A Sender/Receiver Pair Transmission Power Control for Wireless Sensor Networks

Hayder Ahmed Abdulmohsin† *Ali Abduljabbar Mohammed*‡ *Hayder Mohammed Amer*‡‡
†Computer Systems Department, Technical Institute/Qurna Basrah, Iraq
‡Computer Center, Technical College – Basrah Basrah, Iraq
‡‡Computer Systems Department, Technical Institute/Basrah Basrah, Iraq
E-mail: †hayderaam@gmail.com, ‡alijwd@ymail.com‡‡haiderma2@gmail.com

Abstract

In a sensor node there are processing unit, sensing unit, transceiver unit and, power unit. This part of wireless sensor node is built on the Integrated Chip (IC). Reducing node energy consumption is important and vital in WSNs. The battery has very limited energy. Given that replacing/refilling batteries is usually impossible, it is important to use this limited energy as efficiently as possible. In this way we propose a new transmission power control algorithm for transmission power level control for each pair of communication nodes, sender and receiver to save energy as much as possible. The simulation results show the proposed algorithm is good for high energy saving and link quality.

Keyword Transmission Power Control, Energy Consumption, Wireless Sensor Networks.

1. Introduction

WSN technology is promising and gaining popularity day by day in a different applications. The WSN nodes operate on battery power which is often deployed in a rough physical environment; changing the batteries is therefore a complicated task, as some networks may consists of hundreds to thousands of nodes [S. J. Ali and P. Roy, 2008]. The life time of a wireless sensor node depends on available energy sources and its overall energy consumption. Further, increasing the capacity of batteries is not possible due to the small size requirement of the nodes [S. J. Ali and P. Roy, 2008].

The methods in which energy savings can be classified under two headings [M. Vieira, C Jr., D. Junior and J. Mata, 2003]: device level which is hardware component selection and their configuration to achieve low energy consumption and network level which is choice of communication methods and protocols to minimize energy consumption. At the network level, there are two main categories to minimize the energy consumption [J. Sheu, K. Hsieh and Y. Cheng , 2009]. The first is media access control (MAC) layer solution and the other is network layer solution. The network layer solution utilizes adjusting proper transmission power to achieve power saving. The advantage of adjusting transmission power is when transmitting data at low rate not only reducing the amount excessive inference which improves spatial reuse, but also prolongs the network lifetime. Furthermore, it allow several improvements in the operation of wireless sensor networks [J. Sheu, K. Hsieh and Y. Cheng , 2009].

In this way we propose transmission power control algorithm to adjust the transmission power level with environmental changes. However, selecting proper transmission power changes with time and environmental changes may be difficult. Low transmission power may lose link between two nodes and high transmission power consumes large amount of energy from limited battery node. Therefore we propose transmission power control algorithm to dynamically adjust a proper transmission power for both sender and receiver based on a number of experimental results.

The rest of the paper is organized as follow: related works is presented in section 2. In section 3, RSSI (Receiver Signal Strength Indicator) threshold and RSSI threshold range are calculated. In section 4, design of the proposed algorithm is described. In section 5, our algorithm is evaluated through experiments and compared with some of existing schemes. In section 6, conclusions and future work are given.

2. Related Works

There are many literatures about transmission power control for WSNs are reviewed in this section. The authors in [S. Lin, J. Zhang, G. Zhou. L Gu, J. A. Stankovic, 2006] proposed an Adaptive Transmission Power Control algorithm (ATPC). ATPC has two phases: initialization phase and run-time tuning phase. In the initialization phase, each node broadcasts beacons at different transmission power levels. When its neighbors receive these beacons, they measure both RSSI (Received Signal Strength Indicator) and LQI (Link Quality Indicator) values and send these values back by notification packet. When the sender receives these notifications, it builds a predictive model and determines an optimal transmission power level. After the initialization phase, a link quality monitor module in the receiver decides whether a notification packet is necessary. Upon the notification reception, the sender adjusts the proper transmission power level. The drawback of ATPC is that each node broadcasts a number of beacons in initialization phase and unicasts a number of notification packets. These overhead packets increase energy consumption and thus reduce the lifetime of the network.

