

STUDENT TRANSPORTATION MONITORING SYSTEM BASED ON EMBEDDED SYSTEMS AND IOT: A CASE STUDY IN VIET NAM

Nguyen Thanh Nghia

Ho Chi Minh City University of Technology and Engineering

ARTICLE INFO	ABSTRACT
Received: 11/02/2026 Revised: 20/5/2026 Published: 20/5/2026	Ensuring student safety during transportation between home and school has always been a major concern for parents. This study proposes a monitoring and emergency support system for student transportation to prevent students from being forgotten on school buses. The embedded system using a real-time operating system is employed to program and control the system, while the internet of things approach is applied to manage student data. In particular, RFID technology is employed for student attendance tracking, while GPS technology is used for location monitoring and initiating emergency calls. A user interface is designed to provide various functions such as attendance management, monitoring, and communication for three groups of users: the school (for management), drivers (for student supervision), and parents (for tracking their children). The experimental results demonstrate that the system can monitor students' boarding and disembarking times in real time. Schools can manage the driver's route and travel duration, while parents can track their children's arrival time at school.
KEYWORDS	
Student transportation monitoring	
Embedded system	
RTOS	
RFID and GPS	
IoT	

HỆ THỐNG QUẢN LÝ ĐƯA ĐÓN HỌC SINH DỰA TRÊN HỆ THỐNG NHÚNG VÀ IOT: TRƯỜNG HỢP NGHIÊN CỨU TẠI VIỆT NAM

Nguyễn Thanh Nghĩa

Trường Đại học Công nghệ Kỹ thuật Thành phố Hồ Chí Minh

THÔNG TIN BÀI BÁO	TÓM TẮT
Ngày nhận bài: 11/02/2026 Ngày hoàn thiện: 20/5/2026 Ngày đăng: 20/5/2026	Đảm bảo an toàn cho học sinh trong quá trình di chuyển giữa nhà và trường luôn là mối quan tâm hàng đầu của phụ huynh. Nghiên cứu này đề xuất một hệ thống giám sát và hỗ trợ khẩn cấp cho việc vận chuyển học sinh nhằm ngăn ngừa tình trạng học sinh bị bỏ quên trên xe buýt trường học. Hệ thống nhúng sử dụng hệ điều hành thời gian thực được sử dụng để lập trình và điều khiển hệ thống, trong khi phương pháp Internet vạn vật (IoT) được áp dụng để quản lý dữ liệu học sinh. Cụ thể, công nghệ RFID được sử dụng để theo dõi sự có mặt của học sinh, trong khi công nghệ GPS được sử dụng để giám sát vị trí và thực hiện cuộc gọi khẩn cấp. Giao diện người dùng được thiết kế để cung cấp nhiều chức năng khác nhau như quản lý điểm danh, giám sát và liên lạc cho ba nhóm người dùng: nhà trường (để quản lý), tài xế (để giám sát học sinh) và phụ huynh (để theo dõi con em mình). Kết quả thực nghiệm cho thấy hệ thống có thể giám sát thời gian lên và xuống xe của học sinh trong thời gian thực. Nhà trường có thể quản lý tuyến đường và thời gian di chuyển của tài xế, trong khi phụ huynh có thể theo dõi thời gian đến trường của con em mình.
TỪ KHÓA	
Quản lý đưa đón học sinh	
Hệ thống nhúng	
Hệ điều hành thời gian thực	
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Email: nghiant@hcmute.edu.vn

<http://jst.tnu.edu.vn>

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Email: jst@tnu.edu.vn

1. Introduction

In the current context, especially in major cities, most parents are busy with work, and students often commute to school using public transportation or school buses. As a result, parents no longer need to spend time taking their children to and from school. However, when traveling by these means, a serious issue has arisen: students being left behind on school buses. In Vietnam, several tragic incidents have been reported. For example, a 6-year-old boy, L.H.L., a first-grade student at Gateway School (Cau Giay District, Ha Noi), died after being left unattended on a school bus [1]. In another case, a student was left for 20 minutes on a school bus belonging to Archimedes Primary School (Cau Giay District, Ha Noi) [2]. Furthermore, a 10-year-old student in Hanoi was left alone on a school bus in a critical condition [3]. In Thailand, a 7-year-old girl in Chon Buri Province died after being forgotten on a bus [4]. In the UAE, a 4-year-old girl was also forgotten on a school bus by staff members [5]. In Canada, an 8-year-old girl was also left behind on a school bus [6].

