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CSMA/SF: Carrier Sense Multiple Access with Shortest First in Multiple Layers

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Abstract- Energy consumption is the main problem in wireless sensor networks (WSNs) due to mobile devices' limited battery energy. Because the heavy load of nodes that near the receiver, this energy hole issue makes nodes near the receiver have faster energy depletion than others. Because of this, the lifetime of wireless networks, is determined by the power consumption of communication between receiver and sensing nodes that near the receiver, to some extent. To meet this problem, here propose CSMA/SF (Shortest First) protocol to reduce energy consumption of sink-node communication by minimizing power cost in carrier sense during nodes' channel contention. CSMA/SF in multiple layers improves existed CSMA/CA protocol and optimizes channel utilization by reducing the probability of collisions. In place of complete channel contention-based, CSMA/SF in multiple layers make sure that nodes remaining shorter message has higher priority.

Keywords- Energy efficiency, CSMA, MAC

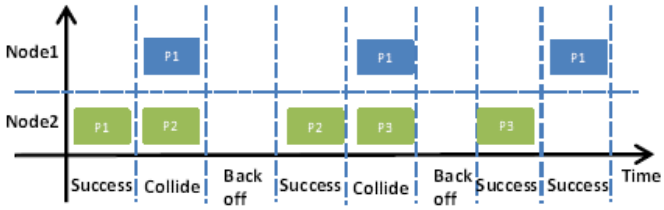
I. INTRODUCTION

Wireless sensor networks (WSNs) are widely applied in many types of applications. There is a long range of WSNs implementation in environmental surveillance, robotic exploration, health monitoring and so on. Despite the large variety of WSN's potential utilizations, the need for aggressive energy saving is always the primary issue. It is because these simple nodes are intended to operate without recharging for a long period of time.

Because of the communication in wireless sensor networks has many-to-one property, the nearer to the receiver, the heavier workload the nodes will have. Generally, a typical WSN contains many sensor nodes and one or more receivers. The sensor nodes are used to sense and collect information from network. And the collected messages will be delivered to the receiver. However, the messages collected from all nodes are transmitted through multi-hop routing will be concentrated to a few receivers . The sensor nodes that around the receiver will need to relay data that collected from outer-ring nodes which far away from the receiver. Thus, the sensor nodes near the receiver will have faster energy depletion than the outer ring nodes. This phenomenon is called energy hole problem[1] [2] [3] or crowded center effect[4].

This paper presents CSMA/SF (Carrier Sense Multiple Access with Shortest First), a new routing protocol designed for WSNs to lengthen their operation lifetime. The aim of CSMA/SF is also to meet the energy hole problem. Different from previous methods, we reduce energy consumption between receiver-node communication in another way. That is to minimize the energy cost of carrier sense process during many-to-one data transmission between nodes and receiver. To realize this, we modify the purely contention-based CSMA/CA MAC protocol to have the attribute of contention priority.

The main idea of CSMA/SF is to let nodes with shorter message first finish their transmission so that they do not need to continuously sense the channel any longer. By doing this, it reduces the power cost of these nodes and minimizes the WSN's overall power cost of carrier sense. Nevertheless, how to realize it is a non-trivial problem.



(a) Channel Contention in CSMA/CA.

(b) Channel Contention in CSMA/SF

Figure 1 Comparison of CSMA/CA and CSMA/SF MAC protocol.

For the ease of understanding, here illustrate a simple example of CSMA/SF in Fig.1. Suppose node1 needs to transmit 1 packet whereas node2 for 3 packets. Because of CSMA/CA's completely contention-based character, there may have high probability of collision. When collision happens, CSMA/CA uses randomly back-off mechanism to reduce probability of collision happens again. In CSMA/CA, the total carrier sense rounds are 5 of node1 (i.e. time slot 2,4,5,7,8) plus 5 of node2 (i.e. time slot 1,2,4,5,7), which is equal to 10. Whereas in CSMA/SF, it ensures nodes with less data has higher priority in transmission. It needs only 6 sensing round in total (i.e. for node1 needs to sense 2,3 slot whereas node2 needs to sense 1,2,4,5 slot). By implementing CSMA/SF can apparently reduce energy cost for carrier sense.

The contributions of this article are summarized as follows. Section 2 surveys the related work . In section 3, first give some preliminaries and then deliver detailed strategy of CSMA/SF protocol. Section 4 concludes the paper.

