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# A Survey on Rendezvous Based Techniques for Power Conservation in Wireless Sensor Networks

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**ABSTRACT:**
*Power conservation is a vibrant research area in wireless sensor networks. Several research works have demonstrated that energy can be conserved significantly using mobile sink in the sensor field, which will collect the data from the sensor nodes via single or multi hop communication. But, the mobility speed of the sink is low, due to which latency will be increased in sensor network especially in delay sensitive applications. To address this issue, various rendezvous based techniques have been described according to which a subset of sensor nodes from the field will be selected as rendezvous points (RPs). Remaining nodes will forward the sensed data to its nearest RP where data will be buffered. A path is then constructed using the RPs through which mobile sink will make a tour and collects the buffered data. This paper explains different rendezvous based techniques and analysis of their advantages and deficiencies with respect to power conservation.*

***KEYWORDS:*** *Data sensing, Mobile Sink, Power conservation, Rendezvous points, Sensor nodes, Steiner Minimum Tree (SMT), Wireless sensor networks.*

## I. INTRODUCTION

Wireless sensor network is an environment built of several sensors to monitor the environmental conditions. These sensor nodes will sense the data from the surrounding environment and forwards it to the central location known as base station (sink) through wireless communication. Today many industrial and consumer applications such as waste water detection, smart home etc. are using sensor networks. The major drawback of the WSN is the battery life of sensor nodes which may not be replaced or recharged. This leads to vital research area in the field of sensor networks. Usually the sensed data will be transferred to the base station for processing using ad-hoc multi-hop network formed by the sensor nodes. Though this technique is feasible, it creates a bottleneck in the network.

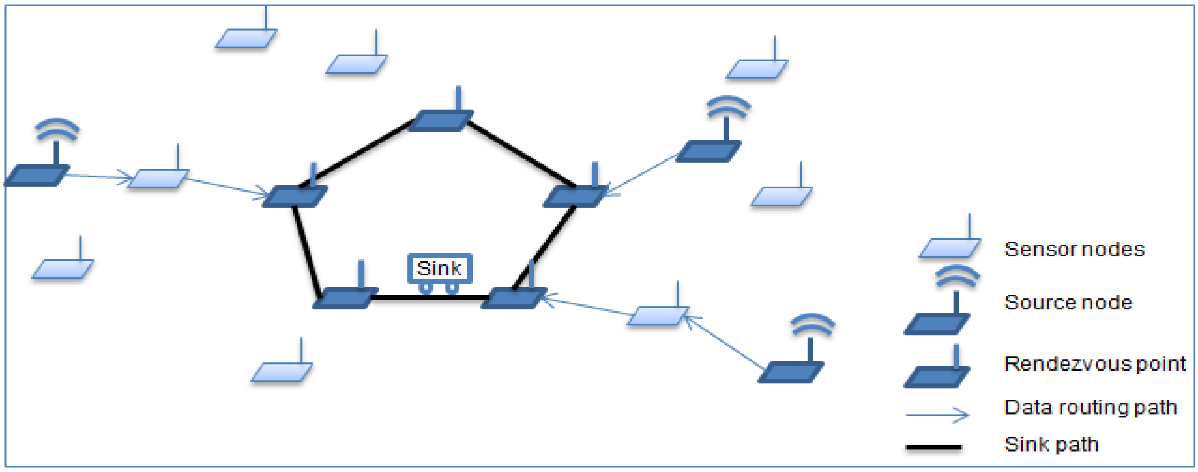


**Figure 1: An example of rendezvous based technique. Source node will forward the sensed data to its nearest RP. Mobile sink will make a tour and collects the data buffered at the RP.**

The nodes near to the sink are overburdened due to the data from the farther nodes and the battery of those nodes will drain very quickly which leads to non-uniform energy level of the nodes which ultimately results in network partition [1]. Various research works have shown that the mobile sink will resolve the problem by collecting the data directly from the sensor nodes via single or limited multi hop communication. This can be formulated as Travelling Sales Man problem (TSP) which is well known problem in graph theory. The aim of TSP is to find the shortest path using which the sink must visit all the sensor nodes exactly once and return back to its original position. However, as the number of nodes increases, this problem becomes impractical [2]. Moreover typical speed of mobile sink is low such that it takes long time to complete a tour in large network area. Due to this drawback of sink mobility, latency will get increase in delay sensitive applications [3], such as fire- detection system. Hence, researchers have proposed rendezvous based technique in which the subset of sensor nodes are selected as RP and non-RPs will just forwards the sensed data to its nearest RP where data will get buffered. For these selected RP, a tour is computed through which mobile sink will travel and gather the buffered data as shown in figure1. In This paper we discuss the different rendezvous based techniques to bind the tour length. Each of the techniques RP-CP, RP-UG, RD-VT, CB and WRP proposed in [2] [3] [4] [5] follow different ways to solve the problem. They have their own benefits and shortcomings in terms of energy consumption in sensor networks.

