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The Design of Wireless Sensor Network Gateway based on ZigBee and GPRS

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Abstract

This paper proposes a design of wireless sensor network gateways based on ARM to solve the poor performance of the network, and low efficiency of communication, which is caused by the poor computing capacity and limited bandwidth in wireless sensor network (WSN). The paper introduces the composition and characteristics of the gateways, and the design of their hardware and software. In this design, the data is transmitted by the network nodes to the gateways with the help of ZigBee near field communication (NFC) technology after its collection, and then the gateways transmit the data to the monitoring center through GPRS. It makes high performance of long distance transmission and the holding of gateways online come true.

Keywords: *Wireless sensor network (WSN), Gateway, ZigBee, GPRS*

1. Introduction

With the development of wireless communication technology and sensor technology, WSN is gradually getting more attention. WSN is a network composed of a set of sensor nodes through wireless medium. A large number of sensor nodes cooperate in a certain way to complete tasks [1].

The computing power and bandwidth of traditional Wireless sensor network nodes are very limited, because of its structure limits, which makes the low performance of the whole network and communication, because of the way of point to point. Aiming at the problems in the traditional network, it proposes the Wireless Sensor Network gateways based on ARM. The network nodes transmits the data after collection to the gateways by using ZigBee NFC, then the gateways remotes data to the monitoring center through the GPRS, which constructs WSN gateways based on ZigBee and GPRS technology.

2. The Composition and Characteristics of the Gateways

The hardware design of WSN gateways is based on ARM microprocessor, which realizes the Collection and transmission of the nodes of wireless sensor network data through the expansion of ZigBee and GPRS module. The WSN gateways structure is as shown in Figure 1.

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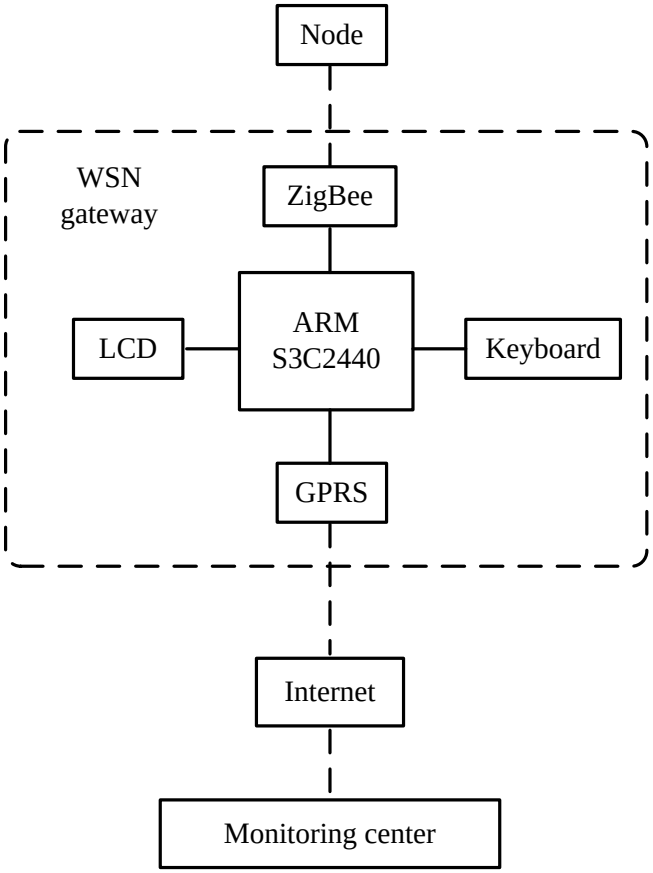

Figure 1. Structure of WSN Gateways

In WSN, the nodes and gateways are usually placed inaccessible areas, so the energy conservation becomes an important indicators. The gateways uses ZigBee technology for energy conservation, as Protocol IEEE 802 15.4 [3]. ZigBee is a kind of wireless communication technology with the advantage of short distance and low power consumption. GPRS is General Packet Radio Service, and it breaks through the mode of GSM network, which only provides a circuit switched. It completes the packet switching only by increasing the corresponding functional entity and reforming the existing base station system. In WSN, the data collected through ZigBee network is uploaded to the monitoring center through GPRS network on Internet. ZigBee network is for the short distance communication, and GPRS network is for long distance communication, so they can complement each other. The gateways make ZigBee network and GPRS network connected together, and then the long distance transmission of the data is realized.

