

J-Care: A Cloud-Based Health Information System and Clinical Data Repository for Sustainable Healthcare Delivery in Jigawa State

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Abstract

This paper proposed J-Care, a cloud-based health information system and clinical data repository for sustainable healthcare delivery in Jigawa State. The main contribution of this work is the provision of a software-as-a-service (SaaS) solution for documenting patients' interactions and effective management and exchange of clinical information, care coordination, decision support, data consolidation, and healthcare access to rural and hard-to-reach communities in Jigawa State. This is achieved by employing a microservices architectural style to create multiple independent healthcare services to enable faster development cycles, easier deployment, and the ability to scale specific services independently based on demand. To evaluate the proposed J-Care, a comparative evaluation method was used to assess the proposed system with equivalent systems based on criteria such as delivery platform (cloud or on-premise), client app (iOS app, android app, desktop web app), software features (clinical workflow, document management, lab integration). It is found that the proposed system is better in terms of clinical workflow, appointment management, referrals, reporting, and analytics. Moreover, J-Care has the potential to improve access to accurate health data records, reduce mortality rates, improve disease surveillance, and the overall well-being of Jigawa State citizens.

Keywords: Clinical Data Repository; CDR; Health Information System; HIS; Cloud-based systems; Telemedicine; Jigawa State

1. Introduction

Jigawa State is one of the 36 states in Nigeria, located in the northwestern part of the country. It was created on August 27, 1991, when it was carved out of the old Kano State. The residents of Jigawa State are predominantly of Hausa or Fulani background. The economy of Jigawa State is largely dependent on agriculture. The state's semi-arid climate poses challenges, leading to outward migration of workers to neighbouring states in search of off-

season work. However, the state enjoys vast fertile arable land and grazing lands suitable for livestock production (Tudunwada & Abbas, 2022). Since its creation, Jigawa State has made significant progress in various sectors. The state government has invested in infrastructure development, education, healthcare, agriculture, and industrialization. Efforts have been made to improve agricultural productivity, especially in the areas of irrigation and mechanized farming. The Gumel Dam, Tiga Dam, and Hadejia-Nguru Wetlands are important water resources in the state. However, Jigawa State has faced challenges such as deforestation and desertification, periodic flooding, and most importantly lack of access to efficient and quality healthcare services (Andersen et al., 2022; Shittu et al., 2020).

The desire to provide patients with the best care possible and discover the best platform for decision-making necessitates the advancement of the medical systems (Hamoud et al., 2018). However, the availability and access to quality healthcare services in Jigawa State have been one of the major bottlenecks which are aggravated by a lack of supporting infrastructure and adequate manpower since the number of trained health personnel needed to provide support services to the state's growing population is not sufficient. Before the advent of digital and electronic devices in healthcare centers or hospitals, a paper-based method of collecting and storing clinical data was adopted (Adeniran et al., 2022; Muhammad & Garba, 2019). However, with the large volume of data to be collected as well as the security and privacy concerns, among others, exposed the inefficiency of the paper-based method, as a result, there is a need to develop a better way to collect and particularly store this large volume of data for easy accessibility and management while uploading the security and privacy requirements of the data (Pham et al., 2018).

Cloud-based health information systems (CHIS) have emerged as a promising solution for improving healthcare delivery and outcomes in many countries (Garai et al., 2019; Mahajan et al., 2023; Pham et al., 2018). Unlike other health information systems such as Standalone EHR, CHIS, has the potential to revolutionize healthcare delivery by providing secure, scalable, and cost-effective solutions for managing patient data and facilitating communication and collaboration between healthcare providers anywhere and anytime.

