Home security alarm system for middle-aged people living alone

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Abstract: How to ensure middle-aged people's security has become an urgent social issue in China. Existing security systems are difficult to initialise with fast electrodes consumption. Therefore, we designed a smart security device suitable for middle-aged and elderly users. We select STM32 and CC2530 as master controller for the device, which is equipped with a camera module, GSM/GPRS module, smoke sensors, flame sensors, and infrared sensors. The camera module is used to capture the live pictures of the monitored areas, then these pictures will be transmitted to the users by the GSM module. Multiple CPU can increase the speed of operation, and ZigBee technology for wireless transmission can lower the loss of the supply. Compared with other security systems, the proposed program optimises the interface to make interaction operation easier for middle-aged and older users. The experimental results show that the proposed system has low power dissipation, convenient operation and high stability.

Keywords: home security alarm system; wireless sensor network; WSN; embedded system; Zigbee; internet of things; IoT.

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1 Introduction

In China, the problem of aging has become more and more serious after entering the 21st century. According to the statistics of the World Bank, China's aging population (the ratio of population aged 65 or above) exceeded 7% of the total population in 2002, and the proportion of the aging population reached 9.18% in 2014 (Guo, 2016). Reference for the structure of China's aging population, there will be more middle-aged and older people soon. Since the end of the 1970s, China has implemented the one-child policy in towns and cities for avoiding excessive population growth. Now, this policy has been in operation for more than 30 years since its inception, the generation of young people affected by this policy have started working or studying away from home, their parents have either already gotten older or have retired and sat idle. The decline of memory or the inconvenience of the legs due to the increase of age will bring obstacles to their lives. So, the safety of parents has become a most worrying problem for the one-child families (Wu, 2013). Therefore, there is an urgent need to develop a home security device for middle-aged and older people.

At present, there are many smart home security devices that are clever and versatile. But these devices are excessively complex in design while ignoring actual needs of users. Their complicated login interfaces and tedious initialisation processes of the existing systems have made it difficult for elderly users to use. For example, to realise the function of real-time monitoring, some products adopt cloud platform to observe the situation of defence areas (Ullrich et al., 2017). However, cloud platforms login procedures are tedious, so people need to remember some accounts and passwords. The cloud platform has serious security risks and is vulnerable to attacks, resulting in leakage of personal privacy. In addition, the long-time activation of camera will also consume a lot of power, resulting in a shorter standby time of the node. In order to overcome this problem, we propose a more suitable solution. Considering that the camera only needs to be turned on when there is danger in the defence area, a solution combining hardware with software to determine whether the camera needs to be turned on was selected. On the one hand, users can turn on the camera by remote control through the mobile phone terminal. On the other hand, when the sensor in the defence area is activated, it indicates that there is danger in the defence area, the camera will be turned on (Shen et al., 2018).

With the development of embedded technology, wireless communication technology and sensor technology, wireless sensor network (WSN) has emerged. As one of the most popular technologies in the WSN area, ZigBee has been widely used in the field of internet of things (IoT) (Al Zamil, 2017; Trab et al., 2018). For example, Wang et al. (2018) designed a billboard collapse monitoring system based on ZigBee technology, which is lower in power dissipation than other wireless communication technologies, such as Bluetooth and Wi-Fi. They use a multi-nodes cascade to achieve long-distance data transmission. However, it has a high rate of packet loss. Lee and Lee (2018) and Talpur et al. (2015) designed a wearable smart device, which uses Bluetooth technology to implement wireless transmission function. It has high cost and short transmission distance. When Bluetooth technology is used in smart homes, it is difficult to cover the entire room. Wi-Fi technology is also a good wireless network solution. But this technology has higher power consumption than Bluetooth and ZigBee. So, it needs to replace the battery frequently or to place the device near a power source, which limits the application scope of the equipment greatly (Li et al. 2011). Compared with the WI-FI and Bluetooth technology, ZigBee has many excellences such as low power consumption, wide coverage, many nodes and the like. It is particularly suitable for the formation of WSNs and more security situations (Khan et al., 2016; Li et al., 2017). In addition, it can support more than 64,000 devices at most and can expand more sensor nodes to facilitate the upgrade and reconstruction of future devices, providing users with better services (Ndih and Cherkaoui, 2016). Therefore, using ZigBee technology as a networking product for smart home products is more simple, stable, robust, safe and easy to use, and takes longer to use than Wi-Fi and Bluetooth. When a terminal joins the network, the coordinator will automatically search for terminals in the network. Moreover, ZigBee uses the IEEE 802.15.4 wireless communication standard to provide many anti-jamming methods, such as dynamic channel selection, idle channel assessment, channel algorithms, etc. These anti-jamming methods make ZigBee and Wi-Fi generate very little interference at close range. Both can coexist well, so Wi-Fi networks used by homes will not affect each other (Liu et al., 2017). As a more widely used wireless network communication method, GSM/GPRS emerges in all aspects of our lives. For example, our daily use of mobile phones, shared bicycles, etc. As a long-distance wireless transmission, GSM/GPRS can realise signal transmission through base stations provided by telecommunication service providers. Furthermore, it is also more secure than the cloud platform (Wang et al., 2012). So, we use them to transfer the images which are captured by the device in the defence areas.

To protect users from these risks such as fire, gas leakage, and theft, we designed this home security alarm system. This device selects STM32 and CC2530 as main control unit (MCU), equipped with a MQ-2 smoke sensor, flame sensor, and a HC-SR501 infrared sensor. The GSM/GPRS module and OV7725 module are used to send live pictures to users. As the combination of ZigBee and GSM, this system has the advantages such as convenient operation, low power consumption, and information security. It can visualise the scene and remind users that the area is in danger just in time (Tseng et al., 2014).

The rest of the article is organised as follows: Sections 2 and 3 detail the design and development in hardware and software. We have optimised the software of our device so that it is easy to operate, and the standby time is longer. Section 4 gives an experiment. The experimental results show that our design works well and basically achieves the expected goal.

2 System outlines

Nowadays, our life is more and more convenient. Complicated home circuit, and various kinds of household appliances all make our life colourful. However, non-standard electricity may cause serious consequences. In view of the danger of electrical leakage or circuit short-circuiting, we introduced switches to avoid these problems at the beginning of designing homes, but fires caused by improper use of electricity cannot be avoided. So, we added a flame sensor to the device to detect the fire. Thanks to the strategy of opening west and transport west gas to east, most families have already used natural gas. The gas is provided by the company and introduced into our homes through pipes directly. When we open the valve, we can use it immediately. However, it is not uncommon for older people to forget to turn off the valve because of memory loss. Cases of gas leaks causing user poisoning are also reported in the newspaper frequently. Taking into account these safety hazards, our device uses fire sensors and gas sensors to detect the existence of this hidden danger and provide users with a reliable reference. At the beginning of natural gas leakage, we can find out the danger in time to avoid fire or serious gas leakage. Considering that these hidden dangers occur when the user goes out, we choose to use the image information to remind the user of the attention so that they can know what is happening in the defence areas anywhere.

Because of the different locations of various hidden dangers, this device is divided into three sub-nodes according to the functions and tasks. Each node is independently powered by a lithium battery. Data transmission and control functions are realised through ZigBee protocol among nodes. The role of the master node is mainly as follows:

1 receiving alarm information from data nodes
2 collecting defence area image information
3 sending text alert messages and live images to users.

The sensor used by the image acquisition module is OV7725. GSM/GPRS assumes the function of data transmission. The user can initialise, turn on or turn off the device through the messages.

The other two sub-nodes are used to collect data, which are divided into two groups according to their functions. One group is used for anti-theft detection. In this node, we select HC-SR501 as the infrared sensor. When the intruder enters the defence area, the sensor is activated. After the controller detects the change of the sensor level, it sends the alarm information to the master node; the other group uses the smoke sensor MQ-2 and the flame sensor which work together to detect whether there is gas leakage or fire.

Figure 1 System module overview

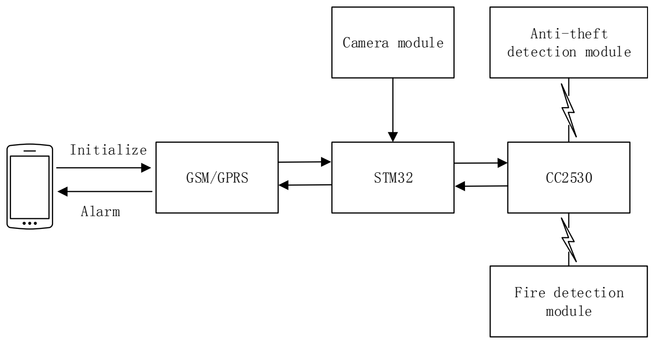
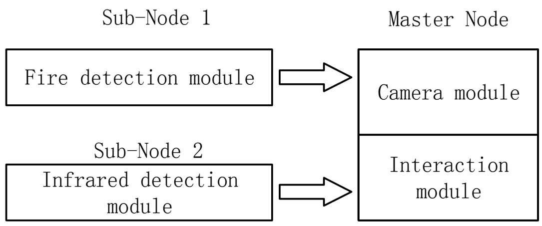


Figure 2 Functional description of each node



Considering the device's capability, we select STM32 chip as the master controller to drive the camera and GSM/GPRS module, and CC2530 as the ZigBee chip to implement wireless data transmitting between multiple nodes. The system diagram is shown in Figure 2 (Wang et al., 2015). As shown in Figure 1, the CC2530 is used to drive the anti-theft detection module and the fire and gas detection module. The master node is driven by dual CPUs to implement the camera and alarm functions. The CC2530 chip at this node is used to implement data transmission with the child nodes. This node acts as a coordinator and is used to receive alarm signals from child nodes. One of the two child nodes is equipped with an infrared sensor and the other is equipped with a flame sensor and a gas sensor. The two child nodes report to the master node when there is a danger in the zone.

