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Developing Web of Things Application for Wireless Sensor Network Based Vehicular Pollution Monitoring

Aijaz Ahmad Reshi, Shabana Shafi and A. Kumaravel

Bharath University Chennai, India

Abstract: The strength of sensor networks is quite vast when it is applied for collecting physical data in real time and storing for further analysis. The impossible measurements by conventional methods have now become possible by using this technology. Air quality which is one of the most important factors for the sustainable development and is one of the challenging areas researchers dealt with long time. The major source of environment pollution happens to be Vehicular Pollution. The high influx of vehicles to urban areas and conventional pollution control measures used by concerned agencies has led to the drastic increase of air pollution. Here we address this problem by introducing a WSN based Vehicular pollution monitoring platform which is capable of measuring different types of pollutant concentrations contained in smoke produced by the vehicle and reports the status automatically whenever required to the concerned agencies. We assure the existence of Wireless Sensor Network platform for automobile pollution control focusing on an easy accessibility of real time data via the Web by following the Web of Things approach. This will form a basis to connect each vehicle as an entity for a web of things infrastructure enabling the direct interaction with existing web applications of the concerned agencies. The real time data will be available to three main groups of users: Owner of the Vehicle, Traffic department and national environmental agencies.

Key words: Wireless Sensor Network · Web of Things · GPRS · GPS

INTRODUCTION

Vehicles are a major source of pollution in urban areas. The drastic increase in number of vehicles has also resulted in a significant increase in the emission load of various pollutants [1]. As shown in the figure 1 sourced from Central Pollution Control Board, Govt. of India, vehicular pollution contributes 72% to total pollution produced by various sectors. The various measures taken presently by the government are: Fitness certification is a statutory requirement for commercial vehicles and public transport vehicles. Periodicity for certification is once in a Year. For non-commercial passenger cars, fitness certification is required for renewal of registration, only after 15 years from the date of first registration. Pollution Under Control (PUC) certificates are required to be obtained every three months for all categories of vehicles. In case of two wheelers no such requirement exists [2]. Since these measures are having significant loop holes, in addition to exclude two wheelers from the process even though according to Society of Indian Automobile Manufacturers (SAIM) Domestic market share of two wheelers in 2011-2012 was 77.32%. Fig. 2 shows the bar chart of domestic share of two wheelers compared to other means of transportation. In addition the measures taken by the traffic department in case of vehicles other than two wheelers are not up to the mark comparing to pollution threats and its exponential increase [3].

Recent advances in sensing technology, particularly in the area of wireless sensor networks (WSNs), now enable environmental monitoring in real time and at unprecedented spatial and temporal scales [3] We are particularly interested in a sensor network in which all vehicles on the time of registration will be attached with a device (Sensor Node), which is able to provide aggregated information about the pollutant concentration released by the vehicle all time.

In this paper we have explored the application of Wireless Sensor Networks and proposed innovative Web of Things application architecture to detect the level of pollutants from the smoke released by the vehicle.

Corresponding Author: Aijaz Ahmad Reshi, Bharath University Chennai, India.

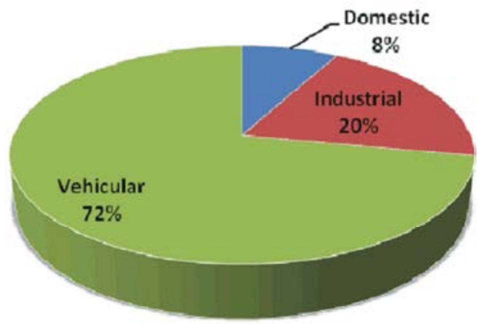

Fig. 1: Contribution of various sectors to the Environmental Pollution.

