Modified Energy Efficient Backup Hierarchical Clustering Algorithm Using Residual Energy for Wireless Sensor Network

Rajesh. P, Priya. S, Priyanka. R

Abstract— ***Clustering is a fundamental performance improvement technique in wireless sensor networks, which can increase network scalability, lifetime and power level. In this paper, we integrate the multi-hop technique with a backup-based clustering algorithm using the residual energy to organize sensors. By using an adaptive backup strategy as well as the residual energy, the algorithm not only realizes load balance among sensor node, but also achieves dynamic cluster head distribution across the network in a timeout manner. Simulation results also demonstrate our algorithm is more energy-efficient compared to other algorithms. Our algorithm is also easily extended to avoid the formation of forced cluster heads, thereby it achieves better network management, energy-efficiency and scalability.***

Index Terms— ***dynamic cluster, forced cluster head, load balance, residual energy.***

I. INTRODUCTION

In wireless sensor network, the clustering is an fundamental improvement technique in which the bandwidth and energy are significantly more limited compared to other networks. These constraints need to be considered and they require the innovative designs. Clustering algorithms appeared from adhoc networks, which is inspired by wired networks, such as the Internet. LEACH[9] is the first typical clustering protocol designed for wireless sensