Sensor observation service for air quality management: a web application for suspended particulate matter pollution monitoring in urban Coimbatore, India

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***Abstract* - Availability of real time air pollution monitoring data with representative spatial resolution is a challenge in urban air quality management. To generate knowledgebase for appropriate management measures, multi domain complementary information, such as that on meteorological and pollution emission for modelling purposes is essential. While the huge upfront and running cost for pollution monitors severely hampers their wide deployment in urban centers, optimal and interoperable access to the domain-specific sensor resources pose greater challenge. This could be alleviated by the use of low cost air pollution monitors drawing upon their vast potential in air quality assessment and in setting up spatial data infrastructure. A web application for implementing sensor observation service is a technical solution to harmonize and link the disparate sensor resources.**

This is being attempted in urban Coimbatore as a case study by orchestrating suspended particulate matter (SPM) air pollution sensors, other real time information resources such as meteorological parameters and satellite derived products for modeling pollution problems. The web portal is developed based on standard network that could communicate with sensor resources for data collection, data organization and visualization in sensor web enablement specification compliant web services such as Sensor Observation Services. This would consist of a web map application with provisions for visualization of the SPM monitoring sensor resources and their time series observations in urban Coimbatore for preview and download.

Index Terms – Sensor, particulate matter pollution, air quality, MODIS

I. INTRODUCTION

Integration of multi source information to derive contextual knowledge is important in operational environmental management. Tools for integrating observations from multiple components of environment can significantly ease time and space relevant decision making. Interoperability standard tools such as Sensor Observation Service (SOS) implementations can provide the interface for orchestrating multi source observations, encourage data reuse and reduce the unnecessary duplication of resources in cost effective manner [1]. SOS is an important sensor web enablement specification evolved for interoperability of sensor observations in Spatial Data Infrastructure (SDI) for data aggregation from live, in-situ and remote sensors [2, 3]. It provides an accessible interface for sensors and sensor data archives for various processes in knowledge generation - data analysis, modeling and information dissemination. Initiatives such as 'Common Scents' [4] and 'Earth Observation, Environmental Modeling for the Mitigation of Health Risks' (EO2HEAVEN) [5] demonstrate management of sensor resources in air quality monitoring. The 'Common Scents' address the management of widely distributed and high spatial resolution sensor resources in urban spaces. EO2HEAVEN is an end-user oriented research project aiming better understanding of the complex relationships between environmental changes and its impact on human health. Both the initiatives explore use of spatial information infrastructure compliant to Open Geospatial Consortium (OGC) standards in integrating sensor observation from different domains, environmental health hazards to human exposure. By utilizing the power of flexibility in specifications of SOS, they demonstrate validation of health hazard model derived from various sensor observations to increase its utility for the end user.

Suspended Particulate matter (dust - SPM) air pollution is a serious issue in fast growing urban areas of India [6]. It involves an array of issues - multi-level interacting components of emission sources, dynamism of atmosphere and implications on public health, ecosystems and environment [7]. Mitigation or management of it requires basic information and predictability on the levels of pollution with adequate temporal and spatial resolution. Urban area real time sensor networks are a necessity and are being considered as a basic infrastructure for addressing the problem in different parts of country [8]. However, with increasing necessity for real time sensor system, huge capital and recurring expenditure required for its establishment is hampering wider installation of such systems [9]. Technical hurdles such as inherent variability and lack of an appropriate bridge system that is interoperable and facilitates optimal usage and access of real-time data are further hampering efficiency and robustness of these networks in deriving information and its dissemination [1]. On the other hand, there

is a growing realization that a low cost monitoring network would be an important enabler in high spatial resolution air pollution observations and related applications [9, 10]. There are field trials that show the low cost sensors with advanced calibration techniques as an important asset for real time air pollution monitoring and management [11]. But it involves a huge challenge in terms of fine-tuning the sensor technology, data management, networks sustenance and development of suitable applications from the collected information [12].

The developed web application for particulate matter air pollution in urban Coimbatore, a fast growing urban conglomerate located in the state of Tamil Nadu (India) provide a tool for acquiring and managing real time data from disparate and scanty sensor resources for air quality modeling and location based dissemination of information for effective management of SPM air pollution. This application utilized sensor web enablement (SWE) specifications of which SOS is a component to organize, and integrate sensor resources and in disseminating information. It integrates a sensor network with more intuitive information models and service capabilities of typical sensor resources available in a region like Coimbatore. This paper describes the development of the web application integrating multiple sensor resources in a standard compliant SOS implementation and visualization platform.

II. SENSOR RESOURCES

To control or manage SPM air pollution through effective regulatory measures and increased awareness requires integration of various atmospheric observations to understand the status of the problem and its future trend. For the web application, developed for Coimbatore urban SPM SOS, three sources were used for data organization and provisions in standard framework. Until now, particle counts from *DYLOS*^{TM} air quality monitor, time series MODIS Aerosol Optical Depth (AOD) products and hourly meteorological observations from multi-agency web portals are integrated through the web application.

A. DYLOS^{TM} *air quality monitor*

DYLOS^{TM} air quality monitor is a laser particle counter, which gives two size range (>2.5 and <0.5 micrometer per 0.01 cubic foot) particle concentration per minute in the ambient air. The reading is displayed in the inbuilt LCD screen. For data transmission, through a serial port, the monitor can be connected to a computer. It is widely used to monitor indoor air quality. Recent studies have established its data reliability and utility in outdoor conditions [11]. This monitor seems to be a low cost alternative for the conventional expensive monitors. A single board computer (such as Raspberry Pi) and GSM based data communication facility [13] if integrated could make the monitor an effective real time device.

B. MODIS AOD products

Moderate Resolution Imaging Spectroradiometer (MODIS) satellites *Aqua* and *Tera* are systems maintained by NASA's Earth Observation System (EOS) Program. AOD is a standard data product derived by atmospheric science teams working with these satellite imageries. Studies show positive correlation of AOD values with ground level particulate pollution level in PM2.5 and PM10 range (SPM size ranges - 2.5 and 10 micrometer per cubic meter) [14]. AODs are used as surrogate values for particulate matter air pollution [15]. The availability of AOD data from 2002 is an important advantage for SPM monitoring since such long term data is scanty, especially in second tier urban spaces such as Coimbatore. Near real-time data as AOD product is provided by NASA's EOS data and information system. Right now, we are working on integrating the web application to visualize the AOD products and to provide interface and temporal data for the study area.

C. Meteorological parameters

The major challenge for SDI is integration of location based data from various sources to derive relevant and time bound information. In our country, the challenge is greater for the existing lacunae in standards and Application Programming Interface (API) in real time data dissemination websites. Web extraction is to be a widely followed solution for this situation. It is a process of capturing data and extracting information from dynamic web sites for use in another context. Real time meteorological parameters are required for SPM dispersion and forecasting, important enablers in air pollution management. As of now, web applications automates extraction of such parameters and implements SOS on the real time meteorological data for Coimbatore region from Tamil Nadu Agriculture Weather Network maintained by Tamil Nadu Agriculture University (www.tawntnau.ac.in) and Weather underground web portal (www.wunderground.com).

III. SOS FRAME WORK FOR PARTICULATE POLLUTION MANAGEMENT DATA REQUIREMENTS

SOS specifications are information and service models for access and control of heterogeneous sensor resources. In the domain of air pollution, SOS specification standardizes data from distinct sensor resources to reduce disparity and improves interoperability of the sensors. In current project, SOS specifications are used for organizing data from *DYLOS*^{TM} air quality monitor, meteorological data repository websites and integrate with other location specific complementary observational resources, such as daily updated remote sensed MODIS AOD values, on Coimbatore geographical region.

OGC SOS (standard version 1.0) based implementations istSOS was used as tool for organizing the data sources for the web application [3]. It provides interfaces to interact with

sensor observations, sensors exploration, measurement retrieval, data management, transactional operations and dispatch of raw data. IstSOS is written in python programming language. It is based on the Apache web server, through mod_python package. It relies on PostgreSQL / PostGIS database for data storage and access. IstSOS uses GDAL library, Psycopg2 for database connections.

A. SOS integration for DYLOS^{TM} air quality monitors

The data from *DYLOS*^{TM} air quality monitors was integrated with SOS using serial connection and networking with central server for real time updating of the SOS. As per the deployment situation either Internet FTP based networking or SMS based networking was used to communicate the reading from remotely deployed *DYLOS*^{TM} monitor to the central server. For Internet based networking, the single board computer Raspberry pi connected with the *DYLOS*^{TM} monitors was installed with a bash daemon script which links a python script for serial reading of the monitored data. A GSM modem was installed with the Raspberry pi. The python script also converts the readings from the monitor into a CSV file, which is in the form to be uploaded into the IstSOS insert observation framework. This is further transferred to central server using file transfer protocol and uploaded into the IstSOS using CSV python importer (Fig. 2).

In case of GSM SMS based communication, GSM modem was used for sending SMS in which the python script converts the serial reading from monitors into a SMS at every 15 minutes intervals. At the server side a python script, supported by Gammu, and SMS management software Kalkun was used to manage the received SMS and to upload the data into the SOS.

B. *SOS integration for MODIS AOD products*

PyMODIS, a python script, was used to automatically download the MODIS products (Fig. 2). The script based on file transfer protocol downloads the imagery in HDF format by scheduling the script on to the CRON job. GDAL library was used to convert the HDF format imagery, clipped to the Coimbatore geographical region, into TIFF format. Geo server application was used to host the imagery and visualize it in the web application. To overcome the non availability of framework for image based observations in IstSOS, an imagery location link was given in CSV file for importing into the SOS.

C. *SOS integration for web extracted data*

Scrapy a python based web extraction framework with Selenium (Selenium IDE) web driver was used to extract the data from meteorological data web pages. For data based on Application programming interface (API) such as 'Weather Underground' portal, a python script was assigned for CRON job to download the JSON files containing the real time observations. Another python script was used for converting the extracted data into standard CSV format to feed into the SOS.

