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Design and Implementation of a Microservices-Based Primary Healthcare Information System with Mobile Telemedicine Support

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Abstract – *Primary healthcare centers require integrated information systems to reduce delays and errors in patient data processing, medical record management, and service reporting. This study presents the design and implementation of a microservices-based primary healthcare information system with mobile telemedicine support for Wonorejo Trisulo Community Health Center. The system was developed using JavaScript and Node.js, with MongoDB for data storage and REST APIs connected through an API Gateway. The web application supports patient registration, emergency and outpatient services, electronic medical records, cashier operations, pharmacy, inventory, laboratory, radiology, and reporting, while the mobile interface enables patients to submit and review telemedicine requests. The system was evaluated through 30 scenario-based black-box functional tests and an initial questionnaire-based user perception assessment involving six healthcare personnel. All functional test scenarios produced the expected outputs. The user assessment showed preliminary positive perceptions of application performance (80%), ease of use (70%), efficiency (63%), interface attractiveness (80%), usefulness (93%), and overall satisfaction (83%). These user-perception results are descriptive and should not be generalized as evidence of overall usability, satisfaction, or system adoption.*

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Keywords: *Electronic medical records, Health information system, Microservices, Primary healthcare, Telemedicine*

I. Introduction

Digital transformation has become an important strategy for improving the accessibility, continuity, and efficiency of primary healthcare services. The World Health Organization emphasizes that transforming paper-based services into person-centered digital systems requires systematic requirements analysis, workflow mapping, structured health data, interoperability, and the involvement of healthcare workers as system users [1]. In Indonesia, the digitalization of healthcare records is also supported by the Minister of Health Regulation Number 24 of 2022 concerning medical records, which provides a regulatory foundation for managing medical records electronically [2]. These developments highlight the need for healthcare facilities, including community health centers, to adopt integrated information systems that support both clinical and administrative activities.

Electronic medical records (EMRs) can improve the availability and timeliness of patient information, facilitate coordination among healthcare personnel, and support more efficient healthcare processes [3], [4]. Nevertheless, successful implementation is not determined solely by the availability of software. Infrastructure limitations, inadequate training, workflow incompatibility, insufficient technical support, and user readiness may influence the adoption and effective use of digital health systems [3]. Therefore, healthcare information systems should be designed according to actual operational workflows and the needs of their intended users.

Wonorejo Trisulo Community Health Center provides primary healthcare services to the surrounding community in Plosoklaten District, Kediri Regency, Indonesia. Before the development of the proposed system, several activities were still performed manually, including patient registration, medical record documentation, medicine inventory management, and service reporting. This condition created difficulties in retrieving historical patient information, maintaining consistent records, monitoring medicine availability, and preparing reports.

Furthermore, different service units required access to related patient and service information, while manually recorded documents were maintained separately. These operational conditions motivated the development of an integrated system connecting registration, clinical examination, emergency and outpatient care, pharmacy, laboratory, radiology, cashier, inventory, medical records, and reporting processes.

An integrated healthcare application consists of multiple business functions with different responsibilities and data requirements. Microservices architecture provides an approach for separating application functions into independently managed services that communicate through defined interfaces [5]. In healthcare environments, microservices have also been proposed to support modularity, service separation, and information exchange among independently managed healthcare components [6]. Although microservices can provide architectural flexibility, their implementation also introduces additional concerns related to service decomposition, communication, monitoring, security, and testing. Therefore, the architecture should be adapted to the operational requirements and scale of the target healthcare environment.

Digital healthcare systems can also extend patient access through mobile health and telemedicine services. Previous studies have reported generally positive experiences with telemedicine in primary care while identifying usability, technological skills, communication, infrastructure, and user preferences as important implementation factors [7]. Telemedicine implementation in resource-constrained and safety-net healthcare settings has similarly demonstrated potential benefits in accessibility while revealing challenges related to infrastructure, workflows, and patient preferences [8]. These findings indicate that telemedicine can complement conventional primary healthcare services when it is appropriately integrated with existing clinical and administrative processes.

Several recent studies have demonstrated different approaches to healthcare information system development. Arcila-Diaz and Valdivia [9] proposed a microservices-based architecture for dental health records using independent databases and an API Gateway. Lagakis et al. [10] developed ClinApp, a microservices-based platform supporting medical appointment scheduling and patient data management. Burka et al. [11] presented a user-centered digital health information system combining a mobile application with a web-based dashboard to support chronic disease management in primary care. In addition to system implementation, usability evaluation has been recognized as an important component of health information system assessment, as demonstrated by Østervang et al. [12]. These studies show that microservices, mobile applications, web dashboards, and usability assessment have increasingly been adopted in digital healthcare systems, although their functional scope and implementation contexts differ.

