July 2015

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Recommended Citation

PREMA, R. and RANGARAJAN, R. (2015) "POWER AWARE AND ENERGY EFFICIENT ROUTING PROTOCOL (PAEERP) FOR WIRELESS SENSOR NETWORKS," *International Journal of Computer and Communication Technology*: Vol. 6 : Iss. 3 , Article 11.

DOL: 10.47893/IJCCT.2015.1304

Available at: <https://www.interscience.in/ijcct/vol6/iss3/11>

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POWER AWARE AND ENERGY EFFICIENT ROUTING PROTOCOL (PAEERP) FOR WIRELESS SENSOR NETWORKS

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Abstract—Several wireless sensor network applications have to decide the inherent discrepancy between energy efficient communication, power aware routing and the requirement to attain preferred quality of service (QoS) such as packet delivery ratio, delay and to reduce the power and energy consumption of wireless sensor nodes. In addition to that the protocols which are developed aims in providing better QoS. For addressing this challenge, we propose the Power Aware and Energy Efficient Routing Protocol (PAEERP), which attains application-specified communication delays at low energy cost by dynamically adapting transmission power and routing decisions along with incorporating a novel cryptosystem. Through extensive simulation in NS2 the results prove that the proposed PAEERP attains lesser delay with reduced power and energy consumption.

Keywords: *Sensor networks, secured power aware routing, energy efficient routing.*

1. INTRODUCTION

Wireless Sensor Networks

Smart environments represent the next evolutionary development step in building, utilities, industrial, home, shipboard, and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world. Sensory data comes from multiple sensors of different modalities in distributed locations. The smart environment needs information about its surroundings as well as about its internal workings; this is captured in biological systems by the distinction between exteroceptors and proprioceptors.

The challenges in the hierarchy of: detecting the relevant quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user displays, and performing decision-making and alarm functions are enormous. The information needed by smart environments is provided by Distributed Wireless Sensor Networks, which are responsible for sensing as well as for the first stages of the processing hierarchy. The importance of sensor networks is highlighted by the number of recent funding initiatives, including the DARPA SENSIT program, military programs, and NSF Program Announcements. Desirable functions for sensor nodes include: ease of installation, self-identification, self-diagnosis, reliability, time awareness for coordination with other nodes, some software functions and DSP, and standard control protocols and network interfaces.

This is an extension of our previous work [1]. In [1] we proposed secured power aware routing protocol for wireless sensor networks.

2. LITERATURE REVIEW

In [2], Chien-Yuan Chen, Cheng-Yuan Ku, and David C. Yen found ways to use the LLL algorithm to break the RSA system even when the value of d is large. According to their proposed cryptanalysis, if d satisfies $|X - d| < N^{0.25}$, the RSA system will be possible to be resolved computationally.

In [3], Kwok-Wo Wong, Sun-Wah Ho, and Ching-Ki Yung, customized the chaotic cryptographic scheme to reduce the length of the ciphertext to a size slightly longer than that of the original message. Moreover, they introduced a session key in the cryptographic scheme so that the length of the ciphertext for a given message is not fixed.

In [4], Chang-Doo Lee, Bong-Jun Choi, and Kyoo-Seok Park proposed a block encryption algorithm, which is designed for each encryption key value to be applied to each round block with a different value. This algorithm needs a short processing time in encryption and decryption, has high intensity, and can be applied to electronic commerce and various applications of data protection.

In [5], Mark G. Simkin discusses five encryption techniques: transposition ciphers, cyclic substitution ciphers, Vigenere ciphers, exclusive OR ciphers, and permutation ciphers. Accompanying these discussions are explanations of how instructors can demonstrate these techniques with spreadsheet models.

In [6], Jun Wei, Xiaofeng Liao, Kwok-wo Wong, and Tao Xiang proposed a new chaotic cryptosystem. Instead of simply mixing the chaotic signal of the proposed chaotic cryptosystem with the ciphertext, a noise-like variable is utilized to govern the encryption and decryption processes. This adds statistical sense to the new cryptosystem.

In [7], Osama Mahmud Abu Abbas, Khalid

Mohammad Nahar, and Mohammad Ahmad Tubishat, uses Arabic letters and their diacritics for encrypting English messages and vice versa. A pseudo random generator is used to generate integer numbers to represent each character in Arabic language. The same numbers are used again after sorting them to represent the English characters. The conclusions that extracted indicate the efficiency of ARAE system according to security and time performance.

Nevertheless, the diversities of all the above stated encryption methods, but all of them are common in some characteristic such as: The encryption operation can be implementing as a one to one relation, Usually there is a language redundancy problem, Semi random encryption methods, and Finding a way to cryptanalysis them is applicable, nevertheless, the needed time is.

