ENERGY EFFICIENT DATA COLLECTION IN WIRELESS SENSOR NETWORK

Nandhini B¹ and Srie Vidhya Janani E²
Department of Computer Science and Engineering, Anna University Regional Centre, Madurai, India
E-mail: ¹nandhini.b.2359@gmail.com, ²esrievidhya@gmail.com

Abstract
Wireless Sensor Network has wide range of applications in the field of networks. The sink nodes need to communicate effectively with other sensor nodes, for effective communication. The facts such as cluster size, energy and lifetime of the nodes should be considered to make the communication effective. While transmitting, the nodes are grouped in clusters with one head per cluster. The cluster, nearer to the sink nodes may run out of energy due to continuous utilization. So an intermediate node for communication is used, called as AGM node. The sensor nodes in the clusters, first send the information to their cluster head (chosen on the basis higher residual energy), the cluster head in turn sends the information to the AGM node whereas the AGM transmits it to the respective sensor node and vice versa. Selection of AGM among many nodes and the entire process is carried out on the basis of the maneuver algorithm, which has 6 phases like compact clustering, AGM selection, Interclustering, Load balancing and data distribution, Communication and replenishment and Reconcile algorithm. In this process the CH transmits data after eliminating redundancy in it. In case of massive damage, Reconcile algorithm is used for the efficient usage of available AGM nodes to regain from the relapsed network.

Keywords:
Sink Nodes (SN), Cluster Head (CH), Agreed Upon Mediator Node (AGM), Mobile Sink (MS), Residual Energy

1. INTRODUCTION

Wireless sensor network (WSN) is a smart environment, which proves to be beneficial for the upcoming generation. It is a self organized network, where the collection of data from each node in an energy efficient manner is ought to be the challenge. The sensor nodes are assigned with responsibilities, whereas they behave as masters and slaves. They could be distributed throughout, in a larger environment. These nodes consume certain amount of energy while transmitting the data. This work joints the methods for reducing the energy consumption without compromising the efficiency of the entire network. A node called AGM node is introduced which is selected by the cluster head, to act as the mediator between the Mobile sink and the cluster head. This in turn reduces the workload of the cluster head, which makes the nodes to prolong in the network thereby increasing the lifetime of the node. In case of failure of single AGM node, the replacement of the particular node will be done by the CH and in turn if a massive damage occurs, regaining of the network is done similar to the 1c spider web algorithm[2]. This will lead to energy efficient network even after the damage of the network.

2. RELATED WORK

Wireless sensor nodes consumes energy while,
1) Transmitting data from one node to another node
2) Performing aggregation and refining data before forwarding
3) Moving from one location to other location
4) Performing election to assign responsibilities

Joint Mobility and Routing approach states that, the nodes which are closer to the base station are exposed to heavy load and work, since all other nodes transmit the data to it, while communicating with the sink node. Hence the nodes which are closer to the sink node depletes in energy. In order to avoid this, the sink node is moved throughout the network. So the nodes nearer to the sink node keep changing. The movement of sink nodes is kept optimum by moving it the shortest path [4]. Hence energy could be conserved and the lifetime of nodes could be increased. But, the path in which the sink should be moved is not addressed [4]. This may result in energy loss while moving in the network over a long distance. In Adaptive Sink Mobility and event driven approach the data is transmitted to other nodes only in an event driven fashion i.e. the data is transmitted only if it known that it is worth to transmit. Moreover, the location of the sink node is not predictable because it might be mobile. Hence the sink node is moved to the optimal location (in terms of shorter distance) and then data is transmitted. So energy could be conserved while transmitting data. This overcomes the drawback of the previous paper [2]. But the workload at each node and distance between the nodes will be greater, which decreases the lifetime of the nodes. Energy could be greatly conserved if data is transmitted over a shorter distance. Hence a mediator is introduced to transmit the data (here its MULE-sensor nodes mounted on common moving objects). MULE overcomes the drawback of the previous paper [6]. MULE operates with UWB (Ultra Wide Band) radio communication technology, which consumes lesser energy while communicating [6], MULE collects data from the nodes which are closer in range, buffers it and then transmits the data to the respective sink node. Hence the lifetime of the nodes could be increased. But the data could be transmitted if and only if the MULE is present in the particular location. If MULEs are present then energy consumption could be greatly reduced.

