Energy Aware Hybrid PUSH-PULL for Data Diffusion in Sensor Networks

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Abstract— In Wireless Sensor Network (WSN), sensor node is limited in energy, thus energy efficiency is an important concern in routing protocol design. And some applications in sensor networks have the requirement of timely delivery, real-time also become needed for routing. Directed diffusion is a classic data-centric routing protocol in Wireless Sensor Networks (WSNs). In the directed diffusion, the path reinforcement scheme is designed for minimum delay and maximum data received during a certain period of time. However, the communication cost and energy balance over the whole WSNs have not been paid enough attention. Hybrid PUSH-PULL data Diffusion (LOHD) is a data dissemination algorithm for data-centric sensor networks. Despite of two Push and Pull routing algorithms that work well when there are a few sources and sinks, respectively. LOHD works well in a wide range of networks and source/sink settings. It adaptively selects an ultra-node through a well-controlled flooding and the ultra-node maintains the gradients from sources to sinks. In this paper we improved this algorithm with considering energy parameter in order to extend the lifetime of the sensor network. The simulation results show that our proposed protocol that we call it ELOHD, is outperform directed diffusion in energy efficiency, energy balance over WSNs, and network lifetime.

Keywords: Wireless Sensor Networks, Directed diffusion, Routing protocol, Energy efficient

1. Introduction

Wireless sensor networks are envisioned to consist of many small devices that can sense the environment and communicate the data as required [1]. The sensor network is one of the multi-hop networks similar to the ad hoc networks. Therefore, each sensor node forwards the data if it receives the data from another sensor node. In ad hoc networks, researchers focus on the communication performance like as the throughput and other factors. However, the most critical requirement for widespread sensor networks is power efficiency since battery replacement is not viable [2].

Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on the battery lifetime. In a multihop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require rerouting of packets and reorganization of the network.

In a sensor network a node communicates with other nodes that lie within the transmittable range to accomplish the given tasks. Due to the constraints of sensors, the sensor network routing protocols are much simpler than any other network routing protocols. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and have to ensure reliable multi-hop communication under the energy limitation.

We think that a more useful metric for routing protocol performance is network survivability [3]. By this we mean that the protocol should ensure that connectivity in a network is maintained for as long as possible, and that the energy health of the entire network should be of the same order. This is in contrast to energy optimizing protocols that find optimal paths and then burn the energy of the nodes along those paths, leaving the network with a wide disparity in the energy levels of the nodes, and eventually disconnected subnets. If nodes in the network burn energy more equitably, then the nodes in the center of the network continue to provide connectivity for longer, and the time to network partition increases.

A number of routing protocols have been proposed for sensor networks [4] [5] [6] [7] [8]. The object of this paper is to extend the lifetime of sensor network. From the simulation results, we evaluate the performance of the algorithm and clarify the effect of that on the sensor networks.

The rest of paper is organized as follow: In section II, we review directed diffusion algorithm. In section III we described the LOHD algorithm. We present our algorithm in section IV. Simulation results are presented in Section V; finally we proposed the conclusion in Section VI.
2. Directed Diffusion

Directed diffusion consists of several elements: interests, data messages, gradients and reinforcements [5]. The base station floods the sensor network with a query about the interested events. The ‘interest’ query specifies the sensing task. The data messages are the events generated by a single or a group of nodes in response to the query sent by the base station. The interest queries are disseminated throughout the sensor network as an interest for named data. This dissemination sets up the “gradients” within the network to draw events. A gradient is a direction state created in each node that receives an interest [5]. The node, which generates the events, sends the events back to the base station along multiple gradient paths. The directed diffusion algorithm assumes that each node knows its location once deployed. A key feature of directed diffusion is that every sensor node can be application-aware, which means that nodes store and interpret interest packets, rather than merely forwarding them along the route. Each sensor node that receives an interest packet maintains a table that contains which neighbor(s) sent that interest. To such a neighbor, it sets up a gradient. A gradient is used to evaluate the eligibility of a neighbor node as a next-hop node for data dissemination. After setting up a gradient, the sensor node redistributes the interest packet by broadcasting. In [10], original DD is extended to a DD protocol family, which includes: a) two-phase pull diffusion, b) push diffusion, c) one-phase pull diffusion, each of which are summarized hereafter.

