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Development of An RFID-Based Tracking System for Special-Education Students in Taiwan

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Abstract. *Safety on campus is a very important issue in need of attention. Schools try to maintain safety by advocating measures meant to minimize risks. Safety management on campus typically involves relevant supporting measures and manuals, but serious safety-related incidents continue to take place on campuses. The goal of campus security should be to identify an incident and resolve it effectively and in real time before the incident evolves into an actual crisis. This study proposes an RFID-based tracking system using radio-frequency identification (RFID) technology for special-education students in support of dynamic accident-prevention mechanisms. Our purpose here is to improve the traceability of students involved in campus activities that is, to identify students' whereabouts throughout the entire school day. When an incident occurs, our system will notify the relevant parties immediately. In the present study, the system real-time event processing increases school staff situational awareness and reduce the likelihood and the severity of unwanted outcomes. In order to validate our proposed system, we present an RFID-based simulation exercise designed to help special-education students in school.*
Keywords: RFID, Tracking system, Accident-prevention mechanisms, Real-time event processing.

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1. **Introduction.** Campuses should provide students with educational activities, and safety on campus is fundamental to all education. Safety incidents occur year after year, resulting in injury to students. To enhance the management of campus safety, schools should consider real-time monitoring of the campus environment. In recent years, campus-safety issues have garnered considerable attention, some of which has taken the form of studies on campus-safety technology. Gow explored the relationship between communication technology and campus safety, and presented some ideas about early-warning mechanisms [1]. The authors also analyzed emergency-notification processes for students, arguing that schools should adopt standardized efficient campus alarm systems. Diane and Estelle explored the relationship between campus safety and campus crime by conducting surveys, by gathering campus crime statistics, by dissecting existing safety technologies, and by comparing small campuses with large campuses in these regards: the overall objective has been to identify whether there is a correlation between campus crime and campus safety [2]. They focused on campus-safety technology, looking for a system capable of efficiently contributing to crime-prevention measures.

Many studies have integrated information technology into campus-safety management. Chen proposed an intelligent campus-safety tracking system using radio-frequency identification (RFID) and Zigbee technology [3]. When an alert occurs, the user can log into a web system and engage in real-time tracking of personal valuable possessions. Users can also manage their own valuables through a website management center. Large-scale deployment of wireless sensor networks, the authors argued, results in strong performance. Yang and Hsiung proposed an innovative application for RFID systems in special-education schools, where the system would monitor body temperature, weight, waste disposal, cleaning processes, and campus visitors in the campus environment [4]. RFID technologies can simultaneously read multiple and diverse data, thus helping to improve the efficiency of the overall system. RFID transponders can store large amounts of data, provide schools with greater data-management and data-analysis capabilities. Ma proposed RFID-based student administration systems. Perhaps not surprisingly, the issue of privacy has become a key issue in system management, so the authors proposed a random ID-update scheme, in which a hash value is generated from both a secret ID and a random number on an RFID tag through the use of an inexpensive hash circuit [5].

The development of campus-safety systems requires the interaction of many participants. Radio-frequency identification systems have many advantages and features over conventional technologies. In this paper, we discuss how to apply RFID principles and techniques into accident-prevention mechanisms. Such specificity has been extensively studied in diverse process-management research. The purpose of this paper is to improve the traceability of accident-prevention mechanisms systems on the basis of RFID technology. We propose an RFID-based system for tracking students during campus activities, thus permitting knowledge of students' whereabouts throughout the entire school day. In this research, we consider identification-prototype systems that can serve accident-prevention mechanisms. Our system would help school staff monitor many types of situations in schools. We explore campus-safety management problems associated with imported RFID-based systems. Our proposed system should strengthen campus safety.

This paper is organized as follows. Section 2 reviews the enabling technology, and Section 3 describes related problems and presents a scenario analysis. Section 4 describes the RFID-based system's design and implementation using RFID technology. Section 5 presents evaluation of the proposed system. The final section presents our conclusions.

2. **RFID technology review.** Radio frequency identification (RFID) is a wireless communication technology the uses radio signals to identify specific objects and to read or

write the relevant data. An RFID system features hardware such as RFID readers [6] and RFID tags [7], and software like RFID middleware [8]. An operational principle of an RFID system is to emit radio-frequency energy and identify the sensing range of RFID tags. RFID tags can be assigned to one of three categories: passive, semi-passive, and active RFID tags (shown in table 1). Passive RFID tags depend on the RFID reader for the supply of power, because passive RFID tags do not have internal power sources. Passive RFID tags contain an integrated chip and generate power from RFID readers' radio signals. Semi-passive RFID tags have on-board power sources, but they use RFID readers' energy to send and receive data. An active RFID tag contains a battery and can transmit the radio signals to an RFID reader on its own. RFID tags can support three types of memory: read-only memory, write-once/read-many memory, and fully rewritable memory. A read-only tag with a traditional barcode has a unique barcode identification number. The information on read-only tags cannot be modified, but the contents of the barcode identification number can be reused. The information on write-once/read-many tags can be reused, but the contents can only be modified once. More complicated than read-only tags, fully rewritable tags can be rewritten many times. The information on fully rewritable tags also can be reused and erased. RFID tags based on radio frequencies can be assigned to one of four categories: low-frequency, high-frequency, ultra-high-frequency, and microwave-frequency tags. Low-frequency tags (125134 kHz) use relatively little power and have short transmission ranges. Low-frequency tags can be used in rugged environments where interference from metals could be prevalent. High-Frequency tags (13.56 MHz) are the most commonly used RFID frequency bands owing largely to the wide adoption of RFID technology based on smart cards. Ultra-high-frequency tags (860-960 MHz) typically offer significantly better range and can transmit data faster than low-frequency and high-frequency tags. Microwave-frequency tags (2.4 GHz and 5.8 GHz) are on the same band used by Bluetooth and Wi-Fi systems. Microwave-frequency tags are used where distance is the key driving force, as they have long transmission ranges [9][10]. RFID technology is an important tool in many fields of study. When the RFID tag cost is very small, employing the RFID technology yields an improved larger expected profit and smaller risk [11]. Liu and Yang developed an application system using contactless IC card and RFID reader related to the improvement of the campus safety protection [6]. Zhang developed an RFID-based tracking and management system for the automotive recovery rate [12]. Kim discussed the problem of handling active RFID tags in RFID middleware, and proposed new APIs for handling active tags [8]. Mustapha developed bus identification and monitoring system using RFID [13]. It indicates that RFID technology will has a bright future because of its big information capacity, high efficiency, security and good reusability [7]. Yang proposed a new scheme for the fast identification of tags based on readers strategically distributed throughout the RFID system [14]. The authors used RFID technology for effective tracking and data management [15][16].

3. **Problem statements and scenario analysis.**

3.1. **Case study.** Using the following case study, we discuss accident-prevention mechanisms at the Tainan School of Special Education in Taiwan. According to the inspection results regarding to our campus visits, most of the students studying in Tainan School of Special Education have multiple disabilities. Therefore, we take the situation of students with special needs into consideration and let them know how we can assure a safe-learning environment. In this paper, we first surveyed the whole campus environment and some areas where students' activities take place. From our survey, we can understand the students' everyday life at school during the whole school days. We then analyzed the

Table 1. RFID technologies differences

RFID Tag Type	Passive Tag	Semi-passive Tag	Active Tag
Internal Power Source	No	Yes	Yes
Rang	Very Short	Long	Long
Life	Unlimited	Limited by Battery(Longer)	Limited by Battery(Shorter)
Size	Small	Medium	Big
Cost	Less Expensive	Less	More Expensive

