Zone Based Indoor Mobile Air Pollution Monitoring

Noura Alhakbani
King Saud University
Riyadh, Saudi Arabia
nhakbani@Ksu.edu.sa

Eiman Kanjo
King Saud University
Riyadh, Saudi Arabia
ekanjo.c@Ksu.edu.sa

UbiComp '13 Adjunct, September 08 - 12 2013, Zurich, Switzerland.

http://dx.doi.org/10.1145/2494091.2496001

Abstract
Pollution is one of the main problems that humans are suffering from. Moreover air pollution is one of the hardest to escape. Although human spend most of their time indoor, most of the previous pollution monitoring studies focused on outdoor air monitoring. In this paper we present a new framework for zone based indoor mobile pollution sensing. Users carry portable pollution sensors along with NFC enabled phones to detect zone (i.e. tag) proximity in a building. NFC here assists in aggregating sensor data for further processing. Our system has been deployed and evaluated through a preliminary user study.

Author Keywords
Indoor pollution; NFC; mobile sensing.

ACM Classification Keywords
C.3.3 [Special-Purpose and Application-Based Systems]:Real-Time and Embedded Systems

Introduction
Air Pollution is one of the main issues that are facing humans and it is very hard to escape from. Standard levels of certain gases have been established by different agencies such as EPA [7]. Indoor air pollution is affected by many factors mainly is the outdoor and surrounding pollution levels in addition to many other factors such as air conditioning, cleaning detergents, and cooking stoves. Many studies have demonstrated that concentrations of many chemicals were much higher indoors than outdoors due to its closed nature and less air volume to dilute in.

Moreover researches [10, 11] indicate that indoor pollution may cause allergy and asthma at home, affect productivity in offices and learning in schools.
Techniques to maintain Indoor Air Quality (IAQ) include source control, air cleaning, cool and dry air, ventilation and building materials. The previous studies revealed that a proper IAQ management strategy requires interdisciplinary knowledge and work. IAQ monitoring is challenging because indoor air pollutants concentration and human motion patterns each vary spatially and temporally within and across rooms. Yet installing a large number of sensors in one place is inefficient as it tends to be concentrated in small areas, leading to similar pollution readings.
Mobile pollution sensing represents an important shift in mobile device usage from communication tool to a networked mobile measurement instrument. Most recent research works has been done on outdoor air pollution and mobile sensing rather than indoor air pollution [3, 4]. However people spend and do most of their activities indoor; at home people sleep, cook, or watch T.V., at office they work, or at universities they study in lecture halls or libraries. Outdoor pollution sensing systems mostly rely on Global Positioning System (GPS) which is not feasible for indoor sensing. New indicators addressing exposure to selected indoor air pollutants and insufficient ventilation require new methods for data collection. In our paper we propose an indoor mobile sensing framework based on zones. Each zone is identified with NFC tag to localize and aggregate the sensor data. The availability of NFC readers in new mobile phones made its use feasible and cost effective. Through mobile sensing, we aim to reduce the number of sensing devices that have to run concurrently in various areas (zones) nevertheless coverage and sensing granularity will be increased. Specifically, we propose a zone-based indoor pollution sensing, which gives better overview of pollution spread around a building by comparing various zones. It also showed a high variability in concentrations between zones.

Sources of Indoor Air Pollution

Indoor pollution has multiple sources ranging from gas and kerosene to furniture and pressed wood, cleaning material and air conditioning outdoor sources such as smoke and tobacco, radon and pesticides [9].
In this study, we experiment with Carbon Monoxide (CO) in indoor environment. Other pollutants will be investigated in consecutive studies.
High CO concentrations can be caused by smoking tobacco or cigar, stoves, fireplaces, and attenuation of external pollution levels within the building. CO has many side effects on humans; it binds to hemoglobin when smoking tobacco [2]. In high concentration CO leads to death because it interferes with the oxygen delivery to blood but in lower concentrations it causes varied symptoms such as fatigue and headaches.

Indoor Location Detection Techniques

In our research our focus will be on indoor zoning for mobile sensing purposes, which aims at creating or differentiating between zones where sensor data is collected and aggregated to a specified zone.
Room fingerprinting or zoning is done currently by assigning Radio Frequency Signals (RFS) such as WiFi to room or using the cellular infrastructure. WiFi signals are inherently noisy and algorithms have to deal with signal reflection, refraction, diffraction and absorption. These methods can be costly or of compromised quality and accuracy [1, 5].
Radio Frequency Identification (RFID) could not be feasibly deployed because RFID readers are expensive [6].

In our research we deployed Near Field Communication (NFC) to detect sensor proximity and to aggregate data associated with the corresponding zone. NFC is an affordable technology. Most mobiles are equipped with NFC technology which makes it handy such as Samsung Glazy S3 and S4 [8].

Architecture of the indoor environmental and pollution data collection system

A mobile application runs on Samsung Galaxy S3 which is equipped with NFC reader. The mobile application collects CO measurements from off the shelf CO sensor via Bluetooth then transfers the readings to a remote server for storage and data processing. To recognize the phone location, our system leverages the NFC to monitor sensor proximity to the tag. Our NFC tags localization can be triggered within 50cm distance. And subsequently the data is physically clustered according to proximity. Figure 1 below shows the architecture of our proposed system.

