Research and Design of Meter Reading System Based on ZigBee Wireless Sensor Network

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Abstract: - With the rapid development of wireless technologies, it is possible for Chinese automatic meter reading system (AMRS) to be equipped with wireless sensor networks due to their low-cost, simplicity and mobility. In the current study, we compared the advantages of ZigBee with other two similar wireless networking protocols, Wi-Fi and Bluetooth, and proposed a wireless solution for AMRS based on ZigBee technology. As an explorative application of ZigBee technology in AMRS, The design reduces the system cost and power consumption and improves the system's flexibility and practicality.

Key-Words: - Wireless meter reading; ZigBee; IEEE802.15.4; JN5121; Profile

1 Introduction

In the information process of the electrical power system, the precision and timeliness of electrical meter reading influence the system's information level，management decision-making and economic benefits directly. Traditional manual meter reading method consumes time and manpower, and the precision and timeless is not reliable which makes relevant marketing and business management software can't get detailed enough and exact raw data. In addition, the manual meter-reading are generally carried out monthly which can't meet the needs of power supply department to make deeper level analysis and decision. As a result, industry demands promote the development of automatic meter reading technology and application [1] [2].

Wireless technologies have been rapidly developed during recent years. Starting from military and industrial controls, it is now being widely applied in environmental monitoring and agriculture. Its advantages include the liability, simplicity, and low cost in both installation and maintenance. In the current study, we compare the advantages of ZigBee with two similar wireless communications, Wi-Fi and Bluetooth, and propose a wireless solution for AMRS based on ZigBee technology.

2 Comparison of ZigBee, Wi-Fi, and Bluetooth protocols

ZigBee is an intelligent digital protocol, operating at three frequencies, with the commonest one being at 2.4GHz.Wi-Fi, Bluetooth and ZigBee work at similar RF frequencies, and their applications sometimes overlap. In the current study, we chose the following five main factors of ARMS networks to compare: cost, data rate, number of nodes, current consumption and battery life [3] [4] [5].

(1) Cost: ZigBee chip is US$ 1 or less, the lowest; Wi-Fi and Bluetooth chips are $ 4 and $ 3, respectively. The overall system cost can be significantly reduced by the employment of ZigBee chip.

(2) Data rate: ZigBee is 250 kbps, while Wi-Fi and Bluetooth are 54 Mbps and 1~2 Mbps, respectively. Despite the lowest data rate, ZigBee is sufficient for AMRS. Generally, data traffic in a ARMS is low—usually small messages. And also, low data rate helps to prolong the battery life.

(3) Number of nodes. The capacity of network is determined by the number of nodes, and ZigBee has up to 254 nodes, the largest among the three. It meets the application demand of more and more sensors and actuators in AMRS.

(4) Current consumption: ZigBee has the lowest current consumption, 30mA, while Wi-Fi, 350mA, and Bluetooth, 65~170 mA. It also greatly helps to prolong the battery life.

(5) Battery life: ZigBee chip has the longest battery life, a few months or even years.

As a whole, ZigBee technology offers long battery life, small size, high reliability, automatic or semi-automatic installation, and, particularly, a low system cost. Therefore, it is a better choice for ARMS than other wireless protocols.

3 Our Wireless solution for AMRS

3.1 Overview of the solution

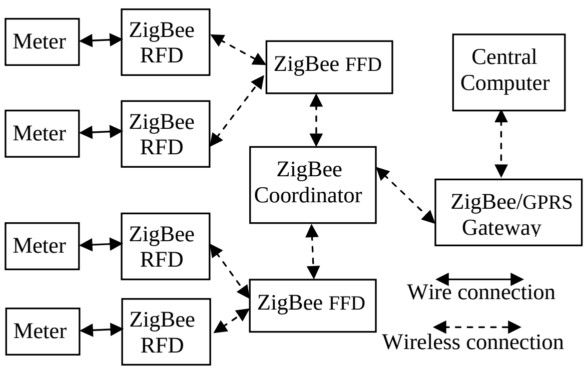

Fig.1 Overview of the solution for AMRS

The constitution of ARMS is shown in Fig.1. This system adopts the gateway of embedded processor S3C4510B with 32 positions of the ARM framework. Meters are controlled through the expanded control module MSP430 and the receiving-dispatching data module JN5121 of the gateway. The gateway also communicates with all child nodes of the network via its wireless module. As shown in Fig.1, the meter is connected to ZigBee RFD module through the RS485 interface to communicate with each other in the wireless automatic meter reading system, the meter's data is transformed to the ZigBee communication protocol package by ZIGBEE RFD module and sent to the neighbour FFD module, then the FFD Module choose a best communication path according to the table-driven routing algorithm, and the package is transmitted to the ZigBee gateway with the help of the other FFD module through the way of multi-class jump along the path. After the gateway node receives the package successfully, it sends back an acknowledgement to the RFD module which sends the data first along the primary path to realize the hand-shaking communication; otherwise the RFD module will continue to send the data, until it receives the acknowledgement. Meanwhile, it transmits the package to the central manage computer which concentrate those data through the GPRS network. So realized the whole process of the wireless automatic meter reading system [6] [7] [8].

