Performance Improvement by Collision Avoidance of Control Packets in Receiver-Driven Multihop Wireless Mesh Networks

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***Abstract*—Asynchronous, receiver-driven communication methods are suited to wireless mesh networks with high node density and low data generation frequency. In such networks, however, control packet collisions between hidden terminals can degrade performance. We propose collision avoidance techniques that improve packet collection rates and delay, and that furthermore decrease power consumption.**

***Keywords*-wireless mesh network; sensor network; collision avoidance;**

I. INTRODUCTION

In wireless mesh networks such as high-density sensor networks, power consumption is an important topic because nodes are generally battery-powered. Reducing energy consumption through intermittent operation, in which wireless nodes sleep to save power and wake up periodically to transmit or receive packets, has been validated as a method for considerably reducing power consumption and extending network operating time [1]. Sun *et al.* [2] showed that receiver-driven communication methods are superior for wireless sensor networks. In particular, we found that in systems with high node density and small data generation frequency, the intermittent receiver-driven data transmission (IRDT) method, an asynchronous, receiving terminal drive-type communication method, is suitable [3]. In IRDT, each node holds the ID of all adjacent nodes and the number of hops to the sink node, and manages up-to-date network status by exchanging this information by using control packets.

Figure 1 shows the data transmission process in the MAC layer of the IRDT protocol. In IRDT, each receiver sends its ID to inform other nodes that it is ready to receive a data packet. Sender nodes wait for a receiver ID, and after acquiring an ID from an appropriate receiver, establish a link by returning an SREQ packet.

II. THE PROBLEM WITH IRDT AND SOLUTION TECHNIQUES

Carrier sensing is ineffective when two or more IRDT transmission nodes are mutually hidden, resulting in SREQ packet collisions. While a node that was unable to receive an SREQ packet will be in a sleep state, if two or more nodes retransmit SREQ packets at the next ID transmission, the packets will collide again. Repetition of this phenomenon results in the data packet being discarded, lowering the packet collection rate and increasing power consumption (Fig. 2).

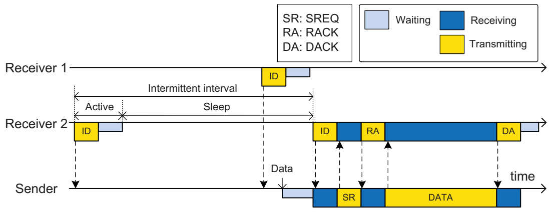


Figure 1. Data transmission process in the MAC layer of the IRDT

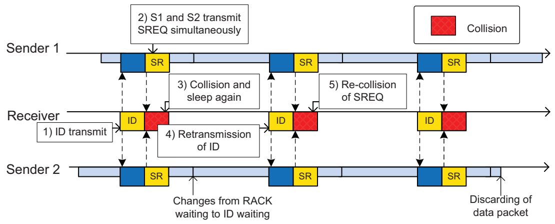


Figure 2. Continuous collision of SREQ packets

A. Control techniques for SREQ collision

1) Backoff (Fig. 3)
Upon detecting an SREQ packet collision, the receiver determines an acceptance period that is an integer multiple of the time required for SREQ transmission, adds that value to the ID, and transmits it. Nodes waiting for an ID that receive this packet set a random timing based on the value, and then transmit the SREQ.

2) Probabilistic retransmission of SREQ (Fig. 4)
When a receiver resends an ID after an SREQ collision, it adds the probability p. Nodes waiting for an ID that receive this packet transmit the SREQ with probability p, or enter a waiting state with probability $1 - p$. Since the number

