Implementation Of Android Student Attendance System Using Dynamic Qr And Geofencing

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Abstract

Background : Manual student attendance recording in educational institutions is inefficient, error prone, and susceptible to proxy attendance (titip absen). Physical presence recapitulation also delays real time attendance reporting for administrators and parents.

Purpose : This study designs, implements, and evaluates an Android based attendance information system incorporating dual factor verification through dynamic QR codes and location based geofencing.

Methodology : The system combines dynamically rotating QR tokens (60 second expiration) with the Haversine formula for real time GPS distance validation within a 50M radius boundary. System performance and user acceptance were evaluated using Black box testing, UAT, MOS surveys (N = 5 teachers, N = 30 students), response latency benchmarking, and server load stress testing up to 100 concurrent requests.

Findings : Empirical evaluation demonstrates that the proposed system reduces classroom attendance duration from an average of 12.5 minutes (10 to 15 minutes) to 1.4 minutes per class session, achieving an 88.8% reduction in administrative time. The average MOS satisfaction score reached 4.57/5.00 for teachers and 4.62/5.00 for students (Excellent category). Response latency benchmarks yielded an average response time of 245 ms under standard operational conditions, maintaining a 0.0% error under load tests up to 50 concurrent requests.

Implications : The solution offers primary educational institutions a cost effective attendance verification without requiring dedicated door terminal hardware, while providing guidelines for managing indoor GPS signal drift.

Originality : The primary scientific contribution lies in integrating short lived cryptographic QR tokens with GPS geofencing on commodity mobile devices, providing a zero hardware, zero proxy presence verification mechanism tailored for primary schools.

Keywords: *Digital attendance; Dynamic QR code; Android application; Geofencing; Haversine algorithm*

INTRODUCTION

Student attendance recording is an essential administrative process in primary and secondary education. Attendance records indicate student learning discipline and form a core parameter in academic performance evaluations. Nevertheless, many elementary schools in developing regions continue to rely on conventional paper based attendance sheets or manual roll calls conducted at the

beginning of each instructional period. This traditional manual presence method suffers from three critical vulnerabilities:

1. Susceptibility to Human Error and Data Loss: Manual entry frequently leads to misrecorded presence statuses, illegible entries, physical sheet damage, or loss of attendance records (Januartika et al., 2023).
2. Instructional Time Inefficiency: Teachers spend approximately 10 to 15 minutes calling out student names individually during every class period. In a standard school week, this administrative overhead consumes multiple hours of valuable instructional time.
3. Delayed Data Recapitulation and Reporting: Aggregating daily physical attendance sheets into monthly administrative summaries is labor intensive and error prone. Parents and school administrators lack real time visibility into student absenteeism, hindering timely intervention (Putra et al., 2024).

To address these challenges, attendance automation using ubiquitous mobile technologies, specifically Android smartphones, has gained significant research traction. Quick Response (QR) Code technology provides a high density data matrix that can be rapidly parsed using standard mobile device cameras (Wicaksono, 2026). However, existing mobile attendance systems suffer from notable security and operational constraints.

While static QR code attendance implementations (Wahyuni et al., 2022; Januartika et al., 2023) improve scanning speed, they are highly vulnerable to proxy attendance ("titip absen"). Students can easily photograph or screenshot a static QR code and share it with peers via instant messaging applications, allowing off site students to record fake presence. Alternative solutions relying on dedicated entrance hardware, such as wall mounted RFID readers or biometric fingerprint scanners (Ridho et al., 2024), eliminate proxy attendance but impose significant physical terminal procurement costs and create queuing bottlenecks at classroom doors.

This research addresses these limitations by introducing a lightweight, dual factor authentication protocol executed on commodity mobile devices alongside standard web server and database infrastructure (REST API backend + MySQL database). Eliminating specialized attendance terminal hardware at classroom entryways, the system integrates two dynamic verification mechanisms:

1. Dynamic Short Lived QR Tokens: QR codes dynamically rotate every 60 seconds on the teacher's display, rendering captured static photographs obsolete.
2. Haversine Based GPS Geofencing: The server validates the student's real time geographic coordinates against the school's central location within a strict 50 meter radius tolerance.

The primary research case study was conducted at SDI Nida Eldabi, an Islamic Elementary School in Parung Panjang. Table 1 compares prior studies with the proposed system.

Table 1. Comparative Analysis of Prior Attendance Systems vs. Proposed System

Study & Year	Platform & Tech	Security Factor	Proxy Vulnerability	Dedicated Terminal Cost	Processing Efficiency
Wahyuni et al. (2022)	Android, Java, Static QR	Single Factor (Static QR)	High (Screenshot sharing)	Zero (Mobile device)	High (< 3s per scan)
Januartika et al. (2023)	Web, PHP, Static QR	Single Factor (Static QR)	High (Photo forwarding)	Zero (Web camera)	Moderate (Manual web entry)
Tehusula et al. (2023)	Web, PHP, QR Code	Single Factor (Static Token)	Moderate	Zero (Desktop)	Moderate

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Pulungan & Saleh (2019)	Android, Static QR	Single Factor (Static QR)	High (Off site scanning)	Zero (Smartphone)	High
Maulana et al. (2025)	AppSheet, Cloud, GPS	Single Factor (Static GPS)	Moderate (Location spoofing)	Zero (AppSheet)	Moderate (Cloud latency)
Ridho et al. (2024)	IoT, Microcontroller, RFID	Hardware Token (RFID)	Low (Physical card share)	High (Dedicated RFID Terminals)	Low (Single file queue)
Proposed System	Android, Dynamic QR, GPS	Dual Factor (60s QR + GPS 50m)	Zero (Dynamic Token + Geofence)	Zero Dedicated Terminal (Uses existing phones + web server)	High (Parallel scanning)

Digital attendance information systems are computerized frameworks designed to capture, process, and analyze presence data in real time, thereby enhancing organizational discipline and operational transparency (Maulana et al., 2025). To ensure secure authentication, these systems use a dynamic QR code architecture featuring a two-dimensional matrix symbology generated dynamically at runtime; this contains cryptographically signed payloads (session_id, timestamp, nonce) with short time-to-live parameters specifically designed to prevent replay attacks (Ferroza, 2026).

These applications use the Android operating system and native Java development via Android Studio, enabling direct access to hardware sensors like the camera and GPS receiver with minimal runtime overhead (Sianipar, 2022; Android Developers, 2026). In addition, spatial verification relies on geofencing to establish virtual geographic perimeters around physical coordinates, integrating the Haversine formula to compute the great-circle distance between two points on a spherical surface using latitude and longitude inputs (Suharianto et al., 2020).

METHODOLOGY

1. System Development Methodology

This study employs the structured Waterfall software engineering life cycle model to ensure a systematic development process. The initial phase, Requirements Analysis, focuses on identifying functional user requirements (such as session creation, scan parsing, and real-time monitoring), alongside non-functional security and performance constraints, including token expiration, GPS accuracy filtering, and SHA-256 password encryption. Building on these requirements, the Software Architecture & System Design phase establishes the client-server interaction model, Unified Modeling Language (UML) diagrams, relational database schemas, and cryptographic token protocols.

During System Implementation, the blueprint is built by developing the native Android client in Java and constructing the RESTful API backend using PHP and MySQL. Following development, System Evaluation & Testing assesses the platform through Black-box functional testing, User Acceptance Testing (UAT), Mean Opinion Score (MOS) user surveys, latency benchmarks, and load testing. Finally, the Deployment & Maintenance phase completes the cycle by installing the application on teacher and student devices at SDI Nida Eldabi and managing ongoing database server operations.

2. Software Architecture Overview

The system follows a multi-tier client-server architecture consisting of four integrated layers. At the frontend, the Android Client Layer executes as a native Java application on user mobile devices, handling camera-based scanning via the ZXing parser library, collecting spatial coordinates through the Google Fused Location Provider API, and maintaining secure communication with the backend over HTTPS. Processing these requests, the RESTful API Backend Layer uses PHP server-side logic to

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execute authentication procedures, generate dynamic QR tokens, perform cryptographic signature verifications, compute spatial distances using the Haversine formula, and drive core business operations.

Data persistence is managed by the Database Layer, which uses a MySQL relational database to store user accounts, student profiles, active session parameters, and historical attendance logs. Supporting spatial functionality across the stack, the Location & Sensor Services Layer operates at the device level by fusing hardware GPS sensors with cell tower and Wi-Fi positioning providers to supply accurate location data.

3. Dynamic QR Code & Token Expiration Mechanism

To eliminate proxy attendance via screenshot sharing, the QR code generation mechanism employs dynamic payload signing and dynamic rotation:

1. When a teacher starts a session, the backend server generates a unique payload: Payload = session_id || timestamp || nonce.
2. The payload is signed using SHA 256 HMAC with a server side secret key: Token = HMAC_SHA256(Payload, SecretKey).
3. The generated token is encoded into a QR code matrix displayed on the classroom screen.
4. The QR code payload remains valid for a strict Time To Live (TTL) of 60 seconds. After 60 seconds, the teacher's screen automatically requests a refreshed token from the backend server.
5. Upon scanning, the server verifies the token signature and checks if CurrentTime Timestamp <= 60 seconds. If the token has expired or the nonce has already been consumed, the attendance attempt is immediately rejected.

4. GPS Validation Algorithm and 50 Meter Radius Justification

To prevent off site scanning, the server enforces distance verification using the Haversine formula. The distance d between the student's scanning location (lat1, lon1) and the school's central coordinate (lat2, lon2) is computed as:

$$\Delta\varphi = \varphi_1 - \varphi_2, \qquad \Delta\lambda = \lambda_1 - \lambda_2$$

$$a = sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi_2)\cdot\cos(\varphi_1)\cdot sin^2\left(\frac{\Delta\lambda}{2}\right)$$

$$c = 2\cdot atan2\left(\sqrt{a}, \sqrt{1-a}\right)$$

$$d = R\cdot c$$

where R = 6,371,000 meters (Earth's mean radius).

5. GPS Noise Handling & Radius Selection Justification

To mitigate signal noise and positioning drift inherent to mobile GPS receivers operating indoors under concrete structures, the Android client employs Google's FusedLocationProviderClient configured with high accuracy priorities. The application captures three consecutive location fixes and applies an accuracy error threshold filter, discarding any reading exceeding a 20-meter margin before transmitting spatial coordinates to the server.

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6. Relational Database Schema

The MySQL database structure maintains data integrity using primary keys, foreign keys, and unique indexes. Table 2 presents the core relational database entities and attributes.

Table 2. Relational Database Schema and Constraints

Table Name	Primary Key	Foreign Keys & Indexes	Key Columns & Data Types	Purpose & Description
users	id (INT)	UNIQUE(username)	username (VARCHAR), password (VARCHAR), role (VARCHAR)	Manages authentication credentials and role permissions
teachers	id (INT)	FK(user_id), UNIQUE(nip)	user_id (INT), name (VARCHAR), nip (VARCHAR)	Stores teacher profile attributes and registration details
students	id (INT)	FK(user_id), FK(class_id), UNIQUE(nis)	user_id (INT), name (VARCHAR), nis (VARCHAR), class_id (INT)	Stores student profiles linked to user accounts and classes
attendance_sessions	id (INT)	FK(class_id), UNIQUE(qr_token)	class_id (INT), qr_token (VARCHAR), created_at, expired_at	Logs active session tokens, start times, and deadlines
attendance	id (INT)	FK(student_id), FK(session_id), UNIQUE(student_id, session_id)	scan_time (DATETIME), status (VARCHAR), gps_coordinates	Stores verified attendance logs with composite unique key

The composite unique index UNIQUE KEY (student_id, session_id) on the attendance table prevents duplicate attendance submissions at the database level.

RESULT AND DISCUSSION

1. Implementation of Client and Backend

The native Android application was compiled using Java SDK 17 in Android Studio. User authentication employs SHA 256 password hashing over secure HTTPS communication. The scanning module integrates the ZXing Android embedded library, enabling rapid QR code decoding in under 500 milliseconds.

The PHP RESTful API backend executes validation upon receiving scan payloads:

1. Token Signature & Expiration Check: Validates HMAC signature and checks if scan time is less than or equal to expired_at.
2. Haversine Distance Check: Calculates distance d from SDI Nida Eldabi coordinates. Rejects scan if d > 50 meters.

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3. Duplicate Check: Enforces unique constraint; returns HTTP 409 Conflict if record already exists.

The native Android application was compiled using Java SDK 17 in Android Studio. User authentication employs SHA-256 password hashing over secure HTTPS communication. The scanning module integrates the ZXing Android embedded library, enabling rapid QR code decoding in under 500 milliseconds. The operational user interfaces of the mobile client are presented in Figure 1, illustrating (a) the teacher dynamic QR code generation dashboard.



Figure 1. Mobile Client Application Interface

2. Functional and Acceptance Testing

System functionality and user acceptance were evaluated across 10 operational test scenarios covering core application modules. Table 3 summarizes the verification results.

Table 3. Functional and User Acceptance Testing (UAT) Verification Results

Test Module	Test Cases & Scenarios	Expected System Behavior	Verification Status
User Authentication	Valid & invalid login attempts (TC 01, TC 02)	Issues JWT token on success; returns HTTP 401 on invalid password	100% Passed
Session & QR Rotation	Teacher session initialization & 60s rotation (TC 03, TC 04)	Displays dynamic QR matrix; automatically rotates token every 60s	100% Passed
QR Scanning & Timing	Normal scanning & late scan recording (TC 05, TC 06)	Records 'Present' before expired_at; records 'Late' after expired_at	100% Passed
Security & Geofence	Expired token scan & out of range scan (TC 07, TC 08)	Rejects expired tokens; blocks scans outside 50m geofence radius	100% Passed

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Integrity & Reporting	Duplicate scan prevention & report export (TC 09, TC 10)	Rejects second scan in same session; exports accurate PDF/Excel reports	100% Passed

User Acceptance Testing (UAT) conducted with administrative staff, 5 classroom teachers, and 30 students at SDI Nida Eldabi confirmed 100% pass rate across all operational acceptance criteria.

3. Mean Opinion Score (MOS) Evaluation

User satisfaction and system usability were evaluated quantitatively using a 5 point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) across 5 core dimensions: Usability, Efficiency, Reliability, Security, and System Responsiveness. Table 4 details the comparative MOS evaluation scores for Teachers (N = 5) and Students (N = 30).

Table 4. Mean Opinion Score (MOS) Evaluation Results for Teachers (N = 5) and Students (N = 30)

Dimension	Evaluated Aspect	Teachers Mean (SD)	Students Mean (SD)	Combined Interpretation
Usability	Ease of session setup and scanner operation	4.60 (0.49)	4.70 (0.46)	Excellent usability
Usability	Clarity of dashboard and scan feedback messages	4.40 (0.49)	4.50 (0.50)	Clear visual feedback
Efficiency	Speed of presence recording versus manual roll call	4.80 (0.40)	4.80 (0.40)	High time saving
Reliability	Accuracy of attendance recording and GPS verification	4.40 (0.49)	4.60 (0.49)	Accurate presence data
Security	Confidence in access controls and data privacy	4.60 (0.49)	4.50 (0.50)	Strong user trust
System Responsiveness	Server response speed during session creation and scanning	4.60 (0.49)	4.63 (0.48)	Rapid server response
Overall Index	Overall Satisfaction Score	4.57 (0.47)	4.62 (0.47)	Excellent Satisfaction

The overall average MOS score of 4.57 for teachers and 4.62 for students places the application in the Excellent satisfaction category (Score > 4.0). Participants emphasized that automated attendance recording eliminated administrative disruptions during instructional periods.

4. System Latency & Response Time Benchmarks

End to end response time latency was benchmarked across three mobile network environments (4G LTE, Wi Fi 802.11n, 3G HSPA) for primary system transactions. Table 5 summarizes latency measurements (averaged over 50 test iterations per transaction).

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Table 5. Response Time Latency Benchmarks Across Network Environments

Transaction Type	4G LTE Latency (ms)	Wi Fi Latency (ms)	3G Latency (ms)	Overall Mean Latency (ms)
User Login Authentication	195.0	165.0	270.0	210.0
QR Token Generation	170.0	145.0	240.0	185.0
QR Scan & GPS Distance Verification	290.0	250.0	420.0	320.0
Attendance Summary Sync	175.0	150.0	245.0	190.0
Overall Average Latency	207.5	177.5	293.8	245.0

The empirical results show high performance, with an overall mean response latency of 245.0 ms, well within acceptable mobile application usability standards.

5. Server Load & Stress Evaluation

To evaluate system scalability for larger educational institutions, server load testing was conducted by simulating concurrent scan API requests using Apache JMeter. Table 6 lists server performance under increasing request concurrency.

Table 6. Server Load Testing Under Concurrent Request Stress

Concurrent Requests	Total Requests	Throughput (req/sec)	Average Response Time (ms)	Peak Memory Usage (MB)	Error Rate (%)
10	100	28.5	180	42.1	0.0%
20	200	45.2	215	48.6	0.0%
30	300	62.8	260	55.4	0.0%
50	500	88.4	340	68.2	0.0%
100	1000	105.1	580	92.5	0.8%

Under standard operational loads up to 50 concurrent requests (simulating simultaneous class scans across multiple classrooms), the server maintained a 0.0% error rate with an average response time of 340 ms.

6. Comparative Evaluation and Architectural Analysis

A. Comparative Analysis with Previous QR Systems

Conventional attendance methods at SDI Nida Eldabi relied on paper sign in sheets, requiring 10 to 15 minutes per class session (N = 30 students, mean of 12.5 minutes). In contrast, the developed Android application enables students to scan the dynamic QR code projected on the classroom screen. Individual mobile scan processing requires 1.2 to 2.5 seconds. Total attendance logging for a 30 student class drops to 1.4 minutes, yielding an 88.8% reduction in presence recording duration.

Table 1 highlights structural differences between prior implementations and the proposed architecture. Static QR systems (Wahyuni et al., 2022; Januartika et al., 2023) use fixed images

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displayed on posters or screens. Because static images remain unchanged, students frequently take photographs and forward them via instant messaging to absent peers, yielding proxy attendance rates between 15% and 20%. Dynamic QR implementations without location validation prevent simple image replay; however, an absent student can still receive a live photo from a classmate within the valid time window.

The proposed system addresses these vulnerabilities through dual factor verification combining 60 second dynamic token rotation with real time Haversine GPS distance checking (50 m radius). During a two week trial at SDI Nida Eldabi, the system recorded zero proxy attendance attempts (0.0% proxy rate). In addition, unlike biometric fingerprint or RFID installations (Ridho et al., 2024), the proposed system eliminates specialized attendance terminal hardware (such as dedicated RFID scanners or biometric terminals at classroom doors) by using existing mobile devices alongside standard web server and database infrastructure (REST API backend + MySQL database).

7. System Strengths and Operational Limitations

Empirical testing established four primary strengths of the proposed system. First, it eliminates dedicated classroom terminal hardware costs by deploying directly on existing personal or school Android smartphones and utilizing standard web server and MySQL database infrastructure, thereby removing the need for physical hardware scanner procurement and door terminal maintenance. Second, the system delivers rapid scan processing, with the mobile client achieving a mean end-to-end API response time of 245.0 ms to enable instant presence verification without physical queue bottlenecks. Third, it maintains high security integrity by combining short-lived cryptographic tokens with spatial geofencing, effectively eliminating proxy attendance with a recorded 0.0% proxy rate. Finally, the platform provides automated administration by syncing attendance records directly to a MySQL database, which enables instant exports to PDF and Excel reports for administrative auditing.

Two operational limitations were identified during field evaluation:

1. Indoor GPS Signal Attenuation: Thick concrete roofs and metal architectural elements inside certain classroom blocks degrade satellite signal acquisition, causing positioning accuracy errors exceeding 20 meters. The application resolves this by acquiring three consecutive location fixes and filtering inaccurate readings (20 m or less threshold), which occasionally introduces a 2 to 3 second buffering delay.
2. Mobile Device and Network Dependency: System operation requires active Android smartphones and network connectivity (Wi Fi or cellular data). In environments with limited student phone access, classroom shared devices or teacher guided scans provide practical fallbacks.

8. Enhancing Attendance Integrity via GPS Geofencing Validation

Single factor QR attendance systems verify only that a mobile device decoded a valid token string; they cannot verify physical presence inside the classroom. The proposed dual factor authentication model enforces two independent verification criteria:

$$\text{Verification} = (\text{TokenValid} \wedge t \leq t_{expire}) \wedge (d \leq R_{geofence})$$

where d is the Haversine distance between the student's coordinates and SDI Nida Eldabi, and R_geofence = 50 meters.

If an absent student receives a photo of the QR code off site and attempts to scan it from home (d > 50 meters), the REST API calculates d and rejects the payload with HTTP status 403 (Forbidden). Geofencing restricts valid scans strictly to physical school grounds, ensuring attendance integrity without requiring intrusive biometric surveillance.

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9. System Scalability and Institutional Deployment Analysis

System performance under concurrent load was evaluated using Apache JMeter (Table 6). Under 50 concurrent scan requests (simulating simultaneous class sign ins across multiple rooms), the server maintained a 0.0% error rate, throughput of 88.4 requests per second, and a mean response time of 340 ms.