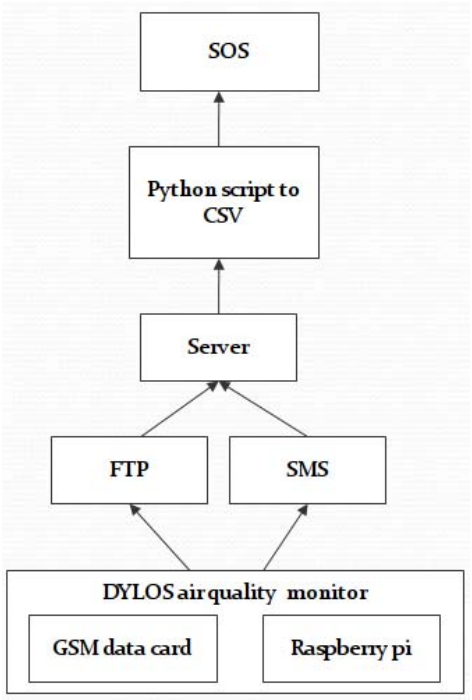

Fig.2. Steps in SOS integration for DYOS air quality monitors

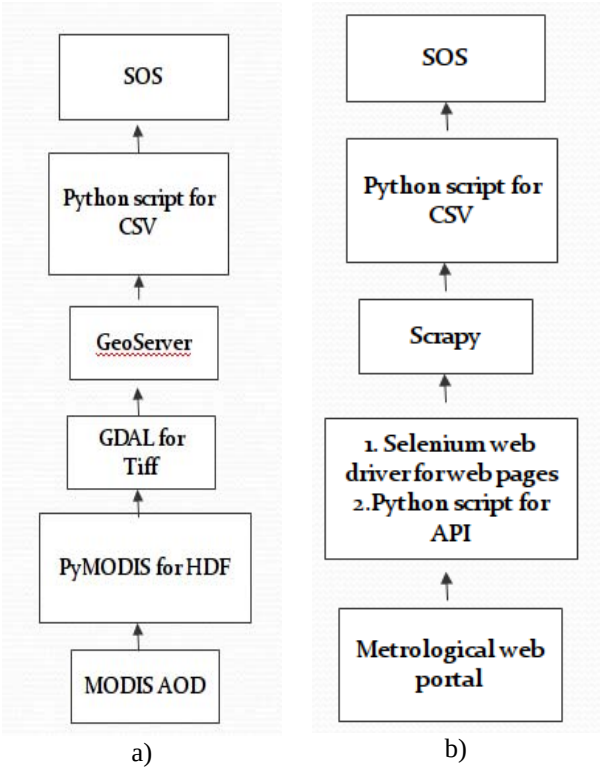

Fig.3. Steps in SOS integration for (a) MODIS AOD product (b) web extracted data

III. WEB APPLICATION

The web application (Fig. 3) parses the data from the SOS implementation (istSOS) and visualizes it in a web mapping interface. The web application is based on QualitySCHU [16], an open source project to visualize the air quality data from 'internet of things' data PACHUBE API's and LANUV German air quality monitoring network. The source code gives extension to integrate SOS implementation IstSOS and other analytical software extensions such as R statistical software package to validate the visualized data.

The web application developed currently for the project works based on JavaScript and requires an Apache web server with a PostGIS database, and istSOS sensor observation service implementation. The client also provides additional functionality of data viewer in the form of tables, charts and interface for downloading the data.

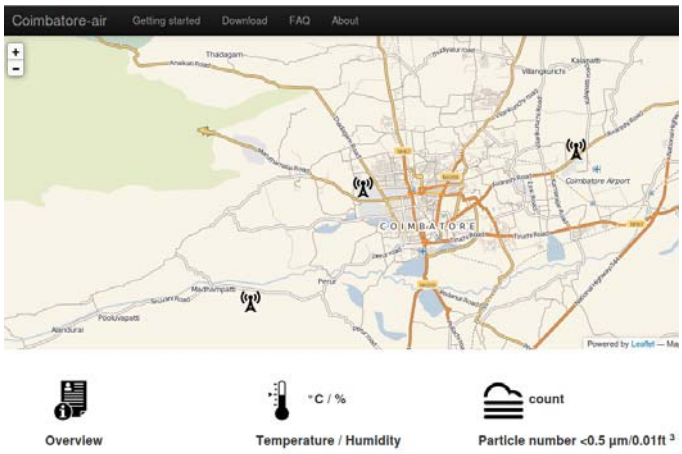

Fig.3. Screen shot of the web application

V. MOBILE APPLICATION FOR LOCATION BASED QUERYING OF SOS

Location relevance improves the utility value of real time information, since the public is increasingly being adept with mobile devices as a primary means for information access. The information access at users' location through mobile devices can open up a large pool of applications in terms of better advisory and creation of awareness through spatial data infrastructure which act as important enabler in air quality management. For integrated environmental management in particulate air pollution management domain, it helps in disseminating important health advisories or warnings specific to users' locality using simple means of communication such as geo-tagged Short Message Services. This objective was achieved by developing an Android application for the mobile phones or tablets and SMS gateway on the server side. The prototype android application comprised of an offline map with touch response screen. The map is created by the software Mobile Atlas Creator. The map can be dragged and zoomed using the functions for volume change on the tablet or the phone. The user can locate their position by either GPS based localization or zooming, or using relative localizations. When the location is positioned the user can touch the map screen, which prompt the latitude and longitude of the position to be send as per a Geo SMS specification to the server side SMS gate way, which in turn would respond the SMS with most recent pollution level in that particular area collected from the SOS of the closest particulate monitor.

VI. CONCLUSION

The paper discusses the development of a web application directed towards integrating multi domain sensor resources in standard compliant sensor observation platform. It deliberates upon the utility of sensor resources for particulate matter air pollution monitoring, mitigation and management, implementation of sensor observation services for those sensor resources, and on the platform for visualizing the observations.

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