International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org, editorijaiem@gmail.com
Volume 2, Issue 7, July 2013 ISSN 2319 - 4847

Pollution Monitoring using Sensors and Wireless Sensor Networks : A Survey

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Abstract

Pollution has been aggravated by developments that typically occur as countries become industrialized: growing cities, increasing traffic, rapid economic development and industrialization, and higher levels of energy consumption . The high influx of population to urban areas, increase in consumption patterns and unplanned urban and industrial development has led to the problem of air pollution. Air pollution has significant influence on the concentration of constituents in the atmosphere leading to effects like global warming and acid rains. To avoid such adverse imbalances in the nature, an air pollution monitoring system is utmost important. Wireless Sensor Networks is an excellent technology that can sense, measure, and gather information from the real world and, based on some local decision process transmit the sensed data to the user. These networks allow the physical environment to be measured at high resolutions, and greatly increase the quality and quantity of real-world data and information for applications like pollution monitoring. In this paper, a survey on pollution sensors and pollution monitoring systems using Wireless sensor Networks is presented.

Keywords: — Wireless Sensor Networks, pollution monitoring, air pollution

1. INTRODUCTION

Present advances in electronic circuit miniature and micro-electromechanical systems (MEMS) have led to the creation of small sensor nodes which integrate several sensors, a central processing unit (CPU), memory and a wireless transceiver. Sensor networks [1,2] are a collection of these sensor nodes which are easily deployable and provide a high degree of visibility into real-world physical processes as they happen, thus benefitting a variety of applications as in Figure 1. Important applications include environmental and habitat monitoring, healthcare monitoring of patients, weather monitoring and forecasting. Military and homeland security surveillance, tracking of goods and manufacturing processes, safety monitoring of physical structures and construction sites, smart homes and offices, and many other uses that we do not yet imagine.

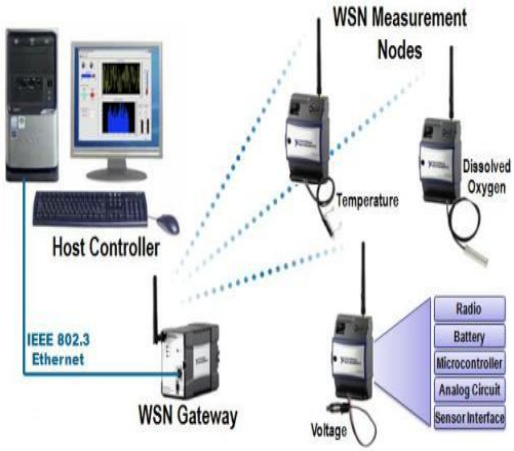

Figure 1. Wireless Sensor Network

In the U.S., all major cities have networks of monitoring stations providing continuous measurements of the most important pollutants. However, the number of these stations is usually very small. Furthermore, currently the data of the different pollutants measured at the different stations in the city are aggregated to a single number, the air quality index (AQI), that is published once a day on a website. In other words, there is not enough data gathered to evaluate air quality in a given neighbourhood and the publicly available information is even more deficient.

2. ISSUES IN ENERGY CONSERVATION FOR SENSORS

One of the biggest challenges in WSNs is the power issue, since sensors have limited source of power which is hard to replace or recharge. Typically, the batteries last only for a few months and the dead batteries pose an environmental

hazard with the hardware left in the environment. Efforts to save power in sensors could be done using the following as in [3,4]:

1) Reducing power consumption starts from the selection of Microcontroller unit (MCU), low power consumption MCU should be considered at first.

2) Choosing chip with low standby current and steady transreceiving current for Radio frequency module

3) Power source with low output voltage and low consumption power itself.

4) Reducing system operating frequency can lower consumption effectively.

5) Lowering system operating voltage influences system power consumption. So under the premise of system credibility, make sure that system is in lower operating voltage.

6) Use interrupts to make the processor into deep sleep. As we all know, sleep and power down mode will lower operating current greatly.

7) Dynamic Power Management: When there is nothing interesting happening around, some modules are idle, switching to low energy consumption sate (sleeping mode). This event-driven energy management is very important to enhancing life cycle of sensor node.

8) Dynamic Voltage Scaling: When calculated load is low, reduce working voltage and frequency of MCU and thereby reduce processing capacity, can reduce power consumption of MCU.

9) Using energy efficient routing algorithms [12] and medium access control schemes. WSN routing algorithms pay much attention to energy savings as it is impossible to replace or recharge batteries of sensor nodes. The operating states of a sensor node can be categorised as transmitting, receiving and idle or sleep states. A sensor node in transmitting state consumes the most energy while in receiving or idle states consumes a little less energy. The energy consumption for data transmission is directly proportional to the square of a wireless transmission distance. A WSN therefore uses routing protocols that are, capable of data aggregation , distribution of energy dissipation evenly and energy efficient in order to increase the network lifetime [13].

10) Use of solar powered sensor networks to increase the life of the network.

3.POLLUTION MONITORING SENSORS

One of the ideas behind the sensors is that if commercialized, they would allow everyday people to be more proactive when it comes to air pollution. Users could avoid areas where the levels are dangerously high, for example, and would perhaps be more motivated to pressure local authorities to do something about the problem.

Also, data gathered from a multitude of the sensors throughout a region could provide the public with much more detailed and accurate air quality reports than is currently possible. According to the university, although San Diego County measures approximately 4,000 square miles (10,360 sq km), it is currently served by only about ten air-quality monitoring stations.

3.1.Waspmote:

Waspmote along with the gas sensors board allows to monitor the following parameters to determine the quality of air we breathe:

- Nitrogen dioxide(NO2) is a gas produced by the rapid oxidation of NO, that is produced by burning fossil fuels in vehicles and industry.Itis toxic and affects the respiratory system and encourages the production of nitric acid(HNO3) responsible for acid rain
- Carbon dioxide(CO2) it is a gas naturally present in our atmosphere. Together with water vapor and other gases is one of the greenhouse gases that regulate Earth's temperature. Production in excess as a result of increased fossil fuel usage could have a direct impact on climate change.
- Carbon monoxide (CO): it is produced in incomplete combustion ,i.e. when part of the fuel does not react completely due to lack of oxygen. Its danger to human and animals, once it sets in hemoglobin, it prevents oxygen transport, whi9ch can be lethal. Although in open space is easily diluted, the CO emission from the engines of cars in congested areas causes may have rates of 50-100ppm, which are dangerous.
- Methane (CH4): it is produced when organic material decomposes in oxygen-poor environments. As carbon dioxide, it is a greenhouse gas so its increase may contribute global warming.
- Hydrogen sulphide (H2S): it is emitted into the atmosphere by various industries, such as paper. It is particularly dangerous because it is highly toxic gas and it is a sulphur dioxide precursor, one of the gases in the processes of formation of acid rain.In addition , this gas is annoying because of its foul smell.
- Hydrocarbons(Ethanol, Propane , Butane etc.): They come from poor combustion of gasoline and diesel or industrial processes. They are, among others responsible for greenhouse effect and contribute to produce respiratory problems.
- Ozone(O3): it is a natural constitute that can be found at sea level with a concentration of 0.01 mg / kg. However, with intense solar radiation and high contamination coming from veicles, its concentration can go upto 0.1 mg/kg being dangerous. In this proportion , the plants may be affected and human may experience irritation of nasal passages and throat and dryness in the lining of the respiratory tracts.

3.2. GUSTO An Open Path Air Pollution Sensor

GUSTO[6] is an acronym for Generic Ultraviolet Sensors Technologies and Observations based on open-path DUVASTM (Differential Ultraviolet Absorption Spectroscopy) technology and measures and transmits the volume mixing ratios (at ppb levels) of key urban pollutants in real-time [11]. The key distinguishing features are:

- Short time scale (of order 2s scan rate)
- Open variable path (up to 30m), enabling measurements to be carried out *in situ* and localised effects to be characterised.

The volume mixing ratios of certain trace atmospheric gases may be determined using differential optical absorption spectroscopy (DOAS). The custom developed DUVAS method makes use of the characteristic narrow band absorption of the gas under study in the UV spectral range 200-270nm. These include SO2, NO, NO2, O3, NH3 and Benzene (all are governed by strict legislative guidelines with respect to acceptable limits of ambient concentration).

3.3.CitiSense:

Researchers at the University of California, San Diego have developed a network of smartphone-based air pollution monitors that allow individuals to track pollution levels in real time (Figure 2) and feed a central database of air quality trends citywide throughout the day. The so-called CitiSense[7] devices are equipped with sensors that measure ozone, nitrogen dioxide, and carbon monoxide, and a digital app that illustrates the color-coded results based on the U.S.

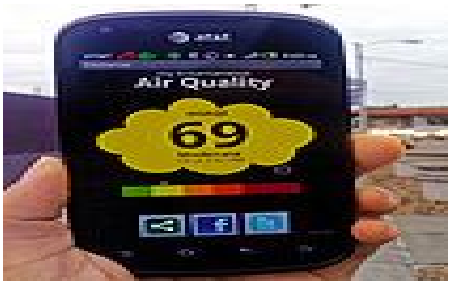

Figure 2: CitiSense device

Protection Agency's air quality ratings. During a four-week test, in which the phones were distributed to 30 volunteers, the system showed hotspots of elevated pollution that shifted over the course of the day. Ultimately, the developers hope to deploy hundreds of devices in order to generate a public database on air quality levels.

3.4.Weather and Air Quality Sensors in the Palm of Your Hand

Netatmo, creator of the world's first personal weather station with air quality sensors, announced the Urban Weather Station's national retail launch with Brookstone, the specialty retailer and product development company. The first personal weather station with air quality sensors, Netatmo is compatible with iPhone, iPad and Android devices as in Figure 3.

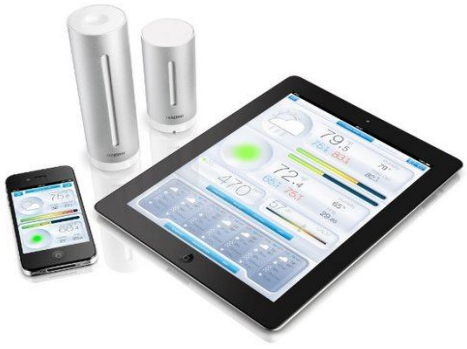

Figure 3: Netamo with iPhone,iPad and Android devices

The Urban Weather Station has been recognized for its innovative design and received three Innovations and Engineering Honoree Awards at the 2013 International Consumer Electronics Show.

Netatmo's Urban Weather Station allows users to track indoor and outdoor environmental elements including temperature, air quality, humidity, barometric pressure, CO2 concentration and more. Created for iPhone, iPad, iPod touch and Android devices, the Urban Weather Station records and wirelessly transmits data via Wi-Fi to the Netatmo App for viewing – anywhere, anytime.

4.POLLUTION MONITORING SYSTEMS

4.1. GPRS- Sensors Array :

An online GPRS-Sensors Array for air pollution monitoring has been designed, implemented, and tested [8]. Theproposed system consists of a Mobile Data-Acquisition Unit (Mobile-DAQ) and a fixed Internet-Enabled Pollution Monitoring Server (Pollution-Server). The Mobile-DAQ unit integrates a single-chip microcontroller, air pollution sensors array, a General Packet Radio Service Modem (GPRS-Modem), and a Global Positioning System Module (GPS-Module). The Pollution-Server is a high-end personal computer application server with Internet connectivity. The Mobile-DAQ unit gathers air pollutants levels (CO, NO2, and SO2), and packs them in a frame with the GPS physical location, time, and date. The frame is subsequently uploaded to the GPRS-Modem and transmitted to the Pollution-Server via the public mobile network. A database server is attached to the Pollution-Server for storing the pollutants level for further usage by various clients such as environment protection agencies, vehicles registration authorities, and tourist and insurance companies. The Pollution-Server is interfaced to Google Maps to display real-time pollutants levels and locations in large metropolitan areas. The system was successfully tested in the city of Sharjah, UAE. The system reports real-time pollutants level and their location on a 24-h/7-day basis.

In this paper, a system that integrates a single-chip microcontroller, several air pollution sensors (CO, NO2, SO2), GPRS-Modem, and a general positioning systems (GPSs) module is developed. The integrated unit is a mobile and a wireless data acquisition unit that utilizes the wireless mobile public networks. The unit can be placed on the top of any moving device such as a public transportation vehicle. While the vehicle is on the move, the microcontroller generates a frame consisting of the acquired air pollutant level from the sensors array and the physical location that is reported from the attached GPS module. The pollutants frame is then uploaded to the General Packet Radio Service Modem (GPRS-Modem) and transmitted to the Pollution-Server via the public mobile network. A database server is attached to the Pollution-Server for storing the pollutants level for further usage by interested clients such as environment production agencies, vehicles regeneration authorities, tourist and insurance companies. The Polution-Server is interfaced to Google maps to display real-time pollutants levels
and their locations in large metropolitan area such as Sharjah City, UAE.

4.2. Indoor Air Quality Monitoring:

Indoor air quality (IAQ) is an important public health issue [9]. Driven by rising energy costs, buildings are increasingly built or renovated to be air tight to reduce unwanted heat loss. In consequence the air quality levels in such buildings are degraded. This study presents a wireless sensor network for monitoring IAQ in buildings. Comprised of various IAQ sensors, this network is capable of measuring IAQ levels at various locations within a building simultaneously. The network is integrated with the heating, ventilation, and air-conditioning systems in the building to ensure acceptable air quality in interior spaces. Using the sensor network, various indoor air pollutants (CO, CO_2, VOCs, and airborne particles) can be measured in spaces that house potential sources of pollutant production. When measured pollutant levels are higher than acceptable, the network will alarm indoor occupants, trigger activation of the building's climate control equipment, exhaust polluted air, and bring in fresh air from the outside. The ultimate aim of this study is to implement the sensor network throughout various building types. To this end, an affordable, low-cost, wireless IAQ controller that can be easily installed avoiding the need for costly wiring was developed.

4.3 Mobile Air Quality Monitoring Network (MAQUMON) : The Networked Embedded Systems Lab at ISIS created the Mobile Air Quality Monitoring Network (MAQUMON)[10] that consists of a number of car-mounted sensor nodes measuring different pollutants in the air. The data points are tagged with location and time utilizing an on-board GPS. Periodically, the measurements are uploaded to a server, processed and then published on the Microsoft SensorMap portal. Given a sufficient number of nodes and diverse mobility patterns, a detailed picture of the air quality in a large area will be obtained at a low cost.

The sensor platform supports autonomous data collection, storage and off-line data retrieval or the streaming of live sensor readings. An integrated Bluetooth module provides a wireless interface for laptop computers or PDAs.

Alternatively, the system can be accessed through a USB cable. This wired interface can also provide power to the board both for on-line operation and for charging the integrated Li-ion battery. The battery life of the device is limited to a few hours (in active data acquisition mode), but in the car mounted scenario, it can be constantly powered from the cigarette lighter. Furthermore, a 2-axis MEMS accelerometer is used to detect if the system is in motion and can automatically turn off all the power hungry components (GPS, Bluetooth, gas sensors) if not in use. Location and time information is provided by an on-board 20 channel SiRF-III-based GPS module at 1 Hz sampling rate. Gas concentration levels are measured by three analog sensors: O3, NO2 and CO/VOC. These readings along with temperature and relative humidity data and GPS information are stored in a serial flash device 2MB. A 2x16 character LCD panel provides immediate visual feedback about the status of the system (connected interfaces, GPS lock, time, motion detection, sensor readings). The Intel 8051-based microcontroller controls every aspect of the system from battery charging to analog/digital conversions and the USB protocol.

Sensor mobility is handled using the SensorMap mobile proxy feature. Overall air quality will be displayed in the form of contour maps utilizing image overlays. The time series data for a given sensor and/or a given geographic location will be also available.

4.4. Real time Air Pollution Monitoring

Air pollution has significant influence on the concentration of constituents in the atmosphere leading to effects like global warming and acid rains. To avoid such adverse imbalances in the nature, an air pollution monitoring system is utmost important. This paper attempts to develop an effective solution for pollution monitoring using wireless sensor networks (WSN) on a real time basis namely real time wireless air pollution monitoring system[11] .

Commercially available discrete gas sensors for sensing concentration of gases like CO_2, NO_2, CO and O_2 are calibrated using appropriate calibration technologies. These pre-calibrated gas sensors are then integrated with the wireless sensor motes for field deployment at the campus and the Hyderabad city using multi hop data aggregation algorithm. A light weight middleware and a web interface to view the live pollution data in the form of numbers and charts from the test beds was developed and made available from anywhere on the internet. Other parameters like temperature and humidity were also sensed along with gas concentrations to enable data analysis through data fusion techniques. Experimentation carried out using the developed wireless air pollution monitoring system under different physical conditions show that the system collects reliable source of real time fine-grain pollution data.

The objective of this work is to come up with cost effective, reliable, scalable and accurate real-time air pollution monitoring system with wireless sensor networks. Commercially available electrochemical and resistive heating type sensors were used to sense the gases like O_2, CO_2, CO and NO_2. Appropriate calibration technologies were developed to calibrate these sensors, which are then interfaced to wireless sensor motes. Zigbee based wireless sensor networks with multihop data aggregation algorithm were implemented to extend the range of monitoring area. The calibration technology for the gas sensor, system architecture of real time wireless pollution monitoring system, field deployment and experimentation with varying physical conditions and various challenges faced during the design, development and deployment of the system are discussed in the following sections.

5. CONCLUSION

This survey has shown that the vast technological developments in wireless communication technology have led to the emergence of many Pollution monitoring sensors and wireless networks for monitoring and reporting pollution . This information could be used by the authorities to take necessary action such as emergency warning messages and evacuation of people to safe places. Further implementing pollution monitoring systems will help to assess how bad air pollution is from day to day and save the environment from further pollution episodes. This survey would help in the design and development of an energy efficient pollution monitoring system for India.

ACKNOWLEDGEMENT

This work is funded by the University Grants Commission as a part of the Minor Research Project titled Energy Efficient Routing in Wireless Sensor Networks for Pollution Monitoring.

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BIOGRAPHY

R.A.Roseline is working as Associate Professor of Computer Science in the PostGraduate and Research Department of Computer Science, Government Arts College (Autonomous), Coimbatore. She is currently pursuing Ph.D. in the area of Computer Networks. She has completed her M.Phil in the area of Mobile Ad-hoc Networks from Periyar University. She obtained M.Sc in Computer Science from Bharathiar University, Coimbatore. She has about 17 years of teaching experience and 5 years of research experience. She has presented papers in eight conferences and published papers in 3 international journals. Her research interests are in Mobile Networks, Robotics, Wireless Sensor Networks and Grid Computing.

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