The Application of Zigbee Based Wireless Sensor Network and GIS in the Air Pollution Monitoring

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Abstract—**With the fast development of the industrialization and urbanization process in the world, the various issues of air pollution are appearing, and most of all are health-related issues. So the air pollution monitoring should be focused on by the human. The paper reviews the development of the technology of air pollution monitoring, point out the shortages of the current monitoring technology, and bring forward the advantage of the technology of the ZigBee based wireless sensor network in air pollution monitoring, discusses the GIS technology, focusing on the requirements of air pollution monitoring system. Finally, based on the above mentioned, the application schema of the ZigBee based WSN and GIS is designed and discussed in detail.**

Keywords-Air Pollution Monitoring; WSN; ZigBee; GIS

I. INTRODUCTION

Generally, the pollution has been defined as the presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects[3].In other words, pollution can causes instability, disorder, harm or discomfort to the physical systems or living organisms they are in[4].With the fast development of the industrialization and urbanization process in the world, environmental pollution problems become one of the common topics in all country of the world. At present, there are air pollution, water pollution and soil pollution in worldwide. This thesis only discusses air pollution. Air pollution is the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects[5].These pollutant substances usually result from vehicle emissions, Industrial emissions and volatile organic compounds. There are various issues of air pollution, and Most of all are health-related issues. In other words, clean air is a basic condition for health. The health issues caused by air pollutants may range from subtle biochemical and physiological changes to difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution[6]. Based the fact above mentioned, the human should focus on air pollution monitoring.

In the area, there are two methods to use to monitor air pollution at present. The one is passive sampling (non-automatic), and the other is continuous online monitoring (automatic). The advantage of the passive sampling method lies in that the monitor equipment is simple and inexpensive, but it can only get on-site monitoring parameters in a certain period, can not provide real-time values. Meanwhile, the results of monitoring effect by the man factor largely and it will seriously damage the health of the monitoring man in the site of high concentration of harmful substances. The procedure of continuous online monitoring method is as follows: use sensors to monitor the parameters, and then send to the control center by network. The way of data transfer include both wired and wireless. The wired way usually uses public telephone network, or fiber-optic to realize data transmission. Although this method is stable and reliable, with high speed of data transmission, but the shortcomings of the method is also obvious in a wide and dynamic range, such as complex network cabling, expensive, etc.

With the rapid development of communication technology, network technology and remote sensing technology, there is a trend that air pollution monitoring system is often designed in wireless mode. At present, the wireless mode in air pollution monitoring system includes GSM, GPRS, etc. But these modes are high cost in both installation and maintenance, and complexity. In the other hand, Wireless sensor network have been rapidly developed during recent years. Starting from military and industrial controls, its advantages include the liability, simplicity, and low cost[7]. Based on these advantages, it is now being applied in environmental monitoring. In air pollution monitor applications, Jong-Won Kwon et al. Designed an air pollution monitoring system using ZigBee networks for Ubiquitous-City. They focus on implementation of air pollution monitoring system, and developed an integrated wireless sensor board which employs dust, CO_2, temperature/humidity sensor and a ZigBee module[8]. In China, Zhang Qian et al. compared the advantages of ZigBee with other two similar wireless networking protocols, Wi-Fi and Bluetooth, and proposed a wireless solution for green-house monitoring and control system based on ZigBee

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technology[7]. Geng Jun-tao et al. introduced the application background and research actuality of wireless sensor network in atmosphere environment monitor, designed the node hardware structure, and discussed the architecture and the system software of the atmosphere environment monitor system[9].

Although some researchers have attempted to use wireless sensor network technology, such as ZigBee, to monitor the air pollution, its application in air pollution monitoring remain few. The paper reviews the development of the technology of the wireless sensor network and ZigBee, discusses the GIS technology, focusing on the requirements of air pollution monitoring system. Based on the above mentioned, the application schema of ZigBee based wireless sensor network and GIS is discussed.

II. WIRELESS SENSOR NETWORK

With the driving of the development of Micro-electronic technology, computing and wireless communications technology, a low-cost, low-power, multifunctional sensor is rapid developing. The function, such as information collection, data processing, wireless communications and others can be integrated to a small size chip. Wireless sensor network is designed to detect events or phenomena, collect and process data, and transmit sensed information to interested users. In other words, wireless sensor network is deployed in the monitor region with a large number of low-cost micro-sensor nodes, and these nodes formed a multi-hop and self-organizing network by wireless communications. The aim of wireless sensor network is perception and coordination, collection and processing of the object of the network coverage in the region and sending the information to observers. Sensors, sensing objects and observers constitute the three elements of the sensor network. Basic features of wireless sensor networks are[10-11]:

•Self-organizing capabilities;

•Short-range broadcast communication and multi-hop routing;

•Dense deployment and cooperative effort of sensor nodes;

•Frequently changing topology due to fading and node failures;

•Limitations in energy transmit power, memory, and computing power.

