Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 3, Issue. 10, October 2014, pg.680 – 686

RESEARCH ARTICLE

A Clustering Framework based Multiple Partitioning Data Gathering Scheme for WSAN

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ABSTRACT: The approach of using mobile sink, has been adopted in wireless sensor networks (WSN) and wireless sensor and actor network(WSAN) to achieve higher efficiency in terms of gathering data from sensors. Mobility-assisted data collection brings in new opportunities to improve the energy efficiency sensor nodes. However, mobile sink also introduces new challenges such as large data collection tency. A lot of research efforts have been devoted to reduce this latency. Cooperated with a novel partition algorithm, a concise and a clustering framework based multiple partitioning data gathering scheme is proposed here. A given area can e divided into several zones with balanced data gathering latency. By modeling the partitioning problem as a Traveling Salesman Problem (TSP), an algorithm is designed to balance the data gathering latency among all the zones. Then mobile sinks are assigned to these zones separately. The data could be gathered by these mobile sinks parallel thereupon. Extensive simulations are carried out evaluate our proposed data gathering scheme. Different distribution patterns are considered. Fictiveness of our proposed data gathering scheme is demonstrated through the simulation results.

Keywords: Framework, mobile sink, partitioning

1. INTRODUCTION

It is known that in a wireless s sensor network (WSN) with s tatics inks, sensors near a sink usually deplete their batteries faster than those far apart because of their heavy load for forwarding packets. Such non uniform energy consumption can cause degraded network performance and shorten the network lifetime. This is the s o-called hot-spot problem. Although many energy-efficient protocols [1, 2, 3] have been proposed to prolong the network lifetime, the hop-s pot problem still exists. Data gathering is one of the most important tasks for wireless s sensor networks (WSN) and wireless

Sensor and actor network (WSAN). Generally two approaches could be adopted by sensor nodes to upload their sensory data to the sink. Firs t: sensor nodes send the data to the sink through a single-hop Wireless link. As a result, the transmission power and energy consumption of sensors increases greatly. When sensors are remote from sinks. Second: sensor nodes collaboratively relay the data through other Sensors towards the s ink. Although the transmits s ion power of sensor nodes can be reduced with a much shorter transmission distance, the sensors located near the s inks will have to relay a large volume of data, which leads to shorter lifetime [4, 5, 7, 8, 9].

Another data gathering approach, i.e., mobility-as sis ted data gathering [10, 11, 12, 13], has attracted a lot of research attention recently. Employing a certain mobile device to collect data from sensor nodes. The energy efficiency of sensor nodes could be improved significantly. The lifetime of network can be prolonged consequently. However, the travel s peed of the mobile device is usually quite slow, which Brings a large data gathering latency. For the WSN with highly real- time requirement, this latency induces huge challenges for engineers. To combat this problem, we propose a novel data gathering scheme with multiple mobile s inks. A zone partitioning algorithm is employed in our proposed scheme to increase e the data gathering efficiency.

The remainder of the paper is organized as follows. In Section 2, we review related research works and discuss the shortcomings of conventional mobility-as sis t data gathering schemes. Our proposed algorithm is presented in Section 3. Experimental results are shown in Section 4. Finally, a brief conclusion is drawn in Section 5.

2. RELATED WORK

Demons trading the effectiveness s of mobility-as sis t data gathering scheme in WSN, MULEs [5] is one of the earliest schemes adopting the mobile s ink. MULEs divide the WSN into a three-tier structure including sensor nodes layer, mobile sinks layer and access point’s layer. The mobile sinks collect data from sensor nodes. The existing mobility-as sis ted data gathering can be classified into three categories [14], such as, random mobility [5], predictable mobility [6] and controlled mobility [7]. A random mobility model is proposed by R. Shah, S. Roy, S. Jain, and W. Brunette [5]. The model assumes two-dimensional random walk for mobility and incorporates key system variables such as number of MULEs, sensors and access points. The MULE motion is modeled as a simple symmetric random walk on the grid. At every clock tick, a MULE moves with equal probability to any of the four neighbors of its current grid position. The performance metrics observed are the data success rate (the fraction of generated data that reaches the access points) and the required buffer capacities on the sensors and the MULEs.

