DEVELOPMENT OF MOBILE AIR POLLUTION MONITORING DEVICE

[1]Lakshmikantha K.S., [2]Rampur Srinath, [3]Chandrika L.S.
[1,2]Associate Professor, [3]P.G. Student
The National Institute of Engineering, Manandavadi Road, Mysore, Karnataka, India
[1]lakshmikantha.ks@nie.ac.in, [2]rampursrinath@nie.ac.in, [3]chandrika.ngg@gmail.com

Abstract:
Ever growing population in cities have increased urban pollution with major increase in road vehicles. Additionally pollutions caused due to industrial wastes and household wastes are also contributing to this pollution. This increase in pollution is one of the primary cause of increase in diseases and has been confirmed by World Health Organization in their annual reports. Thus monitoring of air pollution locally is of prime importance from health perspective. Sensors are becoming ubiquitous in everyday life, thus generating data at an unprecedented rate and scale. With the availability of low cost gas sensors, wireless data transmission devices, cloud storage, open source mobile application development software, high computational power mobile phone has provided a unique opportunity to continuously monitor air quality and map the concentration of air pollution using Google maps or similar applications. Quantification helps in making objective decisions, using the hardware and software developed in this work can be used to monitoring air pollution at low cost.

Index Terms: Ambient Air Pollution, Gas Sensor, Android Application Development, Geo-localized mapping, Internet of Things.

I. INTRODUCTION

Many industries, auto-mobiles and few households emit air pollutants, out of which many pollutants are harmful to health. As per World Health Organization, outdoor air pollution is a major environmental health problem affecting everyone in developed and developing countries alike. More than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed the WHO limits [1]. Everyone has a right to know the pollution he / she is getting exposed, as it is affecting the health of an individuals. Thus quantification of air pollution and plotting is the important aspect of this project. Pollution quantification also helps in identify safe zones in the city to travel and also help local authorities to take necessary action to reduce the air pollution at the relevant zones.

WHO in their report have mentioned, that reducing emissions of pollutants can contribute to health benefits in 3 ways. Firstly, reduction of air pollution and related ill-health directly; secondly from reduction of ozone (O_3) and carbon black effects on paramount weather conditions and also on production of agricultural products and from additional health benefits that are not associated with air pollution but may amass as a result of irrefutable pollution mitigation actions, such as increased physical activity or improved diets. Particulate Matter of size 2.5 micrometer (PM2.5) or less exposure can cause heart disease, stroke, respiratory disease, lung cancer and COPD as shown in Fig. 1 due to Ambient Air Pollution (AAP). Abbreviations used in the figures are as follows, AAP: Ambient air pollution; ALRI: Acute lower respiratory disease; IHD: Ischemic heart disease; COPD: Chronic obstructive pulmonary disease.

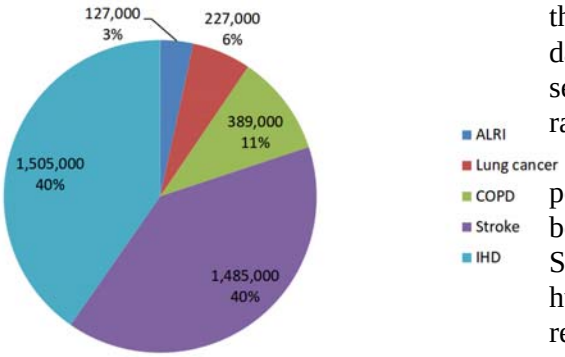

Figure 1: Deaths Attributed to AAP in 2012, by disease.

In India transportation plays a major role in the contribution of air pollution in India. More than 72\% of air pollution is due to vehicles. According to Central Pollution Control Board (CPCB) 97 percent of hydrocarbons, 77 percent of carbon monoxide and 49 percent of NO_x are produced due to emissions from the vehicles [2].

Humans need to walk / jog / run to burn the calories consumed, thus he / she needs to move around, if the atmosphere is causing health issue, then identification of safe path / zone where the ambient air pollution is low is to be determined. Balance is the key phenomenon to maintain human body in good health which requires correct human calorie intake and calorie burning [3].