In the Indonesian context, studies have also investigated the implementation and utilization of digital health information systems. Muchlis [13] examined factors influencing successful electronic medical record implementation in community health centers in Jakarta. Aisyah et al. [14] investigated health information system utilization across public health centers in Indonesia, highlighting variations in implementation and operational conditions. Fu'ad et al. [15] reported the implementation of a cloud-based electronic medical record system at a community health center. Martono et al. [16] further addressed healthcare information interoperability through the development of a Satu Sehat Interoperability Agent, demonstrating the importance of integrating healthcare information systems with Indonesia's national health data ecosystem. These studies provide important evidence regarding EMR adoption, health information system utilization, interoperability, and digital patient-data management in Indonesian healthcare settings. More broadly, previous application-development research has demonstrated that user-centered design and interaction simplification can contribute to improved usability and user satisfaction in interactive applications [17].

Based on the reviewed literature, electronic medical records, microservices-based healthcare systems, primary-care information systems, and telemedicine have been investigated from different perspectives. However, among the selected related studies, implementations that combine administrative and clinical workflows, electronic medical records, pharmaceutical and diagnostic services, a microservices-based backend with an API Gateway, web-based access for healthcare personnel, and mobile telemedicine support within a single community health center remain limited. Accordingly, the contribution of this study is not the introduction of a new microservices protocol or software technology, but rather the practical integration of established technologies into a unified architecture tailored to the operational requirements of a community health center. A comparative analysis between the proposed system and selected related healthcare systems is presented in Section IV.

This study presents the design and implementation of a microservices-based primary healthcare information system with mobile telemedicine support at Wonorejo Trisulo Community Health Center. The system was implemented using JavaScript and Node.js, MongoDB for data storage, and REST application programming interfaces connected through an API Gateway. The web application integrates patient registration, electronic medical records, emergency and outpatient services, pharmacy and inventory management, cashier operations, laboratory examinations, radiology services, and reporting, while the mobile interface supports patient telemedicine requests. The main contributions of this study are threefold: first, it provides a practical integration of administrative, clinical, electronic medical record,

pharmaceutical, diagnostic, reporting, and telemedicine workflows within a community health center environment; second, it implements a microservices-based backend with an API Gateway to support both healthcare-personnel web access and patient-oriented mobile telemedicine services; and third, it provides implementation evidence through scenario-based functional testing and an initial user perception assessment. Therefore, the novelty of this work is primarily integrative and application-oriented rather than based on a new software architecture mechanism.

The remainder of this paper is organized as follows. Section II describes the research and system development methodology, including requirements analysis, system development, functional testing, and initial user perception evaluation. Section III presents the system architecture, service communication, database design, and implementation. Section IV reports the functional and user-evaluation results and compares the proposed system with related healthcare information systems. Finally, Section V concludes the study and outlines potential directions for future development.

II. Research Methodology

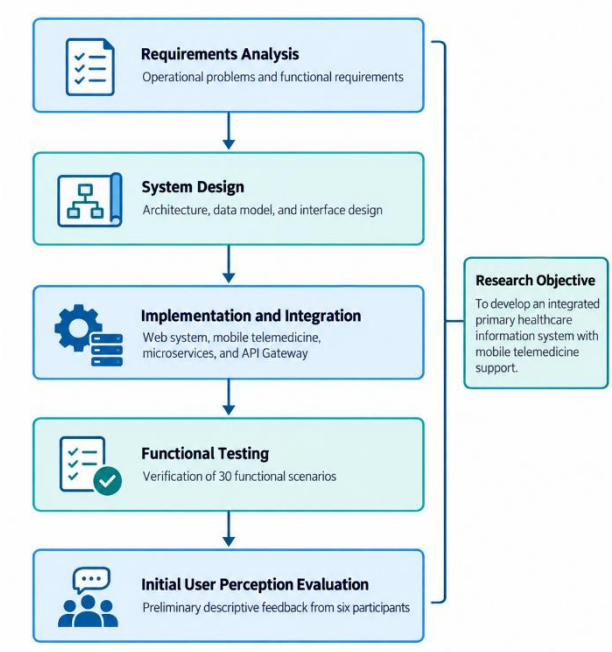


Fig. 1. Research and system development workflow

This study employed a system development and evaluation approach consisting of five principal stages: requirements analysis, system design, implementation and integration, functional testing, and initial user perception evaluation. Each stage produced an outcome directly related to the overall objective of developing an integrated primary healthcare information system with mobile telemedicine support. Requirements analysis identified operational problems and functional requirements; system design translated these requirements into application, data, and interface models; implementation and integration realized the web, mobile, microservices, and API components; functional testing verified the implemented functions against predefined scenarios; and the initial user perception evaluation provided preliminary feedback from personnel in the target deployment environment. The overall research and system development workflow is illustrated in Fig. 1.