For users' convenience, the device can be initialised with messages. After placing the SIM card on the device, the user sends a text message 'AT+initialise+User Number' to the device to set the user account number. Then the device starts to work and sends a short message to the user after receiving a dangerous signal from the node.

3 Product design

3.1 Choice of CPU

ZigBee's next-generation SoC chip CC2530 combines a fully integrated, high-performance RF transceiver and an enhanced 8051 microprocessor. It enjoys small size, fast operation speed, and rich peripheral interfaces (Yin et al., 2013). And it supports low Power consumption wireless communication. The Z-Stack protocol stack is a protocol stack used by ZigBee. This protocol integrates many functions such as sending and receiving, facilitating program development and network establishment. Therefore, gin the development of ZigBee-based applications, developers do not need to design the ZigBee protocol stack repeatedly, and the Z-Stack can be directly used to complete the development. We can trim on the basis of the original ZigBee protocol stack and add the corresponding functions we need to use. The device can be connected to a computer through a serial port and debugged at any time during the programming process.

The alarm module uses STM32F103 as the MCU. The chip is based on the 32-bit ARM chip series of the Cortex-M3 core, and STM32F103ZET6 belongs to this series of high-capacity chips. The on-chip Flash is 512KB, SRAM is 64KB, and the frequency is 72MHz. So, it has significantly higher performance than CC2530. Both chips are easy to develop and emulate. The programming and simulation of the alarm module are done directly in the software Keil (Lin et al., 2017).

Selecting these two chips as the main control chip can effectively improve the running speed of the equipment. The CC2530 is responsible for realising the communication function. The STM32 is responsible for driving the camera device. The amount of data generated by the device is large, and the processing speed of the CC2530 is relatively slow. So, we use two chips to do different tasks. Different devices and chips work together through the serial port to achieve data interchange. After the sub-nodes' data is sent to the master node, the master node's CC2530 sends the data to the STM32, which then turns on the alarm module and sends an alarm message.

3.2 Sensor nodes design

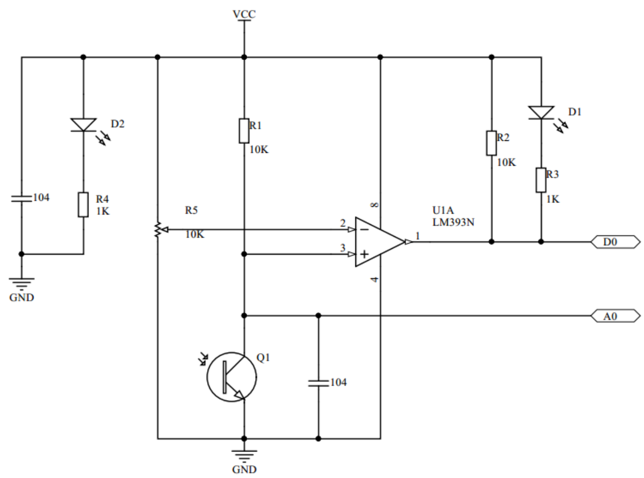
3.2.1 The choice of sensors

The device uses the ZigBee chip CC2530 produced by TI and the STM32F103VET6 chip produced by ST.CC2530's computing speed is lower than STM32's computing speed, but the interface is rich and easy to program, so the former is mainly used to control the sensor and collect the data from sensors. The STM32 has strong driving ability which is used to drive the camera module and GSM/GPRS Module.

Middle-aged and elderly users consider more about battery when choosing an appliance, because it is difficult to remember to switch the battery of the device on time for them. And the nodes of this design are flexible and can be placed anywhere in the home according to the user's needs. The system may initially be placed in a blind spot that is difficult to replace later, resulting in difficulty in continuing to use the device if it has run out of power. Therefore, we considered that the stability of the system must be high, the battery must be easily replaced, and the standby of the equipment should be as long as possible. We choose HC-SR501 as the infrared sensor because of its high sensitivity and low power consumption. Theoretically, the quiescent current of this sensor is less than 50 microamperes, which means that a 3,000 mAh dry cell battery can work continuously for over 60,000 hours.

