

# **Design and Implementation of Smart Home System**

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**ABSTRACT:** The approach of the paper is to design and advance reliable, efficient, flexible, economical, real-time and realistic wireless sensor networks for smart home systems. Primarily, this paper analyzes the features of ZigBee technology, device types, network topologies and ZigBee protocol specification. Furthermore, a design scheme of smart home system based on ZigBee technology is placed forward and deliberated. Then, the hardware design of ZigBee nodes based on CC2530 chip is given. Smart home services using proposed effective methods diminish energy consumption. To support multi-hop communication improved routing algorithm based on Dijkstra algorithm is presented.

**KEYWORDS:** Smart home; ZigBee; WSN, GPRS, Dijkstra Algorithm.

## **I. INTRODUCTION**

A wireless sensor network is assembly of nodes that intermingle with each other in order to form a network. Each node comprises of processing capability, memory, an RF transceiver, power source and various sensors depending on the application. There are several application areas that wireless sensor networks are used in including environmental, military, medical, building automation, entertainment and many others. With the quick development of technology and the enhancement of living standards, the ultimatum of people for home environment is also growing. As an outcome, the technology of smart home turns out, and progresses quickly as the network grows. Smart home is a grouping of modern computer technology, control technology and information technology. The development of smart home technology has undertaken wired and wireless stages [1].

Due to the cable constraint and poor scalability of wired network, wireless technology will be an unavoidable tendency for home network. ZigBee is a recently developed wireless communication technology in short range, which has numerous features, such as short range, low-power, low-rate and low-cost. ZigBee technology can deliver users with a mobile, flexible networking and is very suitable for home control [2, 3].

In order to take the compensations of the characteristics of ZigBee technology and applications in the controlling network, we put presumptuous a smart home system based on ZigBee technology in this paper. The smart home system based on ZigBee technology in this paper does not need wiring and can be installed directly in the home. The system can realize home monitoring and terminal nodes supervisory by user management platform. What's more, in this smart home system, each sensor terminal node can collect environment data in home, such as brightness, temperature, humidity, security state, and each supervisory terminal node can be connected with some home devices, such as light, air condition, electric curtain, alarm, etc.

In smart home system, the current commonly used three kinds of short-range wireless communication technologies are: ZigBee, Bluetooth and Wi-Fi. These three kinds of short range wireless communication technology are compared in Table 1, in which the number of network nodes, the power consumption, the transmission rate, the transmission distance, frequency, device activation time and other technical indicators have been considered.

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Table 1 Comparison of ZigBee, Bluetooth and Wi-Fi technologies

Technical indicators	Zigbee	Bluetooth	Wi-Fi
Number of network nodes	65536	7	32
Power consumption	Low	Medium	High
Transmission rate/bps	250M	1M	1M
Transmission distance/m	10~75	10	100
Frequency/GHz	2.4	2.4	2.4

## II. RELATED WORK

Relating to the communication protocols like Bluetooth, IrDA, GPRS and ZigBee, several possibilities exist. Each of them has some benefits and shortcomings. To pick good one from them, their pros and cons have to be weighted. The different protocols are compared considering the application requirements including data transmission rate, range, battery life and cost [4].

Home Security with Messaging System, Security & Control System, and Remote and Security Control via SMS were the three alarm system that were designed using SMS application to securely monitor the home condition when the owner are away or at night. The system described in [5], is also based on GSM technology. The system is wireless and it provides security against intrusion as well as automates various home appliances using SMS. The system uses GSM technology thus providing universal access to the system for security and automated appliance control.

Liang et al [6] developed a system of wireless smart home sensor network based on ZigBee and PSTN (Public Switched Telephone Network) technologies. To overcome the problems in traditional designs we presented GPRS instead of PSTN technology for better system performance.

Rendering to their supposition it is beneficiary that ZigBee communication protocol is appropriate one which gives advantages like high range, very low power consumption and low cost.

