Uplink Routing based on High Power Sink in Wireless Sensor Networks

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Abstract

In this paper, we consider a heterogeneous power network (HPN) where an electric-supplied sink uses much higher transmission power than battery-supplied nodes. The HPN potentially enables the sink to directly cover the whole area (i.e., all nodes are within one hop transmission range of the sink). Based on the characteristics, we design a fast and light collection protocol (FLC). FLC allows the sink to fast transmit beacon to all nodes via one hop. Each node finds routing path to the sink using both received signal strength indicator (RSSI) of the beacon and expected number of transmissions (ETX). The performance of the proposed FLC is evaluated by computer simulation and it is shown to achieve significant performance improvement over the state-of-the-art protocol (i.e., collection tree protocol).

1. Introduction

Multi-hop routing is a core technique to construct a scalable wireless sensor network (WSN). In particular, monitoring service, one of the most critical applications, needs an uplink routing which helps each node to transmit its data to the sink in a multi-hop manner. For route discovery, each node is required to have proper routing metric and neighbor information. Wrong information may cause inefficient routing path and routing loop. On the other hand, battery-powered sensor nodes suffer large energy consumption when the route discovery requires large control traffic. Thus, it may be desirable to design a routing technique which provides efficient path with low control traffic overhead.

Collection tree protocol (CTP) is state-of-the-art uplink routing protocol in LLNs [1]. To have a routing metric such as expected number of transmissions (ETX), each node should receive a beacon which is propagated from the sink in a multi-hop manner. It provides Trickle algorithm which minimizes the beacon transmission period (to 64ms) when routing metric needs to be updated. CTP can achieve fast route discovery. However, it may suffer from control overhead due to beacon transmission.

To alleviate the problem, broadcast free collection protocol (BFC) has been proposed [2]. BFC allows a node to update its routing metric only by overhearing data packets. Overhearing is one of basic characteristics of low power listening medium access control (MAC) protocols such as BoX-MAC-2 [3]. BFC requires no additional overhead for routing by control traffic elimination. However, BFC requires long time for route discovery since it relies on low rate data traffic (e.g., packet interval of 5mins).

In this paper, we consider a heterogeneous power network (HPN), where the sink can cover all the nodes via one hop using much higher transmission power than sensor nodes. Based on the characteristics, we design a fast and light collection protocol (FLC) to enhance uplink routing performance in WSNs. FLC allows only the sink to transmit beacon, eliminates control overhead of nodes. Each node directly receives the beacon and measures the received signal strength indicator (RSSI). By selecting routing path based on the direct RSSI, FLC can also achieve fast route discovery. As time goes by, each node changes its routing metric to ETX by overhearing data packets, and finally has the best route to the sink. The simulation results show that FLC significantly outperforms CTP.

The rest of this paper is organized as follows. Section 2 describes characteristics of an HPN. Section 3 describes the proposed FLC and Section 4 evaluates its performance by computer simulation. Finally, Section 5 concludes this paper.

2. Heterogeneous Power Network

We propose the use of HPN to enhance performance WSNs. The sink node usually has electric power supply since it directly connected to the server computer. Thus, the sink does not need any power saving mechanism such as duty cycling [2]. Based on the permanent power supply, the sink can use much higher transmission power than low power (0dBm) nodes. The asymmetric power capability of HPNs makes single hop downlink and multi-hop uplink. For example, the sink can cover 3-hop range of low power nodes when it exploits WiFi transmission power (i.e., 17dBm) [4]. We expect such a smart use of infrastructure to be a new direction for WSN researches.

3. Proposed FLC design

The proposed FLC comprise three phases. Phase 1 is the initialization step. The sink starts to transmit beacon which
can be received by all nodes. Each node measures the direct RSSI from the beacon and updates its routing metric. However, it does not know a proper route to the sink since it does not know neighbor information. In Phase 1, FLC makes a node transmit a packet to the sink without route discovery. To this end, a sender includes its direct RSSI in the packet, and transmits it without MAC destination until ACK reception. Neighbor nodes can overhear the data packet. Then, a receiver transmits ACK to the sender and forwards the packet when its direct RSSI is larger than that of the sender. FLC achieves fast routing since each node can send a packet right after receiving a beacon from the sink.

As time goes by, each node gathers neighbor information by overhearing data packets. Then, Phase 2 begins. In Phase 2, each node knows the direct RSSI of its neighbors. It selects a neighbor which has the largest direct RSSI as its parent. Then, it transmits a packet to the parent (i.e., MAC destination is the parent). Thus, FLC allows a sender to find a proper routing path based on the direct RSSI.

The direct RSSI-based routing is fast but not optimal since it does not consider multi-hop environments. In particular, when the direct RSSI of a sender is local maximum, it cannot transmit a packet to any neighbors. Thus, direct RSSI-based routing should be considered as a temporal solution.

To achieve stability, Phase 3 converts direct RSSI-based routing to ETX-based routing. As the packet transmission further goes on, ETX can be propagated in a multi-hop manner [2]. ETX propagation is also based on data overhearing. When a sender obtains ETX of it and its neighbors, it selects a neighbor which has the smallest ETX as its parent. Thus, FLC can first provide temporal routes fast, and then, stable and efficient routes as time goes by.

4. Performance Evaluation

The performance of CTP and FLC is evaluated through computer simulation. For MAC protocol, we use BoX-MAC-2 which is the standard MAC in TinyOS [3]. Assume that each node exploits transmission power of 0dBm, while the sink of HPN exploits 17dBm. Then, the sink covers 191.35m whereas a node covers 58.4m, with the use of path loss model of IEEE 802.15.4 [5]. Then, we randomly deploy 100 nodes in a circular area of radius 191.35m where the sink is in the center. Assume that each node has a buffer which can store 10 packets and generates a 50-byte data packet every 5 minute. Simulation time is 4 hours.

Fig. 1 and fig. 2 respectively depict average latency and average power consumption of nodes according to wakeup interval. Basically, the use of large wakeup interval reduces power consumption since a node can sleep for a long time. However, it makes a node have few chances to transmit a packet, which causes traffic congestion and long latency. It can be seen that FLC can provide lower latency and power consumption than CTP due to fast route discovery and control traffic elimination.

5. Conclusions

We consider the use of HPN to enhance uplink routing performance in WSN. To this end, we design FLC which exploits both direct RSSI and ETX as routing metric. FLC fast provide a temporal route based on direct RSSI. Thus, it allows a node to transmit a packet right after receiving a beacon from the high power sink. FLC can also provide a stable and efficient route as time goes by. Simulation results show the effectiveness of the proposed FLC.

6. Acknowledgement

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7. Reference