The model of the smoke sensor is MQ-2, which has high sensitivity and can detect a variety of gases such as natural gas, and other flammable toxic gases. The flame sensor's circuit diagram is shown in Figure 3, which has a wide detection range and high sensitivity to the tiny flame. Its output can be directly connected to the IO port of the microcontroller, where DO is the TTL switch signal output. When the smoke is detected, the port will have a level jump. When the master detects that the level has changed, it will be judged as a gas leak. A0 port is an analogue signal port, which is not used in the design.

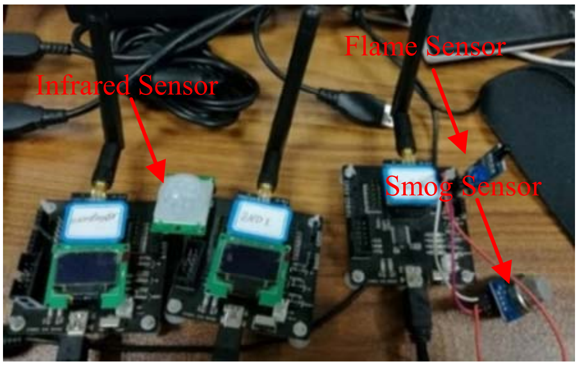
Figure 3 The flame sensor



Smoke sensors, flame sensors, and infrared sensors all use digital data ports to connect to the I/O ports of the master controller. When the sensor triggers, the MCU will read out the level transitions. The MCU will send the sensor's triggering status code to the master node according to the encoding rules. When the master node receives the data, it decodes the zone status according to the code and sends it to the GSM module. The module sends the corresponding text message to the user.

As shown in Figure 4, we separate different sensors into different module with different functions, in which the flame sensor and the smoke sensor are used for fire warning, and two thresholds are used as the discrimination standard to determine the occurrence of a fire. The infrared sensor is connected to another ZigBee chip and can be placed in any area where anti-theft detection is required.

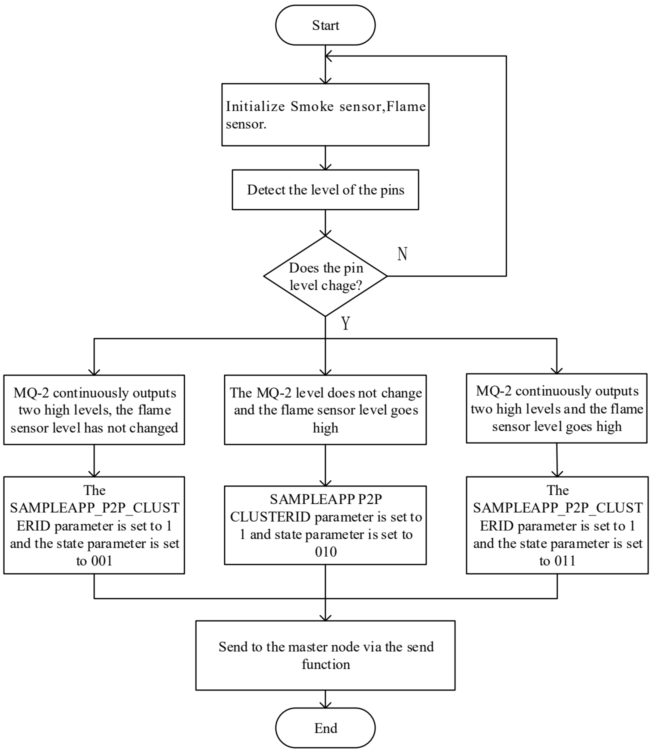
Figure 4 Sensor interface diagram (see online version for colours)



3.2.2 Data collection and transmit

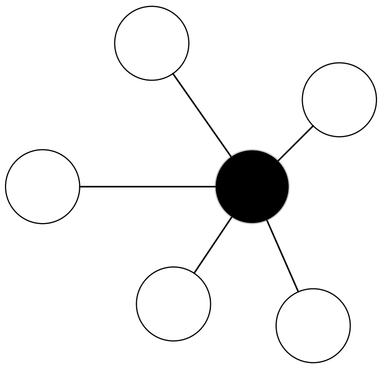
The ZigBee networking module of the software is used to collect and transmit data. There are different sensors in different nodes. After the controller of the node collects data, the data is transmitted through the wireless mode. In the device, the terminal uploads the switch data of the sensor directly to the coordinator, and the coordinator sends the data to the STM32 controller. The STM32 decodes and controls the GSM module to send the corresponding text information and image information to the user.

