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Building an Automatic Model to Measure Environmental Parameters using a Wireless Sensor Network with Zigbee Standards

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A B S T R A C T

In the era of wireless technology development, there are many different data transmission standards, such as Bluetooth and WiFi. However, they are not suitable for control and automation applications in homes or hospitals because of many limitations, such as: high energy consumption, need for continuous power supply, narrow connection, high latency, weak security, requiring high-end hardware, and high cost. This article introduces a wireless sensor network using Zigbee technology combined with sensor nodes. This network can collect and send environmental parameters to the central control station and then store them in the database. Users and managers can view these parameters via the Web, GSM, or smartphone and make appropriate decisions. If the environmental parameters exceed the allowed threshold, the system will alert or alarm the responsible person.

Keywords: Zigbee standards, wireless sensor network, environmental parameters, automatic model

1. Introduction

As technology advances rapidly, there is a growing demand for mobile devices and communication networks. Besides high-speed networks that offer various services and utilities, another network layer that attracts attention and application is wireless personal area networks (WPAN). WPANs are low-speed but low-energy networks that can be set up quickly and flexibly with low cost, simple equipment, and minimal information infrastructure. WPANs follow the IEEE 802.15 standard. One of the most notable WPAN technologies is ZigBee (ZigBee/IEEE 802.15.4), which enables data transmission between sensor nodes for many applications. Sensor nodes used to be hard to produce, costly, and short-lived, so they were not widely used. However, with the progress of science and technology, sensor nodes have become simpler, cheaper, and more energy-efficient, and they can operate in harsh and toxic environments. Therefore, ZigBee has been extensively applied in many aspects of life, such as smart homes, sports and health, health monitoring, traffic, the environment, and the military. ZigBee technology appeals to users with its ability to control devices wirelessly from a distance, transmit data reliably, and consume extremely little energy.

In [1], this paper provides a detailed study of the ZigBee wireless standard, the IEEE 802.15.4 specification, ZigBee device types, the protocol stack architecture, and its applications. In [2], this paper presents ZigBee networking topology, its types, architecture, and applications. In [3], this paper compares and contrasts Bluetooth and ZigBee WPAN standards in terms of their features, performance, advantages, and disadvantages. In [4], this paper discusses the ZigBee technology, its characteristics, advantages, disadvantages, and challenges. In [5], this paper reviews the applications of ZigBee in various domains, such as smart home, health care, traffic, environment, and military.

In [6], this paper studies the performance of the ZigBee wireless sensor network in different environments, such as line-of-sight, non-line-of-sight, and multi-hop. The paper also measures the delay, throughput, and packet loss rate of the ZigBee network. In [7], this paper provides a detailed study of ZigBee technology, including the IEEE 802.15.4 standard, ZigBee device types, protocol stack architecture, and ZigBee applications. In [8], this paper analyzes the feasibility and implementation guide of a dynamic wireless sensor network based on ZigBee, which can change the network structure over time. The paper also discusses some challenges and solutions for a dynamic wireless sensor network. In [9], this paper presents the applications of ZigBee in various fields, such as smart homes, health care, traffic, the environment, and the military. The paper also compares ZigBee with other wireless technologies, such as Bluetooth, UWB, and IEEE 802.11. In [10], this paper designs and implements a ZigBee wireless sensor network for smart homes, which can control smart devices and monitor temperature, humidity, light, and gas. The paper also evaluates the performance and energy consumption of a wireless sensor network.

This paper studies a wireless sensor network model based on ZigBee technology, a wireless standard that is energy-efficient and flexible. The goal of the model is to measure important environmental parameters and provide an online automatic monitoring system for managers and users. The model can be

applied in various fields, such as environment, health, traffic, and military, by using different types of sensors, such as motion sensors, infrared sensors, toxic sensors, radiation sensors, etc.The model can also adapt to different requirements of environmental parameters, network scale, and sensor types by adding, removing, or changing the appropriate sensors. This shows that the model has high flexibility and adaptability. The paper also presents some practical applications of the model at the AD-AF Academy, such as environmental monitoring systems in the facilities, intelligent measurement systems, automatic control systems, and IoT systems. The paper also proposes some directions for further research and development of the model.