The modeling along with simulation results can be used for further analysis and provide certain guidelines for deployment of such systems A predictable mobility method is proposed by A. Chakr abarti[6] , they explore a novel avenue of saving power in sensor networks based on predictable mobility of the observer (or data s ink). To understand the gains due to predictable mobility, they model the data collection process as a queuing system, where random arrivals model randomness in the spatial distribution of sensors. Using the queuing model, they analyze the success in data collection, and quantify the power consumption of the network. Finally, they present a simple observer-driven communication protocol, which follows naturally from the problem formulation and can be used to achieve the predicted power savings. The mobile s ink is controlled to move in the controlled mobility. A controlled mobility method is proposed by M. Ma and Y. Yang [7]. They presented a heurist tic algorithm for planning the moving path/circle of mobile s ink and balancing the traffic load in the network. By adopting a load balancing algorithm that finds the turning points and clusters the network recursively, the network lifetime can be prolonged significantly. In the controlled mobility, to reduce packet deliver y delay and increase network.

In the controlled mobility, to reduce packet deliver y delay and increase network traveling salesman algorithm is utilized by N. Rakhshan [8] to find an optimal Hamiltonian round at the beginning of each clustering period. This scheme is performed by the sinks. Maryam Ahmadi [4] and his research group propose a partition-based nearest job next data gathering scheme which schedules the travel of the mobile sink based on a clustered structure of the network. This scheme divides the sensing field into equal-sized grids and the mobile s ink travels through each grid according to the travel pattern. The single mobile s ink network is modeled as an M/G/1 queue in [15]. Several performance metrics, e.g., the average service time, the average and the distribution of the queue length, are derived and evaluated. It is shown that in order to guarantee the performance of the data gathering schemes , the s ingle round traveling distance of data gathering should not be too long [15].

Another method, based on the s et packing algorithm and traveling sales man problem (SPAT) is proposed by Hide his a Nakayama [16] to access all nodes in the target networks. SPAT guarantees the complete data gathering from all of the sensor nodes in the target field. Moreover, several strategies are employed in SPAT to ensure fairness in terms of data gathering frequency. Firstly, SPAT generates clusters of sensor nodes without redundant clusters. The communications between mobile s inks and all the sensors deployed in the target wireless actuator sensor networks (WSAN) are guaranteed as well. Secondly, the traveling sales man path is calculated among all the clusters ' heads in SPAT. The mobile sink travels along the path. Sensory data from all the cluster heads are collected simultaneously. This idea is derived from one of our earlier mobility methods called Set Covering Algorithm and TSP (SCAT) 17], which aims at achieving the same objective, but lacks fairness due to inability of the set covering algorithm to guarantee coverage of all sensor nodes without overlapping clusters.

Recently, Y. Gu [18] offers a general mathematical model which covers several diversified issues of mobility-as sis t data gathering scheme in WSAN, e.g. s ink mobility, routing, delay, etc. The aforementioned works all focus on optimizing the data gathering schemes in WSN/WSAN for one mobile sink. However, it is quite often that one mobile s ink might not meet the practical requirements.

2.1. Partitioning algorithm

The target area is divided into M areas, and a partition is assigned to one mobile s ink to complete the assigned task of the regional. In order to make the group work the shortest time, it is necessary to balance the task time for each mobile s ink, and as sign adjacent tasks to the same s ink to shorten the traveling distance. We use the following algorithm to partition the target area in order to achieve this purpose.

Given a quadrate target field, a group of sensor nodes are deployed across the field. All of the nodes have sensory data for the mobile sink. The left bottom of the field is s et as the origin of coordinates, M- 1 straight lines are is used from the origin coordinates to divide the field into M zones, such as

Z Z 2… Z *M*

One mobile s ink is assigned to each of the zones. In other words, M mobile s inks collect data in the M zones parallel. In order to minimize the time of data gathering among the whole field, the M zones should be divided balanced with respect to the data gathering latency. Since traveling time is the major part of data gathering latency, an algorithm is proposed to calculate the partitions with balance traveling time.

The straight lines which divide the field are defined as:

$$y = k_i x \quad (1$$

Where, i=1,2, …,M-1. The *I* Sales man Problem TSP) of the *I t h* zone is denoted by Z *t h* zone is *T*

$$\eta = \frac{\max\{T_1, T_2, \dots, T_m\}}{\min\{T_1, T_2, \dots, T_m\}} \times 100\%$$

The partition is considered as balanced when η equals to 1 or approaches 1. Consequently, the partition is valid. Otherwise the partition is considered imbalanced. Theis hould be adjusted until η is 1 or approach 1. A threshold θ can be defined in practice for the balance rate. The partition could be settled when η is no larger than θ. The partition algorithm is shown in the following steps.

