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Rendezvous points selection to enhance network lifetime using mobile carrier in wireless sensor networks

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Abstract — **Wireless sensor networks (WSN) have a wide range of applications for today's needs. They can be applied to simple monitoring systems to body sensor networks. Traditional, static WSN encounters problem such as energy hole problem near the sink .This is because the neighbors of sink are burdened to carry the load of the data of other sensors behind them. So they drain up their energy very quickly resulting in area being drained of energy and resulting in formation of energy hole. This leads to serious problems as the sink becomes unavailable to other sensors near the periphery of the network resulting in network partition. This problem can be solved by adding external mobile carrier (MC) of data to the sink. The work of the MC is to visit the nodes to collect data and deliver to the sink. The MC need not visit the nodes but it can visit the selected points called as rendezvous points (RPs) and collect the buffered data and deliver to the sink. The other nodes can send their data to their nearest RPs where the data will be buffered to be collected by an MC. In this paper we propose an RP based approach to continually monitor and collect data from the area of interest such that the network lifetime is prolonged. This approach is validated with existing schemes and shows considerable performance improvement. This approach prolongs network lifetime in addition to minimizing delay and energy consumption.**

Index Terms: *Mobility, Sink,mobile carrier, rendezvous points.*

1.Introduction

The WSN consists of large populations of wirelessly connected nodes, capable of computation, communication, and sensing. Static WSNs have limitations when applied to support multiple missions or when the network conditions changes often. MCs can be used to address these problems as mobility can significantly increase the capability of the static WSN by making it resilient to failures, reactive to events, and be able to support disparate multiple missions. The feature of MC is that the MC can move all the time. So the growing technique of mobility has enabled many new challenging applications in WSN. Mobility in sensor networks can be categorized into weak and strong mobility. Weak Mobility arises because of topology changes, node joins, and node failures. Strong Mobility occurs because of concurrent node joins, failures and physical mobility which is either because of mobility in the medium or by means of special motion hardware.

Mobility management scheme is needed to ensure that MC mobility is exploited in the best possible way. The sensor network protocol stack [1] includes a common network stack along with power management plane, mobility management plane and task management plane. The mobility management plane is responsible for any sort of mobility of the MC with in WSN. It basically detects and registers the movement of MC, so a route back to the user is always maintained and the MC can keep track of who their neighbors are. By knowing whom the neighbors the MC can balances its task and power usage.

2. Related Work

In an network, not all of the sensor nodes are required to carry out the sensing tasks, subset of nodes can be assigned as special nodes called as RPs to collect and buffer data from their neighbors.

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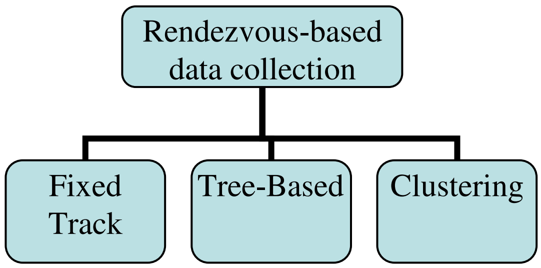

Fig 1. Rendezvous based collection strategies

The RPs are visited by the MC to collect the buffered data and deliver to the sink with time delivery. The RP based approaches can be classified as in the Fig 1.

In fixed track strategy, the path or the trajectory of the MC are fixed. The RPs are the nodes that lie along the path of the MC. In [2] the authors propose to use a straight-line sink path for data collection. The sink is the MC and moves along a straight line and broadcasts a beacon while moving. Then a number of minimum hop shortest path spanning trees are established along its path. The root becomes the RPs. The sink follow the straight line path and the RPs send their own data and their member's data when the sink is within their communication range. In [3] the authors consider multiple data mules [10] that move along the straight line to collect data from the sensors in their path.The tour length of the MC is not defined so it may result in buffer overflow at the RPs and the data is not delivered in time at the sink. So this strategy does not consider the buffer size, timely delivery and is not energy conscious.

