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Implementation on Data Gathering Using Trajectory Selection and Loophole Detection in Wireless Sensor Network

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ABSTRACT

In wireless sensor networks, data gathering is one of the main applications. In data collection energy saving is the main issue as the limited battery life of the sensor node is an issue to resolve so to reduce the energy consumption of sensor nodes a concept of the mobile node is introduced. In this concept, sensor nodes are static whereas the sink nodes are movable which collects the data from the static sensor node process and transfer the data to the base station. For improving the sink mobility, the mobility pattern of the sink should be decided, so that sink can follow the path and gather the data efficiently also in less time. SinkTrail and SinkTrails, are two energy-efficient proactive data reporting protocols that are used to select the shortest path in case of sink mobility.

1. INTRODUCTION

The wireless sensor network is a widely used network as the data gathering paradigm. WSN has been used in many applications such as environment monitoring, forest fire detection, etc. To collect the information from the given network many sensor nodes can be deployed in the network [1]. Which then collect the information from the network andess over it. But once the node is deployed in the network it is impossible to replenish the power supply. This means the sensor nodes are not rechargeable. Therefore, energy-saving is one of the important issues while designing the WSN since the battery life of the sensor nodes are limited.

If the sensor nodes and sink both are static then more energy is required by the sensor nodes to convey the energy to the sink nodes. Thus, to reduce the power consumption of sensor nodes researchers include the concept of sink mobility [2]. Sinks are allowed to move in the network and gather the information from the sensor node and process over it.

Thus, sensor nodes do not require expensive energy to transfer the data toward sink nodes. When the concept of a mobile sink is introduced, the sink can be a robot, vehicle, or animal which are equipped with radio devices are used which are sent into the network and directly communicate with the sensor nodes which results in an optimized data transmission path and reduces the energy consumption.

Sink mobility reduces energy consumption; it introduces new challenges in sensor network applications. When the sink is allowed to move in the network, the path should be followed by the sink so that it can work more effectively.

For the better movement of the sink in the network, the route must be found, on which the sink can move efficiently and gather the data in minimum time. Several algorithms have been suggested to find the optimized route such as on-demand routing, distance vector routing, geographical routing, etc. when geographical routing has used the disadvantage that is, it assumes that the geographical location of all the nodes is known.

Researchers have focused on planning a mobile sink's moving trajectory in advance to optimize the network performance. But in many applications, the predefined trajectory is not applicable. So, without predefining the trajectory we allow the moveable sink to frequently announce the location information throughout the network. SinkTrail, a proactive data reporting protocol is used in a sensor network where the sink moves continuously in the network, at a relatively low speed and gathers the data [3]. At a particular distance after the same time of interval sink nodes broadcast the control message at a much lower frequency than is ordinarily required in the existing data gathering protocol. The position where the message is broadcast is called a "footprint" [4]. This footprint is considered a virtual landmark. Using this virtual landmark sensor node can easily identify its hop count distance from the landmark. These hop count distances combined represent the sensor node's coordinate in the logical coordinate space constructed by the mobile sink. By using the destination coordinates and its own coordinates, each sensor node selects the next hop with the optimized distance. Thus, the protocol finds the optimized path without the use of GPS or any predefined landmark. This protocol reduces the complexity of the routing algorithm as well as increases the battery lifetime of the sensor nodes [5].

2. RELATED WORK

Wired networks focus on maximizing the end-to-end throughput and minimizing the delay. But energy consumption and limited battery life is the main issue in wireless communication, especially in a wireless sensor network. Therefore, recently energy efficiency is getting more attention in a wireless sensor network. Based on the mobility pattern of the mobile nodes data gathering scheme is divided into two categories.

A. Uncontrollable Mobility

In Uncontrollable Mobility, the mobile collector moves randomly [6]. In [7] proposed to use a special type of mobile node as a forwarding agent is used to facilitate connectivity among static sensors and transport data with random mobility. In [8] mobile nodes are not allowed to select a straight route to gather the information in the network. Batalin et al. [9] set proposed a system NIMs, where mobile collectors can only move along fixed cables between trees and ensure that they can be recharged at any time during the movement. A known feature of these approaches is high stability and reliability, and the system maintenance is simple. However, they typically lack agility and cannot be adaptive to the sensor distribution and environmental dynamics.

B. Controlled Mobility

Controlled mobility is the second category in which the mobile collectors move anywhere in the network freely and their trajectory will be planned to move efficiently in the network. To increase the battery life of the sensor nodes, tour planning algorithms are used for achieving a short data gathering tour and to upload all the data within a single hop [10]. While these approaches minimize the energy consumption by completely avoiding multi-hop relays, they may result in long data gathering latency, especially in a large-scale sensor network.