The authors in [J. Kim, S. Chang and Y. Kwon, 2008] propose an On-demand Transmission Power Control algorithm (ODTPC). This algorithm removes overhead packets exchange to maintain good link quality and adjust transmission power level. The ODTPC has two phases: large-scale transmission power control (L-TPC) and small-scale transmission power control (S-TPC). In L-TPC, when a sender has a data packet to be sent, it sends the packet with maximum transmission power level. When a receiver receives the packet, it measures RSSI and roughly approximates the transmission power level and it adds Margin to the approximated transmission power level. Then, the receiver sends RSSI value by an ACK packet. When the sender receives the ACK packet, it roughly approximates transmission power level as the receiver does. In S-TPC, the sender sends a data packet with the approximated transmission power level and the receiver sends an ACK packet with measured RSSI. If the RSSI value is small than a lower threshold, the sender increases transmission power level in fixed step, 1. Otherwise, if RSSI value is large than an upper threshold, it decreases the transmission power level in a fixed step. The lower threshold and upper threshold are RSSI threshold and RSSI threshold+6. The drawback of ODTPC is that a receiver does not determine the optimal transmission power level, but it calculates the approximated transmission power level plus Margin.

In this paper, we develop an algorithm named Sender/Receiver Pair Transmission Power Control (SRTPC) which based on a number of experimental results. SRTPC calculates best transmission power level for both sender and receiver to save more energy.

3. Investigating of RSSI threshold and RSSI threshold range

In order to design the SRTPC we need to calculate some parameters such as RSSI threshold and RSSI threshold range that are important in design process. We choose the RSSI threshold to provide high PDR (Packet Delivery Ratio). To determine RSSI threshold we did some experiments. These experiments are performed using Castalia simulator [A. Boulis and D. Pediaditakis].Section 4 presents the parameters and models used during simulation. In Radio model we set the number of transmission power level to 15 levels from level 1 to level 15 respectively. In these experiments we use two nodes, one as a sender and other as a receiver. The sender transmits 1000 data packet for each transmission power level from high to low at different distances (5 m, 10 m, 20m, 30 m, 40 m and 50 m) and different transmission interval (0.1 sec, 1 sec and 10 sec).Then, we conclude from experimental results that the value of RSSI threshold of -93 dBm will satisfy PDR above than 99% and the relation