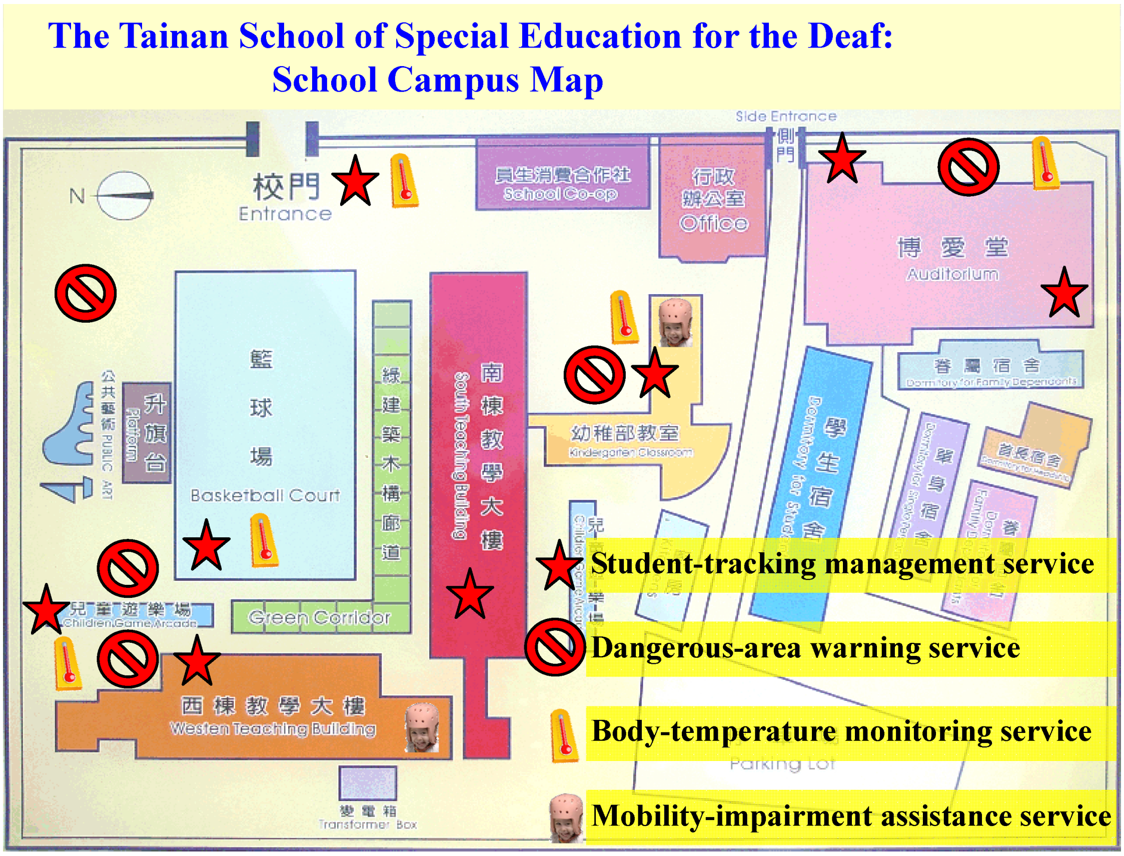

Figure 1. Hardware implementations

findings, paying particular attention to student-safety incidents associated with specific areas on the school campus.

3.2. **Problem statements.** The Tainan School of Special Education in the past only installed surveillance camera at specific fixed points. Students were particularly prone to damage in such dangerous areas as bathrooms, where the school had installed emergency call buttons that, nevertheless, could not provide immediate assistance. Reliance on monitors alone made the monitoring of students difficult. After the occurrence of safety incidents on campus, the school staff began discussing in greater depth various issues related to possible improvements in campus-safety management. Relying on just one specific surveillance camera is difficult to monitor students' activities. If we want to track the current state of the students on campus, it is a really difficult task.

After the occurrence of safety incidents on campus, the school staffs discuss issues related to the improvement of the campus safety management. When the school staffs traced the cause and whole story of the incident, they might not reach an accurate conclusion. In this case, the school staffs don't seem to figure this accident out in the meeting hence it is inevitable that the similar accident may happen again in the future. Once we fail to guarantee a safe campus environment where the students' activities take place, it will result in the inefficiency of campus safety protection. If we do not really realize the reasons causing dangerous accidents, it may result in very serious consequences regarding to the maintenance and operation of the follow-up campus safety issues. We will find out the potential safety problems which make the maintenance of campus safety and operational efficiency too low when we survey a safe-learning environment issues in school. We list the requirements of the campus safety management and research problems as follows:

- Although monitoring devices are available in certain locations on campus, but it is only through a monitoring screen that one can inspect the status of a particular location. The school staff did not have somebody constantly watching the screen.
- The campus has some areas that are restricted to students. Because those places have some degree of risk, we defined them as danger zones, which are scattered about in various locations on and around campus. Securing the zones is a very difficult task in accident-prevention mechanisms.
- Teachers take roll-call in order to determine which students have come to school and which are absent. If a student is known to be on campus but is absent from a particular class, then staff need to engage in the time-consuming task of searching the campus for the missing student. A related problem is when students do not leave the campus at the end of the school day.
- Students are prone to developing colds and other illnesses that can have serious consequences. Temperature abnormalities may be symptomatic of serious diseases such as enterovirus-related diseases, dengue fever, tuberculosis, SARS, and avian influenza. For example, a student who is not feeling well might not take the initiative of informing teachers or other students of the situation. This delay may lead to more serious consequences: a student suffering from a viral infection might pass it on to other students, who would then spread it rapidly on campus. And such initial symptoms as elevated temperature are not easily discernible by campus staff.
- Some special students with mobility-impairment problems face significant risks that security cameras cannot effectively address. Some of these risks, for example, can occur in restrooms, where a mobility-impaired student might enter a bathroom stall, lock the door, and then collapse in the stall outside the view of any camera.

3.3. **Scenario analysis.** We developed several scenarios regarding campus-safety management service. Figure 1 illustrates the hardware implementations of active RFID readers.

- *Student-tracking management service.* Figure 2 illustrates a schematic diagram for a student-tracking management service. Abductions are a serious problem in society, affecting students' safety during the school day. After students come to school, this service can determine, in real time, whether they have entered their classroom or not. In the classroom, this service can accurately determine student's identity, while recording students attend status information. If students have not yet entered a classroom after the start of class, the teacher should immediately track the location by using RFID technology of the students. School staff and the teacher should also confirm using student's tag whether or not the students have remained on campus after school. If a student met a bad person on campus, he can immediately press

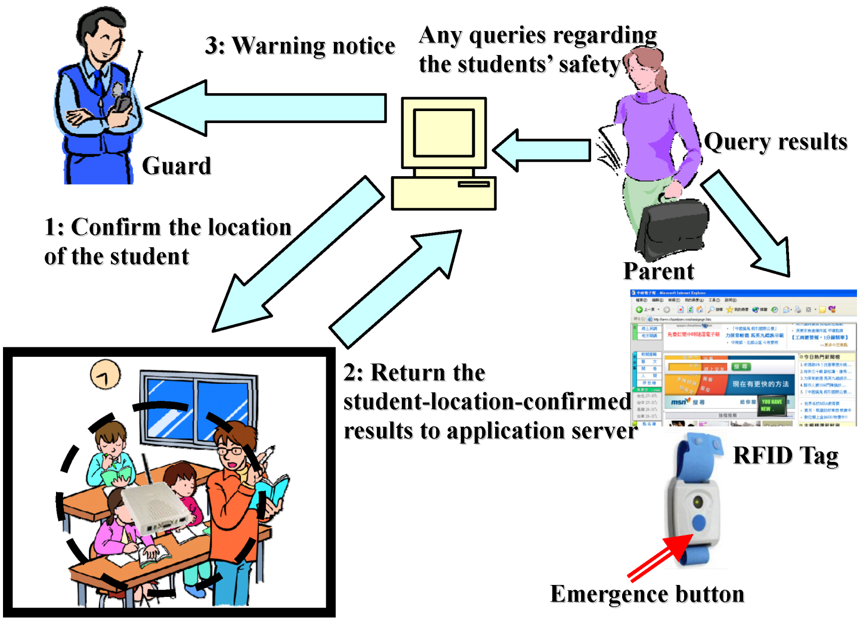

FIGURE 2. Schematic diagram for a student-tracking management service

the emergency button on the RFID tag, and then the system can inform guards go to the site.

