A CENTRALIZED ELECTRICAL HEALTH RECORD MANAGEMENT SYSTEM

BY

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DEPARTMENT OF COMPUTER SCIENCE,

FACULTY OF PHYSICAL SCIENCES,

UNIVERSITY OF BENIN, BENIN CITY,

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF SCIENCE (B.Sc.) DEGREE IN COMPUTER SCIENCE

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CERTIFICATION

This is to certify that this project work was carried out by **AKOBUNDU CHIDOZIE COLLINS** with Matriculation Number **PSC2105481** under my supervision. It is adequate and satisfactory, both in scope and content, for the award of Bachelor of Science (B.sc) Degree in Computer Science of the University of Benin

MR.K.O. OTOKITI	**DATE**
Project Supervisor	

APPROVAL

This project work is hereby approved in partial fulfilment of the requirements for the award of Bachelor of Science (B.Sc.) Degree in Computer Science from the University of Benin.

Dr MRS. ROSEMARY USIOBIAFO

Head of Department

DATE

DEDICATION

This project is dedicated to God Almighty for giving me the strength, wisdom, and grace to see it through to completion, and for His guidance throughout my academic journey. It is also dedicated to my family, friends, and colleagues for their constant love, encouragement, and support, and to my lecturers for imparting knowledge and direction that have shaped my learning experience. Most especially, I dedicate this work to my project supervisor, MR OTOKITI, whose mentorship, patience, and invaluable guidance made the successful completion of this project possible.

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TABLE OF CONTENTS

ABSTRACT

Efficient healthcare delivery relies heavily on accurate, accessible, and secure patient information. In Nigeria, the current method of managing patient records remains largely manual, fragmented, and uncoordinated across different healthcare facilities. This has led to frequent duplication of medical tests, prolonged waiting times, and poor continuity of care. The need for a centralized and interoperable digital solution is therefore essential in improving patient outcomes and overall healthcare efficiency.

This project focuses on the design and prototype implementation of a web-based Electronic Health Record (EHR) system named HealthHive. The system aims to consolidate patient medical data from multiple hospitals into a single, secure, and user-friendly platform accessible to patients, healthcare providers, and administrators. HealthHive emphasizes interoperability, scalability, and data security while ensuring that patient privacy is upheld through role-based access control and encrypted communication.

The project adopts the Object-Oriented Analysis and Design (OOAD) approach, with modeling tools such as Use Case Diagrams and Class Diagrams utilized to represent the system's architecture and interactions. The proposed system demonstrates how centralized digital records can minimize redundancies, promote data sharing between healthcare institutions, and enhance decision-making through accurate medical histories.

Ultimately, this prototype lays the foundation for a national EHR framework capable of transforming healthcare management in Nigeria by improving accessibility, efficiency, and trust within the healthcare ecosystem.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In recent years, digital innovation has transformed several sectors finance, education, communication, yet the healthcare industry, especially in developing countries, still lags behind in many foundational areas. One of the most noticeable and recurring challenges for patients is the fragmented nature of medical records across different hospitals. Each facility acts as an isolated node, disconnected from others, with little or no interactions between systems.

A common experience illustrates this; a patient visits a general hospital and goes through registration, diagnostic tests, consultations, and treatments. A few weeks later, when referred to a specialist or seeking a second opinion at another hospital, the entire process starts again; filling new forms, describing the same symptoms, and repeating tests, all because their medical history doesn’t follow them. In urgent cases, this delay can be life-threatening. In routine cases, it’s an unnecessary financial and emotional burden.

From a Health care professional’s perspective, the inability to access a patient’s past records limits their ability to make fast, informed decisions. Critical details, past prescriptions, allergy records, previous diagnoses are unavailable unless the patient carries printed documents, which are often incomplete or lost. Healthcare providers then rely on verbal accounts from patients, which can be vague or inaccurate. This gap leads to misdiagnoses, duplicate testing, treatment delays, and medical errors that could otherwise be avoided.

In Nigeria, this problem is compounded by overburdened systems, lack of standardized data management protocols, and low digital infrastructure across public hospitals. Even private hospitals, which may have digital record systems, typically maintain them internally with no connection to external facilities.

This project, therefore, aims to take a human-centered approach by designing a practical interface, a visual representation of how a centralized healthcare data system could work; with accessibility, user-friendliness, and trust at its core. Instead of diving straight into infrastructure implementation, this project emphasizes the user interaction aspect: how would a patient access their record from anywhere? What would the doctor see? How is consent managed? What alerts or summaries would improve care quality?

By focusing on the design and interaction layer of such a system, we seek to demonstrate that the idea of centralized health records is not just a technical challenge, but also a design and experience challenge; one that, when solved correctly, could drastically reshape how care is delivered and experienced in Nigeria.

1.2 Statement of the Problem

Healthcare in Nigeria is plagued by fragmentation, where patients are forced to restart the medical process at each hospital due to the absence of a centralized health record system. This results in wasted time, repeated costs for consultations and tests, preventable medical errors, and delayed treatment that can worsen patient conditions. Doctors are left with incomplete information, relying on memory or vague patient accounts, which compromises the accuracy of diagnoses and treatment plans. The system also overburdens healthcare workers with redundant administrative tasks, creating inefficiencies in already strained facilities. Without a unified digital solution, these issues will persist, leading to rising patient dissatisfaction, poor continuity of care, and missed opportunities to modernize Nigeria's healthcare system.

1.3 Aim and Objectives of the Study

The aim of this project is to design and implement an intuitive, centralized health record system that simplifies patient record access and sharing across multiple hospitals in Nigeria.

The objectives are to:

- Identify and visualize pain points in the current medical record handling system through patient and doctor personas.
- Create a user-friendly design prototype using Figma for both patient and doctor interfaces.
- Implement a functional system that demonstrates secure patient-controlled data sharing using patient ID tokens or QR codes.
- Provide a scalable framework that can guide future nationwide adoption of a centralized digital health record system.

1.4 Scope of the Study

The scope of this project is limited to the design and implementation of a prototype centralized health record system that demonstrates how medical data can be securely accessed and shared across hospitals in Nigeria. The project focuses on building an intuitive interface for both patients and doctors, simulating real-life workflows such as registration, medical history retrieval, and doctor-patient interactions. While it will not integrate with existing hospital infrastructures nationwide, it will provide a working model that showcases the feasibility, usability, and potential benefits of such a system within the Nigerian healthcare context.

1.5 Motivation of Study

This project is driven by personal and societal experiences of inefficiencies in hospital systems particularly the long queues, repeated registrations, and preventable medical errors due to lack of medical history access. The motivation also stems from the COVID-19 pandemic, which exposed weaknesses in healthcare systems and the urgent need for digital transformation in patient data management.

1.6 Significance of Study

This project is significant to multiple stakeholders:

I. **For Patients**: It reduces stress, saves time and money, and promotes better, personalized healthcare.

II. **For Healthcare Providers**: It improves decision-making, enhances service speed, and minimizes the risk of error.

III. **For the Health Sector**: It serves as a model for digital healthcare transformation in Nigeria and similar low-resource settings.

IV. **For Researchers and Developers**: It opens avenues for future development in e-Health systems using data design, UI/UX, and secure data protocols.

CHAPTER TWO

LITERATURE REVIEW

2.1 Nigerian Healthcare System

The healthcare system in Nigeria is complex, underfunded, and faces multiple structural challenges that affect both access and quality of care. Nigeria operates a three-tiered healthcare delivery structure**:** primary healthcare (PHC), secondary healthcare, and tertiary healthcare. Primary healthcare serves as the foundation, focusing on preventive and basic health services, while secondary and tertiary facilities provide specialized and referral-based services. Despite this design, implementation has been weak, with PHC centers often poorly equipped and underutilized (Adebayo et al., 2022).

The Nigerian healthcare system is **mixed, public and private**. Public facilities are managed at the local, state, and federal government levels respectively, but they are often plagued by poor funding, lack of accountability, and infrastructural decay. On the other hand, private hospitals and clinics, though better equipped in many cases, are often too expensive for the majority of Nigerians who live below the poverty line. As a result, healthcare access is highly unequal, favoring urban over rural populations and wealthy over low-income households ([WHO], 2021).

Health financing in Nigeria is another critical challenge. Out-of-pocket expenditure constitutes nearly **70% of total health spending** in the country, a figure far above the WHO-recommended maximum of 30–40% ([FMoH], 2020). This high reliance on out-of-pocket payments discourages many Nigerians from seeking care until illnesses become severe, thereby contributing to late diagnoses and preventable deaths.

The fragmentation of health services is further aggrevated by **weak integration of technology**. Paper-based systems still dominate, leading to lost records, duplication of tests, and delays in treatment. While some tertiary hospitals have piloted electronic health systems, interoperability across facilities remains minimal, leaving patients to carry incomplete health information when moving between providers (Onyema & Idowu, 2020).

Overall, the Nigerian healthcare system struggles with **structural weaknesses, financial burdens, and limited use of digital innovations,** making it an environment where poor health outcomes are common. Understanding this background sets the stage for exploring how intuitive interface design in health technology could help bridge these gaps and reduce systemic fragmentation.

2.2 Structure of the Nigerian Healthcare System

Nigeria's healthcare system is one of the largest in Africa, serving a population of over 200 million people. It operates under a three-tier structure: primary healthcare centers at the community level, secondary hospitals at the state level, and tertiary teaching or specialist hospitals at the federal level as shown in Figure 2.1. Despite this framework, the system often struggles to provide consistent, reliable, and coordinated care to patients, largely due to weak infrastructure and poor integration between facilities.

Primary healthcare centers (PHCs), managed at the local government level, provide basic services such as immunization, antenatal care, and treatment of common illnesses. Secondary hospitals, run by state governments, offer more advanced services including surgeries, obstetrics, and diagnostics. Tertiary facilities, like federal teaching hospitals and specialist centers, provide highly specialized services, advanced diagnostics, and serve as training grounds for healthcare professionals.

Despite this hierarchy, the referral process between these levels is weak, and patients often bypass PHCs, heading straight to higher-level facilities. This leads to overcrowding at secondary and tertiary hospitals and inefficiencies in the system. Another major gap is the **lack of interoperability of patient records** across these levels. Each facility maintains isolated records, often paper-based; meaning a patient's history is rarely shared, even when referrals occur. Patients often carry their own medical documents or repeat tests at each new facility. This weakens continuity of care, wastes financial resources, and creates opportunities for errors.