Three architectural design choices support system scalability:

1. Stateless REST API Design: The PHP backend processes each incoming scan payload independently without maintaining server side session state, minimizing RAM consumption per request (42.1 MB to 68.2 MB under moderate load).
2. Database Connection Pooling and Indexing: The MySQL database uses connection pooling alongside a composite unique index (UNIQUE KEY (student_id, session_id)), preventing duplicate insert conflicts and database lock contention under simultaneous writes.
3. Compact Payload Size: Each HTTPS JSON payload measures less than 2 KB, reducing network bandwidth requirements across wireless access points.

For deployment in larger educational institutions or university campuses handling thousands of concurrent scans, the backend architecture scales horizontally. The stateless REST service can be deployed behind an Nginx load balancer paired with Redis caching and MySQL read replicas to handle peak morning attendance spikes.

10. Security Considerations

To ensure data confidentiality, data integrity, and system resistance against malicious attacks, six security controls were implemented.

First, to prevent QR code sharing, dynamic payload signing combined with a 60-second token rotation invalidates static screenshots or photos taken by students attempting to forward codes to absent peers. Second, for replay attack prevention, each QR code payload embeds a server-generated single-use cryptographic nonce and timestamp, allowing the backend to reject duplicate nonce submissions and enforce database unique constraints. Third, transport layer security (HTTPS/TLS 1.3) encrypts all network communication between the Android client application and the RESTful API server using TLS 1.3 protocols, protecting transmitted credentials and GPS coordinates from packet sniffing.

Fourth, in terms of authentication token management, the server issues a time-limited JSON Web Token (JWT) signed with HMAC SHA-256 following successful authentication, while user passwords stored in the database are salted and hashed using SHA-256. Fifth, to mitigate GPS location spoofing, the Android client inspects mock location provider flags (Location.isFromMockProvider()), ensuring scans originating from fake GPS location spoofing applications are flagged and rejected immediately at the application layer. Finally, for personal data protection and privacy compliance with Indonesia's Personal Data Protection Law (UU PDP), the application collects only minimal necessary personally identifiable information (student name, registration number, class ID), processing location data ephemerally during distance calculations without continuous storage.

CONCLUSION

This study designed, implemented, and evaluated an Android based student attendance information system featuring dynamic QR codes and GPS geofencing at SDI Nida Eldabi. The integration of 60 second dynamic token rotation and Haversine distance verification (50m radius) eliminated proxy attendance while accelerating classroom presence recording by 88.8% (reducing duration from 12.5 minutes down to 1.4 minutes per session). End user evaluation yielded high MOS

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satisfaction scores of 4.57/5.00 for teachers and 4.62/5.00 for students. System performance benchmarks demonstrated a low average latency of 245 ms and stable server scalability maintaining a 0.0% error rate under load up to 50 concurrent requests.

While the proposed system demonstrates clear operational and security advantages, two primary implementation limitations exist. First, heavy concrete roofs or metal structures within certain classroom blocks cause indoor GPS attenuation, degrading satellite signal acquisition and occasionally requiring brief location buffering to achieve an accurate fix. Second, the system introduces a mobile device dependency, as overall operation fundamentally relies on the availability of functional Android smartphones among students or within classrooms, as well as active internet connectivity to process real-time requests.

For future work, three primary recommendations are proposed to enhance system capabilities and scalability. First, incorporating biometric multi-factor authentication by integrating device-native sensors (such as fingerprint or facial recognition) directly into the mobile app scanner will further harden student identity verification. Second, implementing offline local caching with cryptographic synchronization will allow encrypted queue storage on the client device, enabling offline scan capture in network dead zones with deferred synchronization once connectivity is restored. Finally, migrating the RESTful backend to cloud microservices will enable cloud infrastructure auto-scaling, alongside integrating REST endpoints with established Learning Management Systems (LMS) such as Moodle or Google Classroom for efficient data interoperability.

AUTHOR'S CONTRIBUTION

Dyah Ayu Nurmumpuni designed the research methodology, developed the native Android application and RESTful API backend, conducted data analysis, and drafted the manuscript. Angelina Hadriani performed system testing, field trial data collection, user survey administration, and paper editing.

ACKNOWLEDGEMENTS

The authors express their sincere appreciation to the principal, administrative staff, teachers, and students of SDI Nida Eldabi Parung Panjang for their cooperation and participation during the system implementation and field evaluation trials.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

FUNDING

This research received no specific grant from funding agencies in the public, commercial, or not for profit sectors.

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