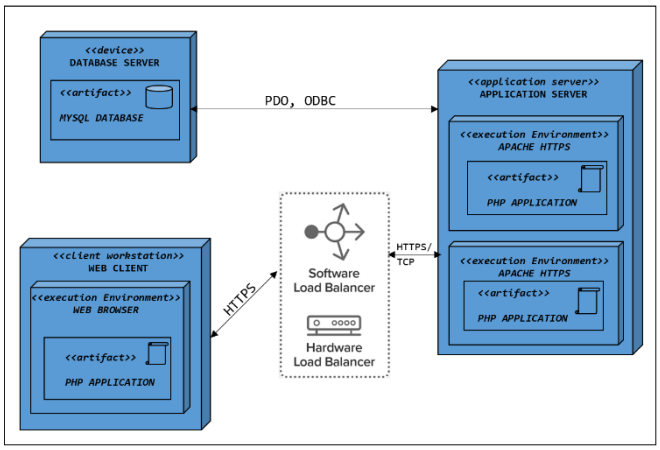

Figure 11: Deployment diagram of the proposed system.

3.8 Site map for the proposed system

The proposed hospital management system socio-technical high-level model below features a top-down site map, allowing users to access and operate various modules and subsystems independently from the landing page.

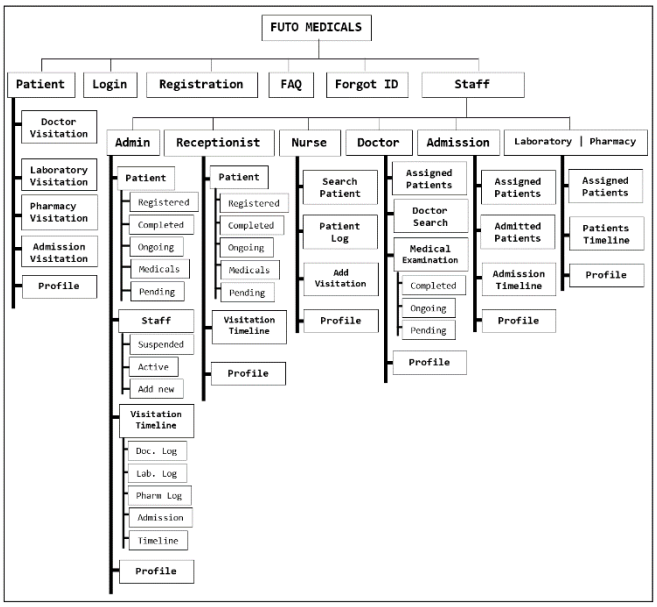

Figure 12: site map for the proposed system

4.0 SYSTEM IMPLEMENTATION

4.1 Hardware Requirements

A server or cloud-based hosting platform, Accessible computers or devices, Network infrastructure for connecting server and devices, and Peripheral devices as needed.

4.2 Software Requirements

Operating system (Windows, iOS, or Apple) for devices and Linux on server, Apache web server for hosting the application, Web browsers like Google Chrome, Mozilla Firefox, Microsoft Edge, Apple Safari, Opera, or Samsung Internet, and MySQL database management system for data storage and management.

4.3 Choice of Development Tools

Front-end technologies: HTML and CSS, Back-end tools: PHP for dynamic websites, JavaScript used for interactive user experiences and service worker scripting, Web App Manifest: JSON file containing name, icons, and metadata for a PWA, and MySQL for storing and retrieving data for various applications.

4.3 System security

To ensure system security, SSL certificates are added to the server for secure HTTPS connection, user authentication, input validation, access control, data encryption, and a PHP Firewall library to block malicious IP addresses or networks. These measures protect the patient management system from common threats and ensure its safe and secure use by authorized users.

4.4 System Testing

System testing for the Patient Management progressive web application involved unit tests, integration tests, and system tests. These tests validated the functionality and performance of the PWA. They included performance and accessibility testing using Lighthouse dev tools, PWA testing, use case testing, and platform testing to ensure compatibility with various platforms.

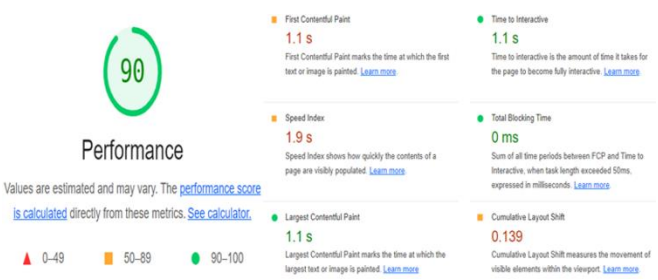

Figure 13: Lighthouse performance testing with 90% score for desktop devices.

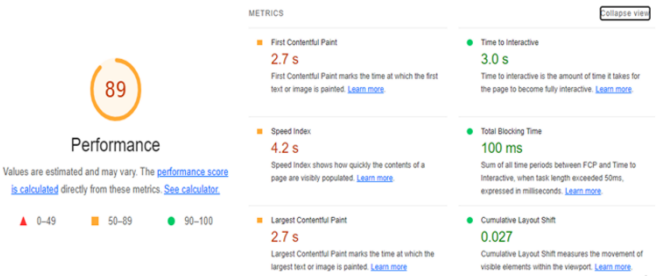

Figure 14: Lighthouse performance testing with 89% score for mobile devices.