Despite these challenges, recent years have seen growing interest in digital health solutions. Mobile health (mHealth) platforms, electronic health records (EHR), and telemedicine are slowly being introduced in urban areas, although adoption remains low in rural communities. These developments highlight a clear opportunity for user-centered digital systems to close gaps in service delivery.

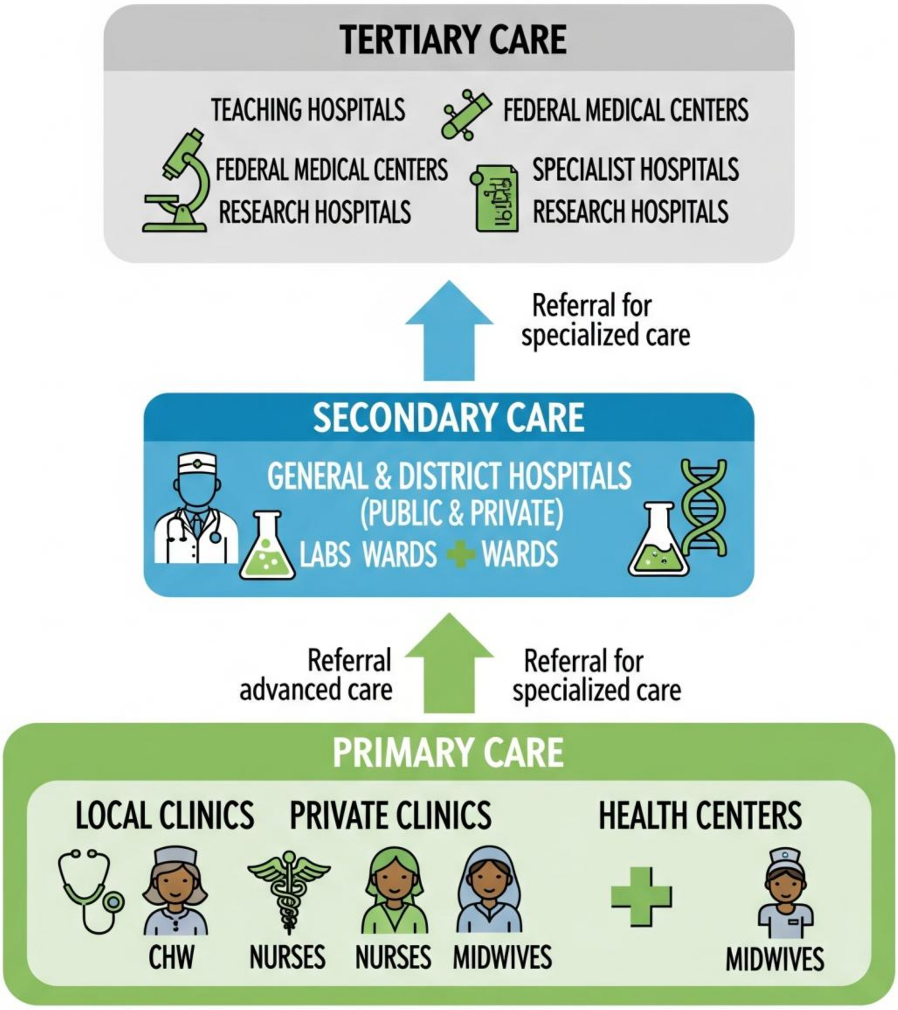


Figure 2.1: The 3 tier Structure of the Nigerian HealthCare System

2.3 Challenges in Nigerian Healthcare

The Nigerian healthcare system faces multiple systemic issues that affect both patients and providers. Access to healthcare remains highly unequal, with rural communities often lacking functional facilities, medical equipment, or trained personnel. Many primary healthcare centers are non-operational, forcing patients to travel long distances for even basic treatment. This unequal distribution of resources worsens health outcomes, especially for vulnerable groups such as women, children, and the elderly. These challenges are clearly highlighted in Figure 2.2.

Financing is another persistent challenge. The National Health Insurance Scheme (NHIS), launched in 2005, has achieved limited coverage, reaching less than 10% of the population, mostly in urban areas and the formal sector. As a result, out-of-pocket payments remain the primary method of funding healthcare in Nigeria. This creates a high risk of financial hardship for families, often leading to delays in seeking care or complete avoidance of medical services due to cost.

Human resource shortages and poor infrastructure compound these problems. Nigeria has a doctor-to-patient ratio of about 1:5,000, far below the WHO's recommended 1:600. The migration of health professionals abroad ("brain drain"), frequent strikes, and poor working conditions further weaken service delivery. Many hospitals also struggle with inadequate power supply, outdated diagnostic tools, and limited access to modern technologies, making it difficult for healthcare providers to deliver efficient, high-quality care.

Technological adoption is another major gap, as most facilities still rely on paper-based systems. Patients are forced to repeat registrations, laboratory tests, and consultations when moving between hospitals, since records are not shared or centralized. This lack of interoperability leads to wasted time, unnecessary expenses, and preventable errors. Coupled with policy inconsistencies, weak governance, and corruption, these challenges create an urgent need for innovative, design-centered digital solutions that can reduce fragmentation and improve continuity of care across Nigeria.

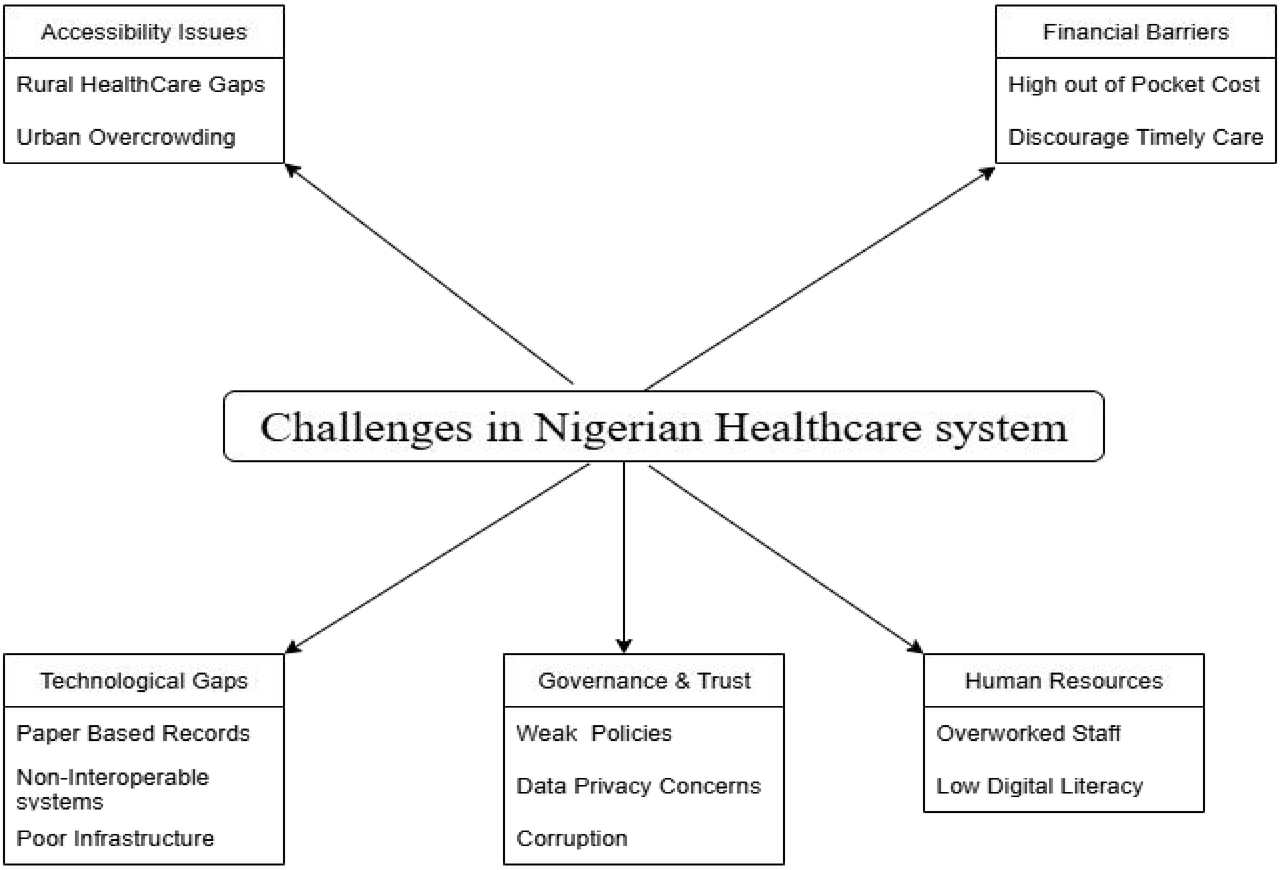


Figure 2.2: Key challenges in Nigerian Healthcare System

2.4 Healthcare Financing and Insurance

Healthcare financing in Nigeria is one of the most critical bottlenecks in achieving efficient and equitable service delivery. Unlike developed countries with universal health coverage systems, Nigeria relies heavily on out-of-pocket expenditure, which accounts for over 70% of total healthcare spending (World Health Organization [WHO], 2021). This structure not only places a heavy burden on patients but also reinforces fragmentation within the healthcare system. Patients who cannot afford services delay care, leading to late diagnoses and increased treatment costs, while providers lack stable financial flows to invest in modern infrastructure, including digital health systems.

Health insurance coverage in Nigeria remains very low, with the National Health Insurance Authority (NHIA) covering less than 10% of the population (NHIA, 2022). Most enrollees are federal civil servants, leaving the informal sector and rural populations largely excluded. This uneven insurance penetration creates disparities in access to care and contributes to inefficiencies in record-keeping and continuity of services. For an EHR system to be successfully implemented, financing models must incentivize providers to adopt digital systems, while Insurance plans should be updated so people can file claims online, and so payments are made using smart systems that analyze data.

From a system design perspective, healthcare financing influences the sustainability of EHRs. If hospitals must absorb the entire cost of technology adoption, uptake will remain low. A **shared financing approach** involving government subsidies, donor support, and private partnerships can reduce the cost burden. Additionally, embedding features such as **automated billing, digital insurance claims, and financial dashboards** into the EHR system can improve transparency, reduce fraud, and streamline resource allocation (Eze & Ibekwe, 2020).