- *Dangerous-area warning service.* There are some public-safety blind spots on campuses where only patrol guards are supervising the grounds. Figure 3 illustrates a schematic diagram for a dangerous-area warning service. Campuses contain dangerous areas: for example, the roofs of campus buildings, temporary construction sites, and maintenance and mechanical rooms. When students near or enter danger zones, the proposed system can immediately determine the students' position and identify the pertinent characteristics of real-time situations. Then the system can inform guards that students are to be removed from the danger zones.
- *Body-temperature monitoring service.* Figure 4 illustrates a schematic diagram for a body-temperature monitoring service. Each student wears an RFID tag which has an important function measuring body temperature on the wrist. When students into the classroom after 20 minutes, this service can accurately determine student's identity, and began to measure the student's body temperature up to 5 minutes average temperature (shown in Figure 5). We set the industry-standard temperature sensors, and it came as the reference value of the indoor temperature. An RFID tag can measure the student's body temperature that it can also measure the indoor temperature. At first, the indoor temperature will be measured by RFID tags in the system and it will be adjusted by industry-standard temperature sensors. Then, we can obtain the temperature error between RFID tags' and sensors' measurement. We further than compared the student's body temperature, the obtained body temperature information is more accurate. If school staff can acquire each student's body-temperature information at any time, they can immediately notify the medical staff, who will inspect the student. The student will remain in isolation when necessary to prevent the spread of serious contagious diseases.
- *Mobility-impairment assistance service.* Figure 6 illustrates a schematic diagram for a mobility-impairment assistance service. When mobility-impaired students wear RFID tags into the restroom after the system accurately determine the student's identity, the system will start record time of students into the restroom. If a student

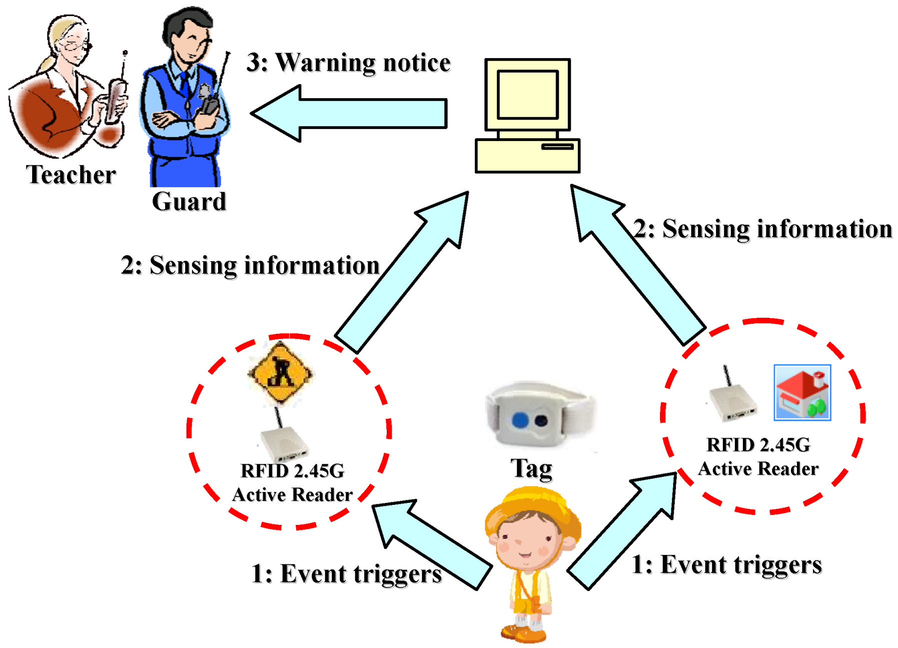

FIGURE 3. Schematic diagram for dangerous-area warning service

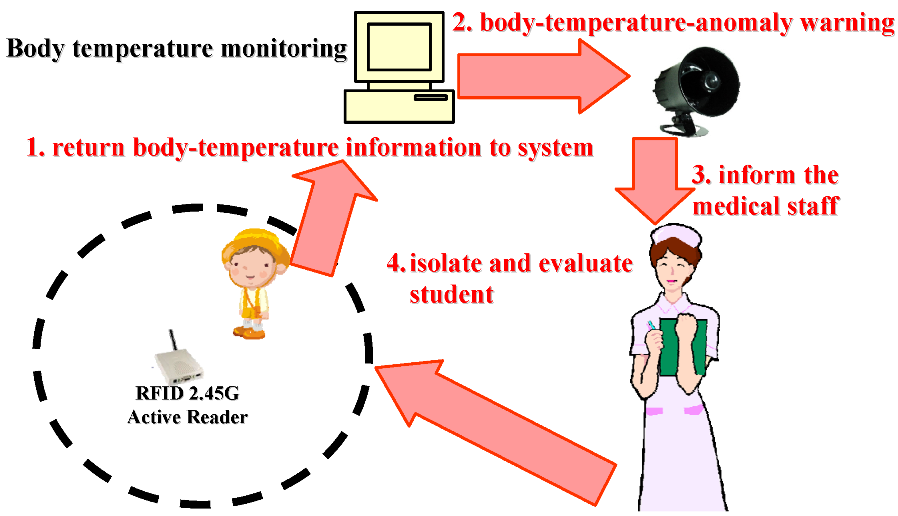

FIGURE 4. Progress of content awareness process and service drive

stays in the restroom for a long time, the system will automatically determine the student in the restroom for unusual events. Then this service will inform school staff go to the restroom and confirm the status of the students. When a student go to the restroom and need assistance, he can immediately press the emergency button on the RFID tag. At the same time RFID reader in the restroom real-time receives help from the student's message, the system will send an emergency SMS to notify the school staff.

4. **System design and implementation.** We propose an RFID-based system for the management of campus safety, and use RFID devices to determine students' identity and location on campus. We also use RFID technology to provide for efficient communication among school staffs.

