A NOVEL Data Reporting Protocol for Wireless Sensor Networks

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Abstract— **A mobile sink cannot move freely in the deployed area, the predetermined route may not be applicable. So a constant location update is needed but the future locations cannot be scheduled in advance. To come out of this two energy efficient proactive data maintenance protocols, Sinkstalk and Sinkstalk-S, for mobile based future data collection data collection is proposed. These protocols offer low-complexity and reduced control overheads. Data sinks' mobility for data gathering is highly preferred, to achieve optimized network performance through predetermined routing in advance. A mobile sink cannot move freely in the deployed area. These protocols provide flexible movement of the device by dynamically adapting the changes of the environment without the need of GPS instead finding the coordinates of the land by sending the data packets.**

Keywords—**Sink Stalk, Sink Stalk-S**

I. INTRODUCTION

THE WIRELESS Sensor Networks (WSNs) have enabled a wide spectrum of applications through networked low-cost low-power sensor nodes, monitoring the forest fire detection . The sensor network will operate under few human interventions either because of the unfriendly environment or high management complexity for labor intensive maintenance. Since sensor nodes have inadequate battery life, energy saving is of dominant meaning in the design of sensor network protocols. In a wireless sensor network, a special node, called a sink, acts as a gateway between the wireless sensor network and the outside network. A query that originates from the outside network must pass through the sink in order to inquire about a given object's location. Recent research on data compilation reveals that, rather than coverage data through long, multi-hop, and error-prone routes to a static sink using tree or cluster network structure, allowing and leveraging sink mobility is more promising for energy efficient data gathering .Mobile sinks, such as animals or vehicles equipped with radio devices, are sent into a meadow and converse directly with sensor nodes, resulting in shorter data communication paths and reduced energy consumption. Each sensor has the capabilities of monitoring the surroundings, collecting data and routing information back to a data sink .Typically, most energy of a sensor is consumed on two major tasks: sensing the field and uploading data to the data sink. Power utilization on sensing is relatively stable since it only depends on the sampling rate. On the other hand, the energy consumption on data uploading is non-uniform among sensor.

It strongly depends on the network topology and the position of the intended data sink. The power of the sensors near the sink is exhausted much faster than others since these sensors need to convey much more packets from the sensors far away from the sink. Besides the energy consumed on monitoring the surroundings with periodical sampling, a large section of force expenses in WSNs is credited to the activities of aggregating data to the data sink. Due to the severe energy constraints in WSNs, recent investigation has striven to concentrate on the topic of energy saving in data aggregation.

In such schemes, data packets are forwarded to the data sink via multi-hop relays among sensors. Some related issues, such as list pattern, load balance, and data redundancy were also jointly considered along with routing to further improve energy efficiency. However, due to the inherent nature of multi hop routing, packets have to experience multiple relays before reaching the data sink. As a result, much energy is consumed on data forwarding along the path. Moreover, minimizing energy consumption on the forwarding path does not necessarily prolong network lifetime as some popular sensors on the path may run out of energy faster than others, which may cause non-uniform energy consumption across the network. In this way, energy consumption at sensors can be greatly reduced, since the mobility of the collector effectively dampens the relay hops of each packet.

II. RELATED WORK

A. *Sink-Oriented Research*

Leveraging data sinks' mobility in sensor data collection has been a topic of tremendous practical interests and drawn intensive research efforts in the past few years. The most challenging part of this approach is to effectively handle the control overheads introduced by a sink's movement. At the first look, broadcasting a mobile sink's current location to the whole network is the most natural solution to track a moving mobile sink. This type of approach is sink- oriented and some early research efforts, have demonstrated its effectiveness in collecting a small amount of data from the network. Several mechanisms have been suggested to reduce control messages.

The TTDD protocol, constructed a two-tier data dissemination structure in advance to enable fast data forwarding. In a spatial-temporal multicast protocol is proposed to establish a delivery zone ahead of mobile sink's arrival. Control messages are flooded to wake up nodes in the delivery zone. Several mechanisms have been suggested to reduce control messages. The TTDD protocol, constructed a two-tier data dissemination structure in advance to enable fast data forwarding. In a spatial-temporal multicast protocol is proposed to establish a delivery zone ahead of mobile sink's arrival. Control messages are flooded to wake up nodes in the delivery zone. Similarly proposed DRMOS that divides sensors into “wake-up” zones to save energy. Fodor lowered communication overheads by proposing a restricted flooding method; routes are updated only when topology changes. The SinkStalk protocol with message suppression minimizes the flooding effect of control messages without confining a mobile sink’s movement, thus is more attractive in real-world deployment. Several mechanisms have been suggested to reduce control messages. The TTDD protocol, proposed in, constructed a two-tier data dissemination structure in advance to enable fast data forwarding.

