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Client Server Model Based DAQ System for Real-Time Air Pollution Monitoring

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ABSTRACT
The proposed system consists of client server model based Data-Acquisition Unit. The Embedded Web Server integrates Pollution Server and DAQ that collects air Pollutants levels (CO, NO2, and SO2). The Pollution Server is designed by considering modern resource constrained embedded systems. In contrast, an application server is designed to the efficient execution of programs and scripts for supporting the construction of various applications. While a pollution server mainly deals with sending HTML for display in a web browser on the client terminal, an application server provides access to server side logic for pollutants levels to be use by client application programs. The Embedded Web Server is an arm mcb2300 board with internet connectivity and acts as air pollution server as this standalone device gathers air pollutants levels and as a Server. Embedded Web server is accessed by various clients.
Keywords **-** Air Pollution, Embedded System, GPS, GPRS, Web Server

I. INTRODUCTION

Many air pollution monitoring systems were reported in recent literature. A wireless mesh network based on embedded microprocessors consisting of multiple sensors and multihop wireless communication is designed to cover a geographic area in [1]. The system monitors and transmits parameters atmospheric environment to a command center. Another wireless sensor network system was developed to monitor indoor air quality in [2]. The indoor environmental parameters were monitored and transferred to a client personal computer or personal digital assistant (PDA) using an RF transmitter. An outdoor air pollution monitoring system using ZigBee networks for ubiquitous-cities was reported in [3]. The system integrates a wireless sensor board which employs dust, CO2, temperature, and humidity sensors. The system's monitoring range is 270 m [3]. An abstract model of a system based on long-range wireless communication was proposed in [4].

All of the available Air pollution monitoring systems in urban and rural areas that measures CO, NO2, and SO2 are based on communication via wired modem, router, or short-range wireless access points. In this paper, we propose a Real-time Embedded System that acts as a DAQ and Web Server. The mobility of Embedded Web Server is attained by using GSM/GPRS modem for connectivity with internet through mobile networks, and a GPS module for location information of Web Server [5]. The whole setup is placed on a moving vehicle in the city in which pollutant data has to be collected. The System responds to client requests by providing acquired air pollutant level from the sensors and location information that is extracted from GPS module. The FTP Server is interfaced to Google maps to display real-time pollutants levels and their locations in the city. These data can be used by the environment protection agencies for the real-time air pollution data collection in the city.

The rest of the paper is organized as follows. Section II we describe the system requirements. Section III we will introduce the details of the aforementioned system. Section IV we will describe the Embedded Web Server Testing and the results. Finally, the conclusion is presented in Section V.

II. SYSTEM REQUIREMENTS

A system can be characterized according to its functional and nonfunctional requirements. Functional requirements describe the primary functionality of a system while nonfunctional requirements describe attributes like reliability and security, etc. The system's functional requirements are as follows.

- System must support accurate and continuous real-time data collection.
- System needs to store the data and provide access to a location map interface.
- System needs to support mobility.
- System must use minimum power.
- System must be accessible from the Internet 24/7.
- System must be compact.
- System must mostly use off-the-shelf devices, components, and standards.

- System must support two-way communication between the client and the server.
- System must be field-configurable.
- System should be easy to deploy.

Nonfunctional requirements for the system dictate that the system is reliable, portable, accurate, maintainable, secure, accessible, and usable. In addition, the system must support performance standards for an adequate response time and storage space for data.

III. REAL-TIME DATA ACQUISITION SYSTEM

Real-time data acquisition system provides a way to monitor the air pollution level in the city using standard web browsers and a PC used by clients. The Web Server is connected with GPRS/GSM modem for wireless connectivity to internet and provides positional information of the Web Server. Digitally acquired Pollutants levels are stored in web server's database. This data is provided to the client, through internet whenever a request is made by the client. The web processes the requests made by the clients and finally connects to the desired Web Server, sends the Pollutants levels to the client browser.

A. Embedded Web Server

An embedded web server is a keil MCB2300 Evaluation Board from NXP LPC2300 ARM family and allows to create and test working programs for this advanced architecture. It has two serial interfaces, analog input, a speaker, two CAN interfaces, USB, LCD, Ethernet makes this board a good platform for our System. MCB2300 Evaluation Board can be expanded to build hardware prototypes for our applications. The Embedded web server also has application software created using MDK-ARM, a complete software development environment for ARM processor-based devices.