A. Requirements Analysis

The requirements analysis was conducted at Wonorejo Trisulo Community Health Center, Plosoklaten District, Kediri Regency, Indonesia. Information regarding the existing healthcare service processes was obtained through observation of operational activities and communication with personnel involved in healthcare-center services. The analysis focused on identifying problems associated with manual data processing, including difficulties in retrieving patient records, documenting medical examinations, monitoring medicine inventory, and preparing healthcare service reports.

The results of this stage were translated into the functional requirements of the proposed system. The identified business processes included user management, patient registration, emergency services, outpatient services, electronic medical records, cashier operations, pharmaceutical inventory, pharmacy services, laboratory examinations, radiology services, report generation, and mobile telemedicine support.

The system was designed to accommodate different categories of users with different access requirements, including administrators, registration personnel, doctors, nurses, pharmacists, laboratory personnel, radiology personnel, cashier personnel, and patients. Healthcare personnel access functions according to their assigned responsibilities, while registered patients access the telemedicine component through the mobile-oriented interface. Thus, the main outcome of the requirements-analysis stage was a set of functional and user-access requirements used as the basis for subsequent system design and implementation.

B. System Development Procedure

The system design stage translated the identified requirements into application architecture, data structures, process models, and user interfaces. The design artifacts included use case diagrams, data flow diagrams, an entity relationship diagram, a conceptual data model, and a physical data model. User interfaces were also designed for the web-based healthcare information system and the mobile telemedicine component.

The implementation stage realized the designed system using JavaScript and Node.js for server-side application development and MongoDB for data storage. Express.js was used to handle HTTP requests, while Mongoose was used to manage access between the Node.js services and MongoDB. The backend components communicated through Representational State Transfer Application Programming Interfaces

(REST APIs), and an API Gateway was implemented as the intermediary between client applications and backend services.

The backend was separated into service components according to their responsibilities. The primary healthcare information service supports administrative, clinical, pharmaceutical, diagnostic, and reporting functions, while the telemedicine service supports patient-oriented remote service functions. Each service operates through an independent service port and manages its corresponding data storage. The web and mobile interfaces were subsequently integrated with these backend services through the API Gateway.

User authentication was implemented to control access to the system, and passwords were processed using bcrypt before storage. The outcome of this stage was an integrated web and mobile healthcare information system capable of supporting the operational functions identified during requirements analysis. The detailed architecture and implementation are described in Section III.

C. Functional Testing

Functional testing was conducted using a scenario-based black-box testing approach to verify whether the implemented functions produced the expected outputs for specified user actions and inputs. The testing focused on externally observable system behavior without examining the internal program structure.

The test scenarios covered the principal functions of the system, including authentication, user management, patient registration, medical record management, emergency and outpatient services, pharmacy and inventory management, cashier operations, laboratory and radiology services, and telemedicine functions.

Testing was conducted at Wonorejo Trisulo Community Health Center from May 31 to June 11, 2022. The application was operated on a Windows-based computer equipped with an AMD Ryzen 3 5300U processor and 8 GB of memory. A test scenario was classified as passed when the observed system behavior was consistent with the expected result. In total, 30 functional scenarios were evaluated. The outcome of this stage was used to verify the functional completeness of the implemented system before interpreting the initial user feedback.

D. Initial User Perception Evaluation

An initial user perception evaluation was conducted to obtain preliminary feedback regarding the implemented application. The evaluation involved six personnel from Wonorejo Trisulo Community Health Center who participated in the system trial and were involved in healthcare-center operational activities. The available evaluation records did not document the specific professional role of each individual respondent; therefore, balanced representation across all intended system-user roles could not be established.

The six participants were actual personnel from the target deployment environment and were familiar with healthcare service processes supported by the application. Nevertheless, considering the small sample size and the absence of complete role-specific respondent information, the evaluation was intended only to provide descriptive feedback on initial user perceptions. It was not designed to establish statistically generalizable conclusions regarding usability, satisfaction, or system adoption.

The questionnaire evaluated six aspects: application performance and stability, ease of use, efficiency and convenience, interface attractiveness, usefulness for users, and overall user satisfaction. Each statement was rated using a five-point Likert scale, with Strongly Agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly Disagree = 1.

