Vehicular Pollution Monitoring Using IoT

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***Abstract*-Degradation of air quality in cities is the result of a complex interaction between natural and anthropogenic environmental conditions. With the increase in urbanization and industrialization and due to poor control on emissions and little use of catalytic converters, a great amount of particulate and toxic gases are produced [1]. The objective of this paper is to monitor air pollution on roads and track vehicles which cause pollution over a specified limit. Increasing number of automobiles is a serious problem that has been around for a very long time. This paper proposes use of Internet of Things(IoT)[2] to address this problem. Here, combination of Wireless Sensor Network and Electrochemical Toxic Gas Sensors and the use of a Radio Frequency Identification (RFID) tagging system to monitor car pollution records anytime anywhere.**

Keywords—IoT; WS; Arduino; RFID; Gas Sensor;

I. INTRODUCTION

The environmental problems are growing rapidly. Air pollutants from cars, buses and trucks, particularly ground-level ozone and particulate matter can worsen respiratory diseases and trigger asthma attacks. Transportation can be responsible for more than 50 percent of carbon monoxide in the air. This carbon monoxide can play havoc on human health as in Figure 1 [3].

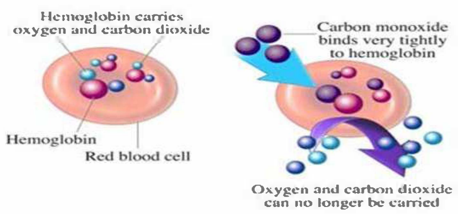

Fig. 1. Effect of Carbon Monoxide on human health

The air pollution may lead to Chronic obstructive pulmonary disease (COPD) [4] and escalates risk of cancer[5]. The public health is affected due to pollution from cars and trucks can also be very high in the large metropolitan cities. One of the major reasons of air pollution is emission of polluting gases from vehicles which is responsible for 70% of the total air pollution. In order to control the air pollution, the amount of air pollution needs to be monitored and vehicles responsible for polluting should be identified. Internet of Things may become helpful in cities for monitoring air pollution from vehicles and also data related to the amount of pollution on different roads of a city can be gathered and analysed.

The Internet of Things (IoT)[6] is a new concept which have attracted the attention of both academia and industry. Internet of Things(IoT) is implemented as a network of interconnected objects, each of which can be addressed using unique id and communicates based on standard communication protocols. This paper proposes IoT-based air pollution moni- toring through indentification of vehicles causing pollution by emitting smoke in a specific region. We propose to use wireless sensor network (WSN) and Radio Frequency Identification (RFID) technology for this purpose. The sensor nodes are equipped with gas sensors and they communicate wirelessly.

Radio frequency identification (RFID) technology has been in use for decades. Only recently, lower cost and increased capabilities made RFID technology to be a commercially vi- able one. RFID emerges as one of the converging technologies and key catalyst playing a significant role in this research work. This paper aims to understand the usefulness of RFID technology to detect vehicles causing air pollution.

Gas sensor technologies are still developing and have yet to reach their full potential in capabilities and usage. Some technologies are very accurate but also very expensive for large-scale deployment. On the other hand, with the use of sensor network, low cost technologies can be used and the problem of false positives can potentially be reduced with the help of multiplicity in data. Large number of outputs collected from individual sensors can be compared for a more accurate analysis. Thus, wireless sensor networks offer powerful new ways to monitor air quality.

This paper presents a framework for anytime anywhere visibility of sensor data from a remote wireless sensor network based on our earlier work[7]. Active RFID tags, combined with sensors and actuators, form the proposed wireless sensor network based on IEEE 802.15.4. Remainder of the paper is organized as follows. Related work is discussed in section II. A brief discussion about Internet of Things is put in section III. The proposed framework is presented in section IV. Implementation of the framework and integration of various technologies are described in section V. Lastly, we conclude with section VI.

