Nodes' Credit based Directed Diffusion for wireless sensor networks*

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Abstract. For data gathering in wireless sensor networks, sensors extract useful information from environment; this information has to be routed through several intermediate nodes to reach the destination. How information can effectively disseminate to the destination is one of the most important tasks in sensor networks. Problem arises when intermediate nodes fail to forward incoming packets. Due to limited power and slow processor in each node, algorithms of sensor networks must be designed carefully. Directed Diffusion (DD) is a typical data-centric algorithm which has been used to provide efficient data transmission. We enhance this algorithm based on nodes' credit by using five factors. Simulation results show that our proposed algorithm is more energy efficient and reliable than DD and has the ability of traffic load distribution.

Keywords: Directed Diffusion, Data gathering, Nodes' Credit, Sensor network.

1 Introduction

A sensor network is a group of wireless nodes randomly distributed in a region. In most data gathering applications, information produced by one or more sources usually has to be routed through several intermediate nodes; these wireless nodes have the ability of packet forwarding, i.e. relaying incoming packets to one of its neighbor nodes. Problem arises when intermediate nodes fail to forward incoming packets. Sensor nodes have many failure modes. Each failure decreases the performance of data gathering procedure. Our approach is designed by considering that nodes maybe not available during the dissemination procedure. Directed Diffusion [1] is a routing mechanism for data gathering in which data consumer (sink)search for the data sources by sending interest packets and

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find the best route to receive the data. Many researches have been done to meet specific need of wireless sensor network applications [6, 8, 11, 12].

Yu et al. [9] discussed the use of geographical information while disseminating queries to appropriate regions. The protocol, called Geographical and Energy Aware Routing (GEAR), uses energy aware and geographically-informed neighbor selection heuristics to route packets towards the destination region. By doing this, GEAR can conserve more energy than Directed Diffusion. Each node in GEAR keeps a cost. The cost is a combination of residual energy and distance to destination. Raicu et al. proposed E3D diffusion (Energy-efficient Distributed Dynamic Diffusion routing algorithm) in [13], in which each node keeps a list of neighbors and chooses the next hop neighbor based on the location information, power and load towards the base station. In this scheme, when a receiver's queue is full, or its power is lower than the sender's power or when it is below a threshold, it will tell its sender to stop forwarding packets.

HDA [2] (hierarchical data aggregation) is proposed for enhancing DD.In HDA, nodes between the sink and the source are arranged in different levels (i.e. hierarchy).packets are only transmitted between two nodes in neighboring level. This new feature can save energy significantly.

In this paper, a new reliable and energy efficient DD algorithm is introduced.

The rest of the paper is organized as follows. In section 2 we briefly review the original directed diffusion algorithm and its limitations. Section 3 presents our algorithm in details. Simulation based performance studies are conducted in section 4.Finally; we conclude our work in section 5.

2 Review: Directed Diffusion

In this section, we first review the original directed diffusion in brief, and then point out its limitations.

2.1 Basic scheme

Directed Diffusion [1] consists of three phases: a) interest propagation, b) Initial gradients setup, and c) Data delivery reinforced path as shown in Fig. 1. Sink node send out its query whenever it wants to obtain some information from sensor nodes. This query is carried by interest packet. When a node receives an interest packet, the packet is cached and broadcast to other neighbors to ensure every node in the network will receive it. Propagation of interest packets also setup the gradient in the network for delivering data to the sink. Gradient is a reply link to a neighbor form which the interest was received. When a node matches an interest, it generates a sample sensed data, which is called exploratory data and sends individually to the neighbors from which the gradient established before. As these exploratory data reach the sink from some neighbors, several paths are established between sink and source.

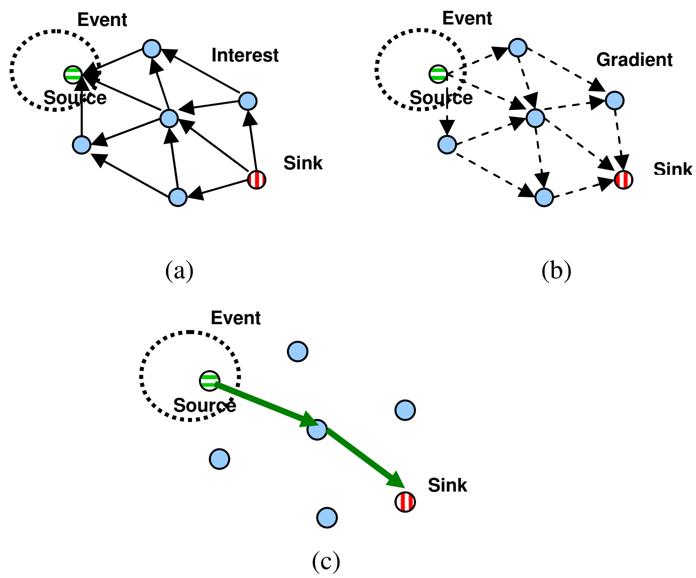

Fig. 1. Directed Diffusion. (a) Interest Propagation. (b) Initial gradients setup. (c) Data delivery reinforced path.