The percentage score for each evaluation aspect was calculated using:

$$P = \frac{\sum S_i}{N \times S_{\max}} \times 100\% \qquad (1)$$

where P represents the percentage score, $\sum S_i$ is the total score obtained from the respondents, N is the number of respondents, and $S_{\max}$ is the maximum Likert score of 5.

The resulting percentages were interpreted using five categories: 0–20% as Strongly Disagree, 21–40% as Disagree, 41–60% as Neutral, 61–80% as Agree, and 81–100% as Strongly Agree. Due to the small number of respondents, the results were analyzed descriptively and were not used to make statistically generalized claims.

III. System Design and Implementation

A. Overall System Architecture

The proposed system was designed to connect healthcare personnel and patients through web-based and mobile-oriented interfaces. The web application serves as the primary interface for healthcare personnel, while the mobile-oriented interface provides telemedicine functions for registered patients. Both interfaces communicate with backend services through Representational State Transfer Application Programming Interfaces (REST APIs).

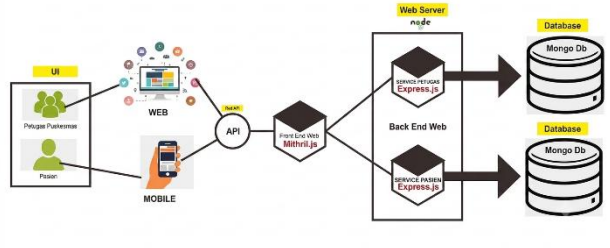


Fig. 2. Overall architecture of the web and mobile primary healthcare information system

Fig. 2 illustrates the overall architecture of the proposed system. Healthcare personnel access the web application to manage administrative, clinical, pharmaceutical, diagnostic, and reporting activities. Patients access the mobile telemedicine interface to submit remote healthcare requests. Requests from both interfaces are directed to the

backend through an API layer that connects the client applications to the corresponding services and data storage components.

B. Microservices and API Gateway

The backend was implemented using a microservices-based approach in which the primary healthcare information service and the telemedicine service operate as separate backend components. Each service is deployed through an independent service port and manages its corresponding MongoDB data storage. The separation of service processes and databases was intended to reduce direct dependency between application components and to allow each service to be accessed independently.

Fig. 3 provides a more detailed representation of the communication between client applications, the API Gateway, backend services, and databases. Both the web and mobile clients communicate with the backend through the API Gateway rather than directly accessing individual services or databases.

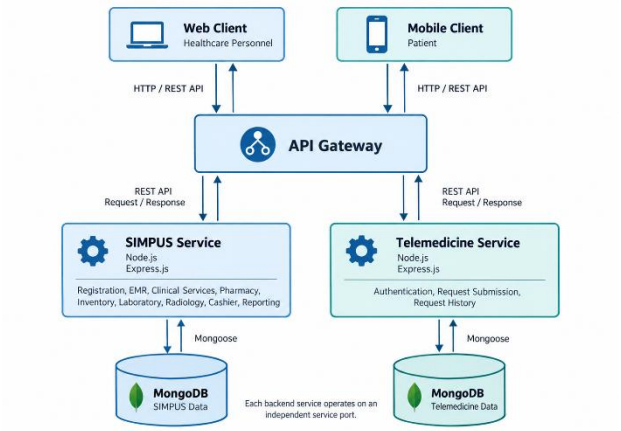


Fig. 3. Detailed service communication through the API Gateway in the proposed microservices-based architecture.

An incoming HTTP request from a client is first received by the API Gateway. The gateway identifies the requested function and forwards the request to the appropriate backend service through its designated service port. The selected service processes the request, accesses the corresponding MongoDB collections when data operations are required, and returns the response to the client through the API Gateway.

The implemented architecture contains two principal backend service groups. The SIMPUS service handles internal primary healthcare functions, including patient registration, electronic medical records, clinical services, pharmacy, inventory, laboratory, radiology, cashier operations, and reporting. In contrast, the telemedicine service handles patient-oriented remote service functions, including patient authentication, telemedicine request submission, and access to request history.

Communication between the API Gateway and backend services is performed using HTTP-based REST APIs. Standard create, retrieve, update, and delete operations are handled through application endpoints. Node.js provides the server-side JavaScript runtime, while Express.js handles HTTP routing and request processing. Database access from the Node.js services is managed using Mongoose.

The overall communication sequence can therefore be summarized as client request → API Gateway → selected service → database operation → service response → API Gateway → client. This communication pattern enables different client platforms to use the same backend environment while keeping database access encapsulated within the corresponding backend service. No direct access from the web or mobile client to MongoDB is required.

User authentication was also implemented to provide controlled access to protected system functions. Passwords are processed using bcrypt before being stored in the database. However, the present study did not include dedicated penetration testing or comprehensive security-performance evaluation. Therefore, authentication, password hashing, and service separation are reported as implemented security and access-control mechanisms rather than evidence of complete system security.

C. Web-Based Healthcare Services

The web application was developed for healthcare personnel whose responsibilities are distributed across several operational units. After authentication, each user is directed to the system dashboard and provided with functions corresponding to the assigned role. The implemented modules are summarized in Table I.

TABLE I
MAIN MODULES OF THE WEB-BASED HEALTHCARE INFORMATION SYSTEM

Module	Main functions
User management	Manages user accounts, access roles, reference data, and database backup or restoration
Patient registration	Registers new patients, searches existing patients, and records outpatient or emergency visits
Electronic medical records	Stores patient identity, visit history, examination results, diagnoses, treatments, and prescriptions
Emergency service	Records nursing and medical examinations for emergency patients
Outpatient service	Manages patient queues and examination records for outpatient clinics
Cashier	Calculates and confirms payments associated with healthcare services
Pharmaceutical inventory	Manages medicines, medical supplies, batches, stock, and distribution requests
Pharmacy	Processes prescriptions, medicine delivery, and non-prescription medicine transactions
Laboratory	Records patients, laboratory procedures, and examination results
Radiology	Manages radiology requests and examination information
Reporting	Generates healthcare and supporting-service reports

The user-management module allows administrators to

create accounts, assign access roles, maintain reference data, and perform database backup and restoration. Role separation restricts users to functions associated with their operational responsibilities. For example, registration personnel access patient-registration functions, whereas laboratory and radiology personnel access examination-related information relevant to their respective units.

The patient-registration module supports both new and returning patients. For a new patient, personnel record identity information and create an initial medical record. For a returning patient, an existing record can be retrieved using patient information or a medical-record number. The patient can subsequently be registered for outpatient or emergency services. This process helps maintain continuous visit information and reduces unnecessary duplication of patient records.

Clinical processes are supported through emergency and outpatient modules. Nurses can record initial examination information, including patient complaints and vital signs, while doctors can complete diagnostic and treatment information such as diagnoses, clinical actions, and prescribed medicines. These clinical records are associated with the corresponding patient medical record.

Supporting modules connect clinical services with cashier, pharmacy, pharmaceutical inventory, laboratory, and radiology activities. Information produced during clinical examination can therefore be used by the appropriate supporting unit without requiring repeated patient-data entry. The resulting implementation establishes an integrated workflow from patient registration and clinical examination to supporting healthcare services and reporting.

D. Mobile Telemedicine Support

The telemedicine component was implemented as a mobile-oriented interface for patients who had previously been registered by healthcare personnel. Patient access to telemedicine is initiated through the primary healthcare information system, where the corresponding patient record is associated with telemedicine access credentials.

The mobile interface provides patient authentication, a telemedicine dashboard, a healthcare request form, and access to previously submitted requests. After successful authentication, patients can select the relevant clinic and doctor, enter a health-related message, indicate whether the condition is urgent, and submit the request to the healthcare center.

The implemented telemedicine workflow consists of five principal activities:

1. healthcare personnel register an eligible patient for telemedicine access;
2. the system assigns or provides patient authentication credentials;
3. the patient logs in through the mobile-oriented interface;
4. the patient submits a telemedicine request; and
5. the patient can review the history of previously submitted requests.

The telemedicine component therefore extends selected healthcare functions beyond the internal web application by providing patients with remote access to request-based healthcare services. However, the implemented feature should be regarded as **mobile telemedicine request and remote-monitoring support**, rather than a complete synchronous teleconsultation platform. The current implementation does not include real-time video consultation, automated diagnosis, integrated electronic prescribing, or remote medical-device connectivity.

E. Database Design, Data Management, and Access Control

The database design was developed through three modeling stages: an Entity Relationship Diagram (ERD), a Conceptual Data Model (CDM), and a Physical Data Model (PDM). These models were used to represent the main healthcare data entities and their relationships before the data structures were implemented in MongoDB. The principal entities include Login, Employee, Patient, Registration, Examination, Cost Type, Prescription, Medicine, Doctor, Practice Schedule, and Polyclinic.

The ERD shown in Fig. 4 illustrates the logical relationships among the principal entities. Patient data are associated with registration records, which subsequently connect to examination and healthcare-service information. Examination records contain clinical information such as complaints, diagnoses, treatments, and physiological measurements and can be associated with prescription data. Prescription records are connected to medicine information, while doctor records are associated with practice schedules and polyclinic services. Login information is also related to healthcare personnel to support controlled system access.

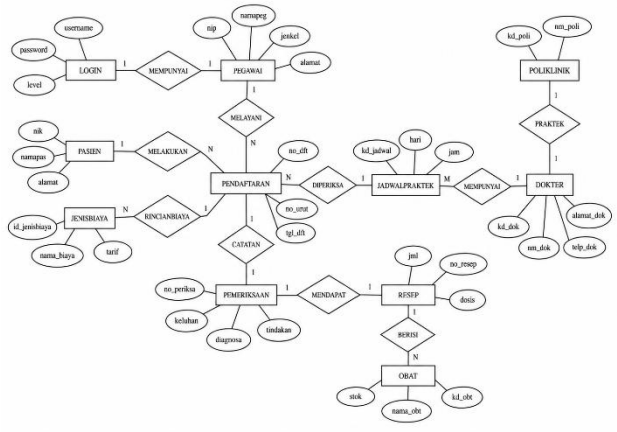


Fig. 4. Entity relationship diagram of the primary healthcare information system.

The conceptual and physical data models further refine these relationships by defining data attributes, keys, and implementation-oriented structures. Due to manuscript space limitations, the complete CDM and PDM are provided as Supplementary Material S1. These models

were used as design references before the corresponding data structures were mapped into MongoDB collections during system implementation.

In the implemented system, MongoDB was used for data storage, while Mongoose was used by the Node.js backend services to access and manage the corresponding collections. Data operations are performed through backend services rather than directly from the web or mobile clients. Client requests are routed through the API Gateway to the appropriate service, which performs the required database operation and returns the response to the client.

The application also implements role-based access control to distinguish functions available to different healthcare personnel. Users authenticate using registered credentials, and passwords are processed using bcrypt before storage. After authentication, users are provided with system functions according to their assigned access roles. The SIMPUS and telemedicine services maintain separate backend processes and corresponding data storage according to their functional responsibilities.

IV. Results and Discussion

A. System Implementation Results

The proposed system was successfully implemented as an integrated web-based primary healthcare information system with mobile telemedicine support. The web application provides role-based access to administrative, clinical, pharmaceutical, diagnostic, financial, and supporting-service functions, while the mobile-oriented interface provides selected telemedicine functions for registered patients.

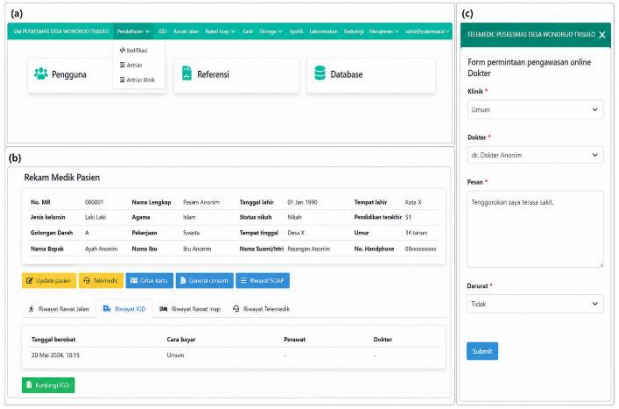


Fig. 5. Selected interfaces of the implemented system: (a) web-based healthcare management dashboard, (b) patient medical record and visit history, and (c) mobile telemedicine request form

Fig. 5 presents selected interfaces of the implemented system. The web dashboard provides access to the healthcare modules according to the assigned user role. The patient medical-record interface presents patient information and previous healthcare activities, while the mobile telemedicine interface enables patients to select a clinic and doctor, provide a health-related message, indicate the urgency of the request, and submit the request to the healthcare center.

The implementation results demonstrate that the requirements identified during the initial analysis stage were translated into operational system functions. Patient information can be reused through registration, clinical examination, pharmacy, laboratory, radiology, cashier, and other authorized workflows. In addition, the mobile telemedicine component extends selected services to patients through the same backend environment and API Gateway structure.

B. Functional Testing Results

Functional testing was conducted using 30 scenario-based black-box test cases. Each test examined whether an implemented function produced the expected response after a specified user action or input. The scenarios covered authentication and system management, patient registration, clinical services, cashier and pharmaceutical functions, diagnostic services, and telemedicine.

Table II summarizes the functional testing results according to the main functional areas.

TABLE II
SUMMARY OF FUNCTIONAL TESTING RESULTS

Functional area	No. of scenarios	Examples of functions evaluated	Result
Authentication and system management	6	Login, dashboard, user management, reference data, database management	Passed
Patient registration	5	Patient search, new and existing patient registration, outpatient and emergency registration	Passed
Clinical services	2	Emergency and outpatient examination workflows	Passed
Cashier, inventory, and pharmacy	9	Payment processing, additional charges, medicine inventory, stock batches, distribution, pharmacy services	Passed
Diagnostic services	4	Radiology and laboratory requests and processing	Passed
Telemedicine	4	Patient telemedicine registration, request handling, mobile access, request submission	Passed
Total	**30**		**30/30 Passed**

All 30 scenarios produced results consistent with the expected system behavior. The tests confirmed that users could authenticate and access appropriate functions, patient information could be processed through registration and healthcare services, and supporting functions such as pharmacy, inventory, laboratory, radiology, and cashier operations could be executed according to the defined workflows. The telemedicine scenarios also confirmed that registered patients could access the mobile-oriented interface and submit remote healthcare requests.

These findings demonstrate functional correctness for the scenarios evaluated in this study. However, the black-box tests were designed to verify system functionality rather than production-scale performance. The evaluation did not measure concurrent-user capacity, response time, throughput, database performance, service recovery, or fault tolerance. Therefore, the results should not be interpreted as evidence that the implemented microservices architecture provides better performance or scalability than other architectural approaches.

C. Initial User Perception Results

The initial user perception evaluation was based on six completed questionnaire responses from personnel at Wonorejo Trisulo Community Health Center who participated in the system trial. The respondents were actual personnel involved in healthcare-center operations. However, the available evaluation records did not document the specific professional role of each participant; therefore, balanced representation across all intended user roles could not be established.

The participants evaluated six aspects using a five-point Likert scale: application performance and stability, ease of use, efficiency and convenience, interface attractiveness, usefulness, and overall satisfaction. Because of the small sample size, the results are presented descriptively and should be interpreted as preliminary perceptions of the participating users rather than as representative measures of usability, satisfaction, or system adoption.

Table III summarizes the percentage score obtained for each aspect.

TABLE III
RESULTS OF THE INITIAL USER PERCEPTION EVALUATION

No.	Evaluation aspect	Score	Interpretation
1	Application performance and stability	80%	Agree
2	Ease of use	70%	Agree
3	Efficiency and convenience	63%	Agree
4	Interface attractiveness	80%	Agree
5	Usefulness for healthcare personnel	93%	Strongly Agree
6	Overall user satisfaction	83%	Strongly Agree
	Average	**78.2%**	**Agree**

The highest score was obtained for usefulness, at 93%, indicating a positive perception of the system's potential usefulness among the participating personnel. Overall satisfaction received 83%, while application performance and interface attractiveness both received 80%. Ease of use obtained 70%, whereas efficiency and convenience received the lowest score at 63%.

The relatively lower score for efficiency and convenience suggests that some participants may not yet have experienced an optimal interaction workflow during the trial. Possible factors include adaptation to a new digital workflow, the number of available modules, and limited familiarity with the application. However, these explanations should be treated as possible interpretations because the questionnaire did not collect qualitative feedback regarding the reasons behind individual ratings.

The average score across the six evaluated aspects was 78.2%, corresponding to the "Agree" category used in this study. Nevertheless, this result represents only preliminary descriptive feedback from the six participants and does not provide sufficient evidence to generalize usability, satisfaction, or system adoption to a broader population of healthcare personnel.

D. Comparative Analysis and Discussion

The results demonstrate that the proposed system integrates multiple primary healthcare workflows within a single web and mobile environment. Patient information recorded during registration can subsequently support clinical examination, pharmacy, inventory, laboratory, radiology, cashier, and reporting processes. The mobile telemedicine component further extends selected services by enabling registered patients to submit remote healthcare requests and review their request history.

The technologies applied in this study, including REST APIs, an API Gateway, Node.js, MongoDB, and microservices, are well-established technologies. Therefore, the contribution of this work is primarily derived from their integration and application within the operational context of a community health center rather than from the introduction of a new architectural mechanism. Table IV compares the proposed system with selected related digital healthcare systems.

TABLE IV
COMPARISON WITH RELATED DIGITAL HEALTHCARE SYSTEMS

Study	Architecture / Platform	Main Scope	Mobile / Telemedicine
Osei-Tutu and Song [6]	Microservices architecture	Healthcare information exchange	Not reported
Arcila-Diaz and Valdivia [9]	Microservices and API Gateway	Dental health records	Not reported
Lagakis et al. [10]	Microservices platform	Appointment and patient data management	Patient-oriented functions
Burka et al. [11]	Mobile app and web dashboard	Primary-care chronic disease management	Mobile application
Fu'ad et al. [15]	Cloud-based EMR	Community health center records	Not reported
Proposed system	Microservices and API Gateway	Integrated primary healthcare services and EMR	Mobile telemedicine requests

Table IV shows that the selected related systems address different aspects of digital healthcare. Previous microservices-based studies mainly focused on healthcare information exchange, dental health records, or appointment and patient data management [6], [9], [10]. Other studies emphasized mobile support for primary-care programs or electronic medical record management at community health centers [11], [15]. In comparison, the proposed system combines a broader set of administrative, clinical, pharmaceutical, diagnostic, financial, and electronic medical record functions with a microservices-based backend and mobile telemedicine support. Thus, its

contribution is primarily integrative and application-oriented, rather than based on a new microservices technology.

The functional testing results support this integration by showing that all 30 evaluated scenarios produced the expected system behavior. However, these results demonstrate functional correctness only and do not establish performance superiority over other healthcare information systems or architectural approaches. Similarly, the initial user perception assessment should be interpreted cautiously because it involved only six participants. The relatively high usefulness score suggests positive preliminary perceptions of the system, whereas the lower efficiency and convenience score indicates that further improvement of interaction workflows may still be required.

The microservices implementation separates the primary healthcare information service from the telemedicine service and uses the API Gateway to route requests to the corresponding backend service. This structure enables both web and mobile clients to access backend functions without direct database access. Nevertheless, the implementation contains a limited number of principal services and should be regarded as an initial microservices-based implementation rather than a large-scale distributed healthcare platform.

The mobile telemedicine component also remains limited to asynchronous request submission and request-history access. It does not currently provide real-time video consultation, integrated messaging, automated diagnosis, electronic prescribing, or remote medical-device integration. Future development and evaluation are therefore required to determine how the system performs under broader operational conditions and whether additional telemedicine functions can improve its practical use.

E. Study Limitations

Several limitations should be acknowledged. First, the initial user perception evaluation involved only six personnel from a single community health center. The available evaluation records also did not provide the specific professional role of each respondent. Consequently, the questionnaire results should be regarded as descriptive and exploratory and cannot be generalized to all intended healthcare-user groups.

Second, the questionnaire was locally prepared and was not based on a standardized usability instrument such as the System Usability Scale. Future evaluation should involve a larger and more diverse participant group representing different operational roles and should employ a validated usability instrument.

Third, the study did not quantitatively compare the implemented system with the previous manual workflow in terms of service duration, data-retrieval time, error rate, or reporting time. The microservices architecture was also not evaluated through performance, scalability, availability, or fault-tolerance measurements. Therefore, no claim is made regarding performance superiority over monolithic or other architectural approaches.

Finally, security evaluation was limited to the implemented authentication, role-based access, and password-hashing mechanisms. Penetration testing, security auditing, encryption evaluation, and regulatory-compliance assessment were outside the scope of this study. The telemedicine component was also limited to asynchronous request support rather than a complete real-time teleconsultation service.

V. Conclusion

This study presented the design and implementation of a microservices-based primary healthcare information system with mobile telemedicine support for Wonorejo Trisulo Community Health Center. The developed system integrates administrative, clinical, electronic medical record, pharmaceutical, diagnostic, financial, and reporting functions through a web-based application, while the mobile-oriented interface enables registered patients to submit and review telemedicine requests. The backend architecture separates the SIMPUS and telemedicine services, which communicate with client applications through REST APIs and an API Gateway and manage their corresponding MongoDB data storage.

Functional testing confirmed that all 30 evaluated scenarios produced the expected system behavior, covering authentication, patient registration, clinical services, cashier and pharmaceutical processes, diagnostic services, and telemedicine functions. The initial user perception assessment involving six healthcare personnel produced an average score of 78.2%, with usefulness receiving the highest score of 93% and overall satisfaction reaching 83%. These results indicate positive preliminary perceptions among the participating users; however, they should not be generalized as evidence of overall usability, satisfaction, or system adoption because of the limited sample size.

The main contribution of this study is the practical integration of multiple primary healthcare workflows, electronic medical records, a microservices-based backend with an API Gateway, and mobile telemedicine support within a single community health center environment. Future work should involve a larger and more diverse group of users, standardized usability instruments, quantitative comparison with previous manual workflows, and performance, scalability, and security testing. The telemedicine component may also be extended with real-time consultation, secure messaging, electronic prescription support, and integration with broader digital healthcare services.

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