II. RELATED WORK

Studies [8], [9], [10], [11] in different countries conclude that transportation is a major contributor to air pollution. Cities with high air pollution must address their problems, especially for health concerns from fine particulate matters, and take necessary steps particularly in the metro areas with unhealthy

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air. The studies suggested that role of various agencies should be strengthened in order to reduce transportation-related air pollution.

Khedo et al [9] proposes deployment of Wireless Sen- sor Networks (WSN) for air pollution monitoring. The pro- posed system, namely Wireless Sensor Network Air Pollution Monitoring System (WAPMS) will monitor air pollution in Mauritius through the use of wireless sensors deployed in huge numbers around the island. It will make use of an Air Quality Index (AQI) and will implement new data aggregation algorithm to merge data to eliminate duplicates, filter out invalid readings and summarize them into a simpler form. A hierarchical routing protocol is also proposed in WAPMS which causes the motes to sleep during idle time.

In [10], Mobile Discovery Net (MoDisNet) is developed to monitor and analyze real time air pollution on the basis of traffic conditions, emissions, ambient pollutant concentration and human exposure. A hierarchical network architecture is formed with the stationary sensors and mobile sensors to gather real time data. Mobile sensors are carried by the vehicles while stationary sensors are fixed on the roadside devices. The evaluation of MoDisNet has been carried out in East London using GUSTO sensor technology. It has been implemented on a mobile sensor grid architecture and distributed data mining algorithms have been used for analysis. Pollution data are classified at different pollution levels and are highlighted on the map in classified manner using different colours.

In [12], it is proposed that RFID technology can be effec- tively used to solve transport related problems such as accident risk management, environment alert, traffic rule violation con- trol, vehicle theft identification and traffic signal management etc. One RFID Tag is placed on each vehicle to send vehicle identification to traffic information database. RFID reader is placed with embedded controller at Toll Gates, Parking areas and also in traffic signal areas.

III. Internet of Things

There are several definitions of Internet of Things (IoT) that also briefly explain what are the main functionalities and characteristics of it and also expectations of the users when they connect Things with each other through the Internet. Internet of Things may be considered as a global network infrastructure where physical and virtual domains are linked using distributed computing like cloud computing, and var- ious data collection and network technologies. IoT allows devices to communicate with each other, to access information on the internet, to store and retrieve data, and to interact with users, thereby creating smart, pervasive and always- connected environments. To acquire such intelligence within the computing environments, major technological innovations and developments are required. The researchers expect that it will be possible to identify a newly formed shape for IoT, together with the explosion of Ubiquitous devices in the near future. The vision of the Internet of Things is that individual objects of everyday life such as cars, roadways in transport sys- tems, pacemakers, wirelessly connected pill-shaped cameras in digestive tracks for healthcare applications, refrigerators, or other household items including cattles can be equipped with sensors, which can track useful information about these objects. Internet of Things is supposed to consist of uniquely addressable objects and their virtual representations on an internet-like structure. Such objects may link to information about them, or may transmit real-time sensor data about their state or other useful properties associated with the object. The uniquely addressable objects are connected to the Internet, and the information about them can flow through the same protocol that connects computers to the Internet. Since the objects can sense the environment and communicate, they are able to understand complex behaviours in the environment, and may often enable autonomic responses to challenging scenarios without human intervention. The large number of devices simultaneously produce data from the environment in an automated way and enable pervasive and ubiquitous computing

Internet of Things (IoT) is envisaged as an integrated part of Future Internet. Thus, in order to enable fast advancement in technologies related to IoT, research must target key issues like identification,interoperability and privacy and security. The integration of big data, cloud technologies and future networks like 5G with IoT must also be taken into account [13].

IV. Proposed Framework

In this section, we would like to present effective use of Internet of Things to address the issue of vehicular pollution. Continuous monitoring of air quality is necessary to ascertain level of pollution and presence of certain harmful pollutants. Various gas sensors (viz. Carbon monoxide, sulphur dioxide, Nitrogen dioxide, Methane etc.) may be pressed into service for this purpose. Polluting vehicles should be identified in order to take appropriate steps.

