Poster: Low Cost Platform Design for Pollution Measurement in Delhi-NCR using Vehicle-Mounted Sensors

Tanishka Goyal
BIT Mesra
tanishkagoyal1011@gmail.com

Ankita Singh
IIEST Shibpur
ankitasingh2119@gmail.com

Smriti Chhaya
IIEST Shibpur
smritichhaya1@gmail.com

Aditi Vikas
IIT Delhi
aditivikas99@gmail.com

Poorva Garg
IIT Delhi
poorva98@gmail.com

Ritika Malik
IIT Delhi
ritikamlk29@gmail.com

Rijurekha Sen
IIT Delhi
riju@cse.iitd.ac.in

ABSTRACT

This poster describes a low-cost and robust embedded platform, designed for vehicle mounted sensing of particulate matter (PM2.5 and PM10). The prototype is specifically designed to be mounted on the Delhi Integrated Multi-Modal Transit System (DIMTS) buses. Movement of the buses adds noise to pollution data. Error in GPS measurement causes issues in detecting moving vs. stationary state of the buses, useful to filter out noisy pollution data collected in the moving state. Intermittent cellular network connectivity causes frequent disconnects with the remote server. Our prototype is designed to handle such real world deployment challenges. Pilot deployment with this platform is currently ongoing. Preliminary data analysis from the pilot deployment will be discussed as part of the poster presentation, along with demonstration of the prototype sensor platform. This hardware prototype has the potential of creating locality wise, dense air pollution data providing crucial insights into the causes of air pollution.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**;

KEYWORDS

mobile sensors, pollution monitoring

ACM Reference Format:
Tanishka Goyal, Ankita Singh, Smriti Chhaya, Aditi Vikas, Poorva Garg, Ritika Malik, and Rijurekha Sen. 2018. Poster: Low Cost Platform Design for Pollution Measurement in Delhi-NCR using Vehicle-Mounted Sensors. In *The 24th Annual International Conference on Mobile Computing and Networking (MobiCom '18), October 29-November 2, 2018, New Delhi, India.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3241539.3267779

MobiCom '18, October 29-November 2, 2018, New Delhi, India

ACM ISBN 978-1-4503-5903-0/18/10.
https://doi.org/10.1145/3241539.3267779

1 INTRODUCTION

Air pollution is a bane for modern civilization, especially in the big cities. Delhi-NCR, being one of the largest and most densely populated urban centers in the world, is no exception. Mitigating pollution needs accurate measurements and identification of pollution sources. Central Pollution Control Board (CPCB) and Delhi Pollution Control Committee (DPCC) have about 30-35 air pollution measurement centers in Delhi-NCR, which are thoroughly inadequate to cover the vast geography. We aim to fundamentally alter this paradigm using vehicle-mounted mobile air pollution sensors to augment the static sensors.

Our key idea is to deploy sensors in vehicles that ply through the city. Even if a fraction of the fleets of vehicles is augmented with pollution sensors, a lot of fine-grained spatio-temporal pollution data can be collected over an extended time period. Analytics with this new dataset from hitherto unmeasured geographical regions can potentially give new insights for pollution sources, eventually aiding more data driven mitigation policies. Our plan is to piggyback sensors onto buses, auto-rickshaws, ride sharing services such as Ola cabs and courier service vehicles, which by the very nature of their job of picking up and dropping passengers and goods, will criss-cross the city.

We have specifically built collaboration with the Delhi Integrated Multi-Modal Transit System (DIMTS) bus authorities. There are 1600 DIMTS buses that ply in Delhi NCR. This poster describes the hardware unit to be mounted in this bus fleet. Pilot runs with prototype hardware are currently ongoing. These results, along with a live demonstration of the embedded platform, will be presented as part of the poster presentation.

2 EXPECTED FUNCTIONALITIES

Measuring PM2.5 and PM10 accurately is the foremost expectation from the embedded platform, as the goal is scalable PM monitoring. As the units will be placed in moving buses, time and location of the data collection is necessary. Thirdly, data should be communicated from the sensor to a central server for analysis. As Wi-Fi hotspots are not present across the city, support for cellular connectivity is a requirement. Also, cellular connectivity in a moving bus will be intermittent, thus local storage of data and server communication of buffered data whenever connection is available will be useful. Finally, the unit will need power for sensing, computations and communication.

