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Intelligent Wireless Safety Management System for Children in Kindergarten

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Abstract: Nowadays, families of double-incomes are more and more than ever. Therefore, the children under six years old of such families are forced to send them to kindergartens for a better care. In order to take care of the children well the safety management for children in kindergarten becomes thus much more important. On the other hand, the Wireless Sensor Networks (WSNs) have also shown their effectiveness in many applications. Which leads the proposed paper aims at designing a safety management system to increase the safety of the children not only in the campus but also on the ways between their homes and the kindergarten. The proposed safety system combines three major wireless network systems including Wi-Fi/3G communication system to communicate between parents and kindergarten, Zigbee position system to locate the children in the kindergarten and RFID system to identify all the related personnel. The proposed system was designed to protect the children from any kind of dangers since the moment they left their parents. With the help of RFID system, the children are identified by the RFID readers as they getting into the school bus and passing through the school gate. The Zigbee position system is also applied to locate the children in the kindergarten to prevent children from dangerous areas with some proper design. Furthermore, the Wi-Fi (or 3G) system provides the communications between the parents and the information system in the kindergarten. All the three wireless network systems are combined by a properly designed information system to implement the proposed wireless safety management system. Some experiments results based on a kindergarten with such design in Taiwan are given to validate the performance of the proposed system.

Key words: Wireless sensor network, RFID, Wi-Fi

INTRODUCTION

Generally speaking, most operating systems treat wireless LANs (local area network) as wired LANs, regarding them as just Ethernet. However, the wireless networks are significantly different from the traditional wired networks because of the mobility of host and the characteristics of continuously changing channel in the wireless networks. If networking protocols and operating systems ignore this fact, then the performance and/or the potential for new functionality will be poor. In this research, the well-known Radio Frequency Identification system (RFID) is applied to identify all the related personnel including children and teachers and then record the time of entering/leaving the kindergarten and the school bus on the school server in the same time. On the other hand, the Wi-Fi and/or 3G system are also introduced to communicate the parents and the kindergarten when notice or inquiry between the parents and the kindergarten is needed.

For the purpose of location and tracking system, some related works in the area are categorized into the followings: (1) IR-based (Infra-Red) systems (Want *et al*., 1992; Azuma, 1993; Adams *et al*., 1993; Harter and Bennett, 1993; Ward *et al*., 1997) (2) RF-based systems (Lee *et al*., 2011; Christ *et al*., 1993; Werb and Lanzl, 1998; Bahl and Padmanabhan, 2000; Hashemi, 1993) (3) Cellular-based (mobile) systems, (Hodes *et al*., 1997; Liu *et al*., 1998) and (4) Everything-else, e.g. ultrasound, X-ray.

The IR-based location systems have several drawbacks such as: (1) The IR-based system scales poorly due to the limited range of the ray, (2) The IR-based system is expensive and (3) The IR-based system is difficult to perform in the sunlight which seems to be a problem in an outdoor area or a room with windows.

The RF-based location system uses RF Receiving Signal Strengths (RSS) to determine user location in a manner similar to the proposed system or measures the Time of Arrival (TOA) of RF signal to estimate the distance between transmitter and receiver. However, some defects cannot be neglected such as: (1) RF-based system requires infrastructure deployment over and above a wireless network, (2) RF-based system depends on specialized hardware, (3) RF-based system usually does not take RF propagation into account and (4) RF-based system does not take into consideration the effect of the user's body orientation on RF signals which in the

proposed position scheme causes a certain error. Because of the above reasons, a tolerance zone called warning area is designed to ensure the safety of children in the danger warning system of the proposed scheme.

The wireless LAN based system for location estimation has been given in some literatures (Hodes *et al*., 1997; Liu *et al*., 1998). The Access Points (APs) transmit beacons with their physical coordinates signal inside. A mobile host estimates its location to be the same as that of the AP to which it is attached. Consequently, the accuracy of the position system is limited by the cell size.

Some location determination systems in the wide-area cellular arena have recently been proposed (Werb and Lanzl, 1998). The technological alternatives for locating mobile involve many parameters such as the signal attenuation, the angle of arrival and/or the time difference of arrival. Although these systems have been found to be promising in outdoor environments, their effectiveness in indoor environments is limited by the multiple reflections caused by the RF signals.

Another very useful outdoors location technique is called the Global Positioning System (GPS) but ineffective indoors because buildings block the transmissions of GPS signals (Enge and Misra, 1999; Tekinay, 1998; Moeglein and Krasner, 1998). But the GPS is not used in the proposed scheme because of a part of the environment of kindergarten being indoors. There are also many different methods developed to locate the positions of objects that can be found in literatures (Ward, 1999). Although these technologies and methodologies are very interesting, they usually suffer from the same drawbacks as their IR and RF counterparts.

The proposed work tackles the problem of location tracking using widely available wireless sensor networks (WSNs) by properly arranging the Zigbee modules to cover the entire campus. With Zigbee badges carried with the children, the proposed Zigbee position system can thus locate their positions and show them on the information system in the office of the kindergarten. The adopted Wi-Fi networking speeds of up to 11 Mbps, wireless LANs have gained rapid acceptance and are widely being deployed in the city Taipei, Taiwan (called WiFly system) where the experiment is conducted under this free Wi-Fi system. The WiFly system is already deployed as same as the 3G mobile communication system in our system which can be used purely communication between the parents and the kindergarten. The experiments are performed in a kindergarten in Taipei and also performed in a small scale of compact model for demonstration. The original webpages are written in Chinese because the experiment is conducted in Taiwan. For a clear understanding, the webpages are rewritten in English with some extra description to explain their meanings in the experimental results.