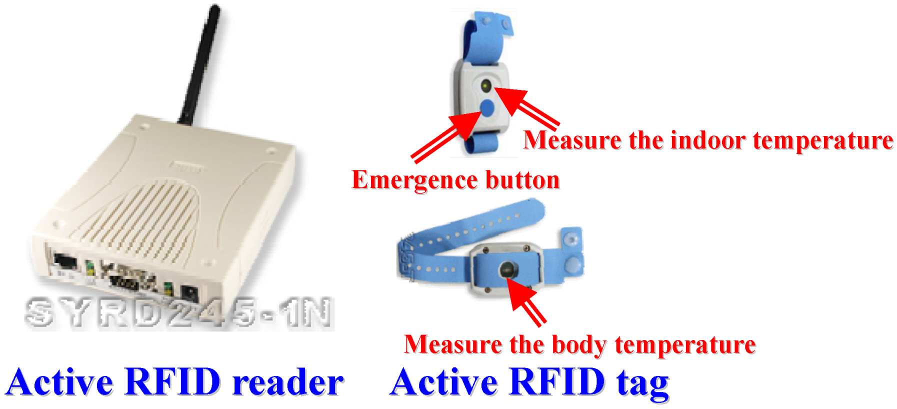

Figure 5. RFID reader and tag

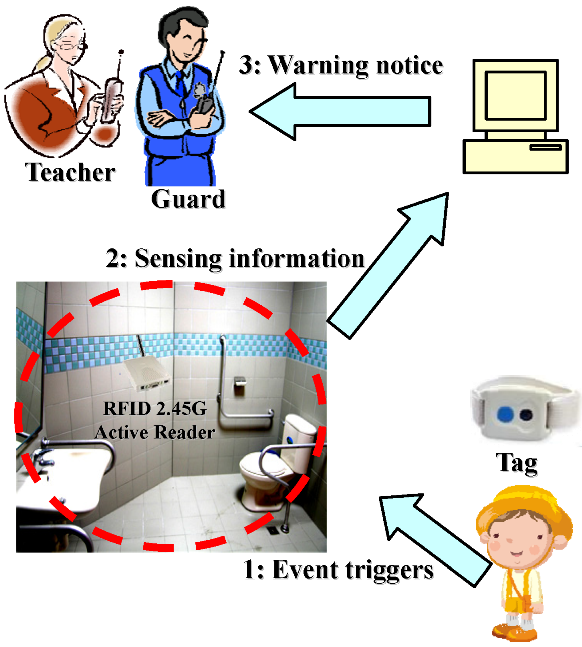

Figure 6. SSchematic diagram for a mobility-impairment assistance service

4.1. **Analysis of the proposed system.** We have tried to design an RFID-based system in the field of accident-prevention mechanisms, and in this endeavor, we have used RFID technology to solve campus-safety issues. Figure 7 illustrates our proposed campus-safety information system. Part one of this paper discussed deployment of RFID systems in campus scenarios, with particular regard to data collection and transmission systems. We summarized students' behavior patterns in different types of scenarios. These RFID readers can cover a wide range of student activities, including off-campus education and recreational activities. The gateway interface would be responsible for real-time data collection and transmission. In part two, we will discuss how our proposed information system integrates RFID technology into accident-prevention mechanisms. We developed the RFID monitoring system to aid students at an assisted-living facility during the school day. The system displays students' location and other pertinent information via a web interface. The system uses active tags to communicate with a number of fixed active readers. The early-warning system is a component of real-time monitoring and recording of data in a campus environment. The early-warning system would involve the transmission of automatic alerts and real-time information to appropriate personnel.

Table 2. Specifications for RFID Tag

Type number	**SYTAG245-TM-AA1**
Communication	2.45 GHz, support read & write
Address	65536
Received signal strength indication	0-255
Link quality indicator	0-255
Tag configuration	Transmission interval programmable/ Wireless tag programming/ set emitting frequency/ receive frequency
Battery life	1 year
Power	3V CR2032*1
Frequency	2.40∼2.48 GHz
Dimension	42W × 30H × 10D (mm)
Communication range	140 meter
Channel	316
Weight	23.4g
Features	Digital RSSI/LQI data providing and Low battery indicator
	Two color LED visual indication and Buzzer
	Emergency button: emergency signal transmission
	Built-in Light sensor for anti-tamper capability
	Built-in two temperature sensors: Detect ambient & skin temperatures

In part three, we will discuss software and hardware features of database system with RFID middleware. In part four, we will discuss automatic early-warning information systems, which can alert parents, teachers, system administrators, and other school staff of potential problems.

4.2. **Development environment.** In order to validate the proposed system architecture, we tested various scenarios which the students may encounter in Tainan School of Special Education. In this paper we discussed the implementation of a system, including different scenarios for the subsystems and hardware devices and clear demonstration for the proposed system design.

The development environment for the prototype system is described below:

- Operating Systems: server = Windows Server 2008; client = Web-based operating system.
- Database: Microsoft SQL Server 2008.
- Application program: Microsoft Visual Studio 2008, ASPs (Active Server Pages), PHP (Hypertext Preprocessor), J2EE technology stack.
- Application Server: Windows Server 2008.
- RFID Tag: 2.45GHz Active RFID Tag (vendor: SYRIS).
- RFID Reader: 2.45GHz Active RFID Reader (vendor: SYRIS).

We adopt Xtive Utility program V2.70 to set the RFID readers and tags shown in Figure 8. In area A, the main function is setting status, reading status, COM port setting, select TAG ID and transmission data. This program will detect available Serial Port automatically. We can select correct COM port to communicate with RFID reader.

Table 3. Specifications for RFID reader

Type number	SYRD245-1N
Communication	2.45 GHz, support read & write
Address	65536
Received signal strength indication	0-255
Link quality indicator	0-255
Frequency	2.40∼2.48 GHz
Power	7.5 VDC ∼ 28 VDC
Dimension	107W x 138H x 30D (mm)
Read range	up to 125 meter
Channel	316
Weight	222g
Interfaces	10/100 base-T Ethernet (RJ-45),
RS232, RS485	
Light	LED Visual indication
Features	Long read range, Standard Ethernet interface, Multi-tag (anti-collision) capability, Compact low-cost design, Antenna attachable, Ease of installation

In area B, the main function is setting reader and tag parameters. Reader Reset button is to reset online reader, which will warm restart. Reader Initial button is to initial online reader and all setting will set to factory default. Get Version button is to get reader's firmware version. Get Reader S/N button is to get reader's serial number. Get Reader ID button is to get the ID of the reader. Set ID button is input the number to ID field and then click "Set Reader ID" to change reader's ID. Set Baudrate is to select communication baud rate and then click "Set Baudrate" to change reader's baud rate. Set Auto Send is change data format of tag from reader to PC client. Set Net Port is select communication port and then clicks "Set Net Port" to change reader's communication port. Set RSSI Level is adjust RSSI level (0 255) to filter tag which have low RSSI signal in reader. Set Gain Level is adjust gain level (1∼7) to control reader's read range. Level 7 is the max range (default setting); Level 1 is the shortest read range. RFID tags detail setting shown in Figure 9. Set TAG Active Time button is to modify transmits frequency of selected tag. Get TAG Active Time button is to get the current transmits frequency of selected tag. TAG Off button that tag will stop signal transmission automatically. TAG On button that tag will start signal transmission automatically. Set TAG Receive Count button is to modify receives frequency of selected tag. Get TAG Receive Count button is to get the current receiving count of selected tag. In area C, the main function is receiving tags information. If COM port select correctly, starting Read TAG will receive tags information from reader. UID is tag's identification number. Reading range and RSSI are inverse proportion. DI is tag's status and indicator. For example, [BAT] means tag battery was low. [SW] means tag emergency button was clicked. [SENSOR] means light sensor have detect light. [START] means tag restart. T1 is ambient temperature sensor value. T2 is skin temperature sensor value. In area D, the main function is start/stop to read tag data, clear received tag data and adjust RSSI filter (0∼255) to reject tags which have low RSSI signal.