Furthermore, financing reforms in Nigeria should move toward **pooled funding mechanisms** that consolidate resources across states and facilities. Lessons from Ghana’s National Health Insurance Scheme demonstrate that pooling funds can reduce administrative fragmentation and promote equity (Agyepong & Adjei, 2021). For Nigeria, aligning financing reforms with digital health adoption will not only improve service delivery but also enhance the reliability and scalability of systems like the proposed EHR

2.5 The Role of User Interface (UI) Design in Healthcare

User Interface (UI) design plays a critical role in making digital healthcare systems usable, safe, and accessible. In the context of Nigeria's fragmented healthcare system, where patients and providers often lack familiarity with complex technologies, intuitive UI design can act as the bridge between technical solutions and real-world adoption. A well-designed interface simplifies navigation, reduces confusion, and ensures that both patients and doctors can interact with the system effectively, regardless of their level of digital literacy.

For patients, UI design influences how easily they can access their medical history, share records, or book appointments. Simple visual cues, icons, and dashboards can help patients understand their health data without requiring advanced medical knowledge. Features such as notifications for upcoming visits or alerts about prescriptions encourage adherence to treatment and reduce the risks associated with forgetfulness or poor health literacy. By prioritizing clarity and accessibility, UI design empowers patients to take a more active role in managing their health.

For healthcare professionals, efficient UI design reduces the cognitive load associated with handling large volumes of data. Doctors and nurses need fast access to patient records, test results, and treatment histories to make quick, informed decisions. A cluttered or poorly designed interface slows them down and increases the likelihood of errors. Conversely, streamlined dashboards and search functions improve efficiency and accuracy, enabling providers to focus more on patient care.

Ultimately, UI design is not just about aesthetics; it is about functionality and trust. In Nigeria, where skepticism about digital systems and privacy concerns are common, user-friendly designs that emphasize transparency, consent, and security are essential for encouraging adoption. By addressing both patient and provider needs, UI design becomes a key enabler of interoperability and continuity of care across fragmented healthcare systems.

2.6 Key Stakeholders

The success of a centralized Electronic Health Record (EHR) system depends not only on the technology but also on the people who interact with it. In Nigeria's healthcare system, stakeholders play different but interconnected roles, and their involvement is critical to overcoming fragmentation.

i. **Patients:** These are at the center of the system. They are currently burdened by repeating medical histories, tests, and registrations at each facility they visit. For patients, the system's design emphasizes **convenience and control**. Features such as secure login, QR-code-based access, and clear record summaries make it easier for patients to carry their medical history digitally. This reduces unnecessary costs and stress while ensuring better continuity of care.
ii. **Doctors and healthcare providers:** These are another key stakeholder group. They require quick and reliable access to patient information to make accurate decisions. In the proposed system, the **doctor interface** would allow providers to retrieve patient histories, update diagnoses, and add prescriptions without relying on incomplete verbal accounts. The design will include features like **alerts for allergies or past conditions**, ensuring safer and faster treatment.
iii. **Hospital administrators:** These also play a crucial role. They manage records, ensure compliance, and coordinate staff activities. A centralized EHR system would reduce administrative burdens by eliminating redundant paperwork and streamlining patient registration. The system's **admin dashboard** would provide oversight of hospital operations while maintaining compliance with data protection policies.
iv. **Government and regulatory bodies:** At policy level these are vital stakeholders. They set standards for interoperability, privacy, and security. Their role in this system

includes ensuring adherence to the **Nigeria Data Protection Act (NDPA, 2023)** and supporting policies that promote integration between public and private hospitals.

v. **IT professionals and researchers: These** are stakeholders who ensure the system remains functional, secure, and adaptable. They will use the system for continuous improvement, data analysis, and innovations in eHealth.

By addressing the unique needs of each stakeholder through tailored interfaces and workflows, the proposed EHR system ensures widespread adoption and maximizes impact across Nigeria's healthcare ecosystem

2.7 Case Studies of Successful EHR Implementations

Several countries have successfully demonstrated how electronic health record (EHR) systems can be implemented even in resource-constrained or complex healthcare environments. These experiences provide Nigeria with practical insights into how to design, scale, and sustain an effective digital health system. A few of the most notable examples are:

i. **Rwanda's adoption of OpenMRS (Open Medical Record System)**; an open-source EHR platform. Initially deployed to support HIV/AIDS programs, it was gradually scaled to cover maternal health, primary care, and hospital services. The success of this rollout hinged on **phased implementation**, which built trust and gave healthcare workers time to adapt. Furthermore, strong government leadership and investments in local capacity building ensured sustainability (Seebregts et al., 2018).

ii. **Estonia adopted the Estonia National Health Information System (ENHIS)** represents one of the most advanced EHR implementations worldwide. Every citizen has a centralized digital health record accessible through secure authentication, and patients have full control over who accesses their data. The system integrates seamlessly with pharmacies, laboratories, and hospitals, reducing duplication of tests and improving patient safety. Estonia's success highlights the power of **interoperability and patient-centered governance** in digital healthcare (Saluveer & Ross, 2020).

iii. In **Kenya**, the Afya Care pilot program and integrations with OpenMRS have improved maternal and child health record-keeping, ensuring continuity of care between local clinics and referral hospitals. This initiative demonstrated how **public-private partnerships** can expand digital health coverage in low-resource environments (Were et al., 2019).

iv. Similarly, **India's Aadhaar-linked EHR pilot projects** show how large-scale digital identity systems can be leveraged to build robust health databases. By linking patient records to a unique national ID, India enabled cross-hospital data sharing, reducing duplication of services and improving portability of patient histories (Kumar et al., 2021).

v. Lastly, **Brazil's Unified Health System (SUS)** successfully integrated EHRs at the primary care level through the e-SUS AB system. By focusing first on **primary care digitalization**, Brazil built the foundation for a nationwide health information system that now supports millions of patient encounters each year (da Silva et al., 2019).

Across these examples, three success factors consistently stand out:

1. **Strong political will and policy alignment** to drive nationwide adoption.
2. **Inclusive stakeholder participation**, ensuring that health workers and patients are part of the design process.
3. **Interoperable and scalable platforms**, tailored to local infrastructure and sustainable beyond donor funding.

For Nigeria, the implication is clear: a phased, locally owned, and interoperable system backed by government policy and stakeholder collaboration is more likely to succeed.**2.8**

3.8 Lessons Learned from Failed Implementations

While success stories offer hope, failed EHR projects provide equally valuable lessons. The most prominent example is the **United Kingdom's National Programme for IT (NPfIT).** Despite costing over £10 billion, it collapsed due to **over-ambitious goals, rigid top-down planning, and poor engagement with clinicians** who felt excluded from decision-making. The program also underestimated the complexity of integrating diverse hospital IT systems, leading to resistance and abandonment (Greenhalgh et al., 2017).

In **Ghana**, attempts to implement donor-driven hospital information systems faced sustainability challenges. Many projects were abandoned once external funding ended, as there was no clear plan for local ownership, ongoing maintenance, or training of staff (Ojo et al., 2020).

Similarly, in **South Africa**, certain hospital-level EHR deployments failed due to **poorly designed interfaces** that required advanced digital skills. Healthcare workers with limited IT literacy found the systems burdensome, leading to resistance and underuse (Fraser et al., 2019).

In **the United States**, the Veterans Health Administration's attempt to transition from its successful VistA system to a commercial Cerner EHR was plagued by cost overruns, technical failures, and usability complaints from clinicians. This case illustrates that even in high-resource settings, **usability and adaptability** are critical (Edwards et al., 2020).

From these failures, three key lessons emerge:

1. **Avoid over-centralization without local engagement** – systems must adapt to the realities of each hospital or clinic.
2. **Prioritize usability and simplicity over technical complexity** – healthcare staff must be comfortable with the interface.
3. **Plan for sustainability beyond donor funding** – long-term local ownership and training are essential.

For Nigeria, these lessons stress that future EHR prototypes must be **human-centered, affordable, and flexible**, developed with both patient and healthcare worker input to ensure adoption and long-term use.

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

This chapter presents the system analysis and design of the proposed Electronic Health Record (EHR) prototype. It begins by examining existing healthcare record systems, identifies their weaknesses, and justifies the need for a new system. It then introduces the proposed EHR system, explains its design principles, and outlines its architecture, including functional modelling through use case diagrams. The aim is to demonstrate how the proposed system can address the challenges of Nigeria's fragmented healthcare sector while remaining scalable and secure

3.1 Analysis of the Existing System

In Nigeria, patient medical data management remains largely inefficient, fragmented, and heavily dependent on manual procedures. In most hospitals and clinics, records are still maintained using paper-based systems or standalone computer applications with no standardized structure or interoperability (Ojo et al., 2020). The operational process typically involves a patient arriving at a hospital, filling out a physical registration form, and being assigned a paper file. This file then serves as the patient's permanent medical record, stored in large filing cabinets that are manually retrieved for each visit.

When a patient returns for follow-up, medical staff must physically search for the folder—often among thousands of files, before consultations can proceed. If the record is missing, misplaced, or damaged, the hospital may be forced to recreate it, leading to the loss of previous data and treatment history. Similarly, laboratory results and prescriptions are often recorded on paper slips that patients must carry between departments. This operational method introduces bottlenecks such as delays, transcription errors, and the risk of data inconsistency.

Furthermore, each healthcare facility operates in isolation. There is no unified system that allows hospitals to share patient records across different locations. For example, a patient treated for malaria in Lagos may need to repeat the same diagnostic tests when visiting a hospital in Abuja because their previous results cannot be accessed electronically. This lack of interoperability wastes resources and undermines continuity of care.

Globally, modern Electronic Health Record (EHR) systems have solved similar challenges by creating connected healthcare ecosystems. Estonia's nationwide EHR, for instance, enables every licensed healthcare provider to access patient information securely, ensuring that treatment decisions are informed by complete histories (Saluveer & Ross, 2020). Rwanda's deployment of OpenMRS also demonstrated the potential of digital health platforms to unify care delivery, first in HIV management and later across general medical services (Seebregts et al., 2018).