Application software has an script to convert the raw pollutant level received from each sensors to pollution standards called air quality index (AQI) using the formula.

$$\mathrm{AQI} = \left(\frac{\text{Pollution level}}{\text{Pollution Standard}} \right) * 100 \qquad (1)$$

The pollution standard is defined according the air quality standards of a particular region.

ARM processor is the responsible part for measuring analyzing air pollutants from sensor nodes. The Measurements are carried out by DAQ mode and the data are sent to client through Embedded Web Server mode is depicted in fig. 1. The RTOS manages all the tasks such as measuring signals, analyze the signals, data base up-dation, sending HTML pages to the clients upon request etc., The RTOS manages the allocation of Processor and Memory for all the tasks in parallel and in small amounts of time. Embedded web server has to be high reliable, secure, portable and controllable for which general web server are unsuitable.

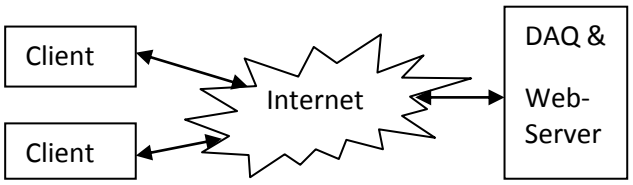

Fig. 1. System Architecture

B. Client-Server Communication Link

The GSM/GPRS modem allows our Embedded Web Server to establish connection to the Internet. The general packet radio service is a packet-oriented mobile data service used in 2G and 3G cellular communication systems global system for mobile Communications. The GSM/GPRS modem has an embedded communication protocol that supports Machine-to-Machine intelligent wireless Transmission Control Protocol features such as E-mail, Simple Messaging Service, and File Transfer Protocol. The modem supports an RS-232 interface that allows serial TCP/IP socket tunneling. All service provides on GSM are giving GPRS service to customers that eases getting connected to the Internet is shown in fig. 2. The pollutants data queried by the client can be relayed once a GPRS connection has been established with the client.

The real-time processing is attained by having quick respond to the client queries by the server. Real time should be fast enough in the context in which the system is operating and reliable as well for mission critical systems. Real-time system correctness depends not only on the correctness of the logical result of the computation but also on the result delivery time [6]. A script is executed immediately after the boot of the operating system, initiating the GSM/GPRS connection software module. A Point to Point Protocol (PPP) connection is established by a GPRS, PPP daemon is used to manage the PPP network connections between the client and the Embedded Web Server module.

The PPP daemon setting up the GPRS parameters, such as baud rate and compression. To access an Embedded Web Server, the IP address of the device should be made available to the clients. We can accomplish this in two ways. A static IP could be used, or the remote device should initiate a connection by reporting its IP. The static IP is preferred for its simplicity however, its overhead may be impractical as it requires a static IP setup by the service provider and involves monthly recurring costs. The other choice is to assign dynamic IP by means of Dynamic Host Configuration Protocol (DHCP) server of the GSM provider for every connection established.

However, this IP also needs to be known by any client requesting Pollutant level to the Embedded Web Server.

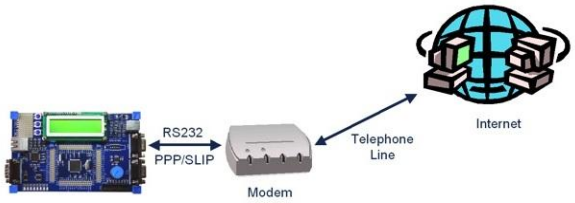

Fig. 2. Modem Connection to Internet

To resolve this problem we used FTP server as a dummy server to broadcast this IP to the client and does not require regular software updates or maintenance. A script on the Embedded Web Server is configured to update its static IP address on the FTP server as an index.htm file using Hypertext Meta-Language, under a folder named by its unique hostname. This script parses the current static IP for that Embedded Web Server and sends an html file with the static IP information of the device to the FTP server. As the index.htm file contains updated static IP addresses of devices, a direct connection can be established with the Embedded Web Server by a simple query.

