# REAL TIME INDOOR $CO_2$ MONITORING AND CONTROL SYSTEM USING WIRELESS SENSOR NETWORKS

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*Abstract*

***Indoor Air Quality has become an important human health and safety concern, clean air is essential for good health and this is especially true when it comes to indoor air. The world atmosphere carbon dioxide level is increased. However, many work environments lack proper detection mechanisms to identify health risks for occupants. Wireless sensor networks have the potential to alleviate this problem. This project proposes a real-time indoor $CO_2$ monitoring and control system using wireless sensor network system. The system aims to monitor and detect the concentration of carbon dioxide in a real-time basis using wireless sensor nodes. If the monitored $CO_2$ level is more than the predefined threshold level, the proposed system automatically opens the window. If the monitored value below the threshold, the system automatically closes the window. Moreover, the system coexists with minimum interference with other systems in the monitoring area.***

***Key Terms –*** ***wireless sensor networks, carbon dioxide monitoring, indoor air quality monitoring, real- time monitoring.***

## I. INTRODUCTION

### HEALTH PROFILE

Health is the level of functional and metabolic efficiency of a living organism. In humans it is the ability of individuals or communities to adapt and self-manage when facing physical mental or social changes. The World Health Organization (WHO) defined health in its broader sense constitution as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity”. Classification systems such as the WHO Family of International Classifications including the International Classification of Functioning Disability and Health (ICF) and the International Classification of Diseases (ICD), are commonly used to define and measure the human health.

## 1 ROLE OF WIRELESS SENSOR NETWORK

A Wireless Sensor Network (WSN) is by hundreds of small, low-cost nodes that are fitted with limitations in memory ,energy, and processing capacity. In this particular form of networks, several problems persist and one such is to learn each node. Recent advances in wireless communications and electronics have enabled the roll-out of low-cost, low-power and multi-functional sensors that are small in dimensions and communicate in a nutshell distances. Cheap, smart sensors, networked through wireless links and deployed in vast quantities provide unprecedented opportunities for monitoring and controlling homes, cities, along with the environment.

Moreover location estimation may enable many applications for example inventory management, transport, intrusion detection, road traffic monitoring, health monitoring, reconnaissance and surveillance. With all the advances inside the integration of sensing and communication Technologies, large-scale wireless sensor networks using a large number of low-cost and low-power sensors are already developed. Within a wireless sensor network lots of money of tiny battery-powered sensor nodes are scattered throughout a physical area. Each sensor in the sensor network collects data, such as sensing vibration, temperature radiation along with other environmental factors.

A wireless sensor network (WSN) includes hundreds to a large number of low-power multi-functional sensor nodes and having sensing, computation and communication capabilities. The essential the part of a node undoubtedly are a sensor unit, an ADC (Analog to Digital Converter), a CPU, an electrical unit as well as a communication unit. Sensor nodes are microelectro-mechanical systems (MEMS) that develop a measurable reaction to a general change in some fitness like temperature and pressure. Sensor nodes sense or measure physical data in the area being monitored. The continual analog signal sensed through the sensors is digitized by an analog-to-digital converter and sent to controllers for more processing. Sensor nodes are of small size, consume extremely low energy are operated in high volumetric densities and will be autonomous and adaptive towards the environment.

## 2 APPLICATION OF WIRELESS SENSOR NETWORK

The applications for WSNs involve tracking monitoring and controlling. WSNs are mainly utilized for health monitoring, object tracking, nuclear reactor control, fire detection, and traffic monitoring.

Healthcare monitoring: The medical applications might be of two sorts: wearable and implanted. Wearable devices are applied to the body surface of the human or maybe at close proximity from the user. The implantable medical devices are the ones that are inserted inside human body.

Environment monitoring: Wireless sensor networks have been deployed in lots of cities to monitor the p ower of dangerous gases for citizens.

Forest fire detection: A network of Sensor Nodes is usually positioned in a forest to detect every time a fire has begun. The nodes is usually with sensors to measure temperature, humidity and gases which are produced by fire within the trees or vegetation.

Water quality monitoring: Water quality monitoring involves analyzing water properties in dams, rivers, lakes & oceans, and also underground water reserves.

Natural disaster prevention: Wireless sensor networks can effectively act to avoid the results of disasters, like floods .Wireless nodes have successfully been deployed in rivers where changes in the water levels have to be monitored in real time.

Industrial monitoring: Wireless sensor networks happen to be developed for machinery condition based maintenance (CBM) as they offer significant personal savings and enable new functionality.

## 3 ROLE OF INDOOR AIR QUALITY

The number of measurements in indoor atmospheric environment is increasing due to growing number of complaints about the indoor air quality (IAQ). Indoor air quality (IAQ) refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health and performance of occupants. The growing proliferation of chemical pollutants in consumer and commercial products, the tendency toward tighter building envelopes and reduced ventilation to save energy, and pressures to defer maintenance and other building services to reduce costs have fostered IAQ problems in most of the buildings.

It has become one of the most important issues of environment and health worldwide considering the principle of human rights to health that everyone has the right to breathe healthy indoor air. If the sampling is planned for a specific environments the locations are preferred inside these environments.

The rest of the thesis is organized as follows, Chapter 2 summarizes some of the related works of carbon dioxide monitoring and control system for the primary issues. Chapter 3 introduce an overview of the proposed system, its characteristics and its advantages over other systems. Chapter 4 explains the implementation and result. Chapter 5 concludes proposed works.

## II. RELATED WORK

S. D. T. Kelly et al.[1] This paper presents effective low-cost and flexible solution for condition monitoring and energy management in home. The basic operations include remote management and control of domestic devices such as electric lamp, water heater etc., monitoring of domestic utilizations and providing ambient intelligence to reduce the energy consumption through IoT technology are the key functions of the developed system. This will support and reschedule the inhabitant operating time according to the energy demand and supply.

The novelty of the system is the internetworking mechanisms, which are practicable to integrate with modules like intelligent home monitoring systems for wellness determination of inhabitants. This also not using for commercial network application.

Hamilton et al.[3] A system with aggressive energy management at the sensor level, node level, and network level is presented. The node is designed with very low sleep current consumption and it contains a metal oxide semiconductor gas sensor and a pyroelectric infrared (PIR) sensor. The contribution to energy consumption reduction to ensure several years long battery lifetime is at three levels:

1) Sensor level : a)Pulse mode operation for measuring gas concentration from the MOX gas sensor b) Early detection of safe concentration conditions.

2) Node level we achieve low power consumption by managing the sleep state and the duty-cycled activity of the node based on the detection of people presence in the ambient.

3) Network level we enhance the power saving of each single node and we increment the lifetime of the whole network by exploiting the information received from the neighbour nodes.

H. Liu, B. Zhang et al.[4] Opportunistic routing with cognitive networking can alleviate the problem. In opportunistic routing the path towards the destination changes dynamically following certain next relay node selection criterion. The selection criterion is crucial in every opportunistic routing protocol and it has high effect on the network performance. The distance from the destination is the node or the link availability are some of the common selection criterion while location information probabilistic forwarding and coding strategies always affect the performance of any opportunistic protocol. Another promising solution is the use of Cognitive Radio (CR) technology along with the wireless sensor nodes. It is possible to apply Dynamic Spectrum Access (DSA) models in WSNs to provide them with access to less congested spectrum. In general, a Cognitive Radio Sensor Network (CRSN) can be defined as a distributed network of wireless cognitive radio sensor nodes, which sense event signals and collaboratively communicate their readings dynamically over available spectrum bands in a multihop manner to ultimately satisfy the application-specific requirements.

The efficiency of an opportunistic routing protocol with cognitive wireless sensor nodes under a CRSN. Cognitive Networking with Opportunistic Routing (CNOR) is presented in further details. The system model and the routing principles such as the neighbour discovery process the packet transmission process and the route maintenance are also described

P. Spachos and D. Hantzinakos et al.[5] The aim is to resolve the conflict between the static status of sensor deployment and the dynamic nature of mission requirements. As mission dynamically changes the lifetime and coverage requirement may not be satisfied at the same time. Then the coverage needs to be traded for the network lifetime we define a new spatial-temporal coverage metric in contrast to the traditional area coverage. The spatial-temporal coverage of each small area is defined as the product of the area size and the length of the period during which the area is covered. NP-hard and Greedy algorithm this problem solved

D.S. Ghataoura et al.[6] Electrostatic precipitators (esps) of various designs are used to remove particulate matter (pm) from gases. Esps for indoor air treatment must have high efficiencies. Esps are classified based on the types of electrodes involved . Two types of esp reactor were designed

A needle-type electrode was also used to shorten the gap Which also decreased the discharge voltage. The sharp tip also Contributed to decreasing the discharge voltage Particle-collecting experiments were performed without a Mesh filter and with one to three mesh filters.

## II. PROPOSED SYSTEM

### INTRODUCTION

Indoor Air Quality (IAQ) refers to the quality of the air within and around buildings and structures. It is an issue of great importance since it relates directly to the health and comfort of building occupants. Common issues associated with IAQ include improper or inadequately maintained heating and ventilation systems as well as contamination by construction materials (glues, fibreglass, particle boards, paints, etc.) and other chemicals. Moreover, the increase in the number of building occupants and the time spent indoors directly impact the IAQ. Air quality can be expressed by the concentration of several pollutants such as carbon monoxide ($CO$), carbon dioxide ($CO_2$), tobacco smoke, perfume, sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), and ozone ($O_3$). Some of these pollutants can be created by indoor activities such as smoking and cooking. IAQ problems are more prevalent in indoor infrastructures such as houses, offices and schools. Consequently, the development of an accurate system for IAQ monitoring is of great interest and control system.

### A. COLLECTION OF REQUIREMENTS

The selection of the application can simplify the system design and optimization but also imposes a number of requirements. The first requirement involves the selection of the sensor type. Metal Oxide Semiconductor (MOS) is fast response times and low cost along with a long lifetime. However, they have high power consumption and low sensitivity while they are sensitive to environmental changes. The second requirement is the selection of the number of

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sensors. The number is related to sensor reliability coverage area and cost. In general as the number of sensors increase the system accuracy increases as well. The third requirement is real-time data aggregation. The packets related to the $CO2$ concentration should be delivered to the control room on time with a minimum delay. The forth requirement is the energy consumption of the sensor units.

**B. WIRELESS MONITORING MODE**

Carbon dioxide sensors are combined with radio modules to form wireless monitoring nodes. The data from the sensor are passed to the radio, formed into packets and transmitted toward the control room. Each sensor node monitors the area around it continuously.

**SENSOR UNIT**

Figure.1 shows in the IAQ2000 gas sensor for $CO2$ detection, indoor air quality sensor modules from Applied Sensor are used. IAQ-2000 sensor can measure $CO2$ levels. It is a sensitive low-cost solution for detecting poor air quality in an indoor environment. The module uses micro-machined MOS gas sensor components to detect gases such as $CO$, $CH4$ and $LPG$. A change of resistance in the presence of these gases generates a signal that is translated into parts per million (*ppm*) $CO2$ equivalent units. Also a threshold can be defined to alert that the climate has changed when the limits are exceeded or to decrease ventilation on minimum VOC levels. It is important to mention that the $CO2$ levels can be affected from changes in the temperature and humidity of the room. The sensor unit monitors $CO2$ concentration in *ppm* in the environment continuously. All the data from the sensor unit are passed to the radio module for initial processing, packet forming and transmission.

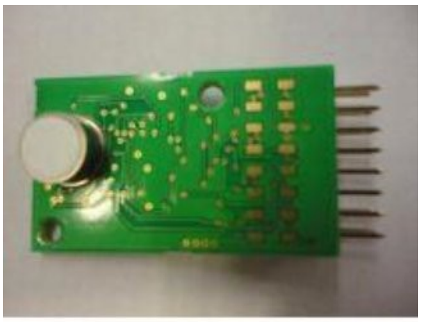

Figure1 Iaq 2000 gas sensor

**C. RELAY NODE**

A wireless ad hoc network system is composed from easy-to-use devices. The relay nodes forward any received packet toward the control room. The protocol supports transmission of real-time sensed data from various sources. The number of the devices vary over time and nodes – either monitoring or relay – can join or leave the network any time.

**RADIO MODULE.**

Figure 2.The main module of the system. It has a microcontroller for programming and two antennas for transmission. The functions necessary to achieve this can be divided into two distinct levels namely the communication and application levels.

At the communication level, the radios have been implemented using a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) method. First the transmitter waits to assemble the packet. When the packet is ready it checks if any of the three channels is idle and available for immediate transmission

At the application level there is a unicast transmission that transmits any data received from the Universal Asynchronous Receiver/Transmitter (UART) to the radio. In unicast mode radios only establish point to point transmission where the transmitter sends the data to the destination.

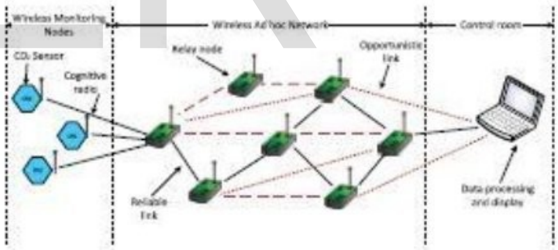


Figure2. Frame work diagram

**D. OPM 15 RELAY NODE**

A radio module that receives and forwards packets is the relay node of our system. A RapidMesh OPM15 board is used as the radio module. The radio is based on the IEEE 802.15.4 standard to realize Opportunistic Mesh (OPM) dynamic networking with multi-frequency. The frequency range is 2.405− 2.483 *GHz*. OPM 15 has a microchip PIC18F26K22 programmable microcontroller. The relay nodes are powered with three AAbatteries, each being 1.5V. The integration of the sensor unit with the radio module builds the monitoring node.

The monitoring node uses one 9V battery as the power source and hence there is a 5V voltage regulator to reduce the voltage before supplying the RapidMesh board and the iAQ-2000 sensor. Next the output of the sensor is connected to the input of the RapidMesh board via a resistor voltage divider. The divider is used to reduce the 5V output of the sensor to 3.3V for the RapidMesh board.

### E.CONTROL ROOM

The data aggregation and network maintenance takes place at the control system. Also, useful network information are collected and used for better network maintenance. It is a simple radio module attached to a computer. The data processing and storage takes place at the control room. All the data packet from the sensor units are forwarded toward the destination node at the control room. one simple transmission(radio) module is connected to a computer. This module decodes the packets and extracts all the useful information. The collected data is also stored in files. If the collected $CO2$ concentration exceeds a user-defined threshold, the application notifies the system administrator. The application can support large scale networks with simultaneous packet decoding from multiple sensors. The following diagram for sensing and monitoring $co_2$ control system.

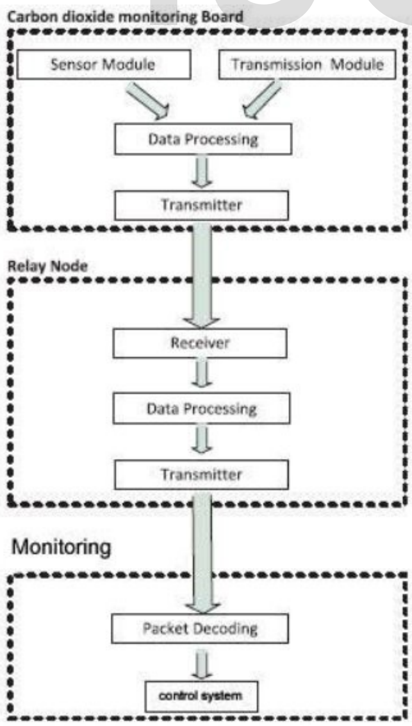


Figure3.Contol flow diagram

## IV.IMPLEMENTATION

### A. ARDUINO UNO

Arduino is an open source physical computing platform based on a simple input/output (I/O) board and a development environment that implements the Processing language. Arduino can be used to develop standalone interactive objects or can be connected to software on your computer. The boards can be assembled by hand or purchased preassembled; the open source IDE (Integrated Development Environment) can be downloaded for free from www.arduino.cc.

The board can operate on an external supply of 6 to 20 volts. If supplied voltage is with less than 7V however the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The ATmega328 has 32 KB . It also has 2 KB of SRAM and 1 KB of EEPROM . The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX).

### B. GAS SENSOR MQ2

Sensitive material of MQ-2 gas sensor is SnO2, which is with lower conductivity in clean air. When the target combustible gas exists, the sensor's conductivity is more; higher along with the gas concentration rising. Convert change of conductivity to correspond to output signal of gas concentration. MQ-2 gas sensor has high sensitivity to LPG, Propane and Hydrogen also could be used to Methane and other combustible steam, it is with low cost and suitable for different application. In order to make the sensor with better performance for MQ2 sensor.

**Features**

Good sensitivity to Combustible gas in wide range
High sensitivity to LPG Propane and
Hydrogen Long life and low cost
**Applications**
Domestic gas leakage detector
Industrial Combustible gas detector
Portable gas detector

### C. PROCESS AND MONITORING

Below screenshot shows the $co_2$ sensor program. This program senses carbon dioxide and Carbon monoxide in atmosphere air. Integrated Development Environment has user interface programming language.

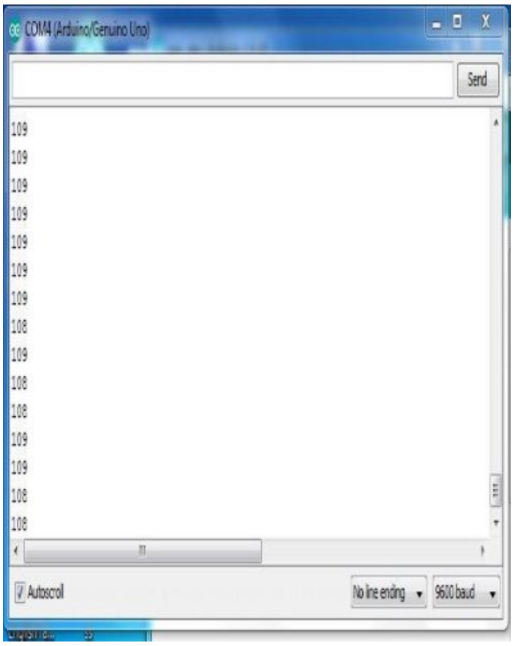


Figure4 sample output for $co_2$ initial level

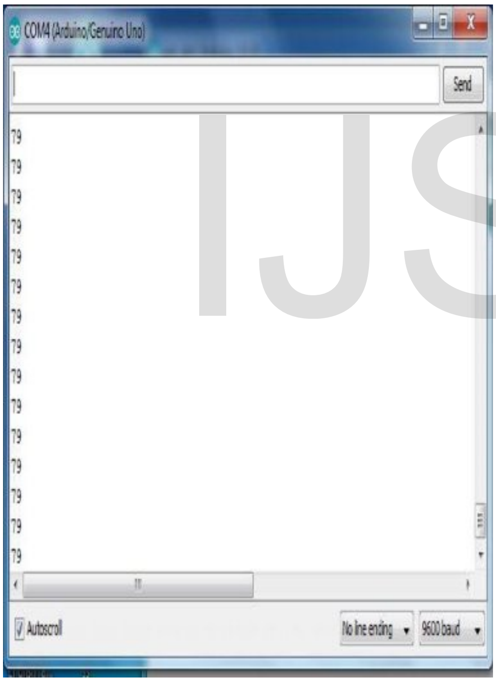


Figure5. sample output for $co_2$ normal level

The above screenshot show the output of initial and normal conditions.

## V. CONCLUSION

A real-time indoor $CO_2$ monitoring and control system using wireless sensor network system. The system aims to monitor and detect the concentration of carbon dioxide in a real-time basis using wireless sensor nodes. If the monitored $CO_2$ level is more than the predefined threshold level, the proposed system automatically opens the window. If the monitored value below the threshold, the system automatically closes the window. Moreover, the system coexists with minimum interference with other systems in the monitoring area.

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