C. Comparison of data gathering schemes

In polling-based approach mobility of the sink is controllable where the path of motion is not decided. In single-hop data gathering (SHDG) [11], a mobile collector stops at some selected sensor nodes to collect data such that single-hop data uploading from each sensor to the mobile collector can be guaranteed. In a controlled mobile element scheme (CME) [12], a mobile collector traverses the predefined track and collects data from the sensors nearby with multi-hop relays.

Table 1: Summary of Various approaches in WSN

	Polling Based Approach	Single Hop Data Gathering	Controlled Element Data Gathering Scheme
Pattern of motion	Can move anywhere, Controllable	Can move anywhere, Controllable	Path is decided, uncontrollable
Locations for data gathering	The movable sink stopsat selected sensor nodes and gather data	The movable sink stops at subset of sensor nodes and gather the data in single hop	Pausing locations arenot predefined
Moving path	Starts from the sink visit each node at least once	Starts from the sink covers all the locations in transmission range	Moves ona predefined path

D. Mobile Data Gathering

When the static hierarchical network is used many problems occur during data gathering. To overcome this problem mobile data gathering scheme has been proposed. In this scheme, mobile collectors are used which connect the static sensors.

The mobile collectors, called data mules, are proposed in [13], which gather the data from nearby sensors store it, and later process it. Although it reduces the energy consumption of the sensor nodes, its moving trajectory is not controllable and packet delay is not predictable.

In [14], and energy-efficient object tracking scheme is proposed in which the number of tracking sensors is minimized through trajectory prediction. Here the mobile agents stay in contact with sensor nodes continuously which are nearer to the object which we have to track.

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Though the mobile data gathering scheme reduces the energy consumption in wireless sensor networks, data gathering latency increases. The scheme mainly focused on minimizing the moving trajectory but did not consider the data uploading time. These observations suggest designing a scheme that minimizes the total data gathering time which includes the moving time of the data collectors as well as the data uploading time of the sensor network. Thus, the joint approach of mobility and space-division multiple access (SDMA) techniques is proposed in [15].

3. Experimental Results

A. Problem Definition

Consider a large, uniform sensor network N of irregular shape deployed in an outdoor area shown in Fig. 1. Nodes present in the network communicate using radio links. By deploying sensors densely, we assume that the whole sensor network is connected. It is also assumed that sensor nodes use a "wake up" state when the data gathering process starts. Mobile sinks are periodically sent into the field in order to gather data from N [16]. These mobile sinks are assumed to have sufficient power.

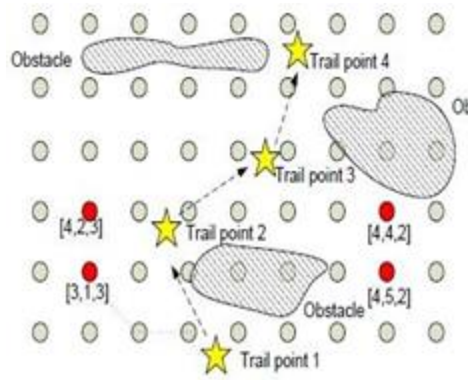

Figure 1: Sensor Network: Data gathering with one mobile sink: yellow stars show the mobile sink's trail points, and Shaded areas indicate obstacles.

and equipped with radios and processors. At the time mobile sinks enter the field data gathering process starts and terminates when:

(1) enough data are collected (measured by a user-defined threshold); and (2) there are no more data reports in a certain period. The SinkTrail protocol is proposed for sensor nodes to proactively report their data back to one of the mobile sinks. To illustrate our data gathering algorithm clearly, we first consider the scenario where there is only one mobile sink in N. The multiple mobile sinks scenarios are discussed later.

B. Moving strategy of mobile sink

The mobile sink moves in a given field with relatively low speed and keeps listening for data report packets during the process of data gathering. When the sink moves in the field it stops at someplace for a very short time, broadcasts a message to the whole network, and moves on to another place. We call these places "Trail Points", and these messages "Trail Messages" [17]. One hop distance of radio transmission is considered as to be the average transmission range. The distances between adjacent trail points are the same to facilitate mobile sink tracking, it is restricted that the distances between any two trail points are the same. A trail message is a very short radio message sent by a mobile sink, it contains a sequence number (msg.seqN) and a hop count (msg.hopC) to the sink. The time interval between two trail points is called one "move". There are multiple moves during a data gathering round. The moving strategy of a mobile sink is summarized in Algorithm 1.

