An Energy-Efficient Multiple Mobile Sink Based Approach in Wireless Sensor Networks

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Abstract— **Wireless sensor networks (WSN), are particularly useful for obtaining data concerning events limited to a well-defined geographic region, such as a disaster site or an agriculture dataset. Power saving is a critical issue in wireless sensor networks since sensor nodes are battery-powered. However, these benefits are dependent on the path taken by the mobile sink, particularly in delay-sensitive applications, as all sensed data must be collected within a given time constraint. An approach proposed to address this challenge is to form a hybrid moving pattern in which a mobile-sinknode only visits rendezvous points (RPs), as opposed to all nodes. Sensor nodes that are not RPs forward their sensed data via multihopping to the nearest RP. The fundamental problem then becomes computing a tour that visits all these RPs within a given delay bound. Identifying the optimal tour, however, is an NP-hard problem. To address this problem, a heuristic called weighted rendezvous planning (WRP)is proposed, WRP is validated via extensive computer simulation, and our results demonstrate that WRP enables a mobile sink to retrieve all sensed data within a given deadline while conserving the energy expenditure of sensor nodes. This method is extended in the case of multiple mobile sinks over a wide area network. Experimental result of proposed system achieves better reduction of energy consumption than with the existing algorithms.**

Keywords— Data collection, mobile sink, scheduling, wireless sensor networks (WSNs).

I. Introduction

Wireless sensor networks (WSNs) are composed of a large number of sensor nodes deployed in a field. They have wide-ranging applications, some of which include military, environment monitoring agriculture, home automation, smart transportation, and health. Each sensor node has the capability to collect and process data, and to forward any sensed data back to one or more sink nodes via their wireless transceiver in a multihop manner. In addition, it is equipped with a battery, which may be difficult or impractical to replace, given the number of sensor nodes and deployed environment. In multihop communications, nodes that are near a sink tend to become congested as they are responsible for forwarding data from nodes that are farther away. Thus, the closer a sensor node is to a sink, the faster its battery runs out, whereas those farther away may maintain more than 90% of their initial energy . This leads to nonuniform depletion of energy, which results in network partition due to the formation of energy holes. As a result, the sink becomes disconnected from other nodes, thereby impairing the WSN. Hence, balancing the energy consumption of sensor nodes to prevent energy holes is a critical issue in WSNs. The data forwarding path from sensor nodes to the sink is dependent on the sink's current position. This requires sensor nodes to dynamically plan one or more data forwarding paths to each feasible site whenever the sink node changes its position over time. A mobile sink that moves at the periphery of a sensor field maximizes the lifetime of sensor nodes. In wireless sensor networks (WSNs), the sink mobility along a constrained path can improve the energy efficiency. Sink mobility is an important technique to improve sensor network performance including energy consumption, lifetime and end-to-end delay.

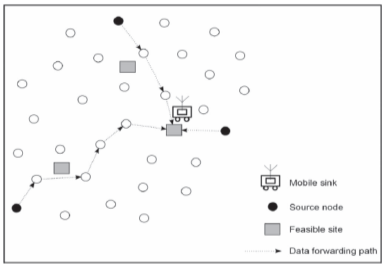

Fig: 1.1 Mobile sink performing data collection

Figure shows the feasible sites of a mobile sink in an example WSN. Specifically, the squares denote the feasible sites that the mobile sink will visit and stop for data collection. The data forwarding path from sensor nodes to the sink is dependent on the sink's current position. This requires sensor nodes to dynamically plan one or more data forwarding paths to each feasible site whenever the sink node changes its position over time. A mobile sink that moves at the periphery of a sensor field maximizes the lifetime of sensor nodes. Intuitively, by changing the position of the sink over time, the forwarding tree will involve a different set of sensor nodes and, hence, will help to balance energy consumption. The traveling path of a mobile sink depends on the real- time requirement of data produced by nodes. Moreover, a mobile-sink node may change its position after a certain period of time and select another data collection/ feasible site. In general, limitations such as the maximum number of feasible sites, maximum distance between feasible sites, and minimum sojourn time govern the movement of a mobile sink. Existing method used weighted rendezvous planning (WRP) which is a novel algorithm for controlling the movement of a mobile sink in a WSN. This method focuses on a single mobile sink or source. This leads to inefficient communication, reducing the network lifetime. Because of this problem, some nodes or parts of WSN are not frequently visited. To deal with this problem, the proposed system uses enhancing energy efficiency by using energy efficient multi-sink clustering based weighted rendezvous planning method (EE-MSCWRP) which uses multiple mobile sink nodes on energy consumption under different scale networks. In this WSN is partitioned into smaller areas known as clusters where each area is assigned a mobile sink by cluster head (CH). Experimental result of proposed system achieves better reduction of energy consumption than with the existing system.

