Chapter LI
Data Warehousing and Decision Support in Mobile Wireless Patient Monitoring

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ABSTRACT

The recent advances in wireless communication technologies have made possible the development of wireless systems for monitoring the health and disease status of patients, in both in-patient hospital settings and outside. The volume of patient monitoring data requires Data Warehousing technologies for storage intended for analysis. The analysis is performed by Decision Support Systems (DSS) that provide clinical diagnoses and treatment methodology consistent with the urgency. The clinical DSS is critical in the analysis of a volume of data beyond the capabilities of a healthcare professional, and is effective in reducing workload, saving money, and providing better care for patients. This chapter also analyzes the technical aspects of the process.

INTRODUCTION

In recent years, the developments in wireless communication systems and technologies have made communication and data transfer capabilities ubiquitous and independent of location, with the possibility of transferring large amounts of data from a mobile location. The users and beneficiaries of this technology include consumers, businesses, and public services [Chaudhry *et al.* 2007]. The mobile technology includes cellular telephones, Internet systems with WiFi, and wireless radio communication.

One area in which wireless communication systems have been increasingly useful, although not as well known, is in clinical data systems and patient monitoring [Falas *et al.* 2003]. The wireless networks and technologies have allowed for a variety of systems for monitoring the health and disease status of patients, such as imaging test results and vital signs such as heart rate and blood pressure, both inside and outside of hospital settings [Koutkias *et al.* 2005]. These wireless patient monitoring systems provide a veritable deluge of data, and *Decision Support Systems* (DSS) are critical elements of processing and analyzing this data [Myers 2003]. Examples of these DSS for wireless patient monitoring include a system to let physicians diagnose a heart attack in the ambulance by sending electrocardiogram (ECG) data to the hospital, or

children with diabetes using a cell phone as a glucose meter and disease monitor [Belazzi *et al.* 2003], and hospital patients that are free of wires but surrounded by automated warnings for their vital signs.

Three of the most common issues of clinical DSS for wireless patient monitoring are data management, data visualization, and data mining and artificial intelligence. After a statement of the background on the medical rationale and technical background for these systems, each of these types of DSS will be explored in turn.

MEDICAL RATIONALE

The rationale for DSS in wireless patient monitoring includes saving lives by faster diagnoses and treatments, faster turnaround and reduced workload for hospital staff saving money for hospitals, health insurance companies, and the patients [Eisenstein 2006]. The necessity of DSS arises because patient monitoring systems generate large volumes of data that is too much for the doctors and nurses to analyze [Abidi 2001].

DSSs are useful for managing, analyzing, and making decisions on large volumes of clinical data obtained from patient monitoring systems. For example, when patient monitoring is continuous, there is more data than can be analyzed by a health care professional [Falas *et al.* 2003]. The targeted users for these DSS consist of doctors and nurses, to aid in diagnoses and direct patient care, patients to facilitate self-maintenance of their conditions, hospital administrators in improving the ability to allocate hospital resources, and public health officials to use the abstracted data from these monitoring systems to provide high-level insights into public health matters [Nanningo & Abu-Hanna 2006].

Any disease or condition can use DSS for wireless patient monitoring, and a wide variety are seen in the literature and in practice. These systems are most useful for chronic diseases or acute attacks [Farmer *et al.* 2005]. These are the scenarios where the patient is at a recurring risk for health difficulties, and thus continual monitoring is preferable. These DSS are applicable to many medical situations, in the hospital, in transport, or elsewhere [Gouaux *et al.* 2003].

There are several important diseases and conditions that are prime targets for patient monitoring. One of the most common diseases in these systems is heart disease [Conforti *et al.* 2006]. Diabetes is one such disease that is common for patient monitoring using cellular networks [Farmer *et al.* 2005], in particular for regular glucose monitoring [Jun *et al.* 2006]. Another condition is sleep apnea, which is when a patient briefly stops breathing repeatedly in the night [Ishida *et al.* 2005]. Asthma is another example, because this common breathing illness leads to attacks that can be deadly if not treated [Ryan *et al.* 2005]. Other examples include wound maintenance care [Braun *et al.* 2005], dialysis [Nakamoto *et al.* 2003], urology [Liatsikos *et al.* 2004], and monitoring the health and safety status of the elderly [Lin *et al.* 2006].

TECHNICAL BACKGROUND OF WIRELESS PATIENT MONITORING

The timeline of patient monitoring reflects the development of technology. One of the earliest examples of transmitting patient data by telephone was in 1906 when Willem Einthoven used a telephone line to send an electrocardiogram (*ECG*) [Hofmann 1996]. When mobile cellular technology arrived, the new and convenient technology was the logical choice to transmit patient data. Although cellular technology began in the late 1940s, it was only in the mid 1980s when the 1G (1st*–generation*) cellular networks were deployed, and these networks began to see use for transmitting patient monitoring data [Shimuzu 1992]. Two-way radio telemetry was then being used to transmit ECGs from ambulances to hospitals [Pozen *et al.* 1977].

The equipment for the initial 1G or first-generation networks were bulky, and use was initially limited to vehicles, such as in patient monitoring during patient transport by ambulance to hospital. In the early days of mobile technology, a general concern about emergencies and disasters was disaster-related secondary communications traffic, *e.g.* individuals attempting to contact their friends and family might overwhelm the local cell preventing the use of the cellular networks for emergency-related transmission of patient data [Koehler 1990]. Since the mid-1990s, these various wireless technologies have become increasingly commonplace and advanced, and useful for clinical Decision Support Systems (*DSS*) [Stacey and McGregor 2007]. In modern times, common wireless technologies using DSS for remote patient monitoring, are cellular phone, satellite phone, WiFi, and Bluetooth. Each of these technologies are compared and described in more detail below.