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Design of Indoor Wireless Sensor Network for Air Quality Monitoring

[1]Rishabh Rastogi, [2]Harsh Ranjan, [3]Jayavignesh T
[1,2] Student, School of Electrical Engineering, Vellore Institute of Technology, Chennai, India
[3]Assistant Professor, School of Electrical Engineering, Vellore Institute of Technology, Chennai, India

Abstract—Indoor air pollution has become a serious issue affecting public health. An increasing amount of air pollution as resulted in the adverse living condition in our homes. An indoor monitoring system helps to monitor the atmosphere condition over a period and subsequently sends a report of the conditions to the user at regular interval of time. In this paper, we have designed a wireless sensor network for AQM to keep the user informed about the air quality. The system consists of micro sensors, XBee radios, MSP430 and BeagleBone Black. Two gas sensors have been used along with MSP430 to report air quality in form of concentration of the gas to a gateway which then gives a summarized report to the user periodically. We have performed node level aggregation of the sensor value in order avoid a redundant number of transmission thereby reducing the energy consumption.

***Index Terms—BeagleBone Black; MQ135; MQ7; MSP430; node level* aggregation**

I. Introduction

Indoor air pollution has been consistently ranked by the US Environmental Protection Agency (EPA) and its Science Advisory Board to be among the top five environmental public health risks [1]. A bad indoor air quality can result in serious health related issues like nausea, fatigue respiratory diseases as well as concentration problems. EPA studies discovered indoor air contaminations were for the most part 2 to 5 times more prominent than outside contamination levels. In some cases, indoor air pollution was 100x greater. An average person spends almost 20 hours per day inside a building which may be his/her school, home, office, industry or shop. Therefore, good indoor air quality is as important as controlling outdoor pollution.

The degradation of air quality cannot be easily figured out as the system designed cannot be operated by the general population and its cost makes it unreachable to an average user. Secondly, the minute changes in air quality cannot be felt by human but exposure to even such minute change for a longer period can result in severe diseases. A recent study shows that realizing the current level of indoor air quality motivates people to alter their behavior and perform activities to improve air quality [2]. Use of chemical household cleaning products like room fresheners may instead degrade indoor air quality. Therefore, there is an imminent need for a widely-accessible IAQ monitoring system that can provide an intuitive sense of air quality conditions in indoor environments.

Two of the major gas that severely adds to the decrease in indoor air quality are Carbon Monoxide and Carbon Dioxide. According to the American Conference of Governmental Industrial Hygienists (ACGIH), the time-weighted average (TWA) limit for carbon monoxide (630-08-0) is 25 ppm [3]. The National Institute for Occupational Safety and Health

(NIOSH) considers that indoor air concentrations of carbon dioxide that exceed 1,000 ppm are a marker suggesting inadequate ventilation.

In this paper, we present an energy efficient low-cost wireless IAQ sensor network system developed using MSP430, XBee modules, micro gas sensors and BeagleBone Black. The system can collect CO and CO_2 concentration as air quality parameters from different locations simultaneously. Also, a database is maintained of the gas concentration in cloud server which is sent to the user at regular interval of time in form of a text file.

II. METHODOLOGY

The paper aims at collecting the gas concentration of Carbon Monoxide (CO) and Carbon Dioxide (CO2) inside two different room using MQ7 and MQ135 gas sensor for respective purpose in ppm. Two different nodes are exhibited in two different rooms, both connected to a gateway node in a star topology fashion. The two sensor node share data and information with the gateway node using person area network created by XBee which works on the ZigBee protocol. ZigBee is a low-cost, low-power, wireless mesh networking standard built upon 802.15.4 [4]. The IEEE 802.15.4 standard specifies the physical and medium access control layers for low data-rate wireless personal area networks [5]. The Gateway node is equipped with a BeagleBone Black which act as a central controller. The gateway node uploads the gas concentration values to the cloud server, where the database is maintained. The user is sent a summarized data every month in a text file. For making the system energy efficient and to reduce communication cost special measures has been taken. Sensor nodes are equipped with Texas Instruments' ultra-low power mode microcontroller – MSP430. Also, XBee radio modules have been used for data transfer which is again a low-power digital radio. Also, instead of transmitting raw sensor values from sensor nodes to the gateway, aggregation of raw data is performed and then the values are transmitted which limits the energy consumption andenhances the battery life. In addition to this, sleep modes of XBee's are exploited and while they are not transmitting the data they are put to sleep to minimize the power loss. Since inside a room, air quality does not change rapidly and dynamically hence the sensor nodes do not need to sense the level of gases every second. Till the time sensors are not sensing the gas concentration, microcontroller, is made to enter the low power mode. This gives an extremely low current drain when the processor is in standby mode. Similarly, while the sensor senses the data, and there is nothing to transmit the XBees are put to sleep, and after a periodic interval, XBees polls the sensor and take the data (gas concentration value) and transmits to the gateway node. The XBee radio at the gateway node works in the synchronization with the sensor node to receive the data correctly. While the XBees are communicating and transmitting the data microcontroller prepares new readings to be sent by XBee by using data aggregation algorithm. The gas concentration values are put away in a buffer over a timeframe and their mean esteem is taken to diminish the mass data and after that, a single frame is transmitted which contains the mean value of the concentration of gases over a timeframe. This spares a great deal of energy since XBees does not have to transmit the bulk information. At the gateway node, when data is received from both the sensor nodes, it is uploaded to the cloud database and after every month the summarized data is sent to the user in a text file. Figure 1 gives the system representation of the entire system:

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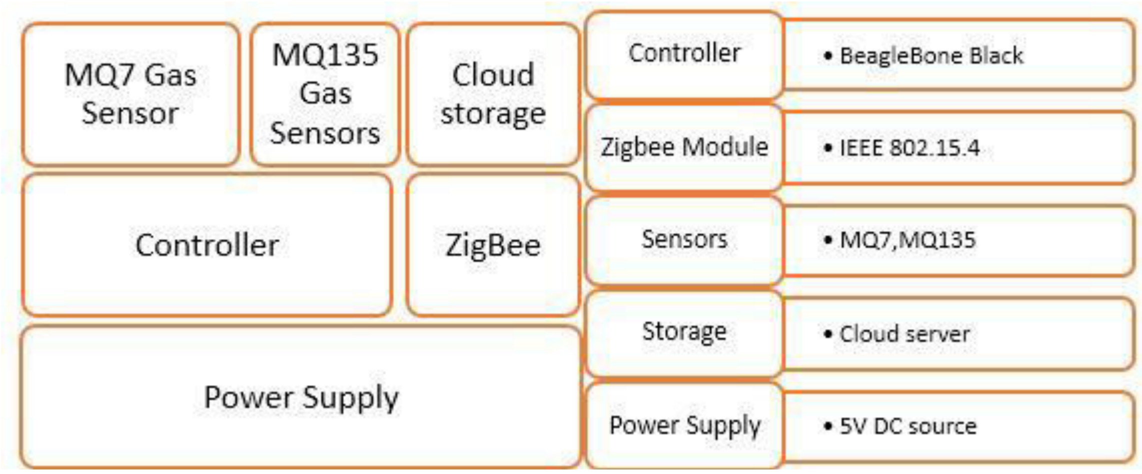

Fig. 1 System Representation

III. WIRELESS SENSOR NETWORK SYSTEM DESIGN

The overall system architecture of wireless sensor network system is shown in figure 2. The system is divided into two physical modules, Sensor node and Gateway node. Two sensor nodes send the gas concentration value to the gateway node which uploads the data to the cloud server in order to facilitate the remote monitoring via the web and mobile application. Figure 2 represents the entire structure of the system.

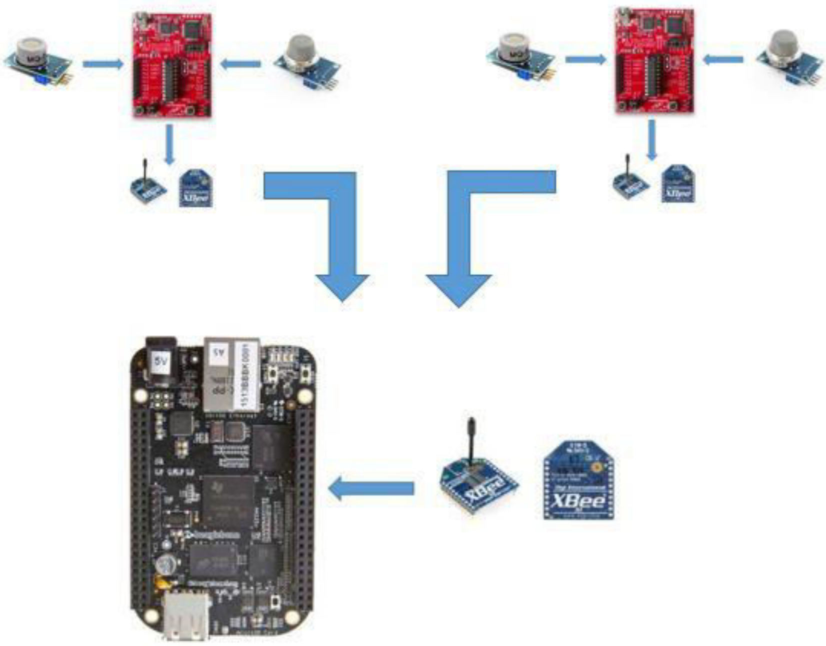

Fig. 2 Network level structure

The sensor node is equipped with two different gas sensors, MQ7 and MQ135, calibrated to sense carbon monoxide and carbon dioxide respectively. It also has a processing unit as MSP430, which performs the node level data aggregation and a transmitting module as XBee radio for wireless communication with the gateway node. XBee radios at the sensor nodes are configured as router

The data is serially received at the gateway node via XBee radio which is configured as coordinator.BeagleBone Black which acts as a central controller to both the nodes use the curl command to post the data to the azure server. Additionally, the summarized data is sent to the user in form of text file via email, at every month.

IV. Results And Discussion

The gas concentration values shown in figure 3 depicts the normal condition of a room during the day. Considering the guidelines issued by Occupational Safety and Health Administration, the values are well within the Permissible Exposure Limit.

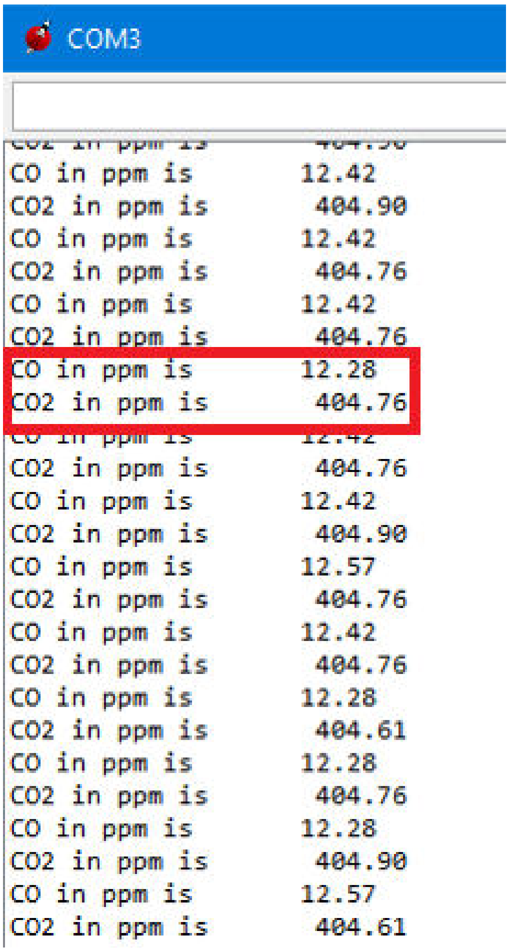

Fig. 3 Gas concentration at normal condition

These values respond to the changes whenever there is any significant change in any of the parameter. Gas concentration in figure 4 depicts the detection of smoke in the target area due to the burning of plastic.

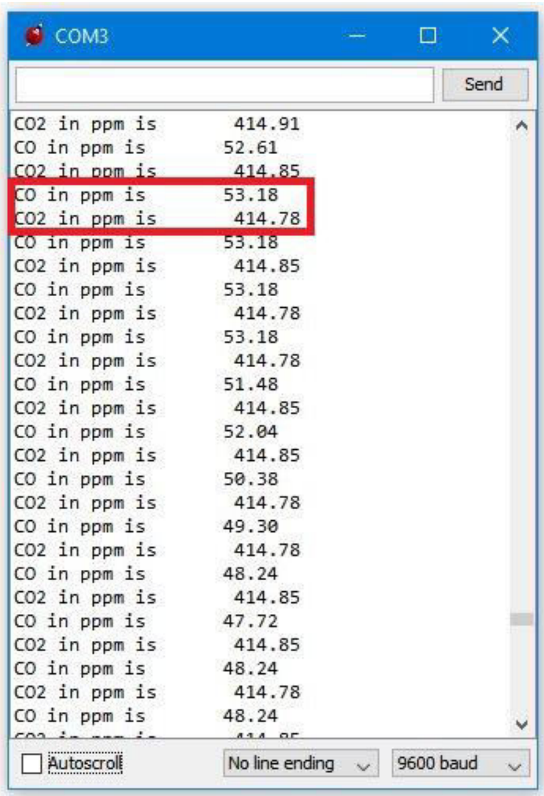

Fig. 4. Detection of smoke during burning of plastic

Microsoft Azure cloud server is used to maintain a database of the gas concentration value. The value received by the XBee at the gateway node is uploaded to the server database via a controller. These values are time stamped to facilitate the analytics later. At the end of every month, these values are emailed to the user in a file. The table 1 shows the database maintained in the azure cloud server.

TABLE 1. AZURE DATABASE STORING TIME STAMPED GAS CONCENTRATION

Node ID	Payload	Time stamp
A	The CO_2 value is 414.12 ppm	2017-05-14, 12:17:14
A	The CO value is 4.12 ppm	2017-05-14, 12:17:14
B	The CO_2 value is 410.24 ppm	2017-05-14, 12:19:14
B	The CO value is 3.01 ppm	2017-05-14, 12:19:14
A	The CO_2 value is 400.09 ppm	2017-05-14, 14:27:35
A	The CO value is 2.05 ppm	2017-05-14, 14:27:35
B	The CO_2 value is 403.55 ppm	2017-05-14, 14:29:35
B	The CO value is 2.27 ppm	2017-05-14, 14:29:35

IEEE 802.15.4 MAC frame is divided into three parts.

- MAC header
- MAC payload
- MAC footer

Every time the data is sent serially, data is encapsulated inside MAC payload section and then a frame is transmitted. The source and destination address which remains constant in this system are carried by MAC header. The size of the MAC header is 37 bytes. In the traditional approach where data is transmitted every time it is sensed by the sensors, these 37 bytes is an overhead and reduces the energy efficiency of the system. In this system, the technique of aggregating the data is employed. The raw data is aggregated over a period of time and then the data from both the sensors are sent via XBee in a single payload using concatenation function of the *serialprint* command. For an instance, if two sensors are sensing the value for a period of 10 seconds by traditional method (where each sensor takes the reading every 1 second) and transmitting the data serially via XBee,

Mathematically, 74 frames would be transmitted for both sensors per second. And hence, the total bytes of MAC header transmitted would be: 2*10*37= 740 bytes. These 740 bytes of data will contain the same information, i.e. source and destination address. However, by using the technique employed in this system this overhead could be minimized. Both the sensors keep taking the reading for entire 10 seconds and keep stored in a buffer. After 10 seconds, the mean of the data collected is taken and this value is transmitted via XBee. Additionally, aggregated data from both the sensors is taken and sent in a single frame. Through this technique, for every 10 seconds, only single frame is transmitted, i.e. an only 37 bytes of header. Also, a lot of energy is saved using data aggregation technique, which lacks in the current systems.

V. CONCLUSION

In this paper, we display a wireless sensor network system for indoor air quality monitoring applications. The system is produced by utilizing low-cost micro gas sensors which are economicallyand commercially accessible in the market and an open source microcontroller development platform MSP430. The star networking capability of the framework is accomplished by using ZigBee module, which incredibly simplifies the development of wireless sensor network system. Such a framework is to a great degree helpful in observing air quality conditions inside structures to better comprehend the present status of air quality and additionally to concentrate the long-haul effects of poor air quality on general wellbeing.

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AUTHOR(S) BIOGRAPHY

Rishabh Rastogi is an under-graduate student in Vellore Institute of Technology (VIT), Chennai. His interest lies in working extensively on wireless sensor networks; predominantly its applications surrounding home automation, tracking and environmental monitoring. He plans to pursue masters in wireless communication in future. The endless possibilities that arise from heterogeneous data through WSNs is something that keeps him hooked onto this space.

Jayavignesh Thyagarajan Is a faculty in Vellore Institute of Technology (VIT), Chennai, India. His research interests include Routing Protocols Design, Analysis of Medium Access Protocols and Congestion Control mechanism in the area of Wireless Adhoc, Sensor, Mesh, Vehicular and Opportunistic networks. He acquired his Masters in Engineering from Madras Institute of Technology, Anna University and secured First Rank with a Gold medal in Communication and Networking program. He obtained his Bachelors in Engineering degree in Electronics and Communication from College of Engineering, Guindy, Chennai.