Few locations, with usually high volume of traffic, may be identified to be monitored. In this framework, for each monitored location, the RFID readers are placed on the either side of a road with a fixed short distance in between them. Each vehicle passing through the road is equipped with a passive RFID tag. Sensor nodes, composed of gas sensors, are placed on the roadside. The sensor nodes may be identified and addressed by unique IP address [14] or a unique ID. These nodes gather sensor data continuously and send it wirelessly to the server. Whenever the sensor nodes sense abrupt rise in pollution, search is initiated for concerned RFID tags, i.e. vehicles causing pollution are identified using the RFID tag attached on them. The RFID readers detect a car passing by it as depicted in Figure 2.

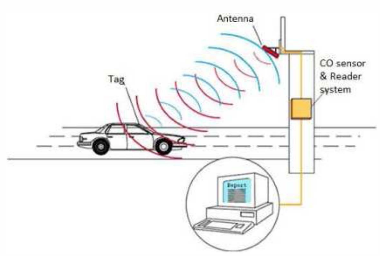

Fig. 2. How RFID works

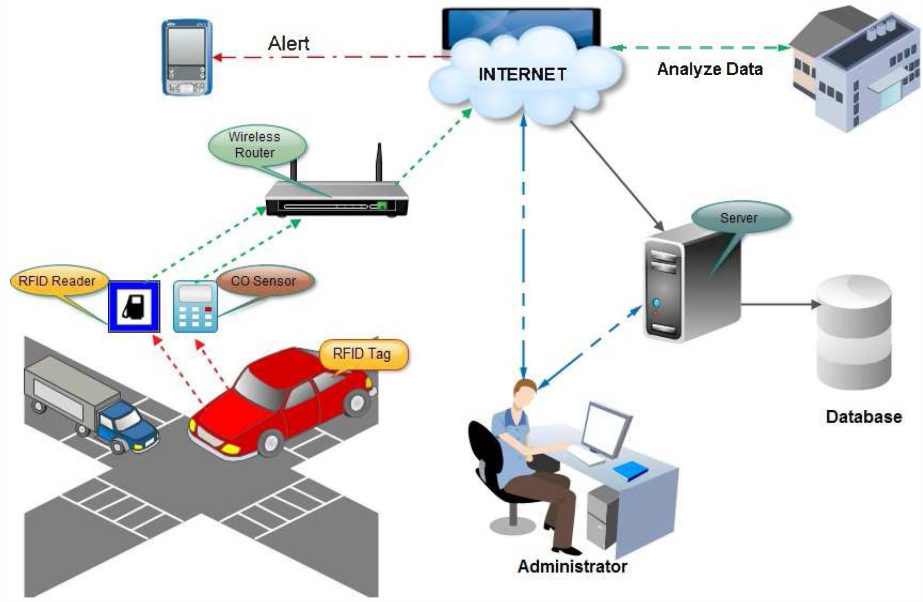

Fig. 3. Proposed Framework

The RFID readers identify corresponding tag number and transmit the same via the GPRS modem to the server. This framework also generates alert when pollution level increases. Authorities may take appropriate actions accordingly. All the gathered data may be monitored and analyzed by authorities concerned, as shown in Figure3.

V. IMPLEMENTATION OF THE FRAMEWORK

In this section, implementation of the framework is dis- cussed. Before that it will be prudent to brief about tech- nologies involved and used in this work. Despite the fact that Internet of Things is a relatively new concept, there are already a few open platforms available which are able to perform remote and seamless management and experimentation with sensor data. These technologies are discussed in the subsequent subsections.

A. Arduino

Arduino is an open hardware platform which is able to work with various sensing and communication technologies. The arduino, depicted in Figure 4 is a flexible micro-controller and development environment that is not only used to control devices, but can also be used to read data from all kinds of sensors. Its extensibility and simplicity attract users and developers. Consequently, various hardware extensions and software libraries are developed, which enable wired and wireless communication with the Internet. Arduino is the perfect open source hardware platform for implementing a system in the world of the Internet of Things.