An additional use of the collected sensor data is empirically evaluating the effect of urban transport policies like the odd even policy piloted twice by the local government in Delhi-NCR in 2017 [1–3] to reduce number of vehicles, and subsequently fuel emissions to improve air quality index in the city. The policy was highly debated in news and social media. As shown by the researchers in [4], most of these debates were driven by political leanings of the social media users, instead of empirical data. If PM is measured before, during and after such a policy implementation, along with images taken simultaneously to count the number of vehicles, then the effect of such urban transport policies on air quality can be empirically evaluated. To this goal, having a camera in the embedded unit, that takes pictures of the road traffic corresponding to the measured PM is useful. The images can be processed by state of the art CNN models for vehicle counting and classification, to correlate with the measured PM values.

3 CHALLENGES

While the expectations from the unit are intuitive as described above, there have been some challenges in building a working prototype. We enumerate these challenges and describe how we handle them.

3.1 Low cost requirement

While scalable pollution measurement is highly desirable, there is an inherent trade-off between cost and accuracy in the domain of pollution sensors. The task of measuring the amounts of different gases and particles of various sizes need significant knowledge of chemical engineering and instrumentation. There are three cost category of devices:

(a) Category A devices: The most accurate sensors cost 50K - 100K USD. These instruments can count even ultrafine particles and compute source segregation (vehicle emission, bio combustion, etc.). The 19 locations in Delhi-NCR shown in IndiaAirQuality.info, where pollution sensors have been set up by the government, has similar high-end accurate instruments.

(b) Category B devices: The second category of sensors of moderate cost (each assembled unit priced at about 1000 USD or 65K INR) [1]. The unit measures O_3, CO, NO, NO_2, SO_2, and PM.

(c) Category C devices: There is a third category of devices assembled and sold by Indian and foreign start-ups and companies (e.g. Atmos, Airveda, Aircasting, Speck, Mylapka). These devices are based on cheap Do It Yourselves (DIY) sensors, typically using a light scattering based PM sensor with some auxiliary temperature, pressure and humidity sensors, a small microcontroller and network connectivity options like Wi-Fi or GSM. Priced at 10K-20K INR, these are being used by data scientists and citizens across the world for measuring both outdoor and indoor pollution.

Given budget constraints for a city wide deployment in 1600 buses, Category C devices are most appropriate for this project.

[1] https://tatacenter.mit.edu/portfolio/air-pollution-sensors/

3.2 Issue with off the shelf platforms

Before building our own platform, we experimented with off-the-shelf Category C sensors. Without mentioning the specific makes, the common issue with all instruments were their assumption of continuous network connectivity. Designed for an indoor deployment setting, the firmware expected continuous wired or Wi-Fi connection, in absence of which the unit needed a manual reboot. Buses moving across the city can never assume continuous network connectivity. Thus we decided to build our own platform based on cellular radio, along with a large SD card for local storage. Our unit buffers data locally and transmits it to the remote server as soon as network connectivity becomes available.

3.3 Non-standard sensor readings

Category C sensors have the known issue of reporting non-standard PM values. Fig. 1 shows two co-located sensors. In two phases of measurement, they showed similar temporal patterns, but there is a difference in the absolute value measured. We have tested this with multiple sensors, and each reports different absolute values while showing similar temporal trends. For map visualizations of pollution levels, spatio-temporal analyses etc. standard values of PM are needed. To handle the standardization issue, each unit is being statically calibrated against a Category A sensor under different temperature and humidity conditions. To correct the sensed PM value, temperature and humidity sensors are also included as part of our embedded platform.

