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ADAPTIVE MEDIUM ACCESS CONTROL (ADT-MAC) PROTOCOL FOR DYNAMIC MEDICAL TRAFFIC WITH QUALITY OF SERVICE (QOS) PROVISIONING IN WIRELESS BODY AREA NETWORK (WBAN)

WAN HASZERILA BINTI WAN HASSAN

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ABSTRACT

In the era of advanced technology, a short-range Wireless Body Area Network (WBAN) has enhanced e-healthcare and well-being applications by providing cost-effective and efficient monitoring solutions. Defined by the IEEE 802.15.6 standard, WBAN consists of low-power, lightweight, and miniaturized sensor nodes deployed on or implanted in the human body, enabling continuous monitoring of physiological parameters. This sensor-equipped network has emerged as a viable alternative to traditional wired medical systems, significantly improving the patient's quality of life. The performance of WBAN is highly dependent on the design of Medium Access Control (MAC) protocols, as the MAC layer manages wireless channel usage, including node conflict detection, priority control, time slot allocation, and transmission order. The main challenge in designing the WBAN MAC protocol is to ensure high-reliability transmission while meeting diverse Quality of Service (QoS) requirements. Although extensive studies have been conducted on WBAN MAC protocols, existing approaches encounter limitations in guaranteeing QoS under dynamic traffic conditions, lack adaptability, and exhibit low energy efficiency. Furthermore, WBAN generates heterogeneous traffic comprising periodic and emergency events, requiring effective traffic management and prioritization schemes. Inefficient traffic prioritization can result in several issues, such as starvation of low-priority traffic and underutilization of network resources. Therefore, an adaptive and scalable MAC protocol is required to achieve high reliability, energy efficiency, and minimal delay. This thesis proposes a QoS-aware MAC protocol, named the Adaptive MAC (ADT-MAC), which accommodates dynamic medical traffic by addressing emergency and periodic traffic requirements. ADT-MAC utilizes a hybrid and adaptive superframe structure based on the IEEE 802.15.6 standard. The proposed ADT-MAC protocol is simulated using Castalia in OMNeT++ to evaluate its performance against state-of-the-art MAC protocols. Additionally, an M/M/l queuing algorithm with a non-preemptive priority is modeled using SimEvents in MATLAB to validate the packet delay of different priority queues. Simulation results reveal that the ADT-MAC outperforms benchmark protocols in Packet Delivery Ratio (PDR), packet delay, energy consumption, and network throughput. It achieves a 66.5 % reduction in packet delay, improvements of up to 27.1 % in PDR, and an 18.5 % increase in throughput. In addition, ADT-MAC enhances energy efficiency with a 90 % reduction in energy consumption. The result of packet delay from priority queues further validates the accuracy of the proposed ADT-MAC and its queueing algorithm. A two-fold simulation approach using Castalia and SimEvents demonstrated that the packet delay for each priority level remains below the 125 ms threshold set by the IEEE 802.15.6 specifications.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

In recent years, developed countries have encountered substantial obstacles in providing sustainable healthcare services and fostering wellness, mainly due to the growing elderly population and the rising prevalence of chronic ailments such as cardiovascular illnesses, kidney disease, diabetes, and various cancers. Regretfully, these health issues have emerged as critical medical priorities and significant contributors to the increasing mortality rates. The World Health Organization (WHO) forecasts that by 2030, diabetes will rank among the leading causes of mortality, with an estimated allocation of up to 15 % of the national healthcare budget towards diabetes care [1]. Furthermore, the increase in the elderly population is a crucial factor driving the rise in chronic diseases [2]-[3]. By 2050, the proportion of people aged 60 and above is expected to double, reaching 23.6 % in the United Kingdom, 35.6 % in Japan, and exceeding 20 % globally [4]. In Australia, the percentage of individuals aged 60 and over was 16.5 % in 2020, with projections indicating an increase to 23 % by 2066 [5]. Figure 1.1 illustrates the projected growth of the elderly population in developed countries from 2011 to 2050. This demographic trend necessitates a transformation in the healthcare systems, emphasizing proactive wellness management, early disease detection, and prevention. To address these needs, developing an innovative and sustainable healthcare system is essential for ensuring the well-being of future generations.