In contrast, Nigerian healthcare institutions face key operational limitations:
i. **Limited interoperability** – Facilities use incompatible systems or remain fully manual.
ii. **Restricted patient access** – Patients cannot view or control their own medical data.
iii. **Weak data security** – Paper-based and basic electronic systems lack encryption or audit tracking.

This analysis clearly shows that the existing healthcare data management approach is inadequate for achieving continuity of care, reliable data security, and nationwide system integration.

3.2 Constraints of the Existing System

The deficiencies of the current healthcare information management system extend beyond operational inefficiency to include technological, structural, and human-capacity barriers. These constraints collectively inhibit the development of a reliable, modern health data ecosystem.

1. **Fragmentation of Patient Data:** Each healthcare facility stores patient information in isolation, resulting in data redundancy and gaps. For example, a diabetic patient visiting multiple hospitals will have scattered records, making it impossible for clinicians to assess the full history of treatment or medication adjustments.
2. **Manual and Error-Prone Processes:** Paper files are susceptible to physical damage, loss, and human error. Misfiled or incomplete records often lead to misdiagnoses, repeated laboratory tests, and patient dissatisfaction. The process of locating, updating, and storing physical files consumes valuable staff time that could otherwise be used for patient care.
3. **Technological Limitations:** Many healthcare institutions, particularly in rural or government-run facilities, lack reliable IT infrastructure. Unstable electricity, poor internet connectivity, and inadequate computer systems further hinder adoption of digital health platforms (Oluwatobi & Fagbohun, 2019).
4. **Usability and Training Barriers:** Where digital systems have been introduced, they are often poorly designed, with unintuitive interfaces that discourage usage among healthcare workers with limited computer literacy. This reduces efficiency and increases resistance to technology adoption.
5. **Data Security and Privacy Concerns:** Inadequate cybersecurity measures leave sensitive medical data vulnerable to unauthorized access. Paper-based systems, in particular, provide no audit trail to detect who has viewed or altered a patient's

information. Even digital systems often lack essential safeguards such as user authentication and encryption.

6. **Limited Policy and Regulatory Enforcement:** Although Nigeria's National Health ICT Strategic Framework advocates interoperability, enforcement and standardization across hospitals remain weak, leading to inconsistent data practices and poor integration.

These constraints highlight the urgent need for a modern, centralized, and secure EHR system that supports efficiency, accessibility, and accountability in healthcare delivery.

3.3 Justification of the Proposed System

The proposed web-based Electronic Health Record (EHR) system aims to bridge the existing technological and operational gaps in Nigeria's healthcare data management. The justification for developing this system lies in the need to ensure secure, efficient, and patient-centered data management capable of supporting both clinical and administrative functions.

Firstly, the system addresses continuity of care by enabling healthcare providers across different facilities to access and update patient records in real-time. For instance, if a patient initially treated in Lagos later visits a clinic in Enugu, authorized doctors can instantly retrieve their previous medical history and treatment details, reducing the need for repeated tests or medication errors.

Secondly, the proposed system enhances operational efficiency by replacing manual paper records with an automated digital platform. Tasks such as patient registration, diagnosis entry, and test result retrieval become faster and more accurate. This digital workflow not only minimizes clerical errors but also improves record organization and searchability.

Thirdly, the system promotes patient empowerment by allowing individuals to manage and control access to their health data. Through authentication-based login, patients can view their records and grant temporary access to healthcare providers, ensuring transparency and privacy.

Fourthly, it supports data security and integrity through encryption, secure logins, and audit tracking, ensuring compliance with data protection regulations.

Finally, the system aligns with Nigeria's digital health transformation strategy, providing a scalable foundation for future integration with telemedicine, mobile health services, and artificial intelligence (AI)–driven health analytics. Over time, the platform can evolve into a national health information exchange, connecting hospitals, laboratories, and pharmacies into one interoperable network.

Thus, the proposed EHR system is not merely a technological solution, it is a strategic response to the inefficiencies of the current model, a means to empower both patients and providers, and a sustainable investment in the modernization of Nigeria's healthcare infrastructure.

3.4 The Proposed System

The proposed system is a web-based Electronic Health Record (EHR) prototype specifically designed to address the fragmentation, inefficiency, and security challenges associated with existing healthcare record management practices in Nigeria. This system seeks to establish a centralized digital platform that seamlessly integrates patient health data across hospitals, clinics, and laboratories within the country's healthcare network.

Unlike traditional systems that rely on localized databases or paper-based records, the proposed EHR platform operates as a **cloud-enabled, interoperable framework** capable of facilitating **real-time access, sharing, and management of patient health data**. This enables healthcare professionals to make informed decisions quickly, ensures continuity of care, and enhances patient safety through the elimination of redundant diagnostic tests and manual data errors.

3.4.1 Core Objectives of the Proposed System

The system is designed with the following primary objectives:

1. **Centralization of Health Records** – To provide a unified and accessible repository for patient data that can be securely accessed from any authorized healthcare facility across the nation.
2. **Enhanced Interoperability** – To ensure compatibility and communication between multiple hospital systems through standardized data exchange protocols and APIs.
3. **Data Security and Privacy** – To safeguard sensitive patient information using robust authentication mechanisms, encryption, and compliance with ethical data governance principles.
4. **Improved Usability** – To design an intuitive and user-friendly interface that accommodates healthcare practitioners with varying levels of digital literacy.
5. **Scalability and Flexibility** – To create a system architecture capable of expanding with emerging technologies such as telemedicine, AI-driven diagnostics, and mobile health applications.
6. **Accessibility and Inclusiveness** – To bridge the digital divide by ensuring system accessibility in both urban and rural healthcare centers through a hybrid online–offline operational model.

3.4.2 Functional Overview

The proposed EHR system comprises three major user categories, Patients, Healthcare Providers, and System Administrators, each interacting with the system through defined, role-based interfaces:

i. **Patients** can register, log in, view their health history, and grant or revoke data access to specific healthcare providers. They also receive notifications on appointments, prescriptions, or test results.

ii. **Healthcare Providers** can securely log in to retrieve, update, or add new medical information to a patient's record. Providers can also generate reports or summaries that aid in diagnosis, treatment, and decision-making.

iii. **System Administrators** oversee the management of all user accounts, system configuration, and data security monitoring. They ensure compliance with national healthcare data standards and maintain system integrity through audit trails and backup routines.

3.4.3 System Features and Capabilities

The main features of the proposed EHR prototype include:

i. **Secure Authentication System:** Multi-factor authentication (MFA) ensures that only verified users gain access.

ii. **Role-Based Access Control (RBAC):** Each user type interacts only with the functionalities relevant to their role.

iii. **Health Record Management:** Centralized management of patient demographics, medical histories, prescriptions, test results, and referrals.

iv. **Data Encryption:** Encryption of all data at rest and during transmission to prevent unauthorized access.

v. **Audit and Reporting:** Automated system logs track data usage, changes, and access patterns for compliance and monitoring.

vi. **Notification and Alert System:** Push notifications alert patients and providers about appointments, new results, and updates.

vii. **Integration Layer:** Standardized APIs allow interoperability with external systems like laboratory and pharmacy information systems.

3.4.4 Benefits of the Proposed System

The implementation of this EHR prototype provides several benefits, including:

i. **Improved Care Coordination:** Seamless access to complete patient information enhances decision-making and continuity of care.

ii. **Reduced Administrative Overhead:** Automation of patient record management minimizes paperwork and reduces staff workload.

iii. **Enhanced Patient Empowerment:** Patients gain greater control over who accesses their medical data, fostering transparency and trust.

iv. **Increased Data Reliability:** Centralized and validated data storage eliminates inconsistencies caused by multiple data entry points.

v. **Support for Health Policy and Research:** Aggregated anonymized data can support national health planning, epidemiological studies, and resource allocation.

3.4.5 Future Integration Prospects

The proposed system is envisioned as a foundation for a scalable national health data network. Its modular structure supports:

i. Integration with **mobile applications** for remote consultations and health monitoring.
ii. Incorporation of **machine learning modules** for predictive analytics and disease trend detection.
iii. Expansion into **telemedicine services,** enabling remote healthcare delivery.
iv. Linkage with **government health registries and insurance databases** for comprehensive service coverage.

In essence, the proposed EHR system does not merely serve as a prototype for academic evaluation but as a **strategic model for the digital transformation of Nigeria's healthcare infrastructure**. It embodies the principles of **efficiency, security, and inclusivity**, aligning with global standards while addressing local challenges unique to the Nigerian healthcare environment.

3.5 Proposed System Architecture

The architecture of the proposed Electronic Health Record (EHR) system follows a three-tier web application model**,** designed to ensure scalability, modularity, and high data security. This layered architecture separates the presentation**,** application**,** and data concerns, allowing for independent development, maintenance, and future expansion of each component.

At its core, the architecture seeks to facilitate secure, efficient, and interoperable data exchange between healthcare stakeholders — patients, healthcare providers, and system administrators — within a unified digital ecosystem.

3.5.1 System Overview

The system adopts a cloud-enabled client–server architecture where users access the EHR platform through standard web browsers. The web application communicates with a centralized database via secure API endpoints. The backend handles authentication, business logic, and access control, while the frontend provides an intuitive interface optimized for ease of use and low digital literacy levels.

This architecture is particularly suitable for Nigeria's healthcare environment, as it allows both **online and offline synchronization**, ensuring that healthcare providers in remote areas with unstable internet connections can still record and retrieve critical patient data.

3.5.2 Architectural Layers

This subsection describes the structural organization of the proposed system based on a layered architectural model**.** Each layer represents a distinct functional boundary within the system, defining how different components interact to deliver end-to-end functionality. By separating the system into clear layers—such as the presentation layer, application (or logic) layer, and data layer—the design ensures modularity, scalability, and maintainability. This architecture allows developers to update or extend one part of the system without disrupting others, promoting reusability and simplifying troubleshooting. The layered approach also reinforces security and data consistency, ensuring that user interfaces, business rules, and database operations remain well-coordinated and logically isolated.

1. **Presentation Layer (Client Interface):**

   This layer acts as the primary point of interaction for system users. It consists of responsive web pages accessible via desktops, tablets, and mobile devices.

i. **Patient Interface:** Enables registration, login, record viewing, and granting of data access permissions. Patients can track medical appointments and receive notifications about test results or prescriptions.

ii. **Healthcare Provider Interface:** Allows doctors and nurses to log in, search patient profiles, update clinical notes, and upload laboratory results.

iii. **Administrator Interface:** Supports oversight functions such as managing user accounts, monitoring data access patterns, and enforcing security protocols.