The sink reinforces one of these paths by increasing the data rate in the interest packet. Usually this path is the one which has the least delay. Eventually only one path remains while other paths are torn down. Finally the real data will send from the source, following the selected path.

2.2 limitations

When the sink starts selecting one particular neighbor in order to reinforce the path, it chooses the neighbor from whom it first received the latest event matching the interest. In this way, each node/sink has limited information about its neighbors to choose them, for example a node can only know which neighbor is nearest with it based on the sequence of interest it receives, without considering the neighbor queue is full or not, energy level and neighbor ability to transmit the data to the base station. This will result in some limitations in term of the amount of traffic generated and hence energy inefficiency. Moreover, if there are multiple sources and one sink, the sink only selects the path based on which neighbor send back exploratory data sooner [2].So in- network aggregation will not effectively be done. If the selected node covers more sources, in network aggregation can do more effectively as shown in Fig. 2 [2].

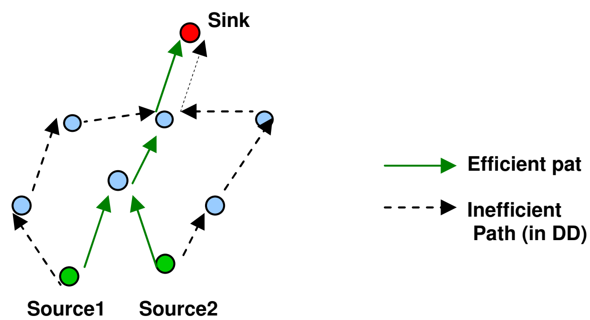

Fig.2. inefficient data aggregation

3 The proposed algorithm

Unlike location centric algorithm each sensor node in Directed Diffusion needs not to know its position information, all its decisions about data transmission are based on its knowledge about the neighbor nodes. The main reason of limitations mentioned, is that this knowledge of nodes about their neighbors is insufficient. Each node chooses that neighbor from whom it first received the last event matching the interest, without considering other parameters, such as energy level, traffic load and neighbor ability to aggregate data more efficiently. To solve such problems, we enhance this knowledge based on credit of nodes. Computation of nodes' credit is done by using five factors; at each node. This credit is computed according to Eq.1.Each node selects one of its neighbors which have a higher credit.

$$V = \alpha_1 \times V_s + \alpha_2 \times V_E + \alpha_3 \times V_B + \alpha_4 \times V_R + \alpha_5 \times V_C. \quad \textbf{(1)}$$
$$\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 = 1.$$

Each of the parameters of above formula has specific coefficient (α) that is amount between [0,1].Different alternatives have been considered for finding the best value of coefficients in order to provide desired result.

The first parameter (Vs) is the number of successful or unsuccessful transmission and how nodes succeeded to deliver packets in the past. A low amount of this parameter of a node means that the node failed to route message in the past. This parameter is increased with each successfully routed packet and decrease with each failing in routing packets.

The second parameter (VE) is the residual energy in candidate node's battery. Eq.2 is used for calculating this parameter. This parameter has an important effect on increasing the network lifetime.

$$V_E = \frac{\text{existing energy}}{\text{capacity of battry}} \tag{2}$$

The third parameter (VB) is traffic load at each node (Figure 3).This parameter is computed according to Eq.3

$$V_B = \frac{\text{free spac of buffer}}{\text{all space of buffer}} \tag{3}$$

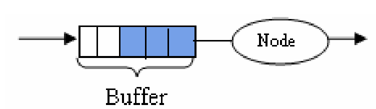

Fig.3. .Scheme of traffic load in buffer

If there would be high traffic load in candidate node end to end delay will increase in sink node, in addition this high traffic load will cause more spending energy in candidate node.

The forth parameter (VR) is the distance of candidate node to destination (sink). Interest message of sink node is able to count and record the number of hops that passes through it. This allows nodes to discover the neighbor with minimum number of hops to the sink.

