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Healthcare with a Smart Biomedical App

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Abstract

The "RFID-Based Quick Registration and Biometric Recognition System" is an advanced, technology-driven initiative designed to address critical challenges in patient registration, data management, and healthcare service delivery, particularly in resource-constrained regions like Nepal. This innovative system integrates RFID (Radio-Frequency Identification) technology with biometric authentication to create a seamless, secure, and efficient process for patient identification and data retrieval. When a patient's RFID card is scanned, their complete medical history, personal details, and treatment records are instantly accessed from a centralized, cloud-based database, enabling healthcare providers across Nepal to retrieve critical information in real-time, regardless of geographic location. The inclusion of biometric recognition ensures robust security, safeguarding sensitive patient data against unauthorized access and ensuring compliance with privacy regulations. In rural areas of Nepal, where healthcare infrastructure is often limited, this system holds immense significance by reducing the dependency on manual record-keeping, minimizing errors, and significantly cutting down patient waiting times. It also facilitates better coordination among healthcare facilities, enabling timely diagnosis and treatment, especially for patients referred from remote areas to urban centers. Furthermore, the system supports telemedicine initiatives, allowing healthcare professionals in rural clinics to consult with specialists in urban hospitals by providing instant access to patient data. By streamlining administrative processes, improving data accuracy, and enhancing inter-hospital communication, this project aims to bridge the gap between urban and rural healthcare services, promote equitable access to medical care, and lay the foundation for a modern, interconnected healthcare ecosystem in Nepal. Its implementation has the potential to transform healthcare delivery, improve patient outcomes, and contribute to the overall development of the nation's healthcare infrastructure.

Keywords: RFID, Biometric Authentication, Cloud Computing, Telemedicine, Healthcare Digitization, Patient Data Security

1. Introduction

In today's digital era, healthcare needs a transformative approach that integrates technology with medical services. A smart biomedical app can serve as a comprehensive solution for managing patient data, predicting diseases, and connecting healthcare professionals efficiently. This document explores an innovative biomedical app that acts as a common database for all patients, incorporating AI-driven disease detection, hospital and doctor directories, and additional smart features to enhance healthcare services.

2. Literature Review

Shinde et al. conducted a systematic literature review exploring the integration of blockchain technology to enhance the security and trustworthiness of AI-based healthcare systems. Their findings suggest that blockchain can address challenges such as data integrity, transparency, and adversarial attacks, thereby improving the reliability of diagnostic systems. (Rucha Shinde, 2023)

Zekiye and Özkasap proposed a decentralized healthcare system that combines federated learning with blockchain technology. This approach enables privacy-preserving, decentralized AI training by allowing multiple healthcare institutions to collaboratively train models without sharing sensitive patient data, thus maintaining data privacy and security. (Abdulrezzak Zekiye, 2023)

Shahsavari et al. provided a comprehensive guide on integrating blockchain with federated learning to support personalized medicine. Their work emphasizes preserving data ownership and security, highlighting how this integration can facilitate secure, personalized healthcare solutions without compromising patient privacy. (Shahsavari, 2024)

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Solaiman and Awad proposed reliable MedIoT architectures that integrate blockchain and AI to ensure real-time data trust and dependable decision-making in healthcare. Their research addresses challenges in trust and dependability within Medical Internet of Things applications, offering solutions to enhance the reliability of healthcare delivery systems. (Ellis Solaiman, 2021)

Verma and Patel (2022) created a multimodal verification system using both fingerprint and RFID for hospital patient registration. This system enhances the accuracy and security of patient identification, streamlining the registration process in healthcare facilities. (Verma, 2023)

McGhin et al. (2019) conducted a comprehensive review of blockchain applications in healthcare, highlighting its potential to enhance data integrity, authentication, and decentralized storage. Their study emphasizes blockchain's ability to securely manage electronic health records (EHRs), facilitate interoperability among healthcare providers, and address privacy concerns through cryptographic mechanisms. (Thomas McGhin, 2019)

3. Objective of the Research

i. To implement an RFID and biometric-based patient registration system that enables secure, real-time access to medical records across healthcare facilities in Nepal, with a particular emphasis on improving service delivery in rural areas.
ii. To integrate a blockchain-secured cloud database to ensure data integrity and privacy, facilitating seamless interoperability among healthcare providers and supporting telemedicine initiatives.

4. Features of Biomedical App

1. Unified Patient Database

The app functions as a centralized medical database where all patient histories, including medical reports, prescriptions, allergies, and past diagnoses, are securely stored. Patients and authorized medical professionals can access this data anytime, reducing redundant paperwork and ensuring better treatment plans.