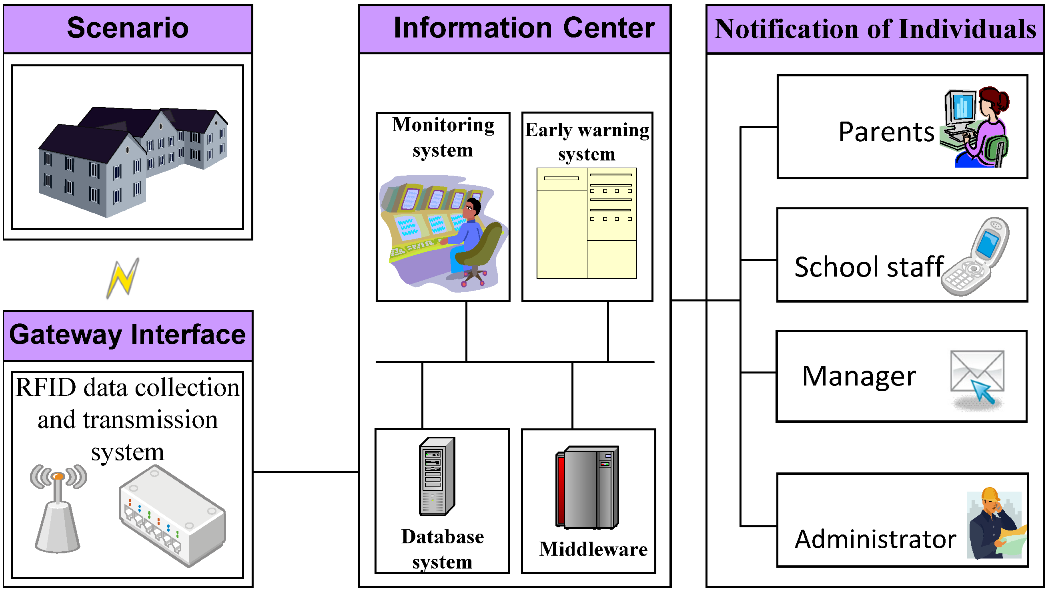

FIGURE 7. Campus-safety information system

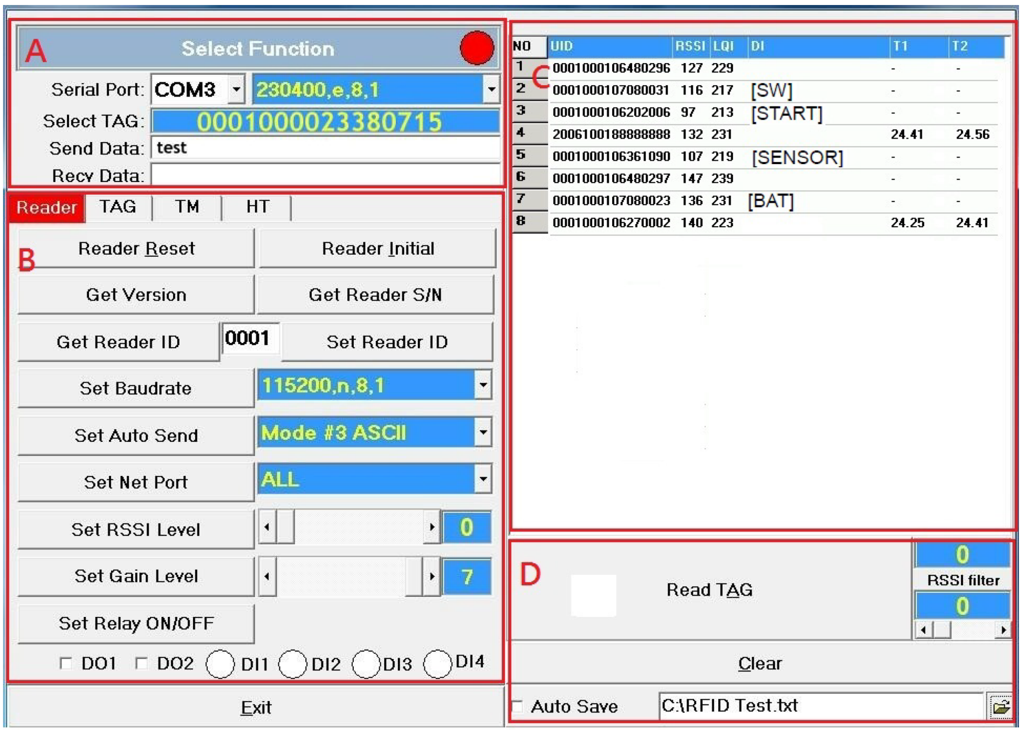

FIGURE 8. RFID reader and tag program setting

4.3. **System implementation.** This paper presents an integrated information system that real-time monitoring in support of dynamic accident-prevention mechanisms. The system is divided into three parts: remote control, web application and RFID middleware server, as shown in Figure 10. We can get through a remote maintenance system via the public network to a remote login for system maintenance. Administrators can query the web application and database system server for stored information. Web application using SSL access authentication mechanism, SSL (Secure Sockets Layer) aims to provide a network between the application software securities of data transmission. The school

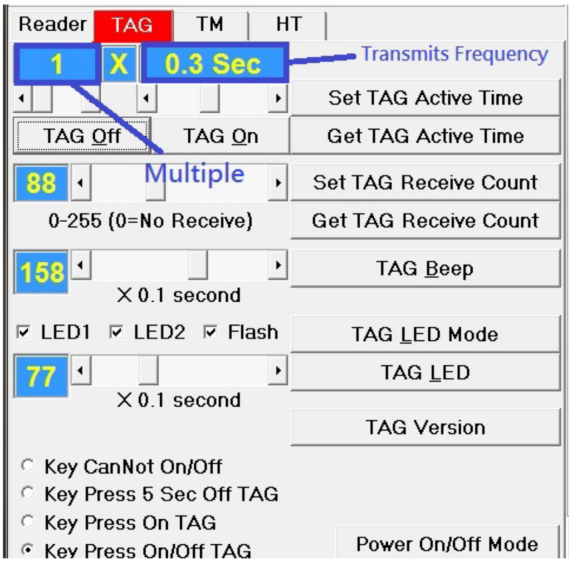

FIGURE 9. RFID tag setting

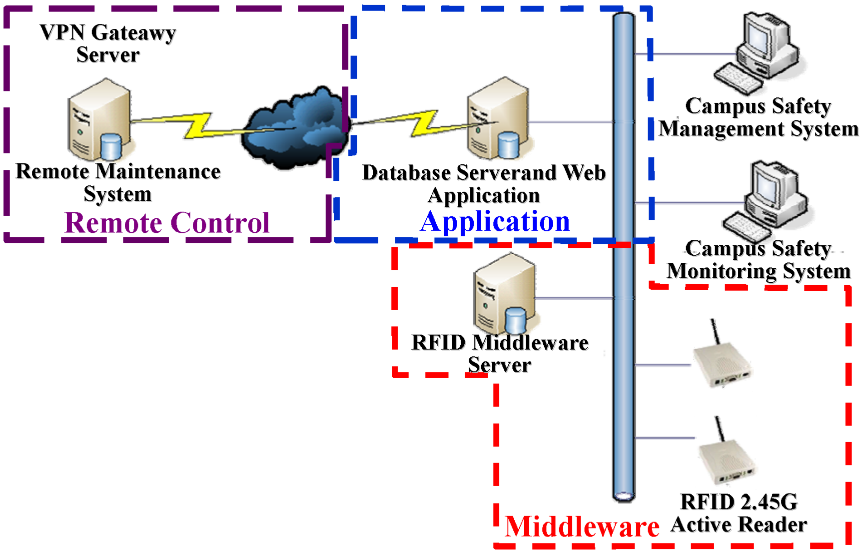

FIGURE 10. RFID system for campus safety

staffs can use the Web browser to connect to the database server, in accordance with the different identities, to query students' relevant information. We stored static information and dynamic information about the students in the database server. Database server use data encryption for the connection, data, and stored procedures offering the highest level of security available in the Tainan School of Special Education. With the RFID middleware server, we can obtain tag-location 'information and student identities.

This information can help ensure the safety of students on school grounds. RFID middleware serves in managing the flow of data between tag readers and safety applications for campuses. An RFID middleware server can help capture data effectively, and data filtering may be necessary for reducing overhead communications. Every region of the campus has several RFID readers. When the RFID middleware server receives information collected from these readers, the RFID middleware server will be responsible for analyzing this information to determine whether the students' independent behavior is normal or abnormal.

