Environmental Monitoring with Mobile Phones *(Ghana)*

Issue: A Need for More Comprehensive Data on Urban Air Quality

"We need to shatter our understanding of mobile phones as merely phones and celebrate them in their new role as measurement instruments," says Eric Paulos of Intel Research in California (United States), a pioneer in the so-called urban-sensing movement. His desire is to add 'super-sensing' tools that transform ordinary mobile devices into tools that can collect and help track environmental trends.

More than 3.5 billion people carry mobile phones today, and researchers are beginning to notice mobile phones' ability to become the 'ultimate data collection machines.' Mobile sensing–also known as 'participatory sensing,' 'urban sensing,' or 'participatory urbanism,'–enables data collection from large numbers of people in ways that previously were not possible. By affixing a sensory device to a mobile phone, mobile sensing provides the opportunity to track multiple data points and collect dynamic information about environmental trends from ambient air quality to urban traffic patterns.

Or as Debora Estrin, a prominent researcher in this field from the University of California at Los Angeles, put it: "We can now manifest the previously unobservable in science."

Response: Empowering Citizens with Data Collection Devices

Mobile sensing represents an important shift in mobile device usage from communication tool to a 'networked mobile measurement instrument.' By aggregating thousands of data points transmitted by individual mobile phones, mobile sensing can paint a complex and dynamic portrait of the environment in which users are based. There are efforts underway to use sensing-equipped mobile phones to monitor a range of environmental factors, from ambient air pollution to transportation and traffic patterns to noise pollution.

The World Health Organization estimates that more than 4.6 million people die annually from the direct impact of air pollution–more than from car accidents every year.[20] According to Paulos, in many cases our knowledge of ambient air quality is limited to "a small handful of government-installed environmental monitoring stations that use extrapolation to derive a single air quality measurement for an entire metropolitan region." He argues that this "sparse sensing strategy does little to capture the very dynamic variability of air quality that depends on automobile traffic patterns, human activity, and output of industries."

To demonstrate the potential of citizen-generated environmental data, Paulos and his team ran a small-scale project in Accra, Ghana, where they equipped a small group of taxi drivers with devices that gauged the amount of pollution in the air. Accra has generally poor air quality, generated by tailpipe emissions, dust, and the common practice of domestic cooking outside using wood, charcoal, and other fuel sources that can spread harmful pollutants across the city. To help monitor air quality, Accra has a stationary monitoring system installed by the U.S. Environmental Protection Agency. This tool makes it possible to compare data from a stationary point with the mobile air

[20]World Health Organization (WHO). *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005* (Geneva: WHO, 2006).

Environment

monitoring of the Intel Berkeley research project.

Outcome: A Clearer Picture of Polluted Air

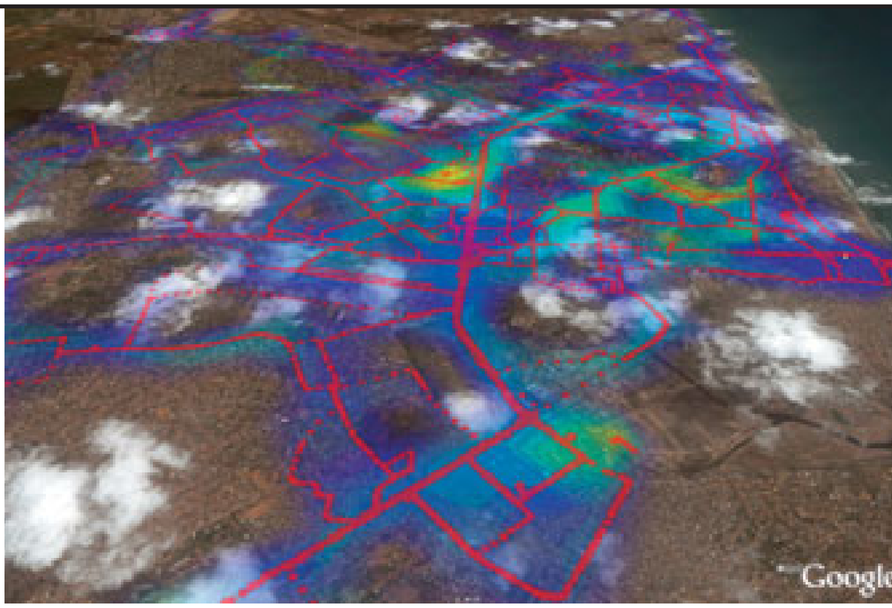
In the Accra study, seven taxi drivers were provided with a dash-mounted global positioning system (GPS) device and a tube to hang from their passenger window. The tube contained a carbon monoxide sensor. Similarly, three students were each given a mobile clip sensor pack containing a GPS device, and a carbon monoxide sensor. The taxi drivers and students were asked to carry their sensors as much as possible during their normal everyday activities. Throughout the day, the sensing system automatically logged sensor data. At the end of each day, the pilot participants dropped off their sensor packs at a central location where the data was then extracted and the sensors recharged.