2. AI-Powered Disease Prediction & Analysis

The app functions as a centralized medical database where all patient histories, including medical reports, prescriptions, allergies, and past diagnoses, are securely stored. Patients and authorized medical professionals can access this data anytime, reducing redundant paperwork and ensuring better treatment plans.

3. Hospital & Doctor Directory with Treatment History

Patients can easily locate hospitals, clinics, and doctors they have previously consulted. This directory ensures seamless follow-ups and allows healthcare providers to review past treatments, improving continuity of care.

4. RFID-Based Quick Registration and Biometric Recognition System

The "RFID-Based Quick Registration and Biometric Recognition System" is an advanced, technology-driven initiative designed to address critical challenges in patient registration, data management, and healthcare service delivery, particularly in resource-constrained regions like Nepal. This innovative system integrates RFID (Radio-Frequency Identification) technology with biometric authentication to create a seamless, secure, and efficient process for patient identification and data retrieval. When a patient’s RFID card is scanned, their complete medical history, personal details, and treatment records are instantly accessed from a centralized, cloud-based database, enabling healthcare providers across Nepal to retrieve critical information in real-time, regardless of geographic location. The inclusion of biometric recognition ensures robust security, safeguarding sensitive patient data against unauthorized access and ensuring compliance with privacy regulations. In rural areas of Nepal, where healthcare infrastructure is often limited, this system holds immense significance by reducing the dependency on

manual record-keeping, minimizing errors, and significantly cutting down patient waiting times. It also facilitates better coordination among healthcare facilities, enabling timely diagnosis and treatment, especially for patients referred from remote areas to urban centers. Furthermore, the system supports telemedicine initiatives, allowing healthcare professionals in rural clinics to consult with specialists in urban hospitals by providing instant access to patient data. By streamlining administrative processes, improving data accuracy, and enhancing inter-hospital communication, this project aims to bridge the gap between urban and rural healthcare services, promote equitable access to medical care, and lay the foundation for a modern, interconnected healthcare ecosystem in Nepal. Its implementation has the potential to transform healthcare delivery, improve patient outcomes, and contribute to the overall development of the nation's healthcare infrastructure.

5. Blockchain Integration for Data Privacy and Security

Blockchain technology provides a secure and tamper-proof solution for managing sensitive medical data in smart healthcare systems. Using a private blockchain with tools like Ganache and smart contracts, patients retain control over access to their records, including medical history, prescriptions, and reports. Each record is stored in a dedicated block with a unique cryptographic hash to ensure integrity and prevent tampering. Smart contracts automate consent management, granting access only to authorized providers. This decentralized approach enhances privacy, ensures accurate sharing of Electronic Health Records (EHRs), eliminates third-party reliance, and strengthens protection against cyber threats. (Thomas McGhin, 2019).

Figure 1. Example of blocks mined reflected on Ganache

5. Research Framework

5.1. Methodology

The system uses RFID cards and fingerprint scanners to quickly identify patients and access their medical records. For hardware, each patient receives a unique RFID card containing their identification number, while fingerprint sensors (like the R305 capacitive scanner) capture biometric data for secure authentication. These components connect to a microcontroller (Arduino or ESP-32) that verifies identities by cross-referencing data with a central cloud database. When a patient scans their RFID card or fingerprint at a hospital, the system instantly retrieves their complete medical history, including past treatments, allergies, and test results.

A mobile/app interface allows doctors to view this information in real-time through tablets or computers. The app displays the patient's current treatment plan, prescribed medications, and the name of the referring physician. For example, if a rural clinic refers a patient to a specialist in another hospital, both doctors can access updated records through the system, ensuring continuity of care. Patients can also use the app to check which doctor they're scheduled to visit next and review previous consultations.

The system automatically updates the "current doctor" information whenever a new referral occurs, with RFID tracking confirming physician-patient interactions during hospital visits. All data transfers through encrypted channels, with blockchain technology ensuring record integrity and preventing unauthorized edits to medical histories. This combination of physical hardware and digital tracking creates a seamless workflow for managing patient care across multiple healthcare providers.

