

Bluetooth-Based Smart Attendance System using BLE and Mobile Devices

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Abstract - This paper presents a Bluetooth-Based Smart Attendance System that automates attendance recording using Bluetooth Low Energy (BLE) technology. Traditional attendance methods are time-consuming and prone to errors such as proxy attendance. The proposed system utilizes the teacher's mobile device as a BLE broadcaster, while student devices scan and detect the signal to confirm their presence. Attendance is marked based on proximity using RSSI (Received Signal Strength Indicator) values along with session-based verification. The system is developed using React Native for the mobile application and Node.js with PostgreSQL for back end services. Experimental results demonstrate improved accuracy, reduced manual effort, and enhanced transparency in attendance management. The system also includes an admin panel for monitoring and analyzing attendance data, making it a scalable and efficient solution for modern educational environments.

Keywords - Bluetooth Low Energy, Attendance System, RSSI, Mobile Application, Proximity Detection, Automation

I. INTRODUCTION

Traditional systems of tracking attendance at educational institutions are inefficient since they rely on manual processes, are error-prone due to human intervention, and involve problems like proxy attendance and faulty data management.

With technological advancements, automated systems such as RFID, biometric authentication, and QR-based solutions have been introduced. Although these improve accuracy, they often require dedicated hardware, involve higher costs, or depend on user interaction. Additionally, biometric systems raise privacy concerns, while QR-based methods are vulnerable to misuse and proxy attendance [1], [4], [8].

To enhance reliability and security, the system incorporates multi-layer verification mechanisms, reducing proxy attendance and unauthorized access [7]. Integration with backend services enables real-time data processing, storage, and analysis, improving transparency in attendance management.

II. LITERATURE REVIEW

Various research efforts have been made to automate attendance systems using different technologies. Traditional methods such as RFID-based systems require dedicated hardware and are costly to implement at scale, while biometric systems provide high accuracy but raise privacy concerns and require physical interaction. QR code-based systems are simple and low-cost; however, they can be easily manipulated and lack real-time automation capabilities [4], [7], [8].

Recent advancements have explored Bluetooth Low Energy (BLE) as a promising solution for attendance automation. BLE offers advantages such as low power consumption, cost-effectiveness, and compatibility with modern smartphones. It enables proximity-based detection without requiring additional infrastructure, making it suitable for scalable and real-time systems [1], [2]. BLE beacon-based approaches, where the teacher device broadcasts signals and student devices scan them, have shown improved efficiency and reduced manual effort [1], [2].

Alternative approaches such as Wi-Fi-based attendance tracking use radio frequency fingerprints to enable zero-effort and privacy-preserving attendance marking, but they depend heavily on infrastructure and may face accuracy challenges [3]. Similarly, face recognition-based systems use AI and computer vision to automate attendance with high accuracy; however, they require significant computational resources and raise privacy concerns [8], [9], [10].

Security-focused methods like two-factor authentication using RFID and biometrics improve reliability but increase system complexity [7], while location-based check-in systems provide flexibility but require additional configuration [5].

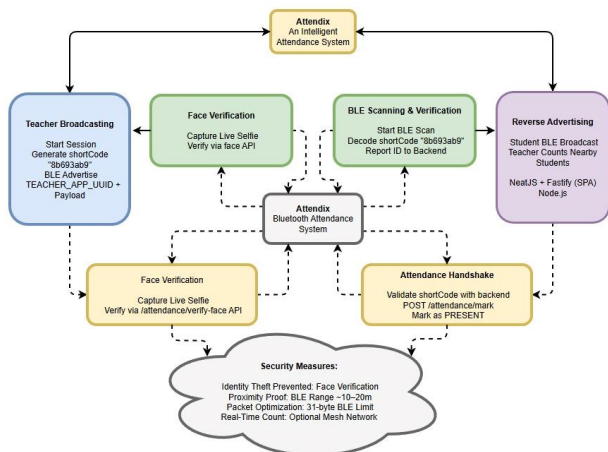
Despite these advancements, existing systems still face challenges such as high cost, infrastructure dependency, privacy concerns, and signal variability. BLE-based systems, although efficient, are affected by environmental interference and RSSI fluctuations [2].

In order to overcome the aforementioned constraints, the suggested architecture integrates proximity detection using Bluetooth Low Energy technology along with session identification, making it both efficient and cost-effective for today's educational systems.

III. PROPOSED SYSTEM

The system is a BLE-based attendance system that utilizes smartphones to automate the process of taking attendance. It uses the teacher's smartphone as the BLE beacon transmitter and broadcasts a unique session ID throughout the classroom. Student devices act as scanners that detect this broadcast signal and use it to confirm their presence within the classroom environment. This approach eliminates the need for additional hardware while ensuring efficient and real-time attendance tracking [2].