SYSTEM ARCHITECTURE

This research begins with the children stepping out from their home into the bus and entering into the kindergarten with the help of RFID system. After children entered the kindergarten, instead of RFID system, the positioning system with Zigbee modules is activated to prevent the children entering the dangerous areas. As the end of the school day, the RFID system works again as same as previously mentioned to guarantee the children safety back to their parents. A powerful management information system is setup in the kindergarten to communicate all the information and refresh the database for both parents and kindergarten. Besides, the Wi-Fi system or 3G mobile system is also needed to connect the users with the information system in the kindergarten via Internet. The block diagram of overall system is given as Fig. 1 below. And, the detailed description of each block is provided in the following subsections. Combining all the subsystems, the sketch of the wireless system can be shown as Fig. 2.

RFID system on school bus: First of all, the children wear the RFID Tags and the teacher along with the school bus carries the portable RFID reader. When the children are stepping on the school bus the teacher should use the

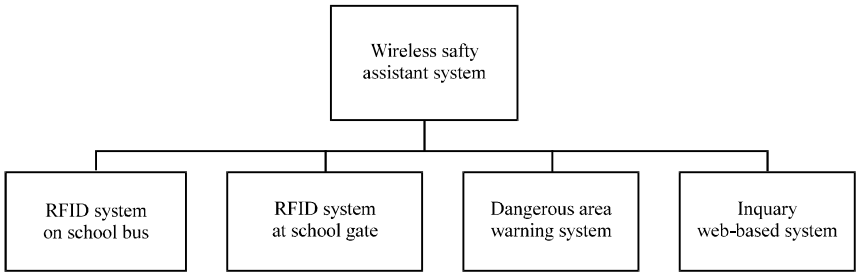


Fig. 1: Block diagram of overall system

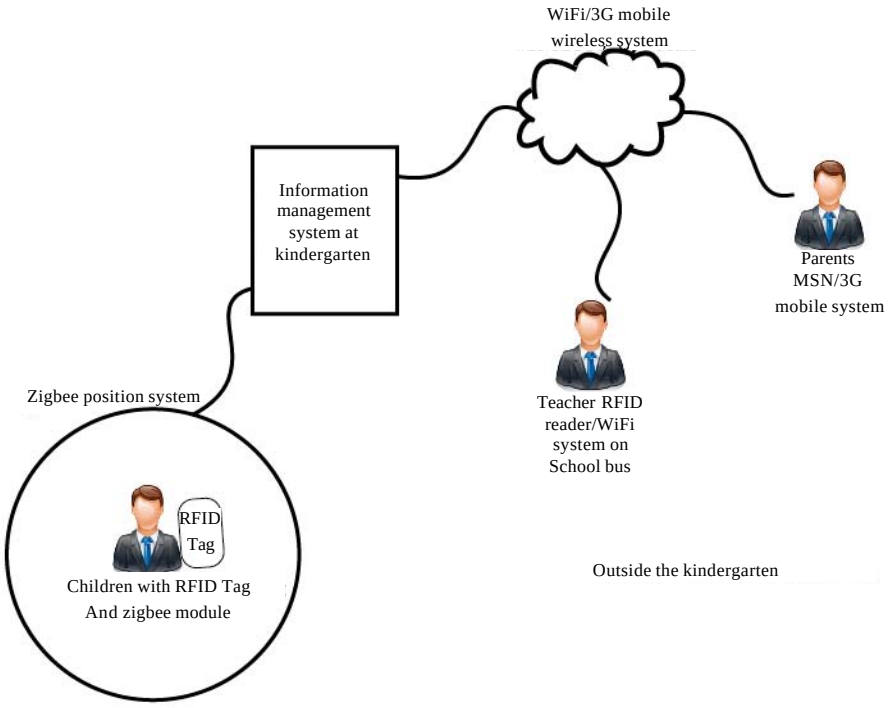


Fig. 2: Sketch of overall system

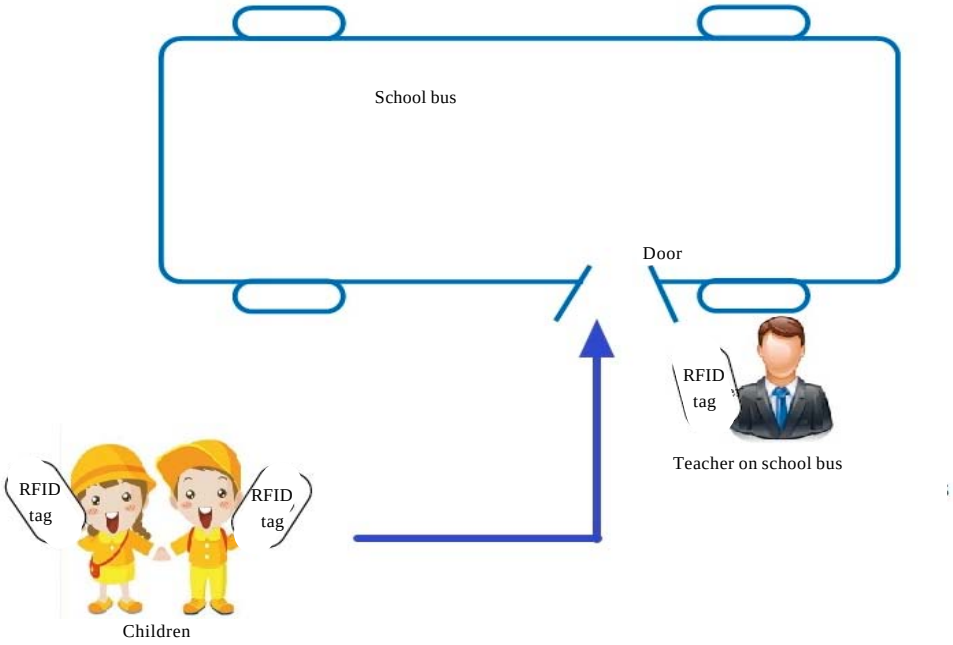


Fig. 3: Sketch of RFID system on school bus

reader to identify the children and send the message back to the information system in kindergarten via the portable reader equipped with Wi-Fi system. The time of the each child gets on the school bus will thus be recorded in the database in the information system of kindergarten and paged to their parents to display the message on their MSN and/or mobile phones. The sketch of such process is demonstrated in Fig. 3.

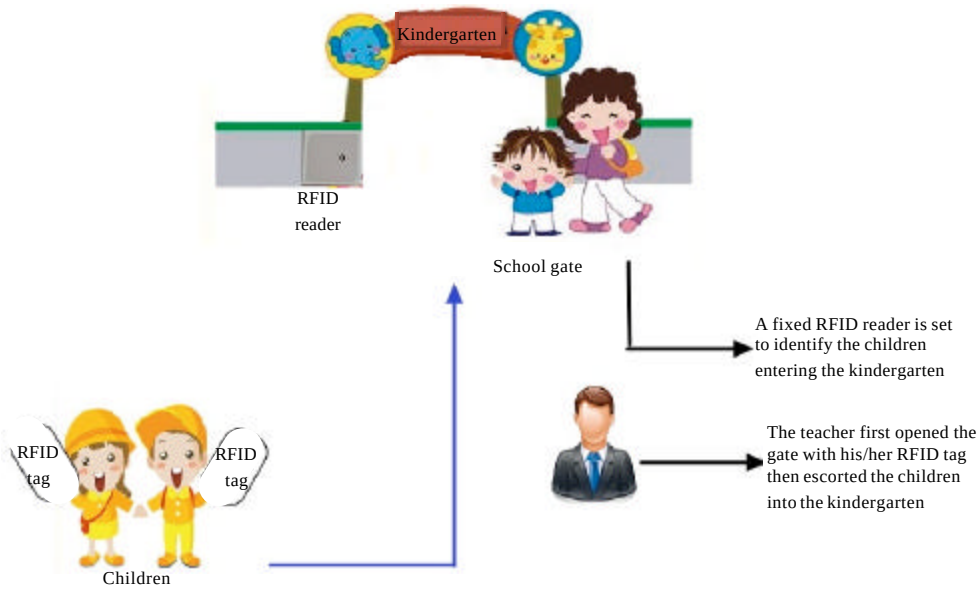


Fig. 4: Sketch of RFID system at the school gate