The Dynamic Host Configuration Protocol approach is more cost-effective solution, as the static IP broadcasting to the FTP server is done only once by the Embedded Web Server. The hypertext file placed on the FTP server will be updated by the Embedded Web Server upon every reboot, thus this method reduces the overhead of running script on the embedded device, reduces the power consumption of the device and in turn reduces the heat generation of processor and reduces the boot time of the system. A PHP program running on the Apache web-server which is installed on FTP Server reads the pollutant data from the mySQL database attached to the FTP Server and plots it on a Google Map using the Google Map API is shown in Fig. 4. In specific, an instance of a GMap object for each client request is created in Map using a JavaScript call. In addition to that a GPolygon object based on pollutant and the latitude, longitude is created for each region in the Map. The color of polygon is based on the pollution category as calculated by the Air Pollution Index (API) script.

C. Air Pollutant Data Management

The embedded Web Server receives the pollutant levels from the sensors (CO, NO2 and SO2) by executing script upon each HTML request from client and also collects information from GPS module through RS-232 communication by extracting the latitude and longitude of the device, sampled date and time. This data is also stored in mySQL database connected to FTP Server.

D. Hardware Requirements

The hardware setup for the remote DAQ system based on ARM processor is shown in fig. 3. The remote DAQ based on embedded ARM platform uses Keil MCB2300 Evaluation Boards that allows us to generate and test application programs for the NXP LPC23xx device family. With this hands-on process, one can determine the hardware and software requirements for current and future product development. The MCB2370 board uses the NXP LPC2378 microcontroller which has a larger package size and pin count than the NXP LPC2368 or LPC2387 [10].

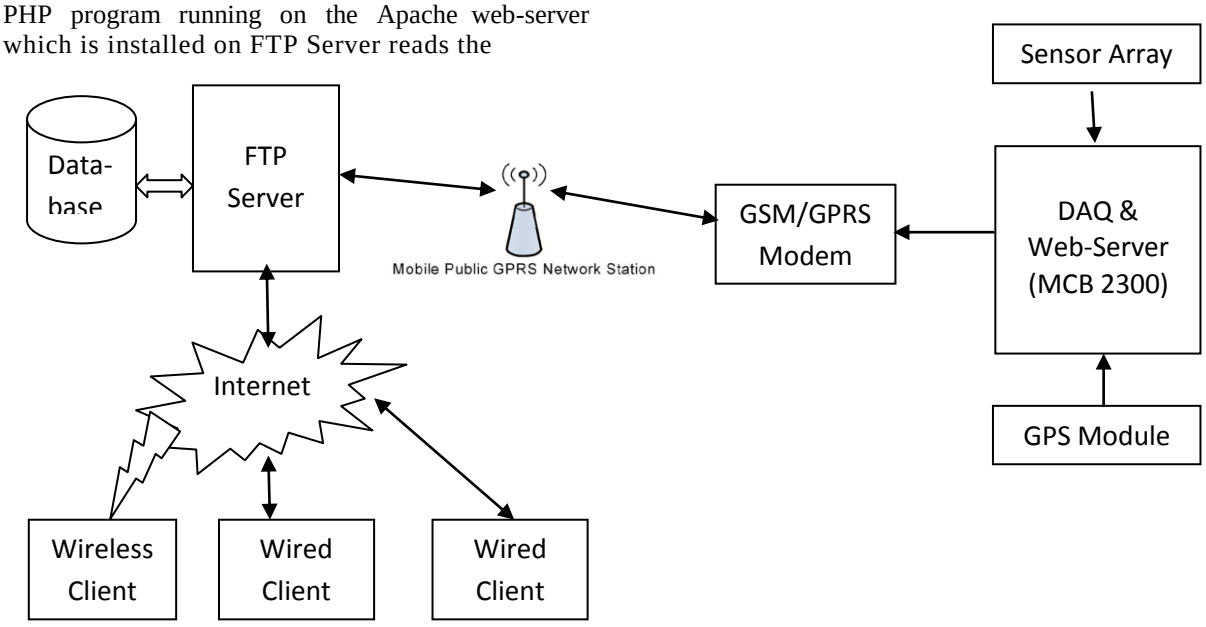

Fig. 3. System hardware basic building blocks

The connectors on the MCB2300 evaluation board provide easy access to many of the on-chip peripherals. The evaluation board supports Dual Serial Ports using Standard DB9 connectors that are on the MCB2300 for both of the LPC2300's serial ports. Web Server uses one port for GSM/GPRS modem connection and another for GPS device. An adjustable analog voltage source is on the MCB2300 board for testing the Analog to Digital output feature of the LPC2300. A configuration jumper enables and disables this feature. A JTAG interface is on the MCB2300 board and, coupled with the ULINK USB-JTAG adapter, allows flash programming. The on-chip debug interface can perform real-time in-circuit emulation of the LPC2300 device.

