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Mobile monitoring of air quality in cities in real time using solid state gas sensors

PrajaktaGudadhe ,Chandrapur, Maharashtra,

PrajaktaGudadhe3@gmail.com

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Abstract- The people who live in towns around the world are mostly influenced by air pollution these days. Air pollution changes the amount of different substances in the atmosphere, which has direct effects like making people sicker and damaging property, as well as secondary effects like acid rains and global warming. A few decades ago, factories were the main cause of dirty air in towns. But in cities, air pollution has gotten a lot worse in the last few decades because so many more cars and trucks are on the road. Air pollution is always changing because the wind speed, direction, humidity, temperature, and other weather factors are hard to predict. So, it's important to be able to check the air quality in real time and cover a big area quickly and cheaply. The goal of this study is to create and build an Ambient Air Quality Monitoring Instrument (AAQMI) that can be used to check the quality of the air on the go in real time using small, inexpensive solid state gas monitors. Cell phone tracking can quickly cover a big area. Solid state gas monitors have been used to create and build an instrument that can measure the amounts of gases like CO, CO2, and NO. The hardware unit of the instrument includes an ARM-7 Module, signal sensor conditioner boards with air pollution sensors, a GPS module, and a personal digital assistant (PDA) that is linked to a GSM receiver. The AAQMI machine measures the amount of air pollution in the area and sends that information, along with its GPS position (latitude and longitude), time, and date, to a database on the internet and to a PDA. It is possible to get the data whenever it is needed for research and control.

Keywords- Pollution in the air, cities, the ARM module, solid-state gas monitors, the GPS module, and real-time tracking of air quality on mobile devices.

INTRODUCTION:

The atmospheric air in urban areas is heavily polluted by various anthropogenic activities. The anthropogenic activities includes domestic, commercial and industrial. Few decades ago the air pollution in urban areas was mainly due to the industrial activities. But, during the last few decades, the air pollution has been ever increasing predominantly by the transportation sector.Transportation systems are increasing everywhere and the improvements in technology are insufficient to counteract pollution growth [1]. The negative impacts of urban traffic growth are well known, e.g., congestion and more traffic noise apart from the increased air pollution levels. Humans can readily see traffic congestion, and can hear traffic noise, but inevitably they are much less aware of odorless, invisible, silent air pollution.

In India, as on date, there are 573 operating stations in 240 cities/towns in 26 states and 5 Union Territories, monitoring air pollution under the National Air Quality Monitoring Programme (NAMP) [2]. Under NAMP, four criteria pollutants namely sulphur dioxide (SO_2), nitrogen dioxide (NO_2), respirable suspended particulate matter (RSPM) and suspended particulate matter (SPM) have been monitored regularly at all the locations. In addition to those four criteria pollutants, benzene, carbon monoxide and Ammonia are measured in the selected cities.

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In Chennai, there are 5 air pollution monitoring stations under operation and 5 proposed. However, the data collected is limited to the vicinity of the monitoring stations. These pollutants are sampled by using High Volume Sampler and analysed using conventional analytical instruments such as mass spectroscopy (MS) and gas chromatography (GC) and Fourier transform infrared instruments (FTIRs) etc. for determination of air pollutants concentration. These methods provide accurate and selective gas readings. But they are expensive, complex, time consuming and large in size. Establishing this type of operating stations sufficiently to cover larger area in cities/towns is costly due to prohibitive cost of land and high cost of instruments used for sampling and analysis. Having few operating stations are not enough in cities to cover such large area running tens and hundreds of square kilometers to know the pollution levels at various places. Hence, an instrument with on-line mobile monitoring will be of much use to cover large urban areas. These should be able to give monitored values in no time and simultaneously be able to

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Thus, solid state gas sensors comes from their numerous advantages, like small sizes, high sensitivities in detecting low concentrations of a wide range of gaseous chemical compounds, possibility of online operation and, due to possible bench production at low cost. Thus, an Ambient Air Quality Monitoring Instrument is designed and built using solid state gas sensors, GPS module and GSM Receiver and Internet for real time mobile monitoring of air pollutants.

LITERATURE REVIEW

In the recent literature, the air pollution systems that utilize sensor array networks and wireless systems have been reported. Recent technological developments in the miniaturization of electronics and wireless communication technology have led to the emergence of environmental sensor networks. According to Tajne, K.M. et al the sensors will greatly enhance monitoring of the natural environment and in some cases open up new technology for taking measurements or allow previously impossible deployments of sensors [3]. The environmental air pollution monitoring system has been implemented by Kularatna, N. and Sudantha, B.H. with the three main functional blocks, the smart transducer interface module (STIM), the network capable application processor (NCAP) and the transducer independent interface (TII) for measuring air pollutants CO, NO_2, SO_2 and O_3 [4].

Kwon, J.W. et al have developed an outdoor air pollution monitoring system using ZigBee networks. This system integrates a wireless sensor board which employs dust, CO2, temperature, and humidity sensors. Its monitoring range is 270 m [5]. Abujayyab, M. et al have proposed an abstract model of a system based on long- range wireless communication [6].

A wireless sensor system for real-time monitoring of toxic environmental volatile organic compounds was developed by F. Tsow et al. This system is based on a smart sensor micro converter equipped with a network capable application processor that downloads the pollutants level to personal computer for further processing [7]. Jung, Y.J. et al have installed an air pollution geo-sensor network consisting of 24 sensors and 10 routers to monitor several air pollutants [8]. Raja Vara Prasad, Y. et al have formed multi-hop mesh network with the array of pre- calibrated sensors interfacing with the wireless sensors motes and have been developed a light weight middleware and web based interface for online monitoring of the data in the form of charts from anywhere on internet [9].

METHODOLOGY

The above air quality monitoring systems are based on sensors that report the pollutants levels to a server via wired modem, router, or short-range wireless access points. In this paper, the authors propose a system that integrates an ARM-7 Processor with single-chip microcontroller, solid state air pollution sensors (CO_2, CO, NO), a Geographical Positioning System (GPS) module and a PDA connected with a GSM-Receiver. The integrated unit is an ambient air quality monitoring instrument that utilizes the wireless networks for public view. The photograph showing the AAQMI is shown in figure 1. The table 1 shows the specifications of the sensors used in the air quality monitoring instrument.

Table I
Specifications Of The Sensors Used In The Ambient Air Quality Monitoring Instrument

Sensor	**CO_2 (ppm)**	**CO (ppm)**	**NO (ppm)**
Resolution (ppm)	<1.5	<1.5	<0.02
Resp. time (t90) (s)	<25	<25	<60
Operating range (ppm)	350 - 10000	0 - 1000	0 - 20
Operating life (yrs)	>2	>2	>2
Diameter in mm	20	20	20

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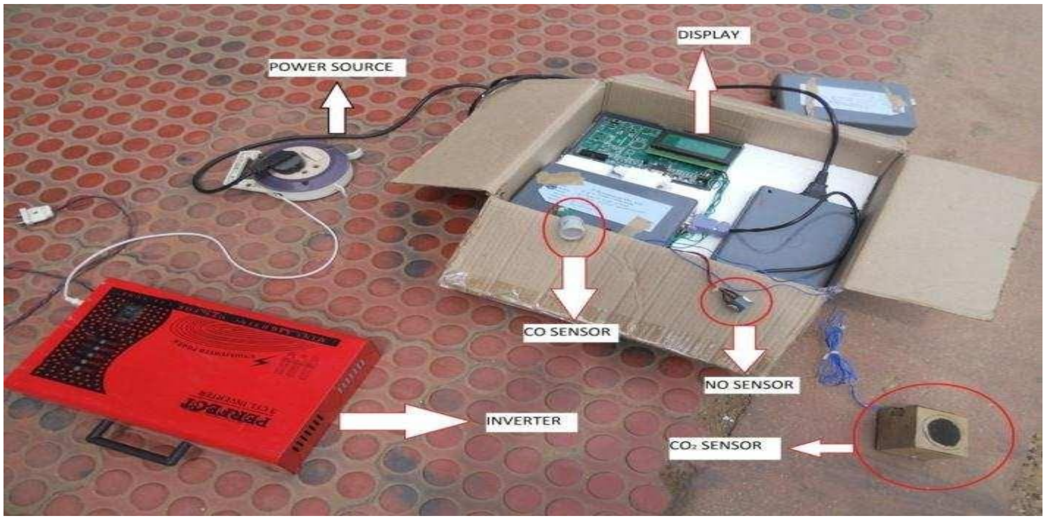

Figure1. A Photograph showing the AAQMI

The unit can be placed on the top of any moving vehicle such as a public transportation vehicles or private vehicles.

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 Global System for Mobile communications (GSM) Receiver and transmitted to the Pollution-Server via Internet.

A database server is attached to the Pollution-Server for storing the pollutants level for further usage by interested clients such as environment protection agencies, vehicles regeneration authorities, tourist and insurance companies and public. The Pollution-Server is interfaced to Google maps to display locations of monitoring places, the table with time and pollutant concentrations and the graph showing the intensity of pollutant levels. One such display depicting the monitoring places, date, pollution table with timings and the graph is shown in figure 2.

I. Hardware Architecture

The AAQMI is designed and made by integrating the following hardware modules which are shown in figure 3. The ARM-7 processor is integrated with sensors using analog ports and GPS receiver. This unit is connected to the personal digital assistant using the RS-232 interface. The GSM Receiver is connected to the PDA for transmitting data to the internet. Each of these components are described below.

A. *ARM-7 Processer*

The ARM-7 processor LPC2129 is the core of the pollution monitoring system. It is a member of the Advanced RISC Machines (ARM) family of general purpose 32-bit microprocessors. The LPC2129 is a high performance, low power device and widely used for wireless embedded systems.

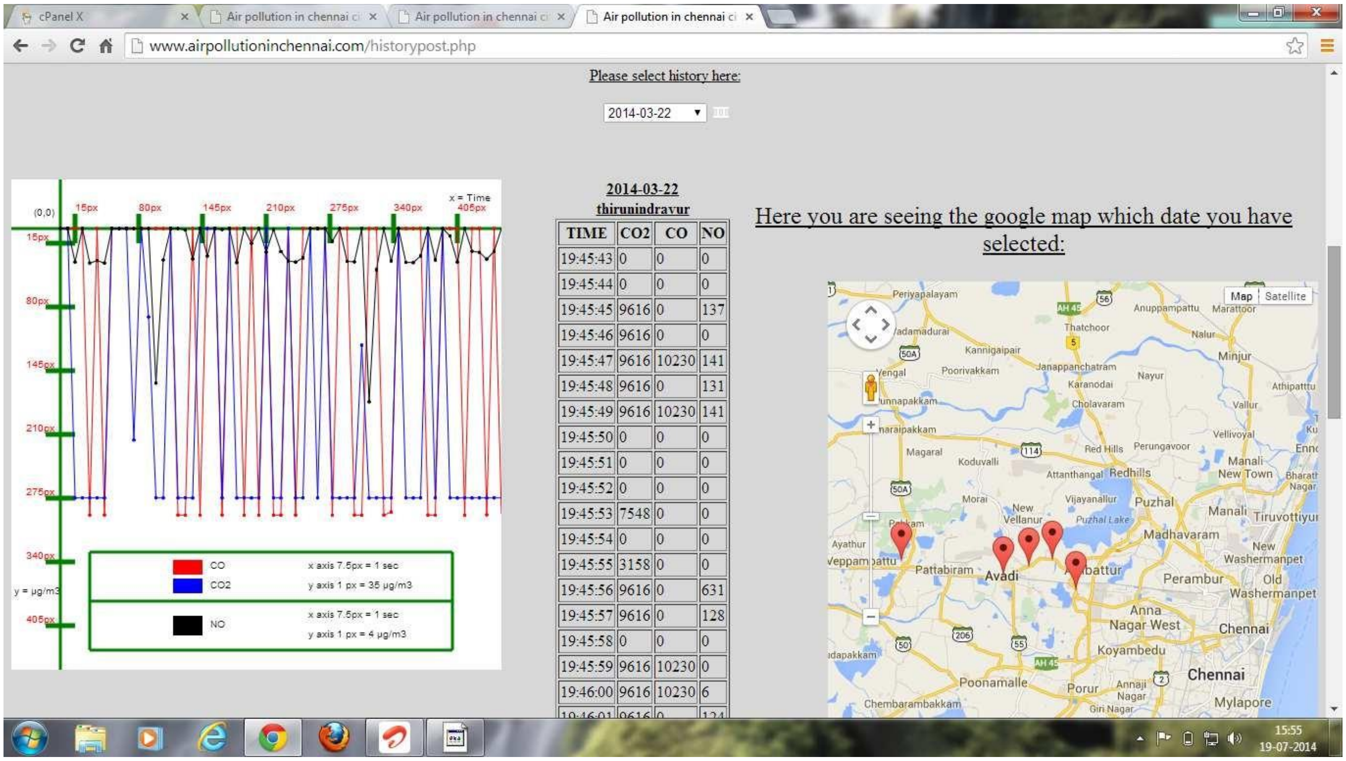

Figure2. Website page showing the monitored data in the form of table, location and graphical view of pollutants concentrations

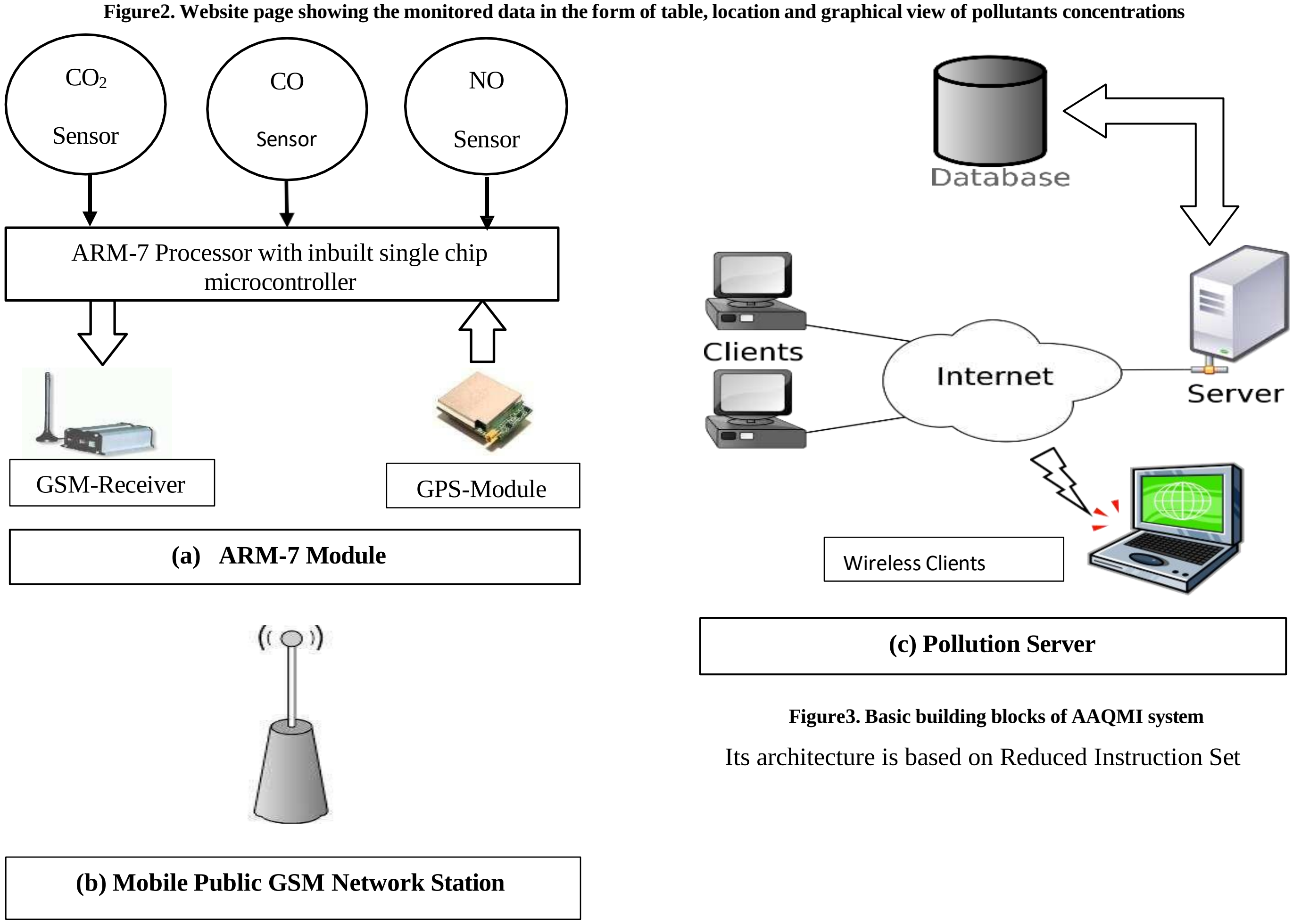

Figure3. Basic building blocks of AAQMI system

Its architecture is based on Reduced Instruction Set

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B. GPS Module

The GPS module provides the physical coordinate location of the mobile air quality monitoring instrument, date and time in National Marine Electronics Association (NMEA) format. The GPS module gives position of AAQMI in latitude and longitude. The GPS modem is interfaced with the microcontroller using the RS-232 communication standard.

C. Solid State Gas Sensors

The sensor array consists of three air pollutant sensors including Carbon Dioxide (CO_2), Carbon Monoxide (CO) and Nitric Oxide (NO). As Table I shows, the resolution of these sensors is sufficient for pollution monitoring. Each of the above sensors has a linear current output in the range of 4 mA–20 mA. The 4 mA output corresponds to zero-level gas and the 20 mA corresponds to the maximum gas level. A simple signal conditioning circuit was designed to convert the 4 mA–20 mA range into 0–5 V to be compatible with the voltage range of the built-in analog-to- digital converter in the 16-bit single chip microcontroller described earlier.

D. GSM Receiver

The general packet radio service (GPRS) is used in 2G and 3G cellular communication systems. The proposed GSM Receiver uses a GPRS as a communication device to transmit time, date, physical location and concentration of air pollutants. The Receiver used for the proposed system has an embedded communication protocol that supports Machine-to-Machine (M2M) intelligent wireless Transmission Control Protocol (TCP/IP) features such as Simple Mail Transfer (SMTP) E-mail, File Transfer Protocol (FTP), and Simple Messaging Service (SMS) services Protocol. The GSM Receiver supports an RS-232 interface that allows Serial TCP/IP socket tunneling.

E. Pollution Server

The Pollution-Server is a standard personal computer with accessibility to the Internet. The Pollution-Server connects the GSM Receiver via TCP/IP through the Internet. The server requires a private IP address for the GSM Receiver and communicates over a pre-configured port. The Pollution-Server connects to a database management system (MySQL) through a local area network (LAN). The Pollution-Server runs a WampServer stack that provides the Apache Web Server in addition to the PHP Server-side scripting language.

Clients such as the environmental protection agencies, insurance companies, tourist companies and public can connect to the Pollution-Server through the Internet and check the real-time air pollutants level using a normal browser on a standard PC or a mobile device.

II. Software Architecture

The system software architecture consists of two layers: physical layer and application layer.

A. *Physical Layer*

This layer is responsible for acquiring the real-time data from the sensors and the physical location, time and date of the sampled pollutants from the GPS module. This information is then encapsulated into a data frame by the microcontroller. The microcontroller then sends each frame to the GSM Receiver through the RS-232 interface. The GSM Receiver, in turn, sends each data frame to the Pollution-Server using the publicly available mobile network and the Internet. The physical layer is implemented using ANSI C language which is compiled to native microcontroller code. The software implementing the physical layer is composed of various functions, are called from a main program that is stored on and executed by the ARM-7 Processor.

B. *Application Layer*

The application layer designed to consist three modules namely *Pollution-Server*, *Graphical display of pollution levels and Google-Map showing the location of monitoring.* The function of Pollution-Server is to collect and store pollutant data from the ARM-7 module, while the Graph displays the pollutants' concentrations against time and the Google-Map shows the places monitored. The figure 2 shows the CO2, CO and NO readings from one of the locations observed at Thiruninravur of Chennai metropolitan in the form of table and graphical display and the locations are shown in the Google-map.

III. Implementation And Testing

The Tamil Nadu Pollution Control Board (TNPCB) in Chennai city has been monitoring air quality since 2001. Their current system of monitoring is based on five static monitoring stations located in Chennai city area. These stations are used for collecting air samples and analyse its concentration levels at their established laboratories and the data is centrally made available in the internet to the public through their Web site (cpcb.nic.in).

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This system has worked well. However, the data collected is limited to the vicinity of the five monitoring stations. But, a mobile real time monitoring system AAQMI built based on the hardware and software architecture described earlier is tested in the Chennai city, proved to be viable for monitoring to cover larger urban areas.

The designed sensor array consisting of CO2, CO and NO was interfaced through a sensor signal conditioners through analogue channels to the single chip microcontroller are as shown in figure 3. The GPS module is connected to COM0 and the GSM-Receiver is connected to COM1 of the microcontroller. The AAQMI was mounted on a car and that was driven from Avadi to Thiruvallur to collect pollutant data. The pollutant data was collected for 1 hr. The figure 3 shows how a user can use the Internet to access pollutant levels in a location covered by the mobile AAQMI mounted on a vehicle. As the figure 2 shows, Google Map is used as the primary interface of location, pollutants data is shown using table and the graph is used to show concentration of the various pollutants' against time.

CONCLUSION

A mobile air quality tracking system that works in real time was designed and built. It has solid state gas sensors, sensor signal filters, and a GPS module that connect to an ARM-7 processor and measure the amounts of different air pollutants. The GPS feature tells you the date, time, and your location's latitude and longitude. The AAQMI device can be put on a car to measure the levels of CO2, CO, and NO in the air. Pollution data from many mobile sensor networks is sent to a central server. This server then makes the data public on the Internet through a Google Maps interface. The numbers show the amounts of pollution and how well they meet area guidelines for air quality. The Ambient Air Quality Monitoring Instrument method needs a lot more work before it can be sold to the public.

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