Reduction in energy consumption by using multiple Mobile-Sinks in Wireless Sensor Networks

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Abstract- Wireless sensor network (WSN) consists of large number of sensor nodes deployed in wide area. Sensor nodes sense data and send it to special nodes called as sink. Sensor nodes are powered with non rechargeable battery. Minimizing energy consumption of the node to prolong network lifetime is a critical issue. Recent research has shown network lifetime of wireless sensor networks improves considerably by using a mobile sinks. Mobile sinks act as data collectors which roam in the WSN to collect data from sensors by short communication path. In this paper proposed Weighted Rendezvous Planning with multiple Mobile Sinks (WRPMSs) algorithm. In this strategy, network is divided into multiple sub networks. A mobile sink is assigned to each sub network. Weighted Rendezvous Planning (WRP) algorithm is applied to each sub network to find out Rendezvous Point (RP) and sink path. Energy consumption is reduced by 40 to 46% in case of 4 mobile sinks compare to the WRP.

Keywords: *wireless sensor networks; mobile sink; Rendezvous Nodes, energy hole, network lifetime*

I. INTRODUCTION

WSN is distributed infrastructure which combines the capability of sensing and wireless communication. Sensor nodes deployed in the field which has capacity to collect and process data from environment (refer figure 1). In WSN nodes can be categorized as source node, sink node and intermediate nodes depending upon functionality in environment.

Sensors that are generating data are called sources. They transmit their data to one or more sinks for processing.

Sinks are special nodes which play role of data collector. Data is transferred from source node to sink node in multihop pattern. Intermediate nodes forward data towards sink node as sinks are out of the transmission ranges of most of sources.

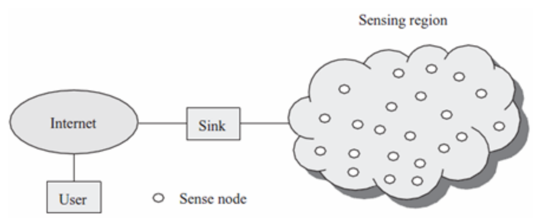

Figure 1 Wireless Sensor Network

Sensors are small, portable, lightweight battery operated device. Nodes are often deployed to hostile environment. Therefore replacing or recharging batteries on a large scale is not realistic.

The energy consumption of sensor nodes should be minimized to maximize the network lifetime of the Wireless Sensor Network. The sensor nodes which are near to the sink drain fast as compare to other nodes in the network as farther away nodes forward their data to sink through these nodes which are near to sink. Farther away nodes initial energy last more than 90% compared to the nodes near to sink [1]. Once exhausted, communication on the corresponding link is stopped which cause the separation of network. Data coming from the link will not reach to sink. Nonuniform exhaustion of energy leads to formation of energy holes [2].

Sink mobility has been exploited to reduce and balance energy expenditure among sensors. By moving the sink in the sensor field, energy hole problem can be mitigated. Usefulness of mobile sink is highly dependent on the data collection method the mobile sink adapted and path followed by the sink in the sensor field. A mobile sink could be mounted on a mobile robot or a vehicle equipped with a powerful transceiver, battery, and large memory.

Depending on how mobile sink collect data from the sources, there are two categories [3]. Direct-contact collection and Rendezvous based data collection. These two categories have further classified depending on their implementation for path selection.

II. LITERATURE SURVEY

Ming Ma et al [4] suggested direct contact collection mechanisms for large scale sensor networks where single or multiple M-collectors (mobile sinks) are used to collect data from the static sensors. M-collector can visit the transmission range of every static sensor, such that sensing data can be collected by a single hop communication without any relay. The mobile data collector starts a tour from the data sink, traverses the network, collects sensing data from nearby nodes while moving, and then returns and uploads data to the data sink. The approach is useful for applications where sensing data are generally collected at a low rate and is not so delay sensitive.

Though it is simple approach, constant monitoring of beacon messages is expensive in terms of energy consumption. Also there is possibility of buffer overflow in case of delay in mobile sink arrival.

K. Almi'ani [5] describes the algorithm called Cluster-Based (CB) algorithm which provides hybrid approach where the network is divided into similarly sized balanced clusters. Each cluster allocates a node, caching points (CPs) which collects data from the sensors in that cluster. When mobile sink reaches a CP, data stored at CP is transferred to the sink. Network lifetime is increased using this algorithm significantly.

The algorithm is based on random selection of clusters which may not give optimal solution for mobile sink tour. Algorithm not considers the network where nodes have heterogeneous communication capabilities.