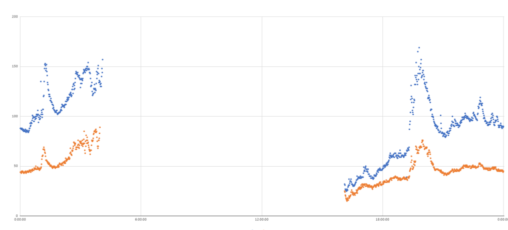

Figure 1: Non-standard sensor readings

3.4 Mobility induced noise in PM data

While using the unit in a bus, we also found PM readings to jump to very high values as soon as the bus starts moving, though the location remains almost the same. It is impossible for PM to change so drastically over such miniscule geographical change, so this is a mobility induced noise. For this reason, we will consider PM data collected only when the bus is stationary. Buses stop at bus-stops, in congestion, at traffic signals and at bus-depots, and will therefore create ample sensing opportunities even if data is collected only during stationary periods. As GPS data is noisy and differentiating stationary periods precisely from moving phases will be difficult, we include inertial sensors like accelerometer and gyroscopes in the unit.

3.5 Mounting challenges

Finally, the unit needs to be robust to be put in a bus. It needs to have excellent shock absorbers to withstand jerks as the bus moves,

(a) GPS, inertial and temperature sensors **(b) Camera** **(c) PM sensor**

Figure 2: Hardware connections in our embedded platform

otherwise the different components will get disconnected. If it is inside the driver's cabin, it needs temperature insulation as the drivers' cabin is 4 degrees hotter than outside. All these buses are non air-conditioned. If the unit is mounted outside, it needs to be water proof.

To try out different mounting positions, we have prototyped three different units, that can be put (a) on dashboard (b) inside the bus on the driver's door (c) outside the bus on the side mirror near driver's seat. Through an ongoing pilot deployment, we are evaluating which mounting works best in terms of getting open air for the PM sensor, wide view for the camera to capture road traffic images and getting the 5V power supply from the bus.

4 THE PROTOTYPES

Our prototypes are based on the Raspberry PI zero boards. There is a GPS unit for location and time (on UART interface), a Plantower 7003 PM sensor (on UART interface), accelerometer (on I2C interface), camera, a JIO-FI WiFi router (which connects to the remote backend via a cellular connection and to the Raspberry PI over Wi-Fi), a 16 GB SD card, temperature and relative humidity sensors (on GPIO interface) and a battery. Since Raspberry PI boards have only one UART interface, we use GPIO pins as UART using bit-blitting to support the two UART devices for GPS and PM. Figure 2 shows the connections among the different components in our embedded unit.

The units are cased in water proof metal boxes, with different kind of metallic springs for shock absorption and cushioning for thermal insulation. Appropriate holes are made for the pollution sensor to get airflow and the camera lens to see traffic view. The manufacturing cost has been 15k INR per unit.

Early results from the prototype deployment in buses (currently ongoing) will be presented in the poster. Live demonstration of the units, mounted on remote controlled cars, will also be shown.

5 DISCUSSIONS AND CONCLUSION

This poster describes the practical challenges faced in designing a vehicle mounted pollution sensor, for scalable PM monitoring in Delhi-NCR. These units have the potential of: (a) a large network of always on robust system of sensors reporting PM 2.5 and PM10 values from different areas of Delhi-NCR, (b) fine-grained spatio-temporal pollution maps of Delhi-NCR using Bayesian matrix completion methods to create spatially fine-grained, real time information maps for citizens and policy makers, (c) fast analytics and querying engine built on top of real time and historical map data, with scalable web server and visualization front-ends and (d) correlations of PM readings with external factors in different areas like traffic congestion, weather, green cover, census data, commercial activities of different geographical areas, using auxiliary sensors like camera and existing web APIs (using GPS coordinates with the Google Maps, Places and Satellite APIs). The success of this pilot project at Delhi-NCR may lead to its adoption in other cities of India in future.

REFERENCES

[1] 2019. Congestion Charge. http://www.politics.co.uk/reference/congestion-charge.
[2] 2019. Paris Implements Odd-Even Rule to Tackle Smog. https://thewire.in/world/paris-odd-even-smog.
[3] TERI: The Energy and Resources Institute. 2018. Measures to Control Air Pollution in Urban Centres of India: Policy and Institutional framework. In *TERI Policy Brief*.
[4] Arnab Jana Rounaq Basu, Aparup Khatua and Saptarshi Ghosh. 2017. Harnessing Twitter Data for Analyzing Public Reactions to Transportation Policies: Evidences from the Odd-Even Policy in Delhi, India. In *Proceedings of the Eastern Asia Society For Transportation Studies (EASTS)*.