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Grade Diffusion Algorithm

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Abstract. In this paper, a grade diffusion algorithm is proposed to solve the sensor node's transmission problem and the sensor node's loading problem in wireless sensor networks by to arrange the sensor node's routing. In addition to them, the sensor node also can save some backup nodes to reduce the energy consumption for the re-looking routing by our proposed algorithm in case the sensor node's routing is broken. In the simulation, the grade diffusion algorithm can save 28.66% energy and increase 76.39% lift time than the tradition algorithms for sensor node. Moreover, our proposed algorithm has the less data package transmission loss and the hop count than the tradition algorithms in our simulate setting. Hence, in addition to balance the sensor node's loading and reduce the energy consumption, our algorithm can send the data package to destination node quickly and correctly.

Introduction

Recent advances in micro processing, wireless and battery technology, and new smart sensors have enhanced data processing [2, 9], wireless communication, and detecting capability. Each sensor node also has limited wireless computational power to process and transfer the sensing live data to the base station or data collection center [4, 5]. Hence, the wireless sensor network usually has a lot of sensor nodes to increase the sensor area and the transmission area [1, 7]. In this paper, a grade diffusion algorithm is proposed to solve the transmission problem and the sensor node's loading problem in wireless sensor networks by to arrange the sensor node's routing. The grade diffusion algorithm increases the sensor node's lift time and the sensor node's transmission effect. Moreover, the sensor node can save some backup nodes to reduce the energy for the re-looking routing by our proposed algorithm in case the sensor node's routing is broken. Finally, the grade diffusion algorithm has the less data package transmission loss and the hop count than the tradition algorithms in our simulate setting. Hence, in addition to balance the sensor node's loading and reduce the energy consumption, our algorithm can send the data package to destination node quickly and correctly.

Relate Work

C. Intanagonwiwat et al. have presented the Directed Diffusion（DD）algorithm in 2003[6]. DD aims the reduction of transmission counts of data relay for power management. Basically, DD is a query driven transmission protocol. The collected data is transmitted only if the collected data fits the query from the destination node, hence the power consumption of transmission is reduced. In the DD algorithm, the destination node provides its interested queries in the form of attribute-value pairs to the other sensor nodes by broadcasting the interested query packets to the whole network. Subsequently, the sensor nodes only send the collected data back to the destination node in case it fits the interested queries.

The routing path of the DD algorithm has some loop and it will increase the energy consumption. Hence, the Ladder Diffusion (LD) [10] algorithm improves this fault. It builds the routing table for every sensor nodes to avoid the loop. Moreover, to insure the safety and the reliability of transmitting the data, LD algorithm provides the backup routes to avoid the waste of the power consumption and the process time for rebuilding the routing table in case part of the sensor node is lost. The LD algorithm combines with ACO algorithm [3, 10] to balance the loading of sensor nodes and increase the life time of nodes.

Grade Diffusion Algorithm

The Grade Diffusion (GD) algorithm fast and completely creates a grade value, a payload value, a grade table and a set of neighbor nodes in each sensor node on whole wireless sensor network by issue the grade creating package from destination node.

In this paper, nodes near the destination node are called “inside-node” and others are called “outside-node”. The grade value is meaning how many numbers of the data relay from the current node to destination node when the current send the data. The grade table is record some relay nodes and their overload if they are in the transmission area of the correct node. The payload value is mean how many “outside-nodes” can transmit data to destination node by the current node. Lastly, the set of neighbor nodes are record some nodes which are able to receive the data from the current node and their grade value are equal to the current node.

The transmission steps of sensor nodes are list as follows when they broadcast the grade creating package in the wireless sensor network:

1. If the current sensor node hasn’t recorded the grade value and it hasn’t created the grade table, it increases the grade value of one and record the grade value when it receives the grade value of grade creating package. Afterward it records the node which sent the grade creating package in the grade table to do a relay node and responds the grade acknowledge. The overload of relay nodes is set to zero in the grade table of the current node and it will update when the current node transmits data by the relay node. Lastly the grade value of the grade creating package is increased of one and the package is broadcasted by the current sensor node.
2. The node which has created the grade value will check of its grade value when it receives the grade creating package again. If the grade value of the current node is bigger than the grade value of the grade creating package, the node which sent the package will be recorded in the grade table of the current node and set its overload to zero by current node. After that the current node will respond a grade ACK. On the other hand it isn’t to do anything if the grade value of the grade creating package is bigger than the current node.
3. In addition, the current node recorded the node which sent the grade creating package in its set of neighbor nodes and the current node didn’t respond any message if the grade value of the package was equal to the current node.
4. The node is going to wait a twg time after it broadcasts the grade creating package. If there is not any node to respond the grade ACK to this node that means this node is the outside-nodes and is the farthest nodes. This node will increase the payload value of one and it sends the payload value to the nodes which are in its grade table.