The idea is based on a software-as-a-service (SaaS) solution for documenting patients' interactions and effective management and exchange of clinical information coupled with a patient-centered database that is updated in real-time and arranged to support quick and easy retrieval of clinical data (Dhaka et al., 2021; Ogwel et al., 2020). This system can especially benefit Jigawa State through care coordination, decision support, data consolidation, and healthcare access to rural and hard-to-reach communities. The remainder of the paper is organized as follows: In section II, the related works are analyzed. In section III, the methodology and J-Care overview is presented. In section IV, a comparative evaluation is presented. Finally, the conclusions and future recommendations are given in section V.

2. Related Works

Over time, an extensive literature has developed on Electronic Health/Medical Records (EHR); their acceptability, and their benefits. To investigate users' acceptability of Electronic Health Record System (EHRS), several empirical studies have been conducted (Alipour, 2013; Asiri et al., 2014; Gagnon et al., 2014; Noor et al., 2012; Wilkins, 2009). Most of these researchers applied the exploratory method to identify the determinants of intention to use the EHR (Gagnon et al., 2014), organizational and professional factors (Asiri et al., 2014), and governmental policies (Noor et al., 2012). For example, Gagnon et al., (2014) assess the EHR acceptance by healthcare professionals given that it's an essential condition to ensure that the expected benefits will materialize.

Table 1 below shows the cloud-based solutions in terms of architecture, algorithms, policies, models, frameworks, etc proposed by various authors and some of the open research issues in the existing research studies towards cloud-based health information systems for sustainable healthcare delivery.

Table 1: Comparison of Cloud-Based CDR/HIS Solutions

Reference	Cloud-based HIS	Contribution	Open Issues
(Manyazewal et al., 2021)	Yes	Digital health technologies that enable access to health innovations	Lacks health data standardization, and lack of clear governance frameworks for cloud-based HIS and experimental analysis.
(Pham et al., 2018)	Yes	Cloud-based smart home environment (CoSHE) for impaired/old Humans	Lacks of interoperability and integration/federation for seamless exchange of health data.
(Oh et al., 2019)	Yes	Smart Cloud-based health information systems (cHIS) for small and medium size hospital	Disparate/independent HIS with fragmented data silos, low interoperability, and suboptimal care coordination.
(Seham, 2017)	Yes	Cloud Solutions in healthcare service to solve the complexity of hospital information systems	Overlook Smart and green features and lack of impact assessment on clinical outcomes and patient satisfaction.
(Satar et al., 2021)	Yes	Cloud-based secured healthcare Framework for Privacy and Integrity of health and medical data	Lacks health data shareability among healthcare service providers which hinders the seamless exchange of patient data
(Ali et al., 2018)	Yes	Prospective cloud-based Healthcare Classification Framework	Lacks robust security measures needed to enable data sharing across multiple systems and protect sensitive patient data from unauthorized access.
(Idoga et al., 2018)	Yes	Cloud-based health system model (CBHSM) with data security	Overlooked healthcare professionals, greenness, workflow integration, and energy efficiency.
(Masana & Muriithi, 2019)	Yes	Integrated Cloud-based electronic record system	Lack of security solutions, collaboration, compliance with healthcare regulations & data sharing in the model.

Collectively, important concepts in the field of safeguarding and protecting patient information include data lifecycle, default privacy, proactive privacy, location of privacy, and privacy-embedded guarantees that the full lifespan of confidential data is managed privately and ethically (Chenthara et al., 2019; Fan et al., 2018; Semantha et al., 2020; Sivan & Zukarnain, 2021). The phases that patient's information undergoes between formation to deletion are referred to as the data lifecycle. The idea of default privacy is to include privacy safeguards in services and systems from the beginning. In other words, users shouldn't need to consciously choose to preserve their privacy (Hathaliya & Tanwar, 2020; Kubo et al., 2019; Yin et al., 2018).

