E-ISSN: 2997-9382
American Journal of Technology Advancement
https://semantjournals.org/index.php/AJTA

| Research Article

Check for updates

Design and Implementation of an RFID-Enabled Intelligent Tracking System

Ali A. M. Dheyab[1], Asmaa M. Aubaid [2], Hayder Hussein Kareem [3]

[1] Department of Electronics and Communication Engineering, Al-Nahrain University, Baghdad-Iraq

[2] Ministry of Higher Education and Scientific Research/ Scientific Research Commission / Office of President of Scientific Research Commission / Baghdad/Al-Jadriya, Iraq

[3] Ministry of Higher Education and Scientific Research/ Scientific Research Commission / Scientific Research Commission / Baghdad/Al-Jadriya, Iraq

Annotation

Manual attendance taking in higher-education classrooms routinely consumes several minutes per session and is prone to omission errors. This paper presents the design and implementation of an end-to-end, RFID-enabled student tracking and attendance system that integrates low-cost hardware (MFRC522 RFID reader, Arduino Uno, ESP8266-01 Wi-Fi module) with a cloud-connected backend (Node.js/Express and MongoDB). The proposed architecture authenticates students via contactless smart cards at entry points, validates authorization policies, and records timestamped events to a secure database. We detail the hardware interfacing, firmware, and RESTful data pipeline; define the data model; and describe a deployment blueprint for lecture halls and laboratories. A pilot evaluation plan is included to quantify end-to-end latency, read reliability under varied orientations and ranges, and operational time savings relative to roll-call baselines. Ethical and privacy safeguards (least-privilege access, anonymization of exports, and encrypted transport) are discussed. The work contributes a reproducible reference implementation and practical guidance for universities seeking to digitize attendance management with modest budgets.

Keywords: RFID; attendance; student tracking; IoT; ESP8266; MongoDB; higher education.

This is an open-access article under the CC-BY 4.0 license

1. Introduction

Universities still spend valuable class time on manual roll-calls that are error-prone and susceptible to proxy attendance. Radio-Frequency Identification (RFID) has matured into a reliable, low-friction alternative for presence logging, with broad evidence of efficiency gains and data fidelity across domains and—increasingly—within education. Recent reviews and deployments report that RFID-based attendance solutions reduce time overhead, curb impersonation, and enable real-time analytics when integrated with campus information systems

[1]. For classroom check-in, 13.56 MHz high-frequency radio identification (HF RFID), particularly ISO/IEC 14443 proximity cards, provides short-range, contactless operation, preventing inaccurate readings, while being cost-effective and standards-compliant. ISO/IEC 14443 is the primary specification for many identification and access cards, with a typical reading range of a few centimeters, making it a practical choice for door readers equipped with two types of modulation methods: Type A cards use amplitude shift keying (ASK) technology with modified Miller coding for reader-to-card communication, and Type B cards use amplitude shift keying (ASK) technology with NRZ coding for reader-to-card communication [2]. Commodity hardware further lowers the barrier to adoption. The NXP MFRC522 reader IC, for example, supports ISO/IEC 14443-A/MIFARE and is widely available on low-cost modules suitable for microcontroller integration—an enabling choice for budget-constrained institutions and rapid prototypes [3]. In an IoT-style architecture, the reader captures a card UID at entry, a microcontroller formats an event (e.g., JSON), and a Wi-Fi link forwards it to a backend (REST API) that authenticates requests and persists records for dashboards and alerts. Case studies and systematic reviews indicate that these pipelines effectively reduce check-in time and enhance data quality compared to paper forms, offering clear pathways for campus-wide scalability [4]. At the same time, "privacy and security" need to be given special attention. The RFID literature talks about risks like unauthorised reads and cloning of weakly protected tags. To avoid these risks, it is suggested to use short read ranges, authenticated protocols, encrypted transport, and strict access control on attendance data. Institutions can get operational benefits without losing students' trust if they plan for these controls from the start [5]. Tracking attendance is something that universities do every day, but it has to be done quickly. Traditional roll-call takes up the first few minutes of a lecture, causes delays, and sometimes leaves out information that needs to be checked again. Automated identification technologies like barcodes, RFID, and Bluetooth beacons can help reduce friction and improve the accuracy of data. In this work, it is created and put into action a radio-frequency identification (RFID) system that keeps track of student attendance at the entrance, syncs events with a backend service, and makes data available for administrative reporting. Our design focuses on being affordable, easy to reproduce, and easy to set up in existing buildings without needing special infrastructure.