2. Zigbee wireless sensor network model

2.1. Overview of wireless sensor networks

Wireless Sensor Network (WSN) is a sub-network layer of WPAN and is applied to many application models, such as Zigbee, Bluetooth, broadband Internet connection, environmental monitoring, etc.A WSN is designed to include many sensor nodes that perform the task of sensing, measuring, and computing parameters, then sending the collected information to the processing device to perform statistics or issue appropriate control commands for each application. These sensor nodes are distributed in space, and their functions are usually similar to each other. In addition, there are special function nodes such as input/output or relay.

Sensors are responsible for converting non-electrical quantities into electrical ones in measurement and control information systems. This is the most basic step that determines the error of the measurement system or measuring instrument. Each sensor node usually consists of basic components such as a sensor, microprocessor, wireless transceiver, and power supply. Figure 1 shows the most general model of a WSN wireless sensor network.

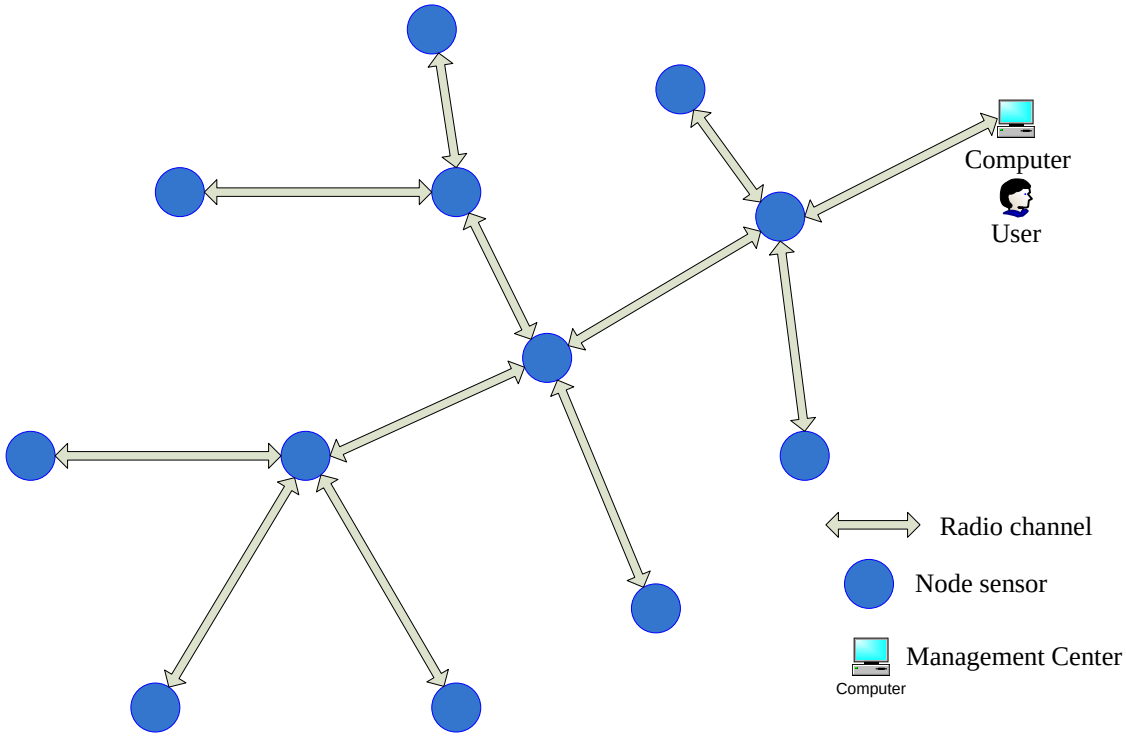

Fig.1. General overview of the WSN wireless sensor network

2.2. Zigbee standards

ZigBee is a set of communication protocols for wireless networks with a short range and low data transmission speed. Wireless devices based on the Zigbee standard operate on three frequency bands: 868 MHz, 915 MHz, and 2.4 GHz.

ZigBee has the following main characteristics:

Low data transmission speed (20–250 kbps)

Low power consumption, low energy consumption

Long battery life

Easy installation and maintenance

High reliability

It can be expanded to 65,000 nodes.

Low investment cost.

The data rate is 250 kbps at 2.4 GHz (global), 40 kbps at 915 MHz (USA, Japan), and 20 kbps at 868 MHz (Europe).

This paper will present the research, design, and fabrication of sensor networks according to the ZigBee standard (IEEE 802.15.4).