![Fig.1. Data Mule](image)
In clustering method, the nodes grouped into clusters with one node as its head, which is based on the maximum amount of residual energy. In unequal clustering method, the nodes which are closer to the base station are sized smaller, so that they consume only lesser energy while communicating within the cluster. The clusters which are farther away from base station will be of larger size [3]. It is obvious that smaller sized cluster will require lesser energy to communicate within the cluster than larger sized cluster. The energy that is needed to communicate within the cluster is conserved in case of small sized clusters to implement unequal clustering [3].

3. THE MANEUVER PROTOCOL

In this protocol, we assume that the location of the sink nodes is unknown and each node has fixed energy levels. Only an adequate number of nodes are assigned as the AGM, so as to replace in case of failure of the AGM. The main assumption with this paper is the nodes which are closer to the sink node could communicate in the easier way. The sink node considered in this paper is mobile; the presence of the sink node is indicated to other nodes by sending BEACON messages. Later this is considered as one of the important parameters for the protocol implementation. The entire process is carried out in two phases namely, enrollment phase and steady phase. The setup phase deals with the overall settings that is done by three process and the allegiance phase performs the committed role and deals with reselection of AGM nodes and/or cluster heads in case of energy exhaustion done by two process [1].

3.1 COMPACT CLUSTERING

3.1.1 Need For Clustering:

Wireless sensor network is a large scale deployment area where the data must be aggregated to necessitate the efficient organization of the network. Hence clustering proves to be an efficient technique, which leads to

- Balanced load across the network
- Prolonging the network life time
- Reduced channel contention
- Reduced packet collisions

While clustering the nodes, the above factors are achieved and it leads to increased throughput. Hence, the concept of clustering is implemented [1].

3.1.2 Clustering Parameters And Its Need:

The parameters needed for clustering and its needs are explained below,

3.1.3 Cluster Size:

Size of the cluster is one of the parameters which need much of concentration. The cluster is a collection of nodes with its own cluster node as its lead (cluster head), whereas the cluster head has to communicate with its own cluster members, the AGM node and other cluster heads. Communication with other cluster heads and AGM nodes are inevitable, where it requires a certain amount of energy. But the energy spent while communicating within the cluster could be minimized considerably, by reducing the size of the cluster.

3.1.4 Selection Of Cluster Head:

Once the cluster size is determined, a lead for the cluster (cluster head), should be appointed. The cluster head is selected on the basis of the amount of residual energy it possess and the proximity of the cluster head from the sink nodes. The cluster head selection and the size of the cluster are on the basis of Compact clustering algorithm. The cluster head collects the data from its cluster members. Then it performs data aggregation, so that energy spent while transmitting the redundant data could be reduced. Once it aggregates the data, it then forwards the data to the respective destined nodes. More over if the node which is elected as the cluster head is nearer to its destination node, the energy spent in transmitting the data (regarding distance) could be conserved.

3.1.5 Selection of cluster members:

Once the cluster head is selected, the cluster head in turn should select its own cluster members. This is based on the amount of residual energy they possess, while electing. If the residual energy of the cluster members is greater, then the node prolongs in the cluster. The proximity of the cluster members to the sink node is also considered. The nodes which are closer to the sink nodes are elected as its cluster members, so that the energy spent in the transmission of the data could be reduced considerably.

3.1.6 Transmission Range:

The transmission range should be determined while electing the cluster members. This depends upon the maximum and minimum distance between the sink node and the node to be elected as the cluster. A detailed description of this competence calculation is given under unequal clustering [3].

3.1.7 Residual Energy:

It is the amount of energy, a particular node possess after transmitting the data i.e. the current energy level after transmission. Since the sensor nodes are deployed in wide environment charging the nodes are less possible, so maximum utilization of the nodes with the available energy should be done. If the residual energy of the node is greater, the node lasts for long time in the network [1].