![Directed diffusion Scheme](image)

**Figure 1** - Directed diffusion Scheme

### 2.1 Two-Phase Pull Diffusion

Two-phase pull diffusion is the original directed diffusion. In two-phase pull diffusion a sinks sends interest to find sources. After receiving the interest, sources forwards exploratory data messages to maintain paths toward the sink. When exploratory data reaches the sink, the sink reinforces its preferred neighbor, establishing a reinforced gradient towards the sink. The reinforced neighbor reinforces its neighbor in turn, all the way back to the data source or sources, resulting in a chain of reinforced gradients from all sources to all sinks. Subsequent data messages are sent only on reinforced gradients rather than to all neighbors.

Moreover, using reinforcement, the data routes can be dynamically changed according to the changes in the WSN. In this case, the sink sends reinforcement messages through a new path other than the current path. Furthermore, negative reinforcement messages are sent through the current path to suppress data transfer through that path.

### 2.2 Push Diffusion

The two-phase pull diffusion works well when there are a few numbers of sinks. In one-phase push diffusion, the roles of the source and sink are reversed. Sinks become passive, with interest information kept local to the node subscribing to data. Sources become active; exploratory data is sent throughout the network without interest created gradients. An advantage of push diffusion compared to two-phase pull is that it omits interest propagation where information is sent throughout the network rather than two phases. Push is optimized for a different class of applications, but where sources produce data only occasionally. Push is not a good match for applications with many sources continuously generating data since such data would be sent through the network even when not needed.

### 2.3 One-Phase Pull Diffusion

A benefit of push diffusion compared with two-phase pull diffusion is that it minimized flooding that can be a significant benefit in large networks. In one-phase pull, when an interest arrives at a source, it does not send exploratory message to establish gradient from source to sink, but instead sends data only on the preferred gradient. The preferred gradient is determined by the neighbor who first sends the matching interest, thus suggesting the lowest latency path. Thus, one-phase pull does not require reinforcement messages, and the lowest latency path is implicitly reinforced. One-phase pull has two disadvantages compared to two-phase pull. First, it assumes symmetric communication between nodes since the data path (source-to-sink) is determined by lowest latency in the interest path (sink-to-source). Two-phase pull reduces the penalty of asymmetric communication since choice of data path is determined by lowest-latency exploratory messages, both in the source-to-sink direction [10]. Second, one-phase pull requires interest messages to carry a flow-id, this requirement makes interest size grow with number of sinks.

3. The Location-Oblivious Hybrid Push-Pull Data Diffusion Algorithm (LOHD)

The pull and push work well when there are a few sinks or sources, respectively. When the number of both sources and sinks increases, neither Push nor Pull can avoid the significant overhead increase. [9] Proposed a novel Location-Oblivious Hybrid PUSH-PULL data Diffusion algorithm (LOHD).
LOHD first finds a rendezvous node called ultra-node, which is selected by the intersection of local flooding respectively from the sources and sinks. In this stage all the sources broadcast the identical messages called SOS (SOURCE Searching) and all the sinks broadcast the identical messages called SIS (SINK Searching).

Node’s distance to its nearest sink is defined as dSI and its distance to its nearest source as dSO. After the SOS/SIS flooding is done, each node with |dSO−dSI| < R will then randomly generate an integer number. By setting R to 1, the selected ultra-node will be exactly in the middle of the sources and sinks.