Indian population has been exposed to dangerously high levels of air pollution and estimates that 660 million people, over half of Indian population, live in areas that exceed the Indian National Ambient Air Quality Standard for fine particulate pollution. Reducing pollution in these areas to achieve the standard would, we estimate, increase life expectancy for these Indians by 3.2 years on average for a total of 2.1 billion life years [4].

introduction of low cost sensors, it is possible to monitor air pollution at different places. These sensors are capable of monitoring different quality of air at different places of cities. In India, these types of sensors are used to measure, different concentrations of the gases at the different places to monitor the air pollution at the fixed stations. These sensors are capable of measuring the different air pollutants such as Nitrogen Oxide NO_x, Carbon Monoxide CO, Ozone O_3, Sulphur Dioxide SO_2 and Particulate Matter (PM). Most of the cities in the world are establishing mobile laboratories in order to measure air quality. The most significant of these is the reliability of measured air pollution data, since most gaseous and particulate matter sensors require independent evaluation under a range of ambient environmental conditions. [5]

Ambient air pollution quantification need to be performed with relatively large sample size for better understanding of the pollution zones. Samples are to be collected at the height of human nose, for measurement to be more realistic to human breathing gas pattern. In order to manage high volume data from multiple nodes, cloud computing services provided by Amazon Web Services play a major role.

Recent improvements in the area of gas sensor development has reduced the cost per sensor and have increased the sensitivity of the gas sensors. This reduction in sensor costs can be leveraged to quantify the gas concentration in urban cities. Apart from reduction in sensor price, wireless communication, open source hardware platform based micrometers and low cost cloud computing are the motivation to take this as major project work.

Increased number of smart phone users and reduced cost of the smart phones, has led to increased number of android applications, thus in this work an attempt is made to plot local gas concentration values over Google map. Not all can purchase sophisticated gas sensor modules, but those who have purchased can share the concentration values over cloud for societal benefits. In this work gas sensor based hardware is designed for measuring gas concentration and upload to cloud for any android smart phone users to download application and check the available gas concentration values.

II. METHODOLOGY

Initially low cost hardware were selected and easily deployable software were selected. Details of the research activity are as mentioned below.

A. Project Activity Details

Following were the major activities planned in this project.

- Purchase of Gas Sensors, Arduino Board, GPS sensor, Power Bank, SD card module, Temperature and Humidity sensor.
- Measure first Gas Sensor data using Arduino board.
- Measure multiple Gas Sensor data using Arduino board.

- Store the sensor readings in SD card and append the data upon restart.
- Setting the hardware to be used using a power bank for mobility purpose.
- Setting the Amazon Web Services for IoT application.
- Sending the first sensor data to Amazon Web Services DynamoDB module.
- Sending the data from SD card to S3 / DynamoDB of Amazon Web Services.
- Setting the Android application development environment for mapping application.
- Reading SD card CSV file from Android mobile.
- Converting the raw latitude and longitude data of the GPS sensor to correct latitude and longitude data.
- Color coding the sensor data to be plotted.
- Plotting the sensor data against Google map with option to change the type of gas being plotted.

B. Hardware Used

Brief introduction of the hardware used are as follows;

- Gas Sensor (MQ-2): MQ-2 is used to detect the leakages of the gases from the equipment's which are used the industries and is also used to detect the gases like i-butane, LPG, propane, alcohol, methane, Hydrogen and smoke detection from 200ppm-5000ppm concentrations.

- Gas Sensor (MQ-3): MQ-3 are suitable for alcohol detection, Breathalyzer with concentration of 0.05mg/l to 10mg/l levels.

- Gas Sensor (MQ-5): MQ-5 are used to detect LPG, Town gas, Natural Gas, Cigarette smoke, alcohol with a concentration of 200ppm-10000ppm. It is also used to detect the equipment in the household and industries.

- Gas Sensor (MQ-7): MQ-7 are used to detect the gases like Carbon Monoxide at household and industry or automobile with detecting concentration of 20ppm-200ppm levels.

- Ammonia (MQ-135): MQ-135 can detect ammonia NH3 with detecting range from 10 ppm to 300 ppm.
- Carbon Monoxide (MQ-7): MQ-7 has high sensitivity to carbon monoxide with detecting range from 20 ppm to 2000 ppm.

- Temperature Sensor (DHT22-AM2302): DHT22 is an humidity sensor based on capacity measurement to provide digital temperature and humidity levels ranging from to 0 to 98 % and -40 to +80 °C with an accuracy of +/- 1 °C.

- Arduino Nano: Arduino Nano is a bread board friendly and a small micro-controller based on ATmega328 chip. It has 8 analog pins and 14 digital Input - Output pins, all the digital pins can be used either as input or output by using pinMode(), digitalRead() and digitalWrite() programming functions. The analog pins provide 10 bits of resolution (i.e. 1024 different values) for each of the 8 analog pins.