3.1.8 Compact Clustering Algorithm:

The nodes competing for cluster head election will be in a particular range. This range is called as Competing range (R). If a cluster head is elected (say $S_i$), then no other cluster heads are
allowed in the range $R$. The clusters are sized smaller based upon the competence value and the residual energy.

**Parameters:**

$R$ is the maximum competence range which is predefined. Using this $R$, the maximum and minimum competence range for a particular node (say $i$) is calculated.

$$R_{\text{max}} = (1 - c)R_i$$

$$R_{\text{min}} = (1 - c)R_i$$

where, $c$ is the constant value ranging from 0 to 1.

Probability of ordinary nodes becoming Cluster Head = $T$ (threshold value).

$$d(S_i, BS) = \text{the distance between the particular node}(S_i) \text{ and the base station (BS)}$$

Competence range.

$$(R_i) = (1 - c)(d_{\text{max}} - d(S_i, BS))/(d_{\text{max}} - d_{\text{min}})R_i$$

$d_{\text{max}} = \text{Maximum distance between the sensor node and the base station.}$

$d_{\text{min}} = \text{Minimum distance between the sensor node and the base station.}$

**Working:**

The sensor nodes participating in the cluster head election will be elected as the Cluster head based on the competence range. Each node will forward its own COMPETE HEAD MSG (Competence range, Residual energy), to all other nodes in the network. Each node participating in the election will also have the information about other nodes. This information is stored in $S_{ch}$. Now each node (say $S_i$) compares its competence value and residual energy with the information it has in the $S_{ch}$. If it finds its own residual energy to be greater and competence range is lesser than all other nodes, it declares itself as cluster head and informs to all other cluster heads by sending FINAL HEAD MSG (Competence range, Residual energy). If the value of $S_i$ is not greater, then it sends QUIT ELECTION MSG to other nodes. Once this message is received all other nodes removes the information about $S_i$ in its own information counter. After the selection of Cluster Head, the elected cluster head (say $S_i$) will now elect its cluster members. The cluster head broadcasts CH ADV MSG to all other nodes. Once this message is received by all other nodes, the sensor node sends JOIN CLUSTER MSG (Competence range, Residual energy) to the cluster head. Now the cluster head elects its cluster members, which are closer to the base station based upon the Competence range. It is obvious that nodes which are closer to the base station will be smaller in number and they are clustered together in smaller size.

**3.2 AGM Node Selection**

The cluster heads will be overloaded by performing operations such as communicating with its cluster members, base station and with the sink nodes. Moreover cluster head has to perform data filtering upon the raw data exploiting the data redundancy. For these obvious reasons, cluster heads may run out of energy and hence we elect a node among the cluster as AGM which acts as a mediator between the cluster head and the sink node. This selection is done based on the Mobicluster technique [1]. The second module of the Mobicluster is used for AGM selection.

**3.3 INTERCLUSTERING**

All the cluster heads will have the information about other adjacent clusters in its information counter. If a cluster head doesn’t find any AGM within the cluster, then the cluster head will attach itself to the cluster head which is located nearby, based upon the information it has. This type of overlapping of one cluster with the other is called as intercluster overlapping. This technique is described in the third module of Mobicluster technique [1].

**3.4 LOAD BALANCING & DATA DISTRIBUTION**

The data accumulated at individual source nodes are sent to local cluster heads with a time period of $T$. Upon receiving the data from the nodes, the cluster head process the data to remove the redundancy by using the following algorithm. If the data is further forwarded to its remote cluster (in case of cluster attachment), data filtering could happen twice. This is done by data distribution algorithm as in Mobicluster technique [1].

**3.5 COMMUNICATION AND REPLACEMENT**

In order to notify the contact time, we make use of an acknowledgement based protocol between AGMs and sink nodes (MS). To indicate the presence of sink node and if it’s idle (not receiving any packet) the sink node transfers a POLL packet. This packet is transmitted at fixed intervals $T_{poll}$, When an AGM receives this packet, it starts transmitting the data. After each transfer of data, the AGM waits for the acknowledgement from the sink nodes. The AGM clears the data from its buffer after receiving the acknowledgement for the previous data transferred. The AGM enrolment may change periodically. If the energy level of the AGM falls below the threshold level, it request the cluster head to engage another node as AGM, in order to avoid the relapsing of network [1].