When the ultra-node is determined, the field is divided into two parts (sinks to ultra-node and sources to ultra-node). The ultra-node then broadcasts SOG (SOURCE Gradients) towards the first part and SIG (SINK Gradients) towards the second part. When the sources (sinks) receive the SOG (SIG) messages, the gradients from the sources (sinks) to the ultra-node are established. Then the sources send the exploratory data and the sinks send the interests to the ultra-node through the established gradients instead of flooding. Therefore, the required gradients between sources and sinks are built.

4. The Proposed Algorithm

Using the shortest path without considering the residual energy of nodes, it is may leads to fail the intermediate nodes and in the worst case it is possible that network partition. To counteract this problem, we propose a new mechanism that we call ELOHD. The basic idea is that to increase the performance of LOHD algorithm by using the energy aware mechanism.

Unlike location centric algorithm each sensor node in LOHD needs not to know its position information, all its decisions about data transmission are based on its knowledge about the neighbor nodes, so that it eliminates the extra requirement for additional hardware and the overhead for complicated localization computation. Each node chooses that neighbor from whom it first received, without considering other parameters, such as energy level.

On relaying the messages, all the nodes record the previous sender. But due to energy limitation maybe intermediate nodes fail to forward incoming packet, thus, in ELOHD each sensor node checks a remaining power capacity of its neighbors and determines the activity of route construction process.

Since the location information is unavailable, gradients are necessary for delaying the data. Our goal is to build the gradients between sources and sinks efficiently.

ELOHD has two stages: First, we select proper ultra-node candidate. By increasing R in original algorithm (LOHD) more nodes can be as the ultra-node candidate; therefore we can choose the one has the maximum energy. As a result, the energy of the ultra-node would last more because all data is sent through the ultra-node, thus the energy of the ultra-node maybe consumed rapidly.

Second, we choose appropriate path (source to ultra-node and ultra-node to sink) depend on node’s energy remaining. Each of the intermediate nodes forwards the exploratory (interest) message to a neighbor with maximum energy. This is continued till the exploratory (interest) packet reaches the ultra-node. At the same time, the energy differences between different nodes are reduced. As a result we try to choose one path with maximum energy connecting the source to the destination.
5. Simulation Results

In this section we compare the proposed algorithm with LOHD. We consider square fields, in which sources and sinks are clustered in the two diagonal corners and we assume that 100 nodes are randomly dispersed into a field with dimensions 50 m². The nodes are fixed and the radio transmission rate is 12 m. A sensor node’s transmitting and receiving power consumption are 0.650 W, 360 W, respectively. The size of data packet is 200 byte. The initial power of each node is given randomly.

Our simulation shows how node’s energy affects the performance of the network lifetime.

Figure 6 shows the average energy as function of network lifetime in WSN. This simulation shows that ELOHD increases lifetime of the network by selecting the energy aware path.

Figure 7 and 8 compares the average nodes energy between LOHD and ELOHD. As can be seen from figures, ELOHD average nodes energy is better than the original algorithm.

Figure 6 - Wireless Sensor Network’s lifetime with one source and one sink

Figure 7 - Wireless Sensor Network’s lifetime with one source and five sinks

Figure 8 - Wireless Sensor Network’s lifetime with one source and 10 sinks
Maybe the number of hops in ELOHD increase due to its mechanism, thus the average delay of the network increases.

6. Conclusion and Future Work

In this paper, we presented a new mechanism to select the intermediate nodes base on energy aware mechanisms; which considers the remaining energy of node to achieve the balance of energy consumption in network, then the probability of each node to be selected to perform transmission task is increased.

The shortest path is not always necessarily good for the network life time. Thus we used energy aware mechanism to choose intermediate nodes with higher amount of energy between several candidate nodes.

Since the proposed protocol consumes less energy, the network has a longer lifetime. In addition, the proposed protocol has a slightly higher delivery fraction than the original PULL-PUSH directed diffusion. By doing this network lifetime increased and the nodes energy balanced in the network.

References