Figure 5 Software design flow chart



The data collection is completed by the sub-nodes, which are equipped with sensors. The MCU detects changes in sensor level to determine whether there is danger in defense areas. Take the gas leakage and fire detection data node as an example. The workflow is shown in Figure 5. First, we set the corresponding two data pins of CC2530 as input, this step is completed in the initialisation function. Then, the state of the pin level is detected, and the detection level change is edited in the send function SampleApp_Send_P2P_Message, and the corresponding data is sent when the level changes. The specific data is shown in the flowchart. Among them, the parameter SAMPLEAPP_P2P_CLUSTERID and state are all parameters of the sending function AF_DataRequest, and the corresponding parameters are sent to the master node by this function. The star topology communication mode is adopted between the master node and the child nodes, that is, each child node communicates with the master node directly. As shown in Figure 6, the black node is the coordinator and the white node is the terminal. This topology is concise, with fewer nodes, convenient networking, and fast data transmission when using (Li et al., 2015).

Figure 6 Star topology



3.2.3 Data receive

The coordinator receives the data from the terminal and encodes it according to the received data and sends it to the STM32 controller through the serial port. The controller determines whether to turn on the camera and the GSM module. The coding is shown in Table 1.

Table 1 Code of defence area alarm signal

State	*Meaning*	*State*	*Meaning*
000	Nothing	100	Smoke alarm
001	Anti-theft alarm	101	Anti-theft and smoke alarm
010	Anti-theft alarm	110	Flame and smoke alarm
011	Anti-theft and flame alarm	111	Anti-theft and flame and smoke alarm

3.3 Monitoring centre design

3.3.1 Module structure and function design

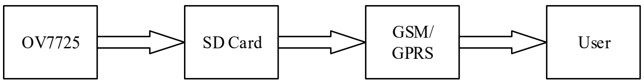
The system uses GSM / GPRS module to meet alarm, remote monitoring and control function. The device uses text information to alert the user of the danger. The module will also send the image information captured in the scene via MMS andsend it together with the text information. The user will have text information to explain while receiving the image. The purpose of this step is to allow users to more intuitively understand the situation on the site and prevent false alarms from occurring.

In this system, the master nodes with GSM/GPRS and camera mainly have the following functions:

1. acquiring digital image information and save the image data to an SD card
2. receiving user's instructions to control the camera
3. sending monitoring information, describing the situation of the defence area by sending text information (Huang et al., 2002).

Figure 7 shows the data flow diagram of the master node. The functions described above will be implemented separately by two MCUs. The ZigBee processor is responsible for receiving data from the child nodes. The STM32 is used to drive the OV7725, SD modules, and communication modules. The transmission of the collected data and the reception of the initialisation data enable interaction between the user and the device.

Figure 7 Interactive module data flow diagram



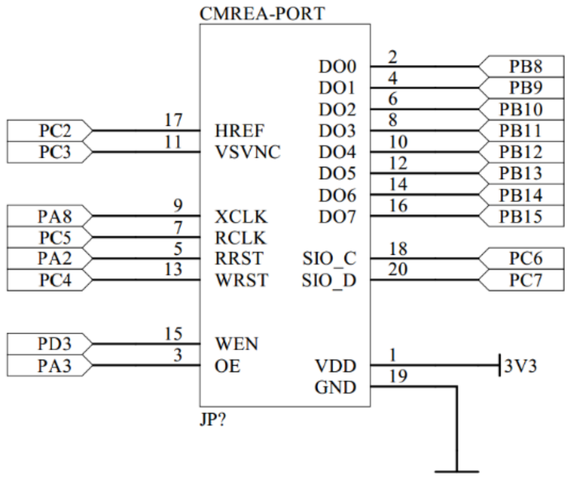
3.3.2 The design of circuit

The main node's CC2530 is used to receive the data sent by the data acquisition node and send the collected data to the STM32 through the serial communication mode. After the STM32 receives data, the software judges the situation of the areas and converts it into text information and then sends it to the GSM module. At the same time, it drives the camera to collect image information.

The GSM module and the master controller are connected through a serial port. Because the timing function of the camera module is complex, we use the FSMC to … to the STM32, while the timing functions of the FSMC and 8080 are similar. The connection diagram is shown in Figure 8.

We use the SIM800C chip as the GSM/GPRS module. This module can effectively implement functions such as voice, SMS, MMS and GPRS networks to meet design requirements. This module is mainly connected to the STM32 through serial communication. The USART1 interface of the STM32 is mainly used. The TX and RX pins of the GSM/GPRS module are respectively connected to the RX and TX pins of the STM32 and are controlled by synchronous AT commands.

