Digital Health Recrd Management System for Migrant Workers

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DOI: https://doi.org/10.51583/IJLTEMAS.2026.150300085

Received: 29 March 2026; Accepted: 03 April 2026; Published: 17 April 2026

ABSTRACT

Migrant workers face significant challenges in maintaining continuous and accessible healthcare records due to frequent relocation, limited infrastructure, and reliance on paper-based systems. These issues often lead to loss of medical history, repeated diagnostic procedures, increased healthcare costs, and delays in treatment. Existing digital healthcare solutions, including cloud-based and blockchain-based systems, are often unsuitable for low-resource environments due to their dependence on continuous internet connectivity, high implementation cost, and complex infrastructure requirements.

This paper proposes a Digital Health Record Management System based on a client-first architecture that enables offline data storage and retrieval directly on the user's device. The system integrates QR-based identification for instant access to patient records, multilingual support for improved usability, and lightweight data management techniques suitable for low-resource settings. Unlike traditional systems, the proposed approach eliminates dependency on centralized servers and provides a portable and cost-effective solution tailored for migrant populations.

Experimental evaluation using a simulated dataset demonstrates that the system reduces data retrieval time from approximately 15–20 seconds to 2–3 seconds, achieving an improvement of nearly 70–80%. Additionally, the system ensures 100% offline accessibility and minimizes the risk of data loss associated with physical records. Usability testing indicates improved efficiency, faster navigation, and ease of use for non-technical users.

The proposed system highlights the potential of client-side digital healthcare solutions in improving accessibility, efficiency, and continuity of care in underserved environments. It also provides a scalable foundation for future enhancements, including cloud integration, advanced security mechanisms, and healthcare interoperability standards.

Keywords—Digital Health Records, Migrant Workers, Offline System, QR Code, Client-First Architecture, Healthcare Accessibility

INTRODUCTION

Healthcare systems worldwide are rapidly transitioning toward digital platforms to improve efficiency, accessibility, and quality of care. However, a significant segment of the population—particularly migrant workers—continues to face challenges in accessing consistent and reliable healthcare services. Due to frequent relocation in search of employment, migrant workers often experience fragmented medical histories, lack of continuity in treatment, and limited access to healthcare infrastructure.

One of the major issues faced by migrant populations is the absence of a reliable system for maintaining and

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue III, March 2026

transferring medical records across different locations. Traditional paper-based records are highly vulnerable to loss, damage, and inaccessibility during migration. This often leads to repeated diagnostic procedures, incorrect medical decisions, increased healthcare costs, and delays in treatment. Furthermore, many rural and low-resource environments lack the infrastructure required to support advanced digital healthcare systems.

Existing solutions such as cloud-based Electronic Health Record (EHR) systems, blockchain-based healthcare frameworks, and mobile health applications have attempted to address these challenges. While these systems offer advantages such as scalability, security, and remote accessibility, they also suffer from critical limitations, including dependence on continuous internet connectivity, high implementation costs, complex infrastructure requirements, and limited adaptability in resource-constrained environments.

These limitations create a significant research gap for a lightweight, cost-effective, and offline-capable healthcare record management system that can function efficiently in low-resource settings. Addressing this gap is essential to ensure equitable healthcare access for migrant populations and to improve continuity of care.

To overcome these challenges, this paper proposes a Digital Health Record Management System based on a client-first architecture. The system enables healthcare data to be stored and managed directly on the user's device, eliminating dependence on centralized servers and continuous internet connectivity. It integrates QR-based identification for instant retrieval of medical records, multilingual interfaces for improved usability, and lightweight data management techniques suitable for low-resource environments.

The novelty of the proposed system lies in its combination of offline-first functionality, client-side data processing, and QR-based portable identity, making it uniquely suitable for migrant workers operating in low-infrastructure environments.

The main contributions of this paper are as follows:

- Design of a client-first healthcare record management system with offline capability
- Integration of QR-based identification for fast and reliable data access
- Development of a lightweight and cost-effective solution tailored for low-resource environments
- Implementation of a multilingual interface to improve accessibility for diverse users
- Performance evaluation demonstrating improved efficiency compared to traditional systems

Related Work

The management of healthcare records has been widely studied using various technologies, including blockchain, cloud computing, mobile health applications, and interoperable electronic health record systems. While each approach offers distinct advantages, their applicability in low-resource environments, particularly for migrant workers, remains limited.