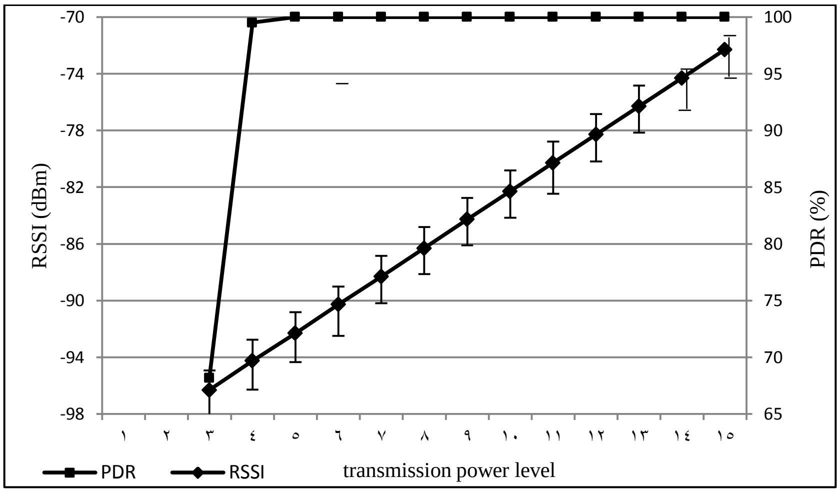


Fig 1.RSSI v. PDR at distance 10m and Tx interval 0.1 sec

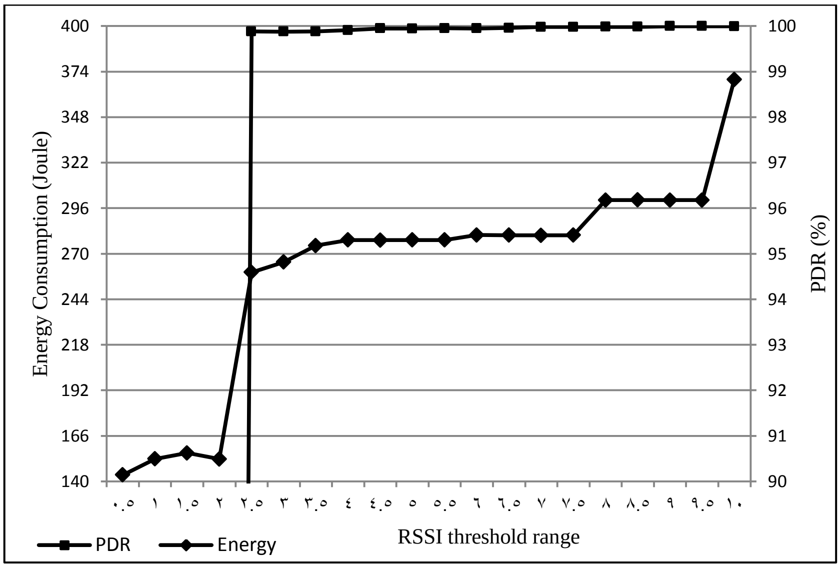


Fig 2.RSSI threshold range v. PDR v. Energy consumption at distance 15m and Tx interval 0.25 sec

between RSSI and transmission power level is linear as in Figure 1.

After we determine RSSI threshold, we choose the RSSI threshold range to satisfy an best energy saving. The RSSI threshold range is critical to energy saving, if the range is small, the oscillation of transmission power level will be high, radio signal fading and PDR low. If the range is big, the optimal power control will not be achieved and energy consumption high. Thus, there is conflict between PDR and energy consumption in determining RSSI threshold range. Thus we must choose optimal RSSI threshold range that satisfies both high PDR and low energy consumption as possible.

We did some experiments to calculate RSSI threshold range, we use two nodes one as sender and another as receiver. The sender sends one, two and four data packets every one second for period of 24 hours at different distances (5 m, 10 m, 15 m, 20 m, 25 m, 30m, 35m, 40m, 45m and 50 m). We conclude

RSSI threshold range of 3; it is best and satisfies our requirements as in Figure 2.

4. Design of SRTPC

In this section we propose SRTPC algorithm design. The aim of SRTPC is determining best transmission power control in both sender and receiver to save more energy as much as possible and every node adjusts its transmission power level with environmental changes quickly and maintains good link quality.

The SRTPC works in the following way:

Step 1: At first time when a sender wants to send a data packet to a receiver, it sends the data packet with maximum transmission power level and this first data packet contains TPL field which is transmitted power level.

Step 2: When the receiver receives the data packet, it measures RSSI of received packet and adjust transmission power level as following:

If (RSSI <-95) Then TPL=TPL+2

If (RSSI <-93 and RSSI ≥-95) Then TPL=TPL+1

If (RSSI ≥-93 and RSSI ≤-90) Then TPL=TPL

If (RSSI >-90 and RSSI≤-88) Then TPL=TPL-1

If (RSSI >-88 and RSSI ≤-86) Then TPL=TPL-2

If (RSSI >-86 and RSSI ≤-84) Then TPL=TPL-3

If (RSSI >-84 and RSSI ≤-82) Then TPL=TPL-4

If (RSSI >-82) Then TPL=TPL-5

Step 3:Then the receiver sends ACK packet contains RSSI of received data packet field to the sender with calculated transmission power level.

Step 4: When the sender receives the ACK packet, it stores RSSI of received ACK packet and adjusts its transmission power level according to above rules.

Step 5: Next time, when the sender wants to send next data packet to the same receiver, it sends this data packet which contains RSSI of received ACK packet field with calculated transmission power level.

Step 6: Go to step 2.

Sometimes the receiver receives the data packet, adjusts its transmission power level and it sends an ACK packet, but this ACK packet does not reach to the sender. In this case the sender sends the data packet again. When the receiver receives the data packet again, it does not adjust its transmission power level again.

Based on the linear relationship between RSSI and transmission power level as in Figure 1, the value of RSSI threshold and the value RSSI threshold range as in Figures 1 and 2, we select the above rules.

In this way both sender and receiver always send their packets with best transmission power level and they adjust their transmission power level quickly over time with environmental changes.

