A ZigBee protocol-based Security and alarm monitoring system at nursing homes

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Abstract—A ZigBee-based security monitoring and alarm system was presented in this study to reduce nursing home staff responsibilities. This method can keep tabs on five different aspects of an old person's health, including their urine in bed, their ambulation, their falling, their posture, and any bathroom accidents. First, the system's overall structure was explained, and then each function module was examined in further depth. For testing purposes, Beijing's Sijiqing elderly home put a monitoring system to the test and found it to be effective.

1) INTRODUCTION

As the world's most populous developing nation, China's ageing population is putting enormous strain on the country's infrastructure and institutions [1]. The "Thirteenth Five-Year Plan" for elderly care identifies a critical gap in the current state of the intelligent aged care business. Many colleges and research institutions are urged to use the newest technology to items for the elderly in the nation that actually assist them. Nursing homes are becoming more and more frequent in the home care service for the elderly. Nursing homes maximise the efficiency of existing institutions for the elderly by bringing together those in need of care. The paucity of nursing personnel and heavy workloads are ongoing issues, resulting in omissions in the everyday care of the elderly. Nurses' workloads and accident sizes will be reduced significantly if new technology is employed to monitor senior mishaps that are expected to occur in their everyday activities.

Numerous studies have been carried out by local and overseas research organisations and businesses on nursing home security monitoring devices. Anti-falling airbags for the elderly have been developed by the Chinese University of Hong Kong and Prog Corporation of Japan [2].

The safety monitoring technologies used in nursing homes across the world have obtained comparable outcomes, but the high cost and poor practicality have hampered their marketing.

It is difficult to address the needs of elderly people since most of the appropriate items have just one function.

Safety monitoring systems for the elderly have been suggested in this study, and a systematic safety monitoring programme for nursing homes has been developed to minimise costs and enhance the quality of care.

2) SYSTEM OVERALL SOLUTION

A. Related Technology Introduction

Using ZigBee technology, you can send and receive data wirelessly across short distances at a cheap cost and with little complexity [9]. Network topologies in the ZigBee network include star, tree and mesh. There are three kinds of nodes in the ZigBee network: coordinator, router and terminal. A wireless full-coverage local area network may be set up in nursing homes to gather monitoring data.

A Linux-based operating system, Android is mostly utilised in mobile devices. Android is the most popular mobile operating system in the world, and it provides efficient technological support for human existence.

B. System Structure

The wireless network security monitoring system is separated into three primary components: the hazardous condition detection alarm terminal, the wireless network communication system, and the security monitoring information management system, as shown in Fig 1. Fig 1.

A toilet timeout detection alarm terminal, an ambulation and urination detection alarm terminal, a falling-detector alarm and regional placement terminal, and a hand-held alarm reminder terminal comprise the risky state detection alarm terminal. In the event of an accident, the hazardous state detection terminal sends out an alarm to alert the elderly to the dangers they face. ZigBee technology is used in wireless network information systems that comprise coordinators, routers, and terminals. The nursing home's hazardous status detection alarm terminals may be connected to the network. Because it transmits both alarm data to the monitoring centre and the instructions from the centre to several terminals at the same time, it serves as a safety net for data exchange. The PC programme that runs the monitoring centre is the hub for collecting, storing, and distributing information. In order to remind nursing staff to process the data submitted through wireless network transmission, it parses the data, saves it in the database, and then shows it on the monitoring interface for the staff. The Android-based remote monitoring programme is a mobile phone application. In order to keep an eye on the elderly's daily routine, it may access the monitoring center's data and show it on a mobile phone client.