RFID system at school gate: A fixed RFID reader is set on the school gate to identify and record the users' information by their RFID tags. With the predefined levels of the tags, the school gate can be opened by teachers only but children. When the school bus arrived at the kindergarten, the teacher used his/her RFID tag to open the school gate and then escorted the children to get into the kindergarten. As the RFID tags of children being read by the fixed reader at the gate, the information system of the kindergarten received the signals and then changed the status of the children from being in the school bus to being in kindergarten and sent the messages to their parents via Internet or/and 3G mobile system. On the other hand, if any child still stayed in the school bus then led to the different number of children between school bus and kindergarten. As a result, a warning alarm is thus shown on both teacher's portable reader and monitor in the office of kindergarten. Under such situation, the teacher would double checks again the children in school bus and kindergarten to guarantee the children being under protection all the time. A tragedy that a child was kept in captivity for hours and found died in the school bus of a kindergarten due to the miscount of children in Taiwan can be avoided in the future. Figure 4 shows the sketch of the process of children entering the school gate.

Zigbee positioning system: Using the Zigbee sensor located in the kindergarten in a proper range, the signal strength from the Zigbee modules being worn by the children can be detected. There are many methods to estimate position by wireless techniques as previously mentioned in Introduction. The most popular two are RSS (received signal strength) method and TOA (time of arrival) method. In the proposed scheme, RSS is adopted to estimate the position of the Zigbee module. If every child wears a Zigbee module then the position of the child will be acquired by using the mathematic formula deduced from the RSS method. In this system, position technique first used triangular methodology but errors occurred due to the variety of environment in kindergarten. A lookup table is applied in the proposed system based on the field experimental results.

