Dual Path Based Data Gathering By Mobile Node Through Load Balanced Clustering In Wireless Sensor Networks

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Abstract*- A three-layer framework is proposed for mobile data collection in wireless sensor networks, which includes the sensor layer, cluster head layer, and mobile collector (called SenCar layer, The framework employs distributed load balanced clustering and dual data uploading, which is referred to as LBC-DDU. The objective is to achieve good scalability, long network lifetime and low data collection latency. At the sensor layer, a distributed load balanced clustering (LBC) algorithm is proposed for sensors to self-organize themselves into clusters. In contrast to existing clustering methods, our scheme generates multiple cluster heads in each cluster to balance the work load and facilitate dual data uploading. At the cluster head layer, the inter-cluster transmission range is carefully chosen to guarantee the connectivity among the clusters. Multiple cluster heads within a cluster cooperate with each other to perform energy-saving inter- cluster communication. Through intercluster transmissions, cluster head information is forwarded to SenCar for its moving trajectory planning. At the mobile collector layer, SenCar is equipped with two antennas, which enables two cluster heads to simultaneously upload data to SenCar in each time by utilizing multi-user multiple-input and multiple-output (MU-MIMO) technique.*

Keywords- Load Balanced Clustering Algorithm, Data Collection, Mobility, Dual Data Uploading

I. INTRODUCTION

Proliferation of the implementation for low-cost, low-power, multifunctional sensors have made wireless sensor networks, a major data collection model for extracting local measures of benefit. Sensors are generally densely deployed and randomly scattered over a sensing field and left unattended after being deployed, which makes it difficult to recharge or replace their batteries. After sensors form into autonomous organizations, those sensors near the data sink typically deplete their batteries much faster than others due to more relaying traffic. When sensors around the data sink exhaust their energy, network connectivity and coverage may not be guaranteed, as sensing data in some applications are time-sensitive, data collection may be required to be performed within a specified time frame. Therefore, an efficient, large-scale data collection scheme should aim at good scalability, long network lifetime and low data latency. Several approaches have been proposed for efficient data collection in the literature.

The first category is the enhanced relay routing [4], [7], [8], [9] in which data are relayed among sensors. Besides relaying, some other factors, such as load balance, schedule pattern and data redundancy, are also considered.

The second category organizes sensors into clusters and allows cluster heads to take the responsibility for forwarding data to the data sink. Clustering is particularly useful for applications with scalability requirement and is very effective in local data aggregation since it can reduce the collisions and balance load among sensors.

The third category is to make use of mobile collectors to take the burden of data routing from sensors. Minimizing energy consumption on the forwarding path does not necessarily prolong network lifetime, since some critical sensors on the path may run out of energy faster than others. In cluster- based schemes, cluster heads will inevitably consume much more energy than other sensors due to handling intra-cluster aggregation and inter-cluster data forwarding. Though using mobile collectors may alleviate non-uniform energy consumption, it may result in unsatisfactory data collection latency. Based on these observations, in this paper, we propose a three-layer mobile data collection framework, named Load Balanced Clustering and Dual Data Uploading (LBC-DDU). A distributed algorithm to organize sensors into clusters, where each cluster has multiple cluster heads. Algorithm balances the load of intra-cluster aggregation and enables dual data uploading between multiple cluster heads and the mobile collector. Second, multiple cluster heads within a cluster can collaborate with each other to perform energy efficient inter-cluster transmissions. A mobile collector is used with two antennas (called SenCar in this paper) to allow concurrent uploading from two cluster heads by using MU-MIMO communication.

The SenCar collects data from the cluster heads by visiting each cluster. It chooses the stop locations inside each cluster and determines the sequence to visit them, such that data collection can be done in minimum time.

II. RELATED WORK

Related work characterizes papers we alluded to create and actualize their idea in our work.