To represent logical coordinates in a network use vector called "Trail References". The trail reference is used as a location indicator for greedy packet forwarding. All trail references are of the same size.

A. Algorithm 1 Mobile sink's moving strategy

1. Initialization
2. msg.seqN ← 0;
3. msg.hopC ← 0;
4. initialize step size parameter K
5. Moving strategies
6. while Not get enough data or Not timeout do
7. Move to next trail point ;
8. msg.seqN! msg.seqN +1;
9. Stop for a very short time to broadcast a trail message;
10. Concurrently listen for data report packets ;
11. end while
12. End data gathering process and exit;

C. Logical coordinates space construction

All the trail references are initialized to [−1,−1, . . . ,−1] at the beginning of the operation. After the mobile sink enters the field, it moves to its first trail point and broadcasts a trailing message to all the sensor nodes in N. To indicate that the first trail message from trail point one, and the hop count to S is zero, the trail message <msg.seqN, msg.hopC> is set to < 1, 0
>.

The nodes which are nearest to the sensor node will be the first ones to hear this message. To check whether the message is new or not, a node compares the sequence number carried in the trail message with the most recent message sequence number a node has recorded, which represents the latest sequence numbers. If this is a new message, the variable will be updated by the new sequence number. And sensor node's trail reference is updated as follows. First, every element in the trail reference is shifted to the left by one position. Then, the hop count in the received trail message is increased by one and replaces the right-most element in the trail reference. This trail message is rebroadcasted with the same sequence number and an incremented hop count after the sensor updates its trail reference [18]. The same procedure repeats for all the other nodes in the network.

B. Algorithm 2 Trail reference update algorithm

1. while Data gathering process is not over do
2. /* Receive a trail message */
3. if msg.seqN > □ then
4. □← msg.seqN;
5. Shift vi to left by one position ;
6. ei^{dv} ← msg.hopC + 1;
7. msg.hopC ← msg.hopC +1;
8. Rebroadcast message;
9. else if msg.seqN = □ then
10. Compare ei^{dv} with (msg.hopC + 1);
11. if ei^{dv} > (msg.hopC + 1) then
12. ei^{dv} ← msg.hopC + 1;
13. msg.hopC ← msg.hopC +1;
14. Rebroadcast message;
15. else
16. Discard the message;
17. end if
18. else if msg.seqN < □ then
19. Discard the message;
20. end if
21. end while
22. /* Reset Variables */
23. For j = 1, . . . ,dv ei^{j} ← −1;
24. □← −1;

C. Algorithm 3 Greedy data forwarding algorithm

1. /* Start a timer */
2. if All elements of the trail reference are updated then
3. Start timer Ti = T0 − μ × ei^{dv}
4. Exchange trail references with neighbors
5. end if
6. /* When timer expires */
7. Set destination as [(dv − 1), . . . , 2, 1, 0]
8. /* Probe mobile sink */
9. if A mobile sink is within radio range then
10. Send data to the mobile sink directly
11. else
12. Choose the neighbor closest to the destination as thenext hop
13. Forward all data to next-hop
14. end if

D. Greedy forwarding

Once a node has updated the 3 elements in its trail reference, it transfers from the "Prepare", state to the "Ready" state, and starts a timer that is inverse proportional to the right-most element in its trail reference [19]. Here, T0 and μ are predefined constants. The choice of the timer function, T0, and μ may vary. However, we assume the timer durations are significantly longer than the propagation time of a trailing message so that timers on all nodes are viewed as starting at the same time. This timer mechanism is mainly used to differentiate data reporting orders, so the clock on each sensor node doesn't need to be perfectly synchronized. Since the right-most element in a node's trail reference is the latest hop count information from this node to a mobile sink, the inverse proportional timers ensure that nodes far away from S have shorter timer durations than those close to S, thus will start data reporting first. When a node's timer expires, it goes into the "Post" state and initiates the data reporting process. Fig 2 shows the impact of moving patterns in different networks.