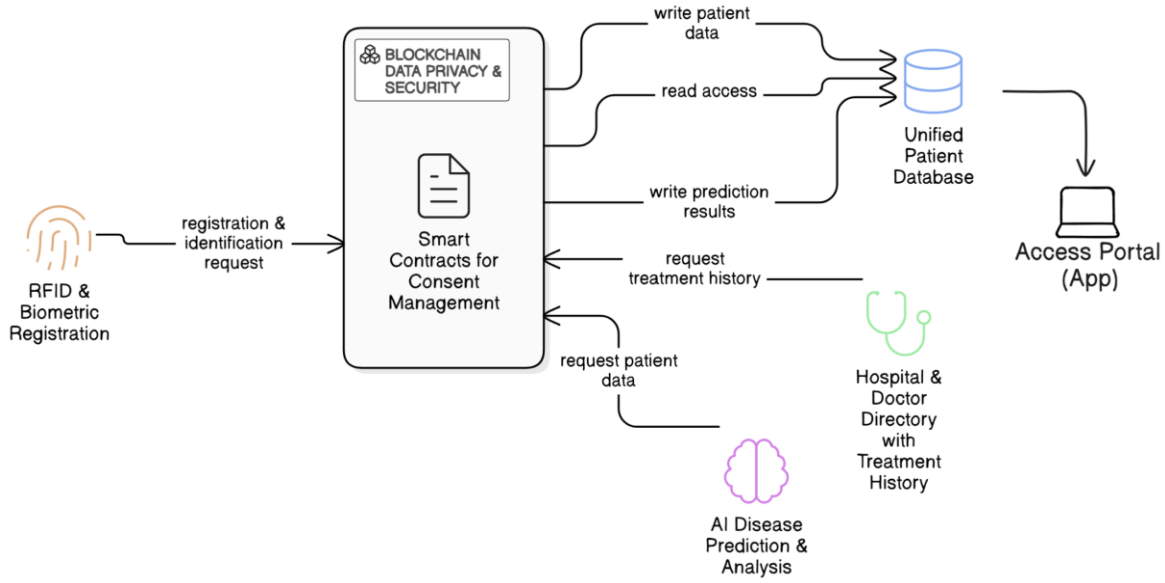

Figure 2. Block Diagram

5.2. Technological Stack

i. **Hardware:** Arduino, ESP-32, RFID reader, fingerprint sensor
ii. **Software:** Flutter (App UI), MongoDB (Database), AI model (under testing)
iii. **Blockchain:** Smart Contracts, Ganache (Local Blockchain Framework), Hash Generation, Patient Data Blocks, App Login Integration (via Smart Contract Authorization)

5.3. Data flow:

a. **Input:** RFID card scan + fingerprint
b. **Processing:** Authentication + AI-based diagnostics
c. **Output:** Patient info retrieval + disease prediction + treatment tracking

6. Modules

i. RFID-based registration
ii. Fingerprint-based secure authentication
iii. Cloud-based centralized medical database
iv. AI diagnostic engine
v. Blockchain-enabled consent and data audit trail
vi. Hospital/doctor directory and patient interaction logs

7. Testing & Validation

i. Functional testing on RFID and fingerprint modules
ii. Database connectivity with real-time access simulation
iii. Security simulation with unauthorized access attempts
iv. User feedback from pilot tests in rural clinics (planned)

8. Tests for databases

Here are the list of tests done for the test of the database of the app with the use of RFID and Fingerprint sensors.

Table 1. RFID sensor test with the database

Test Case ID	Test Description	Expected Result	Actual Result	Status (Pass/Fail)
RFID-01	Scan valid RFID card	Patient data retrieved successfully	Recognized RFID cards and tags were successful in downloading the data.	Pass
RFID-02	Scan invalid RFID card	Access denied	Various RFID cards from the university's ID were tested and unidentified ID did not allow access.	Pass
RFID-03	Scan RFID card with expired data	Alert: Card expired	Date and time of validity was allocated for individual ID and the test was done.	Pass
RFID-04	Scan RFID card with network issue	Error: Database connection failed	The localized server was not able to test the status of network	Fail
RFID-05	Multiple scans in a short time	System handles input correctly	The race time error occurred and the card reading showed the data only on basis of first come first save.	Fail

Table 2. Fingerprint Test with the Database

Test Case ID	Test Description	Expected Result	Actual Result	Status (Pass/Fail)
FP-01	Register new fingerprint	Fingerprint saved in database	The CRUD operations and testing were a success.	Pass
FP-02	Authenticate valid fingerprint	User identified successfully	The page was loaded and downloadable data were made available.	Pass
FP-03	Authenticate invalid fingerprint	Access denied	Invalid fingerprint gave a message of contacting the operator	Pass
FP-04	Authenticate partial fingerprint	Error: Incomplete scan	The page access was denied.	Pass
FP-05	System under multiple fingerprint scans	System handles input correctly	The optical fingerprints were not available and capacitive scanner gave race time error.	Fail

9. Observation and System Design

The system design and development involve creating a cloud-based database to store patient medical history, treatment records, and biometric data while integrating RFID technology for quick patient identification and seamless access to medical records. Additionally, biometric recognition enhances security and prevents unauthorized access. The AI model implementation focuses on training algorithms with medical datasets to detect potential diseases based on patient history and diagnostic images, incorporating machine learning for predictive analytics to assist doctors in early disease detection. To ensure interoperability and data security, blockchain technology is utilized for secure, tamper-proof storage of patient records, along with encryption techniques to protect sensitive medical information from breaches. Deployment in healthcare facilities includes conducting pilot programs in urban hospitals and rural clinics to assess feasibility, providing training for healthcare professionals, and establishing partnerships with hospitals, clinics, and government health agencies for widespread adoption. Finally, performance evaluation and optimization involve gathering user feedback from medical practitioners and patients to enhance system efficiency, monitoring system performance, AI prediction accuracy, and registration response times, and continuously updating the system with improved features based on real-world usage data.

