A Novel Score-Aware Routing Algorithm In Wireless Sensor Networks

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Abstract

Wireless sensor networks are new generation of networks. These networks are appropriate means for collecting and diffusing environmental information, or communicating occurrence of an event to sink node. The main challenge for diffusing information in sensor networks is the limitations in sources and existing bandwidth. Several parameters are involved in selection of middle nodes of information diffusion path, and since existing methods take only some standards into account, it is obvious that they suffer from a number of defects. In our proposed algorithm, five more important factors are combined to score to nodes in routing process. This process called 'SARA[1]' is more flexible, and enhances routing quality through fair division of nodes' roles in transmission of information packets towards sink node. The main objectives of this method are; decrease of consumption energy and the uniform distribution, increase of network lifetime, decrease of traffic load and load balance, possibility of more effective aggregation of data and improving the reliability of formed paths. Several simulations have shown higher competency of this method.

Keywords: Sensor Networks, Routing, Reliability, Load Balance, Lifetime, Score-Aware.

[1] Score-Aware Routing Algorithm

1. INTRODUCTION

Recent years have witnessed considerable advancement in sensor networks. These networks include sensor nodes distributed in the environment. A wireless communication is held between these nodes. Nowadays, there are several applications for sensor networks, and newer applications are still to come. Applications include but not limited to war fields, identifying polluted areas, environmental control, analyzing buildings and roads as well as intelligent highways and medical applications.

The main objective of these networks is collecting and diffusion of environmental information towards sink and it is made through interaction and cooperation between nodes. Therefore, if there is any failure in middle nodes' operation towards sink, the process of information diffusion and ultimately efficiency of network will be reduced. Various factors may cause failure in proper operation of nodes such as termination of nodes' energy. The major aim of all efforts is to overcome difficulties by appropriate approaches which yield to higher efficiency and network lifetime. To do so, a number of information diffusion methods have been created, while each method has had a different approach to each above-mentioned category. Let us review some methods:

The Directed Diffusion (DD) algorithm [1], [2] is a data-centric algorithm for diffusing information in sensor networks. In this algorithm, routing is performed through exchange of local data between neighbor nodes. The mechanism involves diffusion of interest and exploratory packets in opposite direction and reinforcement of selected path. In spite of advantages, this method suffers from defects such as high energy consumption, high traffic, and network division into two separate components.

In [3], two methods are introduced for disjoint and braided multipath routing based on DD algorithm. In braided method, reinforcement packets are sent to some neighboring nodes with higher priority (i.e. nodes that have reached exploratory packet to node sooner), rather than to the first node which has sent exploratory data packet, and thereby multipath are formed towards destination node.

In PCDD algorithm [4], a passive clustering method is proposed to lower consumption energy in DD algorithm. Here, while diffusing exploratory data packets, a tree is formed that in the following execution of algorithm, instead of sending exploratory data packets as a whole, only some part of the tree will be used to send data to the destination node.

The ODCP [5], protocol is proposed to address these two problems: late-aggregation and distinct ED-flooding. In local on-demand clustering protocol, early aggregation and limited ED-flooding can be achieved by using a virtual sink (VS) near the sources. This node plays the role of sink node and broadcasts local interest messages. Therefore the data packets are sent initially to the VS node and then routed toward destination.

In [6], an extension to DD is presented in order to construct multiple paths between the sink and the sensor sources. Using this method, load-balancing is implemented to increase the life-time of the sensor nodes collaborating in the routing process.

The Greedy Multi-path Routing algorithm, [7] is a new localized approach which can produce multiple paths between source and destination nodes. To achieve this, a greedy heuristic method is used in which through implementing efficient load-balancing and energy-aware routing.

In [8], a new mechanism is presented for selecting intermediate nodes for transferring data. It enhances Directed Diffusion algorithm based on nodes' credit.

In this paper, taking a novel approach, we try to introduce an effective method in information diffusion (SARA) so that it optimizes energy consumption and network load distribution with considerable flexibility and assurance. Therefore, parameters such as "closeness to sink", "remaining energy", "sent traffic", "successful sent packets", "number of observable sources" ,that are important to determine middle nodes in information diffusion path, are used. In this

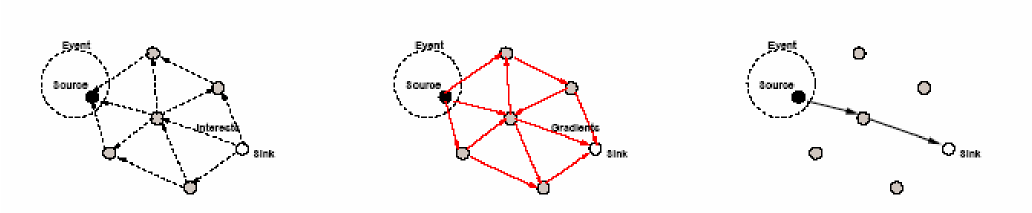
algorithm, during routing phase a series of quotients are used to determine effectiveness of each mentioned parameters and to compute the selection of neighbor node as the next hop.
The paper is structured as follows: Section 2 describes Directed diffusion algorithm and their limitations in wireless sensor networks. The proposed routing algorithm (SARA) is described in section 3. Section 4 outlines our simulation results. Section 5 concludes the paper.