Blockchain-Based Healthcare Systems

Blockchain technology has been extensively explored for secure and decentralized healthcare record management. Mehta and Agarwal (2024) proposed a blockchain-based system utilizing smart contracts to enable secure data sharing among healthcare providers. Similarly, Gupta and Sharma (2024) emphasized blockchain's ability to ensure data integrity and tamper-proof storage.

Despite these advantages, blockchain-based systems suffer from high computational overhead, complex implementation, and significant infrastructure requirements. These limitations make them unsuitable for low-resource environments with limited technical support.

Cloud-Based Healthcare Systems

Cloud computing enables scalable and centralized healthcare data storage. Singh and Verma (2023) developed a cloud-based e-health system for remote data access, while Khan and Das (2023) proposed an IoT-enabled

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cloud monitoring system for real-time health tracking.

However, cloud-based systems depend on continuous internet connectivity and third-party infrastructure. This dependency poses challenges in rural and low-connectivity areas where migrant workers often reside.

Mobile Health (mHealth) Applications

Mobile health (mHealth) applications provide portable healthcare solutions through smartphones. Reddy and Nair (2022) developed an AI-based mobile healthcare monitoring system, while other studies highlight the usability and accessibility of mobile platforms.

Nevertheless, mHealth applications face issues such as data privacy concerns, lack of standardization, and reliance on smartphones and internet connectivity. Additionally, low digital literacy among migrant populations further limits their effectiveness.

Interoperable Electronic Health Record (EHR) Systems

Interoperable EHR systems utilize standards such as HL7 and FHIR to enable seamless data exchange across healthcare platforms. Patel and Roy (2021) demonstrated improved coordination between healthcare providers using standardized EHR systems. Although these systems enhance interoperability and data consistency, they require strict compliance, high implementation costs, and advanced infrastructure. As a result, they are typically limited to large healthcare institutions and are not feasible for low-resource environments.

Smart Card-Based Systems

Smart card-based healthcare systems store patient data on physical cards, enabling portability and offline access. Sharma and Gupta (2020) proposed RFID-based smart card systems for efficient data retrieval. sHowever, these systems are associated with risks such as card loss, limited storage capacity, and dependence on card-reading devices.

Comparative Analysis

The comparison of existing systems highlights their strengths and limitations in the context of migrant worker environments:

System Type	Key Advantage	Major Limitation	Suitability
Blockchain	High Security	High Cost & Complexity	Low
Cloud-Based	Remote Access	Requires Internet	Low
mHealth	Portability	Privacy & Connectivity Issues	Medium
EHR Systems	Interoperability	Expensive Infrastructure	Low
Smart Cards	Offline Access	Physical Dependency	Medium
Proposed System	Offline + QR + Low Cost	Limited Storage	High

Research Gap

From the above analysis, it is evident that existing healthcare record systems fail to address the combined requirements of offline functionality, low infrastructure dependency, high portability, and ease of use for non-technical users. Most existing solutions are either too complex, internet-dependent, or costly, making them unsuitable for migrant worker environments.

Contribution of Proposed Work

To address these limitations, the proposed system introduces a client-first architecture combined with QR-based identification and offline data management. This approach ensures low-cost deployment, high accessibility, and efficient performance in resource-constrained environments, thereby bridging the identified research gap.

PROPOSED METHODOLOGY

System Overview

The proposed Digital Health Record Management System is designed using a client-first architecture, where all major operations, including data processing, storage, and retrieval, are performed on the user's device. This approach minimizes dependency on centralized servers and ensures offline functionality, making the system suitable for low-resource environments.

The system is modular, scalable, and optimized for fast data access and ease of use. It integrates QR-based identification, lightweight storage mechanisms, and basic encryption techniques to ensure secure and efficient healthcare data management.

