A Survey of Rendezvous planning Algorithms for Wireless Sensor Networks

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Abstract—In recent years, sensors in some applications are expected to be remotely deployed in large numbers and to operate autonomously in unattended environments.

For this, we will briefly discuss the operations of various rendezvous planning algorithms, as well as comparisons on the performance with different parameters such as the power consumption and network lifetime. We survey different these algorithms for WSNs; highlighting their objectives, features, complexity, etc. We also discuss improvements to be made for future proposed rendezvous planning schemes. This paper should provide the reader with a basis for research in rendezvous planning schemes for Wireless Sensor Networks.

Keywords: Wireless sensor networks; rendezvous planning algorithms; data collection delay; Network lifetime; Energy consumption

I. INTRODUCTION

With the continued advances in Micro-Electro-Mechanical Systems (MEMS), Wireless Sensor Networks (WSNs) have and will play a vital role in our daily lives. Vehicles have relied on wired sensors for years, for simple tasks such as traffic monitoring, to complex tasks such as area monitoring in urban applications.

One such problem is how to create an organizational structure amongst these nodes [1]. Since the fundamental advantage of WSNs is the ability to deploy them in an adhoc manner, as it is not feasible to organize these nodes into groups predeployment.

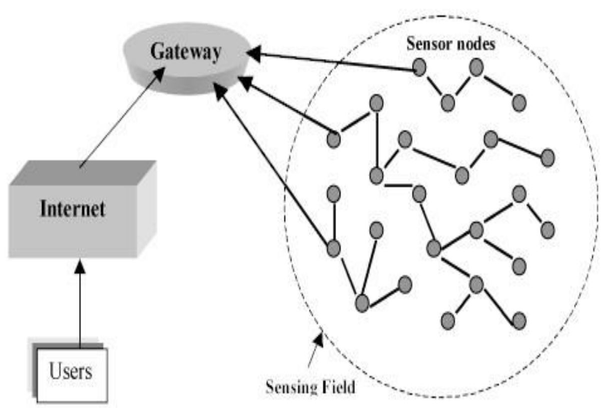

Fig.1 WSN architecture

For this reason, there has been an large amount of research into ways of creating these organizational structures [1]. Looking at Fig. 1, we can see the architecture of a Wireless Sensor Network [2], and examine how the clustering phenomenon is an essential part of the organizational structure.

• Sensor Node: A sensor node is the core component of a WSN. Sensor nodes can take on multiple roles in a network, such as simple sensing; data storage; routing; and data processing.

• Base Station: The base station is at the upper level of the hierarchical WSN. It provides the communication link between the sensor network and the end-user.

• End User: The data in a sensor network can be used fora wide-range of applications. Therefore, a particular application may make use of the network data over the internet, using a PDA, or even a desktop computer. In a queried sensor network (where the required data is gathered from a query sent through the network). This query is generated by the end user.

The clustering phenomenon as we can see, plays an important role in not just organization of the network, but can dramatically affect network performance. There are several key limitations in WSNs, that clustering schemes must consider.

• Limited Energy: Unlike wired designs, wireless sensor nodes are ”off-grid”, meaning that they have limited energy storage and the efficient use of this energy will be vital in determining the range of suitable applications for these networks. The limited energy in sensor nodes must be considered as proper clustering can reduce the overall energy usage in a network.

• Network Lifetime: The energy limitation on nodes results in a limited network lifetime for nodes in a network. Proper clustering should attempt to reduce the energy usage, and hereby increase network lifetime.

• Limited Abilities: The small physical size and small amount of stored energy in a sensor node limits many of the abilities of nodes in terms of processing and communication abilities. A good clustering algorithm should make use of shared resources within an organizational structure, while taking into account the limitation on individual node abilities [4].

• Application Dependency: Often a given application will heavily rely on cluster organization. When designing a clustering algorithm, application robustness must be considered as a good clustering algorithm should be able to adapt to a variety of application requirements.

II.OVERVIEW OF RP ALGORITHMS

Xing *et al.* [8] propose RD-FT, where the movement of a mobile sink is governed by application deadline. They also consider obstacles that restrict the movement of a mobile sink along a predefined path. The objective is to find a set of RPs on the fixed path such that the length of data forwarding paths from sensor nodes to RPs is minimized and that the traveling time between RPs is limited to the required packet delivery time.

In [8], a WSN with a static sink node and a mobile element (ME) is assumed to collect data from RPs. Moreover, RPs performs data aggregation. An algorithm called RD-VT is proposed with the objective of identifying a traveling path that is shorter in duration than the packet delivery time. The algorithm first constructs a Steiner minimum tree (SMT) rooted at the sink node. RD-VT then starts from the sink’s position and traverses the SMT in preorder until the shortest distance between visited nodes is equal to the required packet delivery time. Since, in an SMT, a Steiner point may be a physical position and does not correspond to the position of a sensor node, RD-VT replaces this virtual RPs with the closest sensor nodes. A major limitation of RD-VT is that traversing the SMT in preorder leads to the selection of RPs that in turn results in long data forwarding paths to sensor nodes located in different parts of the SMT. As a result, RD-VT causes nodes to have an unbalanced data forwarding load and energy consumption.