E. Sensors Array

The sensor array consists of three air pollutions sensors in-cluding Carbon Monoxide (CO), Nitrogen Dioxide (NO2), and Sulfur Dioxide (SO2) [7].

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

TABLE I
SENSOR ARRAY SPECIFICATION [7]

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

compatible with the voltage range of the built-in analog-to-dig-ital converter in the 16-bit single chip microcontroller described earlier.

F. GPS Module

The GPS module provides the physical coordinate location of the mobile-DAQ, time and date in National Marine Electronics Association (NMEA) format [8]. NEMA format includes the complete position, velocity, and time computed by a GPS receiver where the position is given in latitude and longitude [8].

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.

G. GPRS-Modem

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). 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 tunneling. The modem also has rugged aluminum en-closure making it suitable for the proposed system [9].

H. Software and Operating System choice

The Real-time DAQ system uses Keil RTX a royalty-free, deterministic Real-Time Operating System designed for ARM and Cortex-M devices [11]. It allows us to create programs that simultaneously perform multiple functions and helps to create applications which are better structured and more easily maintained. Keil also provides middleware libraries like the full TCP/IP Networking Suite which is specifically written for small, ARM and Cortex-M processor-based microcontrollers. It is highly optimized, has a small code footprint, and gives excellent performance. This library provides Full support for TCP/IP, and UDP protocols and Physical layer support for Ethernet and serial (PPP & SLIP), also Includes Common networking applications.

IV. TESTING EMBEDDED WEB SERVER

The Embedded Web Server is implemented and tested for real time DAQ of air pollutant levels. The Server is booted with RTX, DHCP server assigns IP address to the Server. The IP address is updated in FTP server. After successful booting, the Server connection establishment with client is tested by ping command. Now and HTTP request is made by the client by typing the IP address of the Embedded Web Server in browser Address bar. The server collects pollutant level by running script and also extracts latitude and longitude information from the GPS module and respond to the client. These details are displayed in the clients Browser is shown in Fig. 5.

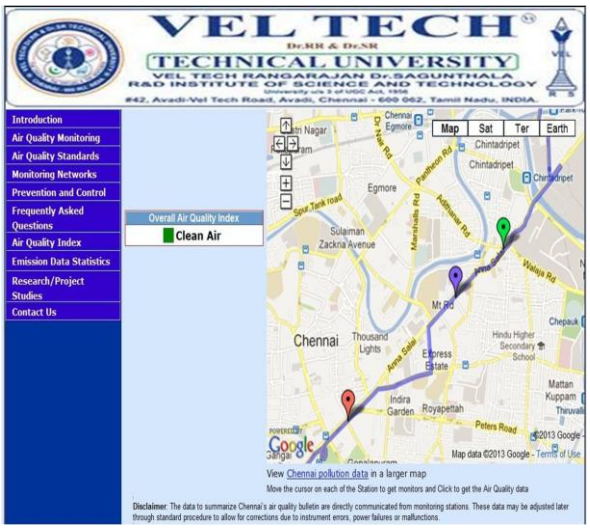

Fig. 4. Google Map Interface

Fig 5. Google Map showing Actual pollutant level

V. CONCLUSION

In this application, a wireless distributed real-time air pollution monitoring system was designed and tested using the GPRS public network. The system collects pollutant gases such as CO, NO2, and SO2. The pollution data from various mobile DAQ is sent to client upon request via FTP Server, a direct bidirectional communication thus reducing overhead. The FTP server reduces the operational costs by relinquish the storage of large data in it. The pollutant data is made available to clients on the Internet through a Google Maps interface. The data shows the air pollutant level based on the local air quality standards.

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