O.Gnanwali et al[1] proposed the method to evaluate the data path & it dividing in two ways. The first is data path approval: information activity rapidly finds and fixes steering irregularities. The second is versatile beaconing: amplifying the Trickle calculation to directing control activity decreases course repair idleness what's more, sends less reference points.

According to O.Gnanwali, there are two principles for wireless routing protocols such as, The first is datapath validation: data traffic quickly discovers and fixes routing inconsistencies. The second is adaptive beaconing: extending the Trickle algorithm to routing control traffic reduces route repair latency and sends fewer beacons.

B.Gedik et al [1] depicts a standout amongst the most conspicuous and far reaching methods for information gathering in sensor systems is to occasionally extricate crude sensor persuing. Be that as it may, this adaptability incorporates examination at the expense of force utilization. and in this paper we grow ASAP-a versatile inspecting way to deal with vitality proficient intermittent information gathering in sensor systems. According to this literature survey, it includes on clustering, sampling, & prediction.

Russian et.al [2] examine a 3 tier architecture for gathering sensor information in spares sensor systems and it concentrates on a basic diagnostic model for comprehension exhibitions as framework parameters are scaled. Moreover, investigatio give certain rules to organizations of such frameworks.

M.Zhao et.al [3] Portrays a versatile authority ought to cross the transmission scope of each detector in the area such that the conveyance of every bundle can be limited to a solitary bounce. Be that as it may, this paper may prompt altogether expanded information gathering dormancy because of the low moving speed of the mobiles gathering.

Xu et al [4] Concentrated on arrangements of transfer hubs to lengthen system lifetime. Gnanwali et al. assessed Collection Tree Protocol (CTP) by means of test beds in CTP registers remote courses versatile to remote connection status and fulfills dependability, strength, productivity and equipment autonomy necessities. In any case, when a few hubs on the basic ways are liable to vitality consumption, information gathering execution will be decayed. Mobile Data Collections Contrasted and information accumulation by means of a static sink, presenting versatility for information accumulation appreciates the advantages of adjusting vitality utilizations in the system and associating disengaged locales.

Shah et.al [5] Researched portability under irregular walk where the versatile gatherer grabs information from close-by sensors, supports lastly offloads information to the wired access point. In any case, irregular direction can't ensure idleness limits which are required in numerous applications. Furthermore, it proposed a solitary bounce information gathering plan to seek after the ideal consistency of vitality utilization among sensors where a versatile gatherer called SenCar is streamlined to end at a few areas to assemble information from sensors in the vicinity by means of single-jump transmission. The work was further reached out in to enhance the information.

III. LOAD BALANCED CLUSTERING

The essential operation of clustering is the selection of cluster heads. To prolong network lifetime, we naturally expect the selected cluster heads are the ones with higher residual energy. Hence, we use the percentage of residual energy of each sensor as the initial clustering priority. Assume that a set of sensors, denoted by S = {s1; s2;…. ; sn}, are homogeneous and each of them independently makes the decision on its status based on local information. After running the LBC algorithm, each cluster will have at most M (>1) cluster heads, which means that the size of CHG of each cluster is no more than M. Each sensor is covered by at least one cluster head inside a cluster. The LBC algorithm is comprised of four phases: (1) Initialization; (2) Status claim; (3) Cluster forming and (4) Cluster head synchronization.

3.1 Initialization phase

In the initialization phase, each sensor acquaints itself with all the neighbours in its proximity. If a sensor is an isolated node (i.e., no neighbour exists), it claims itself to be a cluster head and the cluster only contains itself. Otherwise, a sensor, say, si, first sets its status as “tentative” and its initial priority by the percentage of residual energy. Neighbours with the highest initial priorities, which are temporarily treated as its candidate peers. We denote the set of all the candidate peers of a sensor by A.