Design Objectives

The primary objectives of the proposed system are:

- To provide portable and accessible healthcare records
- To enable offline data storage and retrieval
- To ensure fast and efficient data access using QR codes
- To maintain data privacy and integrity
- To design a low-cost and user-friendly solution

System Model

The system can be represented as a function:

$F(U,D,Q) \rightarrow R$

Where:

U=User input (personal and medical data)

D=Data storage (local storage)

Q=QR-based identification

R=Retrieved healthcare record

Workflow:

1. User inputs data (U)
2. Data is validated and encrypted
3. Stored locally (D)
4. QR code (Q) is generated
5. On scan → system retrieves record (R)

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Functional Modules

Worker Registration Module

This module collects and stores user information.

Steps:

1. Input personal details
2. Validate data
3. Encrypt sensitive fields
4. Store in local storage
5. Generate unique ID

Medical Visit Tracking Module

Maintains patient medical history.

Functions:

- Record diagnosis
- Store prescriptions
- Track follow-up dates

Document Management Module

Handles medical documents.

Process:
File Upload → Convert to Base64 → Store → Retrieve

QR Code Module

Provides fast access to records.

Algorithm:

1. Generate QR using Worker ID
2. Scan QR via camera
3. Extract ID
4. Fetch corresponding data
5. Display profile

Doctor Dashboard

Allows healthcare providers to:

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- Search patient records
- View medical history
- Update visit details

Admin Module

Handles system-level operations:

- Monitor usage
- Manage data
- Maintain logs

Data Flow Process

The system follows a structured data pipeline:

input → Validation → Encryption → Storage → Retrieval → Decryption → Output

This ensures data consistency, security, and efficient access.

Security Model

The system implements an enhanced security framework to ensure data confidentiality and integrity. Advanced encryption techniques such as AES-256 (Advanced Encryption Standard) are used to secure sensitive healthcare data stored on the client device. Additionally, SHA-256 hashing is applied to maintain data integrity and prevent unauthorized modifications.

Access control mechanisms are incorporated to restrict unauthorized access to patient records. QR-based identification enables secure and fast retrieval without exposing sensitive information.

Security Function:

$$S(D) = Enc(D) + Hash(D)$$

Where Enc(D) ensures confidentiality and Hash(D) ensures integrity.

Algorithm for Data Retrieval

Step 1: Scan QR Code

Step 2: Extract Worker ID

Step 3: Search in local storage

Step 4: Verify data integrity

Step 5: Decrypt data

Step 6: Display output

Design Justification

The client-first architecture is chosen to eliminate dependency on internet connectivity and centralized systems. QR-based identification reduces retrieval time and simplifies access. Local storage ensures fast performance, while modular design enhances system flexibility and scalability.

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Advantages of Proposed Methodology

- Works in offline environments
- Reduces data retrieval time
- Requires minimal infrastructure
- Easy to use for non-technical users
- Cost-effective and portable

Limitations

- Limited storage capacity
- Device dependency
- Limited scalability for large-scale deployment
- Dependency on local device/browser environment

System Architecture

Overview

The proposed Digital Health Record Management System is designed using a client-first layered architecture, where the majority of system operations—including data processing, storage, and retrieval—are performed on the client side (web browser). This architectural approach ensures high performance, offline functionality, and minimal dependency on external infrastructure, making it highly suitable for low-resource environments.

The system is modular and divided into multiple functional layers, each responsible for specific operations. These layers interact seamlessly to ensure efficient data flow, enhanced security, and improved usability.

Architecture Diagram

The overall system architecture is illustrated in Fig 2.

Advantages of the Architecture:

- Enables complete offline functionality
- Reduces dependency on centralized servers
- Ensures faster data processing using client-side execution
- Provides a lightweight and cost-effective solution
- Enhances usability for low-resource environments