In a tree based approach, the MCs move along a tree to collect data. In [4] , the sink moves along the selected RPs on a geometric tree , the RPs are selected such as the total length of edges that connect the sources to RPs are minimized. This achieves time delivery as the sink tour is not larger than the maximum distance that the sink can travel within a given data collection dead line. In [5], they propose two algorithms to find a set of RPs that can be visited by mobile elements within a required delay, while the network energy consumed in transmitting data from sources to RPs is minimized. The first one RP-CP finds the optimal RPs when the mobile elements move along the data routing tree. The second one RP-UG finds RPs with good ratios of network energy saving to mobile elements travel distance. The tree based approach results in uneven traffic load and constrained network lifetime.

In cluster based approach [8], the network is grouped into number of balanced clusters. Then an RP is selected from each cluster, and the MC visits each [illegible]ollect data. The authors in [6] propose a [illegible] data collection framework without location information. In this work, a minimum k-hop dominating set of navigation agents and intermediate navigators form a connected overlay graph. Then and distributed TSP algorithm is adopted to find a sink tour of navigation agents over the overlay graph. In [7] a weighted rendezvous planning algorithm with unconstrained mobility pattern for sink is proposed. The nodes are assigned weights based on the number of packets that they forward and their distance from their nearest RP. The objective is to find a sink tour of maximum allowed length choosing the highest weighted nodes as RPs. The cluster based approach described is almost centralized ones requiring full knowledge of the network. They do not scale well and have very limited applicability in practice, because WSN are usually deployed at random and are full of dynamics. In our heuristic we have addressed all the limitations to enhance network lifetime.

3. A Heuristic based approach to maximize network lifetime using mobile carrier

In single hop data collection the MC visits each node in the network (Fig.2.) to collect data resulting in data latency and wastage of energy.

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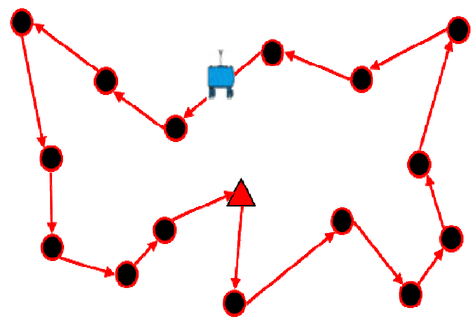


Fig. 2 . Single hop collection of data by MC

In rendezvous based multi-hop data collection, from the whole network a subset of sensors are chosen as RPs as in Fig.3.