2. OVERVIEW ON DIRECTED DIFFUSION

In this section we review DD [1] as a base method for most routing algorithms.

2.1. Algorithm Procedure

DD algorithm is a data-centric algorithm in sensor networks. To form path, it consists of three stages (Figure 1). In first stage, sink node propagate an interest packet which includes related question. Receiving this packet, each node stores a copy of the packet and sends it to its neighbors. In the second stage, after receiving the packet, the source node floods an exploratory data packet through the network. In this stage, necessary gradients are formed in the network in order to draw the path for information flow. It identifies the direction of information flow and the request statues as well. In the third stage, once exploratory data reach sink node, several paths from source to sink are identified. Sink sends a positive reinforcement packet in opposite direction of a covered path by exploratory data, and thereby reinforces gradient of this single path so that it can be used for sending collected data by sources. This selected path usually has the least delay.



a) Interests propagation b) Initial gradients setup c) Data delivery along reinforced path

Figure 1: A simple schematic for directed Diffusion [1]

2.2. Limitations & Problems

A big problem in this method is that usually the shortest path between source and sink (in terms of the number of hops) is selected. This selection might look reasonable at first glance, but through time the energy of selected path nodes will diminish. As other parameters such as remaining energy of node, processing traffic of node, and node capability in sending information are not considered in selecting path nodes, the problem arises when the path near to the previous path which is the shortest one is selected as the substitute path. Considering the routing method in DD algorithm, it is not far from it. Therefore, if we try to transmit information from one remote point in a quite long time to a sink node, after some time the right and left parts of the network will be divided and they will be disconnected. Hence, this method is not appropriate for data delivery in a continuous manner, making it suitable only for applications with discontinuous diffusion rate.
In DD method, one of high-cost stages of routing is flooding exploratory data by sources throughout the network. This should be conducted for each source, and surplus energy will be imposed on the network. During this operation, due to interference (because of existing common communication medium between nodes), the sent data by sources will be lost. This problem will double with increase of the number of sources and increase of density of nodes in network, and it actually threatens the scalability of DD algorithm.

3. THE PROPOSED ALGORITHM BEHAVIOR (SARA)

To enhance quality of routing in terms of decreasing routing energy, increase of network lifetime, increase of the number of received packets in destination, decrease of delay, and also to enhance reliability of paths formed in DD algorithm, score-aware routing algorithm is introduced. In this algorithm, five different factors are employed, i.e. closeness to sink node, node remaining energy, sent traffic by node in the previous phase, number of successful and fault-free sent packets, and the number of observed sources in one node for scoring to the node during routing process. The nodes with higher score have higher chance for selection as path middle nodes.

In proposed algorithm, based on above-mentioned factors, a number of routing parameters are used to enhance DD routing efficiency. Five quotients w_s ، w_h ، w_e ، w_r ، w_t are used to giving weight to each one of these parameters, and each node in the sensor network will use these quotients during routing to determine the effect of parameters in the calculations for selecting neighbor node as the next hop.

In our developed algorithm, the score given to each node in the network will be calculated as follow:

$$S = F_h \times w_h + F_s \times w_s + F_e \times w_e + F_r \times w_r + F_t \times w_t \qquad (1)$$

In this equation, F_s stands for the number of observed sources by a node, F_h corresponds closeness of each node to sink node, F_e is related to remaining energy in each node, F_t stands for sent traffic in each node, and finally F_r indicates assurance degree on relationship between each node and neighboring nodes (link reliability) during one phase of algorithm. While most parameters are transferred through the diffusion of interest packets between the nodes, just the number of observed sources' score is transferred on a limited scale via the exploratory data packets. Based on this method, only the k nodes with higher scores are nominated to receive the exploratory data packets.