Charalampos Konstantopoulos et al [6] suggested cluster based Rendezvous approach for sensor data collection by mobile sink. The proposed protocol called MobiCluster. In this case the mobile sink path is fixed. The clusters near to the mobile sink path have rendezvous nodes. The data from nearby clusters is collected by the rendezvous nodes. When mobile sink reaches in the range of the rendezvous nodes, the collected data is transferred to the sink. As the role of rendezvous nodes changes on residual energy, this approach provides balanced energy consumption among sensor nodes and prolonged network lifetime.

This approach is limited to single mobile sink with fixed mobile sink path.

Xing et al. [7] [8] propose tree based rendezvous planning algorithms: Rendezvous Planning with Constrained ME Path (RP-CP) and Rendezvous Planning with Unconstrained Greedy ME Path (RP-UG). These approaches are useful to various applications having various ranges of delay requirements. But this approach has few limitations. It is a location based algorithm. Nodes and mobile sink must have GPS system to get location of each others. Both the algorithms are based on traversing the tree without considering the density of nodes or their distribution.

In-Seon Jeong et al. [9] proposed two algorithms based on minimum Wiener index spanning tree for small and large WSN with multiple mobile sinks.

Sugihara and Gupta [10] suggested Label covering algorithm to minimize the delay for Traveling salesman problem (TSP) based algorithm. WSN is considered as complete graph where sensors represent vertices of the graph. Also sink initial position is one of vertex of the graph. Each edge of the graph is assigned with cost which is equal to the Euclidean distance between nodes. A label is associated with the edge. Label contains all the nodes having transmission range crossing the edge. Label gives the list of sensors from where the mobile sink can collect data while moving on that particular edge. Objective of algorithm is to find out shortest path for mobile sink so its associated label covers all sensors.

To overcome the limitations of tree base approach, Hamidreza Salarian [11] suggested WRP algorithm for controlling movement of mobile sink. As shown in figure 2, the sensor nodes send data to nearest Rendezvous Point (RP). Mobile sink then collect data from these RPs. Selection of RP depends on Weight of the node. Weight depends on Number of packets forwards and hop distance from mobile sink path.

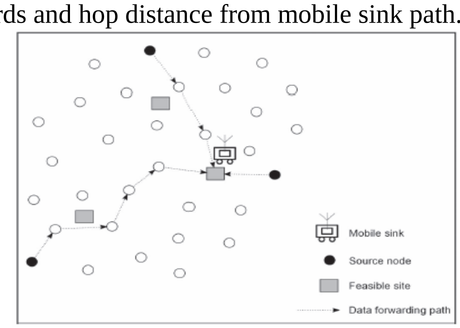

Figure 2 mobile sink collecting data in a WSN [11]

Energy consumption is reduced if node is selected as RP which has more weight. Next step of the algorithm is to find the optimal path to visit all these RPS. It is TSP which is the NP hard problem.

Using WRP algorithm Energy expenditure of sensor nodes is minimized. But results may vary for Large WSN.

III. PROPOSED SCHEME

To improve the life time of the network, this paper proposed Weighted Rendezvous Planning with multiple Mobile Sinks (WRPMSs) approach for WSN.

Assumptions - Nodes are equally distributed in each zone. Mobile sinks tour time is defined. Sink to sensor node communication time and multihop communication delay within sensor nodes are negligible compared to the sink node's roaming time. RP has sufficient buffer size to store all data sent by sensor. The mobile sink halt time is good enough to get all data from RP. The mobile sink is knows the RP location. The network is connected. Data transmission range is fixed and same for all sensor nodes. Data pack size and time interval are same for all sensor nodes.