3. The Design of Hardware of Network

3.1. Microprocessor (S3C2440)

In the system we choose the MCU S3C2440 which is made by SAMSUNG CO. This product is designed to provide hand-held devices and general applications with cost-effective, low-power, and high-performance microcontroller solution in small die size. To reduce total system cost, the S3C2440 includes the following components separate 16KB Instruction and 16KB Data Cache, MMU to handle virtual memory management, LCD Controller (STN & TFT), NAND Flash Boot Loader, System Manager (chip select logic and SDRAM Controller), 3-ch UART, 4-ch DMA, 4-ch Timers with PWM, I/O Ports, RTC, 8-ch 10-bit ADC and Touch

Screen Interface, IIC-BUS Interface, IIS-BUS Interface, USB Host, USB Device, SD Host &Multi-Media Card Interface,2-ch SPI and PLL for clock generation. The S3C2440 was developed using an ARM920T core, 0.18um CMOS standard cells and a memory complier. Its low-power, simple, elegant and fully static design is particularly suitable for cost- and power-sensitive applications. It adopts a new bus architecture called Advanced Microcontroller Bus Architecture (AMBA). The S3C2440 offers outstanding features with its CPU core, a 16/32-bit ARM920T RISC processor designed by Advanced RISC Machines, Ltd. The ARM920T implements MMU, AMBA BUS, and Harvard cache architecture with separate 16KB instruction and 16KB data caches, each with an 8-word line length [11].

In the whole gateways, WSN gateways is responsible for the data transmission of ZigBee network and GPRS network, and also for the network maintenance, such as the construction of ZigBee network and the adding and deleting of node, and it needs the powerful processing ability. Therefore, the main control chip uses Samsung S3C2440 microprocessor. S3C2440 is based on core ARM 920T, and U ART with 3 channel, and can communicate with ZigBee module and GPRS module easily. It also supports the embedded Linux operating system after pruned, so it can easily Transplant and configure the PPP dialing software.

3.2. Wireless Communication Module (CC2430)

In the wireless transceiver module system we use the CC2430 chip which is made by Chipcon Company in November 2003. The chip answers for IEEE802.15.4 agreement with the 2.4 GHz band, and provides packet processing, data buffering, pulse transmission, data encryption, data identification broadcasting channel access, connectivity and reliability of packet timing information support. These features reduce the load of the MCU, and the CC2430 adopts the SPI interface connecting the MCU.

The CC2430 uses a 7 × 7 mm QLP-48-pin package, and can be carves up three modules according to their function, they are receiver circuit, transmitting circuit and communication circuit, we requires only minimal external components, and its use can be realized. The circuits are introduced as follows:

Receiver circuit: Low noise receiver circuit includes amplification, frequency conversion, filtering, A/D converter, automatic gain control, digital demodulation and the final restoration of the transmission to the correct data. The data received by the CC2430 will be stored in the receiving Storage (RXFIFO, and the total of 128 Bytes), and the SPI interface users can read the data in the RXFIFO.

Transmitting circuit: Transmitter is based on the direct up-conversion, when the microprocessor data will be sent through the SPI interface to the transmitting memory (TXFIFO, and total of 128 Bytes), the precursor code and initial frame is automatically generated by the hardware. According to the IEEE802.15.4 standard, every four bit data whose spectrum is spread by the 32 yards Spread Spectrum Sequence is send to the D / A conversion, and then to the low-pass filter. And finally the RF signals are eventually modulated to 2.4 GHz, and amplified to launch [12].