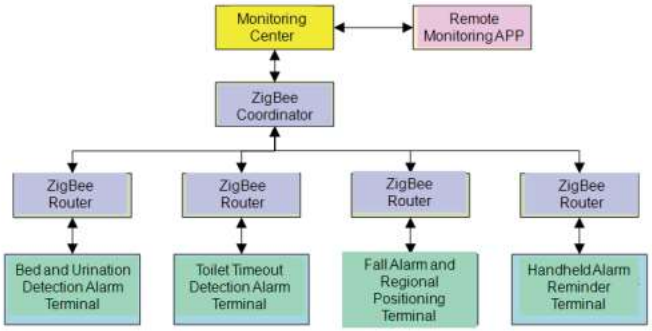

Figure 1. System architecture

III. ALARM TERMINAL DESIGN FOR DANGEROUS STATE

The activities of daily living for the elderly in the bathroom often comprise a variety of different types of toileting, bathing, and laundry. Toileting and bathing are the two most dangerous activities for children. Detecting whether or not an elderly person has entered the restroom and distinguishing between toilet behaviour and other behaviours after they enter the restroom are all parts of the toilet timeout alarm's function. It also records how long the elderly person stays in the restroom and compares the corresponding time threshold based on the type of activity to determine whether or not an alarm should sound. Elderly people may also submit an alert if they feel sick while using the bathroom. To warn the nursing staff in case of an emergency, all the detection data, dwell duration, and alarm information may be broadcast over a network.

The toilet timeout detection alarm terminal's primary control chip is the CC2530. According to the amount and complexity of terminal data, this chip is able to match the functional needs. CC2530 is also a wireless network communication chip. Without the need for extra processing chips, the terminal can do data processing and communication integration. A diffuse infrared photoelectric switch is selected by an infrared sensor (E18-D80NK). Its range of detection may be changed to suit the user's requirements.

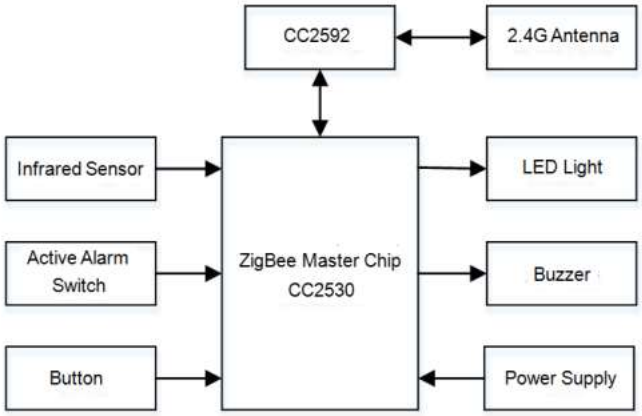

Figure 2. Hardware block diagram

After determining if the two infrared sensors inside and outside the bathroom door are activated, the sensors are triggered in order to determine that an old person has entered the restroom, and if the sensors are not triggered, then the terminal does not do any therapy. The timer begins to count down as soon as the elderly person enters the bathroom. The buzzer will ring and the terminal will send an alert message over the ZigBee wireless network to notify the nursing staff of the elderly's predicament if they remain in the lavatory and click the alarm button. Depending on the behaviour, a different time threshold is assigned. The length of time spent in the bathroom by senior citizens is then compared to a predetermined cutoff point. The nursing team is alerted if the time limit is exceeded. The timer stops recording and transmitting to the monitoring centre the time spent in the restroom by the elderly when they depart without exceeding the time threshold.

A. Ambulation and Urination Detection Alarm Terminal

It is primarily designed to prevent the elderly from leaving their beds at night, as well as the elderly who are half-disabled from falling from their beds while no one is looking. The urine detection alarm is primarily designed to alert nursing personnel to the urination of elderly patients who are either partially or completely handicapped. There are five different ways to use it. First, it is able to determine the health state of the elderly when they get out of bed and while they are still in bed.

Second, the alarm alerts the nursing staff if an old person leaves their bed in an unusual state.

Third, it has the ability to weigh and record the weight of old individuals. Fourth, it may be discovered in time and the senior urinates in bed might be frightened. When an older person has a problem, it sends out a preemptive alert. The wireless network may be used to send detection, weight, and alarm information to the host computer and alert the nursing staff.

The primary control chip, pressure and humidity sensors, an active alarm, network connectivity, and other components make up the majority of the terminal hardware. In Fig 3, you can see the entire hardware diagram.