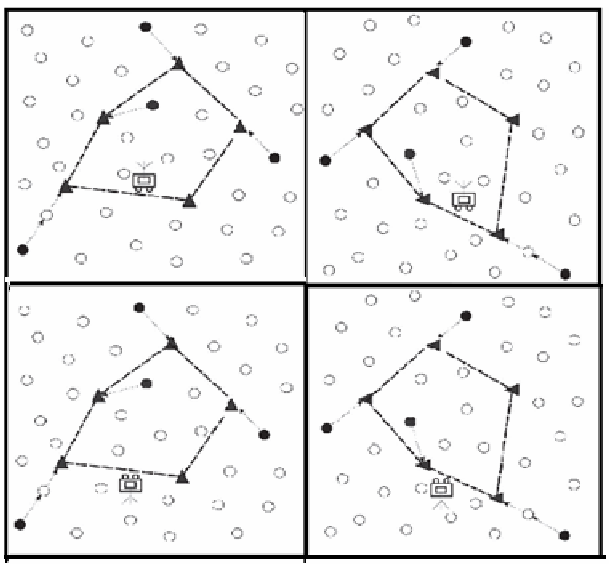

Figure 3 multiple mobile sinks in a WSN

Assume scenario of network shown in Figure 3. Consider the network with randomly deployed sensor nodes. The network is partitioned into the number of sub network (for example 4 zones in figure 3).
Each sub network has a mobile sink. SPT (shortest path tree) rooted at the mobile sink node initial location is constructed. The RP selection and the mobile sink path calculation is an iterative process. Each node in the sub network is assigned weight which depends on the number of packets it forward and the hop distance from the mobile sink path. The node with highest weight is selected as RP. The mobile sink path is calculated by applying TSP. if the calculated path is more than the given mobile sink path length then the RP is removed from the path and next highest weighted node is considered as RP. The weight of remaining nodes is recalculated considering updated mobile sink path. The processes continues till the mobile sink path is less than or equal to the given mobile sink tour length.
Source nodes belong to particular sub network send data to the mobile sink for that network either by direct transfer or by forwarding data to the nearest RP.

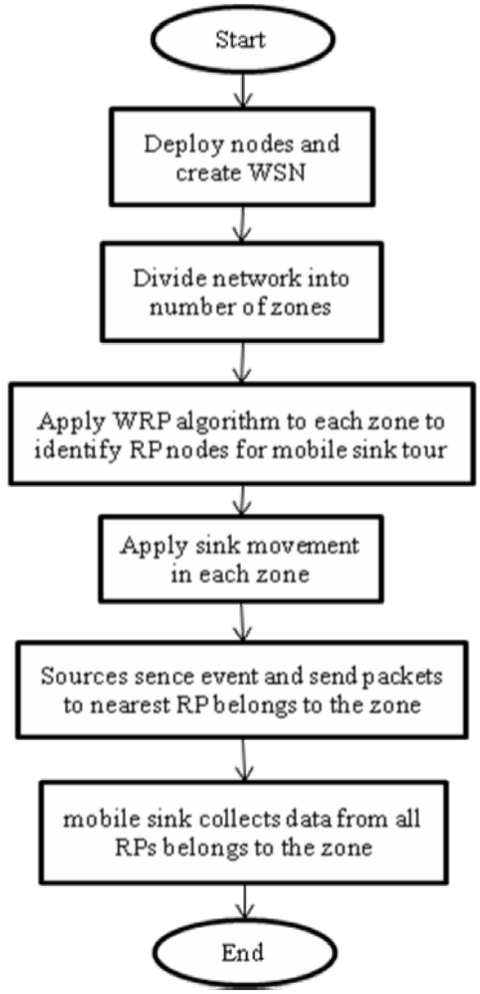

Figure 4 flow chart of proposed solution

Figure 4 shows overall flow of the proposed solution.
WSN is divided into number of zones (1,2,3 zones etc). For each zone WRP algorithm is applied to find out RPs for that zone. Analysis and comparison of the performance of multiple sinks against single sink is done.

IV. SIMULATION RESULTS

Evaluate of proposed scheme is perform on NS2 simulations.

The sensor nodes produce one data packet after every T time that is forwarded to RP through shortest-path tree (SPT). Packet delivery ratio (PDR) is depends on mobile sink speed [12]. PDR increases as sink speed increases. The simulation settings are summarized in following table 1.

Table 1 simulation parameters

Parameter	**Value**
Area	1000m*1000m
Number of static nodes (n)	100 to 250
Packet length (b)	30 bytes
Sensor nodes transmission range	55m
Number of sinks	1/2/3/4/5/6/7/8
Sensor nodes battery	10J
Mobile sink speed (v)	1 m/s
Mobile sink tour	15 minutes
Topology	Grid
Routing protocol	AODV

The topology of the network is generated by uniformly deploying nodes in a 1000 x 1000 m^2. AODV routing protocol is used for analysis. In first step, complete WSN is considered as single zone with even distribution of nodes.

In next step, the WSN is divided into required number of zones (for example 4 zones) considering geometric major and allocate sink to each zone and apply WRP algorithm to each zone.

Results found for multiple sinks (2 to 8 sinks) are compared against single sink for same WSN and simulation parameters.