To detect and alert when students are left behind, an IoT-based system allows parents, schools, and management institutions to track the safety and comfort of children on school buses in real time [7]. In another approach, several studies have proposed combining RFID technology with fingerprint recognition algorithms to send notifications during students' boarding and disembarking processes [8]-[10]. In Vietnam, mobile applications such as Anta [11] and Bus2School [12] have also been developed to support student transportation services. In addition, a system utilizing the LPC2148 microcontroller combined with an RFID module was developed to identify information about a child carrying a unique ID card [13]. In the event of an accident, the school bus can stop automatically, a buzzer alarm is triggered, and an SMS alert is sent. K. Aparna Reddy *et al.* proposed another system that identifies each student using an RFID card and displays the student's name on an LCD screen [14]. The system can issue an alert if a child remains inside the bus after it arrives at its destination by sending an SMS notification to the school administration via a GSM module.

Nowadays, many systems using RFID, GPS, and IoT technologies are applied in industry, healthcare, and various other fields [15]-[17]. Based on the above analysis, the development of an embedded system for monitoring student transportation is essential. The key contributions of this study are: a) Development of a complete embedded hardware system for student transportation monitoring; b) Implementation of a mobile application that enables schools, parents, and drivers to monitor all relevant information; c) Design of an emergency button to assist students in urgent situations. When the button is pressed, the system automatically initiates a call to the driver or student's parents.

2. Material and method

The student transportation monitoring and emergency support system, designed to assist in cases where a student is accidentally left on the bus, is developed based on embedded systems and IoT technologies. The following section presents a detailed description of the proposed system and the related techniques employed in its design and implementation.

2.1. Proposed framework for student transportation monitoring

The complete system for student transportation monitoring and providing emergency assistance in cases where a student is accidentally left on the school bus is shown in Figure 1. The system comprises several functional modules, including a display unit, GPS module, RFID card reader, emergency button, central processing unit, power supply, relay control circuit, audio transmitter and receiver, call and SMS module, and notification unit. All modules are integrated into a single embedded circuit. In addition, an Android mobile application is developed to provide a user interface that connects to Firebase via a 3G or Wi-Fi network for real-time data transmission.

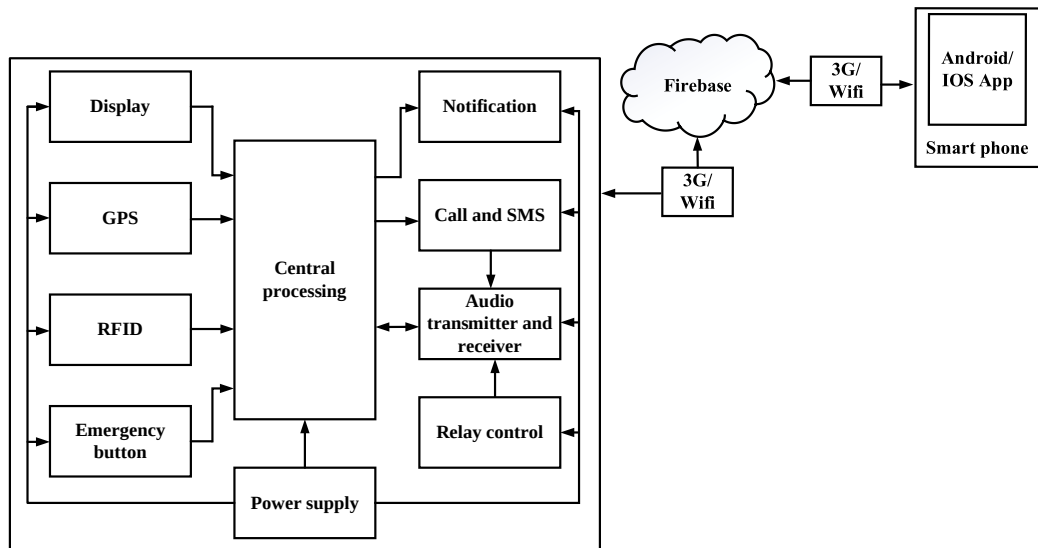


Figure 1. The block diagram of the proposed student transportation monitoring system

The central processing unit uses an ESP32 microcontroller, which communicates with peripheral devices, processes data, and connects to Wi-Fi for communication with Firebase. The GPS module is used to determine the bus's location and send coordinate data to the central processing unit for location tracking. The display screen shows information received from the central processing unit and displays notifications when the emergency button or RFID tag is scanned. An emergency button is designed for students to press if they are accidentally left behind on the bus. The audio amplifier amplifies the audio signal transmitted between the audio transmitter and receiver and the call and SMS module. Relays are used to switch the power supply of the audio transmitter and receiver to improve energy efficiency. The database unit stores all relevant data. The mobile application allows users to view real-time data such as student boarding and alighting times, the bus's current location, and driver information.