One of the difficulties of achieving e-Health services is digital literacy which may impinge the implementation and utilization or the intended social benefit of e-Health in Nigeria (George *et al* 2013). The level of digital literacy in the country is a source of concern for the realization of e-health in Nigeria. There have been calls, especially at the UN level for developing countries to develop frameworks for the utilization of ICT in the health sector. One such call was 2009 Annual Ministerial Briefing of the ECOSOC. Rodrigues and Risk estimate the global demand for telehealth services as far back as 2003 to \$1.25 trillion (Rodrigues & Risk, 2003). This is because e-health solutions or packages it is arguably evolved to provide answers to diverse health system management problems as well as the health care and services demand across jurisdictions (Rodrigues & Risk, 2003).

CDR has been implemented based on several approaches such as a template relational mapping (TRM) archetype-drive approach used in (Min et al., 2016) where results indicated that this implementation is feasible against clinical practices and supports the characteristics of adaptability and user-involved. A DSpace approach was utilized by (Ohmann et al., 2020) to develop a demonstrator repository where results obtained showed that it performed well in terms of handling sensitive personal data, such as that from clinical trials, with 14 requirements met (74%), including support for metadata and identifiers. Oracle 10g was utilized in (Farooqui & Mehra, 2018) for the implementation of a proposed database model for a medical information system that would support decision-making.

Several tools have been proposed and developed in the literature that can be utilized for clinical data management, particularly in the area of improved data querying. For instance, a patient-screening tool was developed by (Li et al., 2021) based on EHRs for clinical research using OpenEHR to solve the issue of concept mismatch and improve the overall query performance. Results obtained showed that 589 medical concepts were found in 500 random sentences of which only 513 concepts could be represented. The BMI Investigator (BMII) tool was proposed by (Mullin et al., 2018) to query structured, unstructured, genomic, and image data contained in a data warehouse.

3. Methodology and J-Care Overview

The architectural style used to implement the system is microservices in which the application is composed of multiple small services, each running in its process and communicating with each other through lightweight protocols, typically over a network. Each microservice is responsible for a specific business capability and can be developed, deployed, and scaled independently of other services. This modular approach allows for better flexibility, scalability, and maintainability of the overall system as shown in Figure 1.

Microservices communicate with each other using well-defined APIs, often through lightweight protocols such as HTTP/REST or messaging systems like RabbitMQ or Apache Kafka. They can be developed using different programming languages, frameworks, and technologies, as long as they adhere to the agreed-upon communication protocols. One of the key benefits of microservice architecture is its ability to promote autonomy and decentralized decision-making. Each microservice team can work independently and make technology choices that best suit their service's requirements. This enables faster development cycles, easier deployment, and the ability to scale specific services independently based on demand.

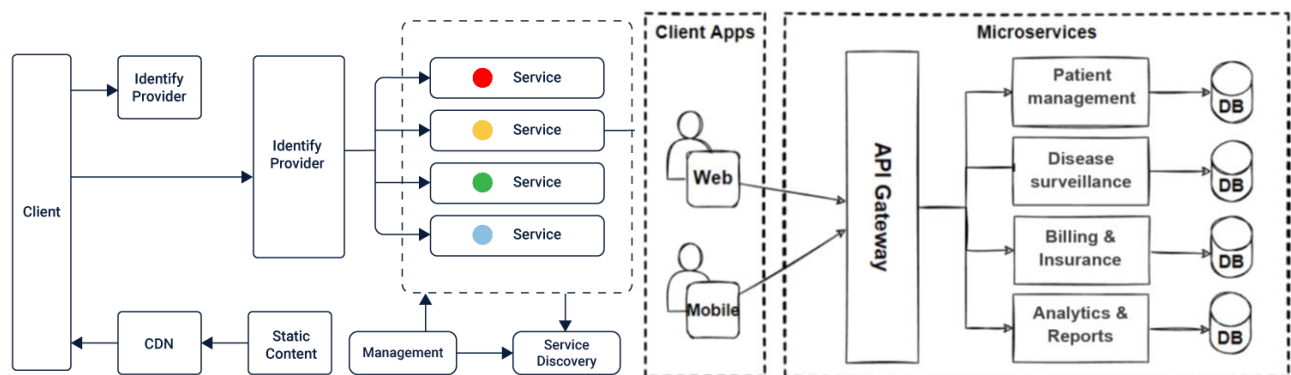


Figure 1: Microservices architectural style (Dragoni et al., 2017; Garba, 2019)