Communication circuit: The CC2430 is installed by the MCU through 4-wire SPI Interface (SI, SO, SCLK, CSn), and the interface is also used to send and receive data read and write. The CC2430 has thirty-three state 16 bit-registers and fifty orders registers and two 8 bit-registers used to access and receive RXFIFO and sent TXFIFO.

The typical application circuit of CC2430 that we use in the system showed in the Figure 2.

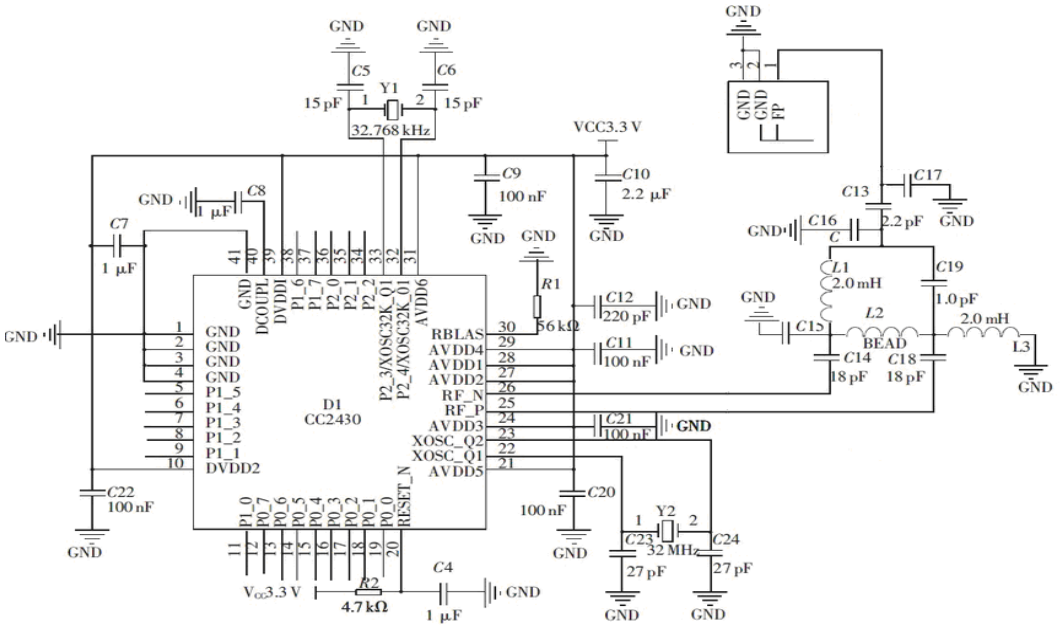

Figure 2. Typical Application Circuit of CC2430

In wireless sensor networks, the energy of node is limited, so the energy conserved protocol is needed in the communication of node-to-node and node-to-gateways. This system adopts the traditional CC2430 chip to realize short distance communication. Because CC2430 has been cured of the ZigBee protocol stack, the gateways transceiver Modular could be configured by adding a simple peripheral circuit.

The GPRS module for long distance communication adopts MC35i produced by Siemens Company, because of its stability. In the process of communication, network sends AT command and data through the RS232 serial port to MC35i, and then MC35i begins to load GPRS gateways, and successfully gets IP address to communicate with long-distance monitoring center. A communication link between gateways with the Internet is established. It is as shown in in Figure 3.