5. Simulation and Results

5.1Simulation Setup

The simulation of the proposed algorithm is tested using Castalia [6] and OMNeT++ [A. Varga]. Castalia is a framework for WSNs that is built on top of OMNeT++. Castalia models the different aspects of WSNs such as the wireless channel, the physical process, the resource manager, the radio model, the MAC layer, the network layer and the application layer. In our simulation, we used S-MAC [W. Ye, J. Heidemann and D. Estrin] as MAC model and CC1000 Radio [Texas Instruments] as Radio model. Table 1 shows some values used in the simulations.

5.2 Simulation Results

In this subsection, The proposed algorithm is evaluated and compared with ODTPC, ATPC, and MAX scheme (MAX scheme always sets the transmission power level to maximum level) with two scenarios.

In scenario 1 we use a network with 49 nodes and multi-hope as in Figure 3. The network in this scenario forms a spanning tree and leaf nodes send packets to sink node where each leaf node send one packet to sink node every 43.92 seconds for period of 3 days. Before transmitting data packets, ATPC has initialization phase: each node broadcast one packet at each transmission power level. These overheads packets in initialization phase consumes more energy where each node broadcast one packet at each transmission power level and unicasts 48 packets.

Figure 4-a shows overall transmission energy consumption in the network, where the arrangement of algorithms from low energy consumption to high energy consumption is SRTPC, ODTPC and ATPC. This arrangement occurs for following reasons: SRTPC always adjust transmission power level at both the senders and the receiver quickly with environmental changes. In ODTPC, the receiver approximates transmission power level and then add margin to the approximated transmission power level. In ATPC, the receiver sends a number

Table 1.MAC and Radio parameter values in simulation

Model	Parameter	Value
MAC	Frame Time	610 msec
MAC	Listen Timeout	305 msec
Radio	Transmission Power Levels	[10, 8, 6, 4, 2, 0, -2, -4, -6, -8, -10, -12, -14, -17, -20] dBm
Radio	Transmission Power Consumption Per Level	[80.1, 60, 47.4, 41.4, 38.4, 31.2, 29.1, 28.8, 26.1, 24.6, 23.7, 22.8, 22.2, 21.3, 15.9] mWatt

of overhead notification packets to the senders to adjust transmission power level at senders. In addition to, ATPC consumes more energy in initialization phase.

Figure 4-b shows PDR of all algorithms where PDR of SRTPC and ODTPC are very close together because these algorithms select the transmission power level based on the pre-determined RSSI threshold which can provide PDR with more than 99% whereas PDR of ATPC is less than SRTPC and ODTPC because ATPC sends a number of overhead notification packets with data packets at same time, this increase traffic in the network.

In scenario 2 we implement one of WSN applications which is periodic reporting application with 120 ordinary nodes and one sink node where ordinary nodes send reports