3.2 System hardware design

The network node hardware design which includes the design of sensor node and gateway node is the basic work to construct the wireless sensor network.

3.2.1 Sensor nodes hardware design

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The constitution of sensor node hardware is shown in Fig.2.The sensor node in the system has adopted MSP430 as its microprocessor . MSP430 has rich memory resource. With 5MHz working frequency, the energy waste of MSP430 is about 1.5mw and this minor-controller has several power saving modes available to choose. Apart from rich memory resource and several power saving modes, MSP430 has several AD interfaces and I/O data lines which make it easy to use software to program. These interfaces can also be used as the interface for connecting sensor.

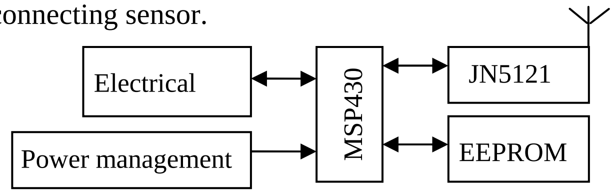

Fig.2 hardware structure of sensor node

The function of the corresponding module of the node of sensors is JN5121 module produced by Jennic Company. The JN5121 is the first in a series of low-power, low-cost IEEE802.15.4 compliant wireless microcontrollers, combining an on-chip 32-bit RISC (Reduced Instruction Set Computing) core, a fully compliant 2.4 GHz IEEE802.15.4 transceiver, 64 kB ROM and 96 kB RAM. The high level of integration helps to reduce the overall system cost. The JN5121 connects upper controller MSP430 through SPI (Serial Peripheral Interface). MSP430 uses master mode, JN5121 adopting slave mode. Fig.3 shows the circuit of the JN5121 module.

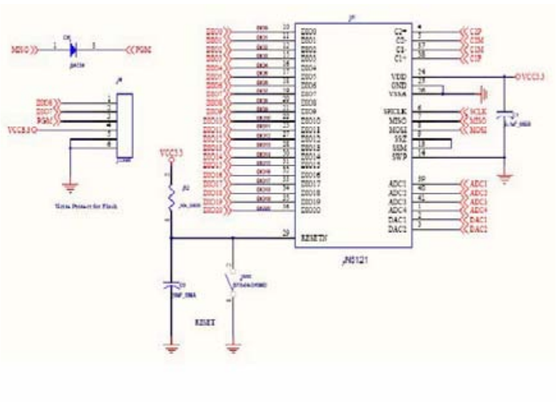

Fig.3 JN5121 circuit

3.2.2 Sensors node hardware design

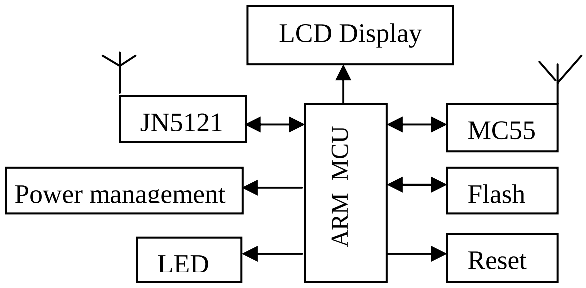

Fig.4 hardware structure of Gateway

ZigBee wireless network system conducts design and installation with a building as the unit. Each unit establishes a gateway. The gateway mainly realizes the work of interconnection between the ZigBee network and Internet network, on the one hand it transmits the data to remote central computer through the GPRS network, and on the other hand it sends the command which comes from the central computer to the sensor nodes of the ZigBee network. Fig4. shows the hardware structure of the GPRS/ZigBee gateway, and the gateway adopts the embedded processor STR912 with 32 bit of the ARM framework, MC55 produced by Siemens Company as the GPRS module. MC55 is a tri-band GSM/GPRS engine that works on the three frequencies GSM 900 MHz, GSM 1800 MHz, and GSM 1900 MHz, has an embedded TCP/IP stack that is driven by AT commands and enables our system easily access the Internet.

3.3 Network establishment and association

IEEE 802.15.4 defines three types of logical devices, a personal area network (PAN) coordinator, a coordinator, and a device. ZigBee denotes them as ZigBee coordinator, ZigBee router, and ZigBee end-device, respectively. For clearness, we utilize the naming of IEEE 802.15.4 from now on. PAN coordinator is the primary controller of PAN, which initiates the network and operates often as a gateway to other networks. Each PAN must have exactly one PAN coordinator. Coordinators collaborate with each other for executing data routing and network self-organization operations. Devices do not have data routing capability and can communicate only with coordinators. Due to the low-performance requirements of devices, they may be implemented with very simple and low-cost hardware. The standard designates these low-complexity nodes as reduced function devices (RFD). Nodes with the complete set of MAC services are called as full function devices (FFDs).