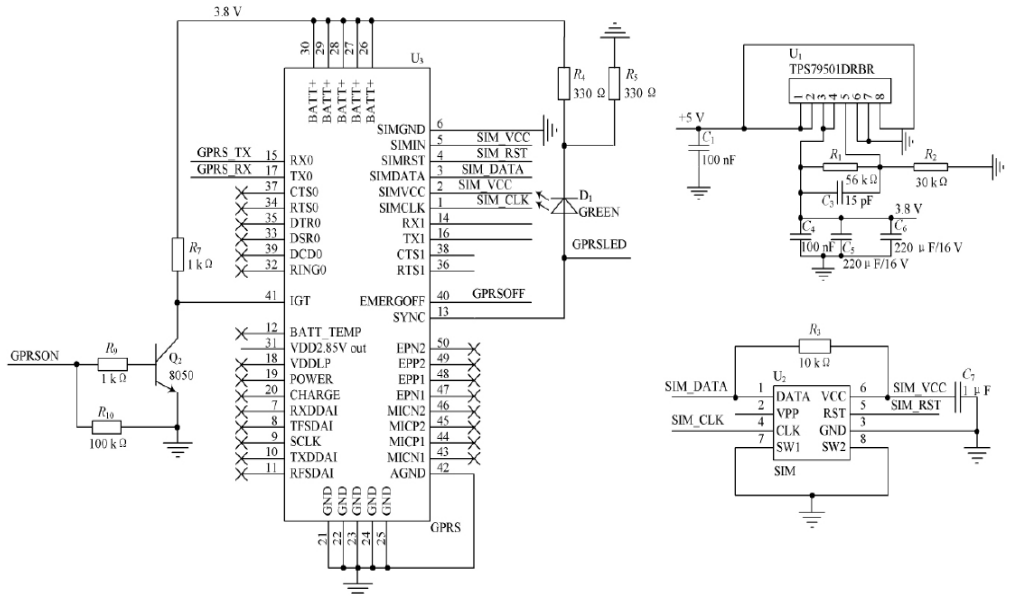

Figure 3. The Application Circuit of MC35I

3.3. Additional Memory

CC2430 uses the frequency of 2.4 GHZ, with the highest transmission speed at 250 kbit / s. while the MC35i theoretical maximum uplink speed is 171.2 kbit/ s, therefore uplink speed of GPRS may become the bottleneck in the real-time transmission of data in the whole gateways. When the amount of data in sensor network is too large to be sent out totally by GPRS, the system will send failure data to the buffer zone, and manage them unified, so the system needs to add memory device as the data cache to alleviate the difficult by different transmission speed. In addition, the S3C2440 and its running operating system Linux require a large amount of memory, so the system adopts external 64 MB data memory as the additional memory for the entire system.

4. The Design of Software of Gateways

The design of WSN gateways Software is a typical embedded software structure, consisting of 3 layers of composition: Boot loader, embedded Linux operating system, and the user program. Boot loader uses U- boot, responsible for initializing the hardware system, setting kernel parameters and starting the kernel. Embedded Linux operating system is pruned, and supports ARM system. It is the platform of application software in gateways. The user program is for the transplantation and configuration of PPP dialing software package.

4.1. Transplantation and Configuration Software

First the transplantation of boot software U-boot that is a powerful Boot Loader, and could directly support the platform based on S3C2440. Its workload of Transplantation is relatively small, and its work is mainly modifying few files related to ARM Hardware including5 files, Smdk2410.h, flash.c, memsetup.c, S3C2440.c Makefile and so on. After the File modification, U- boot Bin is generated by crossing compiled and downloaded to program memory to boot up the operating system.

The establishment of embedded Linux operating system is based on U- Boot, which is actually the process of transplantation of the Linux kernel in S3C2440. According to the characteristics of embedded gateways, the modification and recompilation of Linux kernel is made by the writer, retaining many characteristics, such as the strong network function, the stability and the support of file system. The steps of main construction of the embedded Linux operating system is 3: constructing the crossing compiling environment, compiling the kernel, and generating and configuring the root file system.

The process of establishing the cross compiling circumstance is actually the unpacking process of the compressed package of cross compiler. Before the cross compiling of the kernel, the configuration for the compiler's options is very important. Executing the order 'make menuconfig', then Entering the option 'System Type' and choosing The support on the S3C2440 system plate, and then configuring 'File System' and 'Block device'. After saving the configuration, it is need to modify the file 'Makefile', that is, specifying the path of the cross compiler to a specific catalogue, the modification statements is: CROSS _ Com pile = / usr / local / arm_cross / 3.4.1 / bin / armlinux. Finally compile the kernel under the order 'make dep', 'make clean', and 'make zImage', in order to get the compressed image 'zImage'.