1) Set the s lope *k according* to:

$$k_i = \tan(\frac{90^\circ}{m} \times i)$$

Where i =1, 2, M-1.2) Call the TSP algorithm to calculate the shortest path *T m* point of the TSP algorithm are set at the original point of the given field. *I* for each zone. The starting and the ending
2) Compute the balance rate η according to Eq.1. If η=θ, the partition algorithm will be terminated. Otherwise e go to step 4 and keep adjust ting the partitions.
3) Set the zone with the maximum *T* slope *k I* as Zmax. The zone with the minimum *T* (The adjusting scheme is demonstrated in the next part), then loop to step 2.
4) The end of the partition algorithm.

2.2 Partitioning Adjusting

The s lope *k I* need to be adjusted when the traveling time among all the zones are not balanced. A partitioning adjusting algorithm is proposed thereupon. If Zones Zmax and Zmin are neighbors, adjust the line between these two zones to the side of Zmax. Zmax and Zmin are not adjoining. Moreover, one of Zmax and Zmin locates beside the boundary (the axis x or the axis y) of the given field. Adjust the Zmax and Zmin to make Zmax smaller or to make Zmin larger. Except the above two cases, compute the traveling time of the zones neighboring to Zmax and Zmin. Find the zone with smaller traveling distance from Zmax's two neighbors, such as Zs. Adjust the line between Zs and Zmax to the side of Zmax. Similarly, find the zone with larger traveling distance from Zmin's neighbors (denoted by Zm). Then, adjust the line between Zm and Zmin to the side of Zm. Keep this adjusting process until the threshold θ is achieved.

3. Performance Evaluation

The following experiment we suppose that task execution time is not ignored, and the moving s peed of each mobile s ink is variable. Task times in this case can be simplified to ：

$$T_k = \sum_{i=1}^{n} y_{ik} \cdot t_{q_i} + \sum_{j=0, j\neq i}^{n} \sum_{i=0}^{n} \frac{x_{ijk} \cdot d_{ij}}{v_k}$$

$$\text{Denoted：} D_k = \sum_{j=0, j\neq i}^{n} \sum_{i=0}^{n} x_{ijk} \cdot d_{ij}$$

Do represent the completion of the mobile s ink k through a traversal distance. TSP optimization goals can be simplified as Dk.(k=1,2, …,m) minimum and η close to 1 . With 200 nodes deployed randomly, an area of 200[m] ×200[m] is considered. The number of zones ranges from 1 to 10. The threshold of balanced rate θ is chosen as 1. 15 according to heuristic simulations. Monte Car lo simulations are carried out to record the traveling distances in different scenarios. The relation between the number of zones and the averaged iterations is shown as Fig. 2.

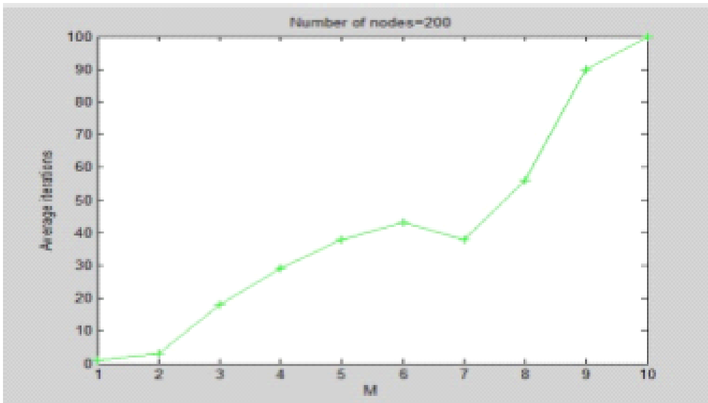

Figure 2. Comparison of average iterations under different partition number

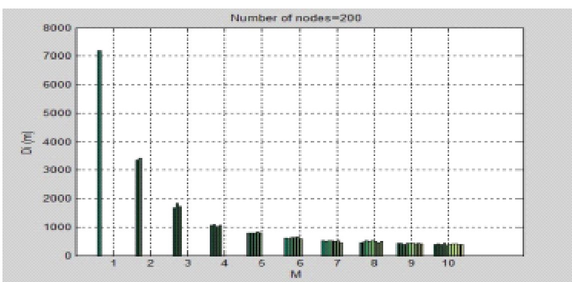

Figure3. Comparison of path distance under different partition number.