The standard supports two network topologies, star, and peer-to-peer. In the star topology, all data exchanges are controlled by a PAN coordinator that operates as a network master, while devices operate as slaves and communicate only with the PAN coordinator. This single hop network is most suitable for delay critical applications, where large network coverage is not required. A peer-to-peer topology allows “mesh” type of networks, where any coordinator may communicate with any other coordinator within its range, and have messages multi-hop routed to coordinators outside its range. This enables the formation of complex self-organizing network topologies. The network may contain also RFDs as devices. Mesh topologies are suitable for industrial and commercial applications, where efficient self-configurability and large coverage are important [9][10][11].

In our project, we established the network according to the mesh topology. As shown in Fig.5, once the FFD is activated for the first time, it establishes its own network and becomes the PAN coordinator. Then it initializes the hardware, stack and application variables, choosing an unused PAN identifier of zero, and broadcasting beacon frames to sensor nodes (RFD).

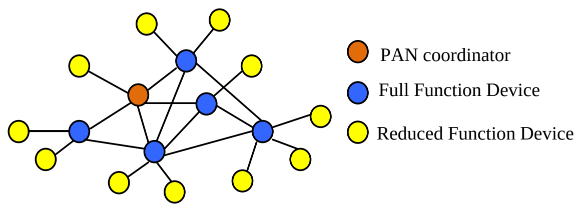

Fig. 5 Mesh Topology

Sensor nodes receiving a frame may request to join the network. The coordinator will add them as a child device in its neighbour list and return a response. The sensor nodes will add the coordinator as its parent in their neighbour list and return an acknowledgement. The coordinator monitors all network nodes in real-time, maintaining the network information database PIB (PAN Information Base).Once a network is formed, it is possible that due to thephysical changes, more than one network may overlap and a PAN ID conflict may arise. In that situation, a coordinator may initiate a PAN ID conflict resolution procedure and one of the coordinators would change its PAN ID and/or channel. The affected coordinator would instruct all of its child devices to make the necessary changes. ZigBee protocol devices store information about other nodes in the network, including parent and child nodes, in an area of non-volatile memory called a neighbour table. On power-up, if a child device determines through its neighbour table that it once was part of a network; it may execute an orphan notification procedure to locate its previously associated network. Devices that receive the orphan notification will check their neighbour tables and see if that device is one of their children. If so, the parent device will inform the child device of its place in the network. If orphan notification fails or the child device has no parent entry in its neighbour table, then it will try to join the network as a new device. It will generate a list of potential parents and try to join an existing network at the optimal depth. Once on a network, a device can disassociate from the network either by being requested to leave the network by its parent or by requesting disassociation itself. The amount of time that a device spends determining the channel energy and available networks on each channel is specified by the ScanDuration parameter. Refer to “ZigBee Protocol Timing” for details on how this parameter is derived. For the 2.4 GHz frequency band, the scanning time in seconds is calculated by the equation as follows:

$$\text{Scanning time} = 0.01536 \times (2^{\text{ScanDuration}} + 1)$$

For the general Stack, ScanDuration may be between 0 and 14, giving a scan time of 0.031 seconds to 4.2 minutes per channel. If ScanDuration is set to 8 and all 16 channels are specified, a device will spend over one minute performing each required scan. ZigBee protocol routers and end devices perform one scan to determine available networks, but ZigBee protocol coordinators perform two scans, one to sample channel energy and one to determine existing networks. The specified scan duration needs to balance the time needed to adequately perform each scan on the specified channels with the amount of time allocated for system start-up.

3.4 Profile customization

Referring to the criterion of the Zigbee application layer, and meeting the need of AMRS, defining the profile of Zigbee network in the ARMS.

3.4.1 Profile ID、Cluster、Attribute setup

Choosing an ID from Zigbee private standard framework as Zigbee network’s ProfileID, which we define as AMR_PROFILEID， the value is 0xC123. In the running of Zigbee network, the Smart Meter working as an endpoint node or router, only exchanges data with the coordinator. In the process of exchange, we take the way of binding directly, and the coordinator establishes binding table through the heartbeat signal of Smart meters.

The output of the Smart Meter: heartbeat signal、collecting data output、setting response output.

The output of Coordinator: collecting order output, checking time order output. Among those, the Smart Meter’s output corresponds with the coordinator’s input, and the coordinator’s output corresponds with the Smart Meter’s input. In data’s transmission, adopting the format of Key Value Pair (KVP) frame, according to the standard of the ZigBee cluster and attribute, we define the cluster and attribute of the ARMS as Table1.