The interface is built using modern web frameworks like HTML5, CSS, and JavaScript, ensuring cross-platform accessibility and user-friendliness.

2. **Application Layer (Business Logic):**

The application layer manages the system's internal logic, coordinating data flow between the presentation and data layers. It ensures that every transaction complies with authentication and authorization rules.

I. Handles login validation, session management, and data encryption.

II. Enforces **role-based access control (RBAC)** so that only authorized users can view or modify specific information.

III. Implements secure APIs for communication between different modules and external health systems (e.g., laboratory or pharmacy databases).

IV. Contains the rules for CRUD (Create, Read, Update, Delete) operations on health records, thereby maintaining consistency and integrity of patient data.

3. **Data Layer (Database and Storage):**

The data layer is responsible for securely storing and retrieving all medical information. It uses a **relational database management system (RDBMS)** such as

MySQL or PostgreSQL, chosen for their robustness and ability to enforce data integrity constraints.

I. **Patient Data:** Includes demographic details, medical history, prescriptions, and laboratory results.
II. **Provider Data:** Contains healthcare staff profiles, credentials, and activity logs.
III. **Access Logs:** Records every interaction with patient data to maintain accountability and compliance with data privacy regulations.
IV. Data security is reinforced through encryption at rest (AES-256) and in transit (SSL/TLS).

    Regular backups and redundancy protocols ensure data availability even during hardware failures.

3.5.3 System Components and Integration

Key architectural components include:

I. **Authentication and Authorization Module:** Manages secure user access through passwords and optional two-factor authentication.
II. **Health Record Management Module:** Controls data input, updates, and retrieval operations.
III. **Audit and Monitoring Module:** Tracks access history for compliance and generates usage reports.
IV. **Notification and Messaging Service:** Sends alerts about appointments, results, or system updates.

V. **Interoperability Interface (API Gateway):** Provides standardized RESTful APIs that allow integration with laboratory systems, pharmacies, and potentially national health databases.

The modular design enables each component to evolve independently. For instance, the authentication module can later be upgraded to use biometric verification without altering the database or interface layers.

3.5.4 Security and Performance Considerations

Security forms the backbone of this architecture. Beyond encryption and access control, the system uses data anonymization for research or analytics access, secure session tokens for API transactions, and automatic logout for inactive sessions.

Performance optimization is achieved through caching mechanisms, load balancing, and asynchronous request handling, ensuring the system can scale efficiently as user numbers grow.

3.5.5 Architectural Diagram

The figure (to be inserted) illustrates the three-tier architecture, showing clear interactions between patients, providers, administrators, the web server (application layer), and the centralized database (data layer). Arrows indicate bidirectional communication and secure data flow between components.

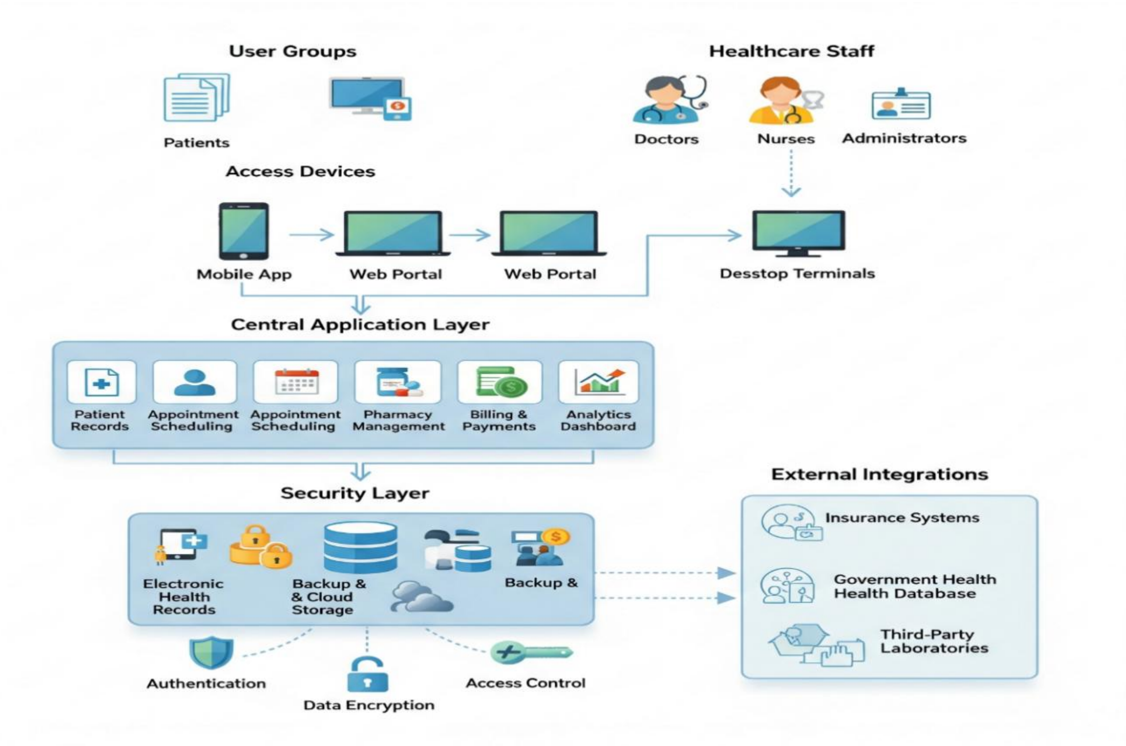


Figure 3.1: System Architecture

3.6 Proposed System Design

The proposed Electronic Health Record (EHR) system is designed as a web-based application that centralizes patient medical data across multiple hospitals, clinics, and laboratories in Nigeria. The architecture follows a modular, layered design to ensure scalability, security, and interoperability. This modular structure allows different healthcare facilities to contribute and retrieve patient information while preserving patient privacy and maintaining consistency in data formats.

At the core of the system is a centralized relational database that securely stores patient demographic details, medical history, laboratory results, prescriptions, and clinical notes. This database is accessed via a middleware layer, which provides standardized APIs (Application Programming Interfaces) to ensure smooth integration between the EHR platform and external systems such as laboratory information systems, pharmacy management systems, and diagnostic tools.

The user interface layer is designed to be intuitive and lightweight, focusing on usability for healthcare workers with varying levels of digital literacy. It consists of role-based dashboards:

I. **Patients** can register, log in, and view their medical history, while also controlling access rights to their records.
II. **Healthcare providers** can retrieve, update, and add new patient medical information.
III. **System administrators** can manage user accounts, monitor access logs, and enforce security protocols.

Security is reinforced through two-factor authentication, role-based access control, and encryption of patient data both in transit and at rest. By adopting a cloud-enabled hybrid architecture, the system supports both online and offline access, ensuring continuity of care in rural areas with limited internet connectivity.

The architecture is flexible enough to support future enhancements such as mobile integration, telemedicine, and predictive analytics. This ensures that the system not only addresses the immediate problem of fragmented health records but also lays the groundwork for long-term digital health transformation in Nigeria.

3.7 System Design Tools

In developing the proposed Electronic Health Record (EHR) Management System, two primary system design tools were employed to effectively model and represent the system's structure and interactions, Use Case Modeling and Class Diagram.

The Use Case Model was utilized to illustrate the various actors (such as patients, healthcare providers, and administrators) and their interactions with the system, capturing the functional requirements and user goals in a clear and structured form.

The Class Diagram, on the other hand, represents the static structure of the system by defining its main classes, their attributes, methods, and relationships. It provides a blueprint for the object-oriented design of the EHR system, showing how data and functionalities are organized and how different entities interact within the application architecture.

Together, these tools ensure a comprehensive understanding of both the behavioural and structural aspects of the system before implementation.

3.7.1 Use Case Modelling

To better illustrate the functionality of the proposed system, Use Case Modelling is employed to represent the interactions between external actors and the system. This modeling approach helps define the expected roles and responsibilities within the application, ensuring clarity in design and implementation as shown in figure 3.2 below.

3.7.2 Use Case Diagram

The Use Case Diagram models the key actors, Patients, Healthcare Providers, and System Administrators, and their corresponding system interactions. This representation ensures that all stakeholders can understand how the system operates without requiring technical knowledge of its internal workings.

1. **Patient Functions**
    a. **Register:** Create a secure patient profile with demographic and health background information.
    b. **Login:** Access the system through a secure authentication process.

c. **View Health Records:** Retrieve personal medical history, prescriptions, and laboratory results.

d. **Grant Data Access:** Provide explicit permission to healthcare providers to view sensitive medical information.

e. **Track Appointments:** View upcoming consultations or diagnostic schedules.

f. **Receive Notifications:** Get alerts about test results, prescription refills, or scheduled visits.

2. **Healthcare Provider Functions**

   a. **Login:** Authenticate into the system with professional credentials.

   b. **Retrieve Patient Records:** Search and access authorized patient records to support diagnosis and treatment.

   c. **Update Patient Records:** Modify existing entries such as prescriptions, diagnoses, or treatment progress.

   d. **Add New Medical Data:** Upload laboratory results, new diagnoses, or referral notes.

   e. **Generate Reports:** Produce patient summaries or treatment histories for clinical decision-making.

3. **System Administrator Functions**

   a. **Manage Users:** Create, update, or deactivate patient and provider accounts.

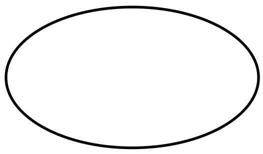
   b. **Monitor Data Access:** Track and log system activity to ensure compliance with privacy regulations.

   c. **Ensure System Security:** Enforce access controls, authentication methods, and data backup protocols.

   d. **Configure System Settings:** Adjust server parameters, performance settings, and system updates.

By organizing use cases under each actor, the system's structure emphasizes role-based access control and ensures that sensitive medical data is only handled by authorized users. The expanded use case list also highlights additional features, such as reporting and notifications, that increase the system's value for both patients and providers while aligning with Nigeria's healthcare needs.