II. LITERATURE REVIEW

Existing methods on using a mobile sink in WSNs can be grouped into two categories: 1) direct, where a mobile sink visits each sensor node and collects data via a single hop; and 2) rendezvous, where a mobile sink only visits nodes designated as RPs. The main goal of protocols in category 1 is to minimize data collection delays, whereas those in category 2 aim to find a subset of RPs that minimize energy consumption while adhering to the delay bound provided by an application. In the following, we review the challenges faced by these protocols. Exploiting sink mobility based technology is gaining more and more popularity in recent years to achieve better energy efficiency and lifetime performance. Many studies have shown that sink mobility technology can significantly balance traffic load and improve network performance. Mobile sink nodes moving at a certain speed throughout a sensing field can collect monitored data from the static sensors in a single-hop or multi-hop transmission manner. In this way, one can effectively reduce energy overhead at sensor nodes near sink nodes, and enable the sensor network to last longer. As the mobile sink nodes change position, their neighbor nodes will also change.

A. Direct

Initial studies used a mobile sink that visits sensor nodes randomly and transport collected data back to a fixed sink node. An example is the use of animals as mobile-sink nodes to assist in data collection from sensor nodes scattered on a large farm. To reduce the latency of visiting each sensor node randomly, researchers have proposed TSP-based data collection methods. In essence, the problem is reduced to finding the shortest traveling path that visits each sensor node. For example, TSP with neighborhood involves finding the shortest traveling tour for a mobile-sink node that passes through the communication range of all sensor nodes. Another TSP-based algorithm called label-covering considers a WSN as a complete graph. For each edge, it calculates a cost and associates a label set. The cost of an edge is the Euclidean distance between nodes, whereas the label set contains sensor nodes whose transmission range intersects with the given edge. The label-covering algorithm selects the minimum number of edges where their associated label set covers all sensor nodes.

B. Rendezvous

The problem with collecting data directly from sensor nodes is that it becomes impractical when there are a large number of sensor nodes. Visiting each sensor node increases the mobile sink's traveling path length and results in sensor nodes experiencing buffer overflow due to data collection delays. To address this problem, researchers have proposed a rendezvous-based model, in which a mobile sink only visits a subset of sensor nodes called RPs. The sensor nodes outside the mobile sink path send theirdata via multihop communications to these RPs.

III. PROBLEM FORMULATION

Let us consider a WSN in which sensor nodes generate data packets periodically. Each data packet must be delivered to the sink node within a given deadline. There is a mobile sink that roams around a WSN to collect data from a set of RPs. The objective is to determine the set of RPs and associated tour that visits these RPs within the maximum allowed packet delay.

A. System Model

Before describing DEETP, we first outline some assumptions.

1) The communication time between the sink and sensor nodes is negligible, as compared with the sink node's traveling time. Similarly, the delay due to multihop communications including transmission, propagation, and queuing delays is negligible with respect to the traveling time of the mobile sink in a given round.

2) Each RP node has sufficient storage to buffer all sensed data.

3) The sojourn time of the mobile sink at each RP is sufficient to drain all stored data.

4) The mobile sink is aware of the location of each RP.

5) All nodes are connected, and there are no isolated sensor nodes.

6) Sensor nodes have a fixed data transmission range.

7) Each sensor node produces one data packet with the length of b bits in time interval D.

B Network Model

A wireless sensor network can be viewed as a directed graph G = < Vnode U Vsink, Enode U Esink >, where Vnode and Vsink represents the set of sensor nodes and sink nodes respectively. Enode represents the set of all links l(i,j), where i and j are neighboring sensor nodes, and Esink represents the set of all links between sensor nodes and sink nodeThe static sensor nodes are randomly dispersed in the monitored area and keep generating data packets. Resolving

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the problem of energy hole is one of the key factors for designing large-scale wireless sensor networks aimed at improving the life spanofthese systems.

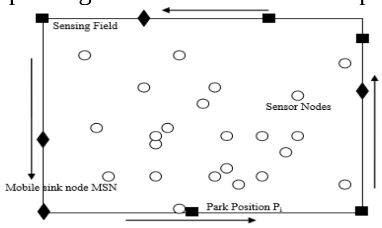

Fig 3.1 Network model

The mobile sink nodes are used togather data packets in different location by moving along network boundary for two reasons. First, it is relatively easy to deploy mobile sink along network boundary rather than along certain optimal trajectory inside. More importantly, network performance is usually better with sink moving along the boundary than inside sensor network. Here, the small squares Pi stands for parking positions of mobile sink nodes. Mobile sink nodes will periodically visit these parking positions and sojourn at each position for a certain time to collect data packets. We can divide the whole process of mobile sink node movement into a moving phase and a collecting phase. In the moving phase, mobile sink nodes only move with a certain speed from one parking position Pi to another position Pj, and they will refuse to receive any monitored data. In the collecting phase, mobile sink nodes will broadcast a notification message to their nearby sensors. The message includes their arrival message and next location message, and then they will receive data packets in a single hop or multi-hop transmission manner.

