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An on demand Data Collection Scheme for Wireless Sensor Network Based on Rendezvous Points

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Abstract – *Mobile nodes can be used for energy efficient data collection in wireless sensor network and to improve the network life time. The main challenge here is to find the most suitable data collection method for the mobile sink which reduces the data collection delay and energy consumption. In this paper Rendezvous points(RPs) are selected from the sensor network according to the weight and other nodes will send their data to this rendezvous nodes in an energy efficient way. An online data collection method is also proposed here to further reduce the energy consumption during the data collection. Whenever an event is detected by the mobile sink it need not visit every nodes to collect information, instead it can directly collect data from the RPs. Simulation is done in NS-2 and the results shows that this scheme helped to reduce the energy consumption of the sensor nodes compared to the existing methods.*

Key Words: Wireless Sensor Network, Mobile sink, Data collection, on demand data collection

1. INTRODUCTION

Wireless sensor network has wide range of application in several areas such as military, health, home, industries etc. Sensor nodes deployed in the network area will collect the data from the environment, store the data and transfer it to the destination known as sink. Transfer of data from each node to the sink takes place through multihop communication. A problem which arises during the data collection is the energy depletion of the sensor nodes near the sink. This is because the nodes near the sink experiences high traffic load since they are always engaged in transferring data to the sink. This causes high energy expenditure in these nodes resulting in the death of the nodes. This problem is known as energy hole problem. These dead nodes forms holes in the network and disconnect the sink from all other nodes. This causes the complete destruction of the network. An analytical model for the energy hole problem is developed in [1]. Many methods were proposed to reduce the energy hole problem in wireless sensor network. Mobile sinks are used for the data collection from each node so that the energy for multihop communication can be saved. Fig .1 shows a sensor network with a mobile sink collecting data from other sensor nodes.

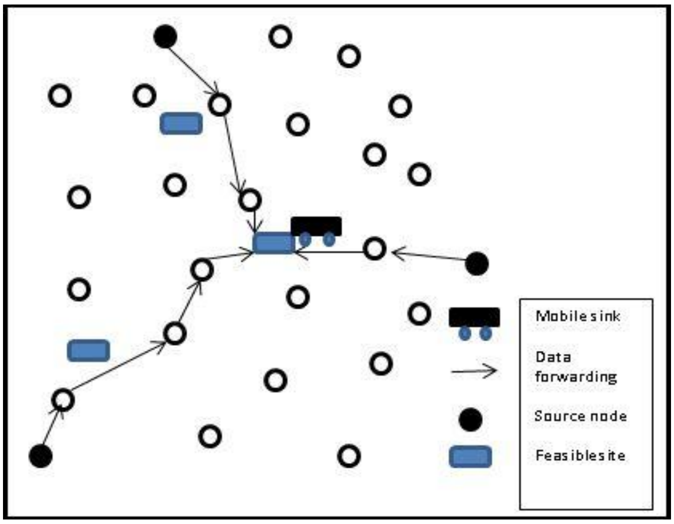

Fig.1:Mobility Based Data Collection

Mobile nodes are special nodes selected from the wireless sensor network for data collection. In [2], MULEs (Mobile ubiquitous LAN Extensions) are used for collecting data from a large farm. Here an animal is used as the MULE for collecting data from other nodes in the farm. MULES collect data and then forward it to the destination. Here the other nodes only have to transmit in a short range so the energy can be saved more. Message ferrying technique is another method for energy efficient data collection. Ferries are special nodes from the network which are selected for relaying the messages to the destination. In [3, 4], ferries are used for data collection. If the ferry location is known to other nodes then the data collection delay can be minimized. Here a power management scheme is also proposed so that the nodes can select a suitable power management mode based on ferries location *ie*, if the ferry is not in the range of a node it can go to sleep mode otherwise it should be in active mode. Two variations for message ferrying technique is proposed in [5], which are node initiated message ferrying scheme (NIMF) and ferry initiated message ferrying scheme (FIMF). In the first one node will initiate the message transfer where as in the