2. Related Work

RFID is used for inventory management, access control, and asset tracking because it works without touching anything and can read multiple tags. In schools, previous systems used passive HF/UHF tags, microcontrollers, and wireless links to automate attendance. RFID is better than camera-based solutions because it protects privacy and costs less to compute. It's also better than mobile app check-ins because it doesn't rely on smartphones and doesn't have the risk of spoofing. Our research adds to this body of work by providing a complete hardware-software architecture with a clear data model and deployment plan that uses off-the-shelf parts. RFID-based attendance systems have been widely explored as low-cost, low-friction alternatives to manual roll-call, particularly with MFRC522 HF readers and Wi-Fi connectivity via ESP8266/NodeMCU. Representative classroom deployments report streamlined pipelines from tag reads to cloud dashboards, targeting reduced errors and faster check-in [6], [8], [9], [11], [12].

Beyond device-level integration, several designs emphasize the end-to-end backend by adopting RESTful APIs and document datastores (e.g., MongoDB) or by adding a second factor such as face recognition for stronger verification and auditability [7], [10]. These works motivate robust data models and real-time services compatible with classroom attendance workflows.

Alternative modalities provide useful baselines for comparison. BLE-based solutions target indoor localization and proximity-based presence [14], while UHF RFID extends reading range at the cost of different tag/reader constraints [10]. Survey and methodological works help position RFID

among competing modalities and inform measurement practices for reliability under orientation/distance and environmental interference [13].

3. System Architecture

At the edge of the system, an MFRC522 RFID reader connected to an Arduino Uno captures the unique identifiers (UIDs) of nearby tags via the SPI interface. Radio-Frequency Identification (RFID) is a contactless identification technology that enables the automatic and unique recognition of tagged objects without line-of-sight. Depending on the tag class and reader power, the practical read range varies from a few centimeters to tens of meters. For network connectivity, an ESP8266-01 module provides Wi-Fi access to a local or cloud server. The firmware running on the Arduino filters and validates each read, formats the event as JSON, and forwards it over the UART link to the ESP8266. The ESP8266 then transmits the event securely to the backend API. Figure 1 illustrates the MFRC522 reader.

Figure1. RFID reader

Figure 2 depicts the ESP8266-01 module; and Table 1 summarizes the ESP8266-01 pin functions relevant to the prototype.

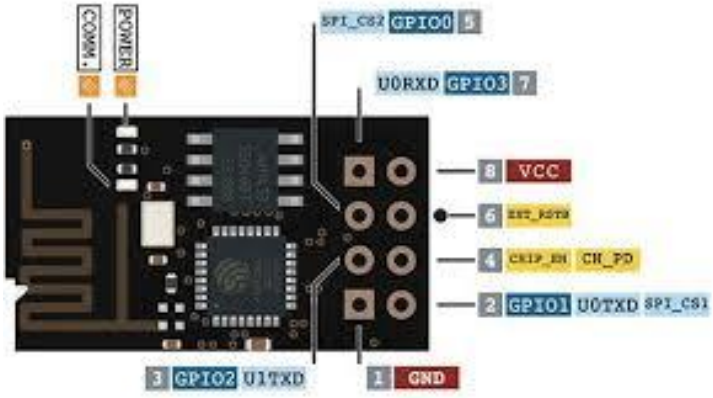

Figure2. Shows the layout of ESP8266-01 chip.

However, table 2. Introduces of pin mode of esp8266-01, table 3. pin descriptions, are explained respectively.

Table 1. Parameters of esp8266-01

Categories	Items	Values
WiFi Paramters	WiFi Protocles	802.11 b/g/n
	Frequency Range	2.4GHz-2.5GHz (2400M-2483.5M)
Hardware Paramaters	Peripheral Bus	UART/HSPI/I2C/I2S/Ir Remote Contorl
		GPIO/PWM
	Operating Voltage	3.0~3.6V
	Operating Current	Average value: 80mA
	Operating Temperature Range	-40°~125°
	Ambient Temperature Range	Normal temperature
	Package Size	14.3mm*24.8mm*3mm
	External Interface	N/A
Software Parameters	Wi-Fi mode	station/softAP/SoftAP+station
	Security	WPA/WPA2
	Encryption	WEP/TKIP/AES
	Firmware Upgrade	UART Download / OTA (via network) / download and write firmware via host
	Ssoftware Development	Supports Cloud Server Development / SDK for custom firmware development
	Network Protocols	IPv4, TCP/UDP/HTTP/FTP
	User Configuration	AT Instruction Set, Cloud Server, Android/iOS App

