Chapter 33
Building Mobile Sensor Networks Using Smartphones and Web Services:
Ramifications and Development Challenges

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ABSTRACT

Wireless sensor networks are composed of geographically dispersed sensors that work together to monitor physical or environmental conditions, such as air pressure, temperature, or pollution. In addition, wireless sensor networks are used in many industrial, social, and regulatory applications, including industrial process monitoring and control, environment and habitat monitoring, healthcare, home automation, and traffic control. Developers of wireless sensor networks face a number of programming and deployment challenges, such as networking protocol design, application development, and security models. This chapter shows how smartphones can help reduce the development, operation, and maintenance costs of wireless sensor networks, while also enabling these networks to use web services, high-level programming APIs, and increased hardware capability, such as powerful microprocessors. Moreover, this chapter examines key challenges associated with developing and maintaining a large wireless sensor network and presents a novel smartphone wireless sensor network that uses smartphones as sensor nodes. We

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validate our work in the context of Wreck Watch, which is a smartphone-based sensor network for detecting traffic accidents that we use to demonstrate solutions to multiple challenges in current wireless sensor networks. We also describe common pitfalls of using smartphones as sensor nodes in wireless sensor networks and summarize how we have addressed these pitfalls in Wreck Watch.

INTRODUCTION

Traditional wireless sensor networks are composed of numerous independent sensors that collaborate to monitor environmental conditions. Sensors traditionally used in these networks have limitations, such as low battery power, meager processing capabilities, or complex networking methods. Initial wireless sensor network research was motivated by defense applications, such as intelligence, surveillance, and reconnaissance. More recently, many other uses have been identified for wireless sensor networks, including industrial process monitoring, traffic pattern surveillance and control, or healthcare applications. This paper examines the pros and cons of using smartphones as sensor hubs in wireless sensor networks to alleviate limitations with traditional sensors.

Developing large-scale sensor networks has traditionally required physically deploying and managing many customized sensor nodes. Likewise, harvesting sensor data efficiently has required complex networking techniques, such as energy-aware routing protocols, data-centric protocols, location-based protocols, or hierarchical protocols (Akkaya 2005) (Zang 2005) (Lee 2006). After sensor data was collected, moreover, substantial effort was needed to process and visualize the data, or to take responsive actions. Physical upkeep of the sensor nodes also required teams to visit and maintain deployed sensors.

Modern smartphones are sophisticated computing platforms with complex sensor capabilities, such as detecting user location, recording high-quality audio, measuring ambient light, sensing geomagnetic strength, and sensing orientation (Mohan 2008). Due to widespread use of smartphones, it is now possible to develop large-scale sensor networks using cellular network technology and deploy applications on end-user devices to collect and report sensor readings back to servers. End-users also often have a keen interest in maintaining their phones, including repairing broken hardware, re-installing faulty software, and maintaining data synchronization with servers. This end-user maintenance helps alleviate much of the burden from operators and other network administrators.

Millions of Apple iPhones and Google Android-based phones have been sold (Betanews 2008). The potential size of smartphone wireless sensor networks is directly related to the number of smartphones being used daily by end consumers. The large number of purchased smartphones suggests that smartphone sensor networks could contain hundreds of thousands of nodes. Much previous work on sensor networks, such as environmental monitoring and first-responder systems, can be adapted to mobile smartphones, where that work will likely achieve more dispersion and adoption per unit of effort than conventional methods of deploying mobile sensor networks (Leijdekkers 2006).

After sensor data has been collected, it must be processed, visualized, and shared with users. Web service APIs are another emerging trend that can help in this task. For example, Google offers public services for geocoding addresses, sharing pictures and video, displaying maps, and overlaying data across satellite imagery. Likewise, some services, such as Google's App Engine and Amazon's EC2 compute cloud, offer free or low cost computational grids for analyzing data (Buyya 2008). Utilization and composition of these types