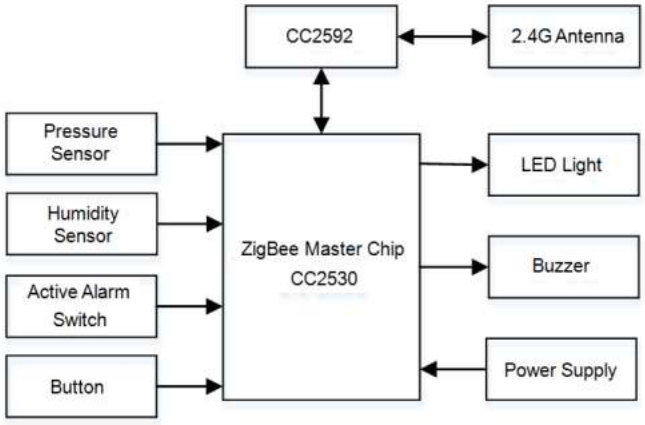

Figure 3. Hardware block diagram

In order to detect ambulation, four resistance strain pressure sensors are used. The HX711 chip circuit converts the acquisition result to A/D and reads the weight information from the CC2530 chip.

The resistance of the humidity sensor pad varies dramatically when it comes into contact with a moist item or water. For example, the circuit is intended to transform its resistance change value into a voltage change value and then the voltage comparison chip LM393 compares the detecting voltage with the specified threshold to determine whether the sensor is wet or not, thereby identifying whether the elderly is wet or dry.

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As the patient moves away from the bed, the off-bed detection procedure begins, followed by data collection and comparison with the patient's previous weight to determine if there has been an increase or reduction. To determine if an elderly person has been successfully transitioned to an on-bed state, the data is compared to the threshold value and communicated to the host computer as an increase in the elderly person's weight. As a result of exceeding the threshold, the elderly are considered to be in an off-bed state rather than an on-bed one. The timing and circumstances of a patient's departure from the bed dictate whether or not the nursing staff should be notified.

The initial step in urinary detection is urination detection. Sensor humidity exceeds the predefined threshold, and an alert is sounded to notify the nursing staff of this fact. Otherwise, the terminal will not function.

To make it easier for the elderly to use, an active alarm is placed next to the bed. Elderly people may touch the active alert button if they are feeling unwell or have other concerns.

B. **Falling Alarm and Regional Positioning Termina**l

The likelihood of a fall in the senior population is quite high. After a fall, if help does not arrive quickly, it might have catastrophic ramifications. Consequently, the terminal contains a fall detection function (which can effectively assess whether the old falls or not) and an

interior and outdoor area positioning function to gather the senior's location data. There should be an easy-to-wear device that older people may use to request aid from nursing staffs.

Using a wireless network, medical personnel may be alerted of a patient's position, their fall, and other relevant data.

STM32, CC2530, MPU6050, GPS, and a power supply are just a few of the components that make up the terminal's hardware. For interior location and wireless communication, we utilise the CC2530 chip; for outside positioning, we use the GPS module; and for detecting falls, we use the MPU6050 module. The STM32 chip is the primary control chip.

The experimental measurements show that when the human body falls, the acceleration of each axis varies, as does the attitude angle. There is no connection between the yaw angle and the direction in which the body is falling. The pitch angle changes dramatically as a person falls forward and backward, and the extreme condition changes by 90 degrees. The roll angle changes dramatically when a person falls to the left or right, and the extreme condition changes by 90 degrees.

As a result, the first criteria for the fall is the total static acceleration (TSA), and the second criterion for the fall is the bigger of the pitch angle and the roll angle. Fig 6 depicts the detection flow diagram.

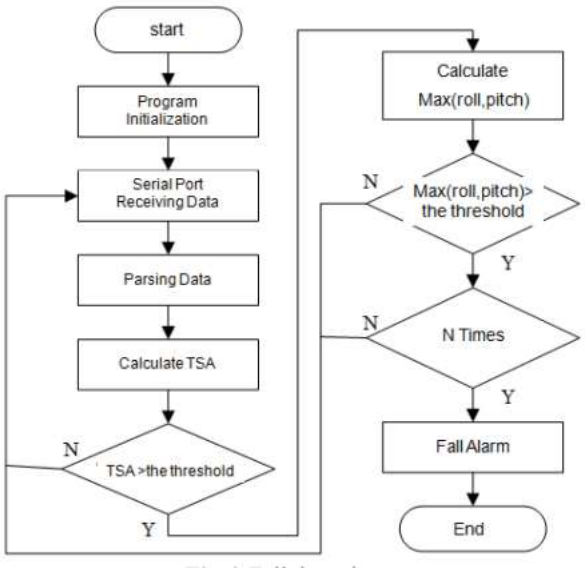

Figure 4. Fall detection process

RSSI-based wireless positioning is used inside in this work. Traditional placement can only be used in an open setting inside. To get a more precise placement impact in the senior apartment's complicated internal environment, more tuning is required. It is sufficient to know the exact location of the elderly in order to meet their genuine demands. Nurses will know whether an older person is in danger when they arrive in this area. To accomplish regional positioning, regional divisions have been created.

As an example, consider a floor of the Sijiqing Nursing Home. There are a variety of amenities on this level, including lobbies, offices, conference rooms, restaurants, and

restrooms. Determine the effective area of the elderly's interior activities by first establishing a coordinate system for the real-world indoor environment.

Because each corridor is many tens of metres long, a rectangular space with a width of 2.65 metres and a length of 1 metre is employed as a minimal positioning area despite the narrow width of the corridor. You'll get close to centre if the four-point placement results fall within this range. Because the room, the bathroom, and the duty room all have limited square footage, the four-point placement method is used to choose a single, central location. The two-dimensional plane area of a big interior facility, such as a hall or a restaurant, is split into a number of regions based on their size and form.

The GPS module's longitude and latitude are used to calculate the outdoor's location. Longitude and latitude are analysed by the algorithm before being mapped to the outside of the senior apartment's outside space. In spite of the GPS module's inaccuracy, it just needs to fulfil the regional positioning criteria for the line of sight range, and because outside environments are comparatively sparse, the outdoor positioning area is split into an even broader one.

C. Handheld Alarm Reminder Terminal

All three of the devices described in the preceding section are aimed at identifying older people who are in a risky condition. Accidental alarm information has to be sent to the alarm reminder terminal in order for the nursing team to locate and rescue elderly people as quickly and effectively. Receiving various types of alarm information, showing alarm information on the screen, vibrating to notify nursing staff that an accidental alarm has occurred, letting the monitoring centre know the alarm processing status, and cancelling the alarm once the accident processing is complete are some of the specific functions of this terminal.

The nursing staff acknowledges receipt of the alarm information by pushing a button on the handheld alarm terminal, and the terminal transmits confirmation information to the host computer programme via the wireless network once it has received the information. The nursing team will respond to the event once they have received the necessary information. Pressing the button again will turn off the alarm after it has completed processing.

IV. WIRELESS NETWORK

A. Wireless Network Hardware Design

There are coordinators, routers, and terminals in the wireless network, which employs ZigBee technology. Network components such as the alarm terminal, finding route, common routing path, and coordinator/monitoring centre are all linked through the terminal node.

In a ZigBee network, the coordinator is the only device that performs both of these roles. In the first place, the complete wireless network must be established and maintained. Secondly, the higher layer software receives and parses information supplied by the route or terminal and distributes it to the route or terminal. This is accomplished by collecting and distributing the information provided by the route or terminal. Figure 5 depicts the coordinator's organisation.

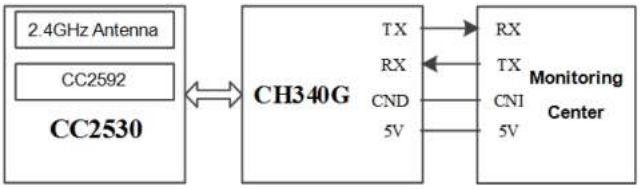

Figure 5. Coordinator hardware structure

Coordination centre master chip utilises CC2530 chip, while communication interface with monitoring centre uses CH340 chip, which can convert CC2530's TTL serial port into monitoring center's USB port.

The ZigBee network's middle layer is routing. Additionally, it aids in the addition of new devices to the network by relaying information from other nodes. Each route is furnished with indications to remind the staff while debugging and working, while preserving the serial debugging interface for it. Figure 6 depicts the typical routing device's structural diagram.

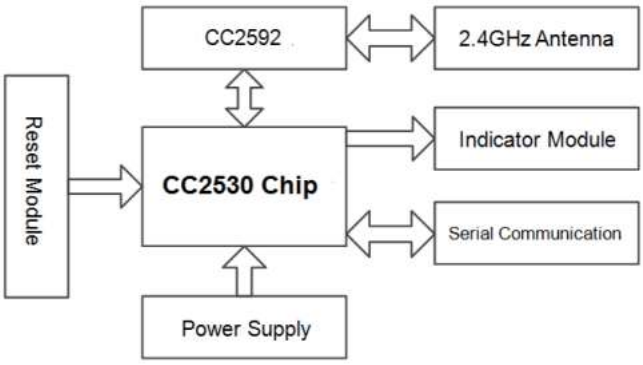

Figure 6. Ordinary routing device hardware structure

B. Principles of Wireless Network Implementation

The full ZigBee wireless network setup may be summed up as follows:

[1]. Nodes may join the network once it has been established by the coordinator.
[2]. To increase the network's reach, the router is added to the mix.
[3]. As a result, it is connected to the network.

When the wireless network is successfully built, the router and the terminal are able to join the network. As soon as an alert is produced, the alarm terminal transmits an alarm message to a coordinator, indicating the sensor's current condition.

V. SECURITY MONITORING INFORMATION MANAGEMENT SYSTEM

a) Database

MySQL is a relational database management system that is geared for small-scale databases. Aside from the fact that it is open source, it has a better storage speed and query speed than other database systems. Hence, the wireless security monitoring system's data base is built around it.

Elderly information, alarm information, equipment information, nursing information, weight information, location information, and location comparison library are all part of the security monitoring system's "entity" section.

b) Monitoring Centre Host Computer Software

The host computer software for the monitoring centre is written in C# using the Microsoft Visual Studio 2015 platform. Basic information management, alarm information inquiry, and alarm display are the three sub-modules inside this module.

There is a basic information management module that focuses on the overall condition of the elderly apartment, basic information about the elderly, different alarm terminal devices, and the information of the nursing staff.

The database will hold all of the alert data produced by the safety monitoring system. Nursing personnel and family members may more clearly see the elderly's inadvertent alert scenario with the use of this module.

Because of its central role in the monitoring centre's overall computer software architecture, the alarm display module is also the most often utilised feature. The module keeps track in real time of the area covered by the senior apartment's security monitoring system. The senior residential setting is shown in the interface map.

c) Android Mobile Applications

The creation of a mobile application software will break through the limits of the local area network and view the everyday lives of the elderly in the nursing homes anytime, anywhere.

According to the functional requirements, the mobile phone application is separated into five major interfaces, login interface, main interface, map locating interface, physiological parameter interface, alert recording interface.

VI. SYSTEM EXPERIMENT VERIFICATION

The application demonstration was place in the Beijing Sijiqing Nursing Home after different types of detection alarm terminals and wireless network equipment were developed. When the test is done, the tester mimics the previous situations to see whether they work. To activate the alarm, the tester hits the alarm button on the terminal. The toilet timeout alarm has been set to go off after 20 seconds. It sounds an alert when the tester stays in the bathroom for more than 20 seconds. Water is dripped on the sensor pad to replicate the urinating detecting function. By leaving the bed as usual, the tester is able to do the test. Testers are used to mimic falls in order to test the fall detection system. The approach used for regional placement involves having the tester roam around with the terminal to several indoor and outdoor locations and count just once in each location. Table 1 shows the statistical success rates for each test after it was run 100 times.

TABLE I. MONITORING SYSTEM ALARM FUNCTION TEST RESULT

Test type	Test method	Test times	Alarm times	Success rate
Actively alarm	Pressing button	100	100	100%
Toilet alarm	Toilet timeout	100	99	99%
Urination alarm	Dripping water	100	93	93%
Ambulation detection	Leaving bed	100	98	98%
Fall alarm	Falling	100	94	94%
Position alarm	Move out of rage	100	100	100%

Nursing homes may use this technology to monitor senior residents' safety since it has an accuracy rate of over 90% for numerous hazardous state detection alerts.

VII. CONCLUSION

Building an application platform for an elderly security monitoring system that monitors ambulation, urination and falls is the goal of this research in order to suit the specific demands of nursing facilities. All monitoring data may be sent wirelessly to the monitoring centre, where it will be received by the nursing staff and dealt with as soon as possible. The monitoring centre data may be accessed using the mobile client. Security monitoring has finished its demonstration in nursing homes and delivered an aged safety monitoring programme with several facets and a systemic approach, reducing labour costs and raising the degree of intelligence in nursing homes.

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