II . RELATED WORKS

Energy efficiency in the energy hole problem has been a main research topic for a long time. The most related works to our CSMA/SF concept are [5] [6]. They meet the energy hole problem by scheduling duty cycling of sensors, in order to achieve energy fairness and efficiency in WSNs. However, they are not specially designed for energy saving in the process of carrier sense, thus they cannot achieve nearly maximum energy saving in this process. Further, these approaches indeed cannot reduce the probability of collisions, whereas CSMA/SF does. Other previous works can be divided in following three categories.

The first category is based on the preassumption that the sink has mobility [7] [8] [9] [10] [11] [12]. They leverage this mobility to reduce energy cost in sink-node transmission. To be more specific, In [7] [12] and [11], the authors leverage sink's mobility with another assumption that transmission is delay-tolerant. The basic idea is to let nodes hold data until sink is relatively close to it. Then the nodes send data in low power in order to save energy. The approach in [8] is focusing on dynamically finding the minimum energy cost multi-hop route for each node's data relay. [9] and [10] are proposed to determine new location for sink with the purpose of energy conservation.

The second category is with static sink model [13] [14] [15] [16]. The authors in [13] [14] mainly focus on building proper routine that can achieve energy efficiency in multi-hop transmission. PEDAMACS in [15] is a extension of single-hop Time Division Multiple Access (TDMA) to multi-hop, which achieve the goal of being energy-efficient. The approach in [16] is a fair MAC protocol used for sink-node transmission with tight upper and lower performance bound.

The third kind is to introduce periodic sleep-action schedules for energy efficiency [17] [18] [19] [20]. These approaches are not limited to save energy of sink-node transmission. They can be utilized throughout all the sinks and nodes in WSNs. By implementing this periodic sleep-action method, it can save the amount of energy as large proportion as the ratio of sleep mode to wake-up mode. However, if this periodic sleep mode does not scheduled well, it will cause multi-hop transmission suspended because of the nodes with inappropriate sleeping cycle.

III. CSMA/SF PROTOCOL DESIGN

The CSMA/SF protocol tries to optimize the energy dissipation of nodes near to the common receiver node. In this protocol the optimization is done in the MAC layer. MAC layer optimization is done by going to a lower energy state while a node is idle. And also optimization is also done at the network layer. A simplified routing protocol with low processing requirement is used to forward packets to the receiver node. Thus the over all energy utilized at the network layer is also reduced.

Here are some basic assumptions in CSMA/SF in multiple layers model. Imagine that all sender nodes are situated in a circular area and all the sender nodes are of the same kind. At the time of the packet transmission, all nodes can directly reach the receiver. For the simplicity, assume that the network is well connected. Each sender node has a unique ID number. Imagine that nodes in the inner side corona is randomly distributed. All nodes in each ring share a single radio channel for contention. And the channel access contention is a per packet process, which is that common CSMA/CA protocol does

Here mainly discuss about the shortest-first scheduling. Different from conventional shortest-first scheduling algorithm which needs a centralized coordinator, this scheduling is totally distributed. The main idea of the distributed shortest-first scheduling is based on the remaining data information of current transmitting node. Other nodes listen to this information and decide whether they have less data to transmit than current transmitting node. If some of them have less remaining data, they get the channel access. Otherwise, they let the current transmitting node finish its transmission

How to get the remaining data length of current transmitting node is the another component of CSMA/SF. To achieve this aim, CSMA/SF utilizes the Length Detection scheme. The Length Detection leverages that within the same band (e.g. 2.4GHz), nodes transmit data in one distinctive modulation scheme in 802.15.4 protocol. And this transmission process is broadcast. So every node which can directly reach to current transmitting node can hear what it transmits.

If link breakage occur due to energy depletion, the path will be updated. In conventional method, packets will just re-broadcasted to the network. Instead of that, we can set up a next-hop selection process. When link breaks the packets will be forwarded through any of the neighboring node While link breakage, the packets received at last node will just dropped out. Instead of that, drop the packets after looking for next hop to transmit. If anyone the next hop found forward the packets. Otherwise, the packets will be dropped.