B. Topology Maintenance

Existing topology maintenance protocols conserve energy by scheduling the network nodes to a sleep mode when a node is not currently involved in a communication activity. Based on the knowledge of the geographical locations of each of the nodes within the network, the GAF protocol divides the total network area into an arrangement of structured smaller grids such that each grid contains only one active node. Span maintains the connectivity and forwarding capability of a wireless network by maintaining those nodes which constitute the backbone infrastructure in an active mode. The idea of PEAS is similar to Span each sleeping node periodically wakes up for checking if any active nodes are within its probing range. If it is the case, it sleeps again; otherwise, it becomes an active node. The probing range can be adjusted to achieve different levels of coverage redundancy. OGDC used a minimal number of sensor nodes to maintain the coverage without any blind spots. Both coverage and connectivity can be proved if the transmission range is two times larger than the sensing distance.

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C. Sink Stalk Protocol

We consider a large scale, uniformly distributed sensor network IN deployed in an outdoor area. Nodes in the network communicate with each other via radio links. We assume the whole sensor network is connected, which is achieved by deploying sensors densely. We also assume sensor nodes are awake when data gathering process starts (by synchronized schedule or a short “wake up” message). In order to gather data from IN, we periodically send out a number of mobile sinks into the field. These mobile sinks, such as robots or vehicles with laptops installed, have radios and processors to communication with sensor nodes and processing sensed data. Since energy supply of mobile sinks can be replaced or recharged easily, they are assumed to have unlimited power.

D. Hierarchical networks

In a spatial-temporal multicast protocol is proposed to establish a delivery zone ahead of mobile sink’s arrival. Control messages are flooded to wake up nodes in the delivery zone. Similarly proposed DRMOS that divides sensors into “wake-up” zones to save energy, lowered communication overheads by proposing a restricted flooding method; routes are updated only when topology changes. Proposed that a mobile sink should move following a circle Stalk in deployed sensor field to maximize data gathering efficiency. One big problem of the multicasting methods lies in its flooding nature. Moreover, these papers either assume that mobile sinks move at a fixed velocity and fixed direction, or follow a fixed moving pattern, which largely confines their application. The SinkStalk protocol with message suppression minimizes the flooding effect of control messages without confining a mobile sink’s movement, thus is more attractive in real-world deployment .To overcome these problems in static hierarchical networks, mobile data gathering schemes have been proposed in such schemes, a special type of mobile nodes (usually called mobile collectors) is introduced for facilitating connectivity among static sensors. Mobile collectors take the burden of routing away from sensors, which is particularly desirable when sensors have limited energy and storage resources

III. SINK STALK PROTOCOL WITH ONE MOBILE SINK

During the data gathering process, the mobile sink moves around in IN with, relatively, low speed, and keeps listening for data report packets. It stops at some places for a very short time, broadcasts a message to the whole network, and moves on to another place. These places are called “Stalk Points,” and these messages are called “Stalk Messages.”

IV. SINK STALK PROTOCOL WITH MULTIPLE MOBILE SINK

A. Sensor node

The proposed SinkStalk protocol can be readily extended to multi sink scenario with small modifications. When there is more than one sink in a network, each mobile sink broadcasts Stalk messages. Different from one sink scenario, a sender ID field, msg.sID, is added to each Stalk message to distinguish them from different senders. Algorithms executed on the sensor node side should be modified to accommodate multi sink scenario as well. Instead of using only one Stalk reference, a sensor node maintains multiple Stalk references that each corresponds to a different mobile sink at the same time.

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B. Sink Stalk-s protocol

In SinkStalk, flooding Stalk messages to the whole network can be nontrivial in terms of energy consumption. To further optimize the energy usage and eliminate unnecessary control messages in the network, we propose SinkStalk- S algorithm as an improvement to the original SinkStalk. SinkStalk-S algorithm is mainly based on the following two observations. First, in a large-scale sensor network, the sensor nodes that are far away from a mobile sink may not be significantly affected by a single movement of the mobile sink. Take the sensor network shown an example, when the mobile sink moves from Stalk point A to Stalk point B, the yellow sensor node at the left bottom corner may still have the same hop count distance to the mobile sink, and the routing path chosen from last “move” of the mobile sink may still be valid. In this case, the Stalk messages can be suppressed with high probability.

