論文の内容の要旨

論文題目:　　Energy-Efficient Protocols in Wireless Multihop Networks
（無線マルチホップネットワークにおける低消費電力プロトコル
に関する研究）

氏　名：　　滕　睿

With the advances in wireless technology and embedded computing, small wireless devices will be capable of self-organizing into wireless multihop networks. Different from traditional cellular networks, wireless multihop networks enable wireless devices to act as mobile routers with multihop routing functions. Examples of wireless multihop networks include mobile ad hoc networks and wireless sensor networks. These networks support a broad range of new applications, such as emergency response systems and environment monitoring.

Power conservation is critically important in wireless multihop networks, since nodes in it rely on batteries for proper operations, such as maintaining the network connectivity and successful delivering packets. Depletion of batteries in these nodes will have a great influence on overall network performance. Moreover, to ensure adequate coverage and fault tolerance, multihop wireless networks will be comprised of a large number of nodes. A large network size eliminates the option of frequently battery replacement.

The objective of our research is to design energy efficient network protocols for wireless multihop networks. In wireless multihop networks, data transmission and reception constitute the greatest part of the energy consumption. Although much has been studied on the energy efficient hardware design and radio technology for wireless devices, it is difficult for wireless multihop networks to handle the heavy protocol stacks with large protocol overhead due to the energy constraints. Our research especially focuses on energy efficient routing issues and node addressing issues. Such networking issues are associated with the amount of packets propagated through the networks and the packet size, leading to a substantial impact on the energy consumption of wireless nodes.

Our research includes two parts. The first part is called HBRD, an efficient route-discovery protocol for ad hoc networks with global connectivity. In this work, we investigate a new application of ad hoc network integrated with wired networks, which would expand communication bases of both ad hoc networks and wired networks. We observed that when ad hoc networks are linked to wired networks by access points, the traffic tends to be non-uniformly distributed in the sense that it is more likely to be concentrated on the access points than on other nodes. Thus, route-discovery operations between mobile nodes and access points will have a substantial impact on the consumption of energy and bandwidth of the network. However, most traditional schemes of ad hoc route-discovery focus on the pure ad hoc network with a uniform traffic pattern.

To design a route-discovery scheme particularly suited to non-uniform route connectivity in terms of low routing overhead, we propose a new route-discovery scheme called Hopcount-Based Route Discovery (HBRD). Although there are various route-discovery schemes and optimization schemes, in essence, route-discovery schemes used in ad hoc networks are based on flooding to discover routes. When using the conventional flooding-based ad hoc route discovery, route-request packets will reach every node in the ad hoc network. Though location based routing is an efficient approach to localized route discovery and reduce routing information propagation, locating system such as GPS might not be always available in ad hoc networks. By using hopcount information, HBRD reduces the number of nodes to whom route-request packet is propagated. HBRD utilizes a set of hopcounts referring to access points to limit route-discovery to a given small region. Such hopcount information is obtained and updated from advertisements of access points. Limiting the route-discovery region results in fewer routing messages and therefore saves the energy consumption. We conduct simulation to evaluate the performances of HBRD. The simulation results show that the HBRD scheme highly reduces routing overhead while preserving high rate of successfully discovering route to the destination.

The second part of our research is called ESAA. ESAA is an energy-efficient sensor address autoconfiguration scheme for sensor network. We investigate the protocol stacks in self-organized sensor networks and observed the data transmitted in a sensor network is usually very small, the length of addresses in the packet overhead should not be ignored. Using a conventional global unique addresses will have too high an energy cost.

We develop a new address autoconfiguration scheme, Energy-efficient Sensor Address Autoconfiguration scheme (ESAA), to automatically configure small-size addresses for sensor networks with energy-efficiency. ESAA achieves energy efficiency in three ways. First, each node attempts to select a candidate address in a sequential order instead of randomly, to reduce the address conflicts during the configuration. Second, in order to reduce the total configuration overhead, ESAA allows multiple sensor nodes to cooperate to configure their addresses, instead of each sensor configuring its address individually. Third, in ESAA, minimum address-size can be setup based on the node number in the network.

ESAA addressing system is implemented on a sensor network testbed, and energy consumption on wireless sensor nodes is measured. We also conduct simulations to evaluate the performances of address configurations in a large scale sensor network, including address conflicts, configuration overhead, etc. The results of implementation and simulations show that the proposed addressing system is energy efficient, and has low configuration overhead and few address conflicts.

Through this dissertation, “energy efficiency” is a key word. We designed two energy-efficient protocols for wireless multihop networks. These protocols achieve energy conservation by either limiting traffic overhead, such as reducing routing overhead by localizing the route discovery based on hopcounts and reducing configuration overhead, or by reducing packet size by configuring nodes with the smallest address length.

The dissertation is organized as follows.

Chapter 1 Introduction

Chapter 2 Energy Efficient Route Discovery for Integration of Ad Hoc Network with Wired Networks

Chapter 3 Energy Efficient Addressing in Sensor Networks

Chapter 4 Implementation of ESAA and Measurement of Energy Consumption

Chapter 5 Conclusion

Chapter 1 provides an overall introduction about this thesis. It gives the background knowledge, scope and objective, key contributions, and organization of the this thesis.

Chapter 2 describes the first part of our research, HBRD. After introducing the motivation and network model for efficient route discovery in the hybrid networks of ad hoc network and wired Networks, we describe the hopcount-based route discovery protocol (HBRD) in detail from three aspects: generation of hopcount information, exchanging of hopcount information and hopcount-based route discovery mechanisms. The evaluation results are obtained from computer simulations. The performance of HBRD is studied when the node velocity, advertisement interval of access points, and other parameters are changed. The effect of our route-discovery protocol is compared with the cases of conventional ad hoc route-discovery schemes.

Chapter 3 and chapter 4 describe the second part of our research, ESAA. We at first present the motivation for node addressing in self-organized networks. After that, the network model and assumptions are described. Then, the porposed energy efficient address autoconfiguration scheme (ESAA) is described in detail from 3 aspects: address representation for sensor networks, ESAA address autoconfiguration mechanisms and address-size setup scheme. The evaluation results are obtained from computer simulations at first. The performance of ESAA is studied when the node number, address size, network and other parameters are changed. The effect of ESAA is compared with the case of IP addressing and Duplicate Address Detection (DAD) autoconfiguration scheme.

Chapter 4 presents the implementation of ESAA to a real sensor network testbed and the experiments on energy consumption measurement. At first, we introduce the system architecture of the sensor nodes used in the testbed. Then, the implementation of our addressing system is described from 2 aspects: address representations together with node states, and address autoconfiguration operations. Energy consumption about node addresses and address configurations is measured by a real-time current measurement system. The effect of ESAA addressing system is compared with the case of IP addressing and DAD autoconfiguration scheme.

Finally, Chapter 5 summarizes the outcomes of this work. It also contains a discussion of the directions for the future research.