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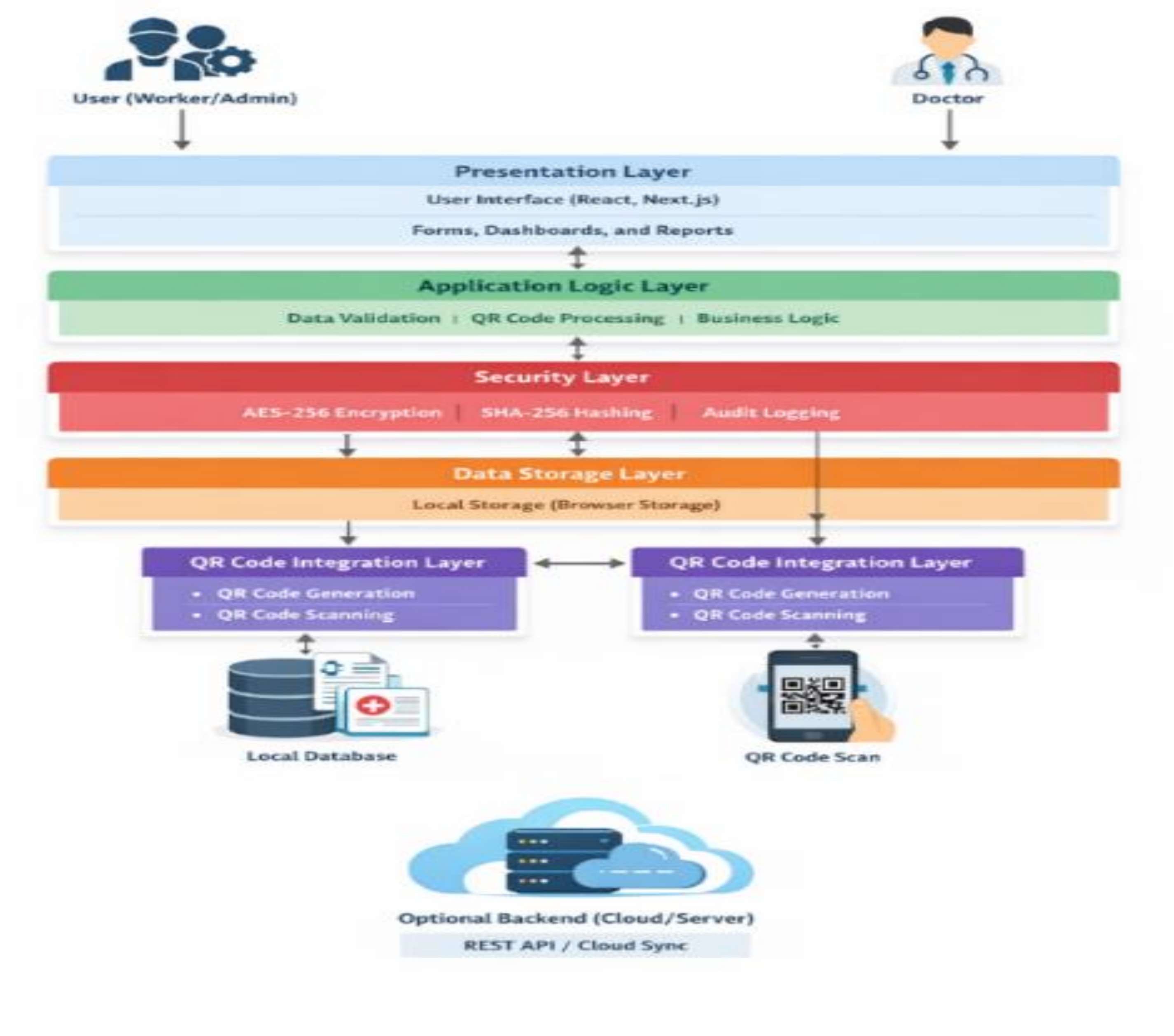

(Fig 1: Architecture Diagram)

Data Flow Diagram (DFD)

DFD Level 0

(Fig 2: DFD Level 0)

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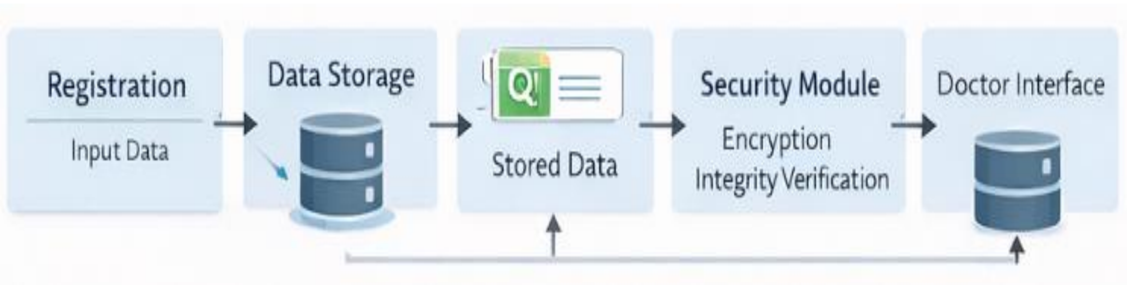
Figure 2 illustrates the Level 0 Data Flow Diagram of the proposed Digital Health Record Management System. This high-level diagram shows major data flows between external entities: the user (worker / admin) and the doctor. At the level, the entire system is represented as a single process, emphasizing overall data interactions.