Wireless sensor network systems usually include sensor node, sink node and the management node. A large number of sensor nodes are deployed randomly in or near the internal sensor field, and can constitute a self-organizing network. Sensor nodes transmit the sensor data along the way of other nodes by single-hop, while the data may be dealt with other nodes. Then it reaches the sink node through multi-hop routing, and finally is transmitted to the management node via the internet or satellite. Users configure and manage sensor nodes on the network by the management node, as well as deploying monitoring task or collecting monitoring data.

Sensor node is usually a tiny embedded system, and its processing power, storage capacity and communications capability is relatively weak. Low power batteries supply its energy. Each sensor nodes act as the end-node and the router of traditional network. In addition to local information collection and data processing, Sensor node is also to fulfill the data storage, management and integration which are transmitted from other nodes. At the same time, collaboration with other node to complete specific tasks is necessary.

A basic sensor node comprises five main components [11-12](Figure 1):
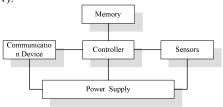

Figure 1. Sensor Node Hardare Component.

Controller: a controller to process data and execute arbitrary code.

Memory: to store programs and data.

Sensors: to observe or control relevant parameters of the environment.

Communication: a device for sending and receiving information over a wireless channel.

Power supply: some forms of batteries to provide energy.

Wireless sensor networks have broad prospects for application. It can be widely used in military, environmental monitoring and forecasting, health care, intelligent home, automatic control, urban transportation, space exploration, a large workshop and warehouse management, as well as airports, agriculture, etc. With the in-depth study and broadly application of sensor networks, it will gradually enter into all areas of human life.

III. ZIGBEE TECHNOLOGY AND GIS

A. ZigBee technology

ZigBee technology is a short distance, low-complexity, low-power, low-data rate and low-cost wireless communication technology. It mainly suit for automatic control and remote control. It can be embedded in a variety of devices, support geographic positioning features. In the other hand, ZigBee is a standard based on the IEEE 802.15.4 standard for wireless personal networks. The ZigBee wireless networking standard fits into a market that is simply not filled by other wireless technologies. In other words, ZigBee aims for low data rates, a tiny stack, controlling a light or sending temperature data to a thermostat, and providing decades or more of use in terms of other wireless network technology[13].

ZigBee is[13-14]:

• Low Data rate. ZigBee through-put is typically 25 kilobits per second. This feature suits to the application requirements of low-rate transmission of data.

• Cost-effective. ZigBee is pretty cheap. Firstly, the development cost of ZigBee is greatly reduced because of

547

low data rate, simple protocol. Secondly, the patent cost of ZigBee protocol is free.

• Low power. The devices in a ZigBee network can operate for years on a pair of AA batteries, which eliminates the trouble of frequent replacement of the battery.

• Short time delay. ZigBee response is fast. Generally, from the sleep state to wake up to the job state ZigBee node only required 15ms, to connect into the network ZigBee node only need 30ms, further saving energy.

• Highly secure. ZigBee has been very careful to ensure the security solution. ZigBee uses the National Institute of Standards and Technology Advanced Encryption Standard (AES) 128-bit security for encryption and authentication.

• An open global standard. ZigBee Alliance developed the ZigBee specification, a standards body with over 250 member companies from every continent in the world. In fact, a ZigBee network is expected to have products from many vendors that all interoperate.
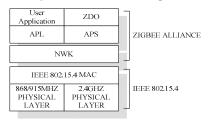

Figure 2.   Component Framework of ZigBee Protocol.

As Figure2 shows, ZigBee protocol designed the three-tier architecture that as same as the sever-tier of the computer network system. The two lowest layers, the MAC and PHY, are defined by the IEEE 802.15.4. They are determined by short-range, Low Rate Wireless Personal Area Network standard. The NWK layer is responsible for routing information discovery and maintenance, management. The top layer is the application layer; it is responsible for application meaning. It contains application support sub-layer (APS), ZigBee device object (ZDO) and user application.

In ZigBee based wireless sensor network, the location information is very important for the monitoring activity of the network. Based on some known location of nodes, ZigBee node can determine its own location according to some kind of positioning mechanism. This is very important for the monitoring application that it be able to report the incident location, to fulfill target tracking, to assist the routing and network management tasks.

