Chapter 13
Prioritization of Patient Vital Signs Transmission Using Wireless Body Area Networks

Baozhi Chen
Rutgers University, USA

Dario Pompili
Rutgers University, USA

ABSTRACT

Triage is the process of prioritizing patients based on the severity of their condition when resources are insufficient. Hospitals today are equipped with more and more electronic medical devices. This results in possibly high level of electromagnetic interference that may lead to the failure of medical monitoring devices. Moreover, a patient is usually moved between different hospital settings during triage. Accurate and quick prioritization of patient vital signs in such environments is crucial for making efficient and real-time decisions. In this chapter, a novel in-network solution to prioritize the transmission of patient vital signs using wireless body area networks is proposed; the solution relies on a distributed priority scheduling strategy based on the current patient condition and on the vital sign end-to-end delay/reliability requirement. The proposed solution was implemented in TinyOS, and its performance was tested in a real scenario.

INTRODUCTION

The rapid growth of wireless technologies and personal area networks enables the continuous healthcare monitoring of mobile patients using compact sensors that collect and evaluate body parameters and movements. These sensors, limited in memory, energy, computation, and communication capabilities, are strategically deployed on a patient, forming a cluster that is called Wireless Body Area Network (WBAN) (Norgall, Schmidt, & von der Grun, 2004). Many works based on WBANs have been proposed that focus on designing wireless sensors for a single vital sign

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and on developing pervasive healthcare systems to monitor vital signs of multiple patients.

In this chapter, we focus on providing a networking solution for *in-hospital triage*, which is the process of prioritizing patients based on the severity of their condition. This process facilitates the ability of the medical team to treat as many patients as possible when resources are insufficient for all to be treated immediately. Existing devices for monitoring patient vital signs are mostly wired, often depend on direct user interaction, have a limited analytic capability, require manual archiving even of digital data sources, and have limited capability to propagate data to the next destination on the patient's path. This is particularly critical in in-hospital settings.

Accurate and reliable monitoring of patient's vital signs during this period is crucial for making efficient and error-free triage decisions. During triage, emergency service providers need to rapidly assess the injured patient and determine the need for trauma center care. In addition to challenges of acquiring patient data, trauma triage is now limited by a reliance on human interpretation of acquired patient data, which requires the emergency service team be adequately trained. During triage (especially for mass casualty scenarios), this may greatly delay the treatment of patients in critical conditions. Using existing technology, the in-hospital environment lacks effective methods for prioritizing information streams, evaluating time-dependent trends, managing incomplete data, and providing effective alerts. Current limitations of patient monitoring represent an important barrier for developing improved trauma triage methods.

To seamless transfer the data when patients are moved between different settings such as the injury scene, the emergency department, and other locations in the hospital, wireless technologies should be used. However, the explosive growth of wireless technologies brings in an important problem. For example, wireless communication and networking devices are being deployed almost everywhere at an incredible speed, resulting in increased spectrum use by a variety of heterogeneous devices, standards, and applications. This holds especially true for the unlicensed Industrial, Scientific, and Medical (ISM) bands that host a number of heterogeneous networks such as Bluetooth, ZigBee, IEEE 802.11b/g. Because radio waves centered at the same frequency emitted from the wireless devices interfere with each other, coexistence of them has become an important issue in order to ensure that wireless services can maintain their desired performance requirements. For instance, in a critical environment such as medical emergency scenarios it is extremely important to avoid the failure of the medical devices that may be caused by radio frequency interference.

With an ever-increasing use of electronics in medical devices of all kinds as well as many wireless communication devices in medical environments, some unforeseen problems are arising: the interactions between the products emitting the electromagnetic (EM) energy and sensitive medical devices. Even the devices themselves can emit EM energy, which can react with other devices or products. It has been reported that medical devices may fail to operate correctly due to the existence of electromagnetic interference (Silberberg, 1993).

To guarantee wireless services in such environments, it is necessary to design a system that can handle such interference. Existing research on wireless healthcare systems has focused on the design of purpose-specific one-BAN system (Chen, Black, Khan, & Jamshaid, 2008; Dabiri, Vahdatpour, Noshadi, Hagopian, & Sarrafzadeh, 2008) (i.e., system used on one patient), in-BAN data processing/fusion (Li & Tan, 2008; Weisenberg, Cuddihy, & Rajiv, 2008), and improvement of network performance metrics such as throughput and energy efficiency (Li & Tan, 2007; Varshney, 2008). In addition, emergency services have been considered in (Malan, Fulford-Jones, Welsh, & Moulton, 2004; Varshney, 2008). While these studies have proposed solutions to access patient healthcare data in real time, no research

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