## III. SYSTEM DESIGN

In the interpretation of network, smart home system is usually divided into three parts: external network, home gateway and internal network. Internal network is recognized by ZigBee nodes, which support user management platform in getting state of appliances and convey the commands from the user organization platform to appliances via ZigBee network. And the users outdoor or in remote areas need to attain the family network monitoring and management through an external network, using a computer, web or mobile phone, which enables the application surface of the system to be broaden. Home gateway plays the role of a manager for the internal network, which can control the nodes in home. For the external network, home gateway works as a protocol converter [8]. The overall framework of smart home system is showed in Fig.1.

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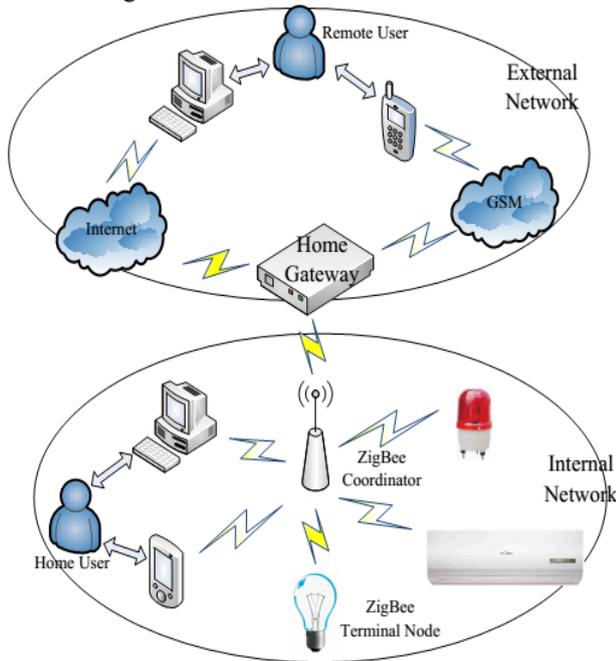


Fig.1. Overall Framework of Smart Home System

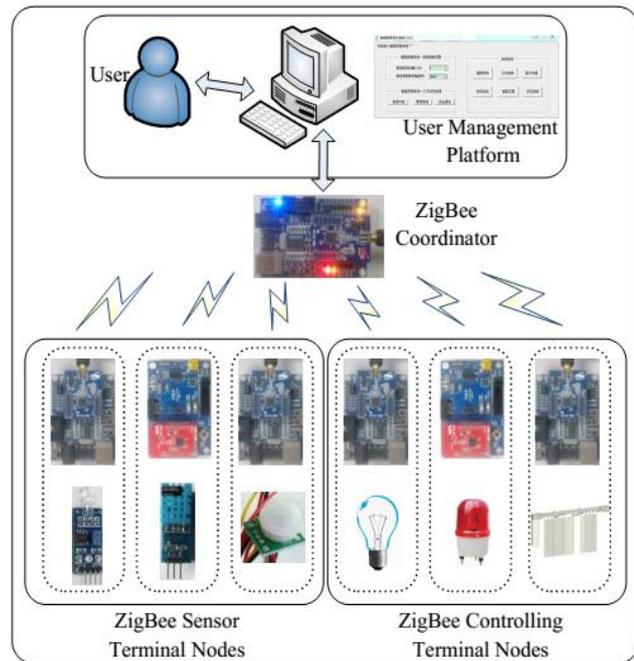


Fig.2 Design Structure of Smart Home System

## A. Design of Smart Home System

The smart home system intended in this paper uses the star network topology and emphasizes on the internal network, which mainly comprises the user management platform, ZigBee coordinator and ZigBee terminal nodes, as showed in Fig.2. Due to the smart home system based on ZigBee technology is reinforced by computer technology, sensor network technology and control technology, so the design of smart home can be divided into three blocks [9].

1) Smart home user management platform: Smart home user management platform is achieved on PC, which realizes the home network management and controlling through the simple man-machine interface.

2) Smart home sensor network: The sensor network is based on the ZigBee protocol stack. Users can control wireless nodes distributed indoor. The sensor network is primarily composed by the ZigBee coordinator, ZigBee sensor terminal nodes and ZigBee controlling terminal nodes.