The fifth factor (VC) is how many sources can cover by each node. When the exploratory data pass through a node the node will record such source ID's. The number of these sources ID represents how many sources are covered by this node. This factor let us to do better in-network aggregation and as a result increasing lifetime of network.

Each node computes its credit based on these factors according to Eq.1. In our proposal, there is also an additional field in the exploratory data that identifies nodes credit. Since each node has computed the credit, it utilizes exploratory message to inform its neighbor about its own credit, by adding a field in the message to denote it. After each neighbor receives this credit, it will record it. When the sink receives the exploratory data, it will respond with the reinforcement message. Since each node has recorded its neighbor's credit, selects higher credit between them. So the sink will select the best path according to this credit to the source. Once a source receives the reinforcement message, it sends out the actual data.

4 Performance evaluation

In this section, we compare our proposed algorithm with Directed Diffusion. we implement algorithm in NS-2 simulator and use the following model for our simulation study.

- The number of nodes which are distributed randomly over a rectangular area of 900m×900m is 100.
- The radio transmission rang R is 50 m.
- a sensor node's transmitting, receiving and idle listening power consumption rate are 0.660W, 0.395W and 0.035W respectively.
- Initial power is 5000 joules.
- The size of data packet is 64 byte.

The value of $\alpha1$, $\alpha2$, $\alpha3$, $\alpha4$, and $\alpha5$ are set to 0.2, 0.3, 0.15, 0.25, and 0.1 respectively.

Three metrics are chosen for evaluating and comparing the performance of our algorithm with DD: system lifetime, reliability of path and load distribution.

System lifetime is used as the measure of energy consumption. The system lifetime is the total time which a wireless sensor network experiences. Fig. 4 shows the system lifetime in terms of nodes' failures. As simulation result shows, using suggested policy causes to increase system lifetime under variant nodes' failure.

Next we analyze our algorithm for finding reliable paths. For this purpose data delivery percentage is selected to delegate reliability of paths. Data delivery is defined as the ratio of the number of data packets successfully received by the sink to the number of data packets send by the data source. Fig. 5 shows that, as the unreliable nodes increase, DD's performance decreases faster than our proposal. This is because of giving higher priority to the reliable nodes in our proposed algorithm.

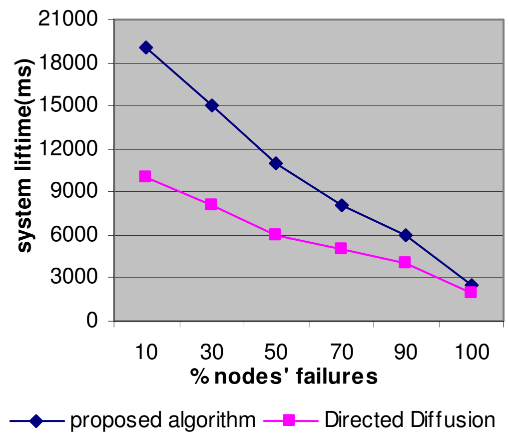

Fig.4. System lifetime

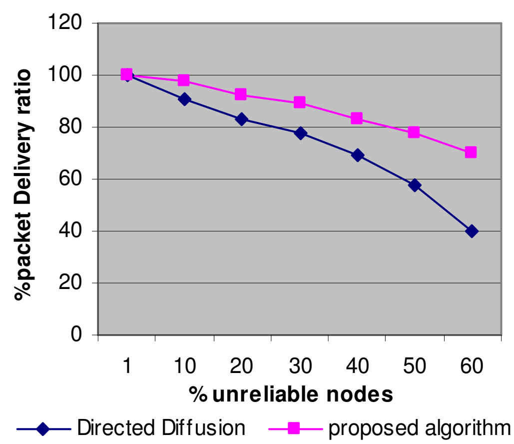

Fig.5. Reliability

Finally, the traffic load distribution on surface of network is one of the metrics of our simulation, Fig. 6 shows the simulation result and its ability to distribute traffic load in terms of increasing source nodes.

