Reliable Data Collection Using Tokens in Wireless Sensor Network

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1 Introduction
We have been developing a token-scheduled data collection protocol named TKN-TWN that provides high throughput and topology adaptability [1]. TKN-TWN provides bi-directional communication between the sink node and source nodes via token passing. Consequently, the lost packets’ information can be piggybacked on token messages to call for retransmission from source nodes, which makes it possible to achieve end-to-end reliability. In this paper, we enhance the protocol with end-to-end NACK (Negative Acknowledgment) to provide end-to-end reliability for periodical data collection.

We also present a congestion control technique to ease the token’s piggyback burden by reducing queue drops. An extensive simulation study in TOSSIM indicates that TKN-TWN achieves reliable periodical data collection.

2 Design

2.1 Token-scheduled multi-channel TDMA
Data transmission of TKN-TWN is arbitrated through a centralized token passing mechanism. When a sensor node is the token owner, it transmits packets generated by the sensor node itself in a burst. Transmission time slot is determined on each sensor node by $TXSlot = (token + hopCnt) \mod 2$, where $token$ is the token type 0 or 1, and $hopCnt$ is the hop count. Each sensor node is assigned a channel named home-channel. Communication is receiver oriented. For instance, source nodes switch to parent nodes’ home-channel when forwarding packets, while staying on its own home-channel when receiving packets from child nodes. The detailed protocol design is presented in [1].

2.2 End-to-end reliability

*End-to-end NACK management:* In TKN-TWN, the sink node needs to keep recording the lost packets’ information for all of the sensor nodes. In order to provide a larger recording capacity while considering memory saving, we design a NACK management method using queue array as shown in Fig. 1. Each queue is composed of $Base$ and offset-bits. $Base$ is the latest updated 4-byte packet sequence number, before which no packet has been lost. Offset-bits are used to indicate whether the corresponding packets are lost or not, where a bit’s offset equals a packet’s sequence number deviation from $Base$. When a packet is lost, the sink node marks the corresponding offset-bit, whose distance from the $Base$-position equals the difference between the packet’s sequence number and $Base$. The mark of offset-bits will be eliminated upon the packets’ arrival through retransmission afterward. TKN-TWN updates the queue array per collection round, increasing the $Base$ and shifting the offset-bits left for later utility.

In TKN-TWN, the sink node loads the lost packets’ information on token messages. Since the capacity of a token message is limited, the NACK information of sensor nodes that have older $Base$ has higher priority to be loaded. Upon tokens’ arrival, source nodes check and retransmit the lost packets in the first place.

2.3 Congestion control
In order to reduce queue drops, TKN-TWN explores the multi-channel communication. With multi-channel communication, sensor nodes are able to avoid packet reception and deliver congestion control indication in an implicit way. When the queue of a parent node becomes full, it refuses to switch back to the home channel so that communication with the child node does not occur any more. Consequently, the child node continuously fails in the following transmission, and implicitly knows that its parent’s queue is full. Hence, it backs off a short period and waits the parent node to dequeue. When the parent node has dequeued to a certain ratio, it restarts to switch back to home channel and resumes the data transfer. As a result, queue drop is properly avoided. Congestion control is optional and can be switched off if high delivery ratio is achievable without congestion control.

3 Evaluation

Evaluation is based on simulation in TOSSIM. 101 sensor nodes are randomly deployed in a 20 x 20 square meter area following the rule that the minimum distance between each pair of nodes is no less than 1.5 meters. Figure 2 shows the sensor nodes’ distribution and the constructed routing topology, wherein we place the sink node in the middle of the field. Figure 3 depicts the CDF of link gains to the topology in Fig. 2.

![Fig. 2 Node distribution.](image1)

![Fig. 3 CDF of wireless links.](image2)

![Fig. 4 DeliveryRatio vs NodeID.](image3)

4 Conclusion and future work

In this paper, we enhance TKN-TWN toward realization of end-to-end reliability for periodical data collection. To ease the piggyback burden, we also present an effective congestion control mechanism. Preliminary evaluation in TOSSIM shows that data collection with 100% delivery ratio can be achieved. Our future work will include the implementation of reliable bulk data transfer as in [2] and [3].

Reference

