International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 12, December 2016
www.ijates.com
ijates
ISSN 2348 - 7550

ROBUST DATA COLLECTION IN WIRELESS SENSOR NETWORKS WITH FIXED PATH AND CONTROLLED SPEED MOBILE SINKS

Mr. Shrikant D. Dhamdhere

Assistant Professor , Department of Computer Engineering

Paravatibai Genba Moze College of Engineering, Wagholi , Pune, Maharstra, (India)

ABSTRACT

Recent work has shown that sink movement along a fixed path and speed control can minimize the energy utilization in wireless sensor networks. Due to the fixed path, a movable sink with fixed speed has limited communication time to collect data from the subsink and member nodes deployed randomly. This method poses significant challenges in jointly improving the amount of data collected and reducing the energy consumption. To tackle this issue, we propose a new method for data collection, called the Maximum Amount Shortest Path (MASP) that increases network throughput as well as conserves energy by optimizing the assignment of sensor nodes to the subsinks. Two phase communication method based on efficiently assignment of the member node to subsinks. Current work also implements a practical distributed 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 MASP with different scenario (MASP-WDS) of controllable movable sink. Which increase also network life time.

Keywords: Sensor Networks, Movable 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). Mobile sinks are mounted on some people or animals moving randomly to collect information of interest sensed by the sensor nodes where the sink trajectories are random [1] [2]. Efficient data collection problems are often concerned to improve the network performance. Path constrained 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]. We study multihop sensor networks with a path-constrained 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 [8], focuses on large-scale dense WSNs with path-constrained 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 neighborhood 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.

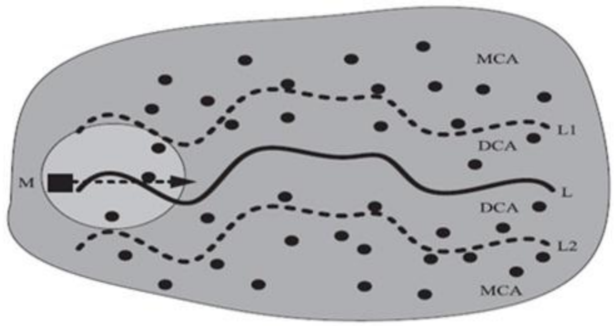

Fig1. An example of path-constrained mobile WSNs

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 (or) between each subsink and the mobile sink is assumed to be fixed due to the fixed movement path and 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. 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. However, 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. We analyze and evaluate effect of mobile sink mobility on data collection strategy.

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ijates ISSN 2348 - 7550

II RELATED WORK

2.1 Data Collection Methods

Different data collection methods are suggested in WSN. Our work focuses on shortest path tree data collection and Rendezvous Based Data Collection to collect the efficient data in WSN. Types of data collection methods are discussed below.

Direct-Contact Data Collection: Mobile sink collects data directly from data sources by one hop communication. Sinks may retransmit data or, if needed, physically carry the data to a fixed base station.

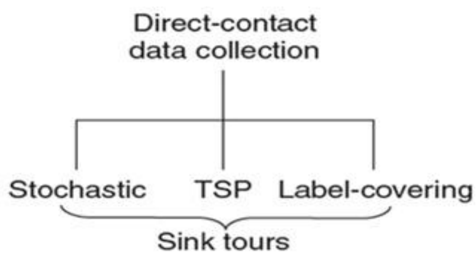

Fig.2. Data Gathering in delay tolerant WSN Direct Contact data collection

Sink Trajectory Methods: Sensors buffered their measurements locally and wait for the arrival of a mobile sink. Energy consumption at sensor side is only due to sink discovery and subsequent data transfer. Sink broadcasts a beacon message while moving. Sensors monitor the wireless communication channel. Whenever a sensor hears the beacon message it concludes that a sink arrives. Constant channel monitoring is very expensive. If sinks move along regular path, then sensors can predict their arrival after being allowed a learning curve for their movement pattern. Data transfer should start in an intelligent way, if a sensor simply transmits as soon as it discovers the sink, data may not be successfully delivered or may be delivered with many retrials, wasting energy. Data transfer should take place in the time interval with minimum message loss probability, which is exactly around the minimum sensor-sink distance point. With controllable sink mobility and knowledge of sensor locations, data collection delay can be reduced by properly selecting sink trajectory. The sink traveling problem as a variant of TSP, known as traveling salesman with neighborhood(TSPN)where a sink needs to visit the neighborhood of each sensor exactly once.