3.1. Used Parameters in SARA Algorithm

Considering the algorithm method on routing, each node should consider some score for each neighbor node. This score is determined through calculation of five introduced parameters and their influence on the procedure. The parameters are calculated as below:

3.1.1. F_h Parameter (Distance Between Each Node and Sink)

To send data towards sink node there should be a parameter so that it can be a standard for closeness of node to sink node. To fulfill this requirement, a quotient is used that directly has something to do with the time of reaching interest packet to node. In the following equation, H_n stands for the order of arrival of interest packets to node. The quantity of this parameter is shown by this equation:

$$F_h = 1 - H_n * 0.1 \qquad (2)$$

3.1.2. F_s Parameter (Number of Observed Sources by Each Node)

To enhance routing, nodes that are nearer to sources have priority for selection. The number of observed sources by each node will be determined when exploratory data packets are diffused. A distance-from-source label will be put on exploratory data packets, and nodes consider the sum of observed sources with counter-distance quotient as Fs parameter. In the following equation, n_S equal the number of observed sources by node, and d_S equals' number of hops between neighbor node and source node.

$$F_s = \frac{\sum_{i=1}^{n_s} \left(1/d_{s_i} \right)}{n_s} \qquad (3)$$

3.1.3. F_e Parameter (Remaining Energy in Each Node)

One important element in selecting node is node remaining energy, and for routing the priority is with neighbor with higher energy, as the node should have the required energy to send packet. The consequence of this selection is the balance of energy consumption in network nodes. This parameter is calculated based on remaining energy in one node in the start of each phase as below where e_r equals remaining energy, and e_i equals initial energy of node.

$$F_e = {e_r}/{e_i} \qquad (4)$$

3.1.4. F_r Parameter (Reliability of Communication Link)

Parameter F_r shows degree of reliability of neighbor's communication link. The value of this parameter is equal to the proportion of N_s, i.e. sent packets to the total number of received packets (N_r) during one phase of routing algorithm. To simulate the links' reliability at the start of simulation, a P_{drop} between zero and $P_{drop-max}$ as the maximum percent of dropped packets in one communication link is assigned to each node, and accordingly, every packet in every node with possibility of P_{drop} will not be sent. The ultimate value of this parameter is calculated as follows:

$$F_r = \frac{N_s}{N_r} \quad (5)$$

3.1.5. F_t Parameter (value of Traffic in Each Node)

This parameter shows passing traffic from one node during one phase of algorithm execution. If one node sends more packets during one phase of algorithm execution, in the next phase its chance for selection as the path node will decrease. The following equation shows calculation of F_t parameter.

$$F_t = 1 - \frac{N_s}{N_{max}} \quad (6)$$

In this equation, N_s stands for the number of sent packets during one phase by one node, N_{max} shows maximum of sent packets during one phase by one source and it is calculated through multiplication of the rate of sent packets by sources during one phase of algorithm execution.

4. SIMULATION RESULTS

To implement algorithm, diffusion 3.20 code along with software NS 2.33 [9] is used.

4.1. Calculation of w quotients

To calculate proportion of w quotients in one scenario, we take the value of w_h as 1, and we consider other quotients zero except one of them, and then calculate the proportion of remaining w to w_h. In all scenarios considered for calculating quotients, a 10*10 grid with average distance of 100 meters between nodes is used.

The simulations' results with varying values assigned to w quotients indicated that the number of received packets in destination reach to their maximum value when w_e equals 0.75, and w_s 3, and w_t 1. Furthermore, to determine the value of w_r we consider the ratio of lost packets to sent ones for each source in a fixed time. Thus the percentage of lost packets for w_r=20 decreased to its lowest value .The following equations are also used to normalize the values of quotients.

$$w_{i-normalaized} = \frac{w_i}{\sum w_i} \quad i=\{r,s,t,h,e\} \quad (7)$$

$$\sum w_{i-normalaized} = 1 \quad (8)$$

4.2. Comparison of SARA Algorithm With DD Algorithm

To compare efficiency of our proposed algorithm with DD, three different scenarios are assumed.

4.2.1. Calculation of Delay Due to Increase of Sources

As shown in Figure 2, the increase of the number of sources leads to a considerable increase of average delay in DD algorithm. However, in SARA algorithm, the average value of delay increases a little. One of the most important reasons for delay decrease in SARA algorithm is deletion of exploratory data packets flooding in each source. Likewise, appropriate load distribution is important in decreasing network nodes' traffic, and thereby in lowering delay for receiving sent packets by source nodes.

As illustrated in the Figure 2, the average delay of received packets in SARA algorithm is about 10 times less than delay in DD algorithm for about 5 sources.

