Chapter 5
SMART:
Mobile Patient Monitoring in an Emergency Department

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ABSTRACT

Patient monitoring is important in many contexts: at mass-casualty disaster sites, in improvised emergency wards, and in emergency room waiting areas. Given the positive history of use of monitoring systems in the hospital during surgery, in the recovery room, or in an intensive care unit, the authors sought to use recent technological advances to enable patient monitoring in more diverse circumstances: at home, while traveling, and in some less well-monitored areas of a hospital. This chapter presents the authors' experiences in designing, implementing and deploying a wireless disaster management system prototype in a real hospital environment. In addition to a review of related systems, the sensors, algorithms and infrastructure used in our implementation are presented. Finally, general guidelines for ubiquitous methodologies and tools are shared based on the lessons learned from the actual implementation.

INTRODUCTION

As technology advances, there are more options available for pervasive monitoring. Sensor miniaturization, wireless communication and increasing processing power in smaller packages allow more efficient, reliable and convenient systems, at least from the end-user perspective. In healthcare, one of the main driving forces behind ubiquitous computing is the increasing need to move patient care from the hospital to non-standard settings such as homes, nursing homes, improvised waiting areas, hazardous locations or the battlefield. For at-risk

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patients, such as those with chronic diseases or the increasingly aging population, being able to live in a familiar and comfortable environment improves quality of life and frees hospital resources. In disaster situations or during seasonal or regional disease outbreaks, response teams move from the hospitals to improvised settings to care for multiple casualties with varying levels of urgency. Firefighters, hazmat teams and soldiers need real-time, ubiquitous monitoring to detect life threatening events. Existing solutions from industry, academia and the military share the same goal of developing unobtrusive, reliable and pervasive monitoring systems.

Powerful, disposable computers, wireless technologies, sensors and energy storage have made possible the development of Body Sensor Networks (BSN) (Aziz et al., 2008). These networks are ubiquitous, allowing patient supervision wherever they may go. Personalized health care is a natural extension of these BSN. Future challenges are user acceptance (from both patients and practitioners), ease of use, and avoiding data flooding with little information.

This chapter presents a particular experience of embedding a pervasive system in a healthcare setting and the steps required in the design and test of such a system in the hospital. We show benefits from fusing information from different sensors, the complications that arise when dealing with untethered subjects and finally the evaluation in a real environment. We also show how the implementation of this system required the skills of a multi-disciplinary team.

BACKGROUND

Pervasive Systems in Healthcare

In healthcare, the main technological components in pervasive systems are sensors and network technologies. The most frequently used physiological sensors measure ECG, SpO_2, temperature, acceleration, sound, and non-invasive blood pressure (BP). Since most physiologic variables present slow variations, networks are usually low bandwidth, adequate to handle the low data rates. Many of these networks are also characterized by short range transmissions, such as in Body Sensor Networks (BSN) or Personal Area Networks (PAN). These low bandwidth, short range networks are usually implemented using ZigBee or Bluetooth networks (Table 1). As the system aggregates data and forwards it to central servers, higher bandwidth is required. Local Area Networks (LAN) use the widely adopted WiFi networks for their wireless requirements. For larger ranges, cellular networks and WiMAX provide a reasonable solution (Fourty, Val, Fraisse, & Mercier, 2005; Kavas, 2007). Currently, cellular networks are the preferred method to relay data from ambulances and other fast moving patients due to its hand-over capability. WiMAX is being updated to allow roaming but its main strength is its suitability to provide wireless Metropolitan Area Network (MAN) capability to rural, low density areas where cellular networks are not economically viable. Naturally, wired networks provide much better bandwidth and reliability and are used at the earliest opportunity.

Location information is also highly desirable. In a distributed system, finding the patient who has a problem is not easy and a location system should be deployed to solve this problem. Positioning technologies range from GPS or cellular tower referencing used outdoors to RFID, ultrasound or infrared used indoors (Table 2). Sometimes the data network infrastructure acts as a location system by using received signal strength to infer positioning. Some solutions offer a combination of technologies in order to improve their performance.

Korhonen & Bardram (2004) review pervasive healthcare as a multidisciplinary field. It involves hardware, software, sensors, embedded systems, human-computer interfaces, wireless communications and distributed systems among others. In