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Robust Data Collection in Wireless Sensor Networks with Mobile Sinks

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***Abstract*— Recent work has shown that sink movement along a fixed path and speed control can minimize the energy utilization in wireless sensor networks. Mobile sink with predetermined path and speed gives inadequate communication time to collect data from the subsink and member nodes deployed randomly. This method creates significant challenges for data collection and energy consumption in wireless sensor network. For tackle this issue, we propose a new method for data collection, called the Optimal Terminal Assignment based Path (OTABP) that increases data collection and minimize the energy consumption as well as optimizing the assignment of sensor nodes to the subsinks. OTABP method based on efficiently assignment of the member node to subsinks. Propose work also implements approximate algorithm to solve the subsinks selection and member node assignment problem. Our aim is to collect maximum data efficiently in wireless sensor networks by utilizing minimum energy using Optimal Terminal Assignment based Path (OTABP)of controllable movable sink.**

***Keywords*— Sensor networks, mobile sinks, fixed path, Speed Control, data collection, minimum energy utilization.**

I. Introduction

Recently, sink mobility has become an important research topic in wireless sensor networks (WSNs). The Mobile sink trajectories are random to collect information of interest sensed by the sensor nodes [1] [2]. Efficient data collections by consuming minimum energy problems are often concerned to improve the network performance. Fixed Path sink mobility is used to improve the energy efficiency of singlehop sensor networks which may be infeasible due to the limits of the path location and communication power [3], [4], [5]. In [6],[8] we study multihop sensor networks with a fixed path mobile sink where the Shortest Path Tree (SPT) method is used to choose the cluster heads and route data that may result in low energy efficiency for data collection. In [9], focuses on large-scale dense WSNs with fixed path mobile sinks that may exist in real world applications, such as ecological environment monitoring and health monitoring of large buildings. As shown in Fig. 1, let a mobile sink M installed on a transportation vehicle move along a fixed trajectory L periodically. Let us assume that sensor nodes are randomly deployed in the neighbourhood of the trajectory. When M arrives at the end point of its path once and returns back to the start point, we say that it has completed one round. The mobile sink collects data from sensor nodes while moving close to them. According to the communication range of M, the monitored region can be divided into two parts, the direct communication area (DCA) between trajectories L1 and L2 (see Fig. 1), and the multihop communication area (MCA) for far-off sensors. Sensor nodes within the DCA, called subsinks, can directly transmit data to the mobile sink due to their closer proximity of the trajectory, L. On the other hand, sensors within the MCA, called members, must first relay data to the subsinks which complete the final data transmission to the mobile sink. In Fig. 1, the communication time between each subsink and the mobile sink is assumed to be not fixed due to the fixed movement path and not constant speed of M. So each subsink has an upper bound on the amount of data that can be transmitted to the mobile sink in one round.

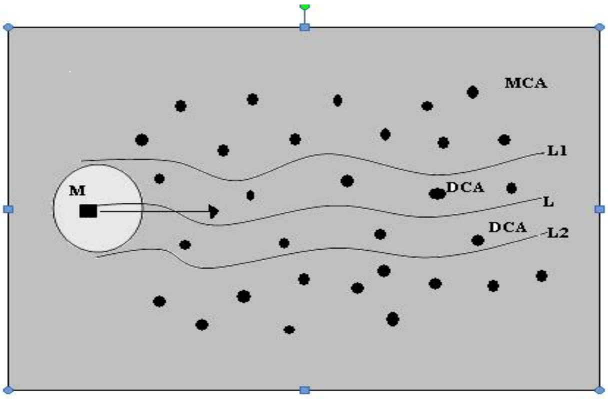

Fig1. An example of path-constrained and controlled speed mobile WSNs

The throughput of the WSN is dependent on the relationship between the upper bound on the data collected and the number of members belonging to each subsink. The main challenge here is to find an efficient assignment of members to the subsinks that improves the data delivery performance as well as reduces energy consumption. Each member chooses the closest subsink in terms of hop distance as its destination and then sends its own data or forwards data from downstream nodes to upstream nodes along shortest path trees. In [9], the number of members associated with each subsink is independent of its communication time, which may cause imbalance in the assignment of members among the subsinks. It is possible that some subsinks with longer communication time own fewer members, implying that the mobile sink may collect less data than expected. On the other hand, some subsinks with very short communication time may own too many members. Consequently, the excess data traffic may result in oversaturated subsinks which are not able to transmit all data to the mobile sink in the limited communication duration. In other words, the SPT method has low energy efficiency for data collection. We focus on data collection strategy by varying mobile sink mobility and speed. We also provide the solution for oversaturated subsink problem using considering the energy of subsink and time give by the mobile sink to subsink to assignment of members among the subsinks . We analyze and evaluate effect of mobile sink mobility and its speed as well as member allocation to subsink for robust data collection using OTABP.