When the current node has finished the process of the payload value update or it had updated the payload value and the time hasn’t over the T_w, the current node sets a random number q. The number “q” is during the number 0 to 1 and the node chooses a relay node according to the equation 1 from its grade table.

$$U(k) = \frac{P_k^{-1}}{\sum_{i\epsilon J} P_i^{-1}} \ , \ k\epsilon J \tag{1}$$

In the equation 1, the J is a set of the grade table of the current node. The P_i is the overload value of the i[th] node. The $U(k)$ is a probability of the nodes to be selected to transfer data. The probability of the node will be decreased when their payload value is bigger than others in the grade table. Hence the equation 1 can to promote the probability of nodes when the nodes are chosen seldom. The current node selects a node in its grade table according to the equation 1 and sends the data package to the node.

The node which receives the data package updates its payload value according to equation 2 and the node which sent the package updates the overload value in its grade table according to equation 3. Both of the payload value and the overload value are increased gradually when the node is selected frequently to transfer data. Then the probability of the node which be selected will be decreased according to the equation 1.

Moreover, there is a threshold L_{th} which is shown on the equation 4. A node of the set of neighbor nodes will be selected to do the relay node at random when the overload values of the current node are over L_{th} totally in its grade table.

$$payload_{t+1} = \begin{cases} 0, \; P_L \leq 0 \\ P_L, \; otherwise \end{cases} \tag{2}$$

$$P_L = payload_t \pm \frac{payload_t}{grade}$$

In the equation 2:

$payload_{t+1}$: The payload value of the node after the current node updates it.

$payload_t$: The payload value of the node before the current node updates it.

grade: The grade value of the current node

$$overload_{t+1}^{i} = overload_{t}^{i} + (payload_{t+1} + payload_{t}) \tag{3}$$

In the equation 3:

$overload_t^i$: It is the payload value of the ith node in the grade table of the current node.

$$L_{th} = avg\left(\sum_{i\epsilon j} overload_i\right) * \left(2 + \frac{payload}{grade}\right) \tag{4}$$

In the equation 4:

j: It is a set of the nodes which are in the grade table of the current node.

$overload_i$: It is the overload value of the ith node which is in the grade table of the current node.

Simulation and Analysis

In this session, we simulate the grade diffusion algorithm according to the session 3. The experiment is designed based on a 3-dimensional space, which is defined with units, and the scale of coordinate axis for each dimension is limited from 0 to 100. The transmission range of the nodes was set to 15 units. In each of these simulations, sensor nodes were distributed uniformly over the space. There are three sensor nodes random distribution in a space, and the Euclidean distance is 2 units at least between two sensor nodes. Therefore, there are 3000 sensor nodes in the 3-dimesion wireless sensor network simulator and the center node is the destination node.

The data packages were exchanged between random source/destination pairs with 300 cycles. Each cycle has 300 data packages sent to destination node from sensor nodes. All in all, the destination node will receive the 90000 data packages. In the simulation, the energies of each sensor nodes are set 3600mw and they consume the energy 1.6mw when they transfer data. The parameter of T_w and T_τ are set that they will be updated every cycle. Other parameters will be set according to equation 1 to 4 during the simulation.

Firstly, we implemented the DD algorithm, the LD algorithm and our proposed GD algorithm, and then compare the performance with them. In Fig. 1, the average energy consumption of the DD, LD, and GD algorithm is 301.885 mw, 170.009 mw, and 215.371 mw after the 300 simulation cycles. The energy consumption of GD algorithm is lesser than DD algorithm about 28.66%, but it is higher than LD algorithm. Because the routing path of DD algorithm maybe has loop, the energy will be consumed on the loop. But the routing path of GD algorithm doesn't have the loop and the routing path is almost from the nodes which have the high grade value to the nodes which have low grade hence it can save the energy.

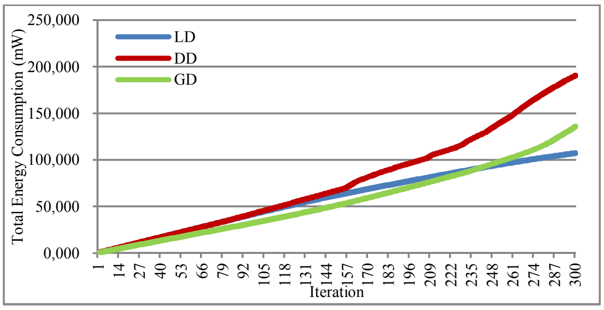
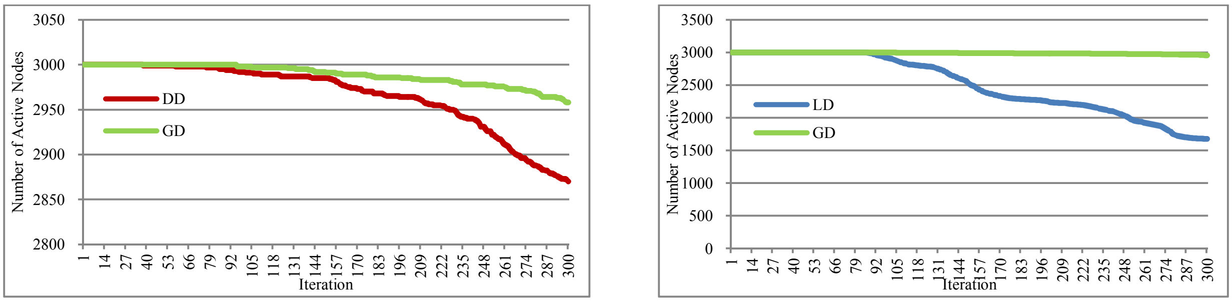