**3.6 AGM NODE PLACEMENT – THE VANTAGE POINT**

If the AGM node runs out of energy, the cluster head will replace it, by referring to its $S_{ch}$ counter. But, if a massive damage occurs because of natural calamities or through combat reconnaissance the entire network will get segmented. In such cases, the remaining AGM nodes should be placed effectively. The AGM node possesses more energy, and it will be in a better communication range, when compared with other sensor nodes in the field. AGM nodes are mobile and they will perform data aggregation and forwarding. For these valid reasons AGM nodes are claimed to be expensive. Hence the number of AGM nodes employed in the field must be minimized and should be effectively placed.

**3.6.1 Reconcile Algorithm:**

The reconcile algorithm concentrates on fixing the multimode failure and to employ optimal positioning. The core idea of this algorithm is to balance the number of hops, by placing the AGM towards the Center of Mass (CoM). The procedure is given as follows.

798
Procedure:
Polygon $\leftarrow$ Convex-Hull (Representatives)
CoM $\leftarrow$ Center-Of-Mass (polygon)
Line Array $\leftarrow$ Create-Lines (polygon, CoM)
Heap $\leftarrow$ buildMaxHeap (lineArray)

While $\leftarrow$ true do
    $L_i$ $\leftarrow$ heap.extractMax()
    Deploy ($L_i$, CoM)
    UpdateLineStatus ($L_i$)
    Heapify()
    If $L_i$ = NOT CONNECTED then
        Break
    end if
end while

lineArray $\leftarrow$ heap.toSortedArray

while true do
    BreakWhile $\leftarrow$ true
    for each $L_i \in$ lineArray do
        if $L_i$.status = CONNECTED then
            If $L_i$.status = RIGHT CONNECTED then
                deploy ($L_i$, $L_i$.left.last)
            else if $L_i$.status = LEFT CONNECTED then
                deploy ($L_i$, $L_i$.right.last)
            else
                deploy ($L_i$, CoM)
            endif
        endif
    endfor
    if breakWhile then
        Break
    EndIf
EndWhile

fillGapBetweenUnattachedSegments

Working:

Once the damage has occurred, the reconcile algorithm gets initiated. At first the cluster head selects few number of sensor nodes from or nearby the damaged segments in a random fashion. The selected nodes are called as representative nodes. In order to determine the Centre of Mass (CoM) convex hull algorithm is applied over the representative nodes. Once the boundary points are determined and a polygon is formed, each of the representative nodes are connected to the CoM. The connectivity between the boundary points and the CoM is referred as $L_i$ and their status is referred as line status, which has an update about the distance between the $L_i$ closer to CoM and the CoM. This line status is arranged in descending order. The remaining AGM nodes (if exist), will get connected while nearing the CoM, because AGM nodes from various points will get closer while reaching the CoM. Segments which are located nearby will get connected earlier, where in case of segments located farther away may need AGM nodes as the mediator. Each segment should be connected on both right and left side or at least on either of the sides. Until, all the segments get connected the AGM nodes will be deployed, based upon the line status. If an AGM node is not connected, one Hence AGM nodes should be used effectively in connecting them. The AGM node deployed should be reachable to its neighboring segments for its status to get updated. This algorithm continues until all the segments get connected in the network, resulting in the usage of less number of AGM nodes [2].

4. SIMULATION RESULTS

In the Simulation Environment, 100 sensor nodes are deployed in a square region 1500 *1500 meters in size. Nodes are distributed in random manner. The performance of MANEUVER is learnt from comparisons with the protocols MOBICLUSTER and IC SPIDERWEB through simulation using NS2 Simulator. The following are the simulation parameters considered:

4.1 MINIMUM ENERGY LEVEL

The implementation of Maneuver protocol yields better residual energy when compared with the previous techniques, RD-FT and Mobicleuster. At the end of every 10 seconds, the residual energy of each node is calculated and it is proved to be greater for maneuver. The graph conveys, that for every 10 sec the energy spent, while using maneuver is less when compared to other protocols.