II. RELATED WORK

Sink Mobility has different types for efficient data collection strategies. Our work focuses on the path constrained sink mobility. Table 1 shows the related work on sink mobility for data collection.

A. Random Path

In [1], [2] 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.

B. 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 [4].

However, it is also assumed that all sensor nodes in MSSN are located within the direct communication range of the mobile sink. In our paper, a data collection scheme based on the multi-hop communication is designed to improve the amount of data and reduce energy consumption. Mobile sensor networks with a path-constrained sink supporting multihop communication. In [6], [8] communication protocol and a speed control algorithm of the mobile sink are suggested to improve the energy performance and the amount of data collected by the sink. In this protocol, a shortest path tree (SPT) is used to choose the cluster heads and route data, which may cause imbalance in traffic and energy dissipation. To address the imbalance problem, the MASP scheme proposed in [9] 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 [7] 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 [7] 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.

TABLE 1 Related Work on Sink Mobility

Communication Mode	Fixed Path Sink Mobility		Path Controllable Sink Mobility	
	Single Sink	Multiple Sinks	Single Sink	Multiple Sinks
Single-hop	[3],[4]	[5]	[10]	[15]
Multi-hop	[6],[7],[8],[9],this paper	[9], this paper	[13]	[14]

C. 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. A partitioning-based algorithm [10], [12] is presented to schedule the movements of the mobile element to avoid buffer overflow. The mobile sinks need to visit all sensor nodes to collect data and the path optimization is based on the constraint of buffer and data generation rate of each node. In [11] the path selection problem of a mobile device is determined to reach the smallest amount of data collection in the case of minimum energy utilization at each sensor node. It is assumed that each sensor node sends its data directly to the mobile device.

However, single-hop communication is not feasible due to the limitation of road infrastructure and requirement on delivery latency. A rendezvous-based data collection approach in [13], is to select the optimal path due to the delay limitation in WSNs with a mobile base station. The mobile element visits exact locations, called rendezvous points, according to the precomputed schedule to collect data. The rendezvous points buffer and aggregate data originated from the source nodes through multihop relay and transfer to the mobile element when it arrives. A distributed and network assisted sink navigation framework is to balance energy consumption and collection delay by choosing appropriate number of multiple hops. In [14] 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.

III. PROPOSED SYSTEM

We proposed data collection scheme OTABP, the main task of OTABP scheme is assignment of member to subsink for robust data collection in wireless sensor network.

A. OTABP algorithm steps

Algorithm 1 shows the details steps on the member allocation to subsink.

Algorithm1. Optimal Terminal Assignment based Path solution

1. if mobile sink node then
   parent=self
   else
   parent=BROADCAST_MAC_ADDRESS
2. Let sink moves from (x1,y1) to (x2,y2)
3. Let n is number of nodes, nc is number of subsinks desired
4. Let node is vector representing node of size n
5. Let distance() is vector representing distance of node from path
6. for i=0 to n
   repeat
   a. distance(i)= sqrt(((y2-y1)*node(i).x-(x2-x1)*node(i).y-x1*y2+x2*y1)^2)/sqrt(((x2-x1))+(y2-y1)
7. for i=0 to n
   repeat
   a. for j=1 to n
      repeat
      if distance(i)>distance(j) then
         temp=distance(i);
         distance(i)=distance(j);
         distance(j)=temp;
         tempNode=node(i);
         node(i)=node(j);
         node(j)=tempNode;
8. select top nc nodes as subsink from sorted list
9. calculate cost matrix(distance) of each node to each subsink
10. Initialize weights for each subsink as 1
11. for each node find and sort list of subsinks
12. Let tradeoff(i) = Cost(i,0)-alpha*(Cost(i,1)
13. find minimum in tradeoff
    a. if weight of subsink is not exceeding limit
       assign node to subsink
       else
       update cost and tradeoff
14. Repeat 13 till all nodes are assigned to some subsink

B. Computation of Energy Module and Data Module

Formula for Data collection,

$$q_{total} = \sum_{i=1}^{n_s} q_i \qquad (1)$$

Total Amount of Data = q_{total}
Amount of Data from subsink i = q_i

Formula for energy consumption,

$$p_{total} = \sum_{i=1}^{n} e(2h_i + 1) \cdot q \qquad (2)$$

Total Energy Consumption= p_{total}
Energy consumption per Bit = e
Total amount of data sensed by each node= q
Shortest hops from sensor node to its Subsink= h_i