Table 2. Pin mode of esp8266-01

Mode	GPIO15	GPIO0	GPIO2
UART	Low	Low	High
Flash Boot	Low	High	High

Table 3. An introduces the pin description of esp8266-01

NO.	Pin Name	Function
1	GND	GND
2	GPIO2	GPIO,Internal Pull-up
3	GPIO0	GPIO,Internal Pull-up
4	RXD	UART0,data received pin RXD
5	VCC	3.3V power supply (VDD)
6	RST	1) External reset pin, active low 2) Can loft or external MCU
7	CH_PD	Chip enable pin. Active high
8	TXD	UART0,data send pin RXD

Finally, the table 4. An introduces of receiver sensitivity of esp8266-01

Table 4. Receiver sensitivity of esp8266-01

Parameters	Min	Typical	Max	Unit
Input frequency	2412		2484	MHz
Input impedance		50		Ω
Input reflection			-10	dB
Output power of PA for 72.2Mbps	15.5	16.5	17.5	dBm
Output power of PA for 11b mode	19.5	20.5	21.5	dBm
Sensitivity				
DSSS, 1Mbps		-98		dBm
CCK, 11Mbps		-91		dBm
6Mbps (1/2 BPSK)		-93		dBm
54Mbps (3/4 64-QAM)		-75		dBm
HT20, MCS7 (65Mbps, 72.2Mbps)		-72		dBm
Adjacent Channel Rejection				
OFDM, 6Mbps		37		dB
OFDM, 54Mbps		21		dB
HT20, MCS0		37		dB
HT20, MCS7		20		dB

The backend, implemented in Node.js/Express, authenticates requests, enforces authorization policies, and persists records in Mongo DB. Administrative dashboards (optional) can be built on top of REST endpoints to provide attendance analytics and alerts.

3.1. Hardware

- RFID: MFRC522 reader with ISO/IEC-14443A tags (student smart cards).
- Microcontroller: Arduino Uno for SPI interfacing and UID processing.
- Connectivity: ESP8266-01 Wi-Fi module for HTTP(S) client requests.
- Power: Regulated 3.3 V for RF module; decoupling capacitors and level-shifting as required.

3.2. Firmware

The Arduino initializes SPI and the MFRC522 driver, polls for cards, and debounces reads. Upon a successful read, the UID and contextual metadata (reader ID, timestamp) are sent to the ESP8266 via serial. The ESP8266 wraps packets in JSON and sends them to the backend using token-based authentication. Secrets are saved in the device flash as opaque tokens and changed every so often.

3.3. Backend & Data Model

The backend exposes REST endpoints for event ingestion and administration. Express middleware handles parsing and basic rate-limiting. In MongoDB, a Student collection stores (name, card_uid, stage, status), and an Event collection stores (student_id, reader_id, timestamp, status). Compound indexes on (student_id, timestamp) accelerate queries. Access control follows least-privilege principles with role segregation.

3.4. Deployment Topology

Readers are installed at lecture hall entrances. Each reader is assigned a unique identifier and connects to campus Wi-Fi. A local edge gateway (optional) can buffer events during outages. The server may run on-premises or in a managed cloud. Dashboards can be implemented with off-the-shelf admin frameworks.

4. Evaluation Methodology

We propose a pilot in two classrooms over four weeks to quantify (i) time saved per session, (ii) read success rate vs. card orientation and distance, (iii) end-to-end latency from tag detection to database commit, and (iv) false-accept/false-reject rates under authorization policies. Statistical

tests (e.g., paired t-test) can compare manual vs. automated attendance durations. All raw data and scripts will be shared upon request, subject to privacy constraints.

5. Design and implementation

In this section, we will explain in detail how to design the tracking system and how the tracking system works. This work is based on four things: Arduino, esp8266-01, RFID, and software that uploads data to a database. In the first, we will go through all the components, how to connect, and how the chips work together, and after that, we will briefly explain how the software of the tracking system works and the technique of sending data. Figure 3. Shows the step-by-step connection of the RFID chip with Arduino Uno, and the software part begins by downloading Arduino's library of the RFID named MFRC522.