DFD Level 1

(Fig 3: DFD Level 1)

Figure 3 presents the Level 1 Data Flow Diagram of the proposed system. It decomposes the main system into five function modules: Registration, Data Storage, QR Code Module, Security Module, and Doctor Interface. This level exposes detailed modules and data flows within the system.

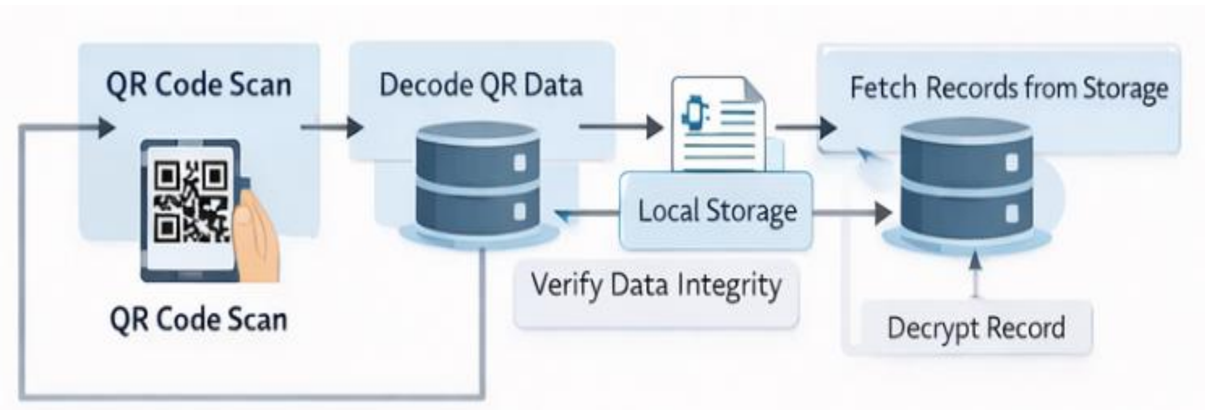
DFD Level 2



(Fig 4: DFD Level 2)

Figure 4 presents the Level 1 Data Flow Diagram of the proposed system. It decomposes the main system into five functional modules: Registration, Data Storage, QR Code Module, Security Module, and Doctor interface. This level exposes detailed modules and data flows within the system.

DFD Level 3



(Fig 5: DFD Level 3)

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Figure 5 illustrates the Level 2 Data Flow Diagram, focusing on the QR-based data retrieval process. This detailed breakdown highlights the steps involved: scanning the Or-code, decoding it to extract the unique worker ID, fetching the records from local storage, verifying data integrity, decrypting the data.

Layer-wise Description

Presentation Layer (User Interface)

This layer interacts directly with users such as workers, doctors, and administrators.

Technologies Used:

- React.js
- Next.js
- Tailwind CSS

Key Functions:

- Display forms, dashboards, and reports
- Accept user inputs (registration, search, uploads)
- Provide multilingual interface
- Enable navigation between modules

Application Logic Layer

This layer acts as the core processing unit of the system.

Functions:

- Data validation and formatting
- Business logic implementation
- QR code generation and decoding
- Search and filtering operations

Components:

- Data Manager
- Workflow Controller
- Utility Functions

Security Layer

This layer ensures the protection of sensitive healthcare data.

Security Mechanisms:

- AES-256 Encryption (data confidentiality)

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- SHA-256 Hashing (data integrity)
- Audit Logging (user activity tracking)

Security Flow:

Data → Encrypt → Store → Verify → Decrypt

Data Storage Layer

This layer is responsible for storing and retrieving system data.

