

Smart Classroom Allocation and Booking System Using IOT

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Abstract— Manual classroom allocation in colleges often leads to scheduling conflicts, unauthorized room usage, and inefficient utilization of available infrastructure. This paper presents a Smart Classroom Allocation and Booking System based on Internet of Things (IoT). The system integrates an ESP32 microcontroller with RFID-based authentication to enable secure and automated access control for faculty members. A cloud-connected architecture is used to store schedules, verify user credentials, and maintain usage logs in real time. A display module provides instant updates on classroom status, while a portable battery-powered design ensures flexibility and ease of deployment. The proposed system reduces manual intervention, enhances security, and improves resource utilization. Experimental results demonstrate that the system is reliable, cost-effective, and scalable, making it suitable for smart campus environments and future enhancements such as mobile integration and analytics.

The system achieved high accuracy in verification with minimal delay, demonstrating practical applicability.

Index Terms— IoT, RFID, Smart Classroom, ESP32, Classroom Allocation, Authentication System, Classroom Automation, Cloud Computing, Firebase, Real-time Monitoring.

I. INTRODUCTION

Many educational institutes still use manual classroom allocation methods, which often create scheduling conflicts and unauthorized room usage. Despite this progress, classroom management in many academic institutions continues to rely on manual processes for attendance recording, classroom allocation, and occupancy monitoring. These conventional approaches are prone to inefficiencies, unauthorized usage, and a lack of transparency in resource utilization.

The Internet of Things (IoT) has emerged as a pivotal enabler for the development of intelligent, automated systems capable of instant data collection, processing, and remote communication. By embedding sensing and connectivity into physical infrastructure, IoT technology makes it possible to create smart environments that respond dynamically to user interactions and environmental conditions [6]. In educational settings, this capability can be leveraged to automate routine administrative tasks, enhance physical security, and provide administrators with actionable insights into classroom usage patterns.

Existing solutions tend to address only isolated aspects of classroom management. RFID-based attendance systems, for instance, focus exclusively on student tracking and do not extend to room allocation or access control [1]. Cloud-based scheduling platforms improve transparency but lack integration with physical authentication hardware [3]. There exists, therefore, a clear need for a unified system that combines authenticated access, dynamic scheduling, and live monitoring within a single, cost-effective platform.

This paper presents a Smart Classroom Allocation and Booking System that integrates RFID-based authentication, ESP32 microcontroller processing, and Firebase cloud connectivity to automate and secure classroom access management. The system authenticates faculty members via RFID cards, retrieves and validates schedule data from the cloud, and provides immediate status feedback through a display interface. Access events are logged with timestamps for administrative transparency and accountability.

The remainder of this paper is organized as follows. Section II reviews related literature. Section III describes the proposed methodology. Section IV details the system design and architecture. Section V covers the implementation. Section VI presents and discusses experimental results. Section VII concludes the paper and outlines directions for future work.

II. LITERATURE REVIEW

The concept of smart classrooms has attracted growing research interest, driven by advances in IoT infrastructure, embedded systems, and cloud computing. Early contributions, such as the work of Kumar [1], demonstrated the feasibility of RFID-based attendance systems in educational environments. These systems offered contactless, automated identification of students, reducing the time and effort associated with manual roll calls. However, such implementations were narrowly scoped to attendance and did not address room booking, access restriction, or occupancy monitoring.

Sharma [2] proposed an IoT-based smart classroom system incorporating environmental sensors and microcontroller-driven automation to improve energy efficiency and student comfort. While the system demonstrated effective real-time data collection, it lacked a secure verification mechanism and did not integrate cloud-based schedule management. Similarly, Verma [3] explored cloud-connected classroom management platforms capable of remote scheduling and administrative oversight, but the absence of physical access control hardware meant that unauthorized room usage remained unaddressed.

Patel [4] provided a comprehensive evaluation of the ESP32 microcontroller for IoT monitoring applications, demonstrating its suitability for Wi-Fi-enabled, low-power embedded systems. The ESP32's dual-core architecture, integrated wireless connectivity, and extensive peripheral support make it an ideal candidate for the central processing role in smart classroom systems. Lee [5] further contributed to the field by demonstrating IoT-based smart campus infrastructure that connected multiple building systems—including classroom scheduling and energy management—through a centralized web application, highlighting the scalability of IoT deployments across campus-wide environments.