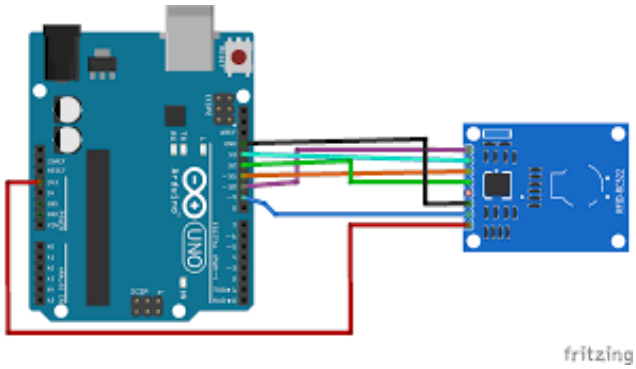

Figure3. Shows connection of the RFID chip with Arduino Uno.

This library let us to play with RFID and program it the way we want. To use the library in our tracking system we should use include instruction. Finally, the following steps will explore the procedures of programming a tracking system by using a flow chart in the figure 4.

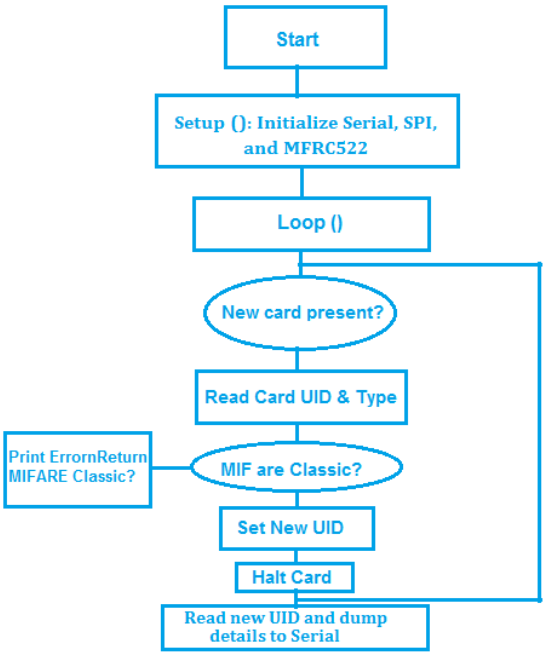

Figure4. Introduces the main steps of tracking system program.

6. Result and Discussion

The system demonstrates how commodity RFID and microcontrollers can digitize attendance with minimal friction. Reliability hinges on tag orientation, reader placement, and environmental interference. Security should be strengthened with HTTPS, signed tokens, and reader whitelisting.

Privacy can be protected through data minimization and anonymised exports for analytics. This paper describes a system that integrates RFID technology with a database to track student activity by recording their arrival and departure from educational facilities such as laboratories, classrooms, offices, and other areas.

The system performs the following functions:

- The Arduino-based system uses an MFRC522 RFID reader to read RFID tags,
- The RFID reader continuously identifies individuals' tags, and upon detection, reads and stores their unique identifiers and passed to the Arduino uno.
- The system prepares attendance data with the classroom number.

The Smart Attendance Monitoring System is a comprehensive solution designed to enhance the efficiency and effectiveness of attendance operations.

7. Limitations and Future Work

Limitations include the need for certain tags to be close enough to see them, the availability of Wi-Fi, and the possibility of tailgating, where more than one student passes at the same time. In the future, there will be multi-antenna portals, edge buffering, role-based dashboards, and connections to institutional SIS/IDMS systems.

8. Ethics and Compliance

The deployment follows the rules set by the institution for personal data. There are consent notices at the entrance, and people can only use the data for attendance purposes. There are set and enforced retention periods, and people can ask to see or correct their data. The design keeps logs from storing raw UIDs when hashed identifiers will do.

9. Conclusion

We will explain how to develop a practical and reproducible plan for a student attendance tracking system based on Radio Frequency Identification (RFID) technology. This system utilizes low-cost devices and a lightweight backend. It reduces manual labor, increases accuracy, and organizes data for educational analytics. This architecture can be used in public settings for access control and facility usage. In short, this system offers several advantages over traditional attendance tracking systems, such as greater reliability and accuracy in data recording.

Furthermore, this system can be used for various applications related to tracking student access to laboratories and libraries within academic institutions (universities, research centers, etc.). It can be used to identify student activities and events, serving as a valuable tool for future student skills assessment.

10. Acknowledgments

The authors thank Al-Nahrain University for support and facilities.

11. Author Contributions

Conceptualization: [Ali]; Methodology: [Ali]; Hardware: [Ali]; Software: [Asmaa]; Validation: [Asmaa]; Writing—original draft: [Asmaa]; Writing—review & editing: [Ali]..

