2015년 춘계학술발표대회 논문집 제22권 제1호(2015. 4)

비신뢰성 링크를 가진 로우 듀티사이클 무선센서네트워크 환경에서 향상된 동적 스위칭 기반 플러딩 방법

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An Enhanced Dynamic Switching-based Flooding scheme in Low-Duty-Cycled WSNs with unreliable links

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Abstract

Duty-cycling could efficiently prolong the life time of Wireless Sensor Networks (WSNs) by let nodes be in dormant state most of the time, and only wake up (for sending or receiving) for a very short period. Flooding is one critical operation of WSNs. Many studies have been studied to improve the delay and/or energy efficiency of flooding. In this paper, we propose a novel time slot design, and the switching decision that reduce energy consumption for the schedule-based flooding tree. Each node, if failed to receive from its parent, will look for other candidate, among its siblings to overhear the flooding packet. By accurately collect information from other siblings, each node can make the best as possible switching decision; therefore the energy efficiency of the network is improved.

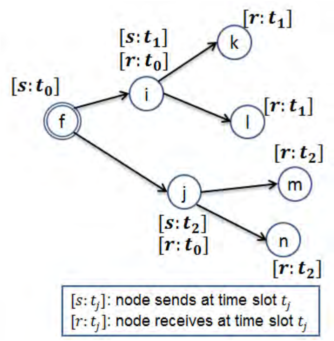
1. Introduction

Wireless Sensor Networks (WSNs) have been intensively studied for decades. With the highly minute size and embodied sensing, computing as well as communicating capabilities, WSNs proved its indispensible role in many applications such as environmental monitoring, surveillance, etc. For years, duty-cycling has shown its promise in terms of energy efficient, by trading off the end-to-end delay. In this mechanism, sensor nodes only wake up for a small portion of time, for either sending or receiving; and go into sleep state for the rest. With a 1% duty-cycling setting, the network life time is said to be 100 times longer than the primitive keep-awake one.

The paper in [1] proposed a switching algorithm in which, a node if failed to receive from its parent will look for a switching chance, to overhear the flooding from its sibling instead. The rationale is that regardless of the switching, its siblings will have to flood the packet to the children. However, the authors overestimated the number of failure transmission, so that the switching decision is made under a very loose condition. So as to improve this, we propose a novel protocol architecture that offers better estimation and heuristically is a more efficient energy consumption scheme.

2. Related Works

Long Cheng et al. studied the dynamic switching-based flooding with the consideration of unreliable links [1]. The author constructed a schedule-based flooding tree, in which sending time slot is assigned to a parent, and all of its children wake up at that time slot to receive (Figure 1). Nodes with the same parent are siblings, and siblings are scheduled to send at different time slots to avoid potential collision.

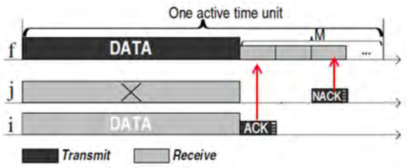


(Figure 1) Schedule-based floding Tree

The authors utilize the ACK/NACK feedback mechanism. Because of unreliable links, the sender will retransmit the packet in the next working period until it collects all the ACKs from its child nodes. A node can dynamically switch to receive from its sibling if (1) it is failed to receive from its parent; (2) it knows that its sibling has received successfully the packet by overhearing the ACK and (3) sending time slot of its sibling is earlier than sending time slot of itself. By doing this way, that node can utilize a number of "free" transmissions from its sibling to the children of its sibling. Each node which has got the packet has to transmit to its children regardless of the switching. If a node decides to switch, it sends NACK to notify its parent and the sibling (called helper node) it will switch to.

Figure 2 explains the arrangement of time slot structure.

Assume that f is parent, and i and j are child nodes. Following the data period, each parent node could accept up to M ACK/NACK messages. The point is that the ACK/NACK sub-timeslot is fixed for each child node, which means the child nodes with subsequent ACK slot can overhear the earlier ACK, and then make the switching decision; but the node with earlier ACK priority does not have complete view of how many siblings has received the packet.