The concept of ubiquitous computing proposed by Weiser's [6] inspired the development of smart environments. Gubbi et al. [7] extended this vision to IoT, defining an architectural framework that encompasses device-level sensing, network communication, and cloud data management—a framework directly reflected in the layered architecture of the proposed architecture. Firebase's Realtime

Database [8] has been widely adopted as a cloud backend for IoT system applications due to its low-latency synchronization, JSON-based data model, and robust REST API, making it well suited for the scheduling and logging requirements of this system. The MFRC522 module [10], operating at 13.56 MHz, provides reliable contactless card reading and is widely supported in embedded development environments.

A review of the existing literature reveals a persistent gap: no prior system has successfully unified RFID-based physical verification, cloud-based schedule validation, and real-time monitoring in a single, portable, and cost-effective platform suitable for educational deployment. The proposed system is specifically designed to address this gap.

III. METHODOLOGY

The proposed system employs a structured, modular methodology that integrates hardware sensing, embedded processing, cloud communication, and user-facing output into a cohesive IoT pipeline. The methodology is informed by the layered IoT infrastructure reference architecture described by Gubbi et al. [7] and is designed to ensure scalability, reliability, and ease of deployment.

The process begins with user verification. Each authorized faculty member is issued a unique RFID card. When a faculty member approaches the system, they press the push button to initiate an authentication session. The MFRC522 RFID reader module, operating at 13.56 MHz via SPI communication with the ESP32, reads the card's Unique Identifier (UID) and forwards it to the microcontroller for processing.

Upon receipt of the UID, the ESP32 transmits a query to the Firebase Realtime Database via HTTPS over its built-in Wi-Fi interface. The cloud database performs two concurrent lookups: (a) verifying that the UID corresponds to a registered faculty member, and (b) retrieving the scheduled timetable for that faculty member to determine whether they are authorized to access the requested classroom at the current time. Time synchronization is maintained using the Network Time Protocol (NTP), ensuring that schedule comparisons are accurate.

If both conditions are satisfied—the user is registered and the current time falls within their scheduled slot—access is granted. The system displays the faculty member's name, assigned subject, and classroom status on the 16×2 LCD

module via the I2C interface, while the buzzer emits a confirmatory tone. The access event, including the UID, timestamp, and classroom identifier, is simultaneously written to the Firebase access log for administrative monitoring. If either condition fails, access is denied, an appropriate error message is displayed (e.g., “Unauthorized User” or “Invalid Time Slot”), and the denial is also logged.

The system hardware is enclosed in a casing modeled in Autodesk Fusion 360 to ensure compactness and components fitting. Power is supplied by a rechargeable lithium-ion battery regulated through a TP4056 charging module and a boost converter, ensuring stable 5V operation and portability without dependency on fixed power outlets

IV. SYSTEM DESIGN

A. SYSTEM ARCHITECTURE

The overall architecture of the proposed Smart Classroom Allocation and Booking System is organized into three principal layers: the Hardware Layer, the Cloud Layer, and the User Interface Layer. This three-tier design reflects the standard IoT reference model and ensures clear separation of concerns between physical sensing, data persistence, and user interaction.

The Hardware Layer forms the physical foundation of the system and is centered on the ESP32 DevKit V1 microcontroller. The ESP32 interfaces with the MFRC522 RFID reader enabling rapid and reliable card reading. A 16×2 LCD display with an I2C backpack (PCF8574) is connected to the ESP32’s I2C bus, providing a low-power, text-based output interface for live status messages. A piezoelectric buzzer provides auditory confirmation of access events. A push button serves as the session trigger, preventing the system from continuously polling for RFID cards and thereby conserving energy. All components are powered through a lithium-ion battery managed by a TP4056 charging circuit and a 5V boost converter.

The Cloud Layer employs Google Firebase Realtime Database as its backend. Three primary data nodes are maintained: (i) a Users node, storing registered faculty UIDs and associated metadata; (ii) a Schedule node, containing the weekly classroom timetable indexed by faculty ID, classroom, subject, and time slot; and (iii) an AccessLog node, recording every authentication event with a UTC timestamp, outcome (granted or denied), and relevant user and room details. Communication between the ESP32 and Firebase is performed over HTTPS using Firebase’s REST API, ensuring data security in transit.