Figure 8 The circuit of camera



After receiving the signal from the child node, the master node judges whether the module needs to be enabled according to the State parameter in Table 1. When the received status data is not low power, the camera is turned on. After the camera captures the image, it saves the image on the SD card. Then, the GSM module reads out the image information, edits it into a multimedia message and sends it to the user.

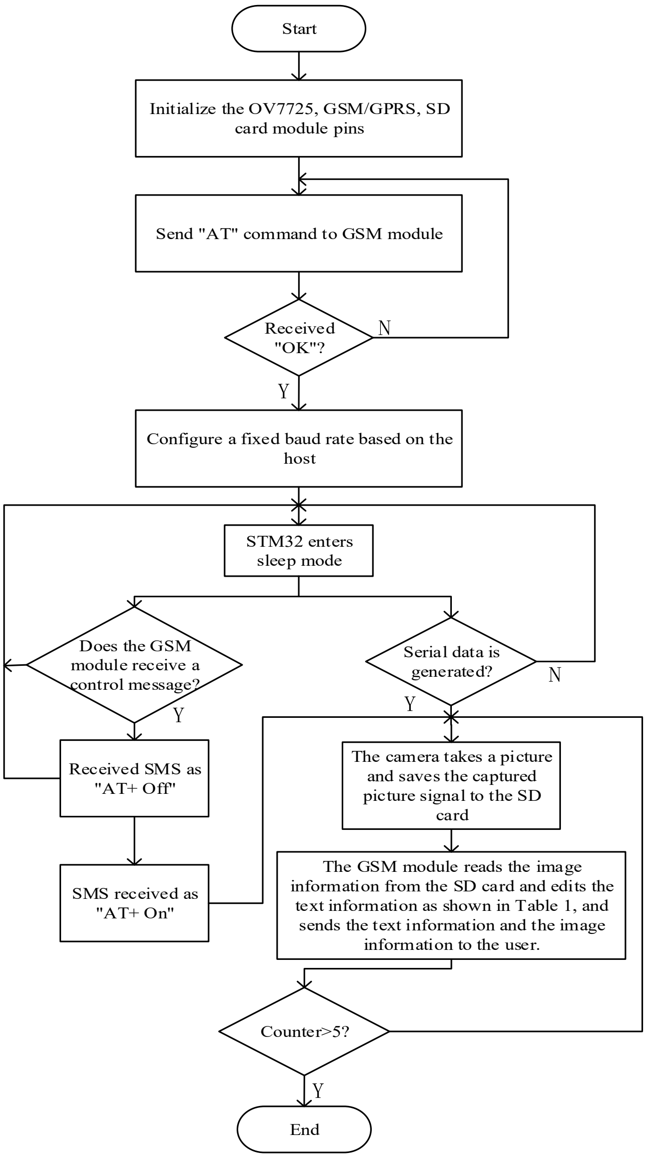
Regardless of whether the alarm module is turned on, users can send information to control the current state of the phone. Send 'AT + ON' command to turn on the camera when the system is turned off. When sending 'AT + OFF' command, you can turn off the alarm and put the module into standby mode.

The camera collects image data once every 30 seconds and collects a total of six times. After each acquisition, the camera saves the image to the SD card and sends it to the user. After each round of collection, if the sensor remains in the trigger state within two minutes, it will collect the image information again and send it to the user in two minutes. If the user finds that there is no danger after viewing the image, they can send the text 'AT+ OFF' command to turn off the alarm function of the device. The specific process is shown in Figure 9.

When the above hardware design method is used, the storage function is less demanding and is mainly used to temporarily store image data. The GSM/GPRS module reads the image information in the SD card through the serial port and edits it into a multimedia message and sends it to the preset mobile phone. The SD card is connected to the STM32 through the SDIO interface. Compared with the SPI communication mode, the SDIO is easy to use and the read speed is greatly improved. This can greatly reduce the memory consumption and power consumption. Each node can work for a long time after connecting the lithium battery, which has obvious advantages over other methods.

When the GSM module is initialised, the baud rate needs to be synchronised. The default serial port of the SIM800 series is adaptive baud. The host must synchronise the baud rate with the module. First, the host sends an ‘AT’ continuously to the SIM800C module until it receives an ‘OK’ response with a successful synchronisation. After the baud rate is synchronised, the SIM800C module can be controlled by sending AT commands through the serial port.

Figure 9 Interactive module software flow chart



4 Results and discussion

4.1 Consumption

Each node uses two 3,800 mAh battery cells and the total power is 7,600 mAh. That is means the battery discharges at 1 mA for 7,600 hours (theoretical value). Taking the fire detection node as an example, the operating currents measured by the experiments for each sensor are: the operating current of the smoke sensor MQ-2 is 27 mA; the operating current of the flame sensor is 20 mA. During the data transmission, the instantaneous current is 29 mA. The data collection adopts the timing acquisition. The terminal node works for 60s every hour. The rest time is in the sleep mode, and the operating current is negligible. If the sensor is triggered 60 times per hour, it can be calculated that the working time of the terminal node is: 6,000 h ≈ 250 days. Because the master node requires sensor triggering and is in the low power mode in the untriggered state, it is negligible and the instantaneous current during data reception is only 24 mA, so the standby time can be longer.