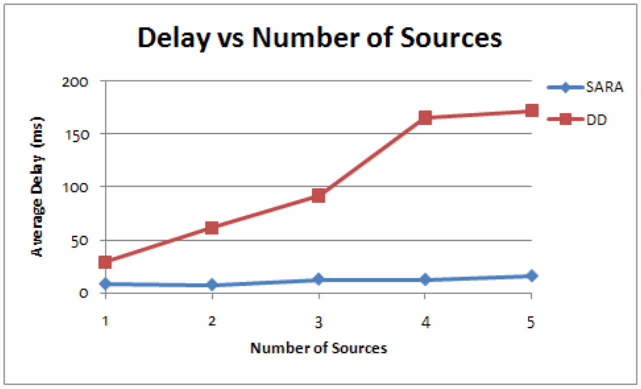


FIGURE 2: Calculation of Delay Due to Increase of Sources

4.2.2. Calculation of Remaining Energy in Nodes Based on Time

As shown in Figure 3, the consumed energy in SARA algorithm is quite half of energy consumption in DD algorithm. The main reasons for decrease of energy consumption are the decrease of exploratory packets and also decrease of traffic in network in SARA algorithm through appropriate load distribution.

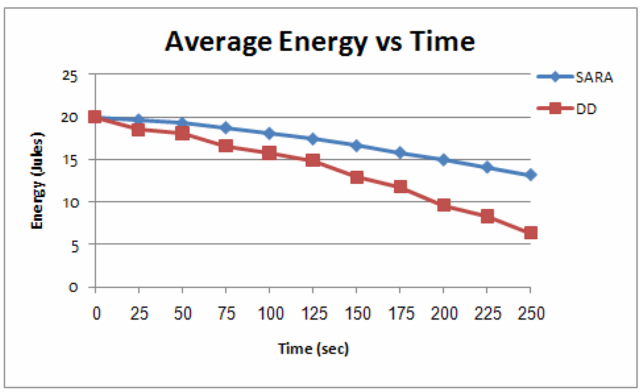


FIGURE 3: Calculation of Remaining Energy of Nodes Based on Time

4.2.3. Calculation of Load Balance in Nodes Due to Increase of Network Density

In Figure 4, to calculate the load balance in nodes, the difference between values of energy of node with the maximum energy with that of the node with the minimum energy is taken as the factor representing load balance. As such, the lower this difference is, the better load balance across network would be.

As illustrated in figure 4, SARA algorithm for higher density and distance between nodes with shorter than 150 meters is more competent than DD algorithm, and as the network density decreases, due to the decrease of possibility of selecting various nodes for path formation, the load balance would decrease.

Likewise, due to the decrease of density, the load balance in DD algorithm firstly decreases, and when the density decrease continues, it goes up until it surpasses SARA algorithm in average distances of grid larger than 150 meters. As mentioned before, the SARA algorithm relies on selection of proper nodes for enhancing load-balancing. However in lower densities, the energy of nodes near the sink is depleted rapidly, leaving no chance for using other energy resources within the network.

Also in lower densities, the broadcasting of exploratory-data in the second phase of algorithm dominates the whole energy usage of the algorithm and affects all of the network nodes. As in SARA algorithm this phase has been omitted and this algorithm has lower energy usage than

DD (about half), the difference between energy of nodes with maximum and minimum energy will be increased in SARA algorithm in this situation.

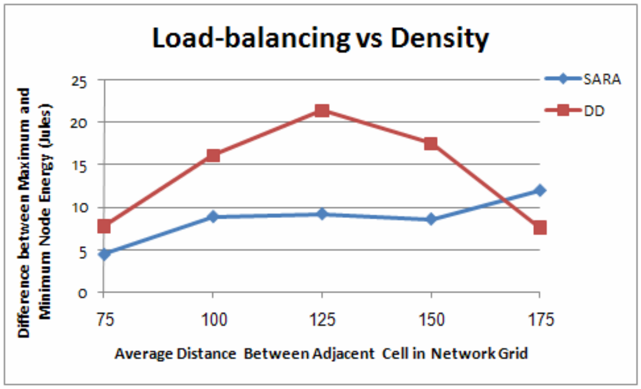


FIGURE 4: Calculation of Load Balance in Nodes Due to Increase of Network Density

5. CONCLUSION & FUTURE WORK

To enhance the routing quality, five different factors are taken into account in the proposed algorithm; the nodes with higher scores have higher chance for selection as the middle nodes of the path.

According to the simulation results, our presented algorithm is more efficient in terms of decreasing delay, decreasing the number of lost packets, improving the load distribution and purposeful network lifetime. It is shown that with higher network density or higher number of sources and higher rate of sent data, the efficiency of our developed algorithm would increase, and such increase is due to the higher number of nodes suitable for selection for routing. Furthermore, since this algorithm unlike DD algorithm, does not need to diffuse exploratory data packets for each source, its scalability will be enhanced considerably.

In future studies, the formal relationship between the parameters and their quotients can be obtained. Then, based on the network status a more precise quotient calculation becomes possible. Forming parallel multi-path routes, by making changes in the algorithm can be considered as a development for the present study.

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