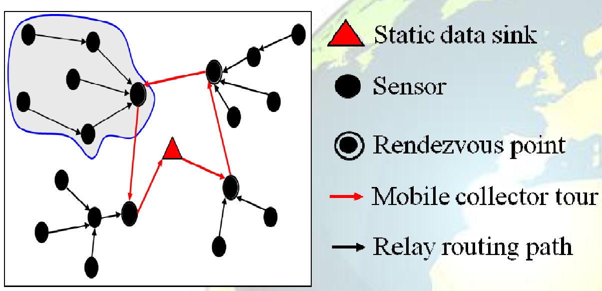
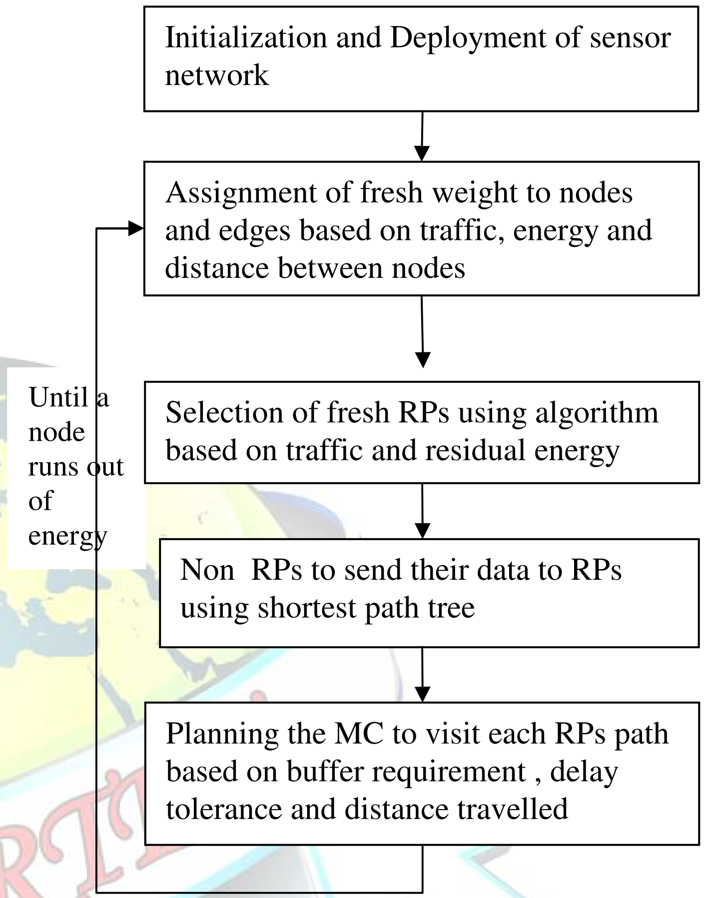


Fig .3 .Multi-hop rendezvous based collection of data by MC

The MC periodically travels along a predefined tour and picks up data at RPs, while nodes that may directly reach a RP buffer data originated from other nodes and transfer the data to the MC when it arrives at the RP. The advantage of this approach, compared with those slow mobility approaches, is that the multi-hop routing can be configured offline, as it does not change with different locations of the MC. Multiple MCs can also be considered.

The algorithm starts with initialization and deployment of the sensor nodes. Then each nodes are assigned weight based on the traffic they carry and the residual energy it has at that particular point of time. The edges between two nodes are assigned cost based on the distance and the energy to send and receive packets. Once the weights are assigned the RPs are chosen which has the highest score. Then an tour is finalized for the MC based on the weight of the edges ,the buffer requirement ,the distance an MC can travel and the energy factors. Then the MC visits all the RPs and collects data and passes it on to data collection point the sink. The flow of the algorithm is given below,



In this paper, a rendezvous based data gathering scheme is proposed. This scheme uses sub set of nodes known as RPs which act a temporary static sink that collect data from other sensor nodes. The RPs buffer and aggregate data originated from the source. The collected data is transferred to the MC when it is found in the communication range. the MC visits the exact locations called RPs according to the pre-computed schedule to collect data. All non-rendezvous nodes should periodically send their data to rendezvous nodes using shortest-length routes. The Proposed algorithm consists of three phases,

1. Selection of RP points
2. Formation of tree on the selected RP
3. Data Collection by the MC

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3.1 Selection of RP points

Each node sends their energy level and neighbor information details and the data to the sink periodically. On the route to the sink, each node check their energy level with the packet received. If the energy is greater than the received packet it replaces the energy level and its node identification in the packet and forwards to the other nodes. This sink, at last receives information about some of the nodes in the network with high energy and analyses their neighbor information to find out a subset of nodes. The sink chooses a subset of nodes to be the RPs. As soon as the RPs receives information from the sink, it advertises to the neighbors. The neighbors attach themselves to the nearest RPs forming sub-trees with RP as the root as in Fig.4.