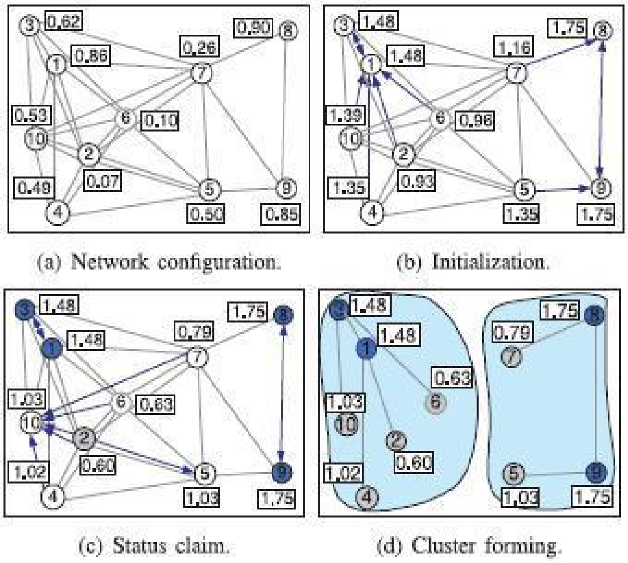


Fig 1. LBC Algorithm M=2

It implies that once si successfully claims to be a cluster head, its up-to-date candidate peers would also automatically become the cluster heads, and all of them form the CHG of their cluster. si sets its priority by summing up its initial priority with those of its candidate peers. In this way, a sensor can choose its favourable peers along with its status decision. Fig.1 depicts the initialization phase of the example, where M is set to 2, which means that each sensor would pick one neighbour with the highest initial priority as its candidate peer.

3.2 Status claim

In the second phase, each sensor determines its status by iteratively updating its local information, refraining from promptly claiming to be a cluster head. Whether a sensor can finally become a cluster head primarily depends on its priority. Specifically, we partition the priority into three zones by two thresholds, th and tm (th> tm) , which enable a sensor to declare itself to be a cluster head or member, respectively, before reaching its maximum number of iterations. During the iterations, in some cases, if the priority of a sensor is greater than th or less than tm compared with its neighbours, it can immediately decide its final status and quit from the iteration. We call this process self-driven status transition. Also, si will announce its current candidate peers to be cluster heads by broadcasting a packet including an ID list, which is referred to as the peer-driven status transition.

3.3 Cluster forming

The third phase is cluster forming that decides which cluster head a sensor should be associated with. The criteria can be described as follows: for a sensor with tentative status or being a cluster member, it would randomly affiliate itself with a cluster head among its candidate peersfor load balance purpose. In the rare case that there is no cluster head among the candidate peers of a sensor with tentative status, the sensor would claim itself and its current candidate peers as the cluster heads. Cluster members that receive this message switch to the initialization phase to perform a new round of clustering.

3.4 Synchronization among cluster heads

To perform data collection by TDMA techniques, intra cluster time synchronization among established cluster heads should be considered. The fourth phase is to synchronize local clocks among cluster heads in a CHG by beacon messages. First, each cluster head will send out a beacon message with its initial priority and local clock information to other nodes in the CHG. Then it examines the received beacon Messages to see if the priority of a beacon message is higher. If yes, it adjusts its local clock according to the timestamp of the beacon message. In our framework, such synchronization among cluster heads is only performed while SenCar is collecting data. Because data collection is not very frequent in most mobile data gathering applications, message overhead is certainly manageable within a cluster[2][14].