Second, when a node has finished data reporting and forwarding, Stalk reference updating becomes meaningless and results in huge waste of energy, especially for peripheral sensor nodes. To properly handle these two situations, we propose a message suppression policy at a small cost of extra state storage at each sensor node. Each sensor node will compare the current hop count distance to a mobile sink with the most recently received one. If these two are same, it indicates the path length through the node to the mobile sink is still same, making it unnecessary to rebroadcast this Stalk message. In case of the second situation, each node maintains a state variable in its memory. When a node finishes data reporting, it marks itself as “finished,” and informs all its neighbor nodes. A node stops Stalk reference updating and Stalk message rebroadcasting whenever itself and all its neighbors are “finished.”

Again, this method is guaranteed by the timer mechanism that ensures sequential data packets reporting order from network peripheral to a mobile sink’s current location. For accidental situations due to timer failure, a new data packet may arrive at a node that has already stopped Stalk reference updating. In that case old Stalk references are used.

B. Equations

Before we proceed the following variables are defined for clear presentation and fair comparison. We consider a network IN that consists of N sensor nodes and M mobile sinks. All the sensor nodes are data sources. We assume sensor nodes are deployed in a grid topology for ease of understanding. However, our analysis can be extended to other uniformly distributed topology. Therefore, the edge of the grid is roughly. Denote the energy cost for transmitting or receiving a control message be and the cost for a data packet. We have since compared to Stalk messages; data packets are usually larger in terms of data size, which is proportional to the energy cost for radio transmission.

C. Other Recommendations

Two factors affect the energy cost of data forwarding: number of data packets and the average route length. The number of data packets is determined by the number of data sources in a network, in this case, N. The average route length, on the other hand, may vary depending on the locations a mobile sink has traveled. We estimate an upper bound of the average route length by considering the situation that a mobile sink appears randomly at a location inside the deployed field. This energy cost upper bound for data reporting will not be affected by the number of mobile sinks, since every data reporting message will travel through the shortest possible path. Increased number of mobile sink will only decrease the total energy cost for data reporting.

V. PERFORMANCE EVALUATION

There are many mobile sink oriented approaches for data collection in sensor networks. These protocols, as in SinkStalk, do not pose any constraint on a mobile sink’s movement, nor do they require any special setup phase, generally referred to as sink-oriented data dissemination approaches. Although SODD approaches may apply different aggregation functions for better performance, similar strategies can be applied to SinkStalk as well. In order to gain more insights on the energy efficiency of SinkStalk, and to demonstrate the advantage of incorporating sink location tracking, we compare the overall energy consumption of SinkStalk with these protocols. Simulation results for SinkStalk-S are also presented to show further improved performance.

VI. COMPARATIVE STUDY

In the SODD approach, whenever a mobile sink moves to a different location, it broadcasts its current position to the whole network. As the message propagates a routing tree is established. Each node reports back its sensed data to parent node and finally, all data are merged at the root. This SODD approach suffers from losing track of the sink when location update is infrequent. To ensure fair comparison, a broadcast frequency higher than typically required by SinkStalk is used to ensure proper termination of SODD. We use one mobile sink in this set of simulations. The mobile sink moves in a rectangular or circular fashion in both algorithms. We set the data gathering threshold to 98 percent.

To demonstrate the effectiveness of message suppression in SinkStalk-S, we simulated SinkStalk-S with circular and linear sink moving patterns and compare the result with the basic SinkStalk protocol. It is worth noting that energy cost for informing neighbors is also counted in implementation. We observe that, although SinkStalk-S spends extra costs on state storage and informing message transmission, the method effectively reduces energy consumption in the investigated scenarios.

