Joint Power-Rate-Slot Resource Allocation in Energy Harvesting-Powered Wireless Body Area Networks

Zhiqiang Liu, *Student Member, IEEE*, Bin Liu, *Member, IEEE*, and Chang Wen Chen, *Fellow, IEEE*

***Abstract*—Wireless body area network (WBAN) has become a promising network for continuous health monitoring of various diseases. The limited energy of sensors in WBAN cannot support the long term work with the high requirements of Quality of Service (QoS) for health applications. Energy harvesting (EH)-powered WBAN, which can provide uninterrupted work, has attracted more attention from both macadamia and industry. However, the time-varying and heterogeneous EH states of different sensors become an important factor when designing the resource allocation schemes in EH-powered WBAN. In this paper, we propose a novel two-phase resource allocation scheme, which optimizes the allocation of transmission power, source rate and slots to improve the QoS performance of EH-powered WBAN. In the first phase, we analysis the relationship between the QoS performance and the source rate for satisfying the Energy Neutral Operation (ENO), and then a joint Power-Rate Control Scheme (PRCS) is proposed to optimize the source rate and transmission power for ensuring the long-term QoS performance based on the statistical properties of EH. Moreover, we design a QoS Aware Slot Allocation Scheme (QASAS) to dynamically adjust the time slot allocation to cope with the time-varying EH states for obtaining better short-term QoS performance in the second phase. Finally, numerical simulation results demonstrate that the proposed joint Power-Rate-Slot resource allocation of EH-powered WBAN can effectively exploit the time-varying EH to improve both long-term and short-term QoS performance.**

***Index Terms*—energy harvesting, resource allocation, wireless body area network (WBAN).**

I. INTRODUCTION

With the rapid development of sensor and wireless communication technologies, wireless body area network (WBAN) can replace complex and wired healthcare requirement to continuously monitor the body's vital signals and provide real-time feedback to the user and doctors without causing any discomfort and interrupting their daily lifestyle [1, 2]. WBAN typically consists of several lower-power, miniaturized and lightweight on-body or implanted sensor nodes to monitor physiological parameters, which are collected and further transmitted to remote medical servers by one energy-efficient hub (Mobile phone or PDA) for various medical and healthcare applications [3]. Generally, most of these applications are life critical and require a long lifetime without interrupting user's daily lifestyle, while still have a strict guarantee of Quality of Service (QoS) in terms of packet loss, delay and so on [4].

However, the limited battery capacity, constrained by the size and weight of sensors nodes, cannot support the long term operation without interruption. Besides, replacing battery or taking off sensors to charge power is not always practical especially for some implanted sensors, which also causes the interruption of the health monitoring system [5, 6]. Although the classical energy saving technologies make efforts to explore different energy efficient schemes in aspects of MAC protocol design, power control schemes and cross-layer resource scheduling strategies to prolong the system lifetime [3, 7, 8], the ultimate goal 'uninterrupted work' cannot be ensured. Fortunately, Energy Harvesting (EH) technology, which can collect energy from various sources around human body, has recently been considered as a promising solution to overcome the bottleneck of energy limited WBANs [9]. For instance, EH-powered sensors can scavenge energy from a variety of limitless ambient sources (e.g., light, heat, electromagnetic radiation) or the body itself (e.g., locomotion, breathing, heartbeat, lactate), and then convert it to usable electric energy for providing continuous power [10]. Thus, EH-powered WBANs have the potential ability to achieve infinite lifetime and perpetual operation, which is called Energy Neutral Operation (ENO) [11]. Furthermore, sensors can also combine several types of EH sources for acquiring more energy to support more strict QoS requirements [5]. Therefore, researchers pay more and more attentions on how to keep in ENO state with considering the QoS performance in EH-powered WBAN.

However, due to the limitation of the sensor size, the energy harvester cannot always satisfy the ENO requirement and the collected energy is scarce. In addition, sensors in different positions on the body may have different types of EH and the energy collection rates are heterogeneous. Meanwhile, harvesters with energy source from the human body have time-varying states caused by the dynamic body movement status. Thus, the time-varying and heterogeneous EH states become a significant factor to design the effective resource allocation scheme for ENO state. Therefore, it is highly meaningful to do some resource management researches on EH-powered WBAN with considering the QoS performance.