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second one ferry will initiate the proactive movement for the data collection. Mobile sink based data collection is proposed in [6]. Here the sink is not a relay and it is the destination of all messages. In [6], people act as the mobile sink but in these methods the data collection latency will be high. Finding the shortest path for the mobile sink is considered as a travelling sales man problem (TSP) and its solution is proposed in [7]. Here the TSP is known as travelling salesman with neighborhood (TSPN). The mobile node has to visit only the neighborhood of each node for data collection. Label covering algorithm in [8] is another TSP based algorithm for finding the shortest path for the mobile sink. Here the sensor network is considered as a graph where the nodes are located at each vertices and the edges are connecting these nodes. Label set of an edge consist of nodes whose transmission range intersect with the edges. Mobile node will select a path through the edges whose label set consist of more number of nodes. In [9], Zone Division hierarchical clustering approach with multiple mobile collectors is proposed. Here the network is divided into different zones and a master node is selected for each zone based on the residual energy. Mobile elements are assigned for each zone for collecting the data.

Direct data collection may be impractical in some cases with tight delay requirements. Rendezvous based data collection methods can be used to reduce the delay together with energy consumption. Rendezvous points are special nodes selected from the network selected based on energy criteria for aggregating the data from other nodes. Mobile sink has to visit only this RPs for data collection so the data collection delay also can be reduced. Path of the mobile sink can be fixed or variable. In [10, 11, 12] the travelling path of the mobile sink is fixed. In [10], public buses are used as the sink for a traffic management system. Here the buses roam around the city for collecting data from sensor nodes placed in the buildings. In [12], RDFT (Rendezvous Design for Fixed Track) is proposed where the mobile sink path is fixed. RDFT also consider the obstacles found in the path of the mobile sink. Mobile sink will collect the data from RPs' which are selected in such a way that the data forwarding path from the sensor nodes to the RPs' is minimized. RDVT (Rendezvous Design for Variable Track), proposed in this paper consider a variable path for the mobile sink. Here the objective is to find a travelling path which is shorter than the given deadline of the packets. RDVT first constructs a Steiner Minimum Tree (SMT) routed at the sink. RDVT then start from the initial position of the sink and then visits all nodes in preorder until the shortest distance between visited nodes is equal to the given delay bound for data collection. Traversing the SMT in preorder will sometimes results in to long data forwarding path to sensor nodes located in the different parts of SMT. this results in unbalanced data forwarding load and energy consumption in the sensor nodes.

In [13] rendezvous planning with a constraint mobile element path (RPCP) is proposed. RPCP constructs a tree which is routed at the sink node and connects all other sensor nodes in the tree. A weight will be assigned for each edge in the tree based on the number of nodes that uses this edge for data transfer. For constructing the mobile element's path, RPCP first find the edges with highest weight until the edge length becomes equal to or less than the required packet delivery time. One of the drawbacks of RPCP is that the travelling path of mobile element is restricted to routing tree edges. An improvement of RPCP is also proposed in [13]. RPUG (Rendezvous Planning with Utility Based Greedy Heuristic) operates in iteration and in each iteration it will add the RPs that minimizes the distance of the sensor nodes from it.

In [14] a cluster based method is proposed in which the mobile element visits only a subset of the nodes (cache points), while other nodes communicate their data to the cache points wirelessly. The algorithm consists of three steps that are clustering step, tour finding step, and tour improvement step. At first, c nodes are selected at random as the initial clusters Centre nodes. Subsequently, every other node is assigned to its nearest cluster, based on the hop distance to the cluster's Centre node. Once all nodes have thus been assigned, the Centre node for each cluster (i.e., the node that has the minimum total hop-distance to all other nodes in the cluster) is determined, and the process is repeated from the beginning based on the new cluster centers. The clustering step terminates when the identity of the clusters' center nodes does not change between two consecutive iterations. The objective of the tour-finding step is to determine the tour with the shortest overall length that visits exactly one node from each cluster. Indeed, even though such a tour will probably end up with suboptimal CPs for the given set of clusters, it allows the overall algorithm to ultimately achieve a larger number of clusters while satisfying the tour length constraint. In tour improvement phase, the algorithm chooses alternative CPs (closer to the respective cluster centers), as long as the tour length constraint remains satisfied.