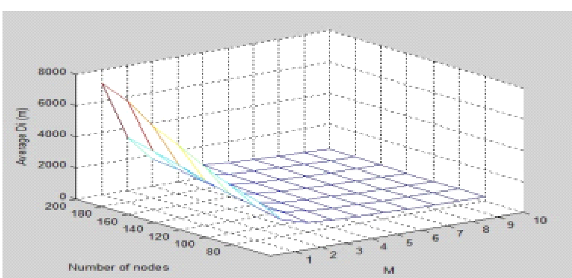

Figure4. Relationship of node number, partition number and average Di Clearly, the averaged iteration increase with the number of zones. It is because the more of the divided zones, the more calculation have to be carried out employing the shuffled frog leaping algorithm.

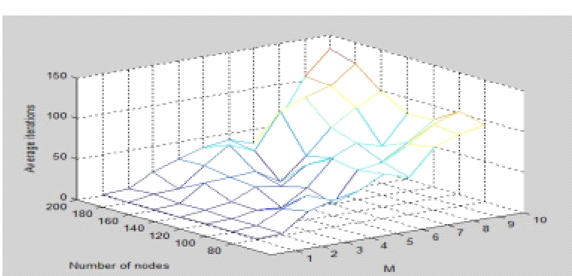

Figure5. Relationship of node number, partition number and average iterations.

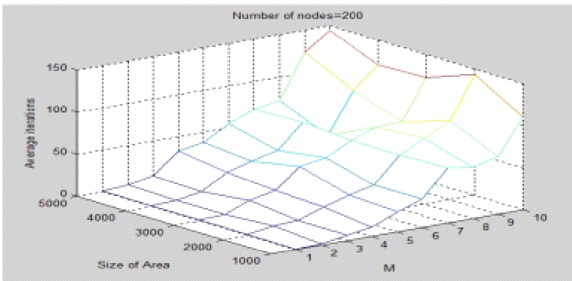

Figure 6 Relationship of area size, partition number and average iterations.

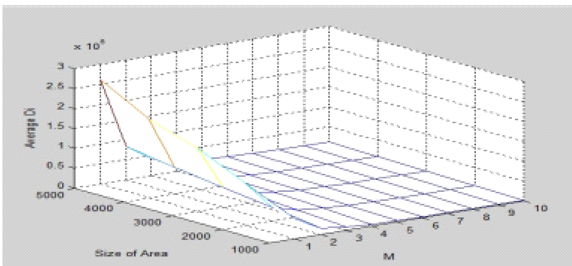

Figure7. Relations hip of area size, partition number and average Di 200 nodes are deployed in the of 5 000[m] ×5000 [m] randomly. The number of mobile sinks is set as 1,5,10. Moving speed of each mobile s ink is set as 5, 10, 15, 20, 25, 30, 35, 40, 45, 50m/s .The threshold of balanced rate θ is set to 1.18. Simulation is performed 10 times in each scene to obtain the relationship between the average delays; s peed of mobile s inks and mobile sink number.

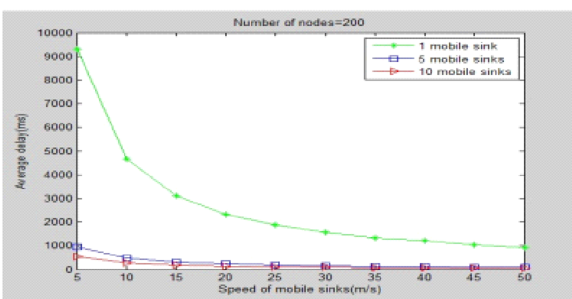

Figure 8 Relationship of mobile s ink speed, mobile s ink number and average delay.

The relation between number of zones and path distances is illustrated in Fig. 3, Histogram is drawn to be demonstrated the averaged path distances Di among all the zones corresponding to each number.

4. CONCLUSION

Cooperated with a novel partition algorithm, a concise and a clustering framework based multiple partitioning data gathering scheme is proposed here. By modeling the partitioning problem as a TSP, an algorithm is designed to balance the data gathering latency and data could be gathered by mobile sinks parallel. Simulations are carried out evaluate our proposed data gathering scheme, and effectiveness of our proposed data gathering scheme is proved by the simulation results. To improve the performance further, grid partition might be used in the future works.

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