Wireless sensor networks are data acquisition systems. Traditional data acquisition systems use a wired network as the transmission medium, which is an indispensable part of control and monitoring systems. However, along with the development of science and technology, control and monitoring systems are increasingly expanding in both scale and technical requirements, requiring data acquisition systems to develop accordingly. For applications with a large number of measurement points and a large floor area, the use of conventional wired data acquisition systems causes many inconveniences, such as:

Complex network infrastructure, causing overlap for the whole architecture.

Difficulty in developing more sensor nodes: when the technology process changes, the system needs to expand.

Difficulty in operation, maintenance, and upgrading the system.

High design and installation costs.

Wireless sensor networks according to the ZigBee standard have the following advantages:

Devices are easy to install, deploy, and expand, both when building new systems and replacing or upgrading old ones.

Flexible in design, it can be easily integrated with old control and monitoring systems.

Allow to expand the number of measurement points up to 65,000 nodes, as well as operate in wide space.

Easy to operate, maintain, upgrade, and replace.

Low energy consumption and long life when using batteries.

Low initial investment cost; the frequency band is completely free.

Besides, there are disadvantages:

Low data transmission speed (20–250 kbps)

Limited frequency band, affected by the environment due to wireless transmission.

3. Designing a wireless sensor network model based on the Zigbee standard to automatically measure environmental parameters

3.1. Design structure of the system

The system is designed based on an energy-saving wireless sensor network according to the ZigBee standard, with a central coordinator device that can communicate flexibly with the user. The sensor nodes will be installed at important positions to form a network, allowing them to collect information and send it to the central coordinator device, serving the purpose of early detection and warning of environmental parameters. The model of the system structure is shown in Figure 2.

The data collected from the wireless sensor network through the central coordinator device will be input into the computer, and the software on the computer will allow it to display and store the received data.

The central coordinator device can also push data to the server via GPRS. This allows managers and users to view the updated data online on the internet, through computers, smart phones, and tablets with internet connections.

When the environmental parameters change beyond the preset limit, immediately on the device or computer, the data displayed on the website will give warnings to the manager and user according to different levels. In addition, emergency notifications, such as making calls or sending messages to the manager, are also performed by the central coordinator device to ensure timely handling.

In this model, the sensor block has the function of measuring the temperature and humidity of the environment and bringing it to the central microprocessor block for processing. The temperature sensor used must have high requirements in terms of energy consumption, so the SHT11 sensor can be selected.

The central microcontroller block has the function of controlling and receiving data from the sensor, from which it processes and decides to control the RF transceiver module to transmit data. The central microprocessor also has high requirements for energy consumption, so the PIC18F26J50 chip from Microchip can be selected. This is an 8-bit microcontroller line using Ultra Low Power technology.

The RF transceiver module plays the role of transmitting data to the intermediate device. The transceiver module is the most energy-consuming component, so choosing the RF module that both saves energy and ensures the communication distance is a very important requirement. To meet this

requirement, we can choose the MRF24J40MC module from Microchip. MRF24J40MC is developed on low-power technology with an external antenna connection and is compatible with the ZigBee IEEE 802.15.4 standard.

In addition, the design also includes: the UART communication module using the PL2303HX chip, which is responsible for sending data to the computer to serve the purpose of displaying and storing data; the SIM900 module, which allows to make emergency calls and send messages to the person in charge when there is a situation; and sending data to the server to store and update data on the website.

