A Data Collection Protocol for Wireless Sensor Networks Powered by Ambient Energy Harvesting

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Introduction

Energy harvesting (EH) that converts ambient energy from the environment into energy has received growing attention to reduce the need for frequent maintenance in wireless sensor networks (WSNs). However, conventional protocols that assume energy are provided by batteries is not applicable to WSNs powered by ambient EH (EH-WSNs). This paper evaluates a protocol for EH-WSNs with the goal of achieving high efficiency in data collection.

System Model and Technical Approach

Our model is based on the repeating charging-and-transmitting model (Fig. 1) as proposed in [1]. At the charge state, node charges up to the amount of energy that is sufficient to receive and transmit a packet. It then enters the receive state for a constant period of time. If there is a packet in the queue when receive state ends and the channel is idle, then the node enters the transmit state and broadcasts the data packet. At this time, if no neighboring node is in receive state, the packet is lost and the overall data collection rate deteriorates.

To overcome the problem of packet loss, we propose the Probabilistic ReTransmission (PRT) protocol that derives the optimal number of times to retransmit. N_i denotes the set of nodes within the communication range of node n_i, and S_i denotes the subset of N_i whose nodes are closer to the sink than n_i. We assume that a n_i can keep measuring a total charging time T_{chi}, a total receiving time T_{rxi} and a total transmitting time T_{txi}. When a node $n_h \in N_i \setminus S_i$ broadcasts a packet to neighbor n_i in its communication range, the reception probability p_i can be approximated as $p_i = \{T_{rxi}/(T_{chi} + T_{rxi} + T_{txi})\} \cdot \{(t_{rx} - t_{tx})/t_{rx}\}$. When n_i broadcasts a packet once, the probability q_i that at least one node can receive the packet is expressed as $q_i = 1 - \prod_j^{S_i}(1 - p_j)$. Assuming the sender repeats transmitting a given packet α times, then the probability that at least one node receives the packet, r_{ai}, is calculated from $r_{ai} = 1 - (1 - q_i)^{\alpha}$. In PRT, let Th denote the reliability threshold on r_{ai}, and we assume that $r_{ai} \geq Th$, is reliable. Then, a sender calculates an optimal number of retransmission, α', which is the minimum value such that the probability $r_{\alpha' i}$ remains above the reliability threshold from $r_{\alpha' i} \geq Th$ and $\alpha' \geq \log_{(1-q^i)}(1 - Th)$, and then it transmits a packet α' times.

Results and Discussion

We evaluate our proposed protocols by simulation where n nodes are deployed randomly in the $500\text{m} \times 500\text{m}$ area with a sink located at the center. The simulation result in Fig. 2 shows that PRT achieves a higher data delivery ratio than the GR-DD and GR-DD-RT [1]. In PRT, each node can adapt to the changes in the node density by computing the optimal number of times to retransmit a packet depending on the number of nodes within its communication range.

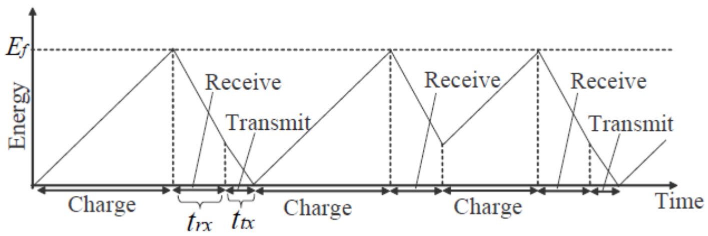

Fig.1 The time history of the stored energy on the node

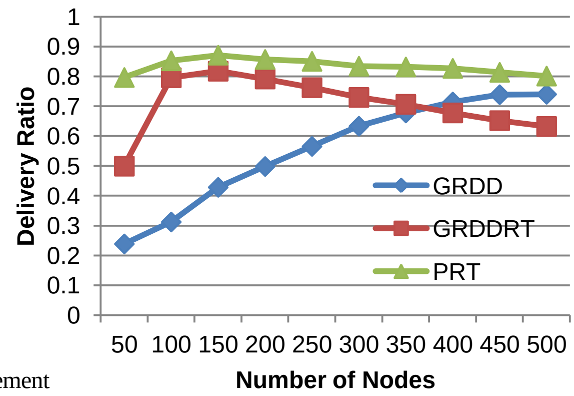

Fig.2 Simulation result

References

[1] Z. A. Eu, H. -P. Tan, and W. K. G. Seah, “Routing and Relay Node Placement in Wireless Sensor Networks Powered by Ambient Energy Harvesting,” in Proc. of the IEEE Wireless Communications and Networking Conference (WCNC), Apr 5-8 2009, Pp.5-8