- Power Bank: A power bank of capacity 10400 mAh is used in this project with output power of 5V/1A.

- GPS Sensor: Global Positioning System abbreviated as GPS is a navigation system based on space that provides accurate location (Geo-positioning details) and accurate time information at all weather conditions. The only requirement for sensing is visibility of at least four GPS satellites through line of sight.

- Data Logger: An SD card module is used to store the sensor readings.

- WiFi Module ESP8266 12E: This new WiFi modules is from Espressif which is setting a high performance standards and high integration wireless System on Chip, designed for low foot print and power consumption generally used by mobile platform designers. This system can be used to extend WiFi capabilities to other working devices with ease or can work as a standalone application, with the low cost and space requirement.

III. OVERVIEW OF AMAZON WEB SERVICES

Amazon Web Services (AWS) is an infrastructure for Information Technology services which provides services to the users in the form of web, hence it is also called as cloud computing. The advantages of AWS are as follows:

- Business people or the application users need not plan well in advance and procure for servers and even need not for any other IT services. Instead of this cloud allows the application users to access any number of servers at the same time within a fraction of service and deliver the results faster.

- Cloud replaces IT infrastructure services with the low cost service.

- Cloud provides on-demand IT infrastructure services to the application users and follows a policy called "Pay as you go" pricing. Which means to say the user need to pay only for the services being used. The services are made available only whenever there is a need.

- Cloud computing allows the user to access storage, application services, memory and database over the internet.

- AWS maintains its own network connected hardware in-order to provide application services to the users.

- AWS built with network architectures and data center architectures in-order to satisfy the requirement of data security aspects.

- AWS follows its own policies, operational processes, architecture to provide the security to the users.

A. IoT Components of AWS

Amazon Web Services consists of the following components under Internet of Things:

- Message broker of IoT: It provides the security mechanism to the IoT applications. This can be used to publish and receive messages from one application to another. Message Queuing Telemetry Transport (MQTT) protocol is used to publish and subscribe the data in IoT component of AWS. HTTP REST interface can be used to publish the data to IoT.

- Rules engine: It is used for integration and processing of messages with other AWS services. AWS provides services such as DynamoDB, S3, Lambda for cloud computing. Structured Query Language (SQL) can be used to select the data, process data and send the data to any other Amazon services.

- Thing Registry: This allows the users to register their thing and allows to associate up to three attributes of each of the thing. This also provides the users to register the resources associated with each of the thing. It also helps to register client IDs and certificates of each of the things in order to improve the capability to manage and debug the things.
- Thing Shadows: This provides representation of the things, users can need to provide the updated information to the shadow, and it will automatically get synchronized with its state whenever it is connected.

- Security and identity service: This provides security and services to Amazon Web Services Cloud. All user things and information credentials must be secured while sending or receiving the messages from message broker. Rule engine and message broker user AWS security policies for sending or receiving the messages to or from device or any other AWS services.

IV. SYSTEM DESIGN DETAILS

MQ-2, MQ-3, MQ-5, MQ-7 and MQ-135 gas sensors are mounted along with DHT22 type temperature and humidity sensor is mounted on the general purpose board and connected to Arduino Nano. GPS sensor is also connected to Arduino Nano which provides latitude and longitude of the sensor location. All these data are saved to Micro SD card. Initial prototype are assembled using general purpose PCB as shown in Fig. 2 and with enclosure in Fig. 3. An additional power bank of 10,000 mAh is used to provide the power supply thus making the system mobile.

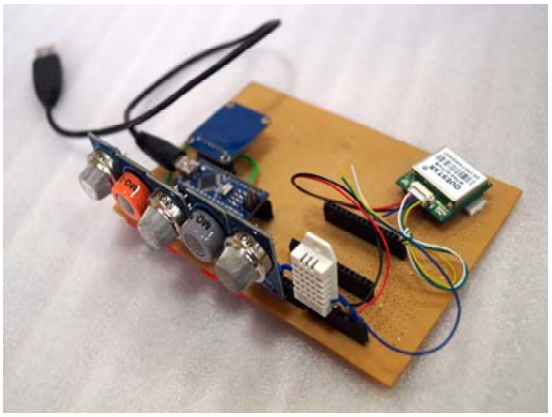

Figure 2: Prototype of Sensor System

The digital pin of the Gas Sensors are utilized to connect the Light Emitting Diodes for sensing gas limit and indicate the digital output as 0 or 1 based on the concentration of the gas at that location. In-order to charge the power bank an USB cable is provided. Additional holes are provided to visualize the GPS indicator, such that during mobile measurement one can ensure the latitude and longitudinal measurements are being captures along with gas sensor. As the GPS sensor needs at least 4 GPS satellites line of sight to get accurately the latitude and longitudinal data.