Energy-efficient routing algorithms allow WSNs to be deployed with smaller battery packs and to achieve longer lifetime for a given battery size [9,10]. There are mainly two ways to achieve energy-efficient route selection in WSNs: Minimum cost routing and maximum network lifetime routing. One classical energy-efficient routing algorithm for minimum cost routing is minimum energy routing (MER). The MER algorithm has been used to minimize the transmission energy in [11–14]. On the other hand, maximum lifetime routing, which aims to extending network lifetime by balancing traffic load is studied in [15–17]. Other energy- efficient routing algorithms focusing on energy-consumption as well as other metrics of network performance such as queueing delay, congestion or maximum data yield have been proposed [18,19].

Energy efficient routing algorithms subject to latency constraints are also investigated in [20]. Recent works have looked at exploiting the data correlation by using data aggregation along the multi-hop path [14–18]. In general routing algorithms with data aggregation fall into one of two categories: Routing-driven aggregation and aggregation-driven routing. In routing-driven algorithms, source data is routed through a specific path to the sink node (e.g. shortest path or minimum energy path depending on the application), data is aggregated opportunistically when data streams meet [21, 26–29].

Most routing- driven algorithms use a full aggregation model, that is, all data packets received from child nodes are fully aggregated into one single packet at the parent node. This assumption may be practical for large scale WSNs where the correlation level between nodes vary significantly. In aggregation-driven routing algorithms [8,23,24], the route selected by each source node to the sink node is informed by the correlation between the data collected by the nodes. As data moves along the route, it is aggregated with data from sources on the route, reducing the traffic load at links closer to the sink. The reduction in the required bit rate resulting

from aggregation affects the relative cost of each link. Thus, the route chosen by any source will not necessarily be the shortest or the minimum energy path to the sink.

3. POWER AWARE ENERGY EFFICIENT ROUTING PROTOCOL (PAERP) FOR WIRELESS SENSOR NETWORKS

3.2.1 Estimation of Link Quality

When a sending node broadcasts RTS packet, it piggybacks its transmission power. While receiving the RTS packet, the projected node quantifies the strength of the signal received.

$$P_R = P_T (\lambda / 4 \pi d)^2 * (UG_T) * (UG_R) \quad \text{--- (7)}$$

Hence,

$$L_q = P_R$$

Where, P_R refers Power of the Receiving node, P_T stands for Power of the Transmitting node, λ stands for wavelength carrier, d is the distance between the sending and the receiving node, UG_R stands for unity gain of receiving omni-directional antenna, UG_T stands for unity gain of transmitting omni-directional antenna.

3.2.2 Energy Efficiency

We assume that there is a target bit error rate (BER) which ensures successful communication across a link. We assume that our system has perfect error detection but no error correction capability. Automatic retransmission request is used so that a packet with error is retransmitted until received correctly. Suppose that the packet length is M . Then the probability of correct reception of the packet is

$P_c(\gamma) = (1 - 2BER(\gamma))^m$ where $BER(\gamma)$ is bit error rate corresponding to a signal to interference and noise ratio (SINR) γ . The $BER(\cdot)$ function will depend on the modulation scheme and the noise environment. In this research work, CDMA system is used for which cumulative interference can be assumed to be Gaussian. Non-coherent frequency shift keying is used by which $BER(\gamma) = 0.5 \exp(-0.5\gamma)$ under Gaussian noise and interference.

The proposed protocol uses synchronous direct sequence CDMA in which nodes use variable spreading sequences. The spreading factor for each transmitter L can be adjusted to meet the Quality-of-Service (QoS) requirements. The minimum spreading gain between the nodes to reach a certain target SINR, is given in the below equation.

$$L_{ij} = \frac{\gamma^* \left[\sum_{k=1, k \neq i, j}^N h_{k,j} P_k \right]}{h_{ij} P_i = \gamma^2 \sigma^2} \quad \text{--- (9)}$$

Where d_{ij} is the distance between the nodes, p is the path loss exponent, σ^2 is the thermal noise power. The energy per bit represents the total energy consumed in order to deliver one data bit to the

destination node. This research considers the energy used for transmission. The energy per bit for packet transmissions between nodes can be defined by the equation (10).

$$E_b^{i,j} = \frac{MP_i}{m\Omega_{ij}P_c(\gamma)} \quad \text{--- (10)}$$

Where M is the length of the packet, m represents the number of control/information bits in a packet, P_i is the constant transmit power.

3.2.3 Working Mechanism of PAEERP

$$RN = \max (L_q \& R_{POW}, \text{Min}[E_b^{i,j}]) \quad \text{--- (8)}$$

Where, CV = Cost Value, L_q = Link quality, R_{POW} = Residual Power, $E_b^{i,j}$ refers the energy consumption of the sensor node

In the proposed work Power Aware and Energy Efficient Routing Protocol (PAEERP) a cost value (CV) is calculated. CV is computed based on the on the quality of the link of each wireless sensor node. Among all the sensor nodes in the network, there are some robust nodes. These robust nodes serve as the backbone for the routing in wireless sensor networks. The remaining sensor nodes are common sensor nodes. Each robust node maintains a table of sensor node power at other robust nodes. So in the route, each robust node will compute the end-to-end power from itself to any other robust nodes. The sensor node power is estimated and updated periodically by each robust node. The robust node which is nearest to the source node finds the robust nodes which are along the route towards destination sensor node. Then packets will be forwarded through these robust nodes to the destination node. Since robust nodes have better communication capability than common nodes, most of the time the power is less than the maximum power.