Table 1 Cluster, Attribute define

Cluster	Attribute	Description
Cls_Meter_Out	Attr_Dat_Rsp	Data response
	Attr_HeartBeat	Heartbeat
	Attr_Settm_Rsp	Set time response
Cls_Codnator_Out	Attr_Data_Req	Data collection
	Attr_settm_Req	Set time request

3.4.2 Endpoint setup

After setting the attributes and clusters of the data exchanging, we need to set data channels for the data changing that is Endpoint. By analysis to the input and output of Smart Meter and coordinator, then set a Endpoint in above devices, make sure the Endpoint ID and Profile ID are same, at the same time the output of one Endpoint corresponding to another Endpoint’s input.

Set the node Endpoint and realize it in function JZA_boAppstart（）, adding simple descriptors to the corresponding nodes respectively, the coordinator sets the descriptors like these:

```
PUBLIC bool_t JZA_boAppStart(void)
{
  uint8 u8DeviceVer = 0x00;
    //set the version number,user-defined
  uint8 u8Flags = 0x00;
    //set simple descreptor's symbol
  uint8 u8EndPoint = 0x50; // set EndpointID
  uint16 u16DeviceId = 0x0000;
    // Endpoint devices' descreptors
  uint16 u16ProfileId = AMR_PROFILEID;
    // Endpoint's ProfileID
  uint8 u8InputClusterCnt = 1;
   // input the number of Cluster
  uint8 au8InputClusterList[]=
        {CLS_METTER_OUT};
   //input the ClusterID
  uint8 u8OutputClusterCnt = 1;
  //output the number of Cluster
  uint8 au8OutputClusterList[] =
  {CLS_COORDINATOR_OUT};
  //output the ClusterID
/* add simple descriptors for the device*/
 (void)afmeAddSimpleDesc(
        u8EndPoint,  u16ProfileId,
        u16DeviceId,u8DeviceVer,  u8Flags,
        u8InputClusterCnt,
        au8InputClusterList,
        u8OutputClusterCnt,
        au8OutputClusterList);
 JZS_vStartStack();
 // start the protocol stack
 return TRUE;
}
```

3.5 Nodes software system design and realization

The main task of the nodes software system is the communication among the wireless nodes. It is divided into two parts, the sensor node software and coordinator node software. We designed the software system according to the Reference Manual: JN5121-EK000 Demonstration Application. The JN5121 module adopts the network layer protocol stack which the Cygwin provides, and this stack achieves the mesh network routing, also provides a range of API for development and a basic operation system (BOS). BOS is a non-preemptive task scheduling system; all the tasks have the same priority, and realize the data interaction through the message mechanism. After the start of BOS and ZigBee protocol stack, BOS adopts a series of functions to control the user program. In each node's code, interrupts are used extensively to synchronize operation, which allows the device to put the CPU to sleep for long periods whilst nothing is happening [12] [13].

3.5.1 Coordinator software design

3.5.1.1 Function analysis of coordinator

The main function of the coordinator is as following:

(1)Receiving the instruction from the PC through the UART1, then analyzing the data frame according to the format of the protocol, lastly making corresponding actions in accordance with the previous analysis result.

(2)Sending meter reading command or time checking command to appointed meter.

(3) Receiving the data coming from the Meter, and transmitting it to the central PC through the GPRS network.

After specifically analyzing the coordinator's function, there are two problems needed to be solved:

One problem is how to find the corresponding net address according to the Meter number of the instruction while receiving the collecting single Meter or checking time order. Base on this considering, we must know the active node in the present network, and corresponding Meter number and net address, so defining a present node router table, and building the table through sending the heart beat signal by the receiving meter node. The main table members are shown in Table 2.

Table 2 Routing table of the Meter nodes

Name	Type	Description
au8MetterNo	uint8[6]	Number of Meter node
u16NetWorkAddress	uint16	Address of Meter node
u8Status	Uint8	Status of Meter node

The reason of building this list is to report the active node in present network to the Central PC, at the same time find the corresponding address of Meter node through the Meter number from the PC, then sending the corresponding command frame to the Meter according to the previous found address through the way of binding directly. Routing table is updated and maintained when the coordinator receives heart beat signal or the timer's time reaches. U8Status stands for the surviving status of node in network, and the node sends one heart beat signal to coordinator every duration of T to show that the node is in the network, at the same time the coordinator updates the routing table once every interval of T, and the value of each node's u8status adds 1; The coordinator also updates the routing table when it receives heart beat signal, and the value of the corresponding u8status is cleared to zero. If the value of u8status is more than the maximum we set, the system will delete the node's information in the routing table, to express that this node is absent in present network, and loses connection with the network. After the coordinator receives the order of collecting data or the checking time, then analyzes the Meter number of the order, and then to find the net address according to the Meter number, if finds, sending the order to the Meter through the way of directly binding.