Intuition: it is sufficient for the sink to be within the communication range (modeled as disk) of a sensor in order to retrieve data from that sensor. The requirement for exact one-time visit of the sink to each sensors communication range. Intuition: Sinks travel time could be long if the length of the intersection of its path and the communication range of each sensor is short. Exact one-time visit may not always be a winning strategy. On the contrary, multi-visits together with proper speed control may yield a better solution. The sink simplified the path trajectory problem by reducing search space to a complete geographic graph, where there are vertices at sensors locations. The sink moves in this graph along edges from vertex to vertex. Each edge is associated with a cost and a set of labels. Cost is defined as Euclidean length of the edge; the label set represents the set of sensors whose communication ranges intersect with this edge. The objective is to find a shortest (minimum-cost) tour whose associated label set covers all sensors. They proved that the shortest label-covering tour problem is NP-hard, and presented an approximation algorithm to solve it. The algorithm finds a TSP tour by any TSP solver. Then, by dynamic programming, it finds the shortest label covering tour that can be obtained by applying shortcutting to the TSP tour.

Shortest Path Tree: The Shortest Path Tree (STP) method is proposed to choose subsinks and relay data from members. 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. However, 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. Aiming at the data delivery problem in large-scale wireless sensor networks with mobile sinks which move along fixed paths with constant speed, we propose an efficient data collection scheme that simultaneously improves the total amount of data and reduces the energy consumption. In our scheme, the members within the MCA are assigned to the corresponding subsinks within the DCA according to the length of the communication time between the mobile sink and the subsinks, thus improving the network throughput.

Rendezvous Points Data Collection: Proposed to achieve trade-off of energy consumption and time delay. Sensors send their measurement to a subset of sensors called rendezvous points (RPs) by multi-hop communication; a sink moves around in the network and retrieves data from encountered RPs. RPs are static, data dissemination to RPs is equivalent to data dissemination to static sinks. The path selection problem of a mobile device is focused to achieve the smallest data delivery latency in the case of minimum energy consumption at each sensor. 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 is to select the optimal path due to the delay limitation in WSNs with a mobile base station. In this work, the mobile element visits exact locations, called rendezvous points, according to the pre computed schedule to collect data.

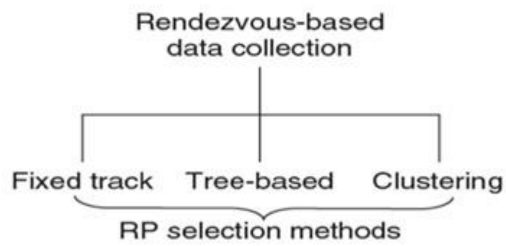

Fig.3. Data Gathering in delay tolerant WSN Rendezvous Based data collection

The rendezvous points buffer and aggregate data originated from the source nodes through multi hop relay and transfer to the mobile element when it arrives. A problem similar to the one is based on multiple mobile elements. A distributed and network assisted sink navigation framework is to balance energy consumption and collection delay by choosing appropriate number of multiple hops. A distributed and localized solution to decide sinks movements when the movement paths are not predetermined in WSNs supporting multi hop communication.

2.2 Sink Mobility Types

Sink Mobility has different types for efficient data collection strategies. Our work focuses on the path constrained sink mobility and Path controllable sink mobility.

1) Random Path: In sensor networks where the path is random the mobile sinks are often mounted on some people or animals moving randomly to collect interested information sensed by the sensor nodes. Due to random mobility, it is difficult to bound the data transfer latency and the data delivery ratio.