Dangerous zone waning system: The dangerous zones should be defined first then the Zigbee sensors are setup in predesigned spots. In order to avoid any danger occurs due to the deviation of position system, a wider zone called warning area is thus designed. When children approach the dangerous zone such as kitchen, parking lot, they first get into the warning area. The warning alert will be given to notice children to leave such area and teachers also be noticed. But, if the children keep approaching the dangerous zone then not only the teachers are noticed again but also the monitor in office shows the status of danger. Besides, the speakers of such ganger area will broadcast the dangerous notice to the children immediately and the teacher will also arrive at the

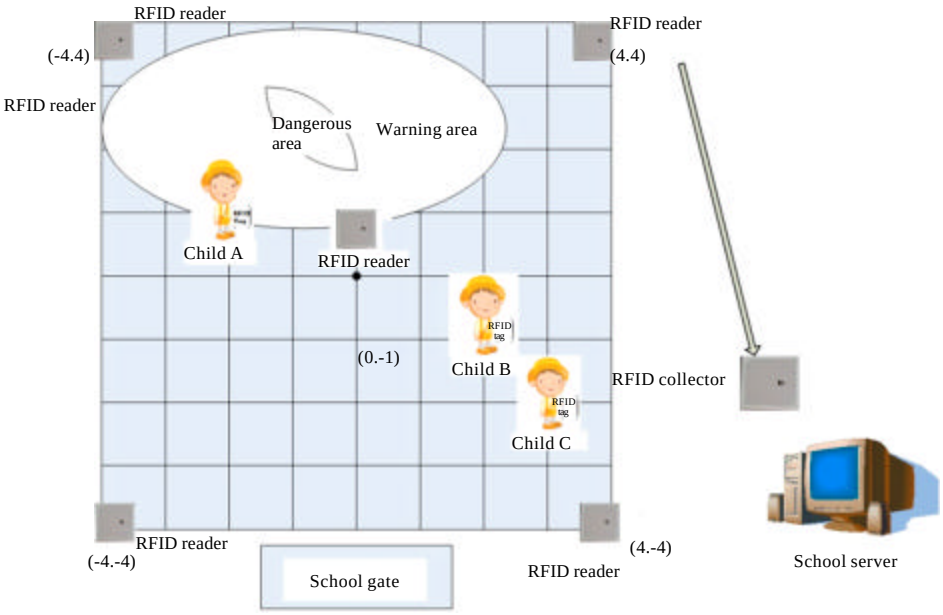


Fig. 5: Dangerous zone warning system

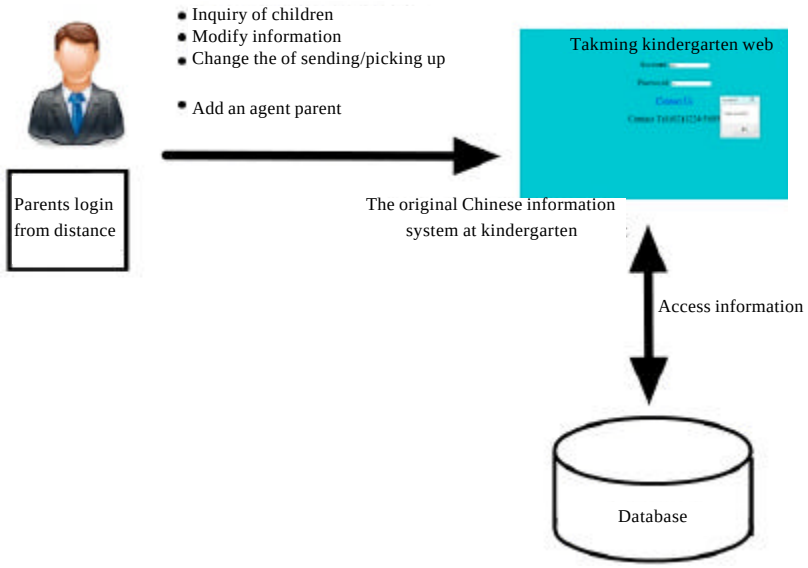


Fig. 6: Sketch of web-based information system

dangerous zone to bring the children back to safe place. The Zigbee position system with dangerous zone warning system is illustrated in Fig. 5.

Real-time inquiry system: Parents can link to the web-based information system via Internet to inquiry their children's statuses, modify their personal information or increase an agent parent, etc. As shown in Fig. 6, parents can log in the information system via Internet to accomplish the tasks mentioned above.

EXPERIMENTAL RESULT

To fulfill the proposed scheme described in previous sections, a series of experiments are held to illustrate the functions proposed in the system.