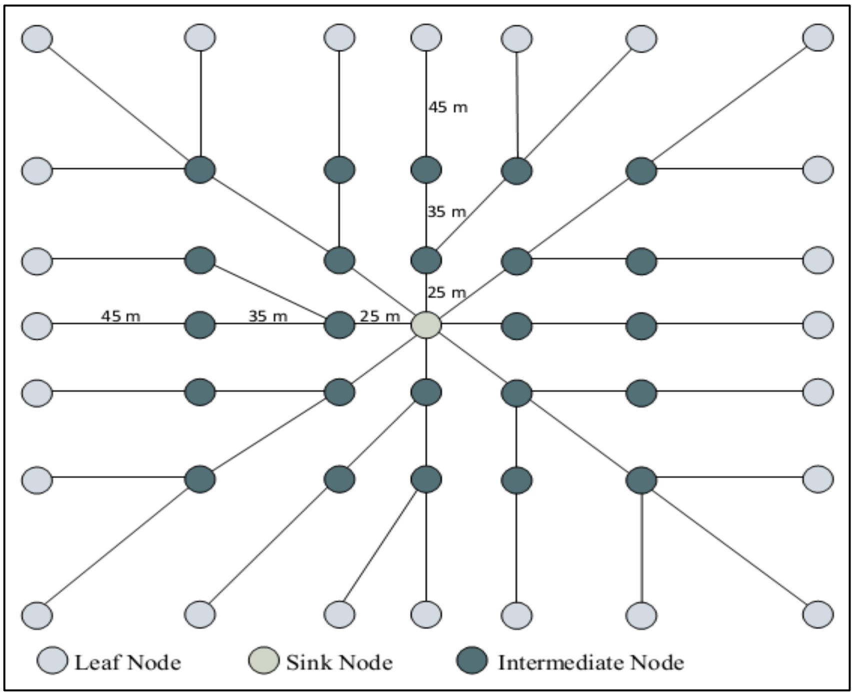
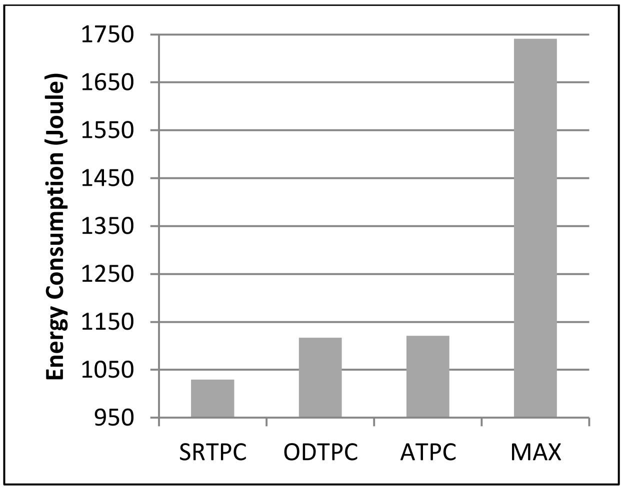
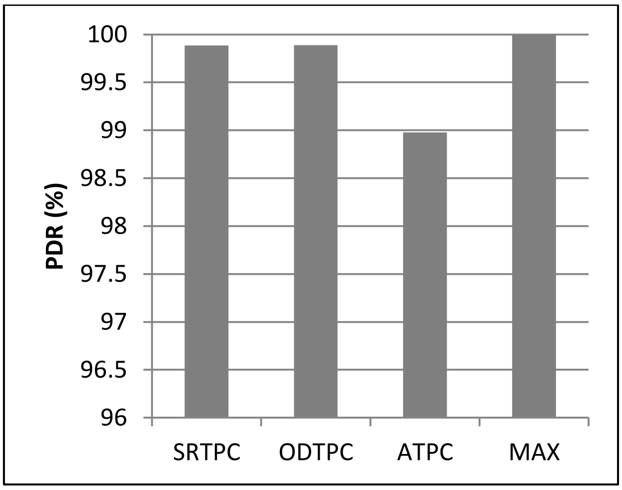


Fig 3. The network in Scenario 1



(a) Energy Consumption



(b) PDR

Fig. 4. Transmission Energy Consumption and PDR in Scenario 1

periodically to sink node, these nodes are distributed uniformly on area of 100*100 m^2. Each ordinary node senses an environment and sends report to sink node every 73.81 second. We set initial energy of ordinary nodes and sink node to 10 joule and 1000 joule respectively. In order to see the impact of transmission energy on lifetime of the network, we set the cost of energy due to reception, listening and sleeping to zero. Before sensor nodes send reports to sink node, ATPC has initialization phase: each node broadcasts one packet at each transmission power level and unicasts 120 packets.

Figure 5 shows average lifetime of ordinary nodes, we can see SRTPC has larger time than ODTPC and ATPC because the ordinary nodes in SRTPC always adjust their transmission power level quickly with environmental changes whereas in ATPC they adjust their transmission power level after the sink node send a number of notification packets to the ordinary nodes and in ODTPC, the ordinary nodes do not determine an optimal transmission power level because they do not use the optimal RSSI threshold range.

Figure 6 shows average transmission energy consumption every one hour in sink node, we can see SRTPC consumes less energy than ODTPC and ATPC because in ODTPC, the sink node approximates transmission power level and then adds margin to the approximated transmission power level and in ATPC, the sink node sends a number of overhead notification packets to the ordinary nodes in addition, the sink node consumes extra energy in initialization phase.

Figure 7 shows PDR in scenario 2. Because we use S-MAC as MAC protocol, so as the number of nodes is large the synchronization among nodes become difficult and the PDR decrease. In this figure, we can see PDR for SRTPC and ODTPC is very close together and we also can see PDR for ATPC is less than other algorithms because the ordinary nodes cannot adjust their transmission power level quickly unless the sink node sends a number of notification packets to them.