1. Each robust node can arrive at nearby robust nodes directly. When a robust node goes out of a grid, it initiates a robust node election process in the grid and a new robust node will be selected.
2. Each Robust node holds a table of node power. Each Robust node can calculate the end-to-end power from itself to any other robust nodes. The node delay is estimated and updated periodically by each robust node.
3. In case a source node S needs to setup a route to a destination D. It is considered by the case where the source node S itself is a robust node. In this case, first the robust node S needs to know about the current location of the destination node D. With the information of D's location, S knows about the grid Ld where D stays, and the Robust node Ltd in the grid Ld.
4. Then S calculates the minimum power between S and Ltd by means of the power table, and also discovers the route with the minimum power. If the minimum power is greater than the required power, then the route can not be established. The source sensor node generates a unique req_id for

each route request. When an intermediate node obtains the REQ packet, it adds the powers of the incoming link and itself to t_power , and compares the updated t_power with the max_power . If t_power is less than the max_power , it adds up itself to the `route_list`, and forwards the REQ packet to the neighbors. If t_power is greater than max_power , the node will drop the REQ packet.

5. If the minimum power between S and Ltd is less than the maximum power, sensor node S will notify Ltd to locate a route to the destination D. Then Ltd will update the t_power by adding the power between Ltd and D. If the updated t_power is less than max_power , a valid route is found. Ltd will send an ACK (acknowledge) packet to S along the reverse path to ascertain that the route is setup. And each node in the route will updates its node power. After that S can start sending data.
6. If S is not a Robust node, then S will first discover a path to the nearby Robust node with less power than required. Node S sends out the route request (REQ) packet by flooding to all the sensor nodes in its grid. Only sensor nodes in the same grid will process and forward the REQ packet. When a node gets the REQ packet, it will update the power from source to their locations (t_power). If t_power is less than max_power , it adds itself to the `route_list`, and forwards the REQ packet to the neighbors. If t_power is larger than max_power , the node will drop the REQ packet. When the Robust node in this grid gets the first REQ packet, it also updates the t_power and compares it with max_power . If t_power is less than max_power , it will calculate the minimum power between itself and the robust node which is nearest to the destination. The remaining steps are the same as above.
7. Sensor node power and current location information of robust nodes has to be updated and distributed among all robust nodes. The distribution is done periodically, and the length of the updating period depends on the network dynamics, such as sensor node mobility, sensor network traffic, sensor node communication capability, etc.

3.2.4 Election of robust node

At the start, one robust node is set in each grid. We need an election mechanism to produce new Robust nodes because robust nodes also move around. When a Robust node leaves its current grid or due to any other reason there is no robust node in the grid. Suppose, there are more Robust nodes in the current grid of the network, then, the next node with least weighted value from the sorted list will be chosen as the new Robust node for the grid. In the proposed routing algorithm, we need to compute the minimum delay between two robust nodes, and find the path with the minimum delay.

For each valid path P_i ,
 For every node nk in P_i
 $t_power = t_power + power(nL, nk) + power(nk)$
 If $t_power \geq max_power$, delete this path, break.
 If $t_power \geq min_power$, delete this path, break.
 If nk is the destination D , and $t_power < min_power$,
 $min_power = t_power$;
 $best_path = P_i + \{nk\}$;
 Else add node nk to the end of the path,
 End For
 End For
 Pseudo code for Robust Sensor node election

4. SIMULATION SETTINGS, PERFORMANCE METRICS

4.1. Simulation settings

Table 1. Simulation settings

No. of Nodes	50, 75, 100, 125 and 150
Area Size	1000 X 1000
Mac	802.11
Radio Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512 KB
Mobility Model	Random Way Point
Pause time	100 Seconds

4.2. Performance Metrics

Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the source sensor node to the destination sensor node.

Average Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets sent.

Energy Consumption: It is the average energy consumption of all the sensor nodes in the network.

5. RESULTS

Fig.1 No. of Nodes Vs Total Energy Consumption

Fig.2 No. of Nodes Vs Delivery Ratio

Fig.3 No. of Nodes Vs Total Power Consumption

6. CONCLUSION

In this paper in order to attain preferred quality of service (QoS) such as packet delivery ratio, delay and to reduce the power consumption and energy efficiency of wireless sensor nodes we proposed secured power aware energy efficient routing protocol (PAEERP), which attains application-specified communication delays at low energy cost by dynamically adapting transmission power and routing decisions along with incorporating a novel cryptosystem. Through extensive simulation in NS2 the results proved that the proposed SPAEERP attains better QoS and reduced power and energy consumption.

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