12. Competing Interests

The authors declare no competing interests.

13. Funding

No external funding was received for this study..

REFERENCES

1. Ishaq, K., & Bibi, S.. IoT Based Smart Attendance System Using Rfid: A Systematic Literature Review., 2023, Available:ArXiv. https://arxiv.org/abs/2308.02591.
2. Tiago M., Paula F.,,Manuel S., and Luis C.,“ Reverse Engineering and Security Evaluation of Commercial Tags for RFID-Based IoT Applications”, Sensors 2017, 17(1), 28, 24 December 2016.
3. A.A. Olanipekun and O.K. Boyinbode, "MFRC522 Standard performance MIFARE and NTAG frontend " Rev. International Journal of Smart Home, Vol. 9, No. 12, (2015), pp. 65-74, Available: https://www.nxp.com/docs/en/data-sheet/MFRC522.pdf?utm_source
4. A.A. Olanipekun and O.K. Boyinbode , “A RFID Based Automatic Attendance System in Educational Institutions of Nigeria.", International Journal of Smart Home, Vol. 9, No. 12, (2015), pp. 65-74, Available: http://dx.doi.org/10.14257/ijsh.2015.9.12.07.
5. A. Juels "RFID Security and Privacy: A Research Survey". IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 24, NO. 2, FEBRUARY 2006. [Online]. Available: https://www.acsu.buffalo.edu/~mblanton/cse708/rfid-survey.pdf.
6. A. Soni, I. Tiwari, A. Gautam, and A. Jain, "RFID Attendance Management System using ESP8266", IRJET, 2025. [Online]. Available: https://www.irjet.net/archives/V12/i4/IRJET-V12I4122.pdf
7. C. Pratham , M. Vaibhav , S. Suhrid , N. Kapil , and B. Priya "Attendance Monitoring System through RFID and Face Detection”, IJRTI, 2025. [Online]. Available: https://www.ijrti.org/papers/IJRTI2505234.pdf
8. A. Shrivastava, S .Prasad, A. Yeruva, P. MANI, P. Nagpal, and A. Chaturvedi "IoT-Based RFID Attendance using Arduino ESP8266 & Adafruit-io", Cybernetics & Systems, Information Systems , Artificial Intelligence , Software 2023. [Online]. Available: https://colab.ws/articles/10.1080%2F01969722.2023.2166243
9. K. Panchal, P. Jingar, Om. Vataliya, and H.Rathod, "RFID Based Attendance System for Department", International Journal of INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING, IJISAE, 2023. [Online]. Available: https://ijisae.org/index.php/IJISAE/article/download/4687/3361/9693
10. P. Bafila, M. Lal , and G. Bafila, "UHF RFID based Attendance using Node.js API, MongoDB, IJRAR , Volume 6, Issue 2, April 2019. [Online]. Available: https://www.ijrar.org/papers/IJRAR19K8905.pdf.
11. B. M Reddy, R. Dilip, M. Gagan, S. Sahana, and M. Punitha, "Student Attendance Tracking System Using RFID", e-ISSN: 2582-5208 , International Research Journal of Modernization in Engineering Technology and Science IRJMETS, Vol.04, Iss. 12/December-2022.[Online]. Available: https://www.irjmets.com/uploadedfiles/paper/issue_12_december_2022/32103/final/fin_irjmets1670952898.pdf
12. P. Raghu , M. Santosh , and C. Lohith, "Student Attendance Monitoring System using IoT & RFID",International Journal of Scientific Research & Engineering Trends, IJSRET, Vol. 9, Iss. 4, 2023, ISSN (Online): 2395-566X2023. [Online]. Available: https://ijsret.com/wp-content/uploads/2023/07/IJSRET_V9_issue4_264.pdf
13. V. Nguyen, H. Khoa, T. Kieu, and Eu. Huh, "Internet of Things-Based Intelligent Attendance System, Electronics ", (MDPI), Journals Electronics Vol. 11 Iss. 19

10.3390/electronics11193151 2022. [Online]. Available: https://www.mdpi.com/2079-9292/11/19/315.

14. A. Puckdeevongs, N. Tripathi, A. Witayangkurn, and P. Saengudomlert, "Classroom Attendance Systems Based on Bluetooth Low Energy, Information", (MDPI), Journals Information Volume 11 Issue 6 10.3390/info11060329 2020. [Online]. Available: https://www.mdpi.com/2078-2489/11/6/329