VII. IMPACT FACTORS

A. Impact of Moving Patterns of Mobile Sink

To numerically model the moves conducted by a mobile sink, we trace the moving Stalk of a mobile sink on a plain and measure the directional change at each Stalk point. Specifically, suppose at some time the mobile sink arrives at Stalk point, we define the angular displacement as the angular variation of moving directions. As an example of recorded angular displacements at multiple Stalk points. As a result, the accumulative angular displacement of a mobile sink becomes a quantitative metric for the moving pattern. For the three moving patterns, linear movement incurs the least energy consumption and the shortest average route length. As to the circular movement case, the mobile sink changes its direction regularly and smoothly, leading to performance close to the linear movement case.

Finally, for the random move case, the results vary in a wide range that indicated by the dashed bars bounding the average values. This is because it is more difficult to track and predict the behavior of a randomly moving mobile sink. Therefore, SinkTail's overall performance may suffer greatly when the directional change is radical at some Stalk point. Although SinkStalk does not place any moving restriction in general, changing directions strategically in a smooth and regular manner is more beneficial than radical and unpredictable moving in SinkStalk.

B. Impact of Number of Mobile Sink

We are interested in finding out how the number of mobile sinks affects the overall system performance. In the scenario with multiple mobile sinks, several logical coordinate spaces are constructed concurrently and data packets are forwarded to the destination reference via the shortest path in any coordinate space. It is natural to think that increasing the number of mobile sinks reduces the average route length and thus reduces the total energy consumption. Nonetheless, more mobile sinks also impose heavier burdens for Stalk message broadcasting and routing information maintenance. Even worse, multiple number of mobile sinks in a network aggravate control traffic congestion and communication delays, which will in turn result in higher packet loss and retransmission rate. To acquire visualized results on the impact, we simulate the multiple mobile sinks scenario using the aforementioned simulation setup. The number of mobile sinks used is up to three and they are injected into the network at the same time. For fair comparison all the mobile sinks moved randomly via different routes, and broadcasted at the same frequency. We averaged the results of 20 simulation runs. The trends shown in the figures confirm our analysis. The average route length is reduced by 46.54 and 53.70 percent for two and three sinks, respectively; while for the total energy cost, using more mobile sinks increases Stalk messages and routing table costs, thereby yield to 17.6 and 33.06 percent energy consumption increment for two and three sinks, respectively. Overall, defining route length deduction over extra energy cost as performance price ratio, we have 2.64 for two sinks and 1.62 for three sinks scenario. According to this, we conclude that adding multiple sinks is more suitable for applications with tight data gathering deadlines.

C. Impact of Broadcasting Frequency

The impact of sink broadcast frequency is two sided. If the mobile sink broadcasts its Stalk messages more frequently, sensor nodes will get more up-to-date Stalk references, which is helpful for locating the mobile sink. On the other hand, frequent Stalk message broadcast results in heavier transmission overheads. Suppose the time duration between two consecutive message broadcasting, we derive a general range to guide the proper implementation of SinkStalk and SinkStalk-S.

As this theoretical range is very broad and application specific, we plotted some simulation results for a number of broadcast frequencies. The broadcasting frequency is indicated by the time interval between two consecutive broadcasts. We can see that shorter broadcast interval, i.e., more frequent control message broadcasting, does benefit the average route length, as Stalk references are refreshed in a timely fashion. However, higher update frequency propagates more messages, thereby incurring more energy consumption, especially for large network size. It is important to find a tradeoff point balancing different requirements when it comes to real application implementation. Based on the conceptual sensitivity analysis in this section, choices of these parameters settings depend on specific application scenarios and user requirements. The analysis here can be used as a guideline for real system design, and can also be used as performance metrics for comparison study with other schemes.

VIII. CONCLUSION

We presented the SinkStalk and its improved version, SinkStalk-S protocol, two low-complexity, proactive data reporting protocols for energy-efficient data gathering. SinkStalk uses logical coordinates to infer distances, and establishes data reporting routes by greedily selecting the shortest path to the destination reference. In addition, SinkStalk is capable of tracking multiple mobile sinks simultaneously through multiple logical coordinate spaces. It possesses desired features of geographical routing without requiring GPS devices or extra landmarks installed. SinkStalk is capable of adapting to various sensor field shapes and different moving patterns of mobile sinks. Further, it eliminates the need of special treatments for changing field situations. We systematically analyzed energy consumptions of SinkStalk and other representative approaches and validated our analysis through extensive simulations. The results demonstrate that SinkStalk finds short data reporting routes and effectively reduces energy consumption. The impact of various design parameters used in SinkStalk and SinkStalk-S are investigated to provide guidance for implementation.

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