2) 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. An architecture of wireless sensor networks with mobile sinks (MSSN) for a traffic surveillance application. 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. A 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 [8] 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 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.

3) Path-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. The work is extended to support more complex scenario with multiple sinks. A partitioning-based algorithm 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. The path selection problem of a mobile device is focused to achieve the smallest data delivery latency in the case of minimum energy consumption at each sensor. It is assumed that each sensor node sends its data directly to the mobile device.

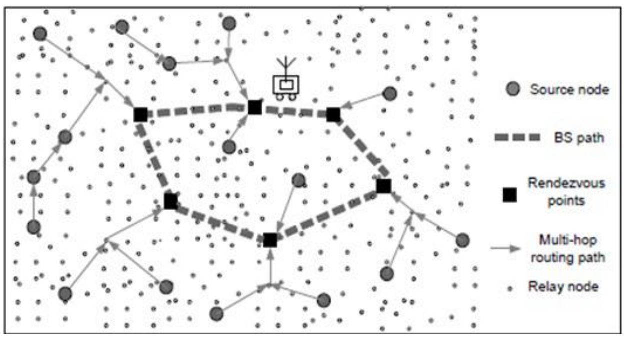

Fig.4. Rendezvous Based Data Collection

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 is to select the optimal path due to the delay limitation in WSNs with a mobile base station. In this work, 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 problem similar to the one is based on multiple mobile elements. A distributed and network assisted sink navigation framework is to balance energy consumption and collection delay by choosing appropriate number of multiple hops. 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 IMPLEMENTATION DESIGN

3.1 Proposed System

1) MASP-D with Two-Phase Communication Protocol: A centralized communication protocol to support the MASP data collection scheme, MASP consists of two main phases: discover phase and data collection phase.

Phase 1: Discover Phase the main tasks of the discover phase include learning the topology information and assigning the members to their corresponding subsinks. To complete the tasks, the discover phase is performed through two different rounds described below.

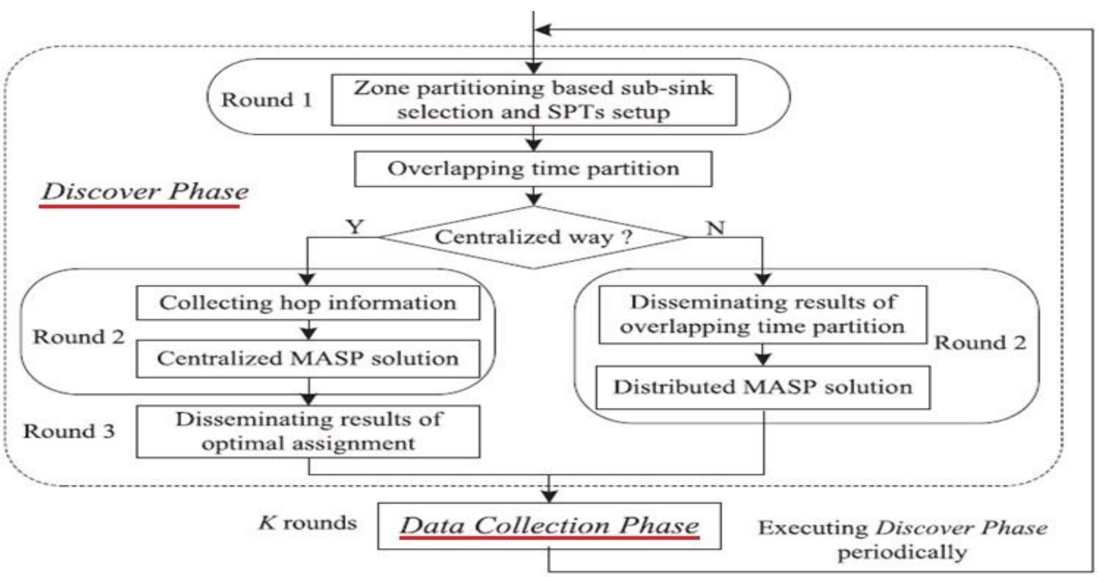

Fig.5. Flowchart of the proposed two-phase communication protocol

Round 1. In this round, the mobile sink transmits broadcast messages continuously. All nodes receiving the broadcast messages from the mobile sinks are automatically selected as subsinks. Then the subsinks start building the shortest path trees (SPTs) rooted from themselves in entire network. As a result, each node obtains the shortest hop information from themselves to all subsinks and then send the related hop information to the corresponding subsink. The latter will transmit the hop information to the mobile sink.