3) Smart home control technology: CC2530 is the core chip of each node in this system. The control technology mainly contains the process of data collecting by ZigBee sensor terminal nodes and the management of the controlling terminal nodes by the coordinator.

## B. Monitoring system using GPRStechonlogy

The network node and the coordinator are keycomponents of the system. Assumption is that thecoordinator will always be connected to the monitoringcenter/server via a computer that can access the Internet orthe GPRS network. When the server sends out a command,the CPU of the network coordinator will read the content ofthe command and get the details by analysing it, such asturning on the air conditioner or microwave oven.Through serial ports, the main control programwithin the network coordinator writes the details to theZigBee module. Then using ZigBee module, messages willbe sent to the family network. Design of Coordinator nodecan be given by using peripheral circuits according to thefunctional requirements, and can develop a networkcoordinator by integrating the ZigBee coordinator node andthe GPRS module together on a PCB board [4]. Fig. 3shows the hardware board of the coordinator node [4]. Inthis way, a monitoring system can be built using GPRSnetwork.

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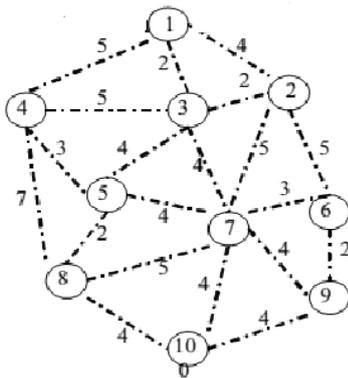
Fig. 3. Coordinator node developed

### C. Routing algorithm

The smart home system using the WSN established can be demonstrated as a (wireless) network, and the routing point is the node in the network. The conventional Dijkstra algorithm [7] produces the shortest path rendering to the order of increasing path length, and insatiably quests path based on the edges connected with nodes. On the other hand, there is no edge in the wireless network. Consequently in this paper, we advise an improved Dijkstra algorithm for the WSN, which attains the shortest path in the network.

Assume that there are  $n$  nodes in a wireless network, and the location of each node is available. Formerly we can get table of distances between nodes by using the following algorithm [8]:

- (1) A node is randomly selected as the root node. After initialized, it will send messages to enclosed nodes requesting for their IDs and location information.
  - (2) In reply to Step (1), the residual  $n-1$  nodes send their IDs and location information to the root node.
  - (3) The distance table is produced after the root node has acknowledged all the information of remaining  $n-1$  nodes.
- For instance, Table II distance table taken using a simple wireless network sample of 10 nodes from figure 4.



Node ID	1	2	3	4	5	6	7	8	9	10
1	0	4	2	5	5	7	6	8	9	9
2	4	0	2	7	6	5	5	7	7	8
3	2	2	0	5	4	5	4	6	7	8
4	5	7	5	0	3	8	7	7	9	8
5	5	6	4	3	0	6	5	2	7	5
6	7	5	5	8	6	0	3	8	2	5
7	6	5	4	7	4	3	0	5	4	4
8	8	7	6	7	2	8	5	0	6	4
9	9	7	7	9	7	2	4	6	0	4
10	9	8	8	8	5	5	4	4	4	0

Fig. 4. An Example Network of 10 Nodes

Table II

The corresponding distance table is shown in Table I and here, we practice an improved Dijkstra algorithm to assume the optimal path. Some symbols and notations used in the algorithm are listed in Table III.

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Table III

Symbol	Description
N	Number of network nodes
v	Sending node
w	Receiving node
k	Transmission radius
u	Relay node
s[i]	Visit mark(if not visited, set [i]=0; else set s[i]=1)
Cost[i][j]	Distance between node i and node j
Dist to w	Distance corresponding to the optimal path from v

The improved Dijkstra algorithm is described in the following:

- (1) Initialization: num=0, dist=+∞, s[i]=0, (i=0, 1, …n);
- (2) If cost[v][i] ≤ k, then set s[i]=1, (i=0,1, …n);
- (3) If s[w]=1, then dist=cost[v][w]; otherwise go to step (4);
- (4)  $\forall i \in \{s[i]=1\}$ , u[num]=1, set s[j]=1 when  $j \in \{\text{cost}[u[\text{num}]] [j] \leq k\}$ , (j=0,1, …n);
- (5) If s[w] ≠ 1, then num++, repeat step (4); otherwise record the path that fulfills s[w]=1, and dist[num] = cost [ v][ u[0]] num-1+Σ cos [ u[j ]][u [ j + 1]] + cost [u [num]] [ w]; J=0
- (6) For num=num+1, repeat steps (4) and (5) until all the paths that fulfil s[w]=1 are obtained;
- (7) Set dist=min{ dist[i], i=0,1 …num}, and output the corresponding path.