Storage Method:

- Browser-based Local Storage

Stored Data Includes:

- Worker personal details
- Medical history
- Documents (Base64 encoded)
- Audit logs

Advantages:

- Fast data access
- Offline functionality
- No server dependency

QR Code Integration Layer

This layer enables fast and efficient access to healthcare records.

Functions:

- Generate unique QR code for each worker
- Scan QR code using device camera
- Extract worker ID
- Retrieve corresponding data

Workflow:

QR Scan → Decode → Fetch Record → Display

Data Flow Across Architecture

The system follows a structured and secure data flow:

1. User inputs data through the Presentation Layer

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2. Application Layer validates and processes data
3. Security Layer encrypts sensitive information
4. Data is stored in the Storage Layer
5. During retrieval:
   - Data is fetched from storage
   - Integrity is verified
   - Data is decrypted
   - Displayed to user

Optional Backend Extension

Although the system is primarily client-side, it can be extended with a backend for scalability.

Possible Additions:

- REST APIs
- Cloud Database (MongoDB, Firebase)
- Authentication (JWT/OAuth)

Benefits:

- Multi-device synchronization
- Secure data backup and recovery
- Improved scalability and performance

Architectural Advantages

- Lightweight and fast execution
- Works in offline environments
- Low infrastructure requirement
- Easy deployment and maintenance
- High usability for non-technical users

Architectural Limitations

- Limited scalability due to client-side storage
- Dependency on a specific device/browser
- Constraints of local storage capacity

EXPERIMENTAL SETUP AND RESULTS

Experimental Setup

The proposed Digital Health Record Management System was evaluated to analyze its performance, efficiency, and usability under practical conditions, particularly in low-resource and limited- connectivity environments.

The testing was conducted in a controlled setup using a simulated dataset to replicate real-world scenarios.

System Configuration:

- Platform: Web Browser (Google Chrome / Microsoft Edge)
- Framework: Next.js with React.js
- Storage: Browser Local Storage
- Device: Standard desktop/laptop
- Network Modes: Online and Offline

Dataset:

A simulated dataset consisting of more than 100 patient records was used to evaluate system performance under realistic conditions.

The system was tested across multiple scenarios, including data entry, record retrieval, QR scanning, and document management.

Performance Metrics

The evaluation was based on the following metrics:

- Data Retrieval Time (DRT): Time required to fetch records
- System Response Time (SRT): Time taken to process and display output
- Accessibility: System availability (online/offline)
- Data Reliability: Risk of data loss
- Usability: Ease of user interaction

Quantitative Results

Parameter	Traditional System	Proposed System	Improvement
Data Retrieval Time	15-20 sec	2-3 sec	~80% Faster
System Response Time	3-5 sec	<1 sec	~70% Faster
Accessibility	Online Only	Offline + Online	100% Improvement
Data Loss Risk	High	LOW	Significant Reduction
Cost	High	LOW	Cost Efficient