Round 2. In Round 2, the mobile sink traverses the trajectory again to broadcast the results of member assignment to the monitored area. The broadcast message consists of the list of the mapping relation between each member and its destination subsink. Each node receiving the broadcast message will get a subsink as its destination. Then the node will delete its own item in the broadcast message and rebroadcast it. Finally, the optimized member assignment information will be disseminated to the entire network.

Phase 2: Data Collection Phase In this phase, all nodes start collecting data from the monitored area formally. The members send the sensed data or forward data to the destination subsinks according to the routing table built in Round 1 of the discover phase. Subsinks precache all data from their members and themselves before the mobile sink enters into their communication range. During the actual data collection, we adopt a handoff method to partition the overlapping time which is consistent with the one used in Round 2. In order to load balance the data originated from members, a roundbin scheme is used to transmit data at the subsinks.

3.2 Project Scope

An efficient data collection scheme called MASP for wireless sensor networks with path-constrained mobile sinks. MASP has good scalability to support sensor networks with low density and multiple mobile sinks. Design a communication protocol that supports MASP and adapts to dynamic topology changes. Two practical algorithms, a zone partitioning based solution and a distributed solution (MASP-D). Also study the impacts of different overlapping time partitioning methods and present an optimal partitioning scheme (Opt- ShareOT). MASP improves the energy utilization efficiency and outperforms SPT and static sink methods in terms of total amount of data with almost the same energy consumption. Also plan to validate the proposed schemes on different scenarios with various movement trajectories of mobile sinks.

3.3 Mathematical model

1) Let S be a system that describes Robust Data Collection in WSN with Path-Constrained Mobile Sink S={ ....}.

2) Identify input as I

S= {I......

I= {M | where M is Broad Casted Message from Mobile Sink or Broad Cast message to member}

3) Identify output as O.

S= {I, O .....

O= { Output | Output is Routing Information about subsink}

4) Identify the processes as P.

S= {I, O, P....

P= {SS, MS, MF}

SS is SubSink process

MS is MobileSink process.

MF is MemberFunction

5) SS= {BroadCasted Message From MobileSink,

BroadCast message to member}

6) MF= {BroadCasted Message From SubSink, Output

Routing Information about subsink, Info}

7) Identify failure cases as F.

S = {I, O, P, F...

Failure occurs when incorrect routing information about subsink is generated due to inefficient data collection

8) Identify Success cases as s

S= {I O, P, F, s...}

Success means correct routing information about subsink is generated with efficient data collection.

9) Identify initial condition IC S= {I, O, P, F, s, IC}

There is no initial condition IC= {All Members must be active}

3.4 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

IV RESULT

Result analysis in Table 1 shows comparative analysis based on data collection and energy utilization of network using Maximum Amount Shortest Path- Distributed (MASP-D) vs Maximum Amount Shortest Path- Distributed with different scenario (MASP-DWDS).

Table 1 represents comparative result analysis by considering lifetime of network.

Table 1: Result analysis

Protocol	Time in ms	Data collection in kb	Energy Utilization in Joules
MASP-D	483.00	32	272
MASP-DWDS	483.00	36	276

MASP-DWDS 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.