II. RELATED WORKS

This is related works

III. SYSTEM MODEL

This is system model

Zhiqiang Liu is with the Key Laboratory of Electromagnetic Space Information, Chinese Academy of Sciences, Department of Electrical Engineering and Information Science, University of Science and Technology of China, Hefei 230027, China (e-mail: lzhq28@mail.ustc.edu.cn).

Bin Liu is with the Key Laboratory of Electromagnetic Space Information, Chinese Academy of Sciences, School of Information and Technology, University of Science and Technology of China, Hefei 230027, China (e-mail: flowice@ustc.edu.cn).

Chang Wen Chen is with Department of Computer Science and Engineering, University at Buffalo, State University of New York, New York 002837, USA (e-mail: chencw@buffalo.edu).

A. Energy Consumption Model

B. Energy Harvesting Model

IV. Long-term Power-Rate Control Scheme

A. Relationship between Source Rate and Uninterrupted Lifetime

B. Join Power and Source Rate Optimal Allocation

C. Optimal Analytical Solution

D. Soure Rate Configuration

V. Short-term QoS Aware Slot Allocation Scheme

A. Energy Harvesting Process Analysis

B. Node state evaluation

C. Slot Allocation Scheme for Energy-Sufficient Nodes

D. Slot Allocation Scheme for Energy-Constraint Nodes

VI. Simulation results

A. Simulation Setup

B. Simulation Results of Power-Rate-Slot Control Schemes

C. The Influence of Different EH Efficiencies on Performance

D. The Influence of Different Mean of Shadowing on Performance

VII. Simulation results

In this section, the performance of the two proposed algorithms and the characteristics of the EH-DCCN are investigated in the performance of the average achievable system rate and the matching probability of EH-DPs. The matching probability of EH-DPs represents the ratio of the matched EH-DPs in N_D.

A. Simulation setup

B. The influence of different EH efficiencies on performance

VIII. Conclusion

In this paper,

Acknowledgment

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Zhiqiang Liu received the B.S degrees in electrical engineering from University of Science and Technology of China, Hefei, Anhui, China, in 2013, and he is currently pursuing the Ph.D. degree in electrical engineering from University of Science and Technology of China. His research interests lie resource allocation, energy-saving and Quality of Service guarantee in wireless body area networks.

Bin Liu received the B.S. and M.S. degrees, both in electrical engineering, from University of Science and Technology of China, Hefei, Anhui, China, in 1998 and 2001, respectively, and the Ph.D. degree in electrical engineering from Syracuse University, Syracuse, NY, in 2006. Currently, he is an Associate Professor with the School of Information Science and Technology, University of Science and Technology of China. His research interests are signal processing and communications in wireless sensor and body area networks.

Chang Wen Chen (F'04) is a Professor of Computer Science and Engineering at the State University of New York at Buffalo, USA. Previously, he was Allen S. Henry Endowed Chair Professor at Florida Institute of Technology from 2003 to 2007, a faculty member at the University of Missouri - Columbia from 1996 to 2003 and at the University of Rochester, Rochester, NY, from 1992 to 1996. He has been the Editor-in-Chief for IEEE Trans. Multimedia since 2014. He has also served as the Editor-in-Chief for IEEE Trans. Circuits and Systems for Video Technology from January 2006 to December 2009 and an Editor for Proceedings of IEEE, IEEE TMM, IEEE JSAC, IEEE JETCAS, and IEEE Multimedia Magazine. He and his students have received eight (8) Best Paper Awards or Best Student Paper Awards and have been placed among Best Paper Award finalists many times. He is a recipient of Sigma Xi Excellence in Graduate Research Mentoring Award in 2003, Alexander von Humboldt Research Award in 2009, and SUNY-Buffalo Exceptional Scholar - Sustained Achievements Award in 2012. He is an IEEE Fellow and an SPIE Fellow.