IV. RESULTS

In this section, comparison shown between CSMA/SF and CSMA/CA. Fig.2, 3, 4 give a more clear result that CSMA/SF achieves better channel utilization by improving throughput with different

amount of nodes (Namely 20, 60, 100 nodes). More precisely, with the nodes number increasing, the difference between CSMA/SF and CSMA/CA become smaller. It is because that, with more nodes contending for channel access, nodes with less data try to occupy channel by interrupting current transmission node. And this increasing number of interruption will cause more collisions.

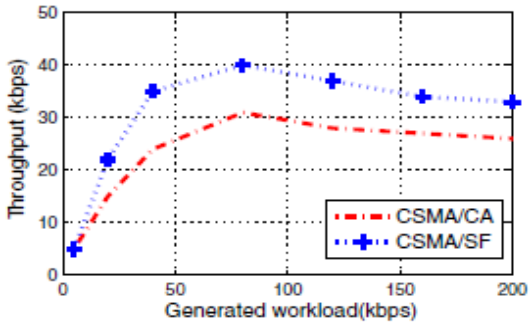


Figure 2 CSMA/SF throughput performance with 20 nodes.

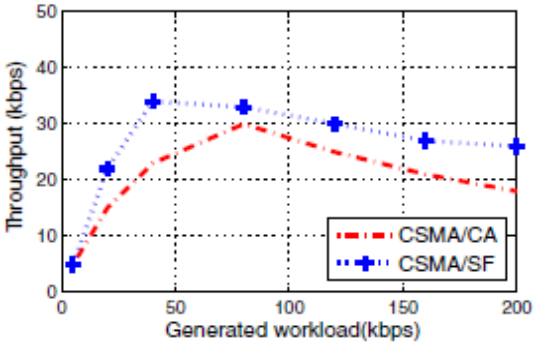


Figure 3 CSMA/SF throughput performance with 60 nodes.

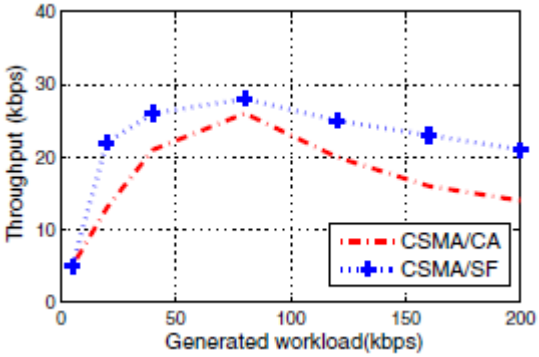


Figure 4 CSMA/SF throughput performance with 60 nodes.

Fig.5 shows the result of power saving that CSMA/SF can achieve with different number of nodes. To be more specific, with the simulation result, CSMA/SF can reduce the power cost on carrier sense. And CSMA/SF can nearly achieve optimal power cost of CS in different scenarios. The difference between optimal power cost and CSMA/SF is mainly because the transmission in optimal scenario is strictly in ascending order of remaining data length.

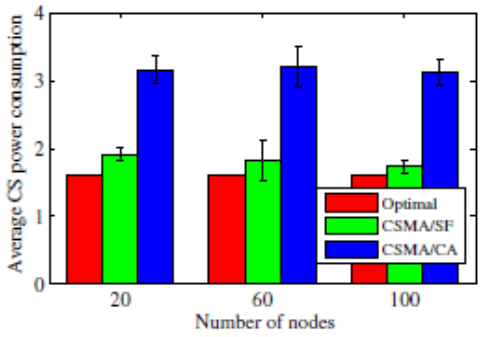


Figure 5 Carrier sense energy consumption of CSMA/SF.

V. CONCLUSION

This paper proposes a new routing protocol CSMA/SF to minimize energy cost in carrier sense process. By modifying existed purely contention-based CSMA/CA with additional priority, we ensure the nodes remain less data has higher priority in channel access contention. To achieve this, we design mainly three components, namely, a distributed shortest first scheduling, Length Detection scheme and Next-Hop Selection mechanism. The distributed shortest-first is used for achieving shortest-first scheduling process in a distributed way. Here incorporate Length Detection scheme to let the listening nodes get the remaining length information of current transmitting node. And Next-hop Selection mechanism is used for assigning next node when link breakage occur. Since CSMA/SF follows traditional MAC protocol design and is very easy to be realized and believe that CSMA/SF can be beneficial to real world applications.

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