## II. RELATED WORK

Many existing methods which uses mobile sink in sensor network have proved that the energy can be efficiently utilized and overall network lifetime can be improved. According to the taxonomy provided in [6], WSN with mobile sink can be divided into two classes: 1) *Direct* and 2) *rendezvous*. In the former method mobile sink will collect the data via single hop and focus on minimizing the data collection delays. Whereas in the latter method, mobile sink only visits the RPs with the aim of minimizing the energy consumption. The pitfalls in *direct* method can be seen when sensor nodes exists in greater number which in turn increases the mobile sink tour length. This results in buffer overflow at the sensors due to data collection delays. To deal with this problem, rendezvous based technique has been proposed. Taxonomy given in [6] further divides the rendezvous method into 3 classes: 1) *Fixed* 2) *Tree based* and 3) *Clustering*. In *fixed* [7], sensor nodes are randomly deployed and the sink path is predefined. The nodes that exist within the communication range of mobile sink will acts as RP. In this method, the length of the sink path is independent on the sensor nodes buffer size or application deadline. Hence, the buffer of RPs may overflow or packets may expire before they are collected.

Xing et al. in [5] proposed a *tree based* algorithm known as RD-VT (rendezvous design with a variable BS track) to find the RP on SMT (Steiner minimum tree) where data will be efficiently buffered and in turn decreasing the sink tour length. A Steiner tree spans a given subset of vertices of a graph. Steiner minimal tree has three major properties. 1) No two edges will meet at an angle less than $120^0$. 2) Each Steiner point has degree of 3. 3) No crossing edges. It uses the equilateral triangle, a circle and a line principle to construct a Steiner point for a set containing three points on the minimum spanning tree [2]. There are two types of Steiner points, *terminals* and *non-terminals.* First type represents real senor nodes and the second one represents a physical position without sensor nodes known as virtual Steiner points. The RD-VT starts with constructing a SMT by considering the sink as root. Then SMT is traversed in pre-order from, until the shortest distance between the visited nodes is equal to the required packet delivery time.

Xing et al. in [3] proposed two rendezvous planning algorithms known as RP-CP (Optimal Rendezvous Planning with Constrained ME Path) and RP-UG (rendezvous planning with utility based greedy heuristic). RP-CP deals with constrained mobile sink path. A tree is constructed which connects all the sensor nodes present in the field with sink node as the root. A weight is assigned to each of the edges present in the tree. The weight corresponds to the number of nodes uses that edge to transfer the data to the sink. To construct a path, RP-CP first sorts all the edges with respect to their weight. Then the highest weighted edge is selected until the length of the selected edges becomes less than or equal to the required packet delivery time.

RP-UG [3] is a greedy algorithm which is an improvised version of RP-CP and deals with non-constrained mobile sink path. As in RP-CP, RP-UG also constructs the rooted tree which is rooted to the sink node and all the edges constructed on the tree are divided into several short intervals $L_0$. All the nodes that join two edges with length $L_0$ are selected as RP. Starting with the sink node, RP-UG operates in multiple iterations. In each of the iteration, the tour of the sink node is increased by adding new RP with greatest utility until the maximum tour length is reached. The utility of RP is defined as the ratio of the network energy saved by including it on the sink tour to the length increase of the tour. As the sink tour is expanded, the utility of the nodes will be dynamically updated which results in better selection of RP.

The hop count of each node to its nearest RP will be related to the power consumption of it imposes on peers. To decrease the number of hops from all the sensors to their nearest respective RP, Khaled Almi'ani et al. in [4] proposed *Cluster Based* algorithm which iteratively obtains the mobile sink tour and the routing trees. According to this algorithm, network is grouped into number of balanced size clusters. By selecting only one RP from each cluster, a sink path is constructed such that the sink visits maximum number of clusters and the tour length constraint is satisfied. In *rendezvous* based technique, the basic problem is to find the RP and computing an optimal sink tour path such that sink visits all the RPs and returns to its initial position. However, this is an NP-hard problem. Hence, Salarian et al. [2] proposed WRP (Weighted Rendezvous Planning algorithm). WRP is a heuristic approach based on hybrid unconstrained mobility pattern for sink. The problem is defined as follows:

- Let $G (V, E)$ be the graph that consists of $n$ number of homogeneous sensor nodes, $V$ and set of edges $E$ between the nodes.
- Let $n_0, n_1, n_2 \ldots\ldots n_n$ be the set of sensor nodes where $n_i \in V$ and are randomly located in a field from where data need to be sensed.
- Let $M = m_0, m_1, m_2 \ldots\ldots m_n, m_0$, be the set of sensor nodes where $m_i \in V$ such that it comprises of high weight and considered as rendezvous points.