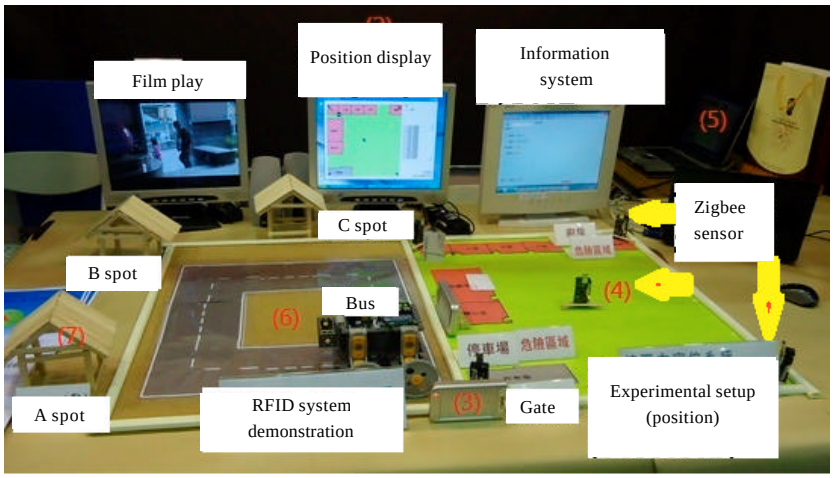
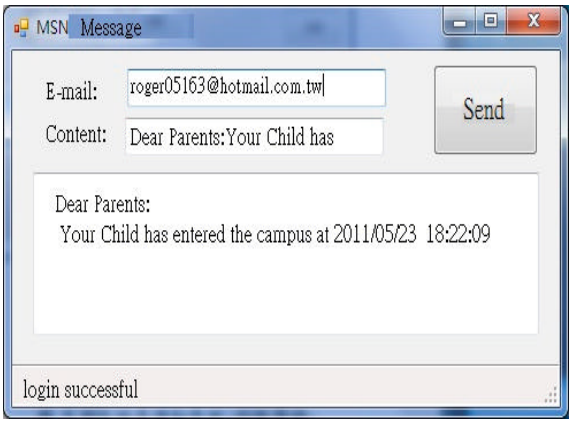


Fig. 7: Experimental setup of a compact model

Experimental setup: The small scale of the compact model including the kindergarten, a school bus and three bus stops is shown as in Fig. 7. The left part is the route of school bus with three bus stops, A, B and C to pick up the children. The right part is the campus of the kindergarten which is equipped with classrooms, a kitchen and a parking lot. The school gate is set in front of the campus. There are three monitors to show the film of the experiment in real scale, the dangerous area warning system and the information server system inside the kindergarten. The kitchen and the parking lot are defined as the dangerous areas in the campus and the warning system activates if the children approached to these areas.

RFID system at school gate: The proposed message system combines both RFID and MSN/3G page system. Using the RFID reader mounted on the school gate, all the entrance information will be recorded but only teachers can open the gate. When the children are passing through the gate, the information system receives the messages simultaneously and then sends the messages to their parents automatically via MSN/3G page system. The parents therefore acquire the time of arrival/departure of their children. The performances of MSN and 3G page system are shown in Fig. 8a,b and 9a,b, respectively. The parents can also check the statuses of their children by using an inquiry interface of the information system via Internet. Figure 10 shows the outcome of such system on webpage.

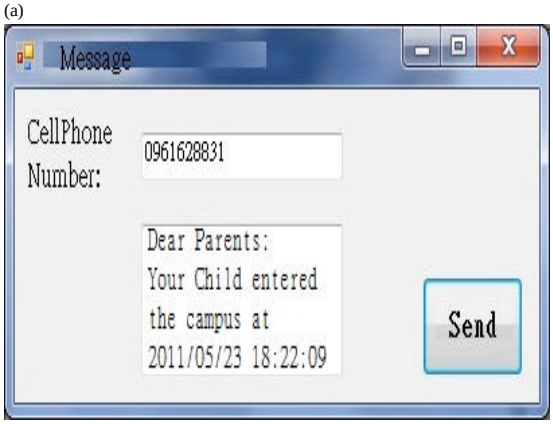
(a)



(b)

Fig. 8(a-b): (a) MSN system-server (kindergarten) and (b) MSN system-client (parent)

(a)



(b)

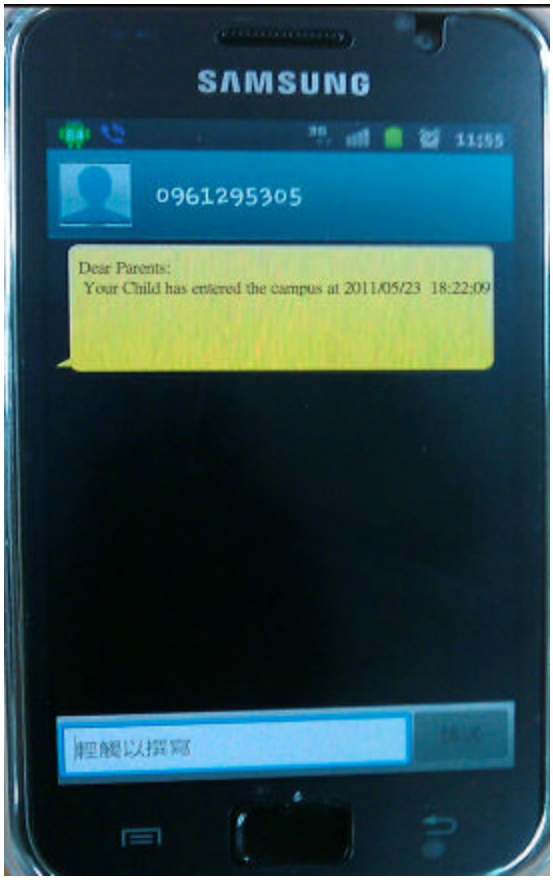


Fig. 9(a-b): (a) 3G text system-server (kindergarten) and (b) 3G text system-mobile (parent side)

Zigbee position system and dangerous area warning system: Besides the successful demonstration in small scale of experimental setup is shown in previous subsection 3.3, the Zigbee position system and dangerous area warning system are also been performed in a real kindergarten in Taipei, Taiwan. The layout of a kindergarten is as in Fig. 11 with a kitchen and a parking lot as the dangerous area in orange color and the proper zone of warning area in yellow within an area 50X50 meters.