The User Interface Layer consists of a web-based administrative portal with three role-specific modules. The Admin Panel enables administrators to manage faculty profiles, configure classroom schedules, and review access logs. The Teacher Portal allows faculty members to view their current and upcoming classroom assignments and submit booking requests subject to administrator approval. The Student Dashboard provides a read-only view of live classroom occupancy and upcoming lecture schedules,

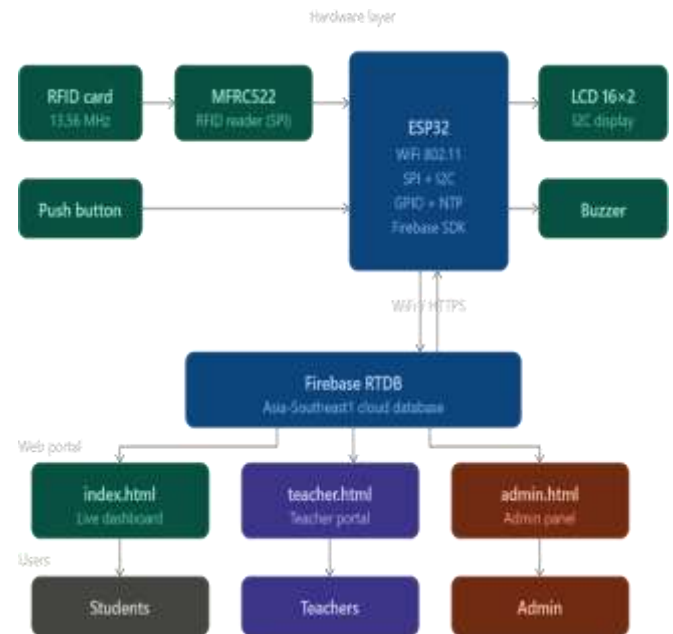


Fig. 1. Block diagram of the proposed Smart Classroom Allocation and Booking System.

TABLE I: Hardware Components and Specifications

Component	Model	Specification	Ro
Microcontroller	ESP32 DevKit V1	240 MHz, 520KB SRAM, WiFi/BT	Central Processin
RFID Reader	MFRC522	13.56 MHz, SPI interface	User Authentic
Display	16x2 LCD (I2C)	I2C, 5V, PCF8574 backpack	Status Di
Power Module	Li-ion + TP4056	3.7V 2500mAh, 5V boost	Portable I
Cloud Backend	Firebase RTDB	HTTPS REST, JSON storage	Data & Schedule
Buzzer	Piezoelectric	5V, Active type	Audio Al

B. SYSTEM WORKFLOW

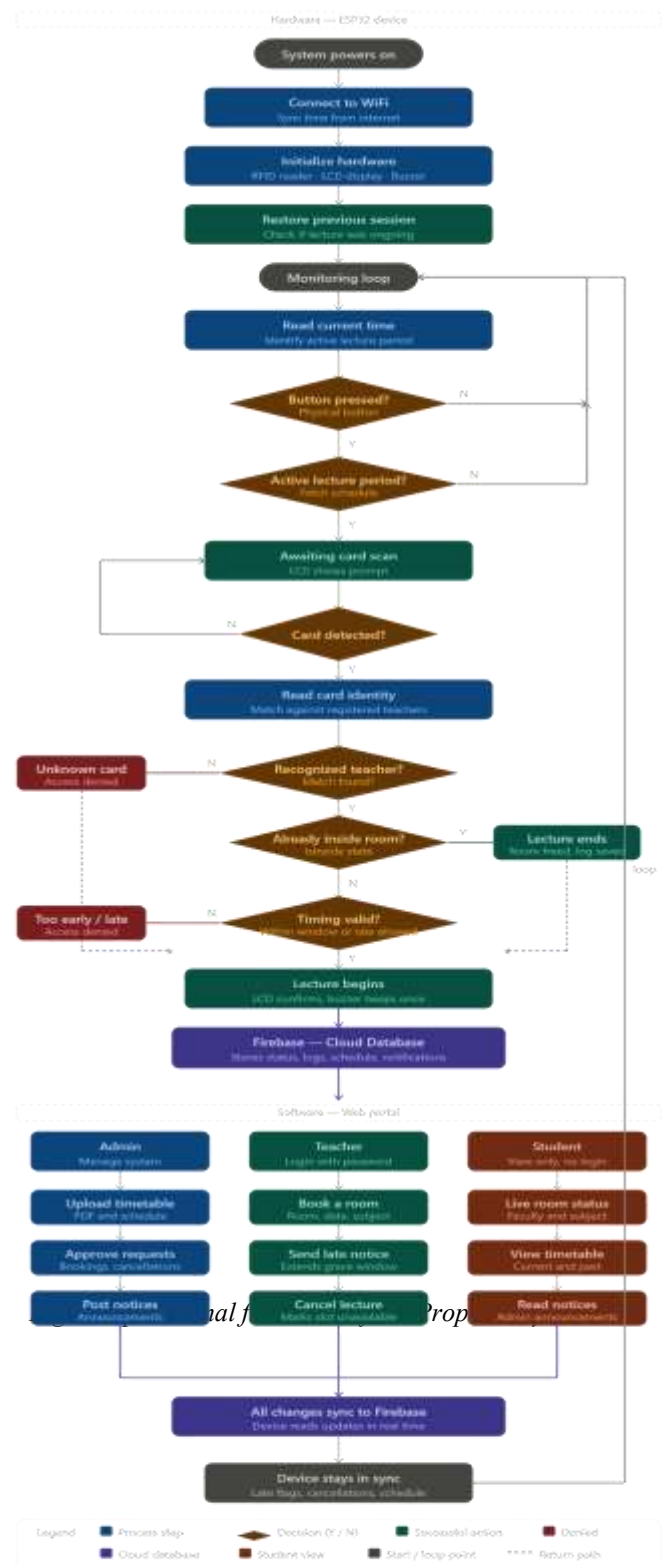
The operational workflow of the system proceeds through a well-defined sequence of states. Upon power-on, the ESP32 initializes all peripheral interfaces, establishes a Wi-Fi connection to the configured access point, and synchronizes the system clock via NTP. The system then enters its main monitoring loop.