Paulos notes: "This study allowed us to collect actual air quality sensor data by citizens across an urban landscape. It also influenced our design for an integrated air quality sensor with a mobile phone." Variations across smaller neighborhoods and different parts of the city are clearly visible.

The data gathered provided a previously unmeasured map of carbon monoxide and air quality across the city. Colors in this image represent the individual taxi drivers' readings while the size of the patch indicates the intensity reading of carbon monoxide during a single day. Variations across smaller neighborhoods and different parts of the city are clearly visible.

Challenge: Harnessing the Potential of the Mobile Sensing Platform

Intel's mobile sensing pilot in Accra produced some interesting unanticipated outcomes, including a 'human aspect' that



A heat-map visualization of carbon monoxide readings across Accra, Ghana rendered atop Google Earth. Colors represent individual intensity reading of carbon monoxide during a single 24-hour period across the city. Red circles are locations where actual readings were taken.

resulted from the participatory data collection process. Paulos tells the story of how Accra taxi drivers, who met at the end of the day at the mobile sensing device charging station, began to share their data, look at roads and areas that were particularly polluted, and trade tips on how to avoid certain routes. He notes that this incident illustrates the potential of 'participatory sensing' to both yield rich and interactive environmental data critical for public health and pollution reduction, and motivate people to become active participants in their environment.

Another area for further exploration is the ability of mobile sensing to contribute to public health by linking health with environmental factors that have not been available before. For example, even though we know that there is a link between asthma symptoms and air pollution, previously it was not possible to directly correlate an individual's symptoms with their exposure to air pollutants. Measuring people's lung performance while measuring ambient air pollution exposure could shed new light on the links between air pollution and asthma, perhaps resulting in better treatments.

Research is also underway to assess whether it is possible to detect avian influenza viruses and other diseases through mobile sensing devices. Similar linkages may be possible in other issue areas, such as in emergency detection and warnings, which are important to public safety, and emergency and disaster response applications.

Next Steps: Securing a Future for Mobile Sensing

Users in mobile participatory data collection projects are divulging private information about their location and context. Security and privacy are therefore of concern. There is considerable discussion about how to ensure privacy while still transmitting useful information. This could include giving users the choice of only selectively sharing direct observations, and designing protocols that ensure a person's anonymity.

Mobile sensing is an emerging area where costs and benefits to date are hard to determine because it is still so early in the research cycle. However, it is also a rapidly developing area of inquiry that will likely see considerable activity and interest, not just on the part of university or commercial researchers but also on the part of citizen groups and environmental advocates.

Using mobile phones as sensing devices and aggregating "crowdsourced" data into sophisticated and previously impossible environmental maps is an emerging field with only preliminary trials. Yet while still in early phases of concept development, the potential of mobile sensing to contribute to environmental conservation and related fields is clear. Ongoing research in this area will continue to provide fascinating data for researchers, citizen groups, and environmental advocates. ■

Mobile Sensing Device or Mobile Sensing Phone?

While the early Accra project used mobile sensing devices but not mobile phones, Paulos and his team are now working on integrating a sensor into a mobile phone as a prototype of a more integrated platform for collecting data in California.

Meanwhile, in Cambridge, England, mobile phones are being used by bicycle couriers to gather pollution information. Each phone is connected via Bluetooth to a sensor attached to a courier's bike. The sensor monitors air pollution while the phone transmits the data back to a research lab at the University of Cambridge. Custom software reports levels of air pollutants and a GPS transmits the exact location of the courier.

Commercial players such as Nokia are beginning to enter this field as well. Nokia recently featured a concept phone with a wearable eco-sensor that detects carbon monoxide, particulate matter, and ground-level ozone. Data would be transmitted to the phone where a user could choose to share the environmental data, aiding in research and increasing environmental awareness.