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AIR POLLUTION MONITORING SYSTEM USING MOBILE GPRS SENSORS

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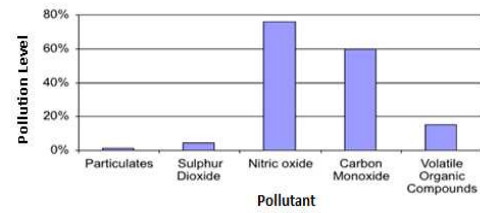
Abstract

This paper contains a brief introduction to vehicular pollution, effect of increase in vehicular pollution on environment as well as on human health. To monitor this pollution a wireless sensor network (WSN) system is proposed. The proposed 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, an 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 pollutant 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 pollutant level for further usage by various clients such as environment protection agencies, vehicle registration authorities, and tourist and insurance companies.

I. Introduction

Air Pollution Is A Major Environmental Health Problem Affecting The Developing And The Developed Countries Alike. The Effects Of Air Pollution On Health Are Very Complex As There Are Many Different SOURCES And Their Individual Effects Vary From One To The Other.

These Chemicals Cause A Variety Of Human And Environmental Health Problems. Increased Car Ownership (Road Traffic) Generates Some Chemical Emissions To The Air To Form Air Pollution. With Various Weather Conditions (Effected By Temperature, Wind, Humidity, Pressure, Etc) These Pollutants Pose Different Air Qualities. When Human Being Exposed To The Polluted Air(Especially Urban Areas),Driving In The Heavy Traffic Near The Highways Or At The Downwind Location With The Dose Response, People May Suffer Breathing Problems And Asthma Attacks, Which Will Contribute To Risk Of Heart Attack Among People With Heart Disease. Graph1. Shows The Vehicles Contribution To Air Pollution Problems.



Graph1. Vehicles Contribution to Air Pollution

ii. System Design

Proposed Methods Of Monitoring Air Pollution Which Contains Wireless Sensors Array, Single Chip Microcontroller, Gps Module, Gprs-Modem, Pollution Server.

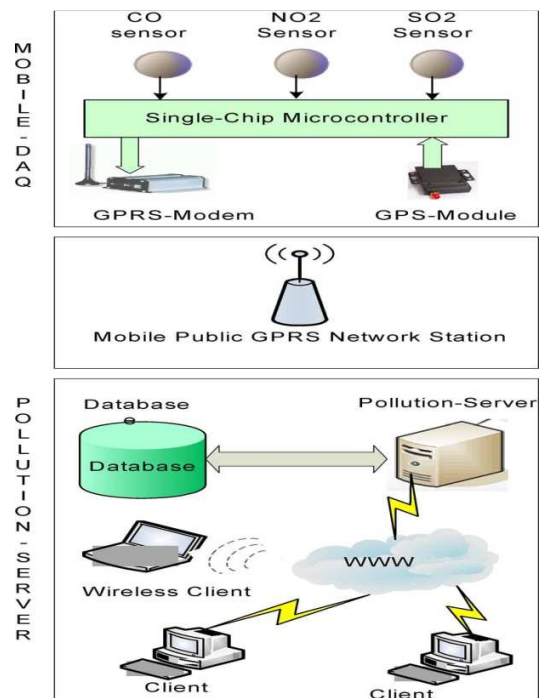


Fig.1. System Hardware Basic Blocks.

Table.1.Sensor Array Specifications

Sensor	CO	NO2	SO2
Resolution (ppm)	<1.5	<0.02	<0.1
Resp. time (t90) (s)	<25	<60	<25
Op. range (ppm)	0-1000	0-20	0-20
Operating life (yrs)	> 2	> 2	>2
Diameter (mm)	20	20	20

Wireless Sensor Array

The Array Of Sensor Consists Of Three Air Pollutions Sensors Including Carbon Monoxide (Co), Nitrogen Dioxide (No2), And Sulphur Dioxide (So2) [10].As Table 1 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 8/Bit Single Chip Microcontroller.

Single-Chip Microcontroller

The Microcontroller Is A Single-Chip Device That Has Rich Built-In Resources For Digital Input/Output Ports, 16 Channels, 8/10 Bits

Analog-To-Digital Converter, 8 Input/output Interrupt-Driven Timers, 12 Kbytes Of Ram, 1024 Bytes Of Eeprom, Two Rs-232 Serial Communication Ports, 4 Control Area Networks Ports, And Spi Communication Ports [9]. These Resources Are More Than Enough For The Proposed Application.

Gps Module

The Data Packet From The Gps-Module Includes An Rms Header Followed By Utc Time, Data Validity Checksum, Latitude, Longitude, Velocity, Heading, Date, Magnetic Variation And Direction, Mode, And Checksum. The Only Information Required For The Proposed System Is Date, Time, Latitude And Longitude. The Gps Modem Is Interfaced With The Microcontroller Using The Rs-232 Communication Standard.

The Gps Module Provides The Physical Coordinate Location Of The Mobile-Daq, Time And Date In National Marine Electronics Association (Nmea) Format [11]. Nema Format Includes The Complete Position, Velocity, And Time Computed By A

Gps Receiver Where The Position Is Given In Latitude And Longitude [12].

Gprs Modem

The Proposed System Uses A Gprs-Modem As A Communication Device To Transmit Time, Date, Physical Location And Level Of Air Pollutants. The Modem 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 Modem Supports An Rs-232 Interface That Allows Serial Tcp/Ip Socket Tunnelling. The Modem Also Has Rugged Aluminium Enclosure Making It Suitable For The Proposed System [12]. The General Packet Radio Service (Gprs) Is A Packet-Oriented Mobile Data Service Used In 2g And 3g Cellular Communication Systems Global System For Mobile Communications (Gsm).

Pollution Server

The Pollution-Server Is Standard Personal Computer With Accessibility To The Internet. As Fig. 1 Shows, The Pollution-Server Connects To The Gprs-Modem Via Tcp/Ip Through The Internet And The Public Mobile Network. The Server Requires A Private Ip Address For The Gprs-Modem And Communicates Over A Preconfigured Port. The Pollution-Server Connects To A Database Management System (Mysql) Through A Local Area Network (Lan). The Pollution-Server Runs A Wampserver [13] Stack That Provides The Apache Web Server In Addition To The Php Server-Side Scripting Language.

Clients Such As The Municipality, Environmental Protection Agencies, Travel Agencies, Insurance Companies And Tourist Companies 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. The Pollution-Server Can Be Physically Located At The Environmental Protection Agency (Epa) Or Similar Government Agencies.

Unit-ID	Pollution-Server IP-Address	Pollution-Server Port #	Time	Date
Latitude	Longitude	CO-Level	NO ₂ -Level	SO ₂ -level

Fig 2. Data-Frame Format

iii. Software Design

The System Software Architecture Is Having Five Different Functions. This Function Is Responsible For Acquiring The Real-Time Data From The Sensors-Array 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 Gprs-Modem Through The Rs-232 Interface. The Gprs-Modem, 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 Five Functions, Namely:

Ports read()Function, Sensor:

Acquisition () Function, Gps-Read()Function, Data-Frame () Function, And Gprs-Transit () Function. Are Called From A Main

Program That Is Stored On And Executed By The Mobile-Daq Microcontroller.

Ports-Read()Function :

Developed To Configure The Digital Inputs/Outputs In Addition To The Resolution Of The Analog-To-Digital Converters That Read The Air Pollutants Level From Sensor Array Outputs.

Sensor-Acquisition () Function:

Reads Each Pollutant Level As A Voltage From The Signal Conditioning Circuit Output Via The Built-In Analog-To-Digital Converter Module Of The Microcontroller.

Gps-Read()Function :

Communicates With The Gps Module Through Rs-232 And Extracts Latitude And Longitude Of The Sampled Air Pollutant Along With Time And The Date.

Data-Frame() Function :

Encapsulates The Ip Address Of The Pollution Server, A Port Number, The Three Pollutants Levels, Latitude And Longitude Of The Sampled Location, And Time And Date Of The When The Samples Were Taken. The Data Frame Is Shown In Fig.

Gprs-Transit() Function :

Selectively Sends The Data Frame To The Gprs-Modem Using The Rs-232 Interface N Port. This Frame Is Sent According To The Algorithm Shown In Fig 2. As The Figure Shows, A Data Frame Is Only Transmitted If The Pollutant’s Level Has Changed Since The Last Reading.

The Implementation Stage Consists Of Three Primary Modules: Pollution-Server, Air-Pollution-Index, And Google Mapper. Pollution-Server Collects and Stores Pollutant Data from All The Mobile-Daqs. Air Pollution-Index Calculates Pollution Categories Based On Local Pollution Policies And Regulations. Air-Pollution-Index Function to Convert the Raw Pollutant Level Received from Each Mobile-Daq to Pollution Standards Called Air Quality Index (Aqi)

Using The Formula [14] .Finally, Google Mapper, Makes This Pollution Information Available Over The Internet.

$$Aqi = \left(\frac{\text{Pollution Level}}{\text{Pollution Standard}} \right) * 100$$

Table..2.Air Quality Description

Index	Air Quality Description	Band
0-100	Clean Air	Green
101-125	Light Pollution	Yellow
126-150	Significant Pollution	Orange
150 above	Heavy Pollution	Purple

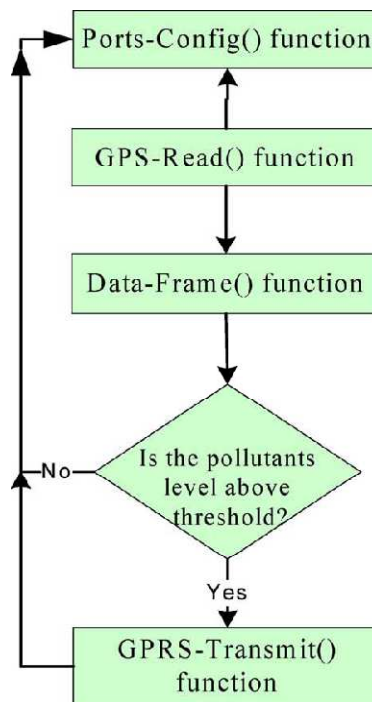


Fig. 3.Mobile-Daq Software Algorithm.



Fig. 4. Google Mapper Data

Iv. Implementation And Testing

The Environment Protection And Safety Section (Epss) In Dubai Has Monitored Air Quality Since 1988 [14]. Their Current System Is Based On Six Static Monitoring Stations Located Around The Dubai Metropolitan Area. These Stations Send Air Pollutant Data To A Central Server Using Fixed Line Modem Connections. The Pollution Data Is Also Available To The Public Through Their Web Site. This System Has Worked Well. However, The Data Collected Is Limited To The Vicinity Of The Six Monitoring Stations. Consequently, A Mobile System Based On The Hardware And Software Architecture Described Earlier Was Built And Tested In The Uae.

The Designed Sensor Array Consisting Of Co, No₂, And So₂ Was Interfaced Through A Signal Conditioning Circuit Through Analogue Channels 5, 6, And 7 Of The Hcs12 Microcontroller. The Sensor Output Voltages Representing The Level Of Gas For Each Pollutant (V_g) Were Converted To A Ppm Value For Each Gas. The Gps Module Was Connected To Com0 And The Gprs-Modem Was Connected To Com1 Of The Microcontroller. Fig.2 Shows A Typical Data Frame Format Being Transmitted From Gprs-Modem To The Pollution-Server. The Mobile-Daq Was Mounted On A University Bus That Was Driven Around The Campus Of The American University Of Sharjah (Aus) To Collect Pollutant Data. The Mobile-Daq Was Mounted On Top Front Of The Bus To Avoid Contamination From The Bus Exhaust. The Pollutant Data Was Collected For 12 H. Fig. 4 Shows How A User Can Use The Internet To Access Pollutant Levels In A Location Covered By The Bus. As The Figure Shows, Google Maps Is Used As The Primary Interface. Pollutant Data Is Shown Using Different Coloured Polygons That Are Superimposed On The Map. The Colour

Code Used For These Polygons Was Consistent With The Aqi Index Of The Dubai Municipality. As The Figure Shows, Different Areas Within The American University Of Sharjah Campus Have Different Levels Of Pollutants. The Yellow Polygon Shows Light Pollution While The Green Polygons Show Clean Air According To The Aqi Index. As Fig.5 Shows, A User Can Click Any Of The Polygons To Retrieve Details Of The Various Pollutant Levels. A User Can Further Drill Down By Clicking To View The Past Data For Any Of The Gases For This Location. For Example, Fig.6 Shows The History Of Co Pollutant For The Last Seven Readings Over An 8 H Period For A Given Day.

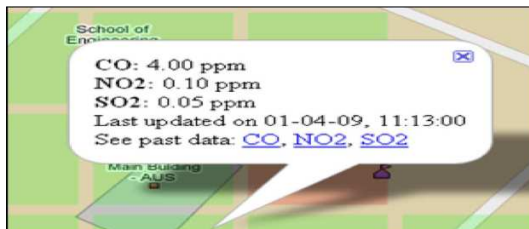


Fig 5. Details Of Pollutant Data



Fig. 6. History Of Co Pollutant

V. Conclusion

Real Time Information About The Level Of Air Pollution For Given Regions, As Well As Provides Alerts In Cases Of Drastic Change In Quality Of Air Provides By The Proposed Wireless Air Pollution Monitoring System. This Information Can Then Be Used By The Authorities To Take Prompt Actions Such As Evacuating People Or Sending Emergency Response Team. A Wireless Distributed Mobile Air Pollution Monitoring System Was Implemented Using The Gprs Public Network Along With Gps. The System Utilizes City Buses To Collect Pollutant Gases Such As Co, No2, And So2. The Pollution Data From Various Mobile Sensor Arrays Is Transmitted To A Central Server That Make This Data Available On The Internet Through A Google Maps Interface. The Data Shows The Pollutant Levels And

Their Conformance To Local Air Quality Standards.

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