Table 3.1 Use Case Notation and Description

Objects	Symbols	Description
Actors		Represents the external users who interact with the Healthcare Data Management System. Each actor performs specific roles: Patients manage personal data access, Providers handle clinical records, and Administrators maintain system control.
Use case		Defines specific services or tasks performed by the system in response to actor interactions. Each oval corresponds to a distinct function within the system.
System		Encapsulates all use cases, defining the scope of the EHR system. Everything inside this boundary represents internal system functions, while actors remain outside as external entities.
Relationship		Depicts direct interaction between an actor and a system function. For example, the Patient actor connects to *Register*, *View Health Records*, and *Grant Data Access*.

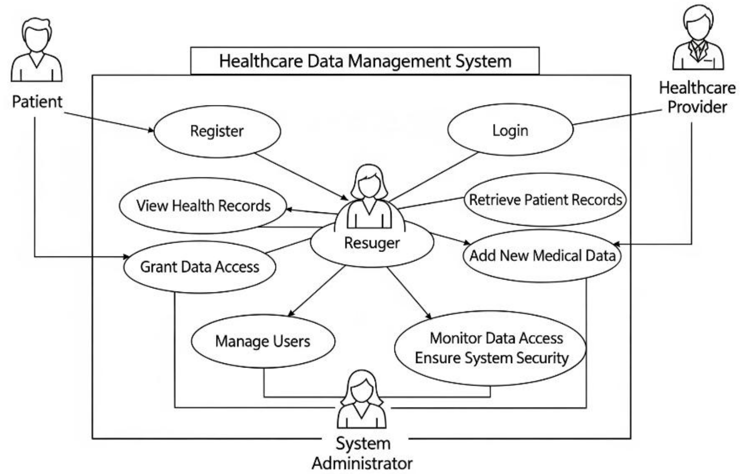


Figure 3.2: The Use-Case Diagram

3.7.3 Class Diagram

The Class Diagram is an essential component of object-oriented system design that provides a static structural view of the proposed Electronic Health Record (EHR) **syst**em. It describes the system's main classes, their attributes, operations (methods), and the relationships between them. Unlike the Use Case Diagram, which focuses on user interactions, the Class Diagram captures the underlying data architecture that supports those interactions as shown in figure 3.3 below.

In the proposed EHR system, the Class Diagram models how patient information, healthcare providers, medical records, and administrative controls are linked together to enable secure and efficient data management. This diagram serves as a **blueprint for database design** and guides developers in defining object relationships and system logic.

Key Classes and Their Descriptions:

1. **Patient Class**

    I. **Attributes:** Patient ID, Name, Date Of Birth, Gender, Contact Info, Medical History.

    II. **Methods:** Register(), Login(), View Health Records(), GrantAccess().

    III. **Description:** Represents the individual receiving healthcare. The patient has access to their medical data and can grant or revoke access to healthcare providers.

2. **Healthcare Provider Class**

    I. **Attributes:** Provider ID, Name, Specialization, Contact Info, Department.

    II. **Methods:** Login(), Retrieve Patient Records(), Update Patient Records(), Add New Data().

    III. **Description:** Represents the medical professional authorized to view and update patient health information based on granted permissions.

3. **Administrator Class**

    I. **Attributes:** Admin ID, Name, Role, Access Level.

    II. **Methods:** Manage Users(), Monitor Data Access(), Ensure Security().

    III. **Description:** Manages the system's operational integrity, overseeing user roles, data flow, and security compliance.

4. **Health Record Class**

   I. **Attributes:** Record ID, Patient ID, Diagnosis, Prescription, Lab Results, Date Created.
   II. **Methods:** Update Record(), Retrieve Record(), Delete Record().
   III. **Description:** Contains all relevant patient medical information that can be updated or retrieved by authorized users.

5. **Access Control Class**

   I. **Attributes:** Access-ID, User-ID, Permission Type, Time-stamp.
   II. **Methods:** Grant-Access(), Revoke-Access(), Log-Access().
   III. **Description:** Maintains and enforces access rights, ensuring that data privacy and security rules are upheld.

Relationships Between Classes can be clearly defined below:

1. The **Patient** class is associated with one or more **Health Record** instances (one-to-many relationship).
2. The **Health care Provider** class interacts with the **Health Record** class through authorized access (many-to-many relationship facilitated by the **Access Control** class).
3. The **Administrator** oversees all classes, maintaining system security and integrity.

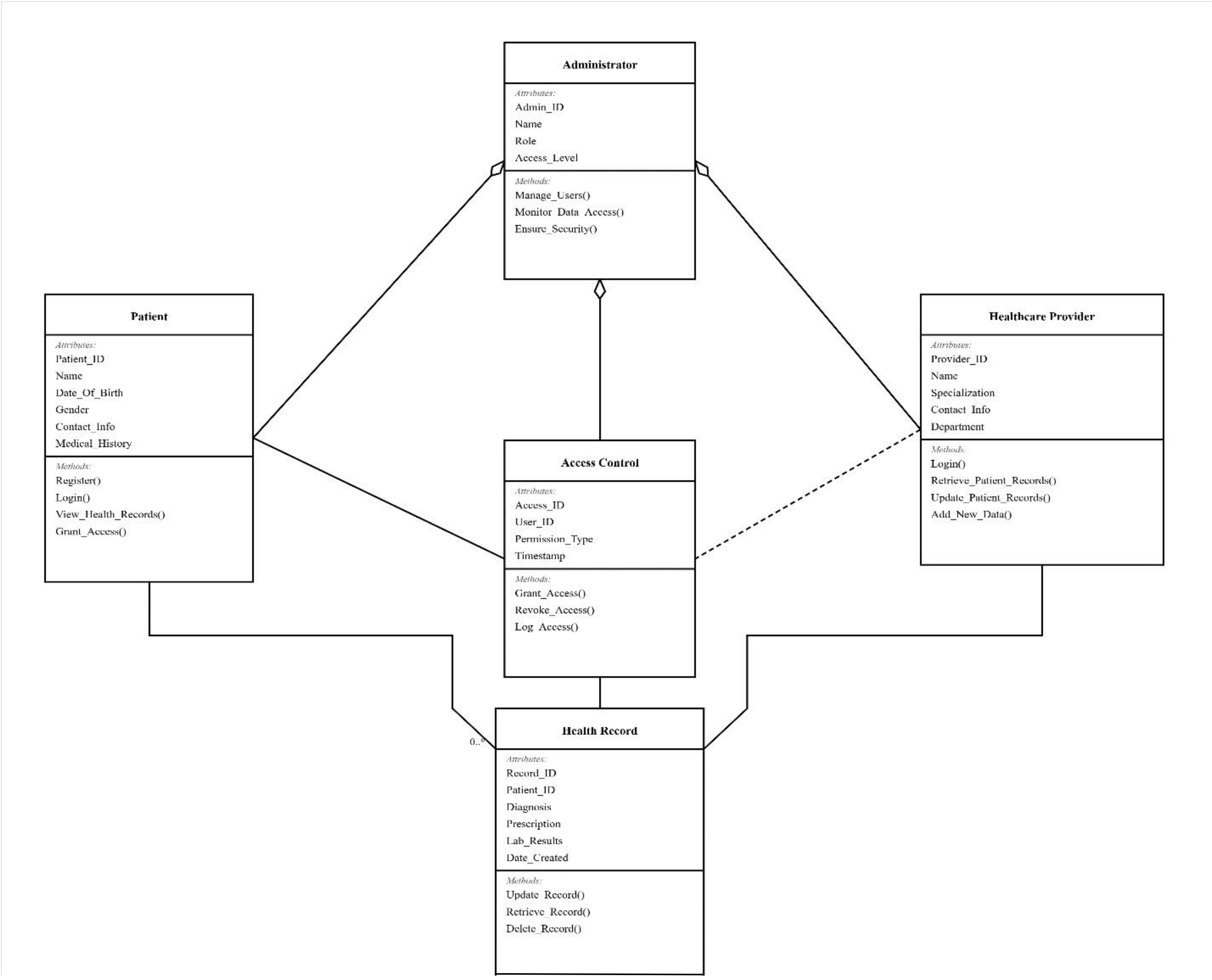
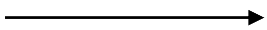


Figure 3.3: The Class Diagram Association

Table 3.2 Class Diagram Notation and Description

Objects	Symbols	Description
Class	Name Attributes Methods	Represents the blueprint defining objects' structure and behavior in the system
Association	.	Indicates a relationship or interaction between two classes.
Multiplicity	Numbers (e.g., 1..*, 0..1) near association lines.	Defines how many instances of a class relate to another (e.g., one patient can have multiple records).
Aggregation		Represents a whole part relationship where one class contains another but can exist independently
Dependency		Indicates that one class depends on another for its function or behavior.
Generalization		Represents inheritance where a subclass extends or specializes a parent class.

CHAPTER FOUR

SYSTEM IMPLEMENTATION

4.0 Introduction

This chapter discusses the implementation phase of the proposed Electronic Health Record (EHR) Management System, focusing on the technical and operational components required to deploy and test the prototype. The system was designed to demonstrate how medical data can be centralized and shared securely among healthcare providers while maintaining patient privacy and ensuring usability for all stakeholders.

Implementation involves the translation of design specifications into an operational prototype using appropriate software and hardware tools. It includes system setup, database configuration, user interface development, backend integration, and testing. The goal is to ensure that the system not only fulfills its functional requirements but also aligns with usability and performance standards.

The implementation stage also highlights the software and hardware resources necessary for developing the prototype, explains the testing procedures carried out to verify its accuracy and reliability, and describes how the application was deployed on a web environment for accessibility.

4.1 Hardware Requirements

The hardware requirements define the physical resources necessary for the development, testing, and demonstration of the proposed web-based Electronic Health Record (EHR) prototype. Because this project focuses on illustrating functionality rather than enterprise-scale deployment, the hardware demands are moderate and achievable with standard computing resources commonly available in academic or small healthcare settings as shown in Table 4.1 below.

The system is structured around a client–server model, where the server handles data storage and application logic, while the client serves as the user interface for patients, healthcare providers, and administrators.

For the server environment, a computer with at least an Intel Core i5 or equivalent processor, 8 GB of RAM, and 512 GB of SSD storage is recommended. These specifications ensure smooth handling of database operations, backend logic, and simultaneous user requests during testing. A stable internet connection (5 Mbps or higher) is also essential for managing requests between the client and server, particularly when demonstrating data retrieval and updates.