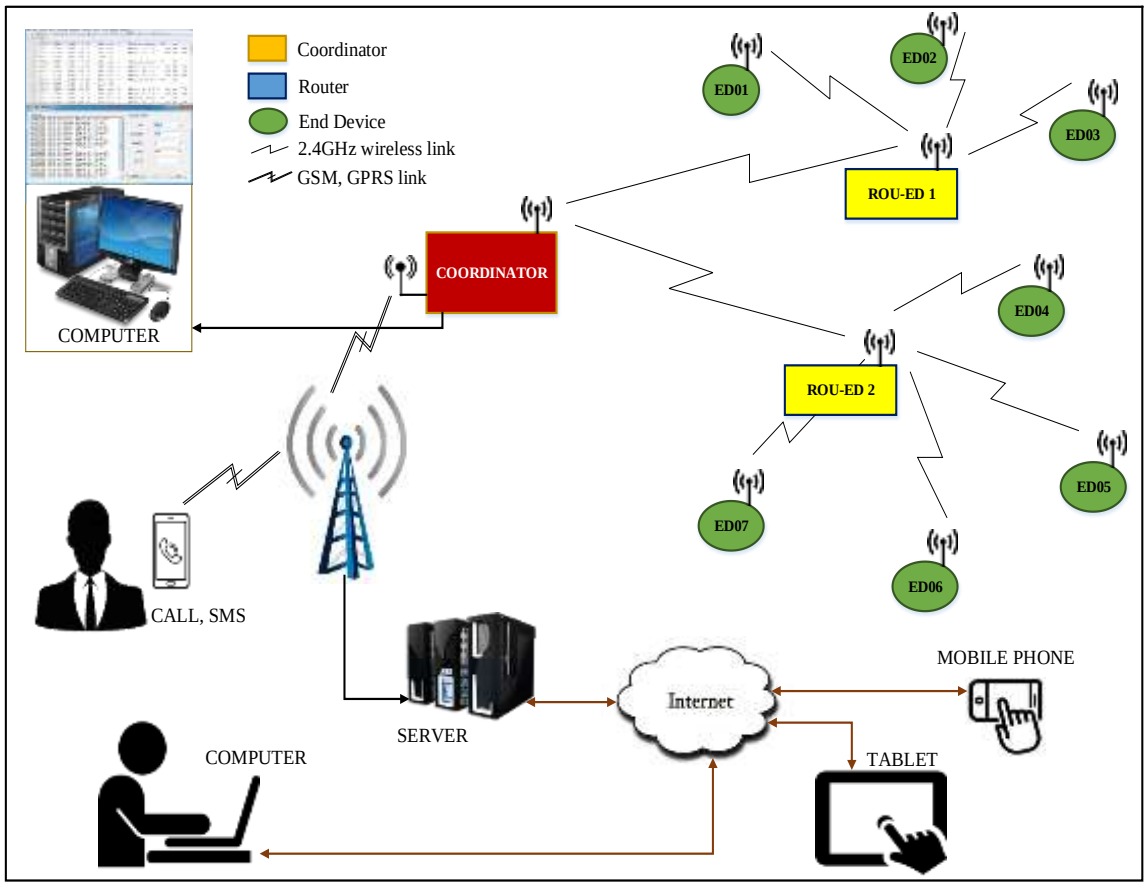

Fig.2. Model of the system structure

3.2. Basic components of a wireless sensor network based on the ZigBee standard

A typical ZigBee network consists of sensor nodes, which include full-function devices (FFD) and reduced-function devices (RFD). FFD plays the role of coordinating the whole network (PAN Coordinator) or coordinating a subnetwork (Coordinator), or it can be a router (Router) or simply a sensor node. RFD is usually just a node that performs the sensing function. FFD has high requirements for processing speed; it also performs input and output functions and communicates with the CPU.

The basic components of the sensor network based on the ZigBee standard are described in Figure 3.

The specific functions of the components in the network are as follows:

Zigbee Coordinator (ZC): This device forms and maintains the overall network architecture, controls and monitors the network, and stores information about the network. Therefore, it requires the largest memory and computing power. It is an FFD device.

Zigbee Router (ZR): A smart device that can extend the coverage of the network by routing and providing backup or recovery routes for congested routes, acting as an intermediate router, and transmitting data between different devices. It can connect with ZC, ZR, and ZED. It is also an FFD device.

Zigbee End Device (ZED): These are sensor nodes responsible for collecting information from the environment. It can receive messages but cannot forward them; it can connect with ZC and ZR but cannot connect with each other. It can be FFD or RFD.

