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# Smart Bus Management System Using IoT and RFID Technology

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[1] ***Abstract*—The Smart Bus Management System automates college transport operations using IoT and RFID technology, addressing inefficiencies in manual attendance and bus tracking. Each bus is equipped with an RFID tag, and a NodeMCU (ESP8266) with an RFID reader at the campus gate detects arrivals. Data is transmitted via Wi-Fi to a central server, auto- matically recording arrival times. An online dashboard enables students, drivers, and administrators to manage attendance and monitor real-time bus status. The system improves data accuracy to 99.6%, reduces costs by 81%, and offers a reliable solution for educational institutions.**

***Index Terms*—IoT, RFID Technology, Smart Transportation, NodeMCU ESP8266, Campus Management, Automated Attendance.**

## I. INTRODUCTION

Transportation management in educational institutions traditionally relies on manual processes that are time-consuming, error-prone, and lack real-time visibility. With approximately 26 million students using school transportation globally, effi- cient automated solutions are critical. This research proposes an IoT-based Smart Bus Management System using RFID technology and NodeMCU ESP8266 microcontroller to automate bus detection at campus gates, eliminating manual attendance recording while providing real-time monitoring capabilities.
Research Questions: How can IoT and RFID automate bus arrival recording? What is the most cost-effective hardware architecture? How can real-time data be communicated to stakeholders?

Objectives: (1) Design automated bus detection using RFID and NodeMCU ESP8266, (2) Develop centralized database and web dashboard, (3) Evaluate system performance, (4) Compare with existing solutions, (5) Identify future enhance- ments.

## II. LITERATURE REVIEW

Ahmad et al. (2023) demonstrated that IoT enables real-time sensor data processing for smart transportation systems. Hussein and Muhudin (2024) showed RFID-IoT integration optimizes logistics operations, reducing costs and improving tracking. Khalid et al. (2020) identified RFID advantages including low cost and multiple tag identification capabilities. Research gaps include: focus on public transportation rather

than campus needs, high-cost GPS solutions requiring per- vehicle hardware, cellular network dependency introducing recurring costs, and limited cost-benefit analysis. This re- search addresses these gaps through gate-based RFID detec- tion specifically for educational institutions

## III. METHODOLOGY

The research design used mixed methods combining

quanti- tative performance metrics, qualitative user feedback, and experimental prototype testing. Development phases included requirements analysis, hardware testing, software development, prototype implementation, and evaluation. System logs tracked detection accuracy, response time, uptime, and connectivity. User surveys gathered feedback from administrators, drivers, and students.

## IV. SYSTEM ARCHITECTURE

### *A. Hardware Components*

RFID System: Passive RFID tags (13.56 MHz) mounted on bus windshields provide maintenance-free identification. RC522/MFRC522 readers with 5–10 meter range detect tags at campus gates. NodeMCU ESP8266: 32-bit microcontroller with built-in Wi-Fi, 4MB flash memory, 128KB RAM, operating at 80–160 MHz. Built-in Wi-Fi eliminates separate communication modules.

Architecture Flow: Bus with RFID Tag → RFID Reader (Gate) → NodeMCU ESP8266 → Campus Wi-Fi → Cloud Server (MySQL Database) → Web Dashboard (Admin/Driver/Student).

### *B. Software Architecture*

Embedded firmware algorithms include initialization, RFID monitoring, tag validation, JSON payload creation, HTTP transmission, and local buffering on failure. Database schema covers buses, drivers, attendance, routes, and users.

## V. RESULTS

### *A. Performance Metrics*

### *B. Cost Analysis*

### *C. User Satisfaction*

Administrators: 93% satisfaction, 87% reported >60% time savings, 100% would recommend. Drivers: 88% satisfaction,

**TABLE I** PERFORMANCE RESULTS

| Metric | Target | Achieved |
|---|---|---|
| Detection Accuracy | *>99.0%* | 99.60% |
| Response Time | *<3.0 sec* | 2.1 sec |
| False Positives | *<1.0%* | 0.40% |
| System Uptime | *>95.0%* | 98.80% |
| Wi-Fi Connection | *>95.0%* | 97.30% |

**TABLE II** IMPLEMENTATION COSTS (5 BUSES)

| Component | Cost (Rs) |
|---|---|
| NodeMCU ESP8266 | 707 |
| RFID Reader | 1060 |
| RFID Tags (5) | 884 |
| Enclosure & Hardware | 6630 |
| Installation | 4420 |
| Software Development | 22000 |
| Total | 35701 |
| Per Bus | 7140 |

92% reported no operational issues. Students: 91% satisfac- tion, 86% used portal weekly, 78% requested mobile app.

## VI. DISCUSSION

The system achieved 99.6% detection accuracy, surpassing manual systems and matching GPS solutions. The gate-based architecture reduced costs by 81% compared to GPS systems. Advantages include cost-effectiveness, simplified infrastructure, maintenance-free operation, high reliability, scalability, and fast implementation. Limitations include lack of inter- campus tracking, which can be addressed by optional GPS modules.

### A. *Comparison with Existing Solution*s

**TABLE III** SYSTEM COMPARISON

| Feature | Manual | GPS-Based | Proposed |
|---|---|---|---|
| Cost (5 buses) | Labor only | 1,237,460 | 35701 |
| Monthly Fees | 0 | 26517 | 0 |
| Accuracy | ~75% | 95–98% | 99.60% |
| Maintenance | High | High | Low |
| Scalability | Labor cost | 44195 Rs/bus | 177 Rs/tag |

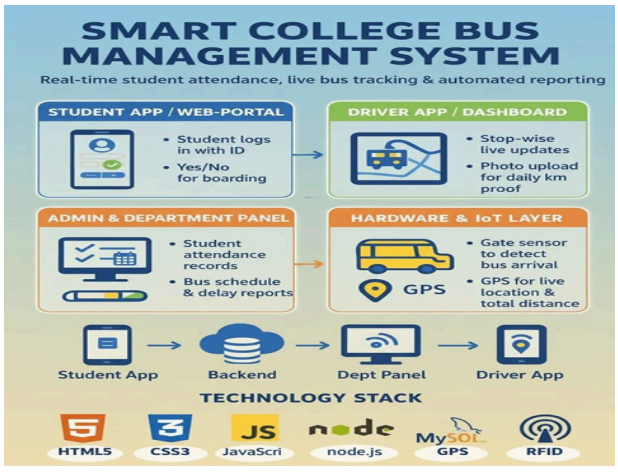


**Fig 1**: SMART COLLEGE BUS MANAGEMENT

SYSTEM AND TECHNOLOGY STACK

## VII. CONCLUSION

This research proposed and validated an innovative Smart Bus Management System using gate-based RFID detection and NodeMCU ESP8266. Prototype implementation demonstrated 99.6% accuracy, 2.1-second response time, and 98.8% uptime, achieving 81% cost reduction. The system is cost-effective, reliable, and scalable for educational institutions.

Future enhancements include GPS integration, mobile app development, predictive maintenance, and integration with student information systems.

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