1 Introduction

Fast data collection tends to be indispensable for wireless sensor networks from the viewpoint of energy efficiency and heavy traffic collection. Although TDMA mechanism enables efficient data transfer, the burden of transmission time slot scheduling and rescheduling for plain TDMA algorithms is complex because they endeavor to allocate a fixed time slot to each sensor node. Such burden is the primary limiting factor of topology adaptability that is practically demanded [1]. To minimize the scheduling burden while exploiting the advantages of TDMA-based data collection, we propose to use two tokens arbitrate transmission, wherein the ownership of tokens are associated with transmission slot assignment to simplify the scheduling and provide topology adaptability. The presented protocol called TKN-TWN also sustains high throughput through burst transmission. We evaluate the throughput of data collection on the indoor deployed testbed with TinyOS and show that TKN-TWN achieves throughput about 7 KByte/s.

2 TKN-TWN Overview

TKN-TWN uses multi-channel TDMA communication for high data rate transfer and further arbitrates transmission through token passing mechanism to simplify the scheduling problem. In TKN-TWN, topology adaptability is implemented by leveraging the broadcasting nature of synchronization messages.

2.1 Multi-channel TDMA communication

To eliminate interference and setup high data rate flow, multi-channel TDMA communication is used. As shown in Fig.1, top-subtrees are divided into two types: 0 and 1, where a top-subtree is defined as a subtree whose root node is the child of sink node. Within each top-subtree channel assignment is hop-based. Communication is receiver oriented, i.e. source nodes switch to destination node’s home channel in communication. Time slot is scheduled to implement TXSlot = (topSubtree + hopCnt)mod2, where topSubtree is the top-subtree type, hopCnt is the hop count, and TXSlot is the time slot in which sensor nodes are prioritized to transmit. Different channels are allocated to two different type of top-subtrees.

The multi-channel media access control is designed as Fig.2. Time is divided by super-frames, which consist of common channel slots for synchronization message and multi-channel slots for data communication.

2.2 Token based scheduling

On the basis of channel allocation and slot assignment, transmission is scheduled using a centralized token passing mechanism. As depicted in Fig.1, the sink node generates tokens that traverse the derived routing tree in a depth-first manner [2]. When a sensor node is the token owner, it transmits packets generated by the sensor node itself in a burst. A burst is defined as the continuous transmission of multiple packets and the number of the packets transmitted is called burst size. Other nodes that are not token owners relay the packets to their parent nodes when necessary. At each time two different tokens: Token0 and Token1 are distributed by the sink node to "0" top-subtree and "1" top-subtree respectively, which provides two active flows to achieve optimized throughput by exploiting the half-duplex nature of sensor nodes.

2.3 Topology adaptability

Network topology might fall apart due to potential node failures if topology adaptability is not enabled. Since slot assignment in TKN-TWN is self-determined based on routing information, TKN-TWN is able to provide better topology adaptability than conventional TDMA-based by reducing the complexity of time slot rescheduling.

Implementation of topology adaptability has two tasks to perform. One is node failure detection and the other is network topology reformation upon node failure. To reduce overhead TKN-TWN uses broadcasting synchronization messages piggyback routing information in maintaining network topology during data collection. The first task is performed based on the joint monitoring of the drop of data packets and the loss of synchronization messages. Precisely, either continuously packet drop in multi-channel slot or consecutive synchronization messages reception failure in common channel slot provides indication of node failure. Meanwhile, either successful data packet transmission or synchronization messages reception produces proof of node liveness. A dedicated task is performed upon parent node’s failure detection. To recover connection the sensor node find from the routing table a new parent node that has the strongest link derived from a link estimator based on LQI (Link Quality Indicator). The parent reselection algorithm avoids routing loop, and the new parent node that has the same type of top-subtree is preferred in the first place in consideration of the load balancing between two type of top-subtrees to maintain the throughput. The changed routing information is broadcast through synchronization messages and will be updated by the related child nodes. As soon as routing information is updated, channel and time slot is automatically reconfigured.

3 Evaluation

We evaluate the throughput of TKN-TWN on a considered testbed that consists of 32 sensor nodes deployed in laboratory environment (36 x 25 meters) as shown in Fig.3. Network topology is constructed to the ETX (Expected Transmission Count) based link estimator [3]. Figure 3 shows the formed data gathering tree in the experiment. Node 0 is the sink node. Figure 4 shows the throughput of 230 rounds of continuous data collection with burst size of 20. To test the topology adaptability, the node 17 and node 18 were manually turned off at the time as marked in Fig.4. It is observed their child nodes reselected parent nodes afterwards. There is impact on collection performance as depicted in Fig.4 because node failure is destructive. Since the network needs time to detect node failure and recover the topology, the performance might not be worse in a short period afterwards. The extent to which the performance is affected varies according to the time when a sensor node fails and the position of the sensor nodes in the tree topology. For example, failure of node 18 causes more impact than node 17 due to the large subtree node 18 has. The throughput gradually recovers to be steady along with the topology re-formation. Since load balancing is considered (Section 2.3), the throughput is almost in the same level on the whole. Token loss is also observed as shown in Fig.4. Since TKN-TWN supports robust token passing, occasional token loss is tolerable. The average throughput of the whole process collection process is about 7 KByte/s.

4 Conclusion

In this paper, we present a topology adaptability enabled high throughput wireless sensor network. Experiment verified a high throughput of 7 KByte/s on local testbed.

Reference