4.2. The Design of Software of CC2430

The transmission path and the process of the data of each node in the CC2430 module are as shown in Figure 4.

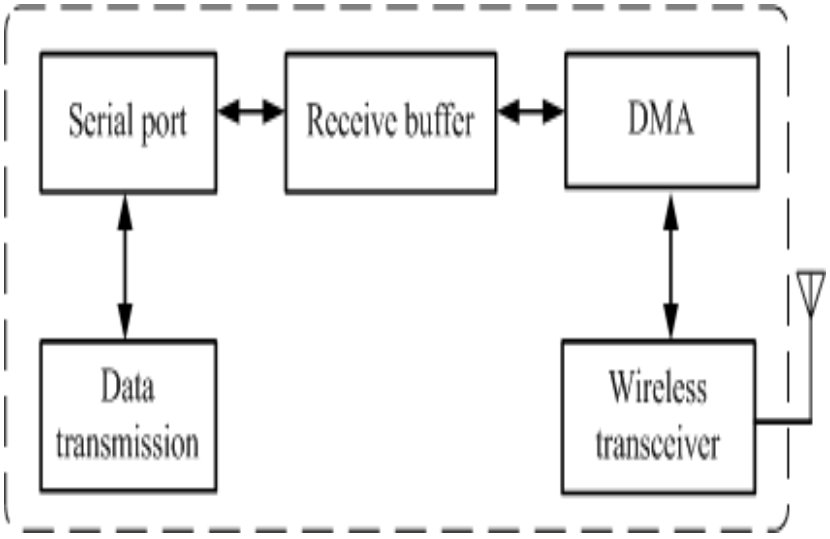

Figure 4. The Schematic Diagram Transmission Path and the Process of the Data of Each Node in the CC2430

CC2430 receives a wireless signal from the antenna, and converts the signal into the data stored in the receiving buffer by a series of internal Hardware processing. Then it sends the data to the low 128 B in storing area by direct memory reading, and finally sends the received data to the gateways or other modules through the serial port. The procedure of DMA (direct memory access) data is as shown Figure 5.

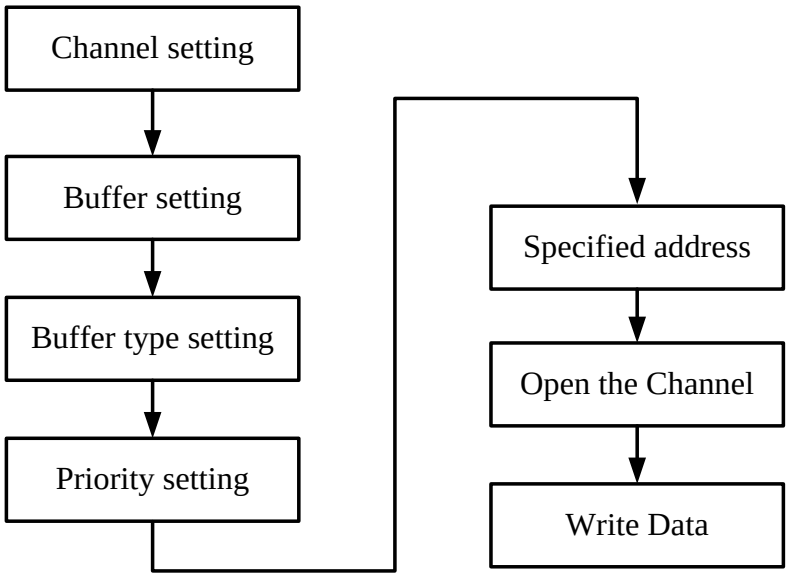

Figure 5. The Flowchart of Writing Data to the Memory by DMA

4.3. The Design of Software of MC35i

Data transmission through GPRS transfers through Internet network, so the package of data transmission must use TCP/ IP protocol. The data transmits through the transmitting layer, then it is packaged by UDP protocol head and IP protocol head, and finally by PPP protocol head. The MC35i Data Format Table is shown as Table 1.