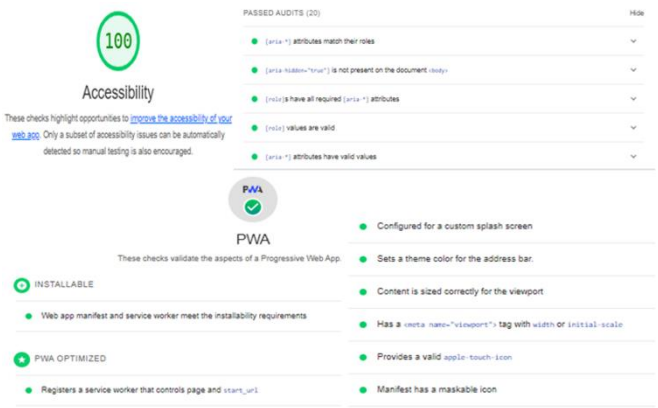

Figure 15: Lighthouse accessibility and PWA testing 100% score for mobile devices.

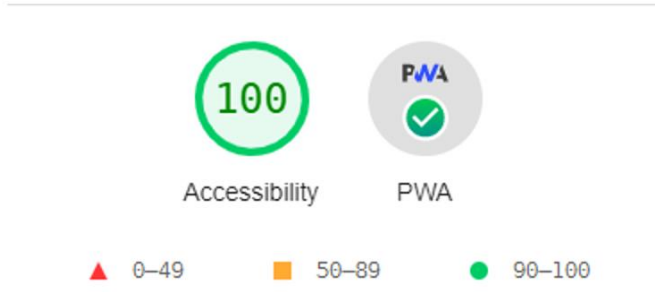

Figure 16: Lighthouse accessibility and PWA testing 100% score for desktop devices.

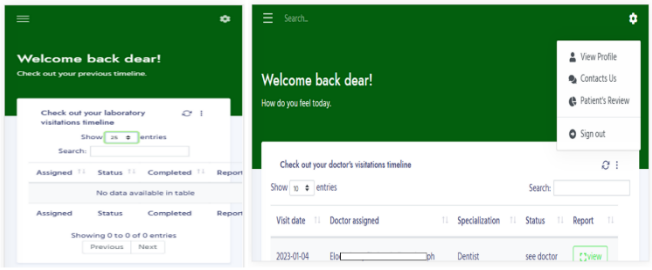

Figure 17: Platform testing - sample user interfaces in mobile view.

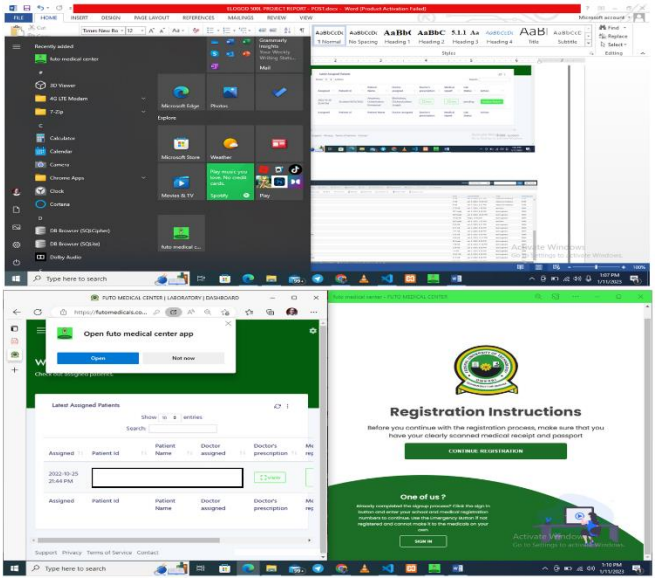

Figure 18: Platform testing - start menu and task bar showing installed medical center app on desktop and opened as a stand-alone application.

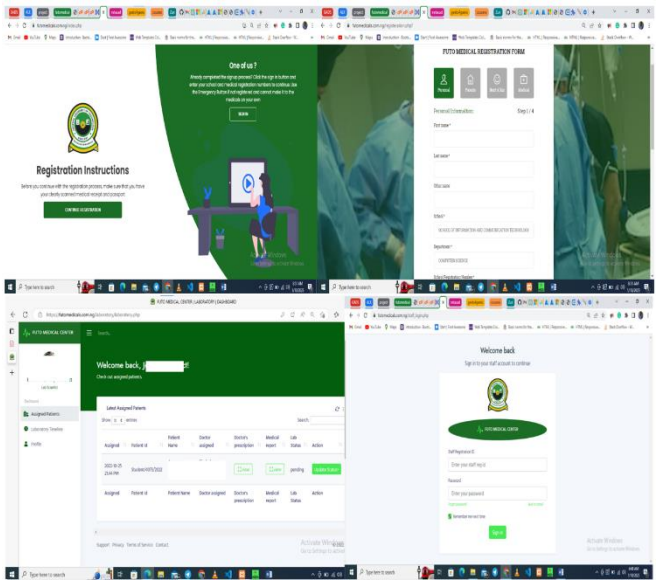

Figure 19: Platform testing - sample user interfaces in desktop view.

5.0 CONCLUSION

5.1 Summary

This project saw the development of a PWA, which helps in mitigating the technological barriers and making primary healthcare accessible smoothly in Nigeria. The architecture was based on actor-network and socio-technical theories, OOADM, and UML, and the development process involved rigorous testing and debugging. With this implementation, you have a website, mobile app, desktop app, and their whole functionalities, such as offline support and push notifications, with one code base, reducing cost and opening opportunities for more technological advancement in healthcare delivery in Nigeria.

5.2 Recommendation for future work

Based on this work, the following recommendations are made for further research and development on the use of PWAs for primary healthcare delivery:

1. Implementation of AI that will deliver safe health advice automatically.
2. Digital medical treatment via telemedicine and in-app messaging platform for emergency response or receiving medical advice without visiting the hospital.
3. Research how you can use a PWA to improve persuasive strategies that will lead to better health.
4. Integrating IoT devices is a means to achieving personalized healthcare delivery.

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