Distributed Sensing Using Mobile Smartphones

If you thought your smartphone was already doing more than enough by allowing you to send e-mail, browse the Web and do word processing, think again. It might just become part of the distributed sensing revolution that is set to sweep the world.

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Mobile phones are proliferating the world over, with well over two billion in use worldwide. In India, about 8 million mobile phones are added each month and the total number of such phones is approaching 300 million. While the vast majority of mobile phones in use are basic phones that only support voice, the share of *smartphones*—programmable phones that can run computer applications—is on the rise. For example, of the billion phones sold worldwide in 2007, 15 per cent—a sizeable 150 million—were smartphones.

Phones get more sense!

The usage of smartphones has thus far focused on voice telephony as well as data applications such as e-mail and Web browsing, and word processing,

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all of which are already well established in the PC space. What next? Are there opportunities that go beyond the phone or the PC paradigms that have defined mobile smartphones thus far? To answer this question, let us take a peek under the hood of a smartphone. What we would find is not just a phone or a computer but rather a combination of computing, communication, and sensing in a mobile package. If the sensing bit surprises you, consider this. All phones by definition have a microphone, which is an audio sensor. Many have a camera. An increasing number of them include GPS. Some have an accelerometer. A few even have a digital compass or an ambient light sensor. With hardware advances, it is quite likely that this collection of sensors will only become richer. For example, future mobile phones might include temperature sensors or air quality sensors.

How would we use this rich collection of sensors? Today, the sensors on a phone are to provide useful functionality or an enhanced experience to the user of that phone. For example, a camera allows the user to take pictures, an accelerometer enables tilt and gesture-based functionality, and an ambient light sensor helps save battery energy by turning off the display's backlight when not needed. However, people are inherently social creatures, so an even bigger opportunity awaits us. The mass of mobile smartphones equipped with such sensors could be turned into a giant distributed sensing system, allowing users to benefit from information gathered via other phones and users. For example, phones could be used to gather traffic information in a city.

Getting sensational

There are a couple of reasons why smartphones are ideally suited for large-scale distributed sensing applications. First, there is already a large and rapidly growing base of such devices, which provides the opportunity for assembling a large distributed sensing system, potentially spanning millions of nodes, purely through software. This avoids the expense and hassle of deploying a special-purpose sensing system -- hurdles that have severely limited the scale of such networks thus far. Second, these devices are mobile, travelling with users as they drive through the city, hop onto a train, or settle down for dinner at a restaurant. This makes it quite likely that there will be phones at the right place at the right time to accomplish the sensing task--a requirement that is critically important. For instance, if we are interested in learning about the speed of traffic flow on MG Road in Bangalore, even a supercomputer

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in a data centre cannot substitute for a phone carried by a user who is, in fact, driving down that road.

While the idea of smartphone based sensing systems is futuristic, early-stage prototypes are taking shape in universities and research labs across the world. This is variously called *opportunistic sensing* or *participatory sensing*, with the distinction between the two being that the former is automated whereas the latter includes the user in the loop. Here is a sample of the wide range of research efforts in this space:

MetroSense (Dartmouth College, USA): This project focuses on people-centric sensing using mobile phones. One example, in particular, is *BikeNet*, where a mobile phone coupled with other sensors is used to record the user's bicycling experience, including their performance and environmental conditions. This information is then available for the user to review later or even share with others.

Nericell (Microsoft Research India): This work uses smartphones that people carry around in normal course, including while they are driving, to perform *rich monitoring of road and traffic conditions*, using sensors such as accelerometers and microphones. Such rich monitoring is of particular interest in developing regions where an extreme heterogeneity of vehicles, variable road quality (e.g., potholes), and chaotic traffic conditions (e.g., braking, honking) make it important to go beyond the traditional approach of just monitoring the speed and volume of traffic.

Micro-blog (Duke University, USA): This is an example of participatory sensing, where an ensemble of phones equipped with sensors is used to provide a *virtual information telescope*. Users can zoom into any part of the populated world and observe events of interest. While the information that is requested may be provided automatically in some cases, the human user may be involved at other times, for instance, in taking pictures or answering queries. Examples of domains where such information telescopes would be useful are tourism and disaster management.

SensorPlanet (Nokia Research Centre, Finland): This project is developing a remote sensing platform for mobile phones, targeted at scenarios such as healthcare and environment monitoring. The project includes a participatory sensing component, including a *Virtual Graffiti* application that allows users to leave *virtual* multimedia 'tags' in their environment, which other users can then look up and comment on.

There are a number of challenges that need to be overcome in making opportunistic or participatory sensing a reality. Many of these challenges arise from one simple fact: a mobile phone is primarily a user's personal device, so any attempt to leverage it for a community application such as distributed sensing must not intrude on the user's use or ownership of their device. Thus, there are technical challenges such as ensuring that the sensing task imposes minimally on battery energy and respects the user's privacy. There are also part-technical and part-social challenges, such as providing users with the right incentives to participate. The good news is that all of these problems are the subject of active research. So if all goes well, you and I might find ourselves as participants in and consumers of distributed sensing applications in the not-too-distant future. It might then seem to us as routine as making a phone call! i.t.