Figure 6 shows graph of Simulation Time Vs Data Collection in MASP-D and MASP-DWDS

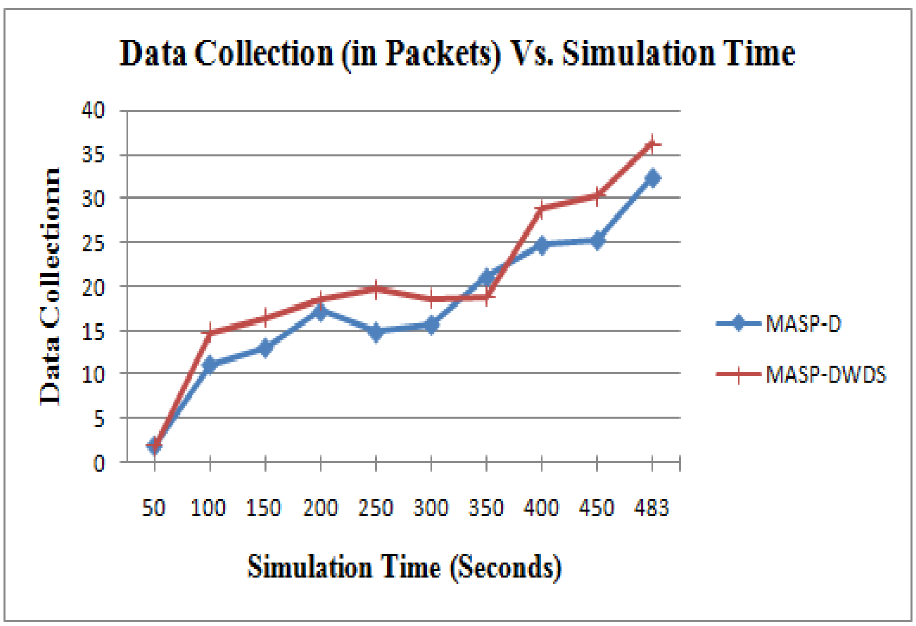

Fig.6. Simulation Time Vs Data Collection in MASP-D and MASP-DWDS

Figure 7 shows graph of Simulation Time Vs Energy utilization in MASP-D and MASP-DWDS

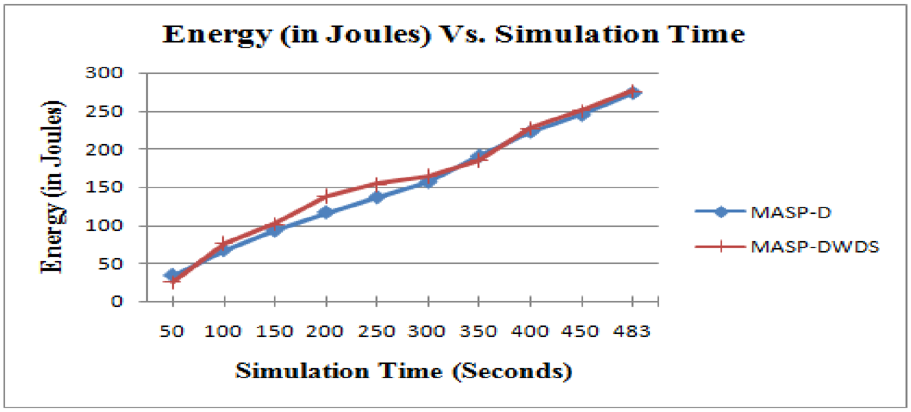

Fig.7. Simulation Time Vs Energy utilization in MASP-D

IV CONCLUSION AND FUTURE WORK

MASP is efficient data collection scheme in wireless sensor networks. In MASP, 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. MASP 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 MASP optimization problem. Design a communication protocol that supports MASP and adapts to dynamic topology changes. To reduce the computational complexity, we have used distributed solution (MASP-D) method. We proposed the schemes (MASP-D) on different scenarios with various movement trajectories and controlling the speed of mobile sinks for robust data collection. To study the dynamic subsink selection problem with network lifetime maximization as the optimization objective as future work.

ACKNOWLEDGMENT

I am Shrikant Dhamdhere and would like to thank the publishers, researchers for making their resources available. I also thank the college authorities Dr. Ayesha Butalia: Research Dean and Dr. N. S. Narawade: Principal of Paravatibai Genba Moze College of Engineering for providing the required infrastructure and support. Finally, we would like to extend a heartfelt gratitude to friends and family members.

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