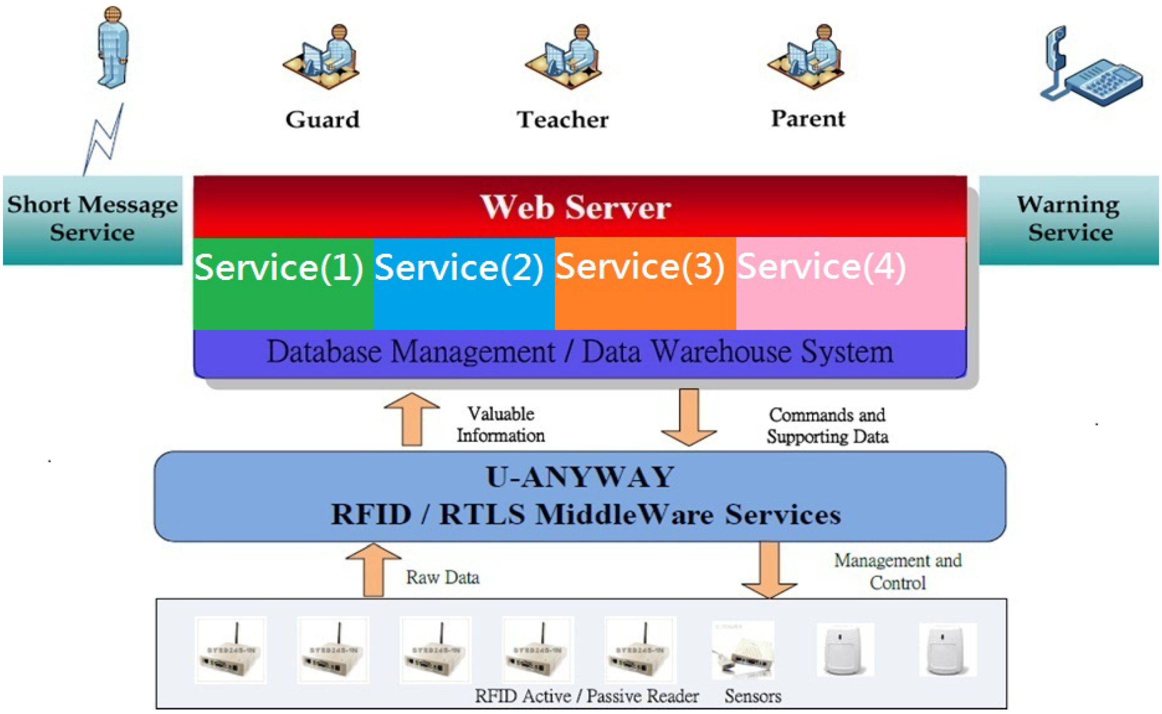

FIGURE 11. RFID information platform integration services

The RFID middleware server will make use of the appropriate decision-making mechanism, and at the same time inform the responsible units in the region. RFID tag use of wireless communications pass packets transmission format, this communication format through special algorithm encoded to interpret the encoding format required technical manuals. RFID middleware server and back-end database system in school, student safety system adopted separation data exchange mode. RFID middleware server only has student ID, no other personal information. Only school staff knows the student ID mapping to the back-end database system. The main components of the system are the RFID readers and tags, a database, and applications. An RFID information platform integration services is illustrated in Figure 11. The intelligent campus-safety system obtains students position via RFID middleware, and then identifies each scenario. The cooperation between readers and tags accomplishes the required functions for accident-prevention mechanisms. The tag constantly transmits trigger signals with a tag ID and other information. Accident-prevention mechanisms services comprise (1) the student-tracking management service, (2) the dangerous-area warning service, (3) the body-temperature monitoring service, and (4) the mobility-impairment assistance service. The system provides a short-message service (SMS) and a warning service to teachers, parents, and guards. The RFID middleware manages various sensors and readers, collects data by using various protocols, and extracts the valuable information stored in the database management system. RFID information system software architecture is illustrated in Figure 12. Type 1 RFID scenario application with the NET Framework developed by the Windows Form application, processing its direct-connected RFID reader induction to the RFID tags information. Wireless network operations center to manage all network devices, RFID readers, RFID tags, such as the management platform to maintain the normal operation of the RFID network system. Type 2 RFID scenario web application is a web application running on Internet Information Services environment.

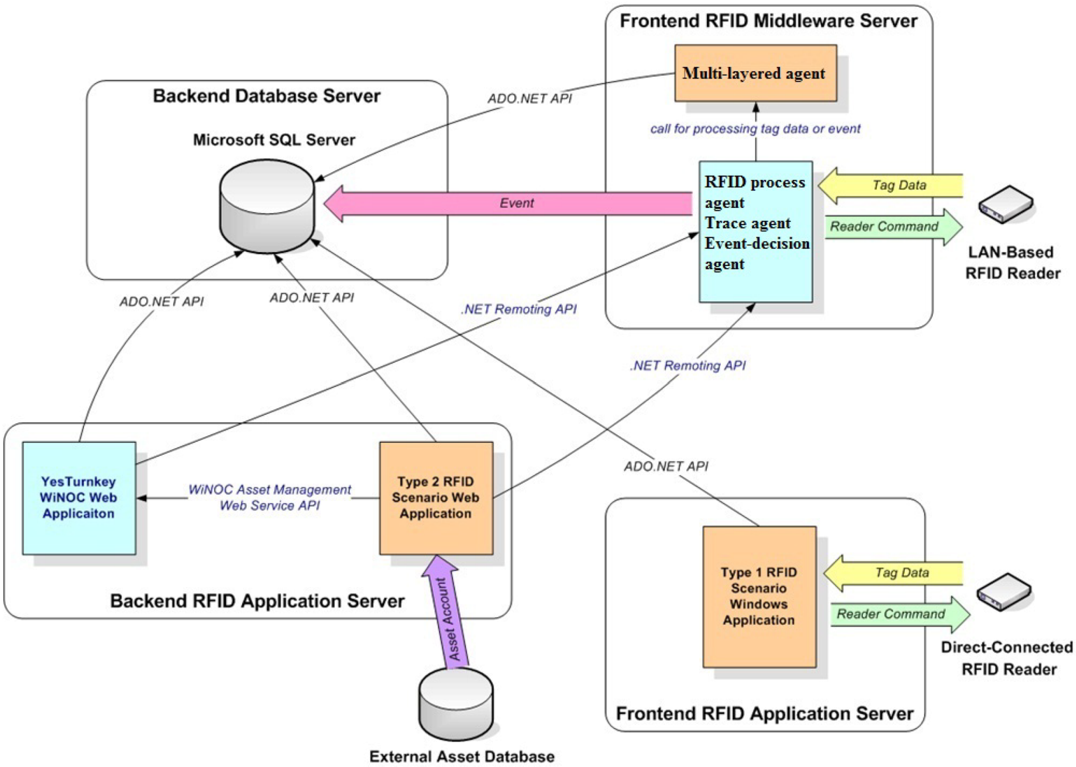

FIGURE 12. Information system software architecture

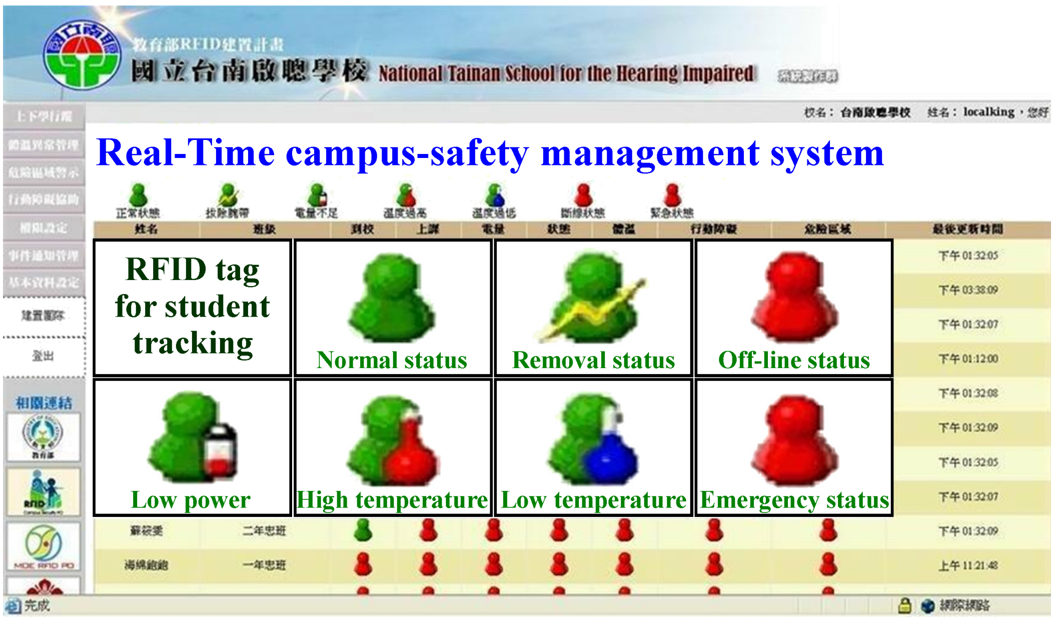

FIGURE 13. Real-time campus-safety management system portal

4.4. **System operations.** In Section 3 of this paper, we explained different scenarios associated with accident-prevention mechanisms. Campus-safety monitoring is ongoing, and school staff can always access real-time information regarding the whereabouts of all events as well as the current status of students through the portals of real-time campus-safety management systems, as shown in Figure 13.