These proposed systems consist of several components such as Cloud Infrastructure, Data Storage, Data Exchange and Interoperability, Security and Privacy, Application and Services, Integration and API Management, Analytics and Reporting, Compliance and Regulatory Considerations. These components work together to provide a secure, scalable, and interoperable health information system that supports various healthcare functions and facilitates data exchange within the healthcare ecosystem as shown in Figure 2. The role of each component is discussed below.

1. **Cloud Infrastructure:** The physical and virtual resources provided by the cloud service provider, including servers, storage, and networks.
2. **Data Storage:** Secure and scalable storage for storing health-related data, such as patient records, medical images, and lab results.
3. **Data Exchange and Interoperability:** Protocols and standards for seamless exchange of patient information between different healthcare providers and systems.
4. **Security and Privacy:** Robust measures to protect patient data, including encryption, access controls, and intrusion detection systems.
5. **Application and Services:** Software applications and services that support healthcare functions, such as electronic health records (EHR), clinical decision support systems, and patient portals.
6. **Integration and API Management:** Middleware and tools for integrating with other healthcare systems and managing application programming interfaces (APIs).
7. **Analytics and Reporting:** Utilizing the cloud's processing power for advanced analytics, data mining, and generating insights from healthcare data.
8. **Compliance and Regulatory Considerations:** Ensuring compliance with healthcare regulations, such as HIPAA or GDPR, and implementing safeguards for data protection.