The system follows a broadcaster-scanner architecture, where the teacher device operates as a peripheral (advertiser) and student devices function as central scanners. The broadcast packet contains a session-specific encoded identifier, which is detected and decoded by student devices. Upon detection, the student application communicates with the backend server to validate attendance, ensuring a seamless and automated workflow [2].



The overall system architecture consists of three major components:

- **Mobile Application Layer** – Consists of the student and teacher modules, built utilizing React Native technology. The teacher module is charged with initiating the attendance sessions and sending out BLE signals, whereas the student module detects the signals and sends out attendance requests.
- **Backend Server** – Developed using Node.js and Express.js, responsible for handling authentication, session management, and attendance verification logic.

- **Database Layer** – Implemented using PostgreSQL with Prisma ORM, which stores student records, session details, and attendance logs in a structured format.

The teacher conducts an attendance activity by using the application in his/her smart device, and this creates a session id. The session id is encrypted and transmitted using BLE technology. The students' smartphones continue scanning for any BLE transmissions and transmit the session id together with their information.

Attendance marking is performed based on two key conditions:

- **Face Recognition Verification** – Confirms the identity of the student using stored facial encodings.
- **Session ID Matching** – Ensures that the student is connected to the correct and currently active class session.
- **RSSI-Based Proximity Validation** – Ensures that the student is physically present within a predefined range using signal strength (RSSI) values.

To further enhance system reliability and security, an optional identity verification layer can be integrated, such as face recognition or multi-factor authentication techniques, reducing the possibility of proxy attendance [7], [8].

The backend server will analyze the received information to determine if all the necessary requirements are met. If the requirements are fulfilled, the attendance will be registered; if not, the request will be denied.

IV. METHODOLOGY

The design of the suggested Bluetooth-based smart attendance system is done using the spiral model of software development that promotes iterative development and constant risk assessment. This software development approach is very appropriate to be used for the design of a multi-component system like a Bluetooth-based smart attendance system.

The methodology is divided into the following phases:

1. Planning Phase

During this stage, the system requirements and objectives were established according to the shortcomings of the existing attendance system such as laboriousness, proxy attendance, and lack of automation.

The design of the system was based on a Broadcast-Scanner model, where:

- The teacher's device functions as a BLE broadcaster.
- The student's device functions as a BLE scanner.

Requirements that were established include:

- Automatic attendance tracking through BLE proximity
- Live session generation and management
- Secure identification through facial recognition
- Validation on the backend and data storage
- Monitoring through an admin dashboard

The flow chart of the whole system process was developed, which includes login, user role (teacher/students), session generation, and automatic attendance tracking.

2. Risk Analysis Phase

The aim of this stage is to identify the practical problems that arise while designing systems and communicating through BLE.

The major threats are:

- RSSI variation caused by barriers and interference
- Detection errors caused by overlap in BLE signals
- Noise interference with BLE signals
- Identity spoofing (proxy attendance)
- Scalability issues in classrooms with many students

The following techniques were used to avoid the above risks:

- BLE-based proximity authentication
- Session ID verification
- Face verification (identity layer)

In addition, these techniques assure that both presence and identity are genuine.

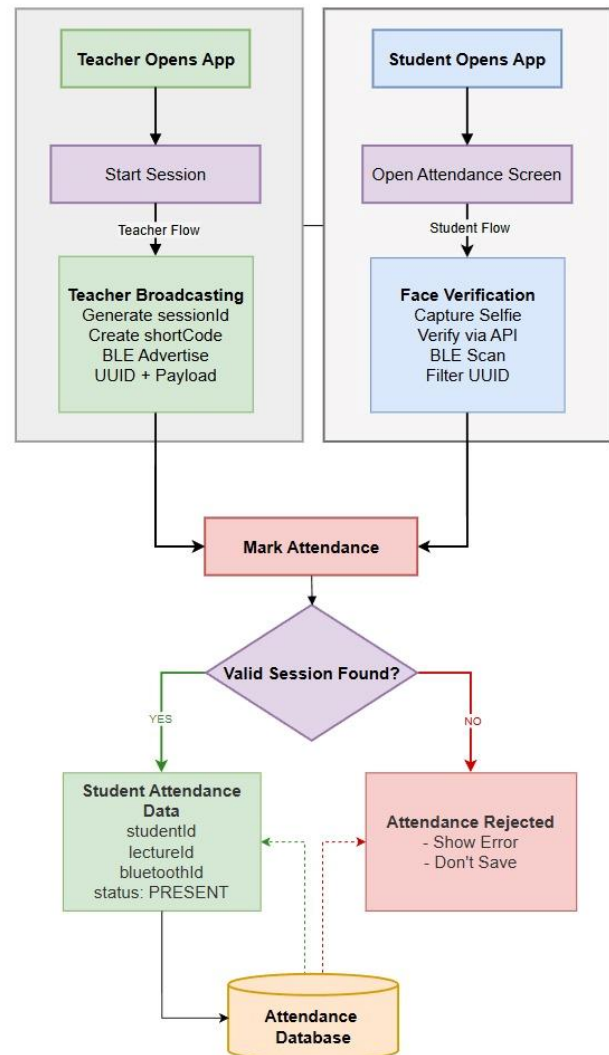
3. Development Phase

The system was developed based on a client-server architecture, integrating mobile applications, BLE communication, backend APIs, and database systems.