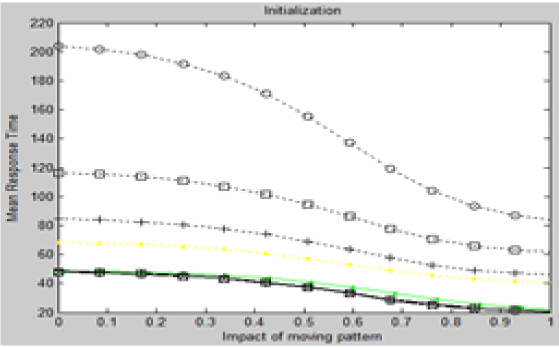

Figure 2: Impact of moving pattern

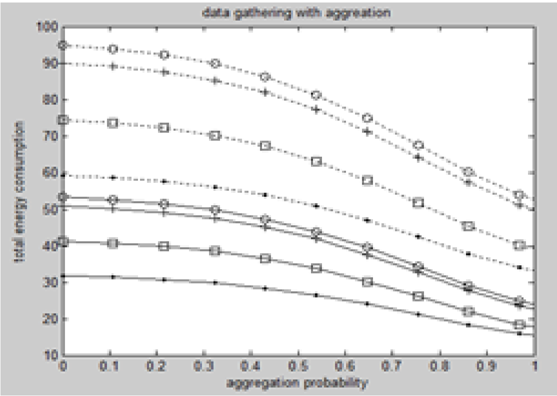

Figure 3: Impact of moving pattern

E. Trail message broadcasting frequency

The impact of sink broadcasting frequency is two-sided. If the mobile sink broadcasts its trail messages more frequently, sensor nodes will get more up-to-date trail references, which is helpful for locating the mobile sink [20]. On the other hand, frequent trail message broadcasting results in heavier transmission overhead. Suppose the time duration between two consecutive message broadcasting is Δt, we derive a general range of Δt to guide the proper implementation of SinkTrail. Assume the trail message is transmitted instantaneously, then Δt is determined by the mobile sink's traveling time Δtm between two consecutive trailing points and sojourn time Δts at each trail point:

$$\Delta t = \Delta tm + \Delta ts$$

In Figure 3 and Fig.4 we plotted some simulation results for a number of broadcasting frequencies. The broadcasting frequency is varied from 0 to 1 per time unit.

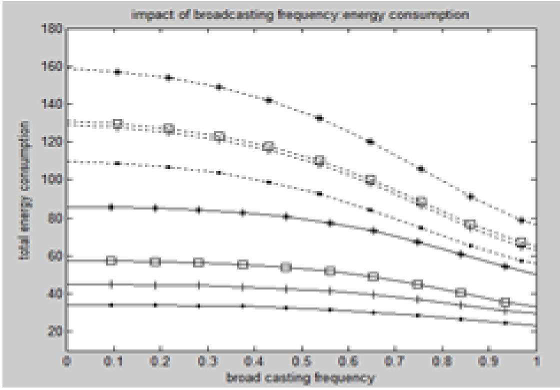

Figure 4: Impact of broadcasting frequency: Energy consumption

We can see that increasing the broadcasting frequency does benefit the average route length, as trail references are refreshed in a timely fashion. However higher update frequency propagates more messages, thereby incurring more energy consumption, especially for large network sizes.

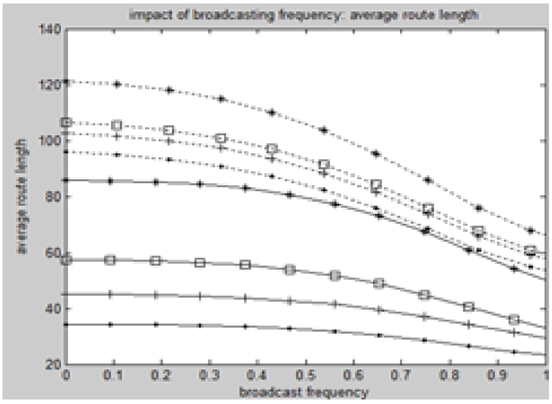

Figure 5: Impact of broadcasting frequency: Average route length

F. SinkTrail protocol with data aggregation

Data aggregation is a popular method for saving energy in sensor networks. A majority part of energy consumption comes from data packet transmission. Therefore, we can save energy by reducing the overall amount of data through data aggregation in intermediate sensor nodes. Recall that the timer mechanism used in Algorithm 3 ensures sequential data reporting based on the position of each sensor node, which is helpful to perform data aggregation in SinkTrail.

4. Conclusion

In this paper various aspects of data gathering schemes such as uncontrolled mobility, controlled mobility, and efficient relay routing. hierarchical infrastructure is discussed. SinkTrail uses logical coordinates to decide distances and establishes a data reporting path by greedily selecting the shortest path to the destination reference. SinkTrail uses logical coordinates to infer distances and establishes data reporting routes by greedily selecting the shortest path to the destination reference. In addition, SinkTrail is capable of tracking multiple mobile sinks simultaneously through multiple logical coordinate spaces.

Conflict Of Interest

The authors declare that they have no conflict of interest.

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