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論　文　要　旨

Body Area Nanonetworks (BANNs) are an important class of emerging nanonetworks, where tiny nano-nodes move in human body and can communicate with each other over peer-to-peer wireless links. Since they can provide inexpensive and continuous health monitoring services, BANNs hold great promises for many important biomedical applications in immune and drug delivery systems. In these systems, it is critical for nano-nodes to collect real-time data information. However, the constraint of extremely limited energy stored in nano-nodes poses a great obstacle to the future applications of BANNS. Thus, a comprehensive study on the energy efficient data collection schemes in BANNs is of great importance for supporting their applications.

We first propose a lightweight data collection scheme under a simple yet efficient scenario with multiple nano-nodes and only one nano-router in BANNs. In the scheme, we employ a sleep/wake-up mechanism to avoid unnecessary energy consumption when no eternal request comes. With a careful consideration of both node available energy and transmission energy consumption, we then design a new node selection strategy to further reduce the energy consumption in the data collection process. We further conduct extensive simulations for both the proposed data collection scheme and the benchmark greedy scheme to validate energy efficiency of our scheme as well as to illustrate the impacts of network parameters on data collection performance.

We further propose a new energy efficient data collection scheme under a complex scenario with multiple nano-nodes and nano-routers in BANNs. In the scheme, we first categorize data as emergent data and normal data with a careful consideration of the energy constraints. Based on such classification, we then generate distinct packets and assign different priorities to them. In BANNs, the normal data is usually sent regularly, while the emergent data is sent immediately. Extensive simulations are also provided to validate energy efficiency of our scheme in comparison with other benchmark greedy scheme, and to illustrate the impacts of network parameters on data collection.
Finally, we propose a relay-based energy-efficient data collection scheme with the minimum energy coding. Under the scheme, we derive the maximum nano-node density for reliable communication in BANNs, and also conduct density-dependent reliability analysis. Both rate-energy and delay-energy tradeoffs are further investi-gated with constant codebook size and constant Hamming distance, respectively. We also provide extensive simulations to validate our scheme.

審査結果の要旨

This thesis studied the energy-efficient data collection in body area nanonetworks (BANNs). First, the thesis proposed a lightweight data collection scheme under a simple yet efficient scenario with multiple nano-nodes and only one nano-router in BANNs. In the scheme, a sleep/wake-up mechanism was introduced to avoid the unnecessary energy consumption when no external request comes. Then, a timing-based energy efficient data collection scheme under a more complex scenario with multiple nano-nodes and nano-routers was proposed. In the scheme, the normal data was usually sent regularly, while the emergent data was sent immediately. Finally, the thesis proposed a relay-based energy-efficient data collection scheme with the minimum energy coding. Both rate-energy and delay-energy tradeoffs are further investigated with constant codebook size and constant Hamming distance, respectively. All theoretical results were carefully validated with extensive simulation results. It is expected that the results developed in this thesis can provide instruction guidelines for the design and optimization of future BANNs and can be helpful for energy-efficient performance study in other BANN scenarios as well.

・論文の構成

Chapter 1 Introduction

Chapter 2 Related Works

Chapter 3 Preliminaries

Chapter 4 Wakeup-based Energy-efficient Data Collection Scheme in BANNs

Chapter 5 Timing-based Energy-efficient Data Collection Scheme in BANNs

Chapter 6 Relay-based Energy-efficient Data Collection Scheme in BANNs

Chapter 7 Conclusion

・研究目的の妥当性，従来の手法との比較においての有意性，および理論・実験手法の新規性

This thesis studies the energy-efficient data collection in body area nanonetworks (BANNs), which is a very important issue for BANNs with the constraint of limited energy. This study can provide valuable insight to improve the design and performance of future BANNs.

Available schemes for the energy-efficient data collection mainly focus on the non-nanoscale body area networks, while the study on energy-efficient data collection in emerging BANNs remains largely unexplored.

As one step towards this direction, the thesis conducts a comprehensive study on three classes of energy-efficient data collection schemes for BANNs, namely wakeup-based scheme, timing-based scheme and relay-based scheme. The fundamental performances in terms of energy, path loss and delivery delay are evaluated under these data collection schemes. It is expected such a study will significantly enhance the ability of future BANNs to support various applications with different performance requirements.

・得られた知見のシステム情報科学の分野における意義

The results of this thesis provide the following insights.

1. The promising energy-efficient data collection schemes proposed in this thesis will provide a strong performance guarantee for various important biomedical applications in future BANNs, like real-time in-body monitoring, immune and drug delivery systems, etc.
2. The fundamental performance study under these data collection schemes will be helpful for the study of energy consumption, path loss and delivery delay in other BANNs scenarios as well.
3. The energy-efficient data collection schemes proposed in this thesis could provide precious insights for the design of data collection schemes in other BANNs scenarios as well.