2.2. Hardware design

Figure 2 presents a schematic of the entire system. Specifically, the central processing unit uses the ESP32 module to control the device and connect to the internet. The RC522 RFID module is used to read RFID tags and send the ID tags to the central processing unit [14]. The SIM800A module is used for making calls and sending text messages and is controlled by a central microcontroller. A 3.5-inch TFT display shows student information during card scanning and various notifications. The GPS module, NEO M10, is used to determine the current location of the school bus. The audio transmission and reception unit includes a PAM amplifier and a 3W speaker, enabling voice communication during phone calls. Detailed specifications of the modules are shown in Table 1.

Table 1. List of modules used in the system

No.	Units	Detail
1	Central processing	ESP32 MCU
2	GPS	Module GPS NEO M10
3	RFID	Module RFID RC522
4	Call and SMS	Module SIM800A
5	Audio transmitter and receiver	Module PAM + Speaker 3W
6	Notification	Buzzer
7	Display	LCD TFT touch 3.5 Inch

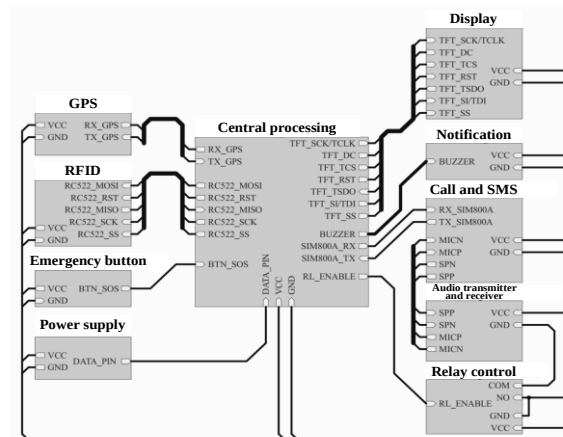


Figure 2. The schematic diagram of the complete student transportation monitoring system

2.3. Software design

In the proposed system, the microcontroller is developed using an embedded system approach with a real-time operating system (RTOS) to ensure optimal task execution. In practice, the system is designed based on an event-driven model, allowing different tasks to interact efficiently through event-driven mechanisms while avoiding conflicts in the overall system operation as shown in Figure 3. Each functional module is assigned a specific task with a predefined priority level. The emergency handling task is assigned the highest priority to ensure immediate response when the emergency button is triggered. The GSM communication task is also given high priority to guarantee timely delivery of calls and messages. The RFID task operates at a medium priority for real-time attendance tracking, while the GPS task is assigned a lower priority since location updates are not strictly time-critical. To prevent system congestion, inter-task communication is managed using queues and event flags, ensuring synchronization without blocking critical tasks. This design allows the system to maintain responsiveness and stability even under multiple concurrent events. In addition, in the event of 3G/Wi-Fi connectivity loss, the system maintains core functionalities locally, including RFID-based attendance tracking and emergency handling, while buffering essential data such as check-in/check-out events and GPS coordinates in local memory. Once the connection is restored, the buffered data are automatically synchronized with Firebase to ensure data consistency and prevent information loss.

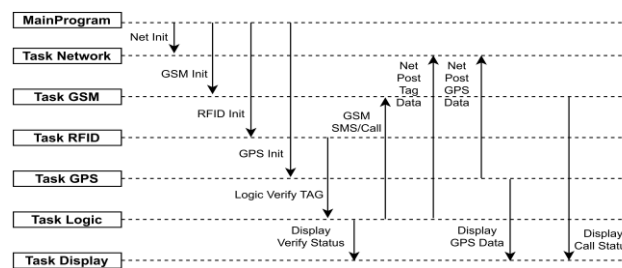


Figure 3. Task schedule for central processing block

3. Results and discussion

The system implementation was carried out based on literature research and data collection through tests and experiments to provide input data for the system. The deployment of the student monitoring and tracking system for school transportation consists of two main parts: the first part describes the operation of the mobile application, and the second part presents the overall operation of the entire system.