On the client side, lightweight configurations are sufficient since users will access the system through a web browser. A personal computer or laptop with an Intel Core i3 processor, 4 GB of RAM, and a modern browser (Chrome, Edge, or Firefox) provides optimal performance. The display should have a minimum resolution of 1366×768 pixels to ensure proper visibility of forms, dashboards, and medical records.

Additional supporting devices enhance usability during testing and demonstration—these include a printer for generating patient reports, an Uninterruptible Power Supply (UPS) to prevent data loss during power interruptions, and external storage drives for backup and transfer of mock data.

Overall, these hardware resources are both cost-effective and scalable, making them ideal for developing a prototype that mirrors real-world healthcare operations. The configuration ensures reliable performance, ease of demonstration, and adaptability for future expansion into a national-scale electronic health system

Component	Minimum Specification	Recommended Specification
Processor (CPU)	Dual-Core 2.0 GHz	Intel Core i5 2.4 GHz or higher
RAM	4 GB	8 GB
Storage	250 GB HDD	512 GB SSD
Display	1366 × 768	1920 × 1080 Full HD
Internet Connection	2 Mbps	5 Mbps or higher
Other Peripherals	Keyboard, Mouse, Web Browser	Same

Table 4.1: Hardware Requirement Specification

The system is cross-platform and can run on both Windows, Linux, and macOS. A stable internet connection is required for the frontend–backend communication and accessing the MongoDB database hosted either locally or on a cloud instance.

4.2 Software Requirements

The software requirements define all the digital tools, programming languages, frameworks, and supporting technologies necessary to develop, test, and run the Electronic Health Record (EHR) prototype. Since this project aims to demonstrate how patient medical data can be centralized and shared securely across hospitals, careful selection of reliable and compatible software is crucial. The software stack must support modular development, enable secure communication, and provide a smooth, intuitive user interface for both patients and healthcare providers. Open-source technologies were prioritized to ensure flexibility, affordability, and easy customization, while maintaining scalability for future integration into a nationwide healthcare system.

4.2.1 System Software

System software refers to the foundational programs and operating systems that support the functioning of both the development environment and the deployed prototype. For this EHR system, the Windows 11 Operating System was used as the primary platform for development and local testing. Windows offers a stable environment for software engineers due to its compatibility with modern development tools, integrated networking capabilities, and strong hardware support.

The Node.js runtime environment forms the backbone of the server-side system software, enabling the execution of JavaScript outside a browser. This allows asynchronous, event-driven programming, which is ideal for handling multiple healthcare data requests concurrently. In combination with Express.js, Node.js ensures fast, lightweight, and reliable communication between the client and server.

The MongoDB Database Engine serves as the database management software. It stores patient data in a NoSQL format, which is highly flexible and efficient for unstructured medical records. MongoDB's document-based model supports dynamic schema evolution — allowing patient records to grow and adapt without complex database migrations. The MongoDB Atlas Cloud **Service** enhances data security and reliability by providing automated backups and multi-region accessibility.

The Vercel Hosting Platform was used as the deployment environment. Vercel is optimized for web applications built with React.js and Node.js, offering continuous integration (CI) and automatic scaling features. This ensures that the system can handle multiple users simultaneously without compromising performance or uptime.

Together, these system software components form the foundation on which the EHR prototype operates, ensuring reliability, security, and responsiveness across various computing environments.

4.2.2 Development Tools and Frameworks

Development tools and frameworks are the technologies used to design, code, test, and deploy the EHR prototype. These tools ensure consistency, maintainability, and scalability throughout the software lifecycle, this tools are clearly shown in Table 4.2 below. Examples of the areas where these tools are utilized are:

1. **Frontend:**
    a. React.js – For building dynamic and reusable user interfaces.
    b. Tailwind CSS – For rapid styling and consistent responsive layouts.
2. **Backend:**
    a. Node.js & Express.js – For managing server logic and API routes.
    b. JWT Authentication – For secure access control across user roles.
3. **Database:**
    a. MongoDB (via Mongoose) – For storing patient records, provider data, and access logs.
    b. MongoDB Atlas (optional) – For hosting a cloud instance of the database.
4. **Development Environment:**
    a. Visual Studio Code (VS Code) – For coding and debugging.
    b. Postman – For API testing and verification.
5. **Deployment and Version Control:**
    a. Vercel / Render – For web deployment and hosting.
    b. Git & GitHub – For version control and collaborative tracking.

Category	Tool/Framework	Purpose and Description
Integrated Development Environment (IDE)	**Visual Studio Code (VS Code)**	Used as the main coding environment for writing and debugging source code. It provides extensions for JavaScript, React, and Node.js integration, as well as Git version control.
Frontend Framework	**React.js**	Enables the development of dynamic, responsive, and modular user interfaces. React's component-based architecture simplifies interface updates and supports real-time data rendering for patients and providers.
Styling Framework	**Tailwind CSS**	Used for efficient UI design through utility-first classes. It ensures a professional, mobile-responsive layout suitable for healthcare applications.
Backend Framework	**Express.js**	A minimalist Node.js framework that manages routes, APIs, and middleware for secure communication between the client and database.
Database Management System	**MongoDB**	Serves as the primary database for storing medical records and user data. Its flexibility accommodates diverse healthcare data structures.
API Testing Tool	**Postman**	Used for testing backend endpoints, verifying data transfer accuracy, and ensuring that all routes perform as expected.

Category	Tool/Framework	Purpose and Description
Version Control System	**Git & GitHub**	Used to manage code versions, track changes, and collaborate efficiently during development. GitHub served as the remote repository for the project.
Deployment Platform	**Vercel**	Used to host the prototype online, allowing remote access for patients, healthcare providers, and system administrators.

Table 4.2 Development Tools and Functions

These tools and frameworks were carefully chosen to reflect the project's emphasis on simplicity, efficiency, and scalability. Each component integrates seamlessly with the others, creating a cohesive development ecosystem that supports the EHR prototype from coding to deployment.

4.3 System Testing

System testing is a critical phase of software development that ensures the entire system functions as intended before deployment. For this Electronic Health Record (EHR) prototype, testing focused on validating core functionalities such as patient registration, record retrieval, authentication, and role-based access. The goal was to confirm that all system components—frontend, backend, and database,interact seamlessly and produce accurate results under normal and exceptional conditions.

The testing process followed a systematic approach, incorporating unit testing, integration testing, and system validation testing. Automated and manual methods were combined to ensure comprehensive coverage of the system's logic, interface, and user experience.

4.3.1 Objectives of System Testing

The primary objective of system testing is to validate that the developed Electronic Health Record (EHR) prototype meets its design and functional requirements. Testing ensures that every component, from data input to output display, works cohesively in the real-world context of Nigeria's healthcare environment. The objectives of system testing for this EHR prototype include:

1. **Verification of Functional Requirements:** Ensuring that the system performs all the operations defined in its specifications, such as patient registration, login authentication, and record management.
2. **Validation of System Behavior:** Confirming that the EHR responds correctly to both valid and invalid user inputs.
3. **Usability Testing:** Ensuring the system is user-friendly, accessible, and intuitive for healthcare workers with varied digital literacy.
4. **Performance Assurance:** Testing how the system behaves under different loads and network conditions.
5. **Security Validation:** Verifying that access control, authentication, and encryption mechanisms protect sensitive patient data effectively.

4.3.2 Testing Strategy

The testing strategy adopted a black-box testing approach, focusing on system behavior rather than internal code logic. This was complemented by white-box testing in select backend modules, particularly during API and database validation.

(a) Unit Testing

Unit testing involves testing individual components or modules of the EHR prototype to ensure that each performs as intended in isolation. Mock data was used to ensure that all inputs and outputs conformed to defined expectations. Each unit was tested independently before integration. This process ensures early detection of coding errors, helping to reduce integration issues and improve overall system stability. Tools such as Jest and React Testing Library were used to automate and validate the results of key frontend and backend functions. This phase focuses on the smallest testable parts of the system, such as:

I. Patient registration form
II. Authentication functions
III. CRUD (Create, Read, Update, Delete) operations for health records

(b) Integration Testing

Integration testing follows unit testing and validates the interaction between multiple modules within the system. It ensures that when individual components are combined, they function as a cohesive whole. In this project, integration testing covered interactions, For example:

I. The login module was linked to the database authentication system.
II. The patient profile module retrieved records correctly after authentication.
III. Healthcare provider and admin functionalities were tested to ensure role-based separation of privileges.

This testing phase confirms data consistency, proper flow between the user interface and backend, and the correctness of API responses under typical and edge-case scenarios.

(c) System Testing

System testing was performed on the entire deployed prototype to validate end-to-end functionality. The tests were conducted through the user interfaces (patient, provider, and admin dashboards) to ensure all features operated correctly under simulated real-world conditions.

(d) Acceptance Testing

A group of 10 test users, including simulated patients, healthcare providers, and system administrators, evaluated the system using predefined scenarios. Their feedback was used to assess usability, response time, and intuitiveness.

4.3.3 Test Environment Setup

The test environment setup establishes a controlled and simulated space where the developed system can be thoroughly evaluated before being deployed in a real-world setting. It replicates the operational conditions of the live system by incorporating similar software, hardware, and network configurations. The primary goal is to detect and correct potential issues such as bugs, compatibility conflicts, or performance bottlenecks in a stable, repeatable environment without disrupting actual operations.

This environment provides a reliable platform for testing all modules of the Electronic Health Record (EHR) system as shown in *Table 4.3*, both individually and as an integrated whole. It supports assessments of functional accuracy, data security, and user interactions under realistic conditions, including varied user roles, data inputs, and network responses. By closely mirroring real-world scenarios, the test environment ensures that the prototype meets its performance, reliability, and usability expectations before moving to full-scale implementation or public demonstration.

Component	Description
Operating System	Windows 11 (64-bit)
Server-Runtime Environment	Node.js (v18.x)
Database	MongoDB (local and Atlas cloud)
Frontend Environment	React.js served via localhost:3000
Browser Used for Testing	Google Chrome, Mozilla Firefox
Testing Tools	Postman (API Testing), Jest (Unit Testing), Browser Developer Console
Network Condition	5 Mbps Broadband Connection

Table 4.3: Test Environment Setup

4.3.5 Usability and User Feedback Testing

Usability and user feedback testing is a critical stage in validating the system's real-world performance and ensuring that its functions align with user expectations. Rather than relying solely on technical testing, this phase emphasizes functional behavior and user interaction within the Electronic Health Record (EHR) prototype. The objective is to confirm that each module performs the intended function accurately, efficiently, and intuitively, particularly for healthcare providers and patients with varying levels of digital literacy.