The objective is to find a tour using set of nodes present in $M$ such that sink only visits the RP and the tour $M$ is no longer than maximum allowed tour length ($l_{max}$) *where,*

$$l_{max} = D \times v \qquad (1)$$

$D$ is maximum allowed packet delay and $v$ is the mobile sink speed. The sensor nodes other than RP, directly forwards the sensed data to their nearest RP. The RP will collects and buffer all the data sent by the sensors and forward it to the sink when it comes to RP's vicinity. WRP will assign a weight to each sensor nodes and computes a tour by selecting the highest weighted sensor nodes as rendezvous point. As per the paper [2], equation to calculate the weight of each sensor node is,

$$W_i = NFD(i) \times H(i, M) \qquad (2)$$

Where, $W_i$ is the weight of node $i$, $NFD(i)$ is the number of packets that the node $i$ will forwards and $H(i, M)$ is the hop distance of node $i$ from the closest RP in $M$. According to the equation, the nodes that are located farther away from the selected RP or the nodes that have more than one packet to be forwarded will have higher priority and it will be selected as RP. If the sensor node that is located only in one hop distance from the selected RP and have only one data packet buffered will get the minimum weight. Hence, by visiting the highest weighted sensor node, the number of multi-hop transmissions will be decreased and load will be balanced among the sensor nodes which ultimately results in power conservation.

## III. ANALYSIS OF RD-VT, RP-CP, RP-UG, CB AND WRP

This section provides the analysis of different rendezvous based techniques in terms of their benefits and drawbacks towards power conservation.

**RD-VT:** SMT based approach Steiner point in RD-VT may not be position of sensor node, and algorithm will replaces the virtual RPs with the sensor node that is closer to them. This approach will provide the desired performance under certain range of settings. In addition, this algorithm will maintain the communication delay and also enables the sink to collect bulk of data at a time from the RP. However, SMT is traversed in pre-order to find RPs, it will results in long data transferring paths to the sensors which are located in different locations of SMT. Hence, RD-VT fails to balance the load among sensors and power consumption [5].

**RP-CP:** RP-CP operates on the SMT by considering the edges of the routed tree and its assigned weights. This technique significantly reduces the power consumption of the sensor network. But, the Sensor nodes on the selected edges will be visited twice by the mobile sink because of constrained sink mobility path on the edges of routing tree [3].

**RP-UG:** RP-UG is an improvised method of RP-CP and utility based greedy algorithm which will operates on the routed tree. As the sink tour is expanded, the utility of the nodes will be dynamically updated which results in better selection of RP. But, RP-UG appoints the sensor node as RP which are closer to the sink which many not have highest energy consumption rate [2]. Hence, the energy consumption rate of the sensor nodes cannot be balanced by the RP-UG which ultimately effects the lifetime of the network. Along with this deficiency, this algorithm uses TSP solver N times in each iteration (N is the number of RPs) and hence, running complexity of this algorithm is $O(N^2 * O(TSP))$ [3].

**CB:** Cluster based algorithm uses binary search method to select the rendezvous points. Initially cluster is formed and algorithm traverses through all the clusters to select one node as RP from each cluster and sink path is constructed that satisfies the tour length constraint. CB will contribute more in terms of power conservation than RD-VT. In some scenario, the sink path does not pass through the dense parts of the network and results in long data transfer path from the sensors to the RP. Hence, the battery of sensor nodes will drain in non-uniform manner which ultimately decreases the WSN lifetime [4].

**WRP:** Weighted Rendezvous Planning heuristic algorithm also uses SMT and selects the set of RPs. When comparing with the RP-UG and RD-VT with WRP, the former two algorithms will replaces the virtual RPs with the nearest sensor nodes whereas in the latter algorithm, virtual RP present in the Steiner tree will not be replaced by any nodes. Instead the virtual Steiner positions present in the tour will be visited by the sink and it will collect the data from the nearest sensor node which leads to fewer numbers of RPs and uniform energy consumption. Hence, WRP performs better than RD-VT and RP-UG. As mentioned in the previous paragraph, unlike CB, WRP will concentrates on hop count while selecting the RP. Hence, WRP minimizes the energy consumption when compared to CB. In addition to this, WRP reduces the occurrence of energy hole problem [6] in sensor networks because the mobile sink visits the congestion points that likely exists in the dense areas [2]. The performance of the sensor network can be further enhanced by using multiple mobile sinks in the field. A sensor network is divided into two or more groups such that each group consists of sensor nodes with similar features. Every group is assigned with a mobile sink and WRP is executed in each group to collect the data.

## IV. CONCLUSIONS

Power conservation is a challenging task in WSN which depends on various parameters. In this paper, different rendezvous based algorithms and their analysis has been discussed. All of them focus on finding RPs and efficient tour for mobile sink path so that the sink only visits the RPs and collect the sensed readings within delay bound. Though there are merits and de-merits in each of the techniques, WRP performs better in terms of energy consumption. It will prevent the formation of energy holes in the sensor network and finally results in overall network power conservation.

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