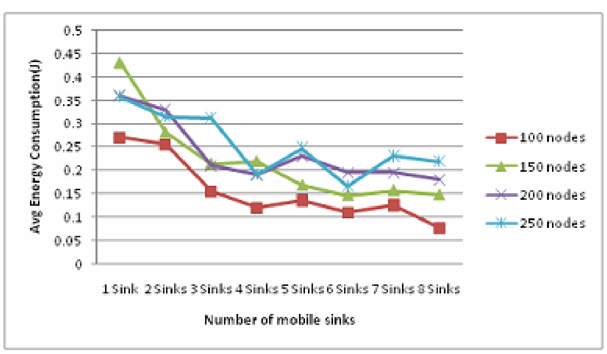

Figure 5 Average Energy Vs No. of mobile sinks

Figure 5 shows graph of average energy consumption against number of mobile sinks used for different nodes scenarios (100 nodes to 250 nodes). Graph shows that as number of mobile sinks increases the average energy consumption decreases as energy consumed in data transfer in multihopping decreases. The decrease in average energy consumption is consistent till 4 mobile sinks for all scenarios. From 5 mobile sinks, in some cases the average energy consumption increases especially for larger number of nodes.

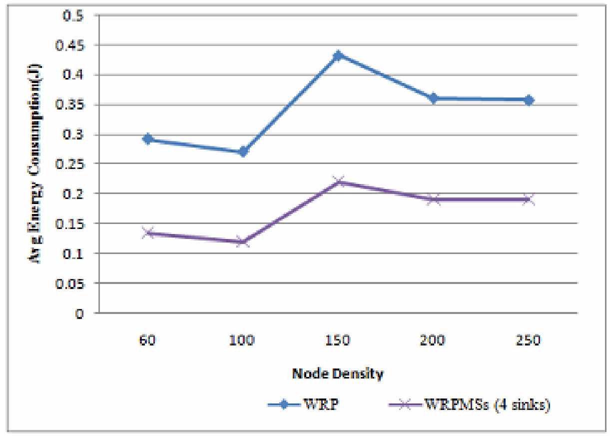

Figure 6 Comparisons between WRP and WRPMSs

Figure 6 shows that energy consumption is reduced by 40 to 46% in case of WRPMSs with 4 mobile sinks compare to WRP. As number of sinks increases the data collection in the given time will also increases as area cover by the mobile sink increases.

Packet delivery ratio is defined as the ratio of data packets received by the destinations to those generated by the sources. The greater value of packet delivery ratio means the better performance of the protocol.

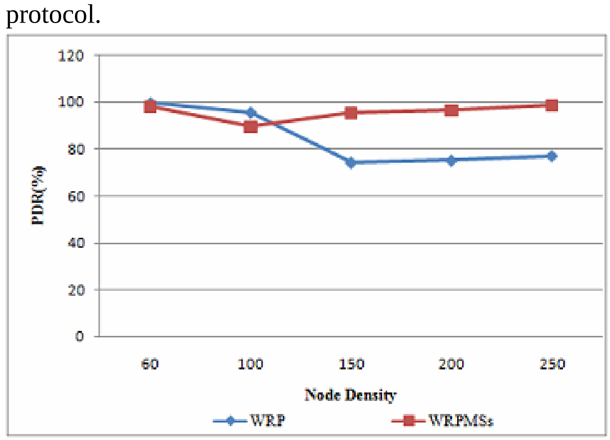

Figure 6 PDR Vs No. of mobile sinks

Figure 6 shows that as number of mobile sinks increases the packet delivery ration (PDR) increases. The increase in PDR is consistent till 4 mobile sinks for most of the cases. From 5 mobile sinks, in some cases PDR deceases especially for less number of nodes.

V. CONCLUSION AND FUTURE WORK

In this paper WRPMSs algorithm for multiple mobile sinks in WSN is proposed and analyzed. Simulation results demonstrate that the energy consumption of the network reduces as we use multiple mobile sinks.

Upto 8 zones (8 mobile sinks) are studied for WSN where node density varies from 100 to 250 nodes. It has been found that till 4 mobile sinks the energy consumption reduces. After that energy consumption varies. Energy consumption is reduced by 40 to 46% in case of 4 mobile sinks compare to the single mobile sink.

In future work –
The given design can be enhance to include data with different delay requirements. This means a mobile sink is required to visit some sensor nodes more frequently than others while ensuring that energy usage is minimized.

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