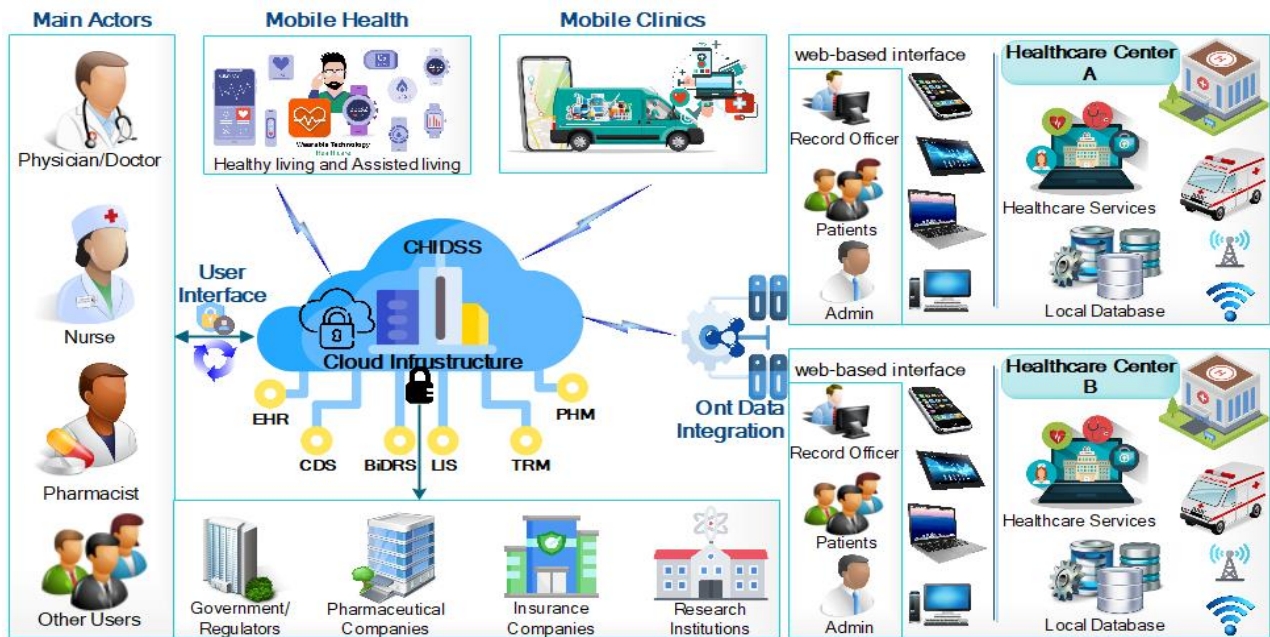


Figure 2: Proposed Conceptual Framework for the J-Care System

The proposed cloud-based health information system and clinical data repository for sustainable healthcare delivery in Jigawa State provide a wide range of functions/services such as clinical decision support (CDS), population health management (PHM), electronic health records (EHRs), and telehealth and remote monitoring (TRM) systems, laboratory information system (LIS). The system is designed for easy integration with various operations, such as Patients’ Diagnoses, Medications, Medical Examinations, Laboratory Tests, Clearance, Admission, Discharge, and Referrals among others as shown in Figure 3. This will allow patients to book appointments, manage prescriptions, and contact Physicians and other medical practitioners with ease.

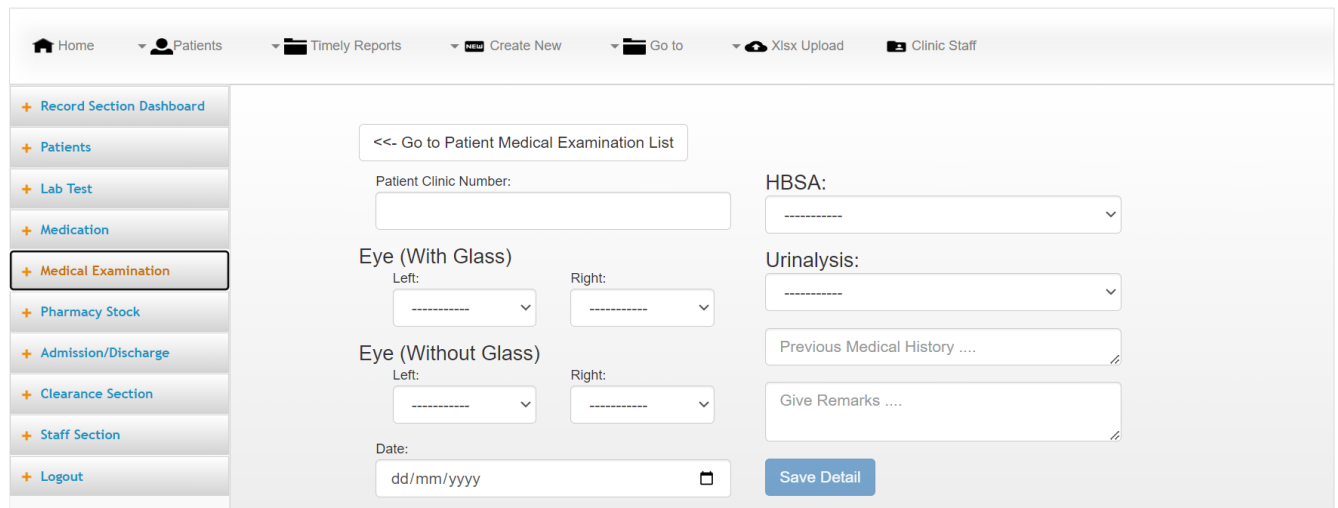


Figure 3: Medical examination microservice in the J-care system

Furthermore, mobile health is integrated for real-time monitoring of infants and the elderly. The system is equipped with an SMS gateway interface that sends reminders to patients about the schedule of activities, drugs/prescriptions, and appointment reminders. The proposed system is designed to allow designated Record Officers (RO) and Medical Administrator (MA) at different healthcare centers to have secured access to up-to-date patients’ clinical records. Moreover, the solution will allow government regulators, pharmaceutical companies, insurance companies, and research institutions limited access on a need-to-need basis or when necessary. The solution will permit cloud-based connection among health centers, as well as mobile clinics for improved health care delivery in Jigawa State.