The other problem is when the coordinator has collected the data of the Meter or received some other acknowledgment, how to send this information to the Central PC. For the heart beat signal which comes from the Meter node, we build routing list on the node to save it, meanwhile adopt the timing mechanism, send the information of the surviving Meter in network to PC. Data the coordinator receives from Meter is collected singly or broadcast; we also take timing mechanism to upload the data. Meanwhile building a table of data collecting in the coordinator, so only needed to judge this table at set interval, if there is data, send it to the central PC through the GPRS network, then empty the table.

3.5.1.2 Coordinator's Software flow and realization

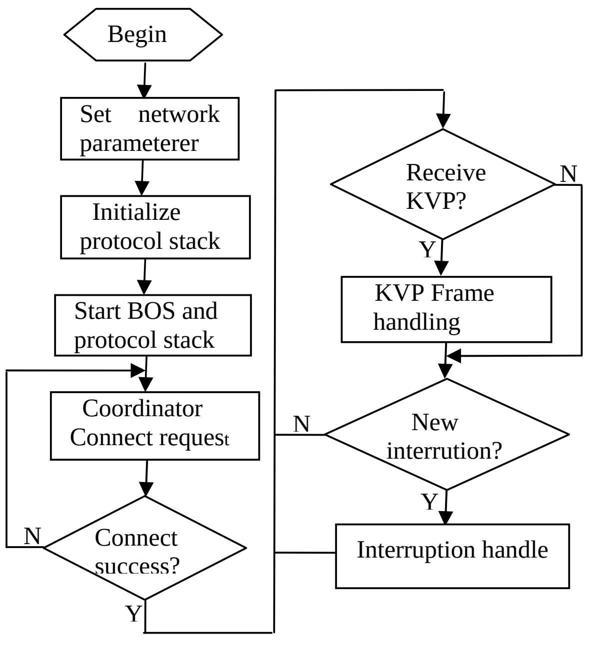

Fig.6 Main flow of the coordinator software

Fig.6 shows the main working flow of the coordinator. When the system is power on, first setting up the PAN ID of connecting network, then initializing the protocol stack by calling the JZS_u32InitSystem( ) Function, including the initialization of the other node's parameter, such as start-up of the timer, initialization of the UART1 baud rate and even-odd check, and so on, at the same time initializing the data structure which defined in procedure. After calling bBosRun( ) and JZS_vStartStack( ), coordinator will make request for connecting network, and start the BOS schedule.

In the process of connecting the network, if failed, the coordinator will be restarted automatically, until connect the network successfully. If success, we will find from Fig.6, there is no exit for the procedure in the flow chart, it is because of success to connect the network, and coordinator will handle the system events circularly under the management of BOS, until the coordinator is power off or restarted. After success to connect the network, BOS will handle the KVP frame and the receiving interrupt.

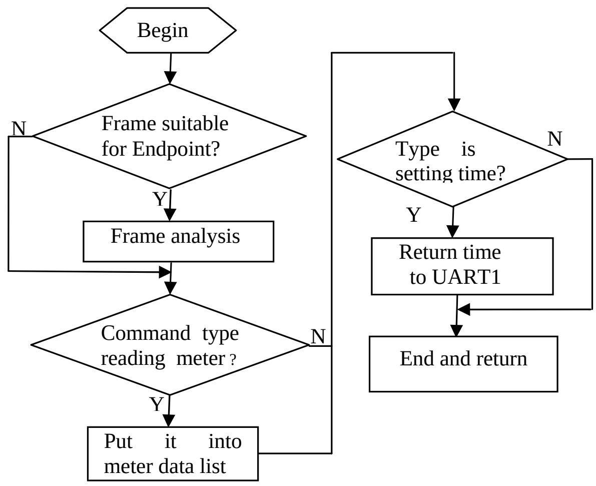

Fig.7 KVP frame handling process

Fig.7 is the handling process of the received KVP frame. In the network, The Meter nodes exchange data with coordinator through transmitting KVP frame, and what the Meter manly sends is the collecting electric quality or the reply that whether the time check is successful, the coordinator will do corresponding handle according to the data's attribute.

For coordinator, interrupt events is mainly divided into two kinds: timer interrupt and URAT1 interrupt. UART1 interruption is caused by the order coming from PC. Fig.8 is the handle flow of coordinator's UART1 interrupt events. The coordinator connects with the GPRS module MC55 through the UART1 interface, and when the central PC transmits the order to ZigBee network, the coordinator receives data from GPRS through UART1; the order's arrival will cause an UART1 interrupt. After receiving interrupt data, coordinator will analysis the data by defined protocol format, and handle it according to the flow as shown in Fig.8.