IV. WEIGHTED RENDEZVOUS PLANNING

WRP preferentially designates sensor nodes with the highest weight as a RP. The weight of a sensor node is calculated by multiplying the number of packets that it forwards by its hop distance to the closest RP on the tour. Thus, the weight of sensor node i is calculated as

$$W_i = NFD(i) \times H(i,M)$$

Based on this, sensor nodes that are one hop away from an RP and have one data packet buffered get the minimum weight. Hence, sensor nodes that are farther away from the selected RPs or have more than one packet in their buffer have a higher priority of being recruited as an RP.

The routing phase

To begin with, all the sensor nodes are booted up. The last node to be booted is the base station. The base station on booting broadcasts a route finding message onto the network. This message carries the node ID of the base along with a hop count field as well as the base station's time stamp. The hop count is initially set by the base station to 1. All nodes within a single hop distance of the base receive this message and set their Parent to be the base station and their Hop Distance to be 1. These nodes also reset their clocks to synchronise with the base station. All these nodes then re-broadcast the routing message writing inside their own node ID instead of the base's, incrementing the hop count by 1 and also update the time stamp of the message. In this manner the route finding messages are flooded through the network and all nodes soon know who their parent node is and also at what hop distance they are residing from the base. All message transmission in the listening period of the node is directed towards the parent node.

The listening phase

After the reception of a routing packet at a node, a short timer is started that signals the end of the routing period and the beginning of the listening period. In this period, the aim of each node is to listen for messages sent out by the transmitter being tracked and then try to route these packets all the way to the base station. Before routing, the nodes augment three pieces of information to
the received message :-

- Node ID
- Time Stamp
- Received Signal Strength (RSSI value)

All the augmented data is essential for the front end processing in order to determine the location of the transmitter. A node ID to coordinate mapping is maintained at the processing server. Hence when the messages reach the server, it knows from where what signal strength is being received. This is the data needed for location estimation. The worst case is when all sensor nodes are marked but not selected as an RP, which means WRP will iterate for |V| times to check the possibility of adding nodes into a tour. After a node is selected as an RP, WRP again unmarks other sensor nodes and restarts the search process. This means our algorithm uses the TSP solver for a maximum of n2 times, where n = |V|. Therefore, the time complexity of WRP is O(n2 ×O(TSP)). We like to point out that WRP always finds a tour when there is at least one possible tour in the network. This is because WRP checks the possibility of adding all sensor nodes to the tour. This is significant when compared with CB and RD-VT because the latter two algorithms fail in the following scenario. In CB, if the only possible tour consists of only the sink and a neighbor in the same cluster, CB will not be able to find this tour because two sensor nodes from the same cluster cannot be in the final tour. As for RD-VT, it will return no tour if the distance of the first sensor node in the SMT, as it starts its depth-first traversal, exceeds lmax.

V. IMPLEMENTATION

1. RANDOM PATH
2. PATH-CONSTRAINEDSINK MOBILITY
3. CONTROLLABLE SINK MOBILITY

RANDOM PATH

In sensor network, path of Mobile sink is random to collect the data from subsink. The mobile sinks are placed on moving object like humankind or animals moving randomly to collect information sensed by the sensor nodes. Because of the random mobility, to collect the maximum data is difficult.

PATH-CONSTRAINED SINK MOBILITY

A mobile sink is installed on a public transport vehicle which moves along a fixed path periodically. However, all sensor nodes can only transmit data to the single mobile sink in one-hop mode. Actually single-hop communication between all sensor nodes and the mobile sink may be infeasible due to the limits of existing road infrastructure and communication power, for a traffic surveillance application. To address the imbalance problem, the MASP scheme proposed in is designed to enhance data collection from the viewpoint of choosing cluster heads more efficiently. Moreover, if a mobile sink is mounted on public transportation, e.g., a bus; the speed cannot often be changed freely to the purpose of data collection. A routing protocol, called MobiRoute, is suggested for WSNs with a path predictable mobile sink to prolong the network lifetime and improve the packet delivery ratio, where the sink sojourns at some anchor points and the pause time is much longer than the movement time. Accordingly, the mobile sink has enough time to collect data, which is different from our scenario. Moreover, in MobiRoute all sensor nodes need to know the topological changes caused by the sink mobility. While in our approach, only the subsinks need to know the change of the sink location and the members just send their data to their respective subsinks chosen in advance. One thing that should be noted is that the routing protocol in can only be used in sensor networks with a single mobile sink. The work is extended to exploit multiple mobile sinks to solve the scalability problem, which assumes that all sensor nodes are located within the direct communication range of at least one mobile sink. The data collection scheme proposed in this paper can be used to support multihop communication in sensor networks with multiple mobile sinks.