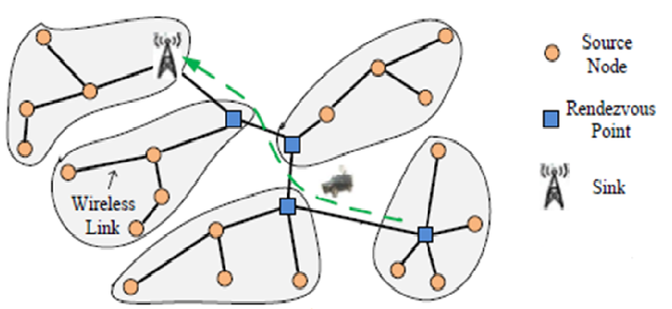

Fig .4 .Formation of sub-trees with RP as the root

3.2 Formation of tree on the selected RPs

Then a tree is constructed on the selected RPs using the Dijkstras Algorithm. The Euclidean distance between the RPs are calculated using the formula $\sqrt{(x-a)^2+(y-b)^2}$ and are assigned as the edge cost. This is used to form the shortest path routing tree using the algorithm given below,

ALGORITHM FOR FINDING THE SHORTEST PATH TREE

```
GIVEN A GRAPH, G, WITH EDGES E OF THE FORM (V1, V2)
AND VERTICES V, AND A SOURCE VERTEX, S

DIST : ARRAY OF DISTANCES FROM THE SOURCE TO EACH
VERTEX
PREV : ARRAY OF POINTERS TO PRECEDING VERTICES
I   : LOOP INDEX
F   : LIST OF FINISHED VERTICES
U   : LIST OR HEAP UNFINISHED VERTICES

/* INITIALIZATION: SET EVERY DISTANCE TO INFINITY
UNTIL WE DISCOVER A PATH */
FOR I = 0 TO |V| - 1
DIST[I] = INFINITY
PREV[I] = NULL
END
/* THE DISTANCE FROM THE SOURCE TO THE SOURCE IS
DEFINED TO BE ZERO */
DIST[S] = 0
WHILE(F IS MISSING A VERTEX)
PICK THE VERTEX, V, IN U WITH THE SHORTEST PATH TO S
ADD V TO F
FOR EACH EDGE OF V, (V1, V2)
/* THE NEXT STEP IS SOMETIMES GIVEN THE CONFUSING
NAME "RELAXATION"
IF(DIST[V1] + LENGTH(V1, V2) < DIST[V2])
DIST[V2] = DIST[V1] + LENGTH(V1, V2)
PREV[V2] = V1
POSSIBLY UPDATE U, DEPENDING ON IMPLEMENTATION
END IF
END FOR
END WHILE
```

3.3 Data Collection by the MC

The MC can follow the travelling sales man algorithm to gather the data from the RPs and send it to the sink. The advantages of the proposed scheme are,

- Less energy conservation can be achieved
- Distribute energy and extend network lifetime
- Broadcasting delay –issue can be minimized for the application of the event monitoring

4. Simulations and Results

In this section, we present the simulation setup and the results. The algorithms are developed using MATLAB. In all the simulations, we consider ideal MAC layer so there is no collision or retransmission of packets thus there is no wastage of energy in this layer. The energy model used is the ideal radio model. Since we have considered ideal MAC and radio model, if the node is within the radio range, both the nodes can communicate without packet loss.

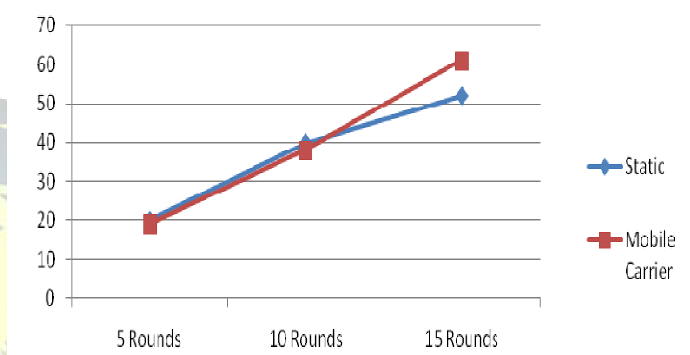

Fig .5 .Static Vs Mobile Carrier

Every values represented in the graph are the average of the results of multiple simulations carried out. The network lifetime increase is compared using other data gathering schemes, the static sink where the sink do not move and the random movement of the MS. The sensors are randomly and uniformly deployed in a field of 100 m x 100 m square area. The initial energy is 1 Joules.