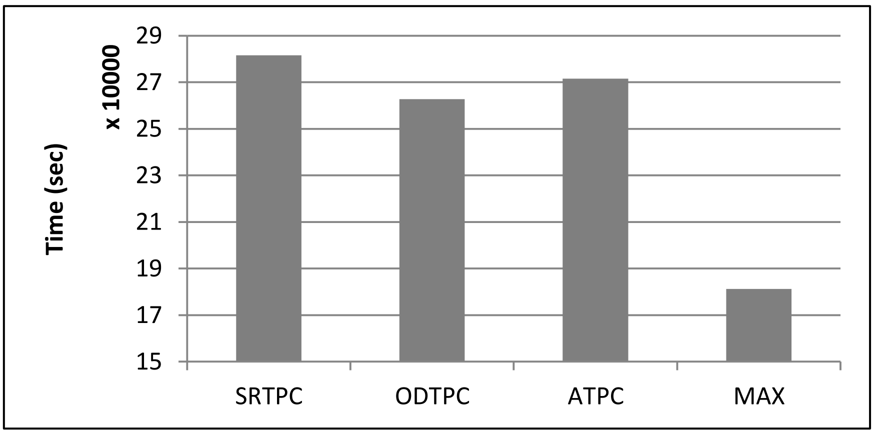


Fig. 5. Average lifetime of ordinary node in Scenario 2

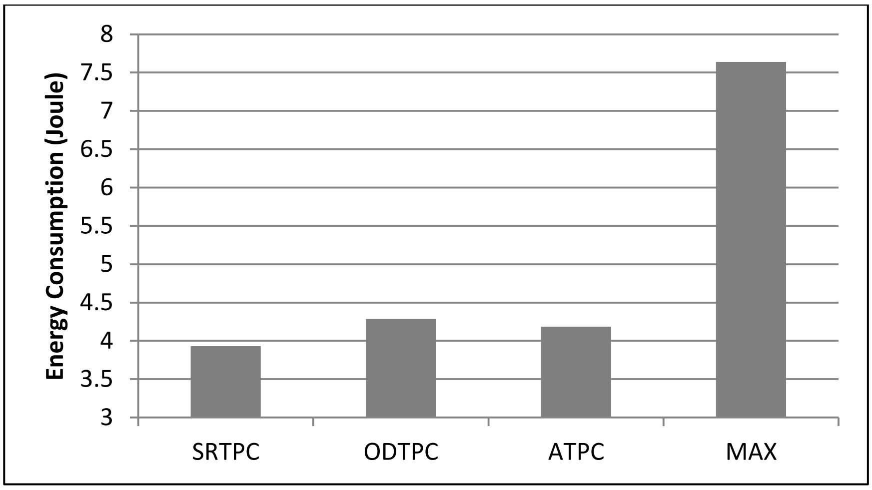


Fig. 6. Average transmission energy consumption at sink node every one hour in Scenario 2

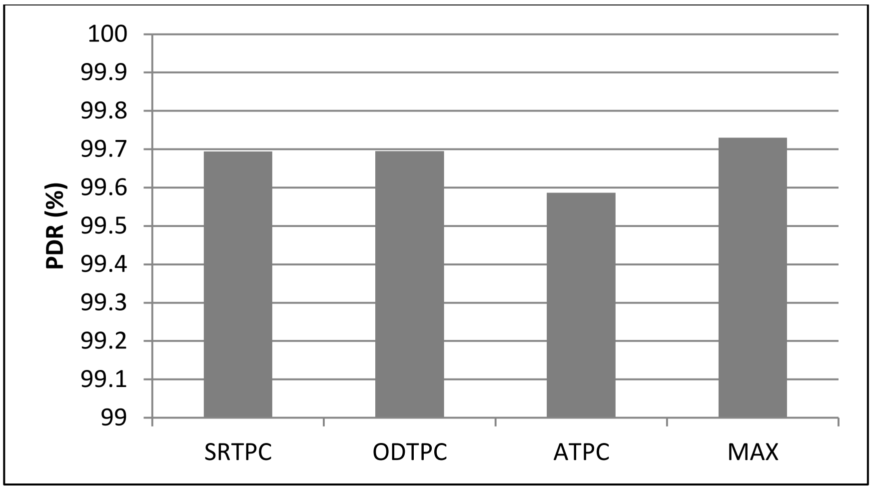


Fig. 7. PDR in scenario 2

6. Conclusions and Future work

The energy consumption is vital in WSNs. In this paper, we propose an algorithm called Sender/Receiver Pair Transmission Power Control (SRTPC) to control transmission power in both sender and receiver over time to save more energy. We did experiment to calculate an optimal RSSI threshold range that satisfies high PDR and low energy consumption as possible because RSSI threshold range is critical to save energy. The simulation results show that SRTPC is good to save energy and provide high link quality.