Fig.3. Average Residual Energy when compared with RD-FT and Mobicleuster

4.2 ACCURACY RATE

The accuracy of the data delivered while using maneuver protocol is greater eventually, when compared with the RD-FT. In this way, it uses the energy efficiently by avoiding the energy exhausted in re-transmission.
4.3 PACKET TRANSMISSION RATE

The transmission rate at which the packets are transferred is greater when compared with RD-FT. The energy spent in transmitting the packets is less and the packets are transferred in the more efficient manner.

4.4 ENERGY LEVEL OF AGM NODES

The implementation of Maneuver protocol yields better residual energy for AGM nodes, when compared with the previous technique, RD-FT and Mobicluster. For every 10 nodes, the residual energy is calculated and it is proved to be greater for maneuver.

5. CONCLUSION

Introduction of AGM nodes along with maneuver protocol will enhance the efficiency of the network and eliminates the draining menace. The damage to the network resulting in single AGM node failure or a massive damage causing multi AGM node failure could be recovered by using this technique. The work for comparing the QoS parameters, to prove that the proposed technique is efficient, is being carried out.

REFERENCES

[1] C. Konstantopoulos, G. Pantziou, D. Gavalas, A. Mptiopoulos and B. Mamalis, “A Rendezvous based approach enabling Energy Efficient sensory data collection with mobile sinks”, IEEE Transactions on Parallel and Distributed systems, Vol. 23, No. 5, pp. 809-817, 2012.

[2] F. Senel, M. Younis and K. Akkaya, “Bio-Inspired Relay Node Placement Heuristics for Repairing Damaged Wireless Sensor Networks”, IEEE Transactions on Vehicular Technology, Vol. 60, No. 4, pp. 1835-1848, 2011.

[3] G. Chen, C. Li, M. Ye and J. Wu, “An Unequal Cluster-Based Routing Protocol in Wireless Sensor Networks”, Wireless Networks, Vol. 15, No. 2, pp. 193-207, 2009.

[4] J. Luo and J-P. Hubaux, “Joint Mobility and Routing for Lifetime Elongation in Wireless Sensor Networks”, Proceedings of 24th Annual Joint Conference of the IEEE Computer and Communications Societies, Vol. 3, pp. 1735-1746, 2005.

[5] Z. Vincze, D. Vass, R. Vida, A. Vidacs and A. Telcs, “Adaptive Sink Mobility in Event-Driven Densely Deployed Wireless Sensor Networks”, Ad Hoc and Sensor Wireless Networks, Vol. 3, No. 2-3, pp. 255-284, 2007.

[6] R. C. Shah, S. Roy, S. Jain and W. Brunette, “Data MULEs: Modeling and Analysis of a Three-Tier Architecture for Sparse Sensor Networks”, Proceedings of the First IEEE International Workshop on Sensor Network Protocols and Applications, pp. 30-41, 2003.
[7] X. Cheng, D-Z. Du, L. Wang and B. Xu, “Relay sensor placement in wireless sensor networks”, Wireless Networks, Vol. 14, No. 3, pp. 347–355, 2008.

[8] E. L. Lloyd and G. Xue, “Relay node placement in wireless sensor networks”, IEEE Transactions on Computers, Vol. 56, No. 1, pp. 134–138, 2007.

[9] A. A. Abbasi, M. Younis and K. Akkaya, “Movement-assisted connectivity restoration in wireless sensor and actor networks”, IEEE Transactions on Parallel and Distributed Systems, Vol. 20, No. 9, pp. 1366–1379, 2009.

[10] K. Akkaya, F. Senel, A. Thimmapuram and S. Uludag, “Distributed recovery from network partitioning in movable sensor/actor networks via controlled mobility”, IEEE Transactions on Computers, Vol. 59, No. 2, pp. 258–271, 2010.