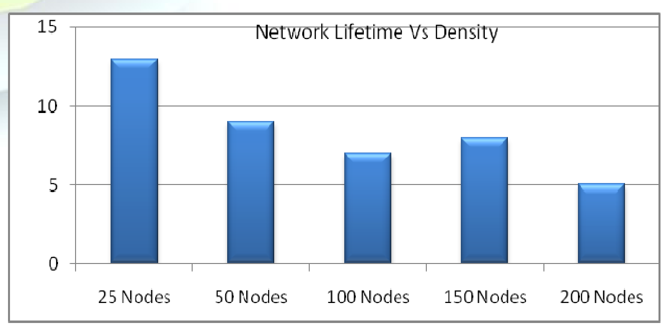

Fig .6 .Network lifetime for different density

The number of sensors in the network is varied from 25, 50,100,150,200, respectively. The sensors at the time of deployment have the initial energy of 5 joules each. Each sensor generates one packet every round

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(1000 bits). We only consider the energy for reception and transmission of packets. The energy wastage when an MS move from one site to the next is considered negligible. The Network lifetime is measured in terms of rounds until a sensor dies. In Fig.5 the simulation shows that network lifetime considerably increases with an MC. In static network lifetime drops suddenly while with MC it gradually looses its lifetime. In Fig.6. it shows the strategies for different node densities. In Fig .7. the various MC strategies are compared and the other strategies like static and random movement of MC are not energy conscious so the network lifetime is less.Our proposed strategy improves network lifetime while multiple MCs excels all the strategies.

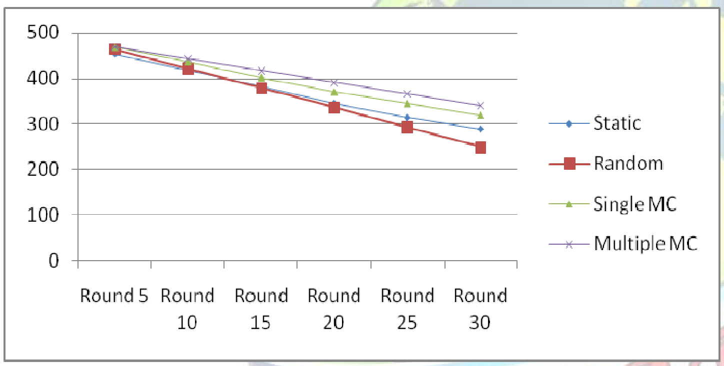

Fig .7 .Network lifetime for different mobility strategies of MC

5. Conclusion and Research challenges

In this work, I proposed a novel rendezvous based data gathering approach for critical t monitoring in WSNs. This scheme follows the concepts of choosing important nodes, and then the MR travels around these points to collect data. The proposed method could essentially decrease the communication latency and energy consumption in WSN. Moreover, the proposed method is independent of the density of nodes in WSN. In addition it maintains the balance between the energy consumption and communication delay. In this scheme the energy of the entire sensor nodes are fully utilized, which in turn prolong the network lifetime. Theoretical analysis and conducted simulations showed that the delay and the energy consumption of the proposed scheme is much lower than that of existing methods. As a future work, we plan to enhance our approach to include data with different delay requirements. This means an MC is required to visit some sensor nodes or parts of a WSN more frequently than others while ensuring that energy usage is minimized, and all data are collected within a given deadline. Moreover, we plan to extend this approach to the multiple MCs [9] case. This case, however, is nontrivial as it involves sub-problems such as interference and coordination between rovers. Having said that, we note that that the proposed system remains applicable if a large WSN is partitioned into smaller areas where each area is assigned an MC. Then the proposed algorithm can be run in each area. The algorithms can also be modified to optimize the path of the tour taken by the MC.

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