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Design of Solar Powered Remote Environment Monitoring System for Industry and Landfill Sites using of Wireless Sensor Networks

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Abstract:

The primary causes of the climate change and global warming on the earth are the greenhouse gases, which are produced as a result of industrial processes, burning fossil fuels, Landfill sites and rice cultivation etc. The impacts of these greenhouse gases on the environment are more troublesome to the living beings. The main theme of this project is to design of solar powered wireless sensor nodes and a monitoring system to measure the concentration levels of different greenhouse gases at the industry and the landfill sites by deploying multiple wireless sensor nodes. And also the major part lies in to monitor the leachate, a toxic liquid released at the landfill sites. The wireless sensor nodes with different gas sensor array, temperature sensor and leachate detection sensor are deployed all around the industry and landfill sites. The main system is built around the MSP430 & Embedded Wi-Fi, which processes the concentration level of greenhouse gases information received from the different wireless sensor nodes and monitors conditions around the industry and landfill sites. The processed information is sent to the corresponding corporations for storage and interpretation of the data. And even the system is designed for open access by any end user, who wants to know the condition around those sites, by real-time mobile & system applications.

Keywords: TGS5042, CDM7160, TGS2611, Real time database application, CC3200 Embedded Wi-Fi, Wireless sensor nodes and ZigBee.

1. Introduction

The air quality in the environment is reducing day by day due to industrial processes and manmade activities. The environment around the industrial area is being exposed more to the greenhouse gases leading to the hazardous effects on the living beings[1]. So the monitoring of the air quality is the prime factor. Timely information of the pollution level at any sites is very important to take precautionary measures over it. Globally, millions of tons of municipal solid waste are disposed in landfills sites every day. Landfill gas is a natural by-product of decayed organic material compiled from household waste, yard waste, food waste, etc., disposed in these landfills. This landfill gas is mainly a combination of methane (CH4), carbon dioxide (CO2) plus a certain amount of non-methane organic compounds (benzene C6H6, toluene CH3, and chloroform CHCl3). Landfill is considered to be the third largest emission source in the world after rice cultivation and biomass burning from manmade activities including industry. Previously, open dumps and unmanaged landfills represented a significant issue in many of the developing countries. Over the last few decades, however, many of these countries have attempted to transfer their waste disposal activities from uncontrolled systems to landfills.

The process of monitoring these landfills is to assess the chemical decomposition of landfill gas within the site[2]. One of the goals of this monitoring is to determine the impacts of the landfill site on the environment and the surrounding area. Currently, most of the landfill sites are designed with leachate collection systems to convert the landfill gas into green power. Traditional monitoring programs, such as field sampling and laboratory testing, consume both time and effort. In cases of their large spatial extent, such monitoring schemes can cost millions of dollars, and it is difficult to investigate the impacts of landfill sites on the surroundings. In this study, the use of low power, less expensive, non-dispersive infrared gas sensors made it easy to measure & monitor the concentration level of different greenhouse gases at industry and landfill sites.

Our previous work was to monitor the environment around the industry & landfill sites using a standalone system which is being integrated with multiple sensor arrays, so which has led to monitor only certain area[4]. So to monitor the entire sites remotely and efficiently, we have come with integrating many number of wireless sensor nodes around the Industry and Landfill sites. As the Wireless sensor networks are gaining increasing attention with regard to environmental monitoring; the extended temporal and spatial resolution provided by distributed sensing nodes enable a wealth of environmental parameters to be measured.

The main monitoring system is built around the high performance, low power ARM7 controller made it easy to control and fast processing of the data and the same is made available to the end user via the GPRS or GSM service. The non-dispersive infrared gas sensors which are incorporated to wireless nodes are being used to measure the gas concentrations because of their fast response and sensitive to the particular gases and stable operation over wide range of temperature. The database is used to store the gas concentrations at different sites [1].

The purpose of this study is to provide useful supplementary information for industry and landfill site monitoring and management, instead of simply replacing the current, more traditional monitoring schemes using low power, reliable and efficient wireless sensor networks.

2. SYSTEM REQUIREMENT AND ARCHITECTURE OVERVIEW

The requirements that adopting a WSN are expected to satisfy in effective remote environments like industry & Landfill sites, monitoring concerns both system level issues (i.e., unattended operation, maximum network life time, adaptability or even functionality and protocol self-configurability) and final user needs (i.e., communication reliability and robustness, user friendliness, versatile and powerful graphical user interfaces). The most relevant mainly concerns the supply of stand-alone operations. To this end, the system must be able to run unattended for a long period, as nodes are expected to be deployed in zones that are difficult to maintain.

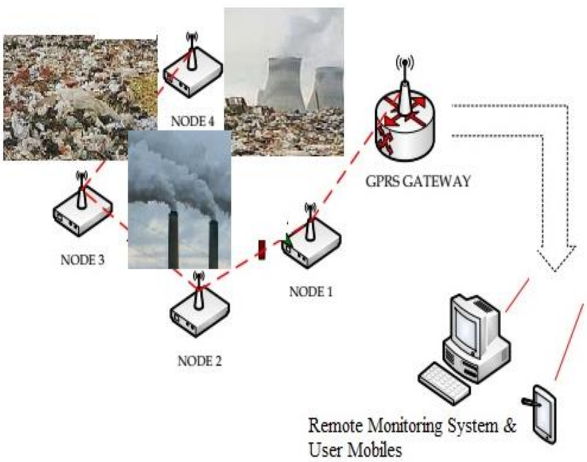

Figure.1: Wireless Sensor Network system overview

A WSN system was developed according to the afore mentioned requirements. The system, shown in Figure.1, comprises a self-organizing mesh WSN endowed with sensing capabilities, a GPRS Gateway, which gathers data and provides it to the remote monitoring system, and a real time database Application, which manages information and makes the final user capable of monitoring and interacting with the instrumented environment.

3. HARDWARE SYSTEM DESIGN

Focusing on an end-to-end system architecture, every constitutive element has to be selected according to application requirements and scenario issues, especially regarding the hardware platform. Many details have to be considered, involving the energy consumption of the sensor readings, the power-on and power-save status management and a good trade-off between the maximum radio coverage and the transmitted power.

3.1 Sensor Node Architecture

In order to manage different kinds of sensors, a compliant sensor board was adopted, allowing up to 16 sensor plugs on the same node;, this makes a single mote capable of sensing many environmental parameters at a time (Mattoli et al., 2005). Sensor boards recognize the sensors and send Transducer Electronic Datasheets (TEDS) through the network up to the central monitoring system, making it possible for the system to recognize an automatic sensor. The overall node architecture is shown in Figure.2.

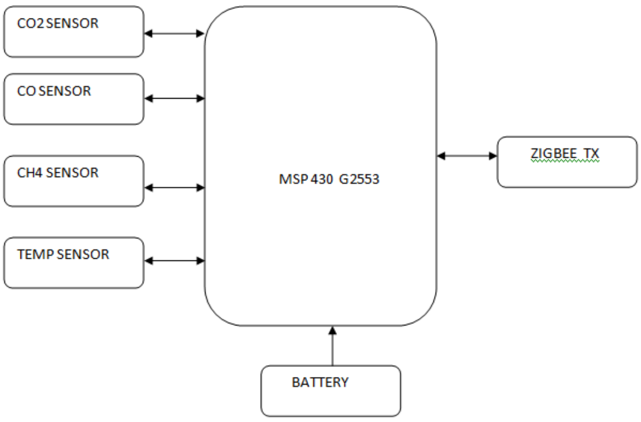

Figure.2 Wireless Sensor Node Architecture

3.2 Main System Architecture

The main monitoring system is designed to acquire the data from the different wireless sensor nodes deployed around the industry and landfill sites. It Consists of ARM7 as central unit integrated with GSM modem, 16x2 LCD module, Mobile unit, Personal computer real time Database application,

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LED/Buzzer unit. The complete block diagram of the monitoring system is as shown in the figure 3.

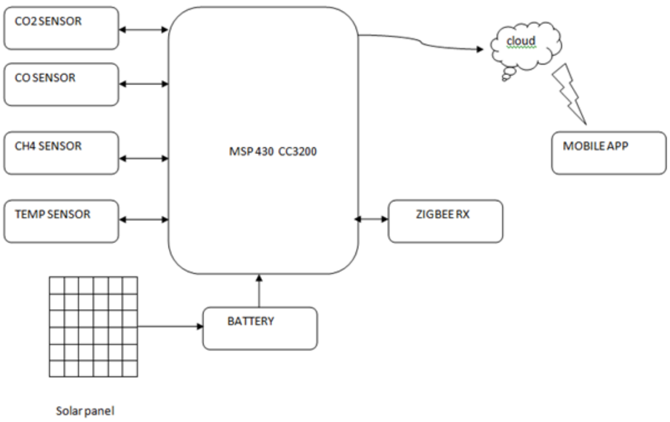


Figure.3: Main monitoring System Architecture

3.3. Sensor Requirements and Description

The different industrial gas sensors like TGS2611 for Methane gas (CH4) sensor, CDM7160 for Carbon Dioxide (CO2) Sensor and TGS5042 for Carbon Monoxide (CO) sensors are integrated in the wireless sensor nodes to detect the CH4, CO2 & CO gas concentration levels which are released into the environment as a result of industrial processes & degradation of compiled waste by the bacterial breakdown at the remote sites like industry and landfills. These different sensors as discussed below.

A. Methane Gas (CH4) Sensor TGS2611

TGS2611 is a semiconductor type gas sensor which combines very high sensitivity to methane gas with low power consumption and long life. Due to miniaturization of its sensing chip, TGS2611 requires a heater current of only 56mA and the device is housed in a standard TO-5 package.

Features:

- High sensitivity to methane
- Long life and low cost
- Uses simple electrical circuit
- Concentration range: 500-10000ppm
- Power requirements: Heater Voltage 5.0±0.2V AC/DC & Circuit Voltage 5.0±0.2V AC/DC with heater current 56±5mA, heater power consumption 280mW±25Mw
- Operating temp range: +32°F to +158°F (0°C to +70°C)

Figure.4: CH4 gas sensor TGS2611

B. Carbon Dioxide Gas (CO2) Sensor CDM7160

The CDM7160 CO2 module uses a compact NDIR CO2 sensor, featuring excellent performance characteristics, including high accuracy and low power consumption. Two detector elements inside the module make absolute measurement possible. Every module is individually calibrated and is provided with both a UART and I2C digital interface. The CDM7160 module is designed for simple integration into a user's products.

Features:

- Small size & Non-dispersive infrared (NDIR) operating principle
- Low power
- High accuracy
- Absolute measurement via dual sensors
- Detection range :300~5,000ppm
- Circuit Voltage & Current :4.75~5.25V DC, 60mA peak, 10mA avg.
- Accuracy: ±(50ppm+3% of reading) in the range of 300~5,000ppm CO2
- Normal operating temperature range: 25°C (±5°C)

Figure.5: CDM7160 CO2 gas sensor

C. Carbon Monoxide Gas (CO) Sensor

Figaro's TGS5042 is a battery operable electrochemical sensor which offers several advantages over traditional electrochemical sensors. Its electrolyte is environmentally friendly, it poses no risk of electrolyte leakage, can detect concentrations as high as 1% CO, operates in a range from -5˚ and +55˚C, and it has lower sensitivity to interfering gases. With a long life, good long term stability, and high accuracy, this sensor is the ideal choice for CO detectors

Features:

- Battery operable
- High repeatability/selectivity to CO
- Linear relationship between CO gas concentration and sensor output
- Simple calibration & Long life
- Typical detection range : 0 ~ 10,000ppm
- Output current in CO : 1.2~2.4nA/PPM
- Response time (T90) : within 60 seconds

Figure 6 shows the basic measuring circuit of CO gas sensor.

Figure.6: a) CO gas sensor module

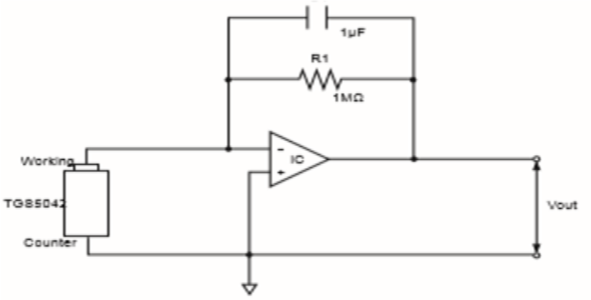
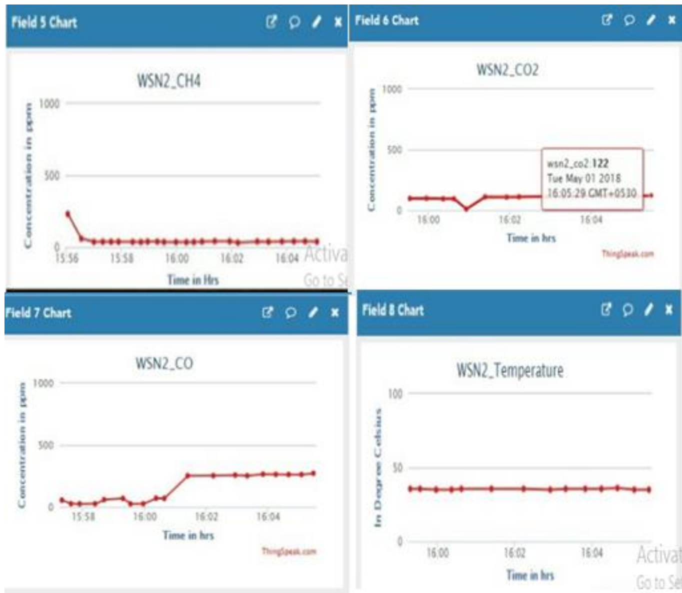


Figure.6 b) Basic measuring circuit of CO gas sensor

The remaining common sensors like, temperature sensor is used to measure the ambient temperature of the surrounding places of dumping yard. Leachate sensor is designed to detect the leachate released as a result of waste decomposition in the landfill sites. Zigbee is used to communicate the individual sensor data among the wireless sensor nodes and the embedded wi-fi is used to upload the sensor data to the Internet of Things (IoT), and the same data is fetched using API keys for remote monitoring using System & Mobile applications.

4. Resutls & Discussions



To monitor the greenhouse gas emissions around the selected dumping yard we designed two sensor nodes & tested at the site. The selected site and the complete system implemented to monitor the greenhouse gas emissions is as shown in figure 7.

Figure 7: Kuppam Dumpig yard and Two nodes setup at the site

As shown in the above figure 7, number of nodes can be designed to cover the large area by connecting through the mesh network. Now for the demonstration purpose only two nodes are designed and it can be implemented further with the multi nodes.

Bothe the wireless nodes are designed with industrial sensors like CDM7160,TGS5042,TGS2611 and TMP006 are used, which are used to detect gases such as Carbon-dioxide (Co2), carbon-monoxide (Co), Methane (CH4),and temperature respectively, finally the data collected the coordinator node is uploaded to the IoT using CC3200 embedded Wi-Fi as shown in figure 8 & 9.

Figure 8: wireless sensor node 1 gas levels displayed on IoT fields

Figure 8: wireless sensor node 2 gas levels displayed on IoT fields

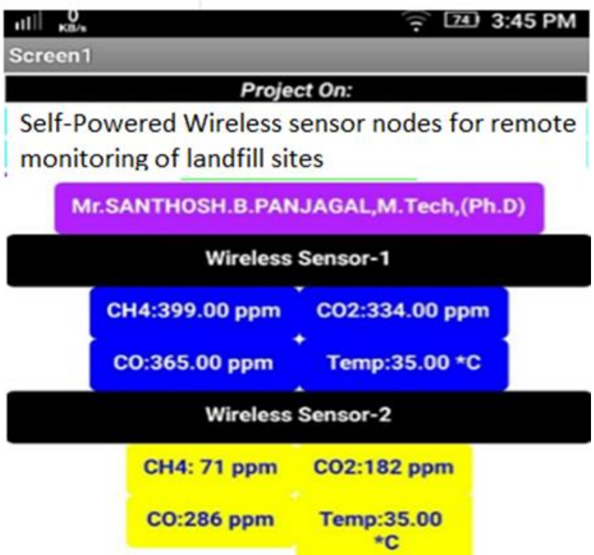


Figure 10: Real-Time mobile application for monitoring Gas levels

After uploading the data to IoT platform an userfriendly mobile application and system application is developed to monitor and assess the greenhouse gas levels at the selected sites. The real-time application data shows the latest gas levels read from the IoT platform as shown in figure 10.

Similarly, a windows application is also designed for remote access and monitoring of greenhouse gas concentrations at the main stations, as shown in the figure 11.

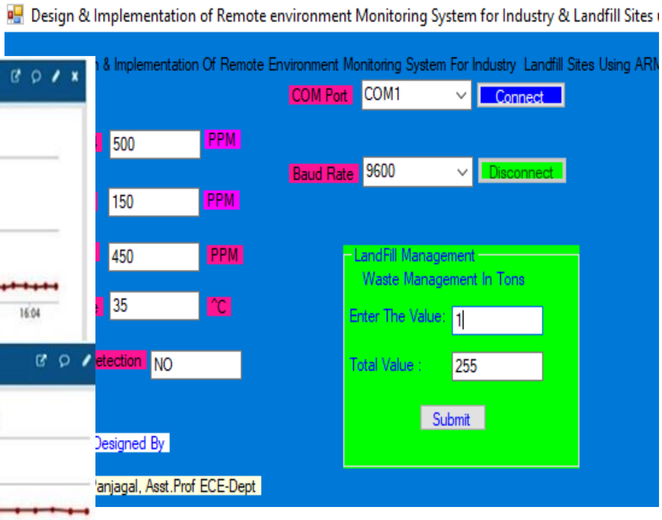


Figure 11: Real-Time windows application for monitoring Gas levels

5. CONCLUSION & FUTURESCOPE

Hence the proposed work describes about the design of a solar powered industrial wireless sensor node based remote environment monitoring system to measure and monitor the gas concentration levels and other information at industry and landfill sites. The system incorporates the low power, cost effective electromechanical and infrared sensors into the wireless nodes to acquire the different conditions at the mentioned sites. The system shows the satisfactory results to monitor the remote environments. A serial communication is established to inform the gas levels, temperature variations around the selected landfill sites/dumping yard. Here Zigbee devices are used to communicate two nodes among each other and the measured data has been uploaded to IoT using embedded Wi-Fi mdule. The system access facility is provided to the end users through the mobile and windows application service, any user can able to know the gas concentrations around the living area of waste dumping site using mobile applications.

A real time database software application is also designed to update and store the data information from the different remote environments. The data information acquired at these sites can be processed in local low powere MSP430 processor and the same is transformed and interpreted to make available to the end users.

In future multiple sensor nodes are deployed around the landfill sites to assess the gas migration and study the health effects of greenhouse gas emissions around the living areas.

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