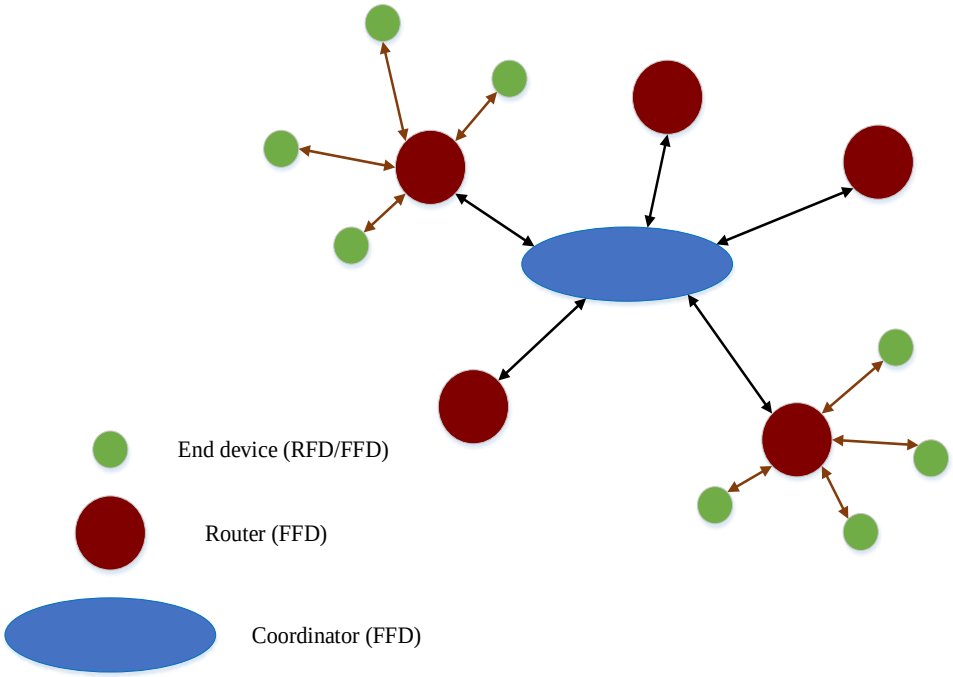

Fig.3. Basic components of a wireless sensor network based on the ZigBee standard

3.3. Some applications of wireless sensor networks based on the ZigBee standard

Wireless sensor networks based on ZigBee are widely applied in many fields, such as:

In the environmental field, it is used to monitor the movement of birds, animals, and insects; monitor environmental conditions such as temperature, humidity, and pressure; and monitor and early warn of natural disasters such as earthquakes, volcanic eruptions, etc.

Smart home: used to control and manage devices, anti-theft, fire prevention, etc.

In agriculture, it is used to measure parameters such as temperature, humidity, pH, light, etc. to serve the irrigation, fertilization, and lighting systems automatically in greenhouses and gardens, or to report those requirements to the manager.In industry, it is used to monitor and supervise the parameters in factories, workshops, manage goods and containers at ports, and manage workers and employees.

In health and sports: Sensor nodes with an extremely small size attached to the bodies of patients or athletes will let the supervisor know the physical condition as well as some basic parameters such as heart rate, blood pressure, etc.

Traffic monitoring allows the supervisor to know the traffic situation of vehicles on the road, including their number and speed.

In national defense:

Monitoring forces, equipment, and ammunition: Commanders and managers will continuously monitor the status of military forces, conditions, and availability of equipment and ammunition on the battlefield by using sensor networks. Military vehicles, equipment, and ammunition can be attached to small sensor devices to report their status. These reports are collected at central nodes and sent to commanders and managers in the military, and this information can also be sent to higher levels.

Monitoring the battlefield: Difficult terrain, roads, trails, and narrow places can be quickly covered by sensor networks and almost monitor the activities of the enemy. When these activities are expanded and new operation plans are prepared, a new network can be deployed at any time when monitoring the battlefield.

Monitoring terrain and enemy forces: Sensor networks can be deployed in key terrains and some important places. Sensor nodes need to quickly measure data and send it to the center.

Assessing the danger of the battlefield: Before and after the attack, sensor networks can be deployed in target areas to assess the danger of the battlefield and detect and explore chemical, biological, and nuclear attacks.

Fig.4. Some applications of wireless sensor networks based on the ZigBee standard

4. Conclusion

The paper has presented a design of a wireless sensor network based on the ZigBee standard to measure environmental parameters and create an automatic online monitoring mechanism for managers and users. This network model can produce products and applications for environmental monitoring. By using more diverse types of sensors, the model will aim to be applied in many fields, especially in the military, with sensors such as motion sensors, infrared sensors, toxic substance sensors, radiation sensors, etc. Based on each specific application with different environmental parameters and scales, we just need to add or change the appropriate sensors, and then the network model presented will still adapt well and operate normally, which shows the flexibility and elasticity of the model. The system built can be applied in reality and in the Academy of AD-AF, such as the environmental monitoring system in the library, warehouses of materials, technical equipment, weapons, infirmary, kitchen, etc.In addition, this model is also an open direction for learning, researching, and developing systems for students and lecturers in the academy in the fields of measurement, smart measurement, automation control, and IoT technology.

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