The control of transmission power level depends on some parameters like RSSI threshold and RSSI threshold range. These parameters may be different from one environment to another. One possible way to allow these parameters to change with different environments. Therefore, enhancement to the proposed algorithm and make it adaptive with different environments is our major future work.

References

[1] S. J. Ali and P. Roy. Energy Saving Methods in Wireless Sensor Networks. Master Thesis in Computer System Engineering, Halmstad University, May 2008.

[2] M. Vieira, C Jr., D. Junior and J. Mata. "Survey on Wireless Sensor Network Devices". In Proc. of ETFA '03. IEEE Conference, Vol. 1, pp. 537-544, 2003.

[3] J. Sheu, K. Hsieh and Y. Cheng. "Distributed Transmission Power Control Algorithm for Wireless Sensor Networks". JOURNAL OF INFORMATION SCIENCE AND ENGINEERING 25, p.p. 1447-1463, 2009.

[4] S. Lin, J. Zhang, G. Zhou. L Gu, J. A. Stankovic. ATPC: Adaptive Transmission Power Control for Wireless Sensor Networks. In proceedings of ACM conference on Embedded Networked Sensor Systems (Sensys), Colorado, USA, pp. 223-236, 2006.

[5] J. Kim, S. Chang and Y. Kwon. ODTPC: On-demand Transmission Power Control for Wireless Sensor Networks. In proceedings of the IEEE 22nd international conference of information networking 2008 (ICOIN 2008), Pusan, South Korea, 2008.

[6] A. Boulis and D. Pediaditakis. Castalia A Simulator for WSNs. National ICT Australia. http://castalia.npc.nicta.com.au.

[7] A. Varga. OMNet++ Discrete Event Simulation System. www.omnetpp.org.

[8] W. Ye, J. Heidemann and D. Estrin. An Energy-Efficient MAC Protocol for Wireless Sensor Networks. In 21st Conference of the IEEE Computer and Communications Societies (INFOCOM), Vol. 3, pp. 1567-1576, June 2002.

[9] Texas Instruments. CC1000 Signal Chip very Low Power RF Transceiver. www.chipcon.com.

التحكم بقدرة ارسال شبكات الاستشعار اللاسلكية باستخدام زوج من عقد الاتصال المرسل / المستلم

حيدر أحمد عبد المحسن† علي عبد الجبار محمد‡ حيدر محمد عامر‡‡

†قسم انظمة الحاسوب، المعهد التقني – القرنة البصرة، العراق

‡مركز الحاسبة الالكترونية، الكلية التقنية – البصرة البصرة، العراق

‡‡قسم انظمة الحاسوب، المعهد التقني – البصرة البصرة، العراق

E-mail: †hayderaam@gmail.com, ‡alijwd@ymail.com ‡‡haiderma2@gmail.com

الملخص

عقدة الاستشعار تتكون من وحدة المعالجة و وحدة الاستشعار وحدة الارسال و الاستلام و وحدة تجهيز القدرة و هذه الوحدات تجمع بدائرة متكاملة (IC). تقليل استهلاك طاقة العقدة مهمة جدا في شبكات الاستشعار اللاسلكية خصوصا ان البطارية ذات طاقة محددة جدا و ان استبدال البطارية غير ممكن عادة لذلك من المهم استخدام هذه الطاقة المحدودة بكفاءة بقدر الامكان. في هذا البحث نقترح خوارزمية للتحكم بقدرة الارسال لكل زوج من عقد الاتصال المرسل و المستلم لحفظ الطاقة بقدر الامكان. توضح نتائج المحاكاة ان الخوارزمية المقترحة جيدة لحفظ الطاقة.

الكلمات الافتتاحية التحكم بقدرة الارسال، الطاقة المستهلكة، شبكات الاستشعار اللاسلكية