IV. CLUSTER HEAD LAYER CONNECTIVITY AMONG CHG'S

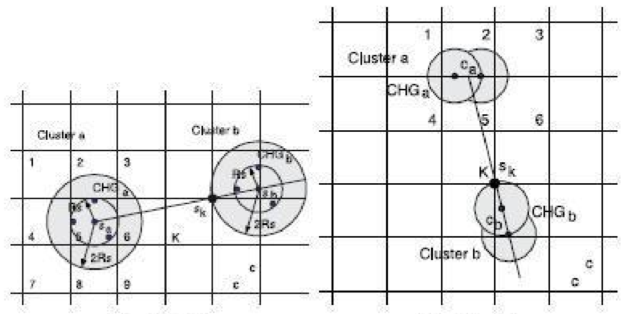
Consider cluster a. no matter where it is located and how it is oriented, it can completely or partially cover at most six cells. The worst case is that all the sensors in these six cells are in the range of cluster a. Thus, the closest sensor Sk outside of cluster a should be at the right bottommost corner of cell k, which is under cell 5. Cluster heads in a CHG as multiple antennas both in the transmitting and receiving sides such that an equivalent MIMO system can be constructed[6][7][8]. The self-driven cluster head in a CHG can either coordinate the local information sharing at the transmitting side or act as the destination for the cooperative reception at the receiving side. Each collaborative cluster head as the transmitter encodes the transmission sequence according to a specified space-time block code (STBC) to achieve spatial diversity. Compared to the single-input single-output system, that a MIMO system with spatial diversity leads to higher reliability given the same power budget. An alternative view is that for the same receive sensitivity; MIMO systems require less transmission energy than SISO systems for the same transmission distance. Therefore, given two connected clusters, compared with the single-head structure, in which the inter-cluster transmission is equivalent to a SISO system, the multi-head structure in LBC-DDU can save energy for inter-cluster communication.

V. MU-MIMO UPLOADING

Multiple cluster heads in a CHG coordinate among cluster members and collaborate to communicate with other CHGs. Hence, the inter-cluster communication in LBC-DDUs essentially the communication among CHGs. By employing the mobile collector, cluster heads in a CHG need not to forward data packets from other clusters. Instead, the inter-cluster transmissions are only used to forward the information of each CHG to SenCar. The inter-cluster organization is determined by the relationship between the inter-cluster transmission range Rt and the sensor transmission range Rs. Clearly, Rt is much larger than Rs. It implies that in a traditional single-head cluster, each cluster head must greatly enhance its output power to reach other cluster heads.

However, in LBC-DDU the multiple cluster heads of a CHG can mitigate this rigid demand since they can cooperate for inter-cluster transmission and relax the requirement on the individual output power. Figure 4 Neighbouring distance between clusters. In the following, we first find the condition on Rth at ensures inter-cluster connectivity, and then discuss how the cooperation in a CHG achieves energy saving in output power.

Once the selected polling points for each cluster are chosen, SenCar can finally determine its trajectory. The moving time on the trajectory can be reduced by a proper visiting sequence of selected polling points. Since SenCar departs from the data sink and also needs to return the collected data to it, the trajectory of SenCar is a route that visits each selected polling point once. This is the well-known travelling salesman problem (TSP). Since SenCar has the knowledge about the locations of polling points, it can utilize an approximate or heuristic algorithm for the TSP problem to find the shortest moving trajectory among selected polling points, e.g., the nearest neighbour algorithm[10][11] MU-MIMO can greatly speed up data collection time and reduce the overall latency. Another application scenario emerges in disaster rescue. For example, to combat forest fire, sensor nodes are usually deployed densely to monitor the situation. These applications usually involve hundreds of readings in a short period (a large amount of data) and are risky for human being to manually collect sensed data. A mobile collector equipped with multiple antennas overcomes these difficulties by reducing data collection latency and reaching hazard regions not accessible by human being[1][2][10]. Although employing mobility may elongate the moving time, data collection time would become dominant or at least comparable to moving time for many high-rate or densely deployed sensing applications. In addition, using the mobile data collector can successfully obtain data even from disconnected regions and guarantee that all of the generated data are collected.



(a) $M > 2$. (b) $M = 2$.

Fig 2.Distance between neighboring clusters assume all the schemes are implemented under the same duty-cycling MAC strategy.