Table 1. MC35i Data Format Table

PPP protocol head	IP protocol head	UDP protocol head	Data	Data Check

MC35i transmits the received data transparently into Internet network. Through the Internet network router, the data will eventually be transmitted to the monitoring center data. The receiving port receives the data, and analysis according to the corresponding level, so as to determine the object program.

The design of software of MC35i adopts layered structure, from the bottom to the top are the serial driver layer (physical layer), PPP protocol layer (chain layer), IP protocol layer (network layer), UDP protocol and ICMP (transport layer) and application layer. the data package is realized by the establishment of the process of the corresponding function at each layer. The bottom software provides the function support for the upper software, and the upper software writes and executes application program by using bottom software. The design makes each function in the system functional and modularization. Each task has a module, and it is designed independently. Ultimately they are managed by the Linux operating system.

In Linux operating system, PPP package controls MC35i to complete network accessing work, the structure is shown as Figure 6.

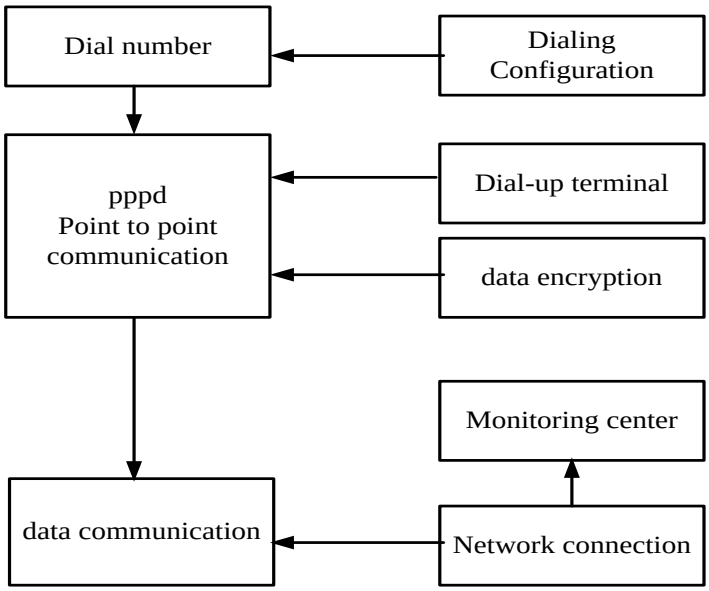

Figure 6. PPP Software Structure

PPP dial-up mainly calls two applications: pppd and chat, and achieves order AT.
PPP dial-up order line is as follows:

pppd [tt y_name] [speed] [options]

<tty_name> means communication on the device. If necessary, it can be led that a / dev / string. If no device's name is given, pppd will use the console terminal.

<Speed> means setting the baud rate of the serial

Dialing file chat can be placed anywhere in the system and the file could be located by the pppd options file, generally placed in / / etc / ppp / chat, as follows:

AT

OK AT + CG DCO N T = 1, "IP". "CMNET"

OK ATD * 99 *** 1 #
CONNECT
AT means sending the string AT, and expecting to get OK, and then setting the China Mobile's GPRS access to CMNET, finally dialing AT D * 99 *** 1 # to gateways GGSN, for getting string CONNECT. After the preparation, the following order could be set in terminal:
pppd/ dev/ t t yS1 19200 connect ' / us rlsbin lchat - v - f / et c/
ppp/ chat '
Finally dial up by PPP.

Order 'AT' is the beginning mode of MC35i, all data which S3C2440 send to serial port is passed to MC35i. After dialing, dialing information should include IP address and DNS address assigned by server dynamically.

4.4. Gateways' Online Keeping

As the network and the signal are weak, the connection between nodes with GPRS network will fail. The design based on State machine could deal with all errors generated in all stages, can protect the establishment of the connection between module and GPRS network. The design task flowchart of GPRS Network link state machine is as shown in Figure 7.