An Arduino board consists of an ATmega328 microcon- troller allows to upload new code without external hardware programmer and with complementary components to provide facilities like programming, incorporation into other circuits. Most of the boards include a 5 volt linear regulator and clock speed of 16 MHz. It has 14 digital input/output pins, 6 analog inputs used to connect multiple number of sensors or different hardware devices, a USB connection used for communicating with the computer, another Arduino or other microcontrollers and a reset button that allows it to be reset by software running on a connected computer without a physical press of the reset button. Input voltage supplied to the board as per recommendation is 7 V to 12 V because 5 V pin may supply less than 5 V and the board become unstable and if we provide more than 12 V the regulator become overheated causing damage of the board and the DC current per I/O pin should be 40 mA. Also the board has a Flash memory of 32KB with 0.5 KB used for the bootloader, SRAM of 2 KB and an EEPROM of 1 KB which can be read or written with EEPROM library. The Arduino UNO, which we have used in this work, is different from all preceding Arduino boards in the way that it does not use the FTDI USB-to-serial driver chip. Instead, it uses the Atmega16U2 microcontroller programmed as a USB-to-serial converter.

B. RFID

Radio frequency identification (RFID) [15] is a very useful technology for electronically identifying, locating, and tracking products, animals, and vehicles. This work uses RFID technol- ogy for tracking vehicles responsible for creating pollution.

Communication takes place between a reader and a transpon- der (Silicon Chip connected to an antenna) often called a tag. Tags can either be active (powered by battery) or passive (powered by the reader field), and are available in various forms including tags, smart cards, labels, watches and even embedded in mobile phones [16]. The frequencies used for communication depend on the application, and range from125KHz to 2.45 GHz. Figure 5 and Figure 6 show RFID tag and RF Receiver used in this work. Output of an active RFID transmitter tag is a unique 16 bit ID in serial data at 9600 bps baud rate and the active RFID transmitter transmits 16 bit unique ID on 433 MHz frequency giving range of around 25 meters.

Fig. 4. Arduino Uno board

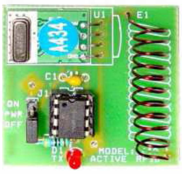

Fig. 5. RFID Tag

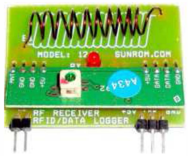

Fig. 6. RFID Reader used in this work

C. Gas Sensors

The MQ series of Gas Sensors used in this research work are simple and cost effective sensors useful for sensing gases in the air. There is a wide range of sensors available each of which are made to detect a specific gas like Methane, N O_x, sO_x, LPG, CNG, Carbon Monoxide and Alcohol. They provide great accuracy and performance. The carbon monoxide (CO) sensor and the module used in this work, are shown in Figure 7 and Figure 8 respectively. It has a simple 4 pin interface: 5V, Gnd, Dout(Digital Output) and Aout(Analog Output). The sulphur di-oxide module is shown in Figure 9.

Fig. 7. CO gas sensor

Fig. 8. CO Gas Sensor Module

Fig. 9. SOx gas sensor module

D. Integration Of Technologies

This research work needs to integrate different types of technologies which are mentioned above. A prototype was built and tested. Overall, the prototype operated well as intended. The Arduino Uno, as shown in Figure 4, is used in this research work. It is a microcontroller board based on the ATmega328 and used to integrate RFID Reader and CO sensor module as shown in Figure10.

The RFID reader is easy to configure. It uses serial protocol to transfer information from RFID cards to the Arduino. Ground, power supply and serial data transmission pins are connected to the Arduino board as depicted in Fig.10 to make it programmable.