Mobile Application Layer

Built with React Native and has two functionalities:

- Teacher App – Starts a session, broadcasts BLE message
- Student App – Detects BLE message, verifies identity, logs attendance



BLE Communication Flow

1. Teacher Broadcasting

- Teacher starts session
- Generates unique session short code
- Broadcasts using BLE (UUID+Payload)

2. Student Verification

- Captures live selfie
- Sends to /attendance/verify-face API

3. BLE Scanning

- Student scans nearby BLE devices and Sends data to backend

4. Attendance Handshake

Backend validates Session ID, Proximity, and Identity

On Valid attendance → Marked as PRESENT

The Backend Layer

Constructed with Node.js and Express.js

Manages the Authentication process, Session control, and Attendance verification

The Database Layer

PostgreSQL with Prisma ORM

Saves Student details, Session information, and Attendance history

4. Evaluation Phase

The system was tested under various real-life situations in order to determine its performance and reliability.

Test conditions included the following:

- Distance variation (BLE range 10-20 meters)
- Indoor environments with interference
- Multiple students scanning simultaneously
- Face verification under different lighting conditions

It has been proven that using the BLE proximity and face authentication significantly decreases proxy participation.

Proximity and Verification Logic

RSSI (Received Signal Strength Indicator) is employed in calculating distances between the teacher's device and the student's device.

Attendance is recorded only when the following criteria are met:

- Session ID Match → correct session for the class
- BLE Proximity Check → student within proximity
- Face Verification → confirms identity

This ensures a secure, tamper-resistant, and accurate system.

Method	Hardware Needed	Security	Scalability
Manual Roll Call	None	Low	Poor
RFID Scan	RFID tags & readers	Medium	Moderate
Fingerprint Biometric	Fingerprint scanners	High	Limited
Face Recognition	Camera + AI software	Medium	Moderate
QR Code Scanning	Smartphone + QR Generator	Medium	Moderate
BLE (Student Broadcast)	Student smartphones	Medium	Limited (scan cap)
BLE (Teacher Broadcast)	Teacher smartphone only	High	High

System Interaction Flow

As per the architectural flow, the operations involved are as follows:

- Teacher starts session through mobile app
- Bluetooth Low Energy signal is transmitted
- Signal is detected by student's app
- The data is sent to backend server
- Conditions are verified
- Attendances are stored in the database
- Attendances can be viewed from the admin panel

Apart from this, the application also supports reverse advertising mode where student's device broadcasts signals that enable teacher's device to detect the number of students nearby.

V. LIMITATIONS

- Unstable RSSI in Real-World Settings
The signal strength of BLE varies depending on factors such as the presence of walls, crowd density, and phone orientation, affecting proximity detection accuracy.
- Device Limitations
Various mobile phones differ in their Bluetooth and camera abilities, resulting in different proximity detection and face recognition outcomes.
- Battery Drainage
The constant scanning and broadcasting process, alongside the use of the camera for face recognition, will drain the battery life of student devices.

- Face Recognition Challenges
Accuracy may be compromised by insufficient lighting, low-quality camera lenses, and incorrect face positions.
- Network Requirement for Verification
Internet connection is necessary for backend validation and face recognition.

VI. FUTURE SCOPE

- Improve proximity accuracy using AI/ML-based RSSI analysis
- Deploy system on cloud infrastructure for large-scale usage
- Implement hybrid positioning systems (BLE + Wi-Fi / GPS)
- Develop advanced analytics dashboard for attendance insights
- Add predictive analysis to identify low-attendance students
- Optimize system for low battery consumption
- Extend support to iOS platform for cross-platform compatibility and wider adoption

VII. CONCLUSION

The BLE-enabled smart attendance tracking system presented in this paper provides an efficient, robust, and scalable method for automating attendance in academic institutions. The system leverages the teacher's smartphone as a BLE beacon and the students' smartphones as BLE scanners, enabling real-time attendance tracking without additional hardware.

By incorporating RSSI-based proximity sensing and face recognition for authentication purposes, the BLE-enabled smart attendance tracking system ensures that attendance is logged exclusively by the presence of the students.

In summary, the BLE-enabled smart attendance tracking system discussed in this paper is a practical application of BLE technology combined with advanced verification techniques.

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