Fig. 1. Average energy consumption.

In Fig. 2, the DD and LD algorithm just left 2870 and 1677 active sensor nodes when they finished the simulation, but the GD algorithm has still 2964 active sensor nodes. The GD algorithm promotes the probability of life about 3% and 76.39% compare with DD and LD algorithm. The GD algorithm can use the energy efficiently and promote the life of nodes when the energy is limited. In the GD algorithm, the inside-nodes (the grade value is lower) can use the set of neighbor nodes to balance the load of node when the sensor node is overloading. But the LD algorithm only uses the inside-nodes to do the relay node and transfer data package. Hence, even though the energy consumption of the GD and DD algorithm are higher than LD algorithm, but the probability of life of LD algorithm is less than GD and DD algorithm. In Fig. 2.-(b), there are 1323 nodes which can not to do the relay node after the LD algorithm finished the 300 cycles. And there are 40% nodes whose energy is not depleted, but they can not to do the relay node and transfer data to others nodes. Because the backup sensor nodes of the sensor nodes are inside-node only in the LD algorithm, they don't have any neighbor nodes to do the backup sensor node. Hence, the sensor node can't send data packages to other nodes when the inside-nodes are depleted even if it still has enough energy.



a. The GD algorithm compares the number of active nodes with GD algorithm

b. The GD algorithm compares the number of active nodes with LD algorithm

Fig. 2. The GD algorithm compares the number of active nodes with DD and LD algorithm

Finally, we compare the loss of the data package because there are some sensors nodes can't to do the relay node and send the data package to destination node. If the number of the data relay is over 20 already, the data will be the loss. The statistic is showed on the Fig. 3.

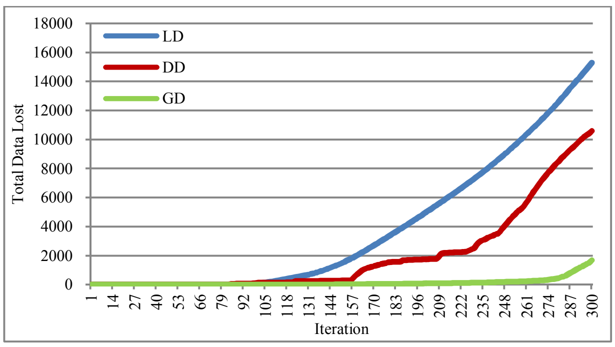


Fig. 3. The total loss of the data package with GD, DD, and LD algorithm

In Fig. 3, the DD and LD algorithm are loss 10581 and 15280 data packages totally after they finished the 300 simulation cycles, but the GD algorithm is only lost 1682 packages. The GD algorithm has the least data loss because its path doesn't have any loop. Hence, the GD algorithm can reduce the energy consumption and the data loss rate. The packages can send to the destination node quickly and correctly in the GD algorithm.

The routing path of the DD algorithm has loop for this reason it has to consume more of the energy and increase the numbers of the data relay. Hence, the numbers of the data relay are more than 20 easily in the DD algorithm and its data loss rate is high than GD and LD algorithm. And the backup sensor nodes of the sensor node have inside-nodes only in the LD algorithm. The outside-nodes can't transfer data to destination node when the energy of inside-nodes is consumption even if outside-nodes have energy. Hence the data loss rate of the LD algorithm is high than GD algorithm.

Conclusion

In the real wireless sensor network, the sensor nodes use the battery to do the power supply. Hence, its energy is limited. This paper propose a grade diffusion algorithm, it can balance the relay load for every sensor nodes, promote the life time of the sensor nodes, and reduce the energy consumption for every sensor nodes. According to the experimental result, our proposed algorithm can save 28.66% energy compare with the direct diffusion algorithm. The energy consumption of our proposed algorithm is higher than ladder diffusion algorithm, but the probability of the life is promoted 43.4% and 3.2% compare with ladder diffusion algorithm and direct diffusion algorithm. Moreover, our proposed algorithm can reduce a lot of data loss rate, whether our algorithm compares with the direct diffusion or the ladder diffusion algorithm in the simulation. Hence, our proposed algorithm can reduce the energy consumption and send the data package to destination node quickly and correctly.

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