Figure 3: Mobile sensor kit

V. PROGRAM

A. Arduino Program

Open source hardware Arduino Nano along with Arduino Integrated Development Environment is used to read sensor data using analog read starting from MQ-2, 3, 5, 7 and 135 along with temperature and humidity. All the senor data are stored along with corresponding latitude and longitude data which is provided by GPS sensor. Obtained data is stored in SD card in tuple in comma separated format. New sensor data is appended every time new a sensor data is received.

Java programming is used to create a map based android application to plot the sensor data. Provision is made in the application to choose the gas type to be displayed / plotted. Android mobile reads the CSV data from default location, which can be pulled from Amazon Web Services S3 or DynamoDB.

WiFi Module ESP-8266 12E is programmed to upload the sensor data to Amazon Web Services DynamoDB, this feature needs continuous WiFi availability. If the signal strength is low, ends in loss of data. Hence in this work the sensor data is initially stored in SD card and at once the CSV file can be uploaded to the Amazon Web Services S3. All such files uploaded in S3 by different sensor units can be analyzed using cloud computing capability of the AWS.

Before plotting the map, the raw data received from GPS latitude and longitude is converted into actual GPS values, thus retaining the raw data until final plotting.

VI. OVERVIEW OF ANDROID STUDIO

Android studio is an IDE (Integrated development environment) which provides a platform for android application development. It provides a faster-tools for the application development on different types of android devices. Android studio consists of world class code for debugging, editing, system build performance tooling and an instant deploy/build a system that allows a user to develop a high quality and unique applications.

Android studio consists of 1 or more modules with resource file and source code files. It consists of different types of modules and are as follows.

- Android library module
- Android application engine module
- Google application engine modules

Android studio by default displays project file in the view of android project as in below fig. Modules organizes project view in order to provide a fast access to project's key source file.

All the build files can be seen at the top level which is under Gradle script and each application module contains the following folders.

- Java: this consists of java source code files and junit test code.
- Res: This consists of resources such as XML layout, bitmap images and UI strings.

- Manifests: this consists of file called AndroidManifest.xml

A. Architecture of Android

The architecture of android consists of android software stack which is composed of following elements:

- Application layer
- Application framework
- Libraries
- Linux Kernel

Linux kernel and libraries communicate with each other through an application framework. Application framework provides a tools for service and management of the android run time applications. Android architecture is as shown in Fig. 4.

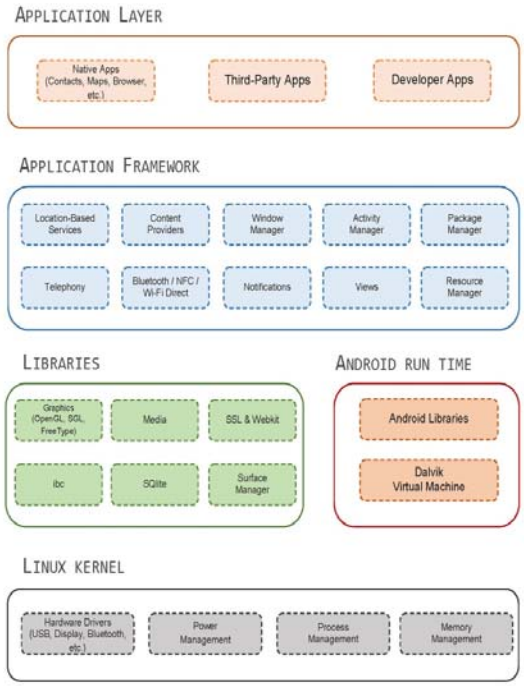

Figure 4: Android architecture

VII. RESULTS

Using low cost sensors, Arduino board, SD card, ESP WiFi module and Amazon Web Services, the gas concentrations are measured and plotted on a Google maps application in an android mobile as shown in Fig. 5 for the gases MQ2.

Figure 5: MQ2 Plot on Android Mobile

VIII. CONCLUSION

Using this hardware, one can quantify the atmospheric pollution and know what he/she is breathing. This helps elders, patients and children to safely move around the city with less polluted breathing.

High pollution concentration zones within the city can be identified and remedial actions can be initiated by suitable authorities, thus helping mankind to increase the life span and healthier living.

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