3.1. Results of the hardware design

The printed circuit board (PCB) design results for the entire system are presented in Figure 4. The circuit was designed as a two-layer board, with peripheral modules implemented in a plug-in form to facilitate easy replacement and maintenance. After completing the PCB design and error verification, the board was fabricated and components were assembled. The final assembled and fully functional hardware implementation is shown in Figure 5.

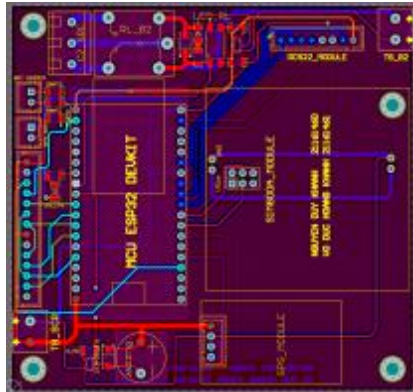


Figure 4. PCB layout of the proposed student transportation monitoring system

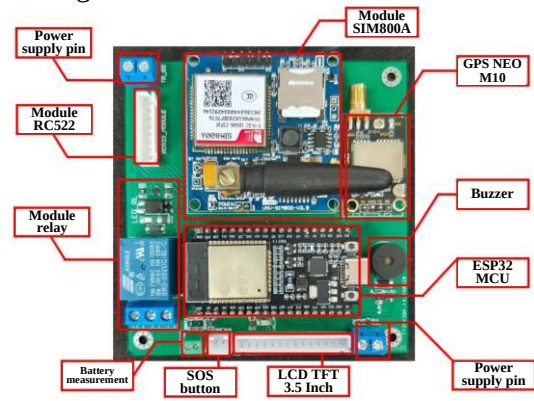


Figure 5. Fully assembled circuit of the proposed student transportation monitoring system

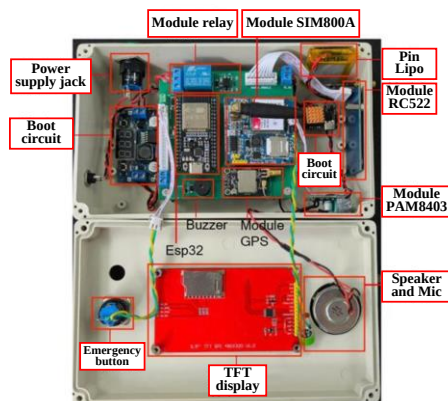


Figure 6. Fully assembled circuit for the student transportation monitoring system

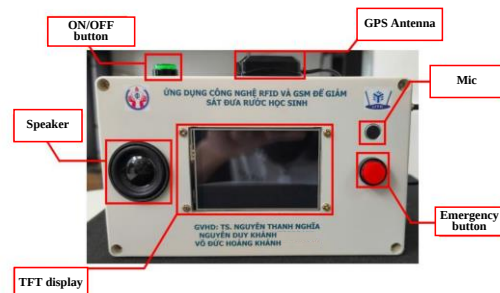


Figure 7. The completed prototype of the proposed system after assembly

After completing the assembly of the circuit components, the installation results are shown in Figure 6, and the front view of the finished product is presented in Figure 7. The main circuit is neatly housed inside the enclosure, while the interface components such as the display, microphone, speaker, button, and power supply jack are mounted on the case surface for convenient operation. The RFID scanning area is positioned near the side of the device to facilitate easy card detection. Moreover, the system is equipped with both an external power source and an internal backup Li-Po battery.

3.2. Results of the software design

In the proposed system, two software components are developed for control and monitoring purposes. The first software is programmed for the central microcontroller to manage all operational activities, while the second software is a mobile application designed for use by schools, drivers, and parents. In practice, the first software is implemented using an RTOS, where control threads operate independently to optimize the system's performance. It includes six control tasks: network, GSM, RFID, GPS, logic, and display. Each task is designed with its own control flowchart; for example, Figure 8 illustrates the algorithm flowchart of the GPS processing

The flowchart illustrates the logic of the Task GPS Handler. It begins with a 'Task GPS Handler' process box, followed by a 'Set timer GPS for network and display' process box. A loop starts with 'Check event and get data'. A decision diamond 'Have GPS content?' has a 'S' (Yes) path leading to another decision diamond 'Have GPS content?'. This second diamond has a 'D' (No) path leading to 'Process and update GPS data', which then leads to 'Sent position data to task network'. The 'S' path from 'Have GPS content?' leads to 'GPS get timer?'. This diamond has a 'S' path leading to 'Sent timer data to task display' and a 'D' path leading back to the 'Have GPS content?' loop. Both 'Sent position data to task network' and 'Sent timer data to task display' lead back to the 'Check event and get data' step.