2. SYSTEM MODEL

Wireless Sensor Network having high degree of sensor nodes is considered here. If all sensor nodes forward the collected data to the sink it will result in energy hole problem. So a new method for data collection with the help of rendezvous points and an on demand data collection method is introduced here.

Some of the assumptions taken are

1) Each selected RP has sufficient buffer for storing data
2) Mobile sink is aware of the position of RPs
3) All nodes are interconnected and there are no isolated sensor nodes
4) Sensor nodes have fixed data transmission range

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5) Each sensor node produces one data packet in a time interval D

Here the Wireless Sensor Network (WSN) can be modeled as a graph, G (V, E), where V is the set of vertices and E is the set of edges connecting these vertices. Nodes are located at each vertices. If a node *p* sends *b* bits to node *q* then its energy consumption is

$$E_{TX}(p, q) = b(\alpha_i + \alpha_2 d_{pq}^{\gamma})$$

Where d_{pq} is the distance between nodes *p* and *q* and α_1 is the energy consumption factor for the transmitting circuit $\alpha_2 d_{pq}$ is the energy consumption of the amplifier circuit. γ is the path loss exponent which usually ranges between 2 to 4. Energy consumption of node p for receiving b number of bits is

$$E_{RX}(p, q) = b\beta$$

β is the factor representing the energy consumption per bit of the receiver circuit.

Selected RPs should be closer to the sink so that the delay for data collection can be minimized. If the selected RPs are closer to the nodes then the number of multihop transmission from the nodes to the sink will be reduced. This will help in energy saving.

For each RP r_p, a data forwarding tree will be constructed from the RP to the nearest node *p*. Number of data packets a sensor node *p* send to the closest RP ,r_p in each time interval *D* is its own data packets plus the number of its children in the data forwarding tree $T_{rp.}$

$$NFD(p) = C(p, Trq) + 1$$

Where *C (p, Trq)* is a function that indicates the number of children that node *p* has in its data forwarding tree rooted at its corresponding RP r_q. From the sensor nodes, RPs are selected according to some rules. First step is to find the number of neighbors each node has. A node with more number of neighbors will have more data packets to send at each time interval. Second step is to find the shortest path from each node to the sink. A node which exists in more number of paths from the sink will get higher priority during the weight calculation for being selected as RPs. Moreover the selected RPs should be closer to the sink so that the data can be delivered by the RP within the given delay bound. Based on these parameters weight of each node is calculated with the equation

$$W(p) = (N(p) + P(p))/D(p,s)$$

ie, weight of a node is directly proportional to its number of neighbors and number of path in which a node lies and inversely proportional to the distance between the node and sink.so highest weighted node will be selected as RPs. If a node with less number of neighbors is selected as RPs it will result in unnecessary energy expenditure since the number of multihop transmissions from the nodes to this RP increases. Neighbor nodes of a node *p* is calculated based on the distance equation

$$D(p, q) = \sqrt{((x_2-x_1)^2-(y_2-y_1)^2)}$$

Where x_1, x_2 is the x coordinates of nodes *p* and *q* and y_1,y_2 is the y coordinates of node *p* and *q*. .If the distance between the nodes is less than a threshold, then only that nodes can be considered as neighbors. Distance between nodes and the sink are also calculated based on this equation. If the RPs are far away from the sink, the sink will take more time to reach these RPs for data collection. This is not possible in delay sensitive application. After the weight calculation and RP selection each node will find its nearest RP .Then the nodes will send their data to these RPs. Periodic data collection from the RPs by the mobile node will be impractical in some cases where the sensed data must be immediately delivered to the sink. In those cases on demand data collection schemes can be used. Here the mobile node has to visit the RP only if an event is detected. For example in a wireless sensor network deployed for fire detection, the nodes will send their sensed data only if the temperature is higher than a particular threshold. All nodes in this area will sense the event and forward the data to the nearest RP.RP will inform the mobile node about the event by sending event detected messages. If more than one RP reported an event the mobile node will find the nearest RP and visit that RP first. Then it will select the next nearest RP and collect data from it. After the data collection the mobile element will return to the sink for data delivery. Nearest Job next data collection scheme is shown in the figure2. Here a mobile element is moving to collect data and it will first visit the nearest node for data collection. Then from that position it will find the next nearest node and then continue the data collection.