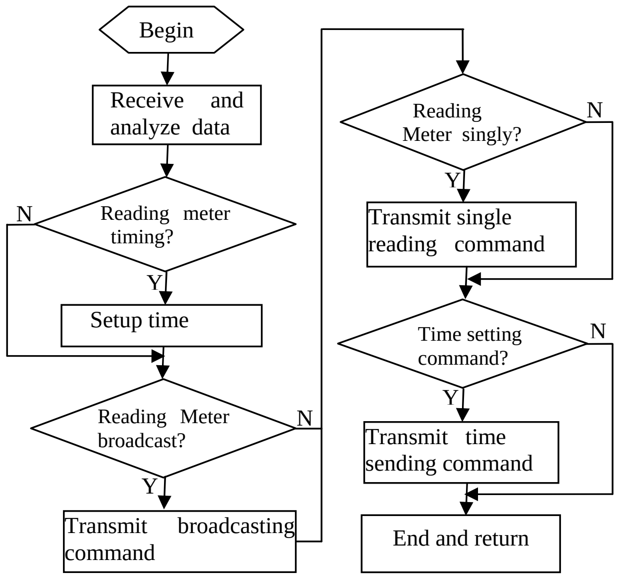

Fig.8 UART interruption handling

The coordinator's timer interruption is mainly used for updating routing table, sending the collecting data order at regular time, transmitting the counter for collecting data to PC, when the value of the counter is equal to the setting, the procedure will make corresponding action, meanwhile clear counter to zero.

3.5.2 Sensor nodes software design

3.5.2.1 Function analysis of Sensor nodes

In the ZigBee network, the Sensor nodes can be used as the end device or router, and their main function in the actual application are as following:

(1) Sending the heartbeat signal to coordinator.

(2) Judging whether it has lost connect with the network, if so, it will restart to connect with the network at regular time.

(3) making corresponding actions based on the order that the coordinator transmit, sending data acquisition order or time checking order, at the same time receiving UART1 data from the terminal, and sending the result to coordinator.

3.5.2.2 Sensor node's Software flow and realization

When the procedure in the sensor nodes starts up, it will run the same flow as coordinator, setting up network parameters, initializing protocol stack, opening the timer interruption, initializing UART1, this part is same with the coordinator. After launching the protocol stack through calling JZS_vStartStack(), the Sensor node will try to join the network in present, if failing, procedure will start a BOS timer, sensor nodes then go to sleep modes, the timer will wake up sensor nodes to join the network at certain time. If success to join the network, BOS will handle the KVP frame and interruption that the procedure receives, there are no exits for the main flow, the procedure will stop until the nodes lose power or restart. The sensor nodes in network make data exchange with coordinator by sending KVP frame, and the data that coordinator sends is mainly the order of collecting electric quantity or checking time, the nodes will do corresponding process according to the data attribute.

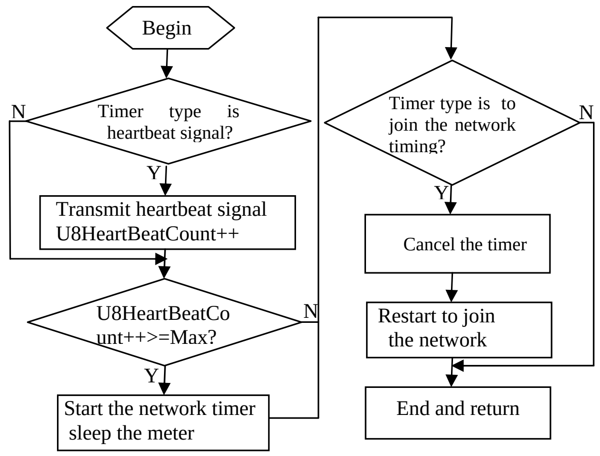

Fig.9 Timer interruption handling

For sensor nodes, same to the coordinator, interruption events are also divided into two kinds: timer interruption and UART interruption. UART interruption is caused by the returning data of the nodes. JN5121 chips are connected with the Meter MCU through UART interface, when Meter MCU returns data to JN5121, it will cause one interruption, and then sensor nodes receive the interruption data from UART interface, the software will analyze the data base on "DL/T 645-1997 multifunction Meter communicate protocol". while receiving the whole data of Meter number, present electricity quantity, current time, current date, and historical electricity quantity, the procedure will encapsulate the data collected, then send it to coordinator according to the pointed frame format; while the receiving data is checking time request, the procedure will send it to coordinator directly.

Fig.9 shows the handle flow of meter node's interruption events. The timer interruption is used to send heart beat signal and join network at certain time. It needs two timers to realize timer interruption. When the timer interruption which request sending the heart beat signal comes, the procedure will send heart beat signal including Meter's table number to the coordinator, at the same time set the type of frame as SET_RESPONSE, so the coordinator must give a request when it receives the message, the network layer will deal with the request, meanwhile, the heart beat counter should add 1; When the procedure doesn't receive the acknowledgment of heart beat signal from coordinator, the heart beat counter will be cleared to zero. In the process of the transmitting the heart beat signal, while procedure finds the heart beat counter reach the maximum, it shows the sensor node has lost contact with the current network, and the chip goes to sleep mode, waiting for be waking up to join network at regular time. If type of the timer is to join network timer, the procedure will join the network again and again, at the same time this timer will be cancelled.