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graph TD
    Start([Task GPS Handler]) --> SetTimer[/Set timer GPS for network and display/]
    SetTimer --> CheckEvent[Check event and get data]
    CheckEvent --> HaveGPS1{Have GPS content?}
    HaveGPS1 -- S --> HaveGPS2{Have GPS content?}
    HaveGPS1 -- D --> LoopBack(( ))
    HaveGPS2 -- D --> ProcessGPS[Process and update GPS data]
    ProcessGPS --> SendPos[Sent position data to task network]
    HaveGPS2 -- S --> GetTimer{GPS get timer?}
    GetTimer -- S --> SendTimer[Sent timer data to task display]
    GetTimer -- D --> LoopBack
    SendPos --> LoopBack
    SendTimer --> LoopBack
    LoopBack --> CheckEvent
  
```

The screenshot shows the Firebase Realtime Database console. The URL is <https://fir-demo-96c0a-default-rtdb.firebaseio.com/>. The database structure is as follows:

- CHECK
- CHECKIN_HOME_1
- CHECKIN_HOME_2
- CHECKIN_SCHOOL_1
- CHECKIN_SCHOOL_2
- CHECKOUT_HOME_1
- CHECKOUT_HOME_2
- CHECKOUT_SCHOOL_1
- CHECKOUT_SCHOOL_2
- GPS
- VEHICLE_1

Figure 9. *Data fields of the Firebase database*

Figure 11. Interfaces of: (a) leave notification, (b) personal information, and (c) attendance history

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3.4. GPS test results

The positioning error can be considered an important criterion for evaluating the accuracy of the system. The error determination was performed by comparing the coordinates obtained from Google Maps with those provided by the system at the same location. In practice, based on the longitude and latitude values returned by the system, the haversine formula was applied to calculate the positional deviation between the system and Google Maps. The coordinate deviation results between the developed system and Google Maps are presented in Table 2. The average deviation was found to be 7.0 meters for school bus 1 and 6.1 meters for school bus 2. In weak signal conditions, the system temporarily stores essential data locally and automatically synchronizes with the server once the network is restored.

Table 2. Experimental results of GPS accuracy measurement

Test no.	Distance error of school bus 1 (meters)	Distance error of school bus 2 (meters)
1	7.1	8.5
2	5.9	5.2
3	6.3	4.8
4	7.5	5.9
5	8.1	6.3
Average	7.0	6.1

3.5. Test results of call and message reception time from the SIM800A module

The process of making calls and sending messages was also examined to evaluate the stability and response time of the SIM800A module during emergency situations. Table 3 presents the duration from the start of execution until the call and message are received. The longest time for the phone to receive a call after initiation was 10.22 seconds, while the shortest was 8.78 seconds. The average time to receive a call and a message was 9.68 seconds and 8.86 seconds, respectively. Experimental results indicate that the system's call and message response times are relatively fast and stable, enabling quicker emergency response for rescuing students left on the bus.

Table 3. Test results of the response times for emergency calls and message reception when students get off the bus using the SIM800A module

Test no.	The response times for emergency calls (unit in second)	The response times for message reception (unit in second)
1	10.22	9.98
2	9.94	8.84
3	8.78	8.85
4	9.82	8.50
5	9.64	8.11
Average	9.68	8.86

4. Conclusion

The student transportation monitoring system has been designed and implemented to simultaneously supervise two school buses. Specifically, RFID technology is applied to track students when boarding and alighting, sending notifications to parents. GPS enables the determination of the school bus's location and travel route. The SIM800A module allows for emergency calls in case a student is left on the bus. Experimental results show that the system demonstrates stable operation and satisfies practical deployment requirements. Additionally, the mobile application allows schools to manage student and driver information, allows families to monitor students' commuting and request leave when necessary, and allows drivers to track student attendance or leave. Data on student boarding/alighting, school bus location, and leave information are continuously updated on Firebase. The experimental results indicate that the system can be effectively applied in real-world student transportation monitoring.

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