VI. PERFORMANCE EVALUATION

The performance of our framework is compared with other schemes. Since the main focus of this paper is to explore different choices of data collection schemes, for fair comparison, we The first scheme for comparison is to relay messages to a static data sink in multi-hops and we call it Relay Routing. It provides more robustness and error immunity. Sensors select the next hop neighbor with the highest residual energy while forwarding messages to the sink. Once some nodes on a routing path consume too much energy, an alternative route will be chosen to circumvent these nodes. In this way, the relay routing method can provide load balance among nodes along the routing path. The second scheme to compare is based on Collection Tree Protocol,[6]. In CTP, the expected number of transmission (ETX) is used as a routing metric and the route with a lower ETX takes precedence over routes with higher ETX. For simplicity, we assume ETX is proportional to transmission distances between nodes. This assumption is reasonable since using fixed power for longer transmission distance would cause attenuated receiving power and potentially increase error probability and expected number of transmissions. Based on this metric, we establish a collection tree rooted at the static data sink at the origin (0, 0)[14]. Each node forwards messages along the path with the lowest ETX towards the sink. Any broken links caused by nodes depleted battery energy would lead to large ETX and are avoided in routings.

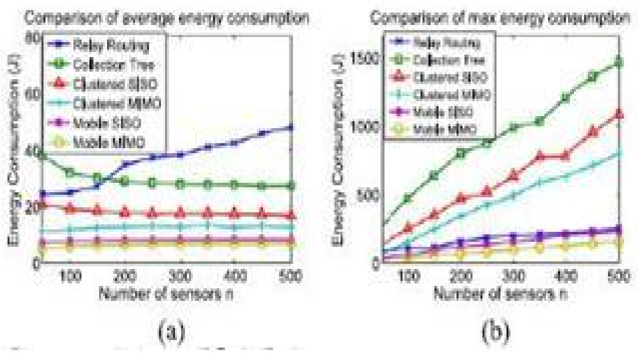


Figure 3(a) shows the average energy consumptions per node and 3(b) shows the maximum energy consumptions per node

The results show that LBC-DDU can greatly reduce energy consumptions by alleviating routing burdens on nodes and balancing workload among cluster heads, which achieves 20 percent less data collection time compared to SISO mobile data gathering and over 60 percent energy saving on cluster heads. We have also justified the energy overhead and explored the results with different numbers of cluster heads in the framework.

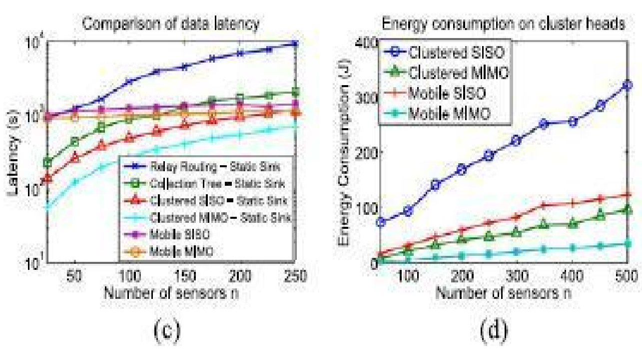


Figure 3(c) shows the companion of data latency and 3(d) shows the energy consumption on cluster heads.

VIII.CONCLUSION AND FUTURE SCOPE

In this paper we have proposed the LBC-DDU Framework for mobile data collection in WSN. It consists of sensor layer, cluster head layer and sencar layer. It employs distributed load balanced clustering for sensor self-organization, adopts collaborative inter cluster communication for energy efficient transmissions among CHGs, uses dual data uploading for fast data collection, and optimizes SenCar's mobility to fully enjoy the benefits of MU-MIMO. Our performance study demonstrates the effectiveness of the system.

Finally, we would like to point out that there are some interesting problems that may be studied in our future work. The first problem is how to find polling points and compatible pairs for each cluster. A discretization scheme should be developed to partition the continuous space to locate the optimal polling point for each cluster. Then finding the compatible pairs becomes a matching problem to achieve optimal overall spatial diversity. The second problem is how to schedule MIMO uploading from multiple clusters. An algorithm that adapts to the current MIMO-based transmission scheduling algorithms should be studied in future.

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