Dynamic Adjustment of Transmission Power in IEEE 802.15.4 for Energy Conservation

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Abstract

In Wireless Sensor Networks (WSNs), many techniques have been proposed to reduce the energy consumption. Among them, one of the outstanding methods is the transmission power control (TPC). In this paper, we propose a TPC scheme that can be easily implemented in IEEE 802.15.4 standard. The simulation results demonstrated that our TCP scheme is effective in conserving energy and can be used in WSN applications.

I. Introduction

Wireless sensor network (WSN) consists of small, inexpensive sensor nodes capable of computing and sensing and must be energy efficient [1-4]. The legacy MAC protocols of WSN conserve energy by introducing the concept of duty cycling. However, there is a tradeoff between energy and latency in duty cycling MACs. Radio-triggered power management [5] and power control scheme [6] are alternative to adjust transmission power for energy conservation. Besides saving energy, power control also improves spatial reuse of the wireless channel [6].

Several MAC approaches on transmission power control for WSNs have been proposed. To adjust the transmission power in WSNs, two approaches are presented in [7]. The first approach employs dynamic adjustments by the exchange of information among nodes, and the second one calculates the ideal transmission power according to signal attenuation in the link. In WSN, Received Signal Strength Indicator (RSSI) readings were found to be extremely dependent on environmental conditions thus the second approach is imprecise to calculate the ideal transmission power. PSMAC (transmission Power control in SMAC) is SMAC based transmission power control protocol for WSNs [1][8]. PSMAC selects the minimum amount of transmitting energy needed to exchange messages between any pair of neighboring nodes. The necessary power for the transmission is calculated using the RSSI of received SYNC packet. In order to assign a minimum and workable transmission power to each communication link, Adaptive Transmission Power Control for Wireless Sensor Networks (ATPC) was designed based on the concept of changing a pairwise transmission power level over time [9]. Two main ideas behind its design is a neighbors table which is maintained by each node and a closed loop for transmission power control which runs between each pair of sensors. The closed loop feedback is used to obtain the minimum transmission power by gradually adjusting the power.

The transmission power of CC2420, which is a single-chip 2.4 GHz IEEE 802.15.4 compliant RF [10], is programmable but, this benefit of this programmable power level is not used by IEEE 802.15.4. However, energy consumption can be reduced by adjusting the transmission power based on the distance between nodes. Thus, we are motivated to dynamically adjust the transmission power to conserve energy using our proposed TPC mechanism.

In this paper, we will show how IEEE 802.15.4 standard can be enhanced by implementing TPC mechanism. The paper is organized as follows: The proposed scheme is presented in Section II. Experiment results are shown in section III, and the paper is concluded in section IV.

II. Proposed Scheme

In the proposed scheme, we proposed a method to change the transmission power based on the distance between two nodes in order to reduce the energy consumption. In this work, Link Quality Indicator (LQI) value is used to estimate the distance between the sensor nodes. In IEEE 802.15.4, every MAC frame contains LQI value that ranges from 0 to 255. However, a packet is only received if its LQI is equal or greater than 128. Thus, LQI obtained ranges from 128 to 255 because the packets whose LQI is below 128 are dropped. From the ns-2 simulation for the transmission range of 15 m, it was observed that the LQI value of 255 is observed when the distance between node and coordinator is less than 12 m and the gradual decrease in LQI observed once the distance exceeds 12 m. Also from simulation, the LQI value between 140 and 170 is enough for the reliable communication between nodes. Thus, based on the ns2 experiment, we proposed the following algorithm for estimating the distance and adjusting the transmission power.

At first, nodes use the default transmission power, which is highest power level (level 31). The receiving node calculates the LQI value of the received packet. However, for adjusting the transmission power, the sender should know about the LQI at the receiver. Thus, for the feedback of the LQI, the LQI of the received data packet is sent in the Acknowledgment (ACK) packet. Once the sender gets the ACK, it knows about the LQI of its sent packet. Now, based on the feedback of LQI, sender readjusts its transmission power such that the LQI received is in
the range of 140 to 170. For filtering the noise, average LQI value is used for decision making, i.e., the average value of multiple LQI received from the same node. Fig. 1 shows the flowchart for adjusting the transmission power. All the nodes maintain a table called TPC table, which stores the required transmission power for each neighbor. However, in the case a node needs to broadcast, the maximum power level is used.

![Fig. 1 Flowchart for TPC](image)

### III. Experimental Results

Topology and network parameters used in the simulation are shown in Fig. 2. Node 1, 2, 3, and 4 transmit data to the node 0. Similarly, node 6, 7, and 8 transmit data to the node 5. The simulation was carried for 500 secs.

![Fig. 2 Topology and parameters used in the simulation](image)

In the first experiment, the message interval was varied from 1 to 4 seconds and packet size was fixed to 50 bytes. Table 2 shows the average Packet Delivery Ratio (PDR) and energy consumption in joules for the conventional IEEE 802.15.4 and modified IEEE 802.15.4 adapted with TPC. It is observed that at the message interval of 1 sec, PDR of IEEE 802.15.4 is higher. The reason is, whenever there is a collision at the same power level, the receiver was successful in decoding the data packet from the node closer to it. However, in the case of TPC, since power was adjusted and have a similar influence to the receiver, all data packets were dropped as the receiver is unable to decode any data packet. However, for higher message interval, PDR is same for both the protocols. As expected, TPC is able to save the energy.

<table>
<thead>
<tr>
<th>Message Interval</th>
<th>IEEE 802.15.4</th>
<th>IEEE 802.15.4 with proposed TPC</th>
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<tbody>
<tr>
<td></td>
<td>PDR</td>
<td>Energy</td>
</tr>
<tr>
<td>1</td>
<td>97</td>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
<td>98</td>
<td>1.49</td>
</tr>
<tr>
<td>3</td>
<td>98</td>
<td>1.45</td>
</tr>
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Table 2: PDR and Energy consumption

In the final experiment, message interval was fixed to 5 sec and packet size to 100 bytes. The results obtained are shown in Table below. The results show that PDR is same for both the protocols, conventional and TPC. However, energy consumption is much less in the case of TPC. Therefore, the results demonstrated that in low traffic, the performance of TPC is better than that of original protocol, without any tradeoff. The TPC delivers the same PDR but with significantly less power consumption. But, in the case of dense traffic, using TPC might not give good results as compared to original IEEE 802.15.4.

<table>
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Table 3: PDR and Energy consumption

### IV. Conclusion

In this paper, we presented a TPC scheme which uses LQI to estimate the distance between two nodes. Based on the estimated distance, the transmission power is adjusted without degrading the link quality. The experimental results showed that TPC can be used in WSN environment where data traffic is not high.

**REFERENCES**