Chapter 17
A Cooperative Routing Algorithm to Increase QoS in Wireless E-Healthcare Systems

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ABSTRACT

The recent increased interest in distributed and flexible wireless pervasive applications has drawn great attention to WNCS (Wireless Networked Control Systems) architectures based on WSANs (Wireless Sensor and Actuator Networks) and the resulting Quality of Service obtained in specific applications. Particularly, in wireless E-Healthcare systems based on WSANs, providing certain QoS specifications is crucial for the actuators as they perform actions based on the vital data received from sensors. This chapter is concerned with the performance evaluation of a cooperative routing algorithm QBAR (Queue Based Ad hoc Routing algorithm) for wireless E-Healthcare systems. Simulations have been carried out in order to quantify the impact of the proposed algorithm on the overall network performance, and a comparison with the existing AODV algorithm is presented. The algorithm performances are validated by the Matlab/Simulink-based simulator, TrueTime, which facilitates the co-simulation of controller task execution in real-time kernels and in a wireless network environment. The simulation results highlight that "cooperation" strategies between wireless healthcare devices can strongly improve the reliability of the wireless network, and hence, they are suitable and rewarding for the management of the future generation of E-Healthcare systems.

INTRODUCTION

The recent increased interest in distributed and flexible wireless pervasive applications has drawn great attention to the QoS (Quality of Service) requirements of WNCS architectures based on WSANs (TF, (2004)). Wireless data communication networks provide reduced costs, better power management, easier maintenance and effortless deployment in remote and hard-to-reach areas. Although WSAN research was originally undertaken for military applications, as the field slowly

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matured and technology rapidly advanced, it has been extended to many civilian applications such as environment and habitat monitoring, home automation, traffic control, and more recently healthcare applications (Hung,(2003); Jovanov, (2003); Gao, (2005); Kafeza, (2004);Varshney,(2005)). In particular, WBAN (Wireless Body Area Network) technology has recently significantly increased the potential of remote healthcare monitoring systems (e.g. Jovanov, 2005; O'Donovan, 2009; Yazdandoost, 2009). WBAN is a particular kind of WSAN consisting of strategically placed wearable or implanted (in the body) wireless sensor nodes that transmit vital signs (e.g., heart rate, blood pressure, temperature, pH, respiration, oxygen saturation) without limiting the activities of the wearer. The data gathered can be forwarded in real time to the hospital, clinic, or central repository through a LAN (Local Area Network), WAN (Wide Area Network) or cellular network. Doctors and carers can at a distance access this information to assess the state of health of the patient. Additionally, the patient can be alerted by using SMS, alarm, or reminder messages. In a more advanced WBAN, a patient's sensor can even use a neighbor sensor to relay its data if the patient is too far away from the central server (e.g. the hospital data storage). This communication mode is called ''Multi-hop'' wireless transmission. Generally speaking, multi-hop not only extends the communication distance but also saves energy consumption since direct sensor-server long distance wireless communication is avoided through hop-to-hop relay.

WBANs will become increasingly pervasive in our daily lives. In many applications (e.g. fetal electrocardiogram monitoring and tele-cardiology), communication links carry vital information between the patient and the monitoring devices that needs to be transmitted in short "bursts", requiring a reliable connection. On the other hand, low "sensitive" file transmissions (e.g. in temperature or breath monitoring) can be delay tolerant. One of the critical issues is to design an appropriate wireless protocol solution providing reliability, energy efficiency, scalability, reduced packet losses and a timely delivery without failure.

Several variants of the AODV (Ad Hoc Distance Vector) protocol (Zhang, 2005) have been proposed in the literature to improve the QoS in wireless sensor networks. We highlight that the existing protocols that utilize AODV as the underlying routing mechanism consider only the end-to-end bandwidth and the distance metrics. Moreover, most proactive and reactive protocols choose a route based on the number of hops to the destination that may be inappropriate when there is congestion. Although recent AODV modifications include load balancing operations during the route set up, once the path is fixed they cannot efficiently deal with a dynamic environment such as is the case with healthcare applications (Argyriou, 2006; Choi, 2003; Jung, 2004; Lee, 2005; Pham, 2004; Saigal, 2004; Yoo, 2004).

Recently, the opportunity of introducing router cooperation in order to improve healthcare system reliability has been suggested (see Zhong, (2007) and reference therein). In this scenario, we propose a routing protocol built on the top of AODV based on a minimal router cooperation where each node is available to route neighbor patient/router packets. Specifically, through the proposed algorithm a patient's sensor/router can dynamically transfer packets from overloaded nodes to underloaded or idle nodes to relay its data to mitigate dynamic congestion phenomena. The main contribution of this chapter is to show the enhancement of performance of a wireless E-Healthcare system through a minimal routing cooperation. In particular, a performance evaluation of an enhanced AODV cooperative routing algorithm QBAR (Queue Based Ad hoc Routing algorithm) for WBAN applications has been assessed demonstrating good performance in terms of reliability, packet losses, scalability and time delays. This would be particularly important in a future real time E-Healthcare application where it will be increasingly necessary for the observed event (or action e.g. SMS, alarm, or reminder mes-