M: number of ACK/NACK slots

(Figure 2) ARQ-based acknowledgement

3. Preliminaries

3.1 asdSystem Model and Assumptions

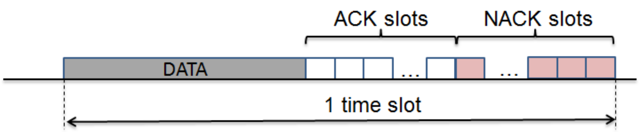
In this study, we use the similar network model to the paper in [1]. Child nodes are scheduled to wake up at the same time slot to receive flooding packet. The protocol uses ARQ-based (Automatic Repeat request) flooding. The goodness of links between nodes is represented by PRR (Packet Reception Rate) value. The time axis is divided to equal working periods, while in turn, each working period is split into a number of time slots. Each time slot is sufficient for one data period and up to *M* ACK/NACK sub slots.

3.2 Problem Statement

In the paper [1], since failed-to-received node has to make the switching decision before its ACK sub slot, it only overhears ACKs from the siblings that do ACK prior to itself. Hence, the decision is made on incomplete information. So as to improve the decision making process, we redesign the protocol that allows each failed-to-received node to have a full view about its siblings. Based on that, the switching decision is made wiser.

4. Protocol Design

The proposed time slot structure is illustrated as in Figure 3. One time slot begins with the DATA period. After receiving the packet, each child node acknowledges by sending the ACK message to its parent. Because of the broadcasting nature of wireless environment, its sibling could overhear the ACK. Following the DATA period is *M* ACK sub-slots. In this period, only nodes who successfully get the flooding message reply with an ACK. Every other node stays listening to the channel. When the ACK period ends, all nodes that do not get the message know that they have missed. But more important, they know the whole picture about their siblings, including (1) which one has gotten the message, (2) which sending time slot that one schedules.

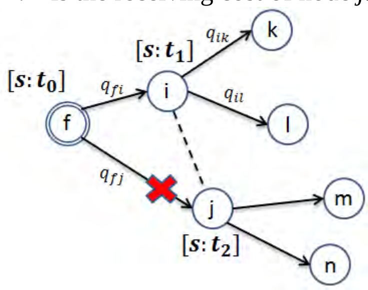


(Figure 3) Protocol Design

The switching decision is made by comparing the energy cost of continue to wait for retransmission from the parent, and the energy cost of switching to receive from one of the sibling. Figure 4 represents the scheme. Suppose that node *j* fails to receive from its parent *f*, the lower bound for expected retransmission cost is derived as in equation (1).

$$C_{ret}^{l} = \frac{1}{p_{fj}} \times \left(\frac{\tau}{n} + \tau\right) \qquad (1)$$

Whereas p_{fj} is PRR from node *f* to node *j*; τ is the time slot duration, *n* is number of child nodes that haven't received the packet yet. $\frac{\tau}{n}$ is the shared sending cost of the parent *f*, while τ is the receiving cost of node *j*.



(Figure 4) Dynamic switching decision

After that, the upper bound of switching cost for node *j* if node *j* switches to receive from its sibling *i*:

$$C_{swi}^{u} = \frac{1}{p_{ij}} \times 2\tau - \min\left\{\frac{1}{p_{ij}}, \frac{1}{p_{ik}}\right\} \times \tau \qquad (2)$$

where *k* is the child node of *i* that cannot switch (to be specific, it is the child node that has the best link quality from the parent). If *j* decides to switch to *i*, node *i* is now responsible for transmitting packet to node *j*. The energy cost for completing the transmission to node *j* is $\frac{1}{p_{ij}} \times 2\tau$, while the minus is the amount of "free" transmissions that node *i* has to transmit to its children, so node *j* takes advantage from that and that amount is excluded.

The two values from equation (1) and equation (2) will then be compared. If the switching offers more saving energy, node *j* will switch. Otherwise, it stays waiting for retransmission from the parent.

5. Conclusion

In this paper, we presented a new protocol design that let failed-to-received node can estimate more precise the receiving status of its siblings, hence is able to make wiser switching decision. The decision is made if it is beneficial in term of energy. In the future, we will conduct intensive simulation and compare with the results in [1].

ACKNOWLEDGMENT

This research was supported in part by PRCP (NRF-2010-0020210), ICT R&D program (14-911-05-006), ICT R&D program (10041244), respectively.

References

[1] Long Cheng, Yu Gu, Tian He, Jianwei Niu, "Dynamic Switching-based Reliable Flooding in Low-Duty-Cycle Wireless Sensor Networks," IEEE INFOCOM, 2013.