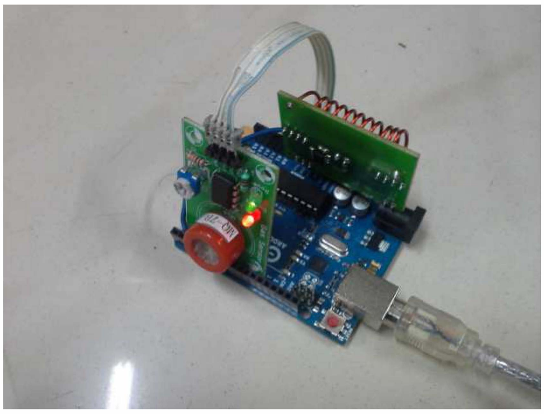

Fig. 10. Integration Of Arduino with RFID and CO gas sensor module

Table I Pollutant Data: Sulphur di-Oxide

Tag ID	Day 1	Day 2	Day 3	Day 4	Day 5
1	426	429	429	427	439
2	424	426	426	428	425
3	427	446	438	459	447
4	439	451	445	457	461
5	438	454	441	459	457

Table II Pollutant Data: Carbon Monoxide

Tag ID	Day 1	Day 2	Day 3	Day 4	Day 5
1	359	401	399	391	409
2	399	355	391	409	379
3	403	401	379	404	411
4	409	389	401	405	399
5	397	405	399	402	407

Now, the RFID reader can communicate with Arduino and send the RFID tag number that it can read. We can print the data on terminal or send the data to server.

VI. EXPERIM ENTAL RESULTS

To test the prototype, we have deployed the RFID readers at an intersection of roads. We also enable the gas sensors which are deployed at roadside to gather data. Few RFID tags are fitted onto the vehicles which regularly pass by the intersection. The sensor data are simultaneously read with data from RFID readers and pollution levels from individual vehicles may be measured in real-time. The data has been collected through five days. These sensors gather raw data. Raw pollu- tant data is shown in Table I and II for sulphur di- oxide and carbon monoxide respectively. Raw data may range between 0-1000. In order to obtain the actual pollution level, some calibration is required for each sensor device. These data is averaged over 5 days for each RFID tag.

In Figure 11, a graph for average pollutant data for different vehicles is shown.

This work presents the design of a system to give a solution for detecting vehicles causing environmental pollution. Based on the experimental results we obtained, this work looks promising to address the problem. The system has a significant meaning in terms of cost and effectiveness in comparison to other non-RFID based vehicle detection system. The image processing solution, GPS and satellites solution requires a large number of expensive and powerful equipment for processing. It is proposed as a low cost solution using RFID and gas sensors. Compared to the other RFID based solutions, this paper proves to yield accurate results while cutting down the costs. We strongly believe that a real-life implementation of the system on a larger scale would function as intended and benefit a large number of people.

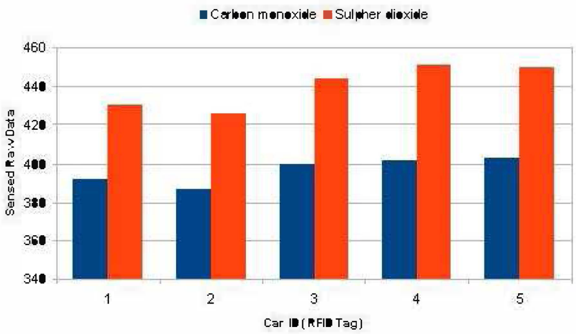

Fig. 11. Pollution level monitoring

Once the pollution level exceeds permissible level, motorists may be advised to avoid that particular area. It may be done using the same Internet of Things. It may enable to reduce the pollution level over a certain span of time. This framework may be integrated as an enabling tool to design intelligent transportation system for Smart City[17].

At a busy intersection where number of vehicles pass at any particular time, pollution level may increase due to the emision of gasses from any of the vehicles. Emission is expected to be high. Here crops up the challange to identify the particular vehicle which actually pollutes as numerous vehicles jostle for space there. Our future work will target these issues.

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