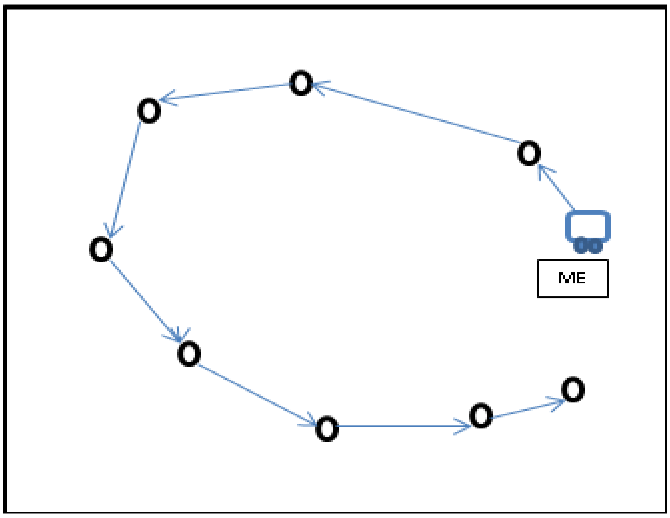

Fig.2: Nearest node first data collection scheme

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On demand data collection with rendezvous point based concept helps to improve the energy saving and also deliver the data as soon as possible. This type of data collection is shown in fig.2. Whenever an event is detected the mobile element visits the RPs according to their distance for collecting data.

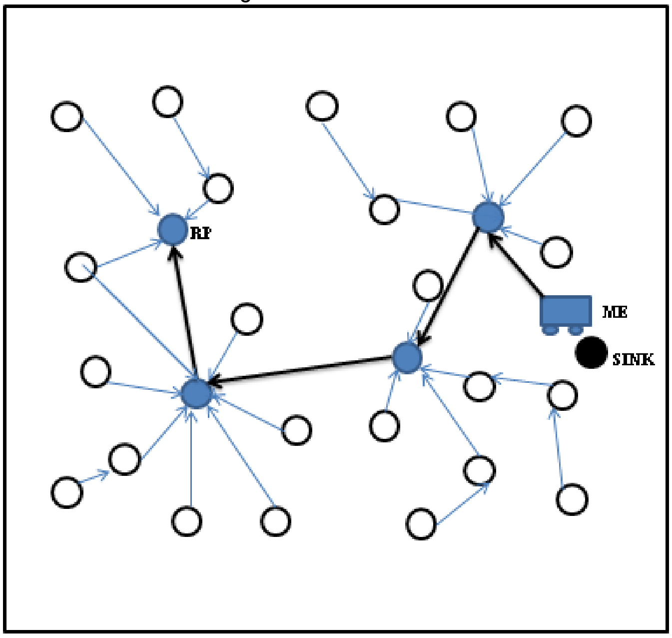

Fig. 3: RP based on demand data collection

3. SIMULATION RESULTS

For the simulation, 35 sensor nodes ,one sink and a mobile element deployed in a sensor field of size 450m*450m is considered. Network simulator NS2 is used for the simulation. The mobile element will visit each RP which reports an event. The speed of the mobile element is taken as 100m/s. At each time interval sensor nodes will produce a data packet of length 30 bytes. Each node has an initial energy of 100 joules. Energy consumption in the transmitter and receiver circuit for transmission and reception of one packet is 50 mw and 20 mw respectively.