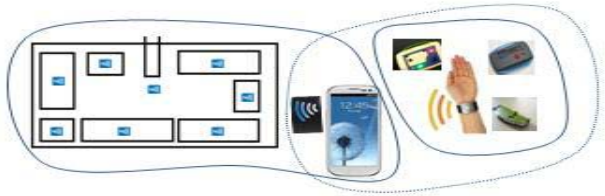

Figure 1: An indoor mobile pollution monitoring system

Results and Data Analysis

In our preliminary user experiment, we have measured the CO at the main building of the College of Computer and Information System (CCIS). Two users carried S3 mobile phones along with the CO sensors around the building for four weeks.

The users moved regularly around the building and specifically in close proximity to the tags in order to collect CO readings and Zone-IDs in 10 different zones located at different floor levels, Figure 2 shows the location of the experiments, and Figure 3 depicts the floor plan along with the locations of the NFC tags.

Figure 2: Map of experimental site with adjacent roads. The location of the experimental site is indicated with the arrow.

Figure 3: NFC Tag distribution across the building

The results of this initial test shows a clear variation in CO concentration between one zone and another which might be a direct result of poor room ventilation or because the room is overlooking a busy road, which is the case in zone 2(tag 2). Figure 4 shows a boxplot figure of the data at each tag location. It exhibits higher values at Tag1 and Tag2 and then it decreases and varies till it reaches its lowest points at Tag9 and Tag10 where they are located at the third floor. Currently, we are working on set of experiments involving distributing 10 sensors on participants and collecting indoor data pollution on campus with more parameters such as Nitrogen Dioxide (NO2), temperature and humidity.

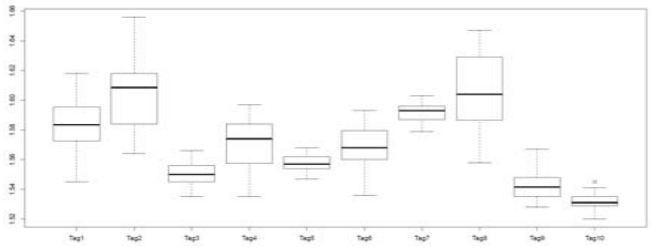

Figure 4: Boxplot showing CO levels at different proximities corresponding to Tag locations

Then we will analyze the data and perform extensive comparative studies between different rooms and buildings.

Conclusion

This study presented a new framework for mobile air pollution indoor zone-based proximity detection method for collaborative sensing, which gives a clear picture of pollution levels in different rooms. The same concept could be applied to different kinds of pollution sensors. We have found a visible pattern of CO concentration across different zones in the same building. Further studies are underway to understand the distribution of various indoor pollutants and its sources.

References

[1] Haeberlen, A., Flannery, E., Ladd, A. M., Rudys, A., Wallach, D. S., and Kavraki, L. E. Practical robust localization over large-scale 802.11 wireless networks, The 10th annual international conference on Mobile computing and networking, 2004, pp. 70–84.

[2] Carbon Monoxide Poisoning-What Happens. http://firstaid.webmd.com/tc/carbon-monoxide-poisoning-what-happens

[3] Kanjo, E., Landshoff, P. ,Roberts, D. ,and Bacon, J. MobSens: Making Smart Phones Smarter , *IEEE Pervasive Computing* 8, 4 (2009), 50-57.

[4] Kanjo, E., Benford, S., Woolard, A., Paxton, M., Woodgate, D., and Fraser, D. S. MobGeoSens: Facilitating Personal MobGeoSensor data collection and visualisation using mobile phones , *Personal ubiquitous computing Journal* 12, 8 (2008) 599 – 607.

[5] Park, J., Charrow, B., Curtis, B., Battat, J., Minkov, E., Hicks, J., Teller, S., and Ledlie, J. Growing an organic indoor location system, in Proceedings of the 8th international conference on Mobile systems, applications, and services, (2010), 271–284.

[6] Ni, L. M., Liu, Y., Lau, Y. C., and Patil, A. P. LANDMARC: indoor location sensing using active RFID, Wirel. Networks 10, 6 (2004), 701–710.

[7] National Ambient Air Quality Standards (NAAQS) Air and Radiation | US EPA. http://www.epa.gov/air/criteria.html

[8] NFC Forum□: About NFC. http://www.nfc-forum.org/aboutnfc

[9] O. US EPA, Indoor Air Quality: An Introduction to IAQ. http://www.epa.gov/iaq/ia-intro.html

[10] Wargocki, P., and Djukanovic, R. Simulations of the potential revenue from investment in improved indoor air quality in an office building , ASHRAE Transactions 111,2 (2005), 699-711.

[11] Bako-Birolt, Z., Weschler, C. J., Wargocki , P., and Fanger, O. P. *Effects of indoor pollution sources and ventilation rate on ozone surface removal rate and the occurrence of oxygenated VOCs in an office space*. The 10th International Conference on Indoor Air Quality and Climate 11, 2 (2005), 2320-2324.