ZigBee is beginning to be used in many, many applications. It could be used in lights and light switches, heating, ventilation, and air-conditioning, electrical, gas, and water metering, irrigation systems, industrial plants that monitor and control production, medical devices and environmental monitoring. In other words, the uses of ZigBee span too many markets to categorize them in a single paragraph.

B.   GIS And its Application in Air Pollution Monitoring

Geographic information is knowledge that generates through processing geographically referenced data. Geographic information systems (GIS) is concerned with the description, explanation, and prediction of patterns and processes at geographic scales[16]. The kernel functions of GIS are as follows:

• Geographical Data Collection. GIS can record object attribute measurements and geographical feature in some kind of geo-referenced frame.

• Geographical Data Management. Through the database technology, GIS can found geo-database, index and retrieve geographical feature class.

• Geographical Visualization. Geographic visualization is a powerful function of GIS for exploration, synthesis and presentation geographical data.

• Spatial Analysis. There are many analysis functions in GIS, such as overlay analysis, buffering, network analysis, and neighborhood analysis, spatial interpolating, etc.

In air pollution monitoring, GIS is used to manage data of monitoring field and site, such as attribute (monitoring parameter) data and geographical data (monitoring site location); to analyze and simulate spatial-temporal distribution of air pollution condition coupled with air pollution model; to visualize the result of analysis and monitoring. Because ZigBee based wireless sensor network can locate the location of the nodes, GIS is also used to manipulate these nodes that have geographical information.

IV.   APPLICATION SCHEMA OF ZIGBEE BASED WSN AND GIS IN THE AIR POLLUTION MONITORING

A.   The Requirements of Air Pollution Monitoring

Continuous and real-time monitoring. It is necessary to carry out monitoring in 24 hours of a day. In other words, the user is able to view the job status of monitoring nodes, read data at any time. On the basis of this, user analyzes the monitor data; evaluate air quality and pollution condition in the monitoring field by relevant evaluation model of air pollution coupled with GIS technology.

Multi-parameters monitoring. There are multiple sensor in a monitoring node in order to get multi-parameters of air quality and pollution in the same time. Meanwhile, it is necessary that these sensors can coordinate in some way.

Maintain easily. This feature require that the monitoring nodes easy to deploy, and can constitute a dynamic self-organizing network automatically without manual operation. In the other hand, these nodes must be low-power requirements because of continuous and unattended monitoring.

B.   Application Schema of ZigBee Based WSN and GIS in the Air Pollution Monitoring

Based on the requirements above mentioned, the concept schema of ZigBee based wireless sensor network and GIS in the air pollution monitoring is designed as follows (Figure3).

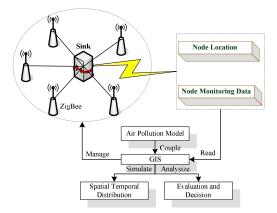Figure 3.   Application Schema of ZigBee Based Wireless Sensor
Network and GIS in the Air Pollution Monitoring.

As can be seen from Figure3, the schema is a wireless sensor network based ZigBee. ZigBee based wireless sensor nodes are spread in the area of air pollution monitoring, and these nodes constitute wireless network through the way of self-organizing. Sensor node will send monitoring data to the sink node through the ZigBee module. The sink node is not only integrated ZigBee wireless modules, but also integrated computer network protocol, which enables sink node can send data to the computer network. Besides to sending the monitoring data, the sensor nodes also send the location of each monitoring node. These data is read by the GIS. Based on these monitoring data and the node location data, coupled with related air pollution model, GIS can implement spatial analysis, simulate temporal and spatial distribution of air pollution monitoring area, and then to carry out air quality assessment and decision support. In addition, because GIS has unique advantages for the management of the location information, it can manage and maintain each node of wireless sensor networks based on the spatial location. The application schema, fully meets the requirements of air pollution monitoring, and integrate GIS technologies, is valuable and adaptable for application in practice.

V.   CONCLUSION

The main purpose of this study is that to introduce a new method for air pollution monitoring. In the first place, the development of air pollution monitoring is reviewed; and wireless sensor network and ZigBee technology are discussed. In the second place, because of the advantages of GIS, GIS technology and its application in air pollution monitoring is also probed. On the basis of these technology and analysis of requirements of air pollution monitoring, the application schema of wireless sensor network based ZigBee

and GIS is designed and discussed. This study was very small; it is a schema only, and not possible to cover any problem about the area of air pollution monitoring. Larger experiments are necessary in order to test and verify the schema. The work will be completed by the further research.

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