C. Section Headings Result

Result analysis in Table 2 shows comparative analysis based on data collection and energy utilization of network using Shortest Path Tree (SPT) vs Maximum Amount Shortest Path (MASP) vs Optimal Terminal Assignment based Path (OTABP).Table 2 represents comparative result analysis by considering lifetime of network**.**

TABLE 2
Result analysis

Protocol	Time in seconds	Data collection in Packets	Energy Utilization in Joules
SPT	2000	7.83	6586.08
MASP	2000	23.08	11809.58
OTABP	2000	597.33	4567.92

OTABP also uses the speed of mobile sink which is useful for increasing the network lifetime. In congested area mobile sink moves slowly and collects maximum data thus it reduces the congestion in the network and also increases the network lifetime.

Fig.2, we make a comparison among SPT, MASP and OTABP to evaluate data collection,

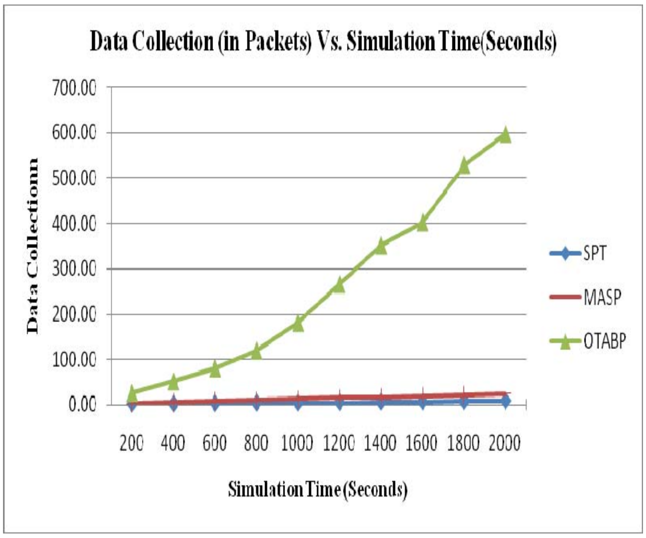

Fig.2. Simulation Time Vs Data Collection in SPT, MASP and OTABP

Fig.3, we make a comparison among SPT, MASP and OTABP to evaluate the energy consumption,

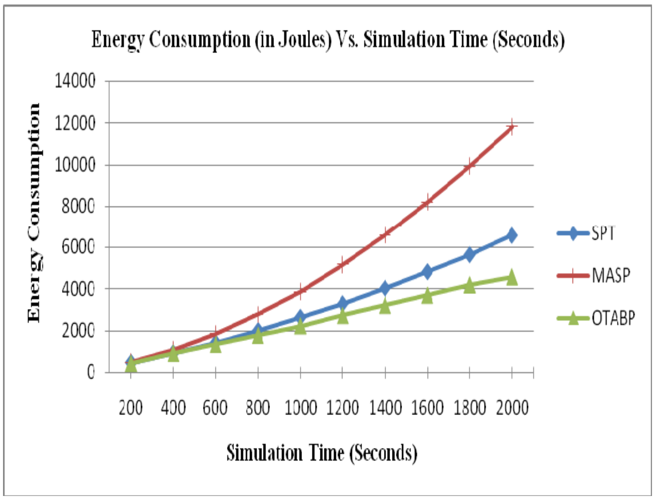

Fig.3. Simulation Time Vs Energy utilization in SPT, MASP and OTABP

IV. CONCLUSIONS

OTABP is efficient data collection scheme in wireless sensor networks. In OTABP, the mapping between sensor nodes (members) and subsinks is optimized to maximize the amount of data collected by mobile sinks and also balance the energy consumption. OTABP has good scalability to support sensor networks with low density and multiple mobile sinks. A heuristic based on genetic algorithm and local search is presented to solve the OTABP optimization problem considering the energy of subsink and time given by Mobile Sink to subsink. Design a communication protocol that supports OTABP and adapts to dynamic topology changes. We proposed the schemes OTABP on different scenarios with various movement trajectories and controlling the speed of mobile sinks for robust data collection. Simulation experiments under OMNET++ show that OTABP improves the energy utilization efficiency, also outperforms MASP and SPT methods in terms of total amount of data with increase the network lifetime. To study the dynamic subsink selection problem with network lifetime maximization as the optimization objective as future work.

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