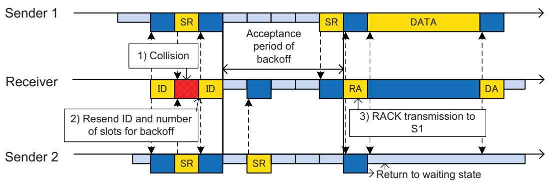


Figure 3. Backoff

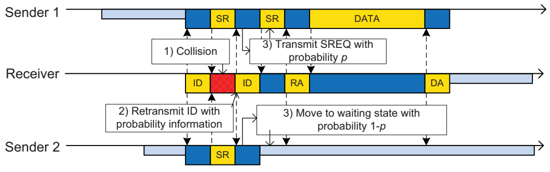
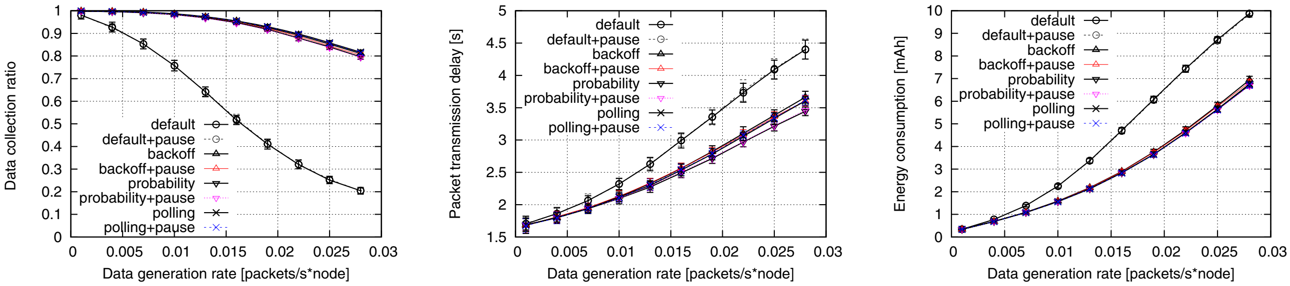


Figure 4. Probabilistic retransmission



(a) Average packet collection ratio (b) Average packet delay (c) Average energy consumption

Figure 6. Comparison of the effect of each proposal technique

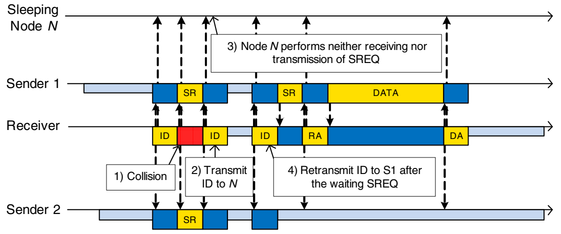


Figure 5. Polling

of nodes which transmits a packet will follow the binomial distribution $B(n, p)$ if the number of competing nodes is assumed to be n, the probability P_{once} that communication will be successful by one retransmission is represented by

$$P_{once} = n \times p \times (1 - p)^{n-1}. \tag{1}$$

Therefore, the probability P_{link} of succeeding in communication by retransmission of ID up to x times is derived as

$$P_{link} = P_{once} \sum_{i=1}^{x} (1 - P_{once})^{i-1}. \tag{2}$$

3) Polling (Fig. 5)
A receiving node chooses, from among the adjacent nodes, a node that permits SREQ transmission, and then resends the ID with added information. SREQ collisions are avoided by choosing a transmission node from among adjacent nodes one by one.

B. *Temporary pausing for collision avoidance*

In this section we explain the controls applied to avoid control packet collisions in addition to the above-mentioned techniques. A node with no established link assumes that it is awaiting packet receipt. When this node receives a RACK packet that is not directed to it, the node judges that communication with nodes within its communication range have started. During this communication period, it becomes sleep state temporarily, and does not communicate, in order to avoid collisions.

Table I
SIMULATION PARAMETERS

Retransmission probability p	0.5
Intermittent interval	1 s
Maximum data packet existence time	5 s
Communication distance	100 m
Maximum transmissions	Minimum hop + 5
Current at transmission	20 mA
Current at receiving	25 mA
Current at sleeping	0 mA
Data packet size	128 byte
Transmission speed	100 kbps

III. PERFORMANCE EVALUATION

We evaluated these proposed techniques using a simulation model that collects the data of a wireless mesh network consisting of 40 nodes and one sink node. Table I lists simulation parameters. First, we considered derivation of the probability p in the case of probabilistic retransmission. From configuration of the nodes which are adjacent of the sink node, it is considered that a possibility that two nodes will compete is the highest. As we already calculated, when the number of nodes which competes is 2, it is that P_{link} becomes the maximum at the time of $p = 0.5$. Therefore, we applied 0.5 as a value of p at the time of performing the simulations which perform probable retransmission.

Fig. 6 shows the simulation results (average and 99% confidence interval). Results indicate that the three proposed techniques improve performance in terms of packet collection rate, packet delay, and power consumption, as compared with the case where no functions are added ("default" in Fig. 6). In addition, packet collision data indicate that temporary pausing can reduce the number of collisions, though performance impacts have not been observed as change of such average performances.

IV. CONCLUSION AND FUTURE WORK

We are examining techniques to further improve performance by utilizing information about adjacent nodes and the load of each node resulting from topology.

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