The use of RFID tags to track students can be divided into the following seven status types: (1) a normal status means that students situation on campus is routine; (2) a

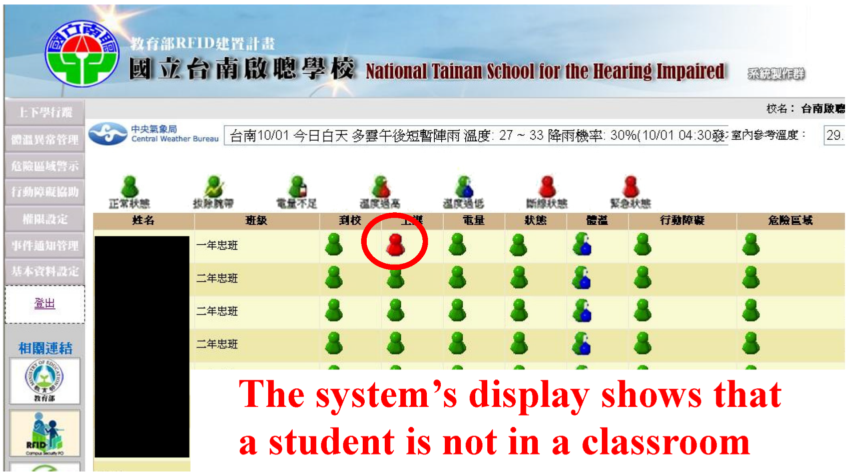

FIGURE 14. System display of the student-tracking management service

removal status means that students' tag already removed from the body; (3) an off-line status means that students' situation on campus is disconnected from the system ; (4) low power means that the battery charge of an RFID tag is low and the battery needs to be replaced; (5) a high-temperature reading means that a student on the campus is running a fever; (6) a low-temperature reading means that the body of a student on campus is abnormally cold; and (7) an emergency status means that a student on campus needs assistance. System display of the student-tracking management service is illustrated in Figure 14. We can know from the system screen that a student has been to school but not in the classroom. Figure 15 illustrates the system's dangerous-area warning service. Specifically in this case, the system is warning of two students entering a danger zone, and so the system informs guards that they should remove the students from the danger zone's vicinity.

5. **Performance evaluation.** We will now present a test scenario for the dangerous-area warning service. The system was successfully deployed and is currently in use by the Tainan School of Special Education. Figure 16 presents a diagram of the dangerous-area test architecture. The danger zone size is 2.5M by 2.5M. When a student into the danger zone that the average walking time requires is 4.5 seconds, the average running time that a student requires is 1.5 seconds. In order to prevent students from entering the danger zone, both RFID Reader 1 and RFID Reader 2 can simultaneously detect an active tag. We used 10 active tags for carrying out this simulation. The percentage of accurate tag readings is illustrated in Figure 17. Figure 18 presents the tag-reading response times. From Fig. 17 and Fig. 18, we can see that increasing tag not only decreased the accuracy, but increased the response time. The result is caused because signals would interfere with each other between the Tags. Based on this reason, we used two tags for sensing student near or enter dangerous-area respectively in the scenario of dangerous-area, and reduce signal interference area between each other tag.

We will present a test scenario of the student-tracking management service. The system was successfully deployed and is currently in use by the Tainan School of Special Education which has approximate 50 students and 8 students per classroom. There is a blackboard in the front of the classroom and we can call the initial position A0. We set up a vertex every 1.8 meters to complete the coordinates of all vertices in the classroom A illustrated in Figure 19. We placed an RFID Reader in the middle of classroom A. In each test, we assigned an RFID tag to each vertex, and we set the RFID tag-transmission frequency

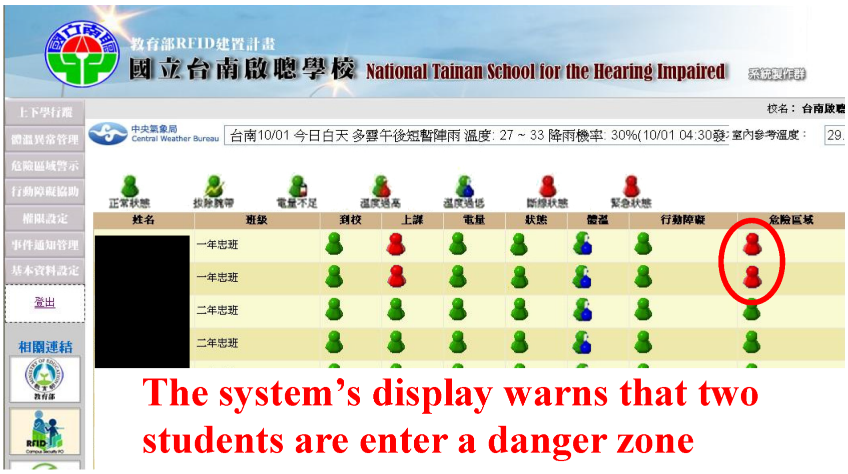

Figure 15. System display of the dangerous-area warning service

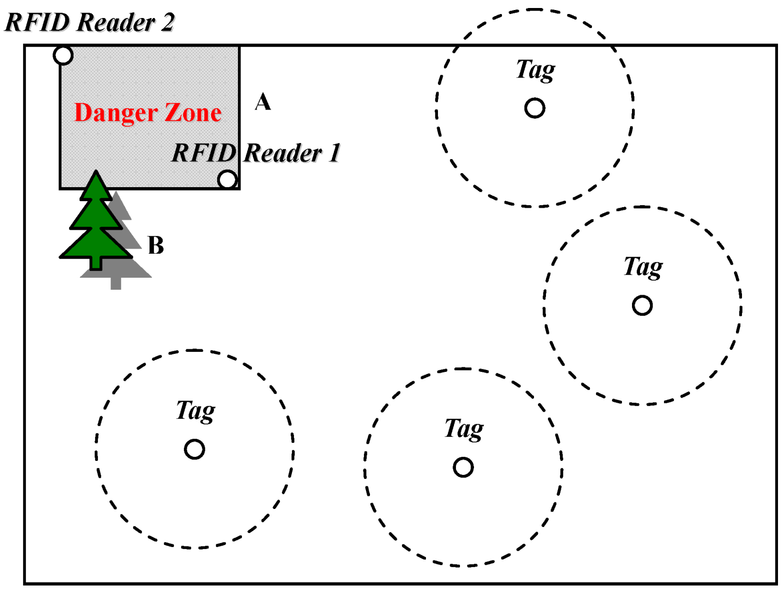

Figure 16. Diagram of the dangerous-area test architecture

Table 4. The time required for RFID reader to read 100 RFID tags

Number of times	Duration (in seconds)	Number of times	Duration (in seconds)	Number of times	Duration (in seconds)
1	8.99	11	5.44	21	5.61
2	7.16	12	4.18	22	6.91
3	7.24	13	6.18	23	4.23
4	6.29	14	4.08	24	6.24
5	7.6	15	5.59	25	3.56
6	3.95	16	5.34	26	7.02
7	6.33	17	6.72	27	7.58
8	6.22	18	6.28	28	3.85
9	5.77	19	6.09	29	5.77
10	6.79	20	6.4	30	5.67