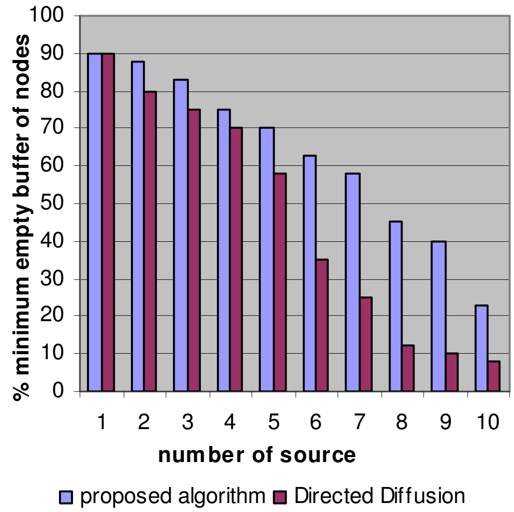

Fig.6. Traffic load distribution

5 Conclusion

In this paper, a new mechanism is presented for selecting intermediate nodes for transferring data. The aim of this paper is making the directed diffusion of data centric algorithm of sensor networks in a good order. For this purpose, desired parameters in this policy include number of successful or unsuccessful transmissions, number of existence processing loads in candidate node, amount of energy in selective node's battery, location and the distance between selective candidate node and destination node (sink) and number of sources that candidate node covers. Each of these parameters has specific coefficient which has influence on selecting node. Finally, between several candidate nodes, nodes with higher preference will choose. The proposed approach is deduced an energy efficient and reliable algorithm with supporting traffic load distribution.

6 References

[1]C.Intanagonwiwat, R.Govindan, D.Estrin, J.Heidemann, F.Silva,"Directed Diffusion for wireless sensor networking" Networking Volume 11, Issue 1, Feb. 2003 Page(s):2-16 Digital Object Identifier 10.1109 /TNET .2002 .80 8417

[2] B.Zhou, L.H.Ngoh, B.S.Lee, C.Peng “HDA: A hierarchical data aggregation scheme for sensor networks” Computer Communications, Volume 29, Issue 9, 31 May 2006, Pages 1292-1299.

[3]C.Schurgers, M.B.Srivastava “Energy Efficient Routing in Wireless Sensor Network” Electrical Engineering Department University of California UCLA .CA 2006.

[4]C.Yanrong, C.jaheng.”An improved Directed Diffusion for Wireless Sensor Networks” Wireless Communications, Networking and Mobile Computing, 2007. International Conference on 21-25 Sept. 2007 Page(s):2380 - 2383 Digital Object Identifiers 10.1109/WICOM.2007.593.

[5]Max do V. Machado, Antonio A. F. Loureiro and Jose Marcos Nogueira, “Data Dissemination Using the Energy Map”, Proceedings of the Second Annual Conference on Wireless On-demand Network Systems and Services (WONS.05), 2005.23-34

[6]Jae-Hwan Chang, Leandros Tassiulas, “Maximum Lifetime Routing in Wireless Sensor Networks”, Networking, IEEE/ACM Transactions on Volume 12, Issue 4, Aug. 2004 Page(s):609 - 619 Digital Object Identifier 10.1109/TNET.2004.833122

[7] Q.Han, S.Mehrotra, N. Venkatasubram ”Application-aware integration of data collection and power management in wireless sensor networks” Journal of Parallel and Distributed Computing, Volume 67, Issue 9, September 2007, Pages 992-1006

[8] Pai-Hsiang Hsiao, Hwang, A., Kung, H.T., Vlah, D. ”Load-balancing routing for wireless access networks” INFOCOM 2001. Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE Volume 2, 22 26 April 2001 Page(s):986 - 995 vol.2 Digital Object Identifier 10.1109/ INFCOM .2001.916291

[9] Y.Yu, D. Estrin, and R. Govindan. “Geographical and energy aware routing: A recursive data dissemination protocol for wireless sensor networks” Technical Report TR-01-0023, UCLA Computer Science Department Technical Report, May 2001.

[10] I. Raicu, L. Schwiebert, S. Fowler, and S. K.S. Guipta”Local load balancing for global efficient routing in wireless sensor networks”. International Journal of Distributed Sensor Networks, 1:163 – 185, 2005.

[11] E.Fasolo, M.Rossi, J.Widmer,M. Zorzi, “In-network aggregation techniques for wireless sensor networks: a survey” Wireless Communications, IEEE Volume 14, Issue 2, April 2007 Page(s):70 87 Digital Object Identifier 10.1109 /MWC .2007.358967.

[12]. S.Wu, K. Selçuk Candan” Power-aware single and multipath geographic routing in sensor networks Ad Hoc Networks, Volume 5, Issue 7 ,September 2007, Pages 974-997.

[13].Min Chen, T.Kwon, Yanghee Choi “Energy-efficient differentiated directed diffusion (EDDD) in wireless sensor networks” Computer Communications, Volume 29, Issue 2, 10 January 2006, Pages 231-245.