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IAQ MONITORING SYSTEM USING ZIGBEE NETWORK

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ABSTRACT

Indoor air quality refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. Wireless sensor networks are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. In this paper, an indoor air quality monitoring system using a ZigBee network is studied.

Keywords: *indoor air quality, wireless sensor network, ZigBee, LAN communication*

I. INTRODUCTION

Indoor air quality (IAQ) is a term which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants [1]. IAQ can be affected by gases (including carbon monoxide, radon, volatile organic compounds), particulates, microbial contaminants (mold, bacteria), or any mass or energy stressor that can induce adverse health conditions. Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings. Residential units can further improve indoor air quality by routine cleaning of carpets and area rugs. Determination of IAQ involves the collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces, and computer modeling of air flow inside buildings. IAQ is part of indoor environmental quality (IEQ), which includes IAQ as well as other physical and psychological aspects of life indoors (e.g., lighting, visual quality, acoustics, and thermal comfort). Indoor air pollution in developing nations is a major health hazard. A major source of indoor air pollution in developing countries is the burning of biomass (e.g. wood, charcoal, dung, or crop residue) for heating and cooking. The resulting exposure to high levels of particulate matter resulted in between 1.5 million and 2 million deaths in 2000.

Wireless sensor networks (WSN), sometimes called wireless sensor and actuator networks (WSAN), are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location [2]. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

In this paper, an indoor air quality monitoring system using a ZigBee network is studied, which is illustrated in Fig. 1.

Figure:

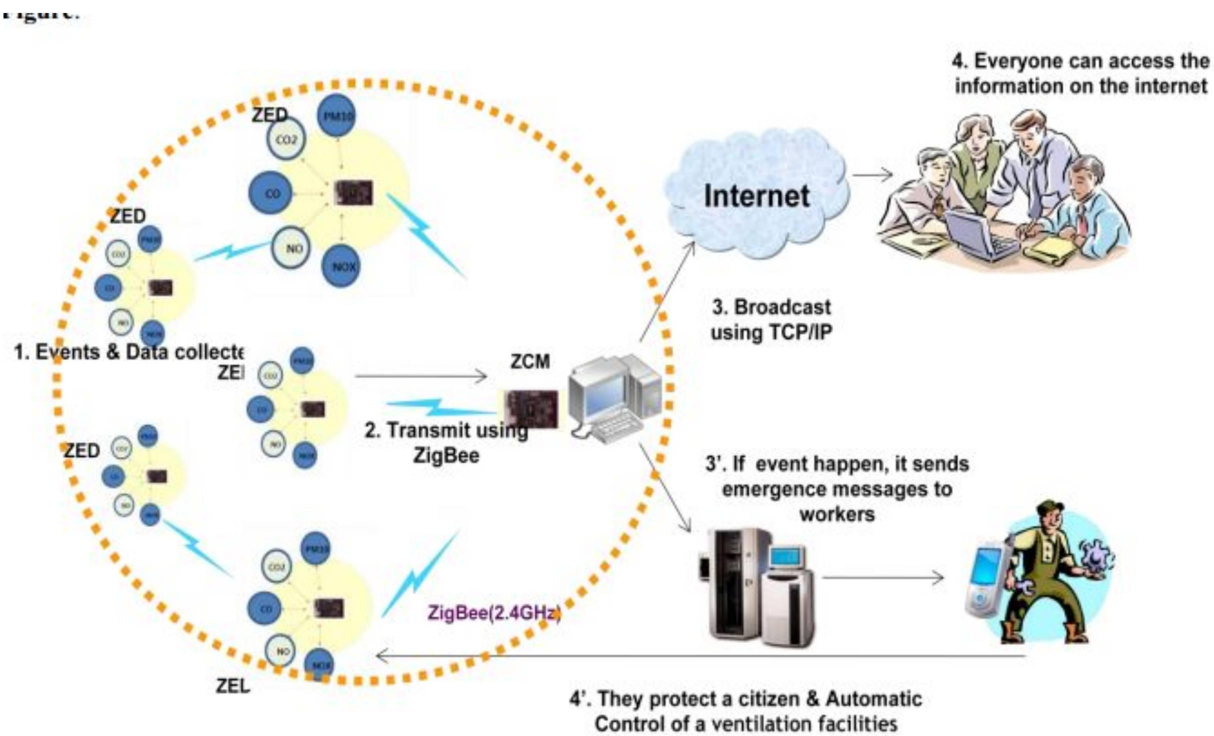

Figure 1. Schematic diagram of an IAQ monitoring system using a ZigBee network

II. ZIGBEE WIRELESS COMMUNICATION

2.1 ZigBee network

ZigBee is a low-cost, low-power, wireless mesh network standard targeted at the wide development of long battery life devices in wireless control and monitoring applications. Zigbee devices have low latency, which further reduces average current. ZigBee chips are typically integrated with radios and with microcontrollers that have between 60-256 KB of flash memory. ZigBee operates in the industrial, scientific and medical (ISM) radio bands: 2.4 GHz in most jurisdictions worldwide; 784 MHz in China, 868 MHz in Europe and 915 MHz in the USA and Australia. Data rates vary from 20 kbit/s (868 MHz band) to 250 kbit/s (2.4 GHz band). The ZigBee network layer natively supports both star and tree networks, and generic mesh networking. Every network must have one coordinator device, tasked with its creation, the control of its parameters and basic maintenance. Within star networks, the coordinator must be the central node. Both trees and meshes allow the use of ZigBee routers to extend communication at the network level. ZigBee builds on the physical layer and media access control defined in IEEE standard 802.15.4 for low-rate WPANs. The specification includes four additional key components: network layer, application layer, *ZigBee device objects* (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration. ZDOs are responsible for some tasks, including keeping track of device roles, managing requests to join a network, as well as device discovery and security. ZigBee is one of the global standards of communication protocol formulated by the significant task force under the IEEE 802.15 working group. The fourth in the series, WPAN Low Rate/ZigBee is the newest and provides specifications for devices that have low data rates, consume very low power and are thus characterized by long battery life. Other standards like Bluetooth and IrDA address high data rate applications such as voice, video and LAN communications.

ZigBee supports several network topologies; however, the most commonly used configurations are star, mesh and cluster tree topologies as shown in Fig. 2 [3]. Any topology consists of one or more coordinator. In a star topology,

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the network consists of one coordinator which is responsible for initiating and managing the devices over the network. All other devices are called end devices that directly communicate with coordinator. This is used in industries where all the end point devices are needed to communicate with the central controller, and this topology is simple and easy to deploy. In mesh and tree topologies, the ZigBee network is extended with several routers where coordinator is responsible for staring them. These structures allow any device to communicate with any other adjacent node for providing redundancy to the data. If any node fails, the information is routed automatically to other device by these topologies. As the redundancy is the main factor in industries, hence mesh topology is mostly used. In a cluster-tree network, each cluster consists of a coordinator with leaf nodes, and these coordinators are connected to parent coordinator which initiates the entire network. Due to the advantages of ZigBee technology like low cost and low power operating modes and its topologies, this short range communication technology is best suited for several applications compared to other proprietary communications, such as Bluetooth, Wi-Fi, etc.

Figure:

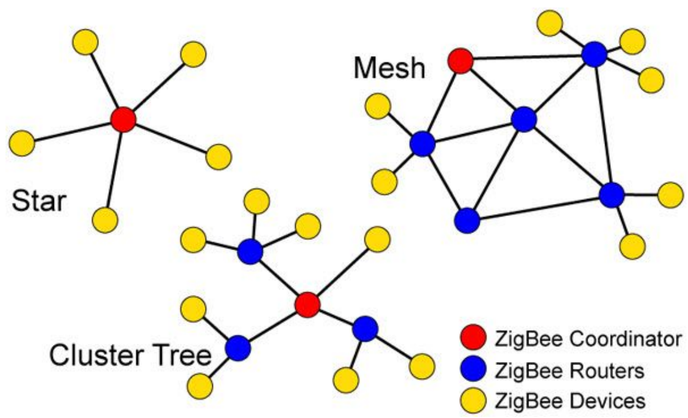

Figure 2. ZigBee topologies

Figure:

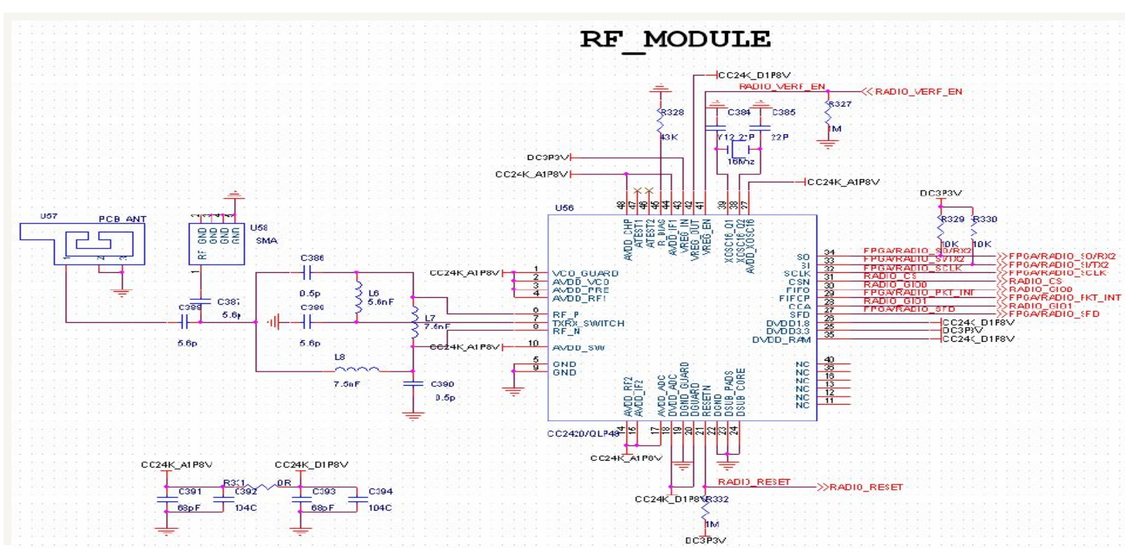

Figure 3. Circuit diagram of RF part

2.2 Implementation of ZigBee module

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Digi XBee and Digi XBee-PRO ZigBee RF modules provide cost effective wireless connectivity to electronic devices [3]. They are interoperable with other ZigBee PRO feature set devices, including devices from other vendors. Digi ZigBee Development Kits are the perfect way to begin ZigBee application development. Digi XBee and Digi XBee-PRO ZigBee modules are ideal for applications in the energy and controls markets where manufacturing efficiencies are critical. The Serial Peripheral Interface (SPI) provides a high-speed interface and optimizes integration with embedded microcontrollers, lowering development costs and reducing time to market. Products in the Digi XBee family require little to no configuration or additional development. Programmable versions of the Digi XBee and Digi XBee-PRO ZigBee module make customizing applications easy. Programming directly on the module eliminates the need for a separate processor. Because the wireless software is isolated, applications can be developed with no risk to RF performance or security. Digi's ZigBee compatible module is based on the Ember EM35x (EM357 and EM3587) system on chip (SoC) radio ICs from SiliconLabs, utilizing 32-bit ARM CortexTM M3 processor. The S2D EM3587 version has a larger memory footprint for customers who may want to upgrade to Thread, an IPv6 based networking stack. Fig. 3 shows the circuit diagram of RF part. Fig. 4 shows ZCM(ZigBee coordinator modem) and ZED(ZigBee end device) developed for ZigBee network. Fig. 5 shows an implemented ZigBee module.