Performance Graph Analysis

Performance comparison between traditional and proposed system

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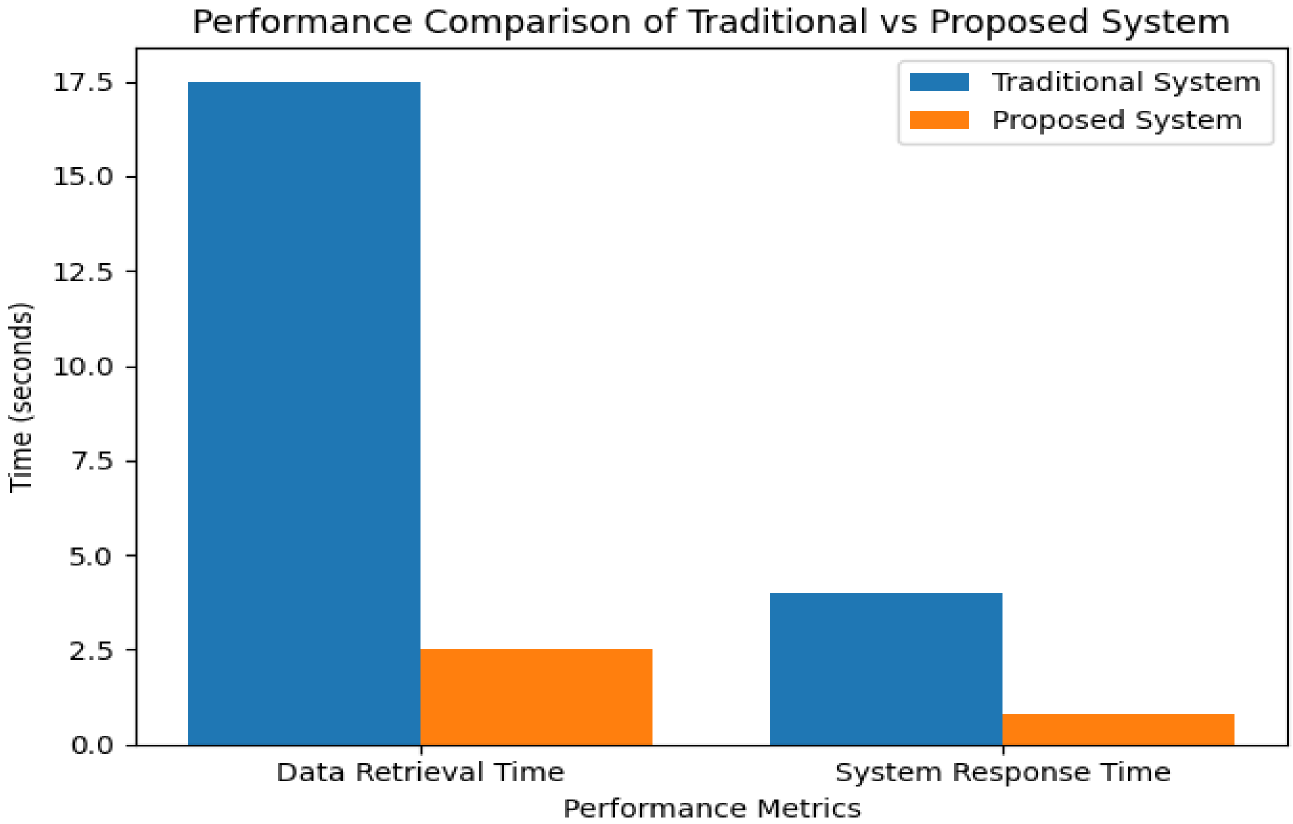
The graphical comparison of system performance is shown in Fig. 5



(Fig 5: Performance Graph Analysis)

Description:

The graphical analysis clearly shows that the proposed system significantly outperforms the traditional system in terms of data retrieval time and system response time. The reduction in time is primarily due to the use of client-side processing and local storage, which eliminates server communication delays.

The proposed system demonstrates faster execution and minimal latency, making it highly efficient for real-time healthcare data access in low-resource environments.

Observations:

- Significant reduction in data retrieval and response time
- Faster performance due to client-side processing
- Minimal latency compared to traditional systems

Performance Interpretation

The proposed system demonstrates superior performance due to the following factors:

- Use of local storage eliminates server communication delays
- Client-side processing reduces computational overhead
- QR-based identification enables instant record retrieval

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These factors collectively contribute to an overall performance improvement of approximately 70–80% compared to traditional systems.

Functional Testing Results

Worker Registration

- Accurate data capture and storage
- Validation and encryption performed

Medical Visit Tracking

- Proper recording of diagnosis and treatment
- Effective follow-up management

Document Management

- Files stored in Base64 format
- No data corruption observed

QR Code System

- Fast QR generation and scanning
- Instant access to user records

Usability Evaluation

The system was evaluated for usability across different user scenarios.

Findings:

- Simple and intuitive user interface
- Minimal learning curve
- Multilingual support enhances accessibility
- QR-based system reduces manual effort

Efficiency Analysis

The system achieves high efficiency due to:

- Client-first architecture
- Local data storage
- Lightweight system design

Overall efficiency improvement is estimated at 70–80% compared to traditional systems.

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Limitations of Evaluation

- Testing conducted in a controlled environment
- Limited dataset size
- Lack of large-scale real-world deployment

Result Summary

The experimental evaluation confirms that the proposed system is fast, reliable, and efficient. It significantly improves data accessibility, reduces retrieval time, and enhances usability. These characteristics make it highly suitable for migrant workers in low-resource environments.