Chart 1 depicts the average remaining energy of the sensor nodes for weighted rendezvous planning (WRP) and on demand data collection scheme. Initial energy of the sensor nodes is 100 joules. Results indicate that the average remaining energy of the sensor nodes in on demand data collection scheme is more than that of WRP in each time interval. After 25 seconds, the remaining energy of sensor nodes in WRP is 70 joules and that of on demand data collection scheme is 92 joules. This is because in WRP sensor nodes send their data to the RPs periodically and the mobile element visits these RPs along a fixed path for data collection. But in on demand scheme nodes send their data only if it detects an event *ie,* if the sensed value is higher than a particular threshold. So unnecessary energy expenditure for periodic data transfer is avoided here and this method helps to improve the lifetime of the sensor network.

In chart 2, Packet Delivery Ratio (PDR) for both the schemes is plotted. PDR indicates the ratio of total number of packets successfully received by the sink to the total data packets send by the sensor nodes.

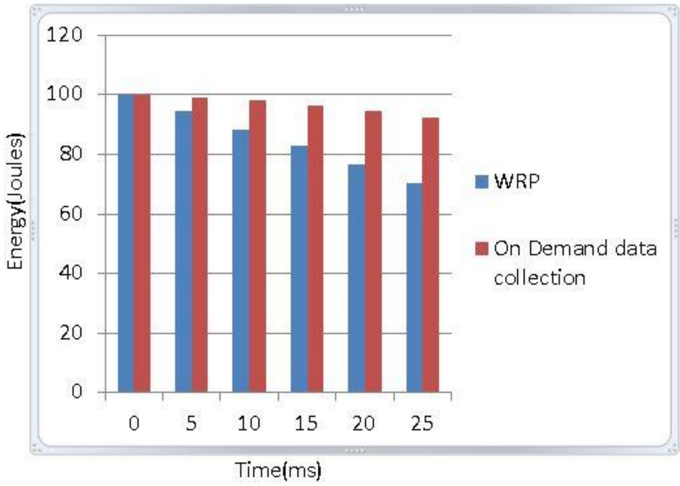

Chart .1: Average Energy

Packet delivery ratio is high in on demand data collection scheme because here the mobile element collects data from the event detected RPs as soon as possible with minimum delay. In WRP mobile element has to visit all RPs periodically for data collection. Before the mobile element reaches the RPs the data may be lost sometimes due to the buffer overflow of RPs. So on demand data collection scheme always outperforms WRP in energy consumption and PDR.

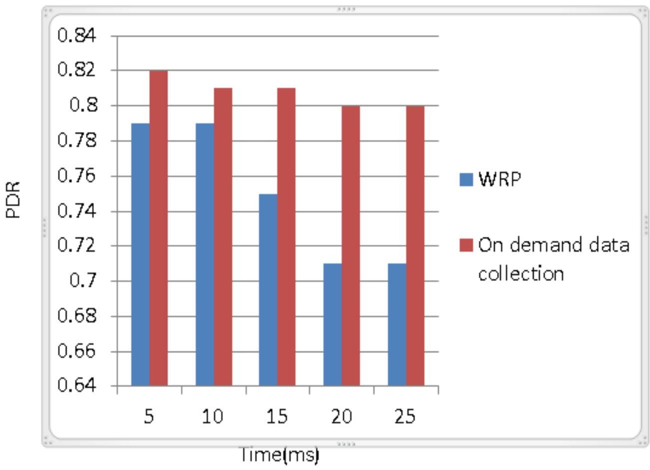

Chart .2: PDR

4. CONCLUSION

A new method of data collection based on the concept of rendezvous points is proposed here. Rendezvous points are special nodes in the sensor network which are selected according to the weight calculation. Weight depends on the number of neighbors and the distance of the node from the sink. An on demand data collection method is also

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proposed here where the nodes send their data to the selected RPs only if an event is detected by the nodes. Simulation results show that this data collection scheme reduces the energy consumption and improves the network lifetime compared to other data collection methods.

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