With the proper arrangement of Zigbee wireless sensor network and the help of a look up table of position to RSS being previously measured, the positions of the students can be acquired by the RSS of related sensors. There are three students with the Zigbee badges and shown as the round dots in the Fig. 11, the green means safe and the red denotes dangerous. If a student is shown in red and entering the area in yellow then the warning system will send a message to the teacher nearby to notice this situation and the teacher should take a proper action as shown in Fig. 11. However, if the student walks into the dangerous area then the warning system will not only send the warning message to teachers but also broadcast the message to notice the student away from the dangerous area right away as shown in Fig. 12.

Real-time web-based inquiry system: The parents can acquire the positions of school bus and the statuses of their children via the real-time web-based inquiry system. The teacher along with the school bus had to log in the information system before the school bus left the kindergarten. And, the position of the school bus on the regular route including the children be picked up on which bus stops is shown on the webpage as shown in Fig. 13. If the children are late for the bus then the system will send messages to notice the parents and the time of next bus. The parents are also allowed to modify their personal information such as telephone no., address, etc. on line as shown in Fig. 14. The web-based inquiry system also provides a service of appointing the agent parent especially for those parents who are busy to pick up their children. The parents can appoint agent parents to pick up their children via Internet. This agent parent appointing system also produces a random number after the agent parent being appointed and such random number then be sent to the true parent. The agent parent meets both the correct information and the correct random number who can pick up the child. In that case, the wrong pick up of the children becomes almost impossible. The webpage of appointing an agent parent is shown in Fig. 15.