Figure:

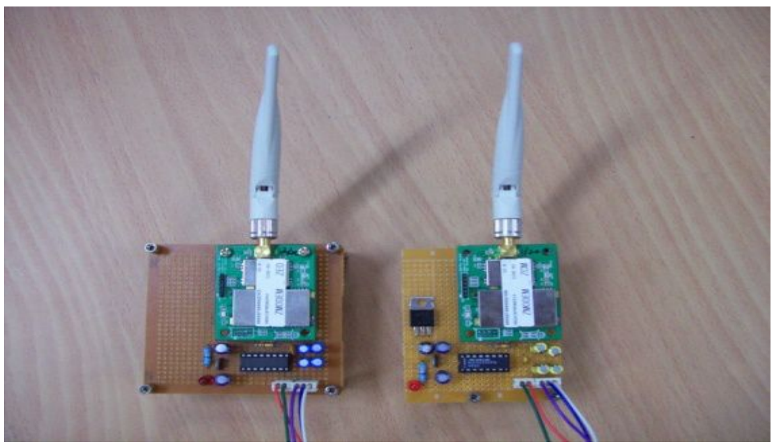

Figure 4. left : ZCM(ZigBee coordinator modem) , right : ZED(ZigBee end device)

Figure:

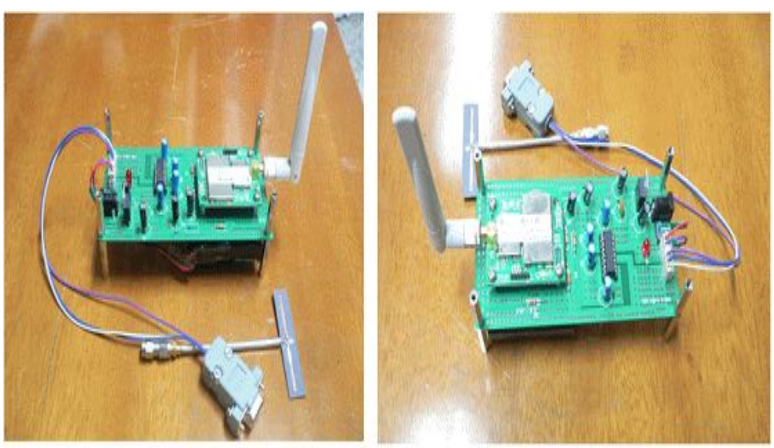

Figure 5. Implemented ZigBee module

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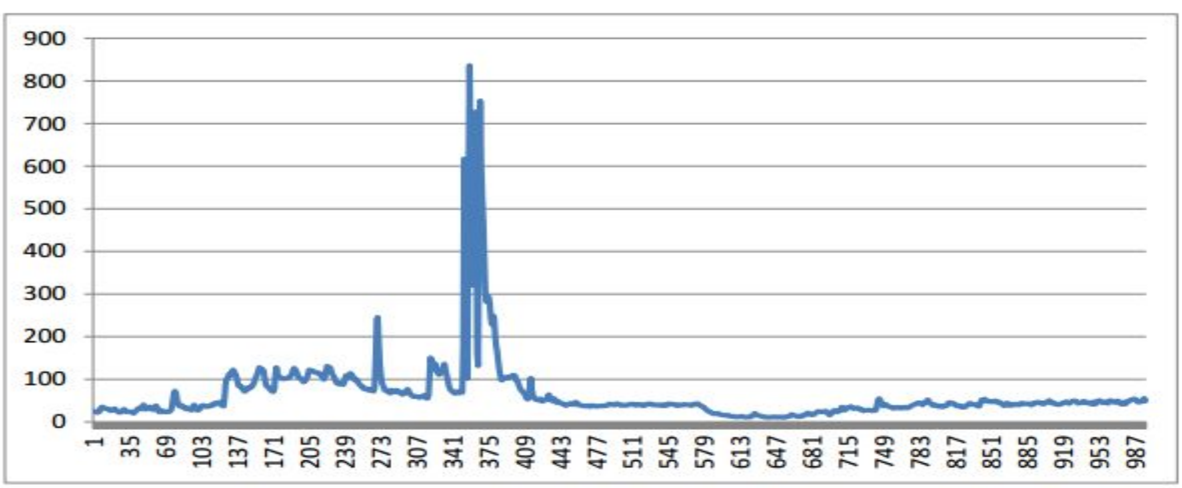
III. EXPERIMENTAL RESULTS FOR IAQ MONITORING SYSTEM

Fig. 6 shows the screen shot of an IAQ monitoring system [4, 5]. There are "topology of ZigBee network", "graph di splay", "sensor node number", "data tables", "connct configuration", and "received data" on the screen monitor. Fig. 7 shows the PM_{10} concentration in a waiting room of a subway station which was monitored for 1000 minutes. Fig. 8 shows the CO_2 concentration in a waiting room of a subway station.