[11] J. Tang, B. Hao and A. Sen, “Relay node placement in large-scale wireless sensor networks”, Computer Communications, Vol. 29, No. 4, pp. 490–501, 2006.

[12] E. B. Hamida and G. Chelius, “Strategies for Data Dissemination to Mobile Sinks in Wireless Sensor Networks”, IEEE Wireless Communications, Vol. 15, No. 6, pp. 31–37, 2008.

[13] M. Demirbas, O. Soysal and A. Tosun, “Data Salmon: A Greedy Mobile Basestation Protocol for Efficient Data Collection in Wireless Sensor Networks”, Proceedings of the 3rd IEEE International Conference on Distributed Computing in Sensor Systems, pp. 267-280, 2007.

[14] L. Friedmann and L. Boukhatem, “Efficient Multi-Sink Relocation in Wireless Sensor Network, Networking and Services”, Proceedings of Third International Conference on Networking and Services, pp. 90, 2007.

[15] S. Nesanomy, M. K. Vairamuthu and M. E. Orlowska, “On Optimal Route of a Calibrating Mobile Sink in a Wireless Sensor Networks”, Proceedings of Fourth International Conference on Networked Sensing Systems, pp. 61-64, 2007.

[16] A. Kashyap, S. Khuller and M. Shayman, “Relay placement for higher order connectivity in wireless sensor networks”, Proceedings of 25th IEEE International Conference on Computer Communications, pp. 1-12, 2006.

[17] M. Younis and K. Akkaya, “Strategies and techniques for node placement in wireless sensor networks: A survey”, Ad Hoc Networks, Vol. 6, No. 4, pp. 621–655, 2008.

[18] J. L. Bredin, E. D. Demaine, M. Hajiahayi and D. Rus, “Deploying sensor networks with guaranteed capacity and fault tolerance”, Proceedings of the 6th ACM International Symposium on Mobile and Ad Hoc Networking and Computing, pp. 309–319, 2005.

[19] F. Wang, D. Wang and J. Liu, “Traffic-aware relay node deployment for data collection in wireless sensor networks”, Proceedings of the 6th Annual IEEE Communications Society conference on Sensor, Mesh and Ad Hoc Communications and Networks, pp. 351–359, 2009.

[20] J.Y. Hsiao, C.Y. Tang and R.S. Chang, “An Efficient Algorithm for Finding a Maximum Weight 2-Independent Set on Interval Graphs”, Information Processing Letters, Vol. 43, No. 5, pp. 229-235, 1992.

[21] A. Kinalis, S. Nikoletseas, D. Patroumpa and J. Rolim, “Biased Sink Mobility with Adaptive Stop Times for Low Latency Data Collection in Sensor Networks”, Proceedings of IEEE Global Telecommunications Conference, pp. 1-6, 2009.

[22] A. Keshavarzian, H. Lee and L. Venkatraman, “Wakeup Scheduling in Wireless Sensor Networks”, Proceedings of the 7th ACM International Symposium on Mobile Ad Hoc Networking and Computing, pp. 322-333, 2006.

[23] C-Y Chang, C-T Chang, Y-C Chen and H-R Chang, “Obstacle-resistant deployment algorithms for wireless sensor networks”, IEEE Transactions on Vehicular Technology, Vol. 58, No. 6, pp. 2925–2941, 2009.

[24] D. M. Flickinger, “Motion planning and coordination of mobile robot behavior for medium-scale distributed wireless network experiments”, M.S. Thesis, Department of Mechanical Engineering, University of Utah, Utah, 2007.

[25] M. Sheldon, D. Chen, M. Nixon and A. K. Mok, “A practical approach to deploy large scale wireless sensor networks”, Proceedings of IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, pp. 250, 2005.

[26] S. Soro and W.B. Heinzelman, “Prolonging the lifetime of wireless sensor networks via unequal clustering”, Proceedings of the 19th IEEE International Parallel and Distributed Processing Symposium, Vol. 13, pp. 236, 2005.

[27] I. Stoimenov and S. Olariu, “Data-centric protocols for wireless sensor networks,” Handbook of Sensor Networks: Algorithms and Architectures, pp. 417-456, 2005.