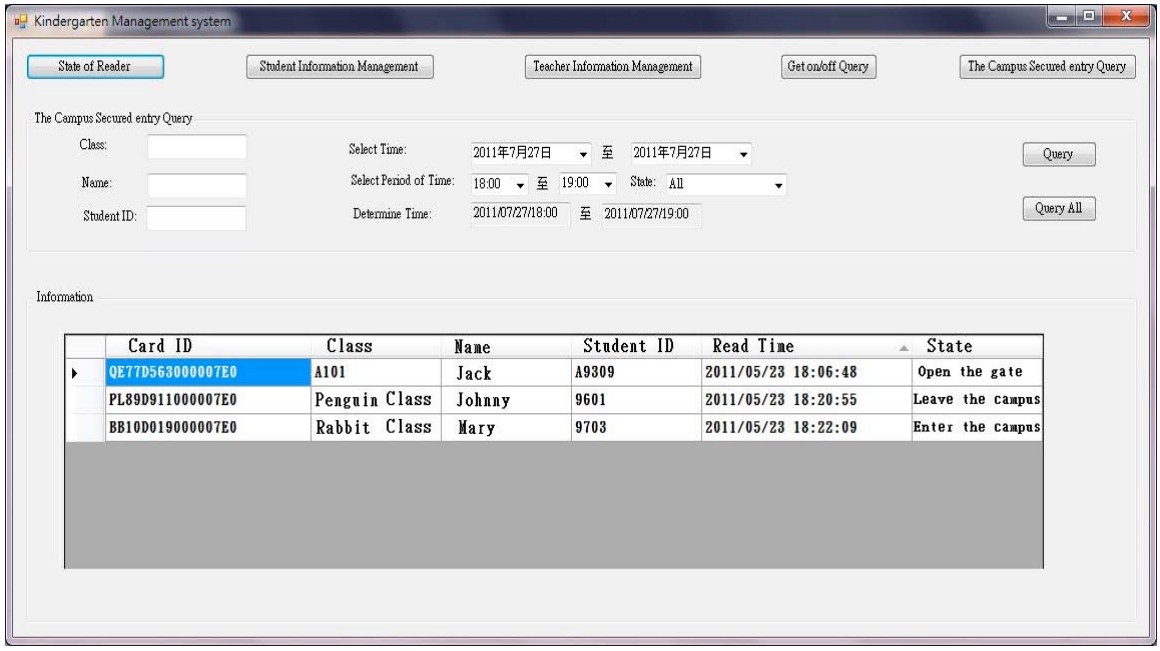


Fig. 10: Result of inquiry shown on the webpage

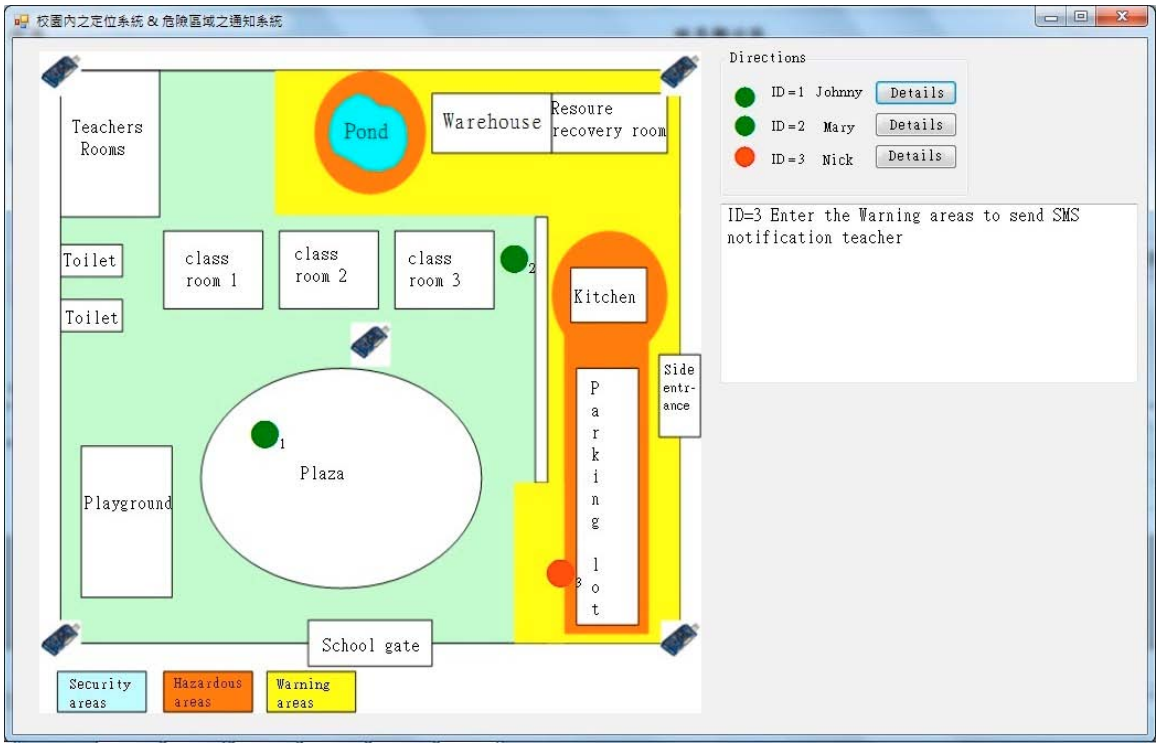


Fig. 11: Zigbee position system and the dangerous area warning system-entering warning area

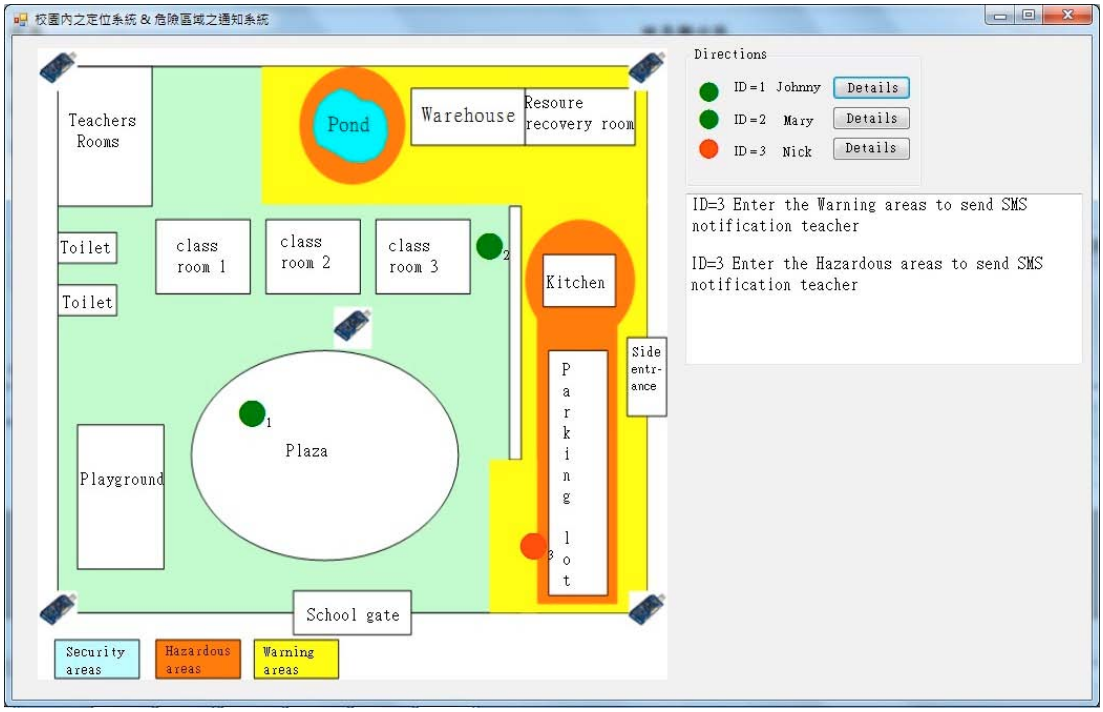


Fig. 12: Zigbee position system and the dangerous area warning system-entering dangerous area