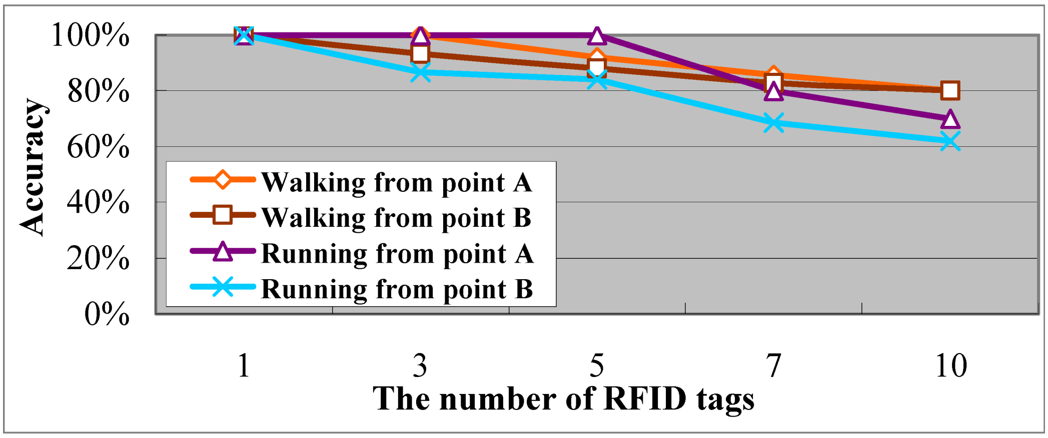

FIGURE 17. The percentage of accurate tag readings

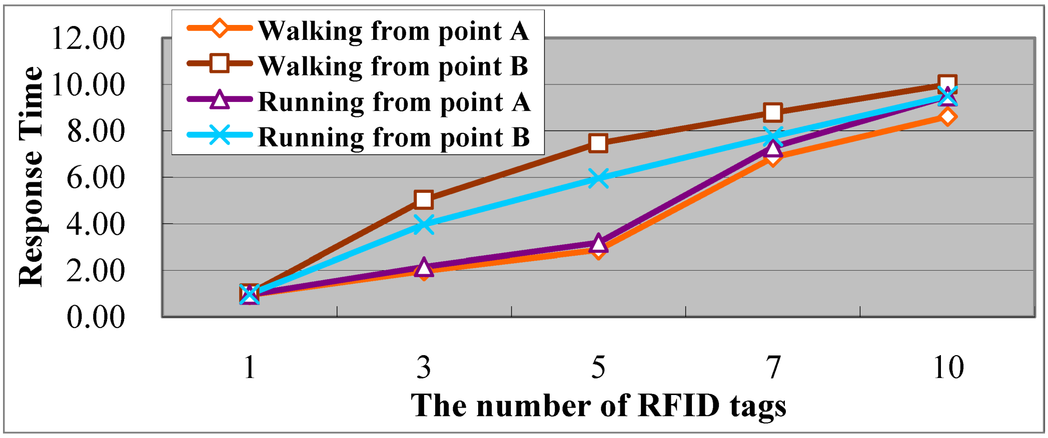

FIGURE 18. Tag-reading response times

to two times per second. The true purpose of calculating the receiving rate based on the number of receptions shown in table 5. The tags placed in the classroom B exhibited a bad receiving rate because isolated within the wall so that RFID reader cannot receive any signal. The tags placed in classroom A exhibited a good receiving rate of over 70%. We used both RFID 2.45G active reader and RFID 2.45G active tag to carry out the simulation. We used RFID reader at the same time to read 100 RFID tags, we calculated the time that the teacher required to take a real-time roll call, and then we repeated this sequence of steps thirty times, as shown in table 4. According to table 4, the average time that the teacher required to take a real-time roll was 5.693 seconds.

The following table compares traditional tracking technology with our proposed tracking technology for campus-safety management systems. We found that the use of RFID technology improved the overall accident-prevention mechanisms. It seems obvious that RFID technology can significantly reduce the potential for human negligence and can improve data accuracy. In addition to real-time tracking of student status, our system can greatly enhance campus safety.

6. **Conclusion.** Longitudinal analyses of historical database can provide evidence of crisis events will occur in school. Campus-safety experts should explore the deep structure of campus-safety incidents in order to determine why the incidents occurred. Through RFID technology, we can transform passive security systems into active security systems. When students encounter emergencies, their RFID tags can send out a distress message from

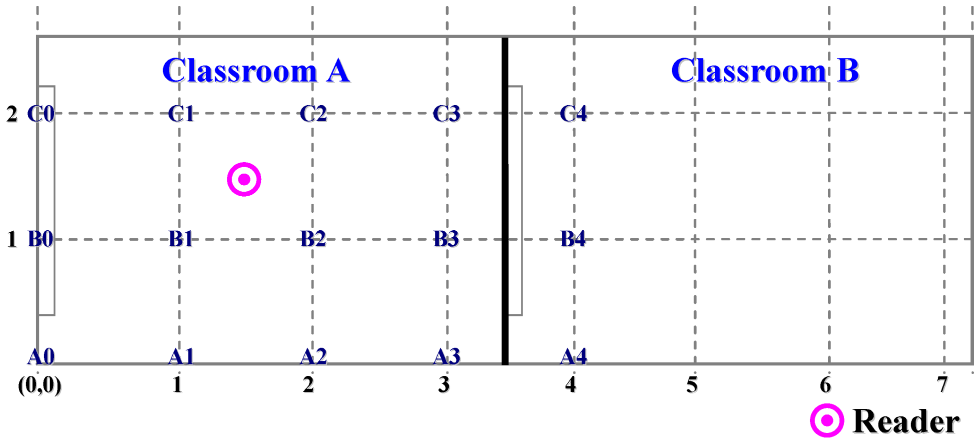

FIGURE 19. RFID reader and RFID tag deployment in a classroom

TABLE 5. The number of receptions and the receiving rate

RFID tag location	The number of receptions	The receiving rate
A0(0,0)	23	76.67%
A1(1,0)	23	76.67%
A2(2,0)	22	73.33%
A3(3,0)	23	76.67%
A4(4,0)	0	0.00%
B0(0,1)	23	76.67%
B1(1,1)	23	76.67%
B2(2,1)	24	80.00%
B3(3,1)	23	76.67%
B4(4,1)	0	0.00%
C0(0,2)	23	76.67%
C1(1,2)	23	76.67%
C2(2,2)	22	73.33%
C3(3,2)	22	73.33%
C4(4,2)	0	0.00%

any corner of a campus. Basically, in this paper, we aim to demonstrate the feasibility and applicability of utilizing RFID-based technologies to the special-education students. In summary, this research makes the following contributions to improving the traceability and the efficiency of campus-safety management systems.

- We proposed an RFID-based tracking system using RFID technology to strengthen real-time monitoring and dynamic accident-prevention mechanisms in respect of ubiquitous campuses.
- We classified students' behavior patterns regarding different types of scenario relationships.
- The proposed framework can indeed improve the traceability of students throughout the entire school day.
- Our system can provide both school staff and parents with real-time information, helping them both respond to the status of students in real time and make better decisions in handling independent events.

Table 6. Comparison between two information systems regarding campus-safety tracking

Criteria	Traditional campus-safety tracking system	RFID-based tracking system
Auto Discovery	Cannot support auto discovery	Automatic detection and execution monitoring
Efficiency	Operational efficiency is too low	Can read many tags at once
Accuracy	Significantly prone to human negligence	Reduces the potential for human negligence and improves data accuracy
Traceability	Campus environment obstructs tracking of student status	Allows detailed tracking of student status
Speed	Delayed processing of events	Real-time processing of events
Triggers/Alerts	Very poor	Established satisfactory mechanisms
System log	Could depend only on manually accessed records	Could receive reports from the system

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