3.5.3 Router nodes

In the ZigBee network, the meter can be used as router or allowing other nodes to join the network. In the actual distribution of nodes, however, if the distance of different units in the community is too far, or the user's meters are intentionally placed into one iron box, a special node is needed to join in the network as a router. The difference between this router node and smart meter playing the role of router is that the former doesn't collect data, only routes and connects the network, meanwhile allows joining the network again and sends the heartbeat message. As this heartbeat message doesn't have meter number, it will be directly thrown away, not to deal with, when the coordinator receives the message.

4 System network performance test and analysis

In order to demonstrate the feasibility of system, we conduct a test from ZigBee network transmission distance, packet loss rate, the stability of the system, and analyze the network capacity for analysis, based on the result of testing and analysis, propose a distribution program of nodes.

4.1 Test environment

Considering the actual test requires a large amount of ZigBee nodes, to spend a great deal of money, in the phase of the program, it is impossible to realize, so we put forward a few of the typical program, combining with theory analysis, to achieve the results. Test environment is as follows:

(1) Hardware environment: one coordinator, ten Meter nodes with ZigBee modules, five router nodes compose the first ZigBee network; one coordinator, one router, one node, compose another ZigBee network which has the same channel and different PANID compare to the former network; one reception node with ZigBee module.

In the first ZigBee network, ten Meter nodes with ZigBee modules can be set up as the router or end device in accordance with the need; the second ZigBee network in the same channel launched is used as network interference.

(2) Software environment: ZigBee as a new wireless standard, there is no available testing software, so during the test of transmission range and packet, we use dedicated capture software DainTree for ZigbBee package to capture and analysis.

4.2 Test program

In the course of testing, we will transform the situation in accordance with the distribution of node location, used to determine the effective transmission range of nodes. At the same time, in order to test the packet loss rate, we change the way of collecting in meter nodes, every three seconds to send acquisition data to coordinator, the data including current electric quantity, the date and time, Meter number. Laptop computer equipped with DainTree software, is used to capture and save the package Meter nodes transmit. Generally, the computer is placed around the coordinator. In different conditions, after a period of time based on comparison between the actual received the package and in theory should be sent by the meter, we can achieve the package loss rate.

4.3 Test results

In accordance with the above-mentioned test program between building A and building B, a lot of tests have been done, and the test results have been recorded. Because each time the test conditions and real-time network environment is different, based on each individual test results, which can't objectively reflect the system, so all the comprehensive test results can be more objective reflection of the operation of the network effect.

(1) Test results of transmission range and analysis: the range of operation of a wireless system is very important to the user. Although the theoretical transmission range of JN5121 module with ordinary power module is 100m outdoor, with high-power module is 1km, but the actual test results are not. For the meter nodes with ordinary power module, to penetrate two interior walls (Thickness of the walls is 37cm), transmission distance is about 30m or so; After penetrating three walls, performance will be degraded greatly, and it is easy to be disturbed, if someone walk through or other obstacles will result in sending packet loss; Outdoor living environment with cars and trees, the transmission range is about 80m. For the router nodes with high-power module, to penetrate four interior walls (37cm), transmission distance is about 300m; more than four, performance will be degraded. In the general outdoor environment, the transmission distance is about 800m.

(2) Packet loss rate of the test results and analysis: Inside the transmission range and the test time is 30 minutes; the packet loss rate of the test results is as shown in the Table 3. Under normal circumstances, we can see from that the packet loss rate is about 1%, indicating the packet transmission precision in the ZigBee network is very high when the number of the nodes is less.

Table 3 Packet loss rate of the test results

Test condition	Sending packet	Receiving packet	Loss rate
Normal	6000	5938	1%
Interference	6000	5876	2%

In the same channel by adding a different PANID Zigbee network, we will see the packet loss rate rises. Combining with the process ZigBee network layer starts and joins the network, we can find the reason of the increasing packet loss rate is that node in the current channel scan will find that there are two alternative network to join, and it will try to join one network, but in the process of launching the network, the PANID found unsuitable, it will disconnect the connection, then try to connect another network, in this process the time to establish the network will rise, so during the same time, the received packet reduces, and the packet loss rate rise. However, if calculating from the node beginning to join the network, packet loss rate should be equal to normal to join the network.

From this result combining with analysis, we consider that the time to establish the network will increase in same channel with different PANID, but in the process of running interference will not occur each other.