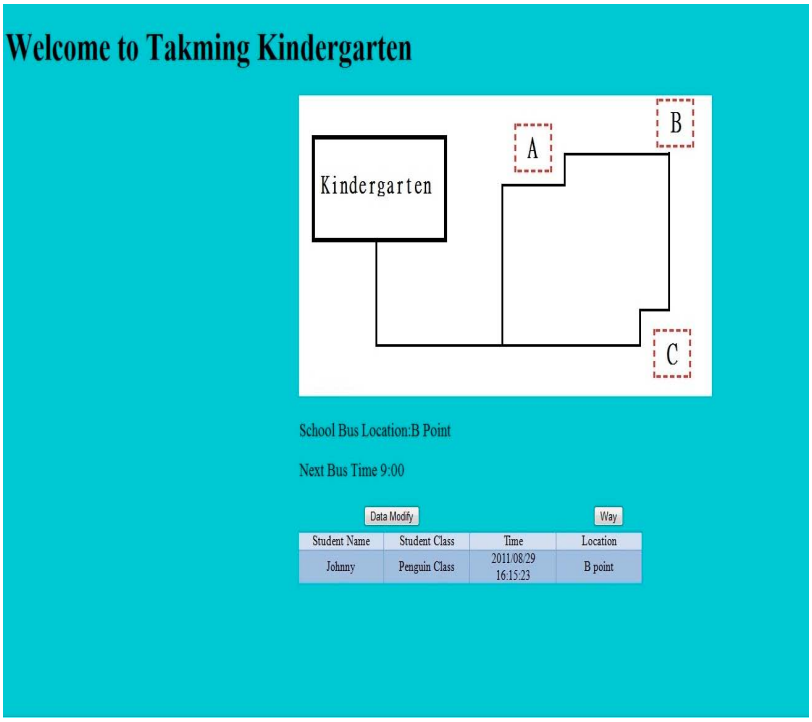


Fig. 13: Inquiry system-route of school bus

Fig. 14: Inquiry system-modify information

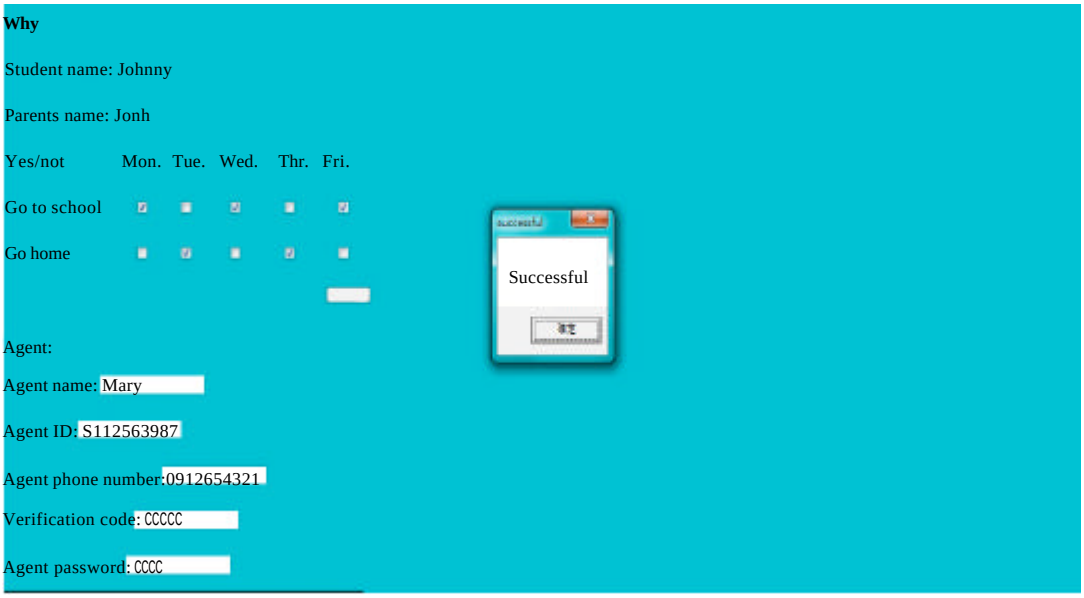


Fig. 15: Inquiry system-appointing an agent parent

CONCLUSION

The wireless network including RFID system, Zigbee (WSN), Wi-Fi system and mobile 3G system were used in this study Nowadays, children are much more precious than ever. The safety management system for the children in kindergarten becomes more and more important. This work tried to increase the safety of children in

kindergarten from the moment they had left their home to the moment they were back to their parents. The RFID tag is combined with a Zigbee element to provide the information not only the identification but also the positions of the children. With the help of Wi-Fi and 3G systems, the parents can acquire the situations of their children, modify their information and appoint the agent parents via the real-time web-based information system of the kindergarten. The statuses of children are documented as the time their tags being read by the RFID readers along with the school bus and mounted on the school gate. The information of such process is transmitted back to the information system (server) in the kindergarten. On the other hand, the Zigbee position system is activated when the children with Zigbee badge entering the campus of the kindergarten. A dangerous area warning system was also developed to guarantee the safety of the children in the kindergarten. The teachers can prevent the children from entering the dangerous area with the help of such system. To compensate the deviation caused by the Zigbee position system, an extra warning area is designed to deal with such problem. Both filed experiment and a small scale model of the overall system were conducted to demonstrate the performance of the proposed system. The proposed safety management system can actually help the teachers to ensure the safety of the children in kindergarten.

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