To calculate the performance of routing algorithms, a general apprehension would be the energy consumption of the network nodes. If a node is put into sleep as long as it has no data to receive or send (and all state switching overheads are negligible), its energy consumption will be approximately proportional to the number of times it is visited (i.e. the number of packets it has transferred).

## IV. SOFTWARE DESIGN OF THE SYSTEM

Software design of the system is mainly divided into two parts: software design of ZigBee nodes and user management platform. Software design of ZigBee nodes is based on the ZigBee protocol stack which chooses IAR Embedded Workbench as the software platform. It includes the software design of coordinator, sensor terminal nodes and controlling terminal nodes. ZigBee coordinator is the core of wireless sensor network, which is responsible for network establishment, address assignment, information management and data transmission, etc. In addition, it communicates with the PC through RS232 serial port [10]. The workflow of ZigBee coordinator is showed in Fig.5.

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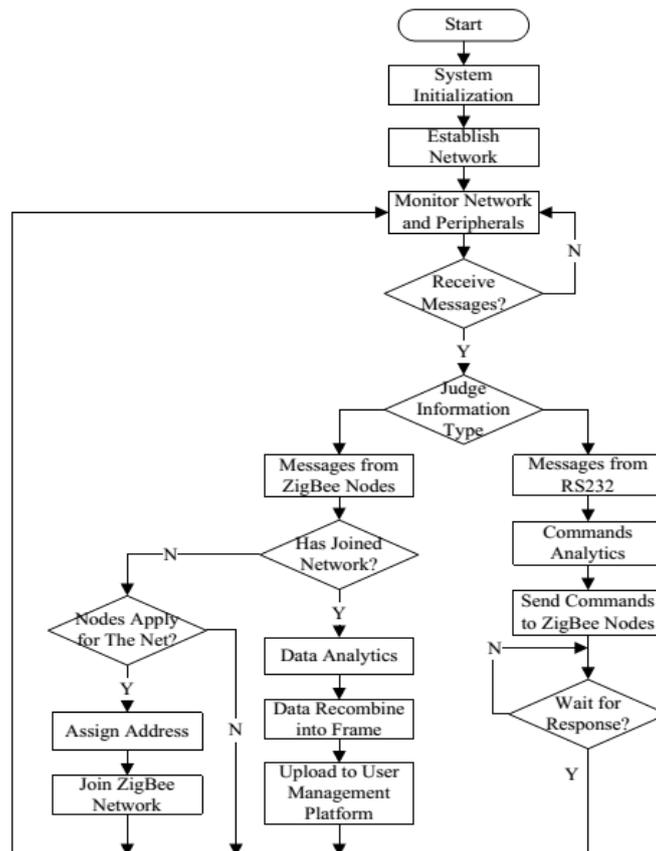


Fig.5. Workflow of ZigBee Coordinator

## V. CONCLUSION

The smart home system based on ZigBee technology is a new solution that used to meet the demand of high automation and intelligent home. In this paper, we introduce the advantages of ZigBee technology, architecture of ZigBee protocol, topologies and device type of ZigBee network. Then we put forward and discuss a design structure of smart home system. After that, the details of hardware and software design in smart home system are also given, which include the design of coordinator, terminal nodes and user management platform. Also, this paper presents Dijkstra shortest path routing algorithm along with evaluation of performance which give energy consumption of network nodes. Because of the prominent advantages of low cost, low power and flexibility, and as the further development of wireless network technology, ZigBee technology will become a foreseeable trend in the development of smart home.

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### BIOGRAPHY



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