(3) Self-healing network capacity: in the course of testing, dynamic moving the node outside the scope of the network, the node is disconnected, and then moving it to the network within range, you can also see the success of the accession to the network. Results of experiments showed that nodes can join the network dynamic, and the network routing performance is good.

4.4 Nodes distribution program

According to the ZigBee standard, one ZigBee network nodes capacity can reach 65,535, but in practical application, considering the chip's actual capacity and the waste of the network address, the true capacity is far from reaching the standard.

In the current JN5121 Stack for the ZigBee protocol, the max depth of the network is 5, the max number of child nodes that each node allows is 20, while the router is as the child node, the max number is 6. In this condition, the network may reach the node capacity of 31100. According to the analysis of testing the node's transmission range, one ZigBee network should cover 4 to 5 kilometers. In the actual nodes distribution, however, considering the impact of node's transmission distance, if it is too far, it needs more routers to realize the function. As thus, if the node distribution is not reasonable, maybe there are just one or several nodes as child nodes under one router node, according to the ZigBee address assignment arithmetic, it will waste the network address, and reduce the capacity of network rapidly.

In the case of actual nodes distribution, coordinator, router should use high-power module. The coordinator should be placed in the central area of residential district, at the same time; the router nodes which connect with coordinator directly should be dispersed as possible to cover the whole district. Meanwhile, the lower routing of the router also should be dispersed. In the buildings, if the Meters are placed by floor, usually one router each 4 floors. Inside the range that the node can transmit, should increase each router's network capacity as possible.

5 Conclusion

In this paper, we discussed the wireless solution of AMRS based on ZigBee technology, and designed the wireless nodes, network establishment and software system. With the capabilities of self-organizing, self-configuring, self-diagnosing and self-healing, the ZigBee based AMRS provides nearly unlimited installation flexibility for transducers, increases network robustness, and considerably reduces costs. According to results of the test and analysis of the ZigBee network node's transmission range, packet loss rate and the Self-healing network capacity, it shows the reliability of the ZigBee network and routing capability of the network layer, combing the test and analysis, put forward nodes actual distribution program, proof the feasibility of meter reading scheme based on ZigBee. We, therefore, conclude that the ZigBee-based monitoring and control system can be a good solution for AMRS.

References:

[1] XIE Huipeng, WANG Jianming, ZHANG jingjing, Design and implementation of a wireless and low power consumption meter reading system based on zigbee technology, *Journal of Beijing Normal University*, Vol.44, No.2, 2008, pp. 174-176.

[2] Wang Dong et al, Building Wireless Sensor Networks by Zigbee Technology,*Journal of Congqing University*, Vol.29, No.8, 2006, pp. 95-110.

[3] ZHANG Qian, YANG Xianglong, A wireless solution for greenhouse monitoring and control system based on ZigBee technology, *Journal of Zhejiang University SCIENCE A*, Vol.8, No.10, 2007, pp. 1584-1587.

[4] TAO Xiaoling, HUANG Tinglei, WANG Yong, The study of Zigbee mesh network technology, *Journal of Guangxi Teachers Education University*, Vol.23, No.3, 2006, pp. 67-71.

[5] Jennic Ltd., 2006a. Data Sheet-JN5121 IEEE802.15.4/ZigBeeWireless.

[6] Jennic Ltd., 2006a. Reference manual: JN5121-EK000 Demonstration Application. Http://www.jennic.com.

[7] LONG Xuexiang, ZHANG Jing, DAI Yuxing, concentrator based on ZigBee in wireless meter reading system, *Journal of Hunan University*, Vol.12, No.2, 2007, pp. 14-17.

[8] YAN Yinfa, Gong Maofa, TANG Yuanxin, Design of wireless network wireless meter reading system based on ZigBee technology, *Electrical Measurement & Instrumentation*, Vol.43, No.486, 2007, pp. 3-45.

[9] WANG Xiaoyong, Xiao Siyou, FANG Yuefeng, Research on technology for building high-efficiency informational supervision platform to realize global logistics, *Wseas transactions on system*, Vol.7, No.4, 2008, pp. 342-351.

[10] Kevin Dankwardt, Real-time and Linux, *Embeded linux Journal*, Vol.13, No.4, 2002, pp. 154-156.

[11] QIN Shihong, LU Yaling, HU Sheng, ZHAO Qing, Management of electrical power through GSM wireless-recording system, *Journal of Huazhong University of SCIENCE and Technology*, Vol.35, No.12, 2007, pp. 53-55.

[12] QU Mingyou, LEI Hong, GUO Wensheng, Design and realization of a spot data acquisition system based on ZigBee, *Telecommunication Engineering*, Vol.48, No.4, 2008, pp. 34-38.

[13] Jian, YUAN Shenfang, Yin Yue, Ding Jianwei, Wireless sensor networks and application research based on ZigBee technology, *Measurement & Control Technology*, Vol.27, No.1, 2007, pp. 13-15,20.