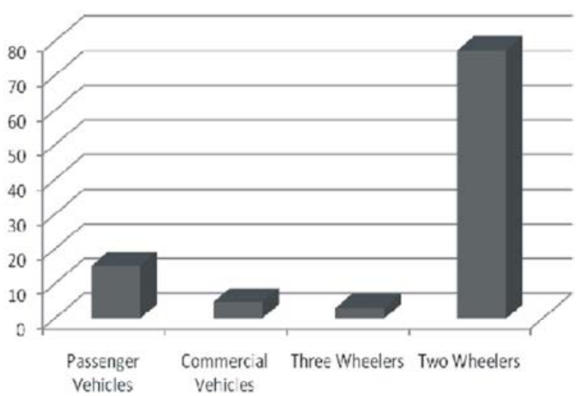

Fig. 2: Domestic Market Share for 2011-12

In addition the System is capable of raising alarms and alerting the concerned person/agencies using advanced ICT methods like mobile phone communication and web. We are particularly interested in web enabled sensor nodes, which are able to provide aggregated information about the status of the vehicle pollution. These wireless sensor nodes embedded on the vehicles may act as sensing devices, taking up certain stimuli and transform them into useful observations. Or they are able to do something, e.g. turning on and off an alarm buzzer or displaying the gathered data on a local display (Attached to the dashboard of the vehicle) along with communicating the observations by encapsulating them in data frames to the desired base stations. This work investigates the application of Web of Things approach to a wireless sensor network deployed in a transport system for vehicular pollution control use case using web enabled wireless sensor network as to explore the feasibility and practical requirements. Aim is to develop a sensor platform which is easily deployable in which whole network is available and each vehicular node is a first class citizen on the WWW. Each individual sensor node will offer a unified Representational State Transfer (REST) API to access the real time sensor observations [4-8]. The rest of this paper will be organized as, in section (II) related work will be outlined, section (III) describes the case study and section (IV) describes Hardware design, Software architecture is described in section (V). The paper ends with conclusion (VI).

Related Work: Wireless Sensor Network (WSN) is an active field of research due to its emerging importance in many applications including environment and habitat monitoring, health care applications, traffic control and military network systems [4]. With the recent breakthrough of Micro-Electro-Mechanical Systems (MEMS) technology [5] whereby sensors are becoming smaller and more versatile, WSN promises many new application areas in the near future. Typical applications of WSNs include monitoring, tracking and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection, traffic monitoring etc. Initial development into WSN was mainly motivated by military applications. However, WSNs are now used in many civilian application areas for commercial and industrial use, including environment and habitat monitoring, healthcare applications, home automation, Controlling, fire detection and traffic control [5]. The vision of the two related research fields Wireless Sensor Networks and Web of Things is on integrating general, real world things with the Internet or Web, respectively. Examples for such things are household appliances, embedded and mobile devices, but also smart sensing devices. Often, the user interaction takes place through a cell phone acting as the mediator within the triangle of human, thing and Internet/Web. The application fields of the Internet of Things are influenced by the idea of ubiquitous computing [6]. They reach from smart shoes posting your running performance online, over management of logistics (e.g., localization of goods in the production chain), to insurance (e.g., car insurance costs based on the actually driven kilometers). Web of Things leverages existing Web protocols as a common language for real objects to interact with each other. Things are addressed by URLs and their functionality is accessed through the well-defined HTTP operations (GET, POST,PUT, etc.). An already established approach for integrating sensors with the Web is the Sensor Web Enablement (SWE) framework defined by the Open Geospatial Consortium (OGC) [7]; SWE specifications are very generic and powerful since intended use cases are broad and often complex (e.g. disaster management.

A wireless sensor node is deployed to every vehicle which consists of number of sensor nodes capable of capturing the pollutant level and communicating the real time data to the base station web application. Each senor node is equipped with various gas sensors that measure the concentration of gases present in the smoke and GPRS module. The GPRS module of the node acts as an interface that bridges the Web with sensor nodes having a direct Internet connectivity and running a web application on it.

Each node is accessible via a RESTful API from the server web application. The sensor information once collected on the base station web application, it may be open to the vehicle owner, traffic department and environmental agencies. The concerned authorities have the options to access the sensor nodes and data through various means like, using mobile devices, through a pc client or local display units [9-11].

Case Study: By taking the current scenario in consideration we evaluate the following use case: A specialized device is mounted to the vehicle. This device is able to measure pollutant concentration present in the smoke released by the vehicle by utilizing a sensing unit consisting of array of sensors, a processing unit and a transmission unit to communicate with the Server. Once switched on, the device automatically connects to the Web. Once connected, it can send sensor observations in a specified frame format to the remote server and also displays the observations on a local display unit (may be on dashboard of the vehicle). The sensor information once collected in a database on the server may be open to various institutions such as traffic authorities, environmental agencies or private companies. The concerned organization, which owns the sensor network infrastructure, decides about granting access to this information. Configuration and tasking sensor nodes will be handled restrictively [12-15].