Limitation And Future Work

A. Limitations

Despite the effectiveness of the proposed Digital Health Record Management System, certain limitations exist due to its design and implementation constraints.

Limited Storage Capacity

The system relies on browser-based local storage, which imposes restrictions on data capacity. This limitation may affect scalability when handling large volumes of medical records or high-resolution documents.

Device Dependency

Since data is stored locally on the user's device, access to healthcare records is restricted to that specific device and browser environment. Loss or damage of the device may result in data unavailability.

Limited Security Implementation

Although the system incorporates encryption and hashing mechanisms, it may not fully meet advanced healthcare security requirements for large-scale deployment. Additional security enhancements are necessary for real-world applications.

Lack of Multi-Device Synchronization

The current system does not support synchronization across multiple devices due to the absence of centralized or cloud-based infrastructure. This limits accessibility for users operating across different locations.

Limited Large-Scale Validation

The system has been evaluated in a controlled environment using a simulated dataset. Real-world deployment in large-scale healthcare systems may introduce additional challenges such as concurrency, data consistency, and performance under heavy load.

Future Work

To overcome the identified limitations and enhance system capabilities, the following improvements are proposed:

Hybrid Cloud Integration

Future development can incorporate a hybrid architecture combining offline-first functionality with optional

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cloud synchronization. This will enable scalable data storage, secure backup, and multi-device accessibility.

Advanced Security Mechanisms

Implementation of advanced security techniques such as AES-256 encryption, role-based access control, and secure authentication can enhance data protection. Compliance with healthcare standards will further strengthen system reliability.

Multi-Device Synchronization

Integration of APIs and cloud services will allow seamless synchronization of healthcare records across multiple devices and locations.

AI-Based Healthcare Analytics

Artificial intelligence can be integrated to provide predictive analytics, early disease detection, and personalized healthcare recommendations, improving decision-making and system effectiveness.

Mobile Application Development

Developing a dedicated mobile application will enhance accessibility, usability, and real-time interaction, especially for users in remote and low-resource environments.

Scalability and Load Testing

Future work should include large-scale testing with real-world datasets to evaluate system performance under high user loads and ensure reliability in practical deployments.

Interoperability with Healthcare Standards

Integration with healthcare standards such as HL7 and FHIR (Fast Healthcare Interoperability Resources) will enable seamless data exchange and compatibility with existing healthcare systems.

Summary

The proposed system provides a lightweight and efficient solution for healthcare record management in low-resource environments. Addressing the identified limitations through future enhancements will significantly improve scalability, security, and real-world applicability. These advancements will help transform the system into a robust and widely deployable healthcare solution.

CONCLUSION

This paper presents a Digital Health Record Management System designed to address the challenges faced by migrant workers in maintaining accessible and continuous healthcare records. Due to frequent relocation and limited infrastructure, traditional healthcare systems often fail to provide reliable and portable solutions. The proposed system overcomes these limitations through a client-first architecture, enabling offline functionality, fast data access, and minimal infrastructure dependency.

The system integrates QR-based identification, local data storage, and lightweight processing techniques to ensure efficient and reliable healthcare data management. Experimental evaluation demonstrates significant performance improvement, reducing data retrieval time from approximately 15–20 seconds to 2–3 seconds and achieving an overall efficiency gain of 70–80%. Additionally, the system ensures 100% offline accessibility, making it highly suitable for low-resource environments.

The key contribution of this work lies in the development of a cost-effective, portable, and user-friendly

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healthcare solution tailored for migrant populations. Unlike existing cloud-based and blockchain-based systems, the proposed approach eliminates dependency on continuous internet connectivity while maintaining high efficiency.

In practical scenarios, the system has strong potential to improve healthcare accessibility, reduce treatment delays, and enhance continuity of care for underserved communities. Furthermore, it provides a scalable foundation for future enhancements, including hybrid cloud integration, advanced security mechanisms, and interoperability with healthcare standards.

Overall, the proposed system represents a significant step toward developing inclusive, efficient, and accessible digital healthcare solutions for resource-constrained environments.

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