To achieve this, **functional test cases** were created to assess each feature of the system. Each test case specifies a unique function (e.g., login authentication, patient data retrieval, or record update), the expected outcome, and the actual result obtained during testing. These test cases serve as a benchmark to verify that every operation in the system, from user login to data management, behaves as designed and meets usability standards.

During testing, participants including system administrators, healthcare providers, and test users interacted with the prototype under controlled conditions. Their actions and feedback were recorded to measure the accuracy of outputs, ease of navigation, and satisfaction with the interface layout. This process helped identify areas needing refinement, such as form validation, response time, and clarity of user instructions.

The results from the **functional test case Table 4.3,** provides insights into system performance, ensuring that the EHR prototype meets its usability goals while maintaining technical accuracy and operational stability

Test Case ID	**Functionality Tested**	**Expected Result**	**Outcome**
TC001	Patient Registration	User account created successfully and stored in database	Passed
TC002	Patient Login	Valid credentials grant access; invalid credentials return error message	Passed
TC003	Record Retrieval	Patient records fetched accurately based on user ID	Passed
TC004	Record Update	Authorized provider can modify patient data; unauthorized cannot	Passed
TC005	Admin User Management	Admin can create, view, and deactivate accounts	Passed

Test Case ID	Functionality Tested	Expected Result	Outcome
TC006	Data Security	Passwords encrypted, no plain-text storage	Passed
TC007	Role-Based Access	Each role (patient, provider, admin) restricted to its privileges	Passed
TC008	Network Disruption Recovery	System displays offline warning and retries connection	Passed
TC009	Log-Out Function	User session terminated correctly	Passed

Table 4.3 Functional Test Case

4.4 System Implementation

System implementation represents the process of translating the system design into a fully functional prototype. For this EHR system, the implementation phase involved developing the frontend user interfaces, backend server logic, and database connectivity. The goal was to create a seamless flow between patients, healthcare providers, and administrators while ensuring data integrity, usability, and security. The system follows a **three-tier architecture,** frontend, backend, and database, each developed using lightweight, modern technologies. Implementation also involved hosting and deployment to a live testing environment, allowing remote access and evaluation. Maintenance and version control were handled using Git and GitHub to track changes and ensure consistency across builds.

4.4.1 System Setup

The system setup involved installing and configuring the necessary development tools and frameworks required for running the application. The setup process also included configuring environment variables for secure database connections, defining API routes, and preparing the project directory structure for both client (frontend) and server (backend) operations. Once configured, the development server was started to allow real-time testing of all modules through the browser. The development environment was prepared using:

I. Node.js (v18) and npm for backend dependency management.
II. VS Code as the IDE for integrated development.
III. Git for version tracking.
IV. MongoDB installed locally for testing.

4.4.2 Frontend Implementation

The frontend of the EHR system was developed using **React.js**, chosen for its efficiency in building responsive and modular interfaces. The user interface was designed with **Tailwind CSS**, which simplified styling and ensured consistent design across devices. Separate dashboards were implemented for patients, healthcare providers, and administrators. Key functionalities such as form submissions, record viewing, and role-based navigation were handled through React components. **Axios** was used to make API calls between the frontend and backend. The frontend was designed to be lightweight, accessible, and easy to use, particularly for healthcare workers with varying levels of technical proficiency. These Dashboards are:

I. LoginPage.js – Handles user authentication and role-based redirects.
II. PatientDashboard.js – Displays medical history and access controls.
III. ProviderDashboard.js – Allows providers to update or create new patient records.
IV. AdminDashboard.js – Displays user accounts, roles, and logs.

4.4.3 Backend Implementation

The backend was implemented using **Node.js** with the **Express.js** framework, providing a robust and scalable environment for handling data processing and API management. It serves as the middle layer that processes client requests, communicates with the database, and returns appropriate responses. The backend includes routes for authentication, record management, and access control. **JSON Web Tokens (JWT)** were implemented to manage secure user sessions and protect sensitive endpoints as shown in *Table 4.4*. Error handling and input validation were incorporated to ensure data integrity, while middleware functions managed authentication and request logging. The backend structure allows for easy modification and scalability in future updates. The Express.js backend manages all server-side logic, authentication, and data exchange with MongoDB.

Endpoint	**Functionality**
/api/auth/login	Handles login for all users.
/api/patients/:id	Retrieves patient data and medical records.
/api/records/add	Allows providers to add new health records.
/api/admin/users	Enables administrators to view or remove users.

Table 4.4: Main API Endpoints

4.4.4 Database Implementation

The database layer was built using **MongoDB**, a NoSQL database chosen for its flexibility and scalability. The MongoDB's document-oriented design allows efficient storage of varying patient details and medical histories without rigid schemas. Data relationships were handled using Mongoose schemas to maintain consistency. For enhanced security, sensitive data such as passwords were hashed using **bcrypt,** and access logs were created to monitor activities across roles. Backup and restore scripts were configured to ensure data durability during system updates or network failures. . The system's core collections for storing relevant structured and unstructured data include:

I. patients
II. providers
III. admins
IV. health_records
V. audit_logs

4.4.5 Deployment

The deployment phase involved hosting the EHR prototype on **Vercel,** a modern platform optimized for React and Node.js applications. This made the system publicly accessible for testing and demonstration purposes. The deployment pipeline was integrated with **GitHub**, allowing continuous deployment whenever updates were pushed to the main branch. Environment variables were configured securely through Vercel's settings to manage API keys and database connections. The deployed system replicates the local development environment, providing a realistic demonstration of how the prototype could function in production, including real-time data interactions and user management. The system was hosted using:

I. **Backend:** Render (Node.js hosting)
II. **Frontend:** Vercel
III. **Database:** MongoDB Atlas (Cloud)

The deployment ensured that the system could be accessed publicly for testing, with API endpoints secured through HTTPS.

4.4.6 Maintenance

System maintenance is essential to ensure the EHR prototype remains stable, secure, and easy to update. It was managed using **Git**, allowing the development team to track changes, revert faulty updates, and collaborate effectively. Regular commits documented system progress, while branches were used for developing new features without disrupting the main build. Maintenance activities included debugging, patching security vulnerabilities, optimizing system performance, and refining user interface elements based on feedback. This continuous improvement process ensures that the system remains adaptable and sustainable, providing a reliable foundation for future scalability and integration into national e-health infrastructure. GitHub was used for version control with feature-based branching:

I. main branch for stable releases.

II. dev branch for testing new features.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATION

5.0 Summary

This study focused on the design and development of a web-based Electronic Health Record (EHR) system aimed at addressing the inefficiencies and fragmentation prevalent in Nigeria's healthcare data management practices. The research was motivated by the challenges identified in Chapter Two, such as the dominance of paper-based records, lack of interoperability, data redundancy, and poor patient data security.

The study began with an in-depth analysis of the existing healthcare information management system which was shown clearly in Chapter Three, revealing operational constraints such as manual record-keeping, limited access to patient histories, and security vulnerabilities. These challenges highlighted the urgent need for a centralized and secure data management solution.

Subsequently, a proposed system architecture and design was introduced. The design followed a modular, three-tier structure consisting of presentation, application, and data layers. Functional modelling using UML tools, specifically Use Case and Class Diagrams, helped illustrate user interactions, data flow, and system relationships between core entities such as patients, healthcare providers, and administrators.

Implementation (Chapter Four) was carried out using modern web technologies including HTML, CSS, JavaScript, React JS, and Tailwind CSS, supported by backend technologies and relational databases for structured data management. System testing ensured that all modules operated efficiently and that the intended objectives, such as secure access control, interoperability, and user-friendliness, were met.

Ultimately, the project demonstrated that a well-designed EHR system can significantly improve healthcare delivery efficiency, enhance data accessibility, and strengthen patient–provider communication, thus setting a digital foundation for Nigeria's evolving healthcare infrastructure.

5.1 Conclusion

The successful development and evaluation of this prototype confirm that digital transformation in healthcare is both achievable and beneficial within Nigerian when guided by user-centered design and scalable architecture. The proposed EHR system effectively addresses the limitations of traditional record management by integrating patient data into a unified, secure, and interoperable digital environment.

Through automation and role-based access control, the system enhances data accuracy, operational efficiency, and information security. Furthermore, the use of web-based technologies ensures accessibility across various devices and locations, promoting nationwide healthcare connectivity.

Beyond its technical success, the study underscores the importance of stakeholder inclusion—patients, healthcare professionals, and administrators—during the design and deployment phases. Their active participation fosters acceptance and ensures that the system aligns with real-world workflows.

In conclusion, this project not only delivers a functional prototype but also presents a scalable model that can serve as a foundation for national health information exchange. With appropriate policy backing, infrastructure investment, and user training, the system can transform how healthcare data is managed and shared across Nigeria.

5.2 Recommendations

Based on the findings and outcomes of this study, the following recommendations are proposed:

1. **Government and Institutional Adoption:**
   The Federal Ministry of Health should champion the adoption of standardized EHR systems across healthcare facilities, beginning with pilot programs in tertiary hospitals and expanding nationwide.
2. **Infrastructure Improvement:**
   Adequate investments should be made in ICT infrastructure, particularly reliable internet access and power supply, to ensure stable system performance across urban and rural healthcare centres.
3. **Data Governance and Privacy Regulation:**
   Strong enforcement of data protection laws such as the Nigeria Data Protection Act (NDPA, 2023) is essential to safeguard patient information, ensure accountability, and foster public trust.
4. **Capacity Building and Training:**
   Healthcare workers should receive continuous digital literacy training to enhance system adoption and minimize user resistance.
5. **Integration with National Health Insurance and Telemedicine Systems:** The EHR platform should be gradually integrated with other national digital health initiatives to streamline claims processing, enhance telemedicine services, and support analytics-driven policymaking.
6. **Future Research and Development:**
   Further studies should explore the incorporation of Artificial Intelligence (AI) and

predictive analytics into the EHR framework to support disease trend monitoring and personalized care recommendations.

By implementing these recommendations, Nigeria can move closer to achieving a cohesive, data-driven, and patient-centered healthcare system that aligns with international digital health standards.

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