Hardware Design: The wireless sensor node consists of three main subsystems, Sensing subsystem, Processing Subsystem, Communication Subsystem. The sensing subsystem consists of array of sensors responsible for sensing the corresponding gases, like Carbon Monoxide, Carbon Diaoxide and overall smoke level. Three different types of sensors are being used in our case, MQ 7 sensor for Carbon monoxide, MQ 2 sensor for smoke level and MQ-135 gas sensor used to measure NOx, Benzene, CO2 concentration. Figure 3 shows the Sensor node

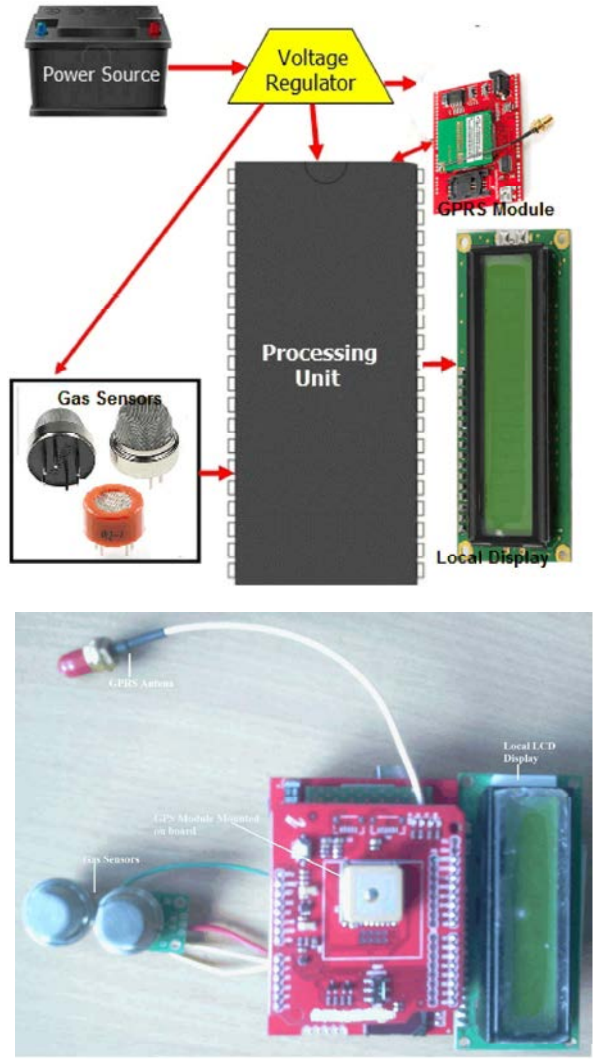

Fig. 3: Node Architecture

architecture and its operational components. The node consists of sensing unit implemented by different sensors.

The processing unit uses the microcontroller board with Atmega 328P-PU microcontroller. The microcontroller has 14 digital input/output pins and 6 analog input pins. The analog pins are used to gather the inputs from the sensors which are analog in nature. These inputs are then fed to the Analog-to-digital converter (ADC) for the conversion. The converted digital data can then be passed to the processing unit for further processing. The digital pins are used as outputs from the microcontroller as the inputs to the output devices, like Display unit to display data locally or to the communication module for web accessibility [16-17].

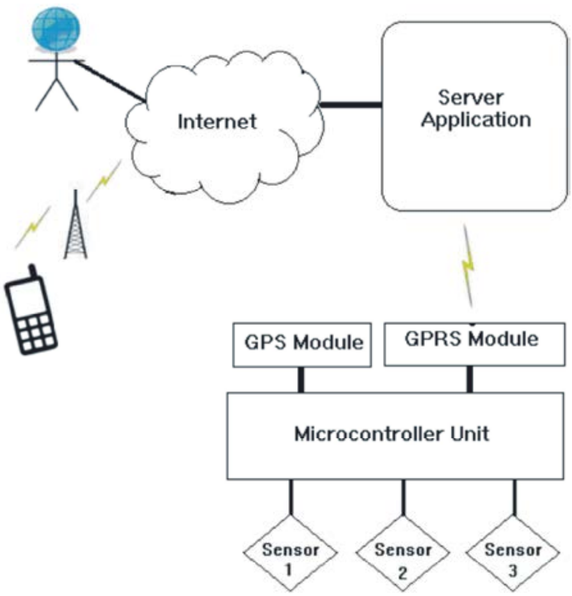

Fig. 4: General Architecture

The communication and web interface unit was implemented using SM5100B-D GPRS module and GTPA010 GPS module to track the present location and time awareness. The web connectivity is established by the GPRS module so that all collected and processed data is available on the web in real time. The web accessible data within our prototype setup is mostly derived from the output of gas sensors and GPS module. Gas sensors.