CONTROLLABLE SINK MOBILITY

Most of the current work about path-controllable sink mobility has focused on how to design the optimal trajectories of mobile sinks to improve the network performance. Mobile element scheduling problem is studied, where the path of the mobile sink is optimized to visit each node and collect data before buffer overflows occur. However, single-hop communication is not feasible due to the limitation of road infrastructure and requirement on delivery latency.. A distributed and network assisted sink navigation framework is to balance energy consumption and collection delay by choosing appropriate number of multiple hops. In a distributed and localized solution to decide sinks movements when the movement paths are not predetermined in WSNs supporting multihop communication. With the help of shortest path tree and Rendezvous Based Data Collection methods collect the efficient data and also use the methods of sink mobility to collect the data. Path constrained and limited Path controllable sink mobility types are used for robust data collection.

VI. EVALUATION AND PERFORMANCE

We compare WRP against three existing methods that have the same objective as ours, namely CB, RD-VT, and RP-UG, using a custom simulator written in C++.1 We consider a connected WSN where nodes are placed uniformly on a sensor field of size 200×200 . We note that interconnecting disconnected sensor nodes using a mobile node is a well- known and separate problem. Having said that, WRP can be also made to interconnect disconnected nodes if the required delivery time for data packets is greater than the shortest traveling tour to visit all sensor nodes. The reason that we have assumed uniform sensor-node distribution is because energy holes are more likely to form when nodes are distributed uniformly. Experimental results in demonstrated that, if sensor nodes are distributed uniformly, up to 90% of residual energy is unused when the first sensor node dies. In addition, we adopt uniform distribution to ensure fair comparison with RD-VT, CB, and RP-UG. multiple mobile sinks for WSNs can balance energy consumption, prolong network lifetime, and reduce sensor nodes' overhead near mobile sink nodes. Besides, they are well suited for sparse or disconnected sensor networks. They can also provide well guaranteed network connectivity. However, the cost of mobile sinks is relatively higher than that of normal sensor nodes.

Parameter	Value
Maximum allowed packet delay (D)	100 to 300 seconds
Number of sensor nodes (n)	7 to 200
Mobile sink speed (v)	1m/s
Sensor nodes transmission range	20m
Packet length (b)	30 bytes
Consumed energy in transmitter circuit	42mW
Consumed energy at the receiver circuit	29mW
Sensor node's battery	100J

Two sets of experiments are carried out. Initially, the number of nodes is limited to 20, and WRP is compared against a brute- force approach that yields the optimal tour with 2.5 min as the required tour length. In the second experiment, the number of nodes is increased to 200, and WRP is compared against RD-VT and CB with 5 min as the required tour length. In all experiments, we designate the node with the highest ID as the sink node, and the results are an average of ten simulation runs over different topologies.

VII. CONCLUSION

In this paper, we have presented WRP, which is a novel algorithm for controlling the movement of a mobile sink in a WSN. WRP selects the set of RPs such that the energy expenditure of sensornodes is minimized and uniform to prevent the formation of energy holes while ensuring sensed data are collected on time. In addition, we have also extended WRP to use an SPT and an SMT. Apart from that, we have also considered visiting virtual nodes to take advantage of wireless coverage. Our results, which are obtained via computer simulation, indicate that WRP-SMT reduces the energy consumption of tested WSNs by 22% in comparison to CB. We also benchmarked WRP against existing schemes in terms of the difference between sensornode energy consumption. Our simulation results show that WRP uniformly distributes energy consumption by 39% and 44% better than CB and RD-VT, respectively. As a future work, we plan to enhance our approach to include data with different delay requirements. Moreover, we plan to extend WRP to the multiple mobile sinks/roverscase. Having said that, we note that WRP remains applicable if a large WSN is partitioned into smaller areas where each area is assigned a mobile sink. Energy-efficient multi-sink clustering predicated weighted rendezvous method (EE-MSCWRP) is proposed to minimize the energy consumption so that data from different nodes are amassed within a given deadline. We will further study several known routing algorithms or protocols using multiple mobile sink nodes, and discuss the influence of sink moving speed and movement trajectory on packet delivery delay. Besides, to effectively organize and manage sensor nodes, we will study how to combine clustering technology with sink mobility technology.

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