Energy Efficient & Delay Optimized MAC for Wireless Sensor Networks

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ABSTRACT
Research in the field of wireless sensor networks, one of the key technologies for the success of ubiquitous computing, has mainly been focusing on the issue of energy efficiency. Such a research activity could result in a number of energy efficient mechanisms to be proposed, but with a penalty of end-to-end delay increase. In this paper, we propose a new sensor MAC protocol for minimizing data latency as well as reducing the energy consumption by using physical carrier sensing range of each sensor node.

Keywords
Wireless Sensor Networks, MAC protocol

INTRODUCTION

The major technologies of ubiquitous computing areas are context awareness, autonomic computing and self-growing mechanisms. These technologies mostly require obtaining information of various environments through sensor devices. Advances in MEMS (Micro Electro Mechanical Systems) have enabled the development of smart sensor which has sensing, processing and networking capabilities. A wireless sensor network consists of the number of smart sensors that has a limited battery life and low rate radio communication. Especially, minimizing power consumption is a primary goal in wireless sensor MAC protocol design because a power drain of each sensor node can cease all the necessary functions of sensor networks. However, energy efficient scheme can cause the data latency problem which must be alleviated for delay-sensitive applications in military or healthcare areas.

S-MAC [1], one of the most famous energy efficient MAC protocols in sensor network, also reveals some serious problem in end-to-end delay. Fig. 1 shows our ns2 simulation results for S-MAC in terms of its delay performance. Note that, as the number of hops between source and sink increases, the delay performance of S-MAC becomes significantly worsen as well. For example, with 12x12 topologies, sink node has to wait almost in average 24 seconds to get any the sensing data from source node. This is clearly too long to serve delay-sensitive applications.

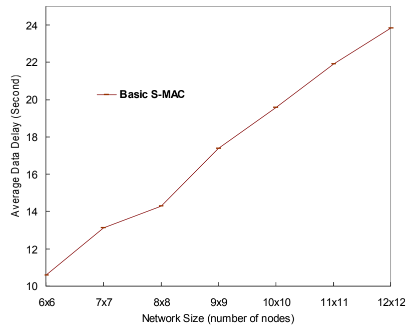

Fig. 1. Data Delay of S-MAC in multi-hop environments

Such a long delay in S-MAC is ironically caused by the periodic sleeping mechanism of each node, which is the main concept for achieving energy efficiency in S-MAC. When a sender has a packet to transmit, it must wait until the receiver wakes up. We call this latency period as sleep delay. To reduce this latency, adaptive S-MAC [2] suggests the adaptive listening scheme in which node receiving NAV information will remain awake and try to communicate in sleep period without waiting for the next listen/sleep cycle. DSMAC [3] supports multiple duty cycles which are automatically adjusted based on the measurement of the energy consumption level and delay in order to reduce more latency than S-MAC. However, these protocols consider a data latency problem in one or two hop ranges only. Therefore, the schemes suggested in [2] and [3] still have the end-to-end delay problem in more than two-hops scenarios. This observation leads us to propose a new scheme for energy efficient and delay optimized sensor MAC protocol.

PROPOSED SCHEME

The proposed scheme uses the physical carrier sensing range of control packets (i.e. RTS and CTS) to reduce the end-to-end delay in multi-hop data transmission. Node locating in the carrier sensing range but not within the transmission range of a sender can sense the fact that the

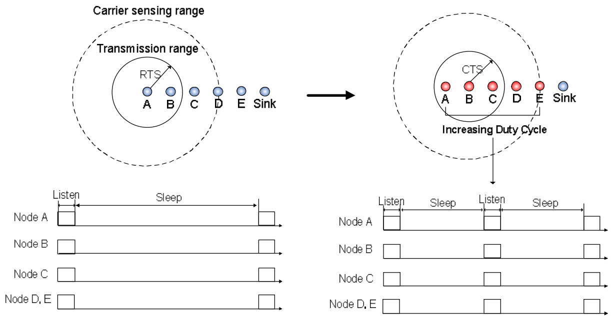

Fig. 2. Increasing the duty cycle of nodes in the carrier sensing range of sender and receiver.

sender has transmitted something, but cannot correctly decode what it really is. The carrier sensing range is typically larger than the transmission range. According to [4], the carrier sensing range is almost twice the actual transmission range. By using carrier sensing range, our scheme can make the sleep nodes on the routing path wake up early without waiting for the next listen/sleep cycle, so the packet can be consecutively transmitted to the destination node (usually sink node) faster than S-MAC.

A time frame in periodic listen/sleep scheme is divided into two parts: one for a listen period and the other for a sleep period. During the listen period, SYNC and RTS/CTS control packets should be transmitted for the purpose of synchronization and an announcement of the following data packet transmission. Only two nodes exchanging the RTS/CTS packets in the listen period keep in awake state and start data transmission during sleep period. All other nodes can enter the sleep mode in order to avoid any wasteful idle listening and overhearing problems [1]. Nodes entering to the sleep state are required to wait until the next listen/sleep cycle, in order to participate in communication again. If the number of hops between source and destination node is 2, S-MAC may wait for 2 listen/sleep cycles to deliver the data packet. This latency is getting larger as the number of hops on the route towards sink node increases. However, unlike S-MAC, our proposed scheme can communicate with many nodes along the routing path in one listen/sleep cycle. In our scheme, if a node senses the carrier of RTS and CTS in the listen period, it wakes up in between the sleep period and tries to continuously transmit data. Fig. 2 shows the operation of our scheme more in detail. The data packet flows from source node A to the sink node through node B, C, D and E which are located on the multi-hop route path. Node A and B exchange the RTS/CTS packets during the listen period. At that time, node C, D and E which locate in the carrier sensing range can be aware of the fact that some data transmission is started around them because carriers in the RTS and CTS time of listen period mean the announcing data transmission. In this case, they increase their duty cycle at twice and wake up during the sleep period as seen in Fig. 2. It makes node C, D and E be able to transmit the packet consecutively in one listen/sleep cycle.

SIMULATION RESULT

In the simulation part, primary performance metrics are the data latency and the energy consumption according to increasing network topology size. We evaluate the performance of our schemes compared to Basic S-MAC [1] and Adaptive S-MAC [2]. For our simulations, we modified the CMU wireless extended version of ns2. Fig. 3 shows the energy-delay cost per bytes according to network size. The result shows that the proposed scheme is more efficient mechanism of energy and delay aspects than other schemes.

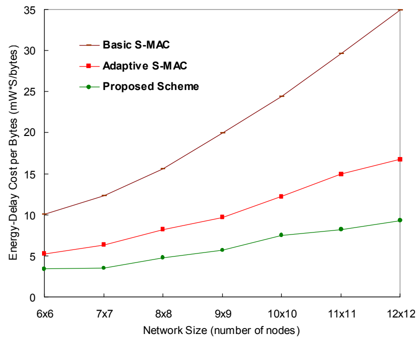

Fig. 3. Energy-Delay cost per bytes.

CONCLUSION

In this paper, we focus on the minimizing latency of the data transmission along a multi-hop route. We propose a noble scheme that the nodes sensing the carrier of the RTS and CTS packet increase their duty cycle in single listen/sleep cycle. We prove the improvement of our scheme in terms of the end-to-end latency from source node to sink node and energy consumption through simulation studies. Our proposed scheme is useful in various delay-sensitive applications and scenarios which desire to receive sensing data within a certain time period.

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