Software Architecture: The design of the software can be viewed from the general architecture shown in Fig. 4. In its bottom layer the microcontroller has been programmed to retrieve the raw sensor observations from gas sensors and the location and time information from the GPS module [18]. The program then translates the raw sensor data observations along with GPS information to descriptive observations by applying the specialized processing steps. The processed data are then packed to a specialized message format and forwarded to GPRS module. GPRS module is responsible to transmit the data messages (possibly in the form of SMS in this use case) to the server application. Server application consists of a Data acquisition module, a Specialized Alert system and a Database. Data acquisition module acts as a gateway for the data transmitted by the sensor node to the Server application. Alert subsystem is used to send the alerts to the desired users (vehicle owner, concerned traffic personal), when the vehicle starts to cross the specified threshold of pollution. Alerts enable the users to know the particular vehicle is not meeting Pollution Under Control (PUC) conditions, so that certain actions can be taken. Once received the message from the node the database handler receives the event and stores the observation in the database [19]. Henceforth, the observation can be accessed via the SOAP interface. In order to provide data gathered to other Web applications, a web application architecture using REST API for accessing measured observations is designed. The key abstraction of information in REST is a resource. Any information that can be named can be a resource. Resources are addressed by URIs and their functionality is accessed through the well-defined HTTP methods like GET, POST, PUT, DELETE etc. These REST APIs in addition to interact with sensor nodes via web can be used to display various visualizations generated from data gathered by the sensor node.

The general architecture of the proposed architecture as shown in Figure 2. In its bottom layer, is the sensor which node gathers the raw sensor data and is able to process them to observations with more descriptive metadata (e.g. unit of measure, Node ID, Location). The microcontroller firmware programming language is used to process the raw sensor data and send the processed information to the GPRS module, which provides communication and web interface to sensor node. On top of node setup is the REST API, which is used to access the resources (e.g. Sensor Observations archived or real time) [20-24].

For example a sensor node can be accessed by following the URI http://vehpollution. snaca.in/nodes/<vehId>.

A collection of observations by a sensor node with specified id can be accessed as:

http:// vehpollution.snaca.in/nodes/<nodeid>/observs.

CONCLUSION

This work presents the a Wireless sensor network platform for automobile pollution control focusing on an easy accessibility of real time data via the Web by following the Web of Things approach. The integration wireless sensor nodes with the web was accomplished by using the GPRS module which made it possible to access the sensor nodes as the REST resources. The system provides real-time surveillance, monitoring and automatic alerts. As discussed earlier the RESTful API is used over HTTP rather than web services like SOAP-WS, Table 1 shows the comparison of the two methodologies.

TABLE I. REST VS SOAP

	REST	SOAP
Scalability	High	Medium
Interoperability	High	Low
Performance	High	Low
Multi Device	High	Low
Reliability	Medium	High

*Source: http://www.infosysblogs.com/microsoft/2009/08/how_i_explained_rest_to_a_soap.html

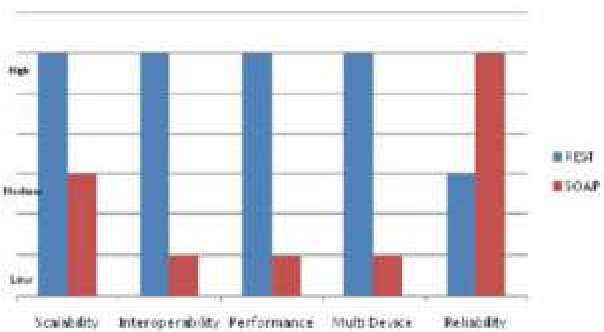

Fig. 5: Bar Graph for SOAP vs REST Comparison

Thus, the proposed architecture can be seen as an extensible, interoperable with good performance control system for environmental pollution surveillance and control. In future, this use case setup will be refined, but also other use cases will be investigated to prove the broader scope of the Concept. The full benefit of the concept can be achieved after investigation of legal feasibility, reliable business models, trustworthiness, etc. In future, we plan to evolve design leveraging on total Web of Things concept to deploy in various other application areas.

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