4.2 Initialisation and alarm interface

The initial interface is shown in Figure 10. When the user sends the number to the terminal, the device can be activated. Because the user group is elderly, the initialisation and control functions of the device are simplified. As the experiment is conducted on the development board, it is initialised in English to simplify the programming. In the later improvement process, the Chinese initialisation will be used to make the control device more understanding.

Figure 10 The initialisation interface and alarm interface (see online version for colours)

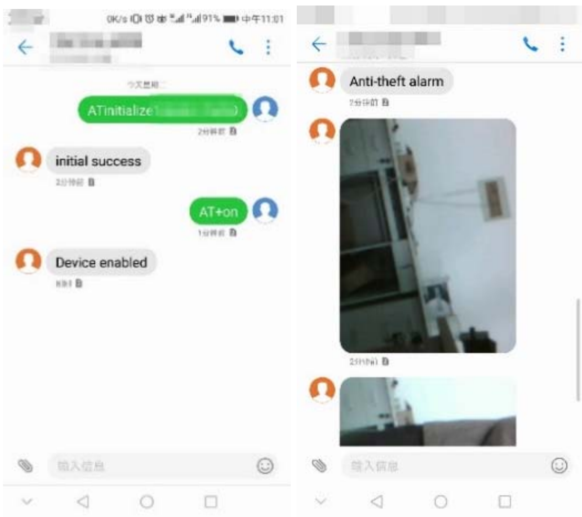


Figure 11 shows the working status of the device when someone enters the area. When the sensor triggers, the camera module works and collects intruder images. When several other sensors work, the effect is similar, and the image information is relatively straightforward. In case of false alarms, the user can make decision through the picture.

4.3 Sensor reliability test

During the experiment, the entire system ran well, and its functions were complete. After the completion of the overall system test, we simulated the reliability of each sensor. The flame sensor and smoke sensor performed excellently, and the infrared sensor performed well. From the experimental results, the infrared sensor is most suitable for three to five meters. A short distance will lead to continuous detection errors. Because the flame sensor testing involved safety issues, a small flame was selected during the test. One can test its sensitivity and the second guarantees experimental safety. We used lighter flame to test flame sensor, and the detection effect within 40 cm is better. The smoke sensor is mainly used to test whether it works normally by generating a threshold exceeding the smoke concentration in a small enclosed space. Table 2 shows the probability of failure of each sensor test under one hundred test results.

Table 2 Sensor test results

Test number	*Testing times*	*Success times*	*Failure rate*
Infrared sensor	100	95	0.05
Smoke sensor	100	99	0.01
Flame sensor	100	96	0.04

Figure 11 The anti-theft alarm (see online version for colours)

5 Conclusions

The smart home system designed in this article is aimed at users who are pursuing practicality. Because the design focuses on low power consumption, special attention is paid to reducing power consumption throughout the entire process. Each node which is powered by lithium-ion battery can work for a long time and can be placed anywhere in the home.

The software adopts TI's Z-stack protocol stack. Through the optimisation of the software, the convenience of the system is improved, and the power consumption is lower. In addition, the sensors of the system all enjoy the characteristics of low cost, high stability, and wide application, etc., so that the equipment is easy to maintain and upgrade. Due to the use of ZigBee networking technology and GSM/GPRS technology to shared data, the information is not easy to leak, and security is improved.

We have optimised the initialisation and operation interface to make it easier for middle-aged users to use. The device allows nodes of different functions to accomplish different tasks separately in different areas. The fire discrimination is determined by the dual sensor common discrimination, which makes the identification more accurate. The operation of the device is simple and convenient. It is omitting the complicated login and initialisation process and simplifying the function of the entire device, so it has a certain market application prospect.

References

Al Zamil, M.G.H. (2017) 'A verifiable framework for smart sensory systems', *IJES*, Vol. 9, No. 5, pp.413–425.

Guo, J. (2016) 'The global positioning of china's aging and the problems and solutions of China's aging research', *Academic Research*, February, Vol. 2, No. 2, pp.61–67.

Huang, J.H., Su, S.L. and Chen, J.H. (2002) 'Design and performance analysis for data transmission in GSM/GPRS system with voice activity detection', *IEEE Transactions on Vehicular Technology*, Vol. 51, No. 4, pp.648–656.