The tested portal was designed using flutter and the testing was done with mongodb database. The image processing and identification aspects are still under the test in the design.

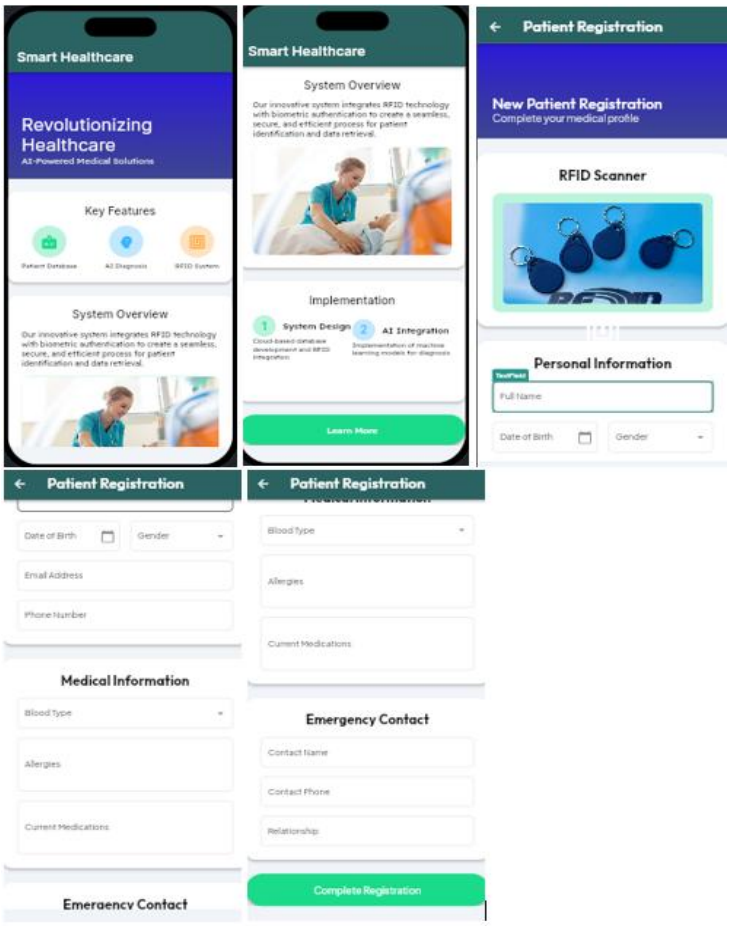

Figure 3. Developed Software

The compact hardware unit integrates fingerprint sensor and RFID technologies for rapid patient registration and identification. It features an RFID card reader for quick data retrieval and a biometric scanner for secure authentication. The device connects to a central database (cloud-based) via a secure connection. We tested with arduino and ESP-32 for the project. Its small form factor makes it portable and suitable for various healthcare settings, including remote clinics. The hardware is designed for durability and ease of use, minimizing maintenance requirements.

10. Conclusion

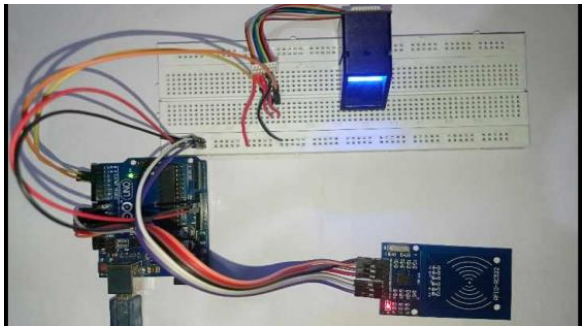

Figure 4. Hardware Design

In conclusion, the integration of RFID and biometric technologies within a smart biomedical application presents a viable solution to the challenges faced by Nepal's healthcare system, particularly in rural areas. By facilitating quick patient registration and secure, real-time access to medical records, the system enhances the efficiency and effectiveness of healthcare delivery. The incorporation of blockchain technology further ensures the integrity and privacy of patient data, fostering trust among users. While initial tests indicate promising

results, addressing the identified shortcomings, such as network reliability and handling of concurrent inputs, is essential. Future work will focus on refining these aspects and expanding the system's capabilities to include comprehensive AI-driven diagnostics, thereby contributing to the modernization and accessibility of healthcare services in Nepal.

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