Figure:

Figure 6. Screen shot of an IAQ monitoring system

Figure:



(x-axis : minute, y-axis : ug/m³)

Figure 7. PM_{10} concentration in a waiting room of a subway station

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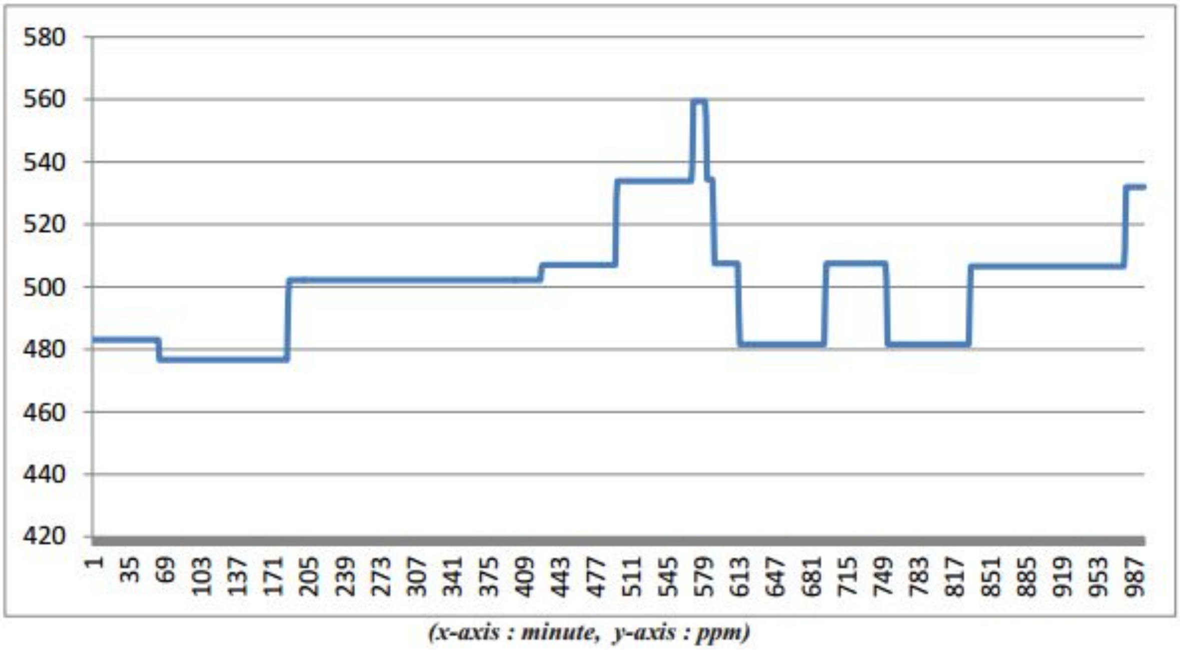
Figure:



(x-axis : minute, y-axis : ppm)

Figure 8. CO_2 concentration in a waiting room of a subway station

IV. CONCLUSION

The area of sensor network has a long history and many kind of sensor devices are used in various real life applications. Here, we introduced a wireless sensor network system based on ZigBee modules and an IAQ monitoring system. As an example, we monitored the PM_{10} concentration and the CO_2 concentration in a waiting room of a subway station 1000 minutes. Through these experimental studies, we believe that the implemented ZigBee-based IAQ monitoring system would be helpful in protecting many people from the dangers associated with indoor pollutants exposure.

V. ACKNOWLEDGEMENTS

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