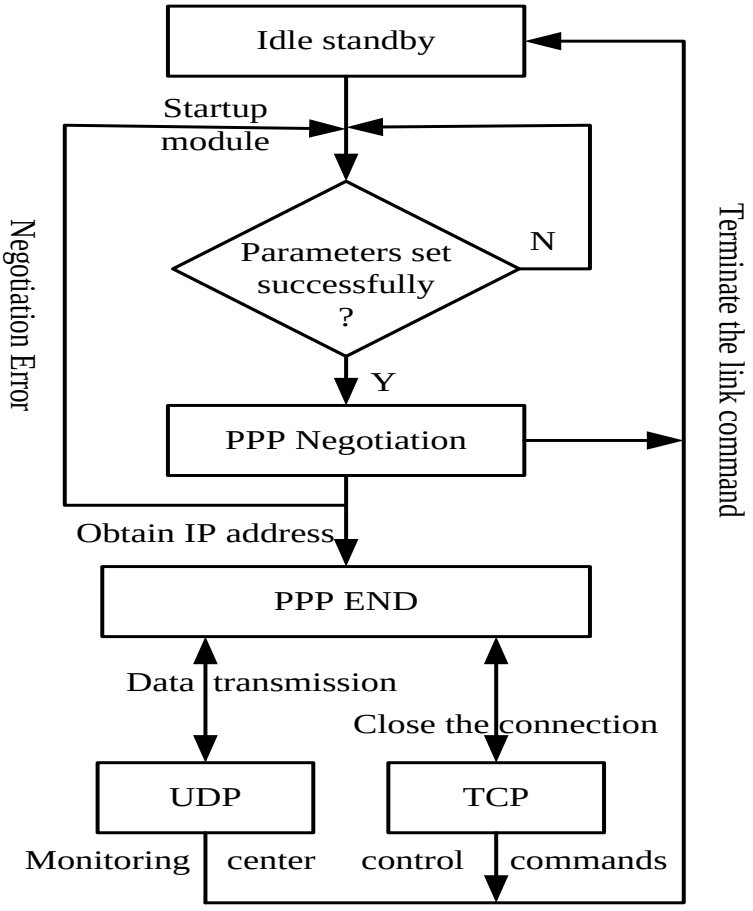

Figure 7. The Design Task Flowchart of GPRS Network Link State Machine

5. System Test Results

The design of the system was tested and the results show that the data can be stably transmitted to the target computer of server. The area of test information includes the three routing node data reported. Between the two hexadecimal bytes 7E (start flag bytes) of data, it can be obtained 64 MAC address 0940970E650E6C0E (14 to 21 bytes) of terminal node and its short address of routing nodes and corresponding RSSI. If the first 7E of routing nodes short address is the 8th and 9th (B83C), RSSI value is 13 (25th byte).It can be determined theoretically that the max value of RSSI is nearest of the routing terminal node. Three of Group (RSSI_1 RSSI_2 RSSI_3) reported short routing node addresses and the corresponding RSSI values shown in Table 2. The data display terminal node routing node closer B83C.

Table 2. RSSI Value Reported from the Route Node

route node address	RSSI_1	RSSI_2	RSSI_3
DB 3C	13	13	13
17 40	OE	OE	OE
B9 3C	05	08	05

6. Conclusion

In this paper, the design is based on ZigBee wireless communication module and GPRS modules, and makes the ARM processor as the kernel device to build the wireless sensor network (WSN) gateways, and proposes a communication scheme based GPRS and ZigBee wireless sensor network gateways. The design improves the gateways' transmission speed, has a complementary advantage between ZigBee short-distance transmission and GPRS long-distance transmission, and finally achieves long-distance transmission with high performance, and the holding of gateways online.

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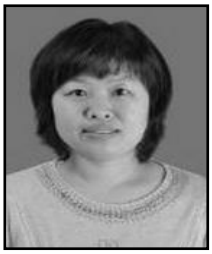

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