4. Comparative Evaluation

The comparative evaluation methodology is a systematic approach used to assess and compare software solutions based on predefined criteria. This process typically starts with defining the evaluation criteria, which are the key factors and requirements that the software must meet. The criteria for this evaluation include delivery platform (cloud or on-premise), client app (iOS app, android app, desktop web app), software features (appointment management, clinical workflow, document management, insurance and claims, lab integration, medical templates, patient history, patient portal, referrals, reporting and analytics, scheduling, e-prescription).

This comparative evaluation only considered three comparable HIS and CDR published in peer-reviewed journals that were written in English Language only and were published between 2018 to 2023 as shown in Table 2. These systems are therefore rated based on the stated criteria to objectively compare the strengths and weaknesses of the selected systems against the proposed system.

Table 2: Comparative Evaluation of Cloud-Based CDR/HIS Solutions & J-Care

Criteria/Reference	HealthFog (Tuli et al., 2020)	CoSHE (Pham et al., 2018)	MCC (Eneyew et al., 2019)	J-Care (This Work)
Delivery Platform				
Cloud	✓	✓	✓	✓
on-premise	✗	✗	✗	✓
Client App				
iOS app,	✓	✓	✓	✓
android app,	✓	✓	✓	✓
desktop web app	✓	✓	✓	✓
Software features				

Criteria/Reference	HealthFog (Tuli et al., 2020)	CoSHE (Pham et al., 2018)	MCC (Eneyew et al., 2019)	J-Care (This Work)
appointment management	✓	✗	✗	✓
clinical workflow	✗	✗	✗	✓
document management	✓	✗	✓	✓
insurance and claims	✗	✗	✗	✗
lab integration	✓	✓	✓	✓
medical templates	✗	✗	✗	✓
patient history	✓	✓	✓	✓
patient portal	✗	✗	✗	✗
Referrals	✓	✗	✗	✓
Scheduling	✓	✓	✗	✓
e-prescription	✓	✓	✓	✓
reporting and analytics	✓	✗	✗	✓

Overall, the comparative evaluation shows that J-Care is better in terms of clinical workflow, appointment management, referrals, reporting, and analytics. The provision of analytics and reporting mechanisms can facilitate the prediction since clinical data can be easily harvested from the repository. Compared with HealthFog, CoSHE, and MCC, J-Care has the potential to revolutionize healthcare delivery by providing secure, scalable, and cost-effective solutions for managing patient data and facilitating communication and collaboration between healthcare providers anywhere and anytime in Jigawa State. Moreover, J-Care has the potential to provide an equitable and sustainable strategy for healthcare delivery, thereby, improving access to quality healthcare, access to accurate health data records, reducing mortality rates, improving life expectancy, disease surveillance for national planning, and overall well-being of Jigawa State and the country in general.

5. Conclusion

Cloud-based innovations can effectively address the geographical constraints, and resource limitations, thereby significantly, expanding healthcare access to the entire population in Jigawa State. This paper proposed J-Care, a cloud-based health information system and clinical data repository for sustainable healthcare delivery in Jigawa State. A microservices architectural style is used to create multiple independent healthcare services to enable faster development cycles, easier deployment, and the ability to scale specific services independently based on demand. After comparative evaluation, the result shows that J-Care is better in terms of clinical workflow, appointment management, referrals, reporting, and analytics. J-Care offers numerous benefits, ranging from preserving patients' medical records for follow-up care and prescriptions to enabling the development of intelligent models that can predict and potentially mitigate serious health conditions. Future research will be devoted to exploring and assess the security and privacy in Cloud-Based HIS, interoperability and data integration of Cloud-based HIS, sustainability of Cloud-based HIS, and finally Bi-directional Referral System.

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