Xing *et al*. [7] propose rendezvous planning with a constrained ME path (RP-CP). Similar to RD-VT, the authors consider a WSN with a fixed sink node and a ME. The RP-CP first constructs a routing tree that is rooted at the sink node and connects all sensor nodes. Then, each edge of the routing tree is assigned a weight that corresponds to the number of nodes that use that edge to forward their data to the sink

node. The ME is restricted to moving only on the edges of the tree. To construct the ME's traveling path, RP-CP first sorts all edges according to their weight. It then selects the edges with the highest weight until the length of the selected edges becomes equal or less than the required packet delivery time. The problem with RP-CP is that the traveling path of the ME is restricted to routing tree edges. This also means that the ME will visit the sensor nodes on the selected edges twice.

In [7], the authors propose an improvement to RP-CP, which is called the RP-UG algorithm. Initially, a geometric tree, which is rooted at the fixed sink node, is constructed, and all edges on the tree are split into multiple short intervals, which are denoted as *Lo*. All points that join two edges with length *Lo* are considered RP candidates. RP-UG starts from the sink's position and, in each step, adds the RP that minimizes the distance of sensor nodes from selected RPs and also results in the shortest traveling tour between RPs. RP-UG uses a TSP solver to calculate the tour length. To finalize the tour, RP-UG replaces virtual RPs with the closest sensor nodes and marks them as RPs. RP-UG does not balance the energy consumption rate of sensor nodes, which has a significant impact on network lifetime.

Charalampos Konstantopoulos et al., [16] proposed MobiCluster Protocol; MSs are mounted upon public buses circulating within urban environments on fixed trajectories and near-periodic schedule. Our clustering algorithm borrows ideas from the algorithm of Chen et al. [9] to build a cluster structure of unequal clusters. The clustering algorithm in [9] constructs a multisized cluster structure, where the size of each cluster decreases as the distance of its cluster head from the base station increases. RNs lie within the range of traveling sinks and their location depends on the position of the CH and the sensor field with respect to the sinks trajectory. Suitable RNs are those that remain within the MS's range for relatively long time, in relatively short distance from the sink's trajectory and have sufficient energy supplies. In addition to lying in a short distance from MS trajectories, the best candidates RNs are the SNs with sufficient residual energy that receive a relatively high number of BEACON packets. The last phase of MobiCluster protocol involves the delivery of data buffered to RNs to MSs. Data delivery occurs along an intermittently available link; hence, a key requirement is to determine when the connectivity between an RN and the MS is available. Communication should start when the connection is available and stop when the connection no longer exists, so that the RN does not continue to transmit data when the MS is no longer receiving it.

In [17], the authors propose an improvement of existing algorithm, called Weighted Rendezvous planning (WRP). WRP preferentially designates sensor nodes with the highest weight as a RP. The weight of a sensor node is calculated by multiplying the number of packets that it forwards by its hop distance to the closest RP on the tour. Thus, the weight of sensor node *i* is calculated as

$$Wi = \text{NFD}(i) \times H(i,M). \quad (1)$$

Based on (1), sensor nodes that are one hop away from an RP and have one data packet buffered get the minimum weight. Hence, sensor nodes those is farther away from the selected RPs or have more than one packet in their buffer have a higher priority of being recruited as an RP.

The energy consumption is proportional to the hop count between source and destination nodes, and the number of forwarded data packets. Hence, visiting the highest weighted node will reduce the number of multihop transmissions and thereby minimizes the energy consumption. In addition, as dense areas give rise to congestion points due to the higher number of nodes, energy holes are more likely to occur in these areas. Hence, a mobile sink that preferentially visits these areas will prevent energy holes from forming in a WSN.

Table 1 Comparison of RP algorithms

Rendezvous planning approaches	Mobile sink travelling path	RP Selection	Complexity of Failure recovery	Parameter for determine mobile sink's tour
RD-FT	Fixed	Preset	High	Length of data forwarding path
RD-VT	Fixed	Preset	High	Traversing preorder position
RP-CP	Fixed	Variable	Moderate	Weight of no. of nodes forward their data to sink
RP-UG	unconstrained	Variable	Moderate	Shortest distance from sink's position
Mobicluster protocol	Fixed	Preset	Low	Position of CH and sensor field trajectory
WRP	unconstrained	Variable	Low	Weight of no. of hops and forwarded packets

Table 1 shows the Comparison of various RP algorithms based on the metrics such as travelling path of the mobile sink, RP selection, complexity of failure recovery and parameter for calculating tour length.

III.CONCLUSION

The paper describes the comparison between various methods involved in the energy efficient rendezvous planning system. It also illustrates that there are many techniques that can be followed for increasing lifetime efficiency. This kind of comparison reflects that the efficiency differs from each method. This means a mobile sink 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. This paper shows the usage of rendezvous planning mobile system to increase efficiency.

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