Khan, M., Silva, B.N. and Han, K. (2016) 'Internet of things based energy aware smart home control system', *IEEE Access*, Vol. 4, pp.7556–7566, DOI: 10.1109/ACCESS.2016.2621752.

Lee, B.G. and Lee, S.M. (2018) 'Smart wearable hand device for sign language interpretation system with sensors fusion', *IEEE Sensors Journal*, February, Vol. 18, No. 3, pp.1224–1232.

Li, K., Wen, Z., Wang, Z. et al. (2017) 'Optimised placement of wireless sensor networks by evolutionary algorithm', *International Journal of Computational Science and Engineering*, Vol. 15, No. 2, pp.74–86.

Li, L., Xiaoguang, X., Ke, C. and Ketai, H. (2011) 'The applications of WiFi-based wireless sensor network in internet of things and smart grid', *6th IEEE Conference on Industrial Electronics and Applications*, Beijing, pp.789–793.

Li, L-x., Li, Y-w., Cai, G-y. and Chu, H-b. (2015) 'Research and development of security system in smart home based on the technology of internet of things', *Control Engineering of China*, Vol. 22, No. 5, pp.1001–1005.

Lin, S., Wang, G., Chen, Y., Wang, L., Qiao, Z. and Gao, F. (2017) 'Ware-house environment parameter monitoring system and sensor error correction model based on PSO-BP', *Transactions of Nanjing University of Aeronautics and Astronautics*, Vol. 34, No. 3, pp.333–340.

Liu, Q., Li, X., Quan, Z. et al. (2017) 'An adaptive hybrid ARQ method for coexistence of ZigBee and WiFi', *International Journal of High Performance Computing & Networking*, Vol. 10, No. 4, p.310.

Ndih, E.D.N. and Cherkaoui, S. (2016) 'On enhancing technology coexistence in the IoT era: ZigBee and 802.11 case', *IEEE Access*, Vol. 4, pp.1835–1844, DOI: 10.1109/ACCESS.2016.2553150.

Shen, J., Zhou, T., Chen, X., Li, J. and Susilo, W. (2018) 'Anonymous and traceable group data sharing in cloud computing', *IEEE Transactions on Information Forensics and Security*, April, Vol. 13, No. 4, pp.912–925.

Talpur M.S.H., Bhuiyan, M.Z.A. and Wang, G. (2015) 'Energy-efficient healthcare monitoring with smartphones and IoT technologies', *International Journal of High Performance Computing & Networking*, Vol. 8, No. 2, p.186.

Trab, S., Bajic, E., Zouinkhi, A. et al. (2018) 'RFID IoT-enabled warehouse for safety management using product class-based storage and potential fields methods', *International Journal of Embedded Systems*, Vol. 10, No. 1, pp.71–88.

Tseng, K.C., Lin, B.S., Liao, L.D., Wang, Y.T. and Wang, Y.L. (2014) 'Development of a wearable mobile electrocardiogram monitoring system by using novel dry foam electrodes', *IEEE Systems Journal*, September, Vol. 8, No. 3, pp.900–906.

Ullrich, J., Zseby, T., Fabini, J. and Weippl, E. (2017) 'Network-based secret communication in clouds: a survey', *IEEE Communications Surveys & Tutorials*, 2nd quarter, Vol. 19, No. 2, pp.1112–1144.

Wang, F., Xiong, J., Zuo, Q. and Meng, X. (2012) 'Research on the real-time trans-mission of high-capacity traffic video information based on mobile internet, *IET International Conference on Information Science and Control Engineering 2012 (ICISCE 2012)*, Shenzhen, pp.1–4.

Wang, H., Dong, L., Wei, W., Zhao, W.S., Xu, K. and Wang, G. (2018) 'The WSN monitoring sys-tem for large outdoor advertising boards based on ZigBee and MEMS sensor', *IEEE Sensors Journal*, February, Vol. 18, No. 3, pp.1314–1323.

Wang, L.H., Chen, T.Y., Lin, K.H., Fang, Q. and Lee, S.Y. (2015) 'Implementation of a wireless ECG acquisition SoC for IEEE 802.15.4 (ZigBee) applications', *IEEE Journal of Biomedical and Health Informatics*, January, Vol. 19, No. 1, pp.247–255.

Wu, Y. (2013) 'One-child policy and elderly migration', *Sociological Studies*, August, Vol. 28, No. 4, pp.49–73.

Yin, J., Yuan, J., Jiao, Z., Wu, B., Zhang, Z. and Yu, J. (2013) 'Research and development of smart control system based on arm and ZigBee', *Computer Measurement & Control*, Vol. 21, No. 9, pp.2451–2454.