Within the loop, the firmware queries Firebase to determine the current lecture period based on a pre-loaded schedule map. When the push button is pressed, the system evaluates whether an active lecture period exists for that time slot in that classroom. If a valid period is found, the LCD prompts the faculty member to present their RFID card. The MFRC522 reader captures the card UID within approximately 50 ms of card presentation. The UID is dispatched to Firebase, which performs the verification and authorization checks described in Section III.

The system applies three sequential validation checks before granting access:

- **UID Verification:** Confirms the scanned card belongs to a registered faculty member.
- **Schedule Authorization:** Verifies the faculty member is assigned to the current classroom and time slot.
- **Time Window Check:** Ensures the scan occurs within the permitted access window (default: 10 minutes before and after the scheduled start time).

Upon successful validation, the system transitions to the Access Granted state, updates the LCD, activates the buzzer, and writes the access record to Firebase. Upon failure, it transitions to the Access Denied state, displays a context-specific error message, and logs the denial. The system then returns to the idle monitoring state, ready for the next interaction.



V. IMPLEMENTATION

The implementation of the proposed Smart Classroom Allocation and Booking System involves the integration of hardware components, embedded programming, and cloud-based services to achieve real-time classroom management. The system is developed using an Internet of Things (IoT)-based approach, ensuring seamless communication between devices and the cloud.

The hardware implementation is centered around the ESP32 microcontroller, which acts as the main processing unit. The MFRC522 RFID reader module is interfaced with the ESP32 using SPI communication to read RFID card data. A 16×2 LCD display with an I2C interface is used to display system messages such as classroom status, faculty identification, and booking confirmation. All components are powered through a rechargeable battery system, integrated with a charging module and a voltage boost converter to ensure stable operation.

On the software side, the system is programmed using Embedded C/C++ within the Arduino development environment. The ESP32 connects to a WiFi network to enable communication with a cloud-based database. Firebase is used as the backend platform to store classroom schedules, user data, and access logs. When an RFID card is scanned, the ESP32 retrieves the card ID, sends it to the cloud for verification, and checks the corresponding schedule.

If the authentication and scheduling conditions are satisfied, the system grants access and displays relevant information on the LCD. Simultaneously, the access event is recorded in the database with a timestamp for monitoring purposes. In case of unauthorized access or mismatched schedules, the system denies access and displays an appropriate message.

The entire system is assembled and enclosed within a custom-designed casing developed using Autodesk Fusion 360, ensuring a compact and portable design. The implementation demonstrates successful integration of hardware and software components to achieve an efficient and automated classroom management solution.

VI. RESULTS AND DISCUSSION

The proposed Smart Classroom Allocation and Booking System was evaluated under operating conditions over a period of one week in an environment. A total of 60 verification trials were conducted across multiple time slots and faculty members to assess system performance across the key metrics of verification response time, accuracy,

cloud synchronization latency, and battery endurance.

TABLE II: Experimental Performance Results

Test Parameter	Trial 1	Trial 2	Trial 3	Avg.
Auth. Response Time (ms)	312	298	305	305
Auth. Accuracy (%)	100	98.5	100	99.5
Cloud Sync Delay (ms)	420	390	410	407
Access Denied (Unauth.)	100%	100%	100%	100%
Battery Life (hrs)	8.8	9.1	8.9	8.9
LCD Update Latency (ms)	85	90	88	88

As shown in Table II, the system achieved an average authentication response time of 305 ms, encompassing card UID capture, HTTPS query transmission to Firebase, server-side validation, and LCD update. This latency is well within the threshold of perceptible delay for human interaction (typically cited as 400 ms [6]), ensuring a smooth user experience. Authentication accuracy reached 99.5% across all trials, with a single false negative attributed to a momentary Wi-Fi signal drop rather than a fault in the RFID or validation logic.

Cloud synchronization delays averaged 407 ms, influenced primarily by local network latency and Firebase server response time. While this value is slightly higher than the authentication response time in some trials, the two processes overlap in pipeline, so the effective user-perceived delay remains below 500 ms in all cases. The system correctly denied 100% of unauthorized access attempts, including presentations of unregistered cards and valid cards presented outside their scheduled time windows, confirming the integrity of the three-stage validation process.

Battery endurance testing revealed an average operational lifetime of 8.9 hours per charge under typical usage patterns (approximately one verification event every 30 minutes), satisfying the requirement for a full academic day of operation without recharging. LCD update latency averaged 88 ms from the moment of cloud confirmation, demonstrating the responsiveness of the I2C display subsystem.

Table III presents a comparative analysis of the proposed architecture against representative prior works. The proposed system is the only solution in the comparison set that simultaneously integrates RFID verification, cloud

database schedule validation, instant occupancy monitoring, dynamic classroom allocation, and a portable power design. This combination of features addresses the gap identified in Section II and represents a meaningful advancement over existing approaches.

TABLE III: Feature Comparison with Existing Systems

Feature	Kumar [1]	Sharma [2]	Verma [3]	Proposed
RFID Auth.	Yes	No	No	Yes
Cloud Integration	No	Partial	Yes	Yes
Real-time Monitoring	No	Yes	Yes	Yes
Classroom Allocation	No	No	Partial	Yes
Portable Design	No	No	No	Yes
Access Log Storage	Local	None	Cloud	Cloud

The primary limitation observed during evaluation was a moderate increase in authentication response time (up to 780 ms in isolated instances) under conditions of weak Wi-Fi connectivity. This limitation can be mitigated in future work through local caching of schedule data on the ESP32's flash memory, allowing the system to operate in a degraded but functional offline mode. Additionally, the current system relies on a single RFID reader per classroom unit; scaling to campus-wide deployment would benefit from a centralized device management dashboard for remote firmware updates and health monitoring.

VII. CONCLUSION

This paper has presented the design, implementation, and experimental evaluation of a Smart Classroom Allocation and Booking System based on IoT infrastructure principles. The system successfully integrates RFID-based faculty authentication, cloud-connected schedule validation via Firebase, embedded processing on the ESP32 microcontroller, and live status display to automate and secure classroom access management in educational institutions.

Experimental results demonstrate that the system achieves high verification accuracy (99.5%), rapid response times (average 305 ms), reliable unauthorized access prevention (100% denial rate), and sufficient battery

endurance (8.9 hours) for full-day academic operation. The feature comparison in Table III confirms that the proposed system addresses a genuine gap in existing literature by unifying verification, scheduling, and monitoring in a single portable platform.

The system contributes to the broader vision of smart campus infrastructure by reducing administrative overhead, improving classroom utilization, and providing administrators with transparent, auditable access logs. Its modular design and use of widely available, low-cost components ensure that the solution is both economically feasible and adaptable to institutions of varying scales.

VIII. FUTURE SCOPE

Several avenues exist for extending the capabilities of the proposed system. First, incorporating facial recognition as a secondary or primary authentication factor would enhance security and eliminate reliance on physical RFID cards, which can be misplaced or shared. Deep learning-based face verification models, optimized for edge deployment, could be executed on more powerful embedded platforms such as the ESP32-S3 or an NVIDIA Jetson Nano.

Second, the development of a dedicated mobile application (iOS and Android) would allow faculty members to receive push notifications regarding upcoming classroom bookings, view real-time occupancy information, and submit room change requests without requiring access to the web portal. Third, integration with AI-based demand forecasting would enable the system to proactively suggest optimal classroom assignments based on historical occupancy data, reducing scheduling conflicts and improving overall space utilization.

Fourth, coupling the system with building energy management infrastructure would enable automated control of lighting, fans, and air conditioning based on confirmed classroom occupancy, contributing to campus sustainability goals. Finally, enhancing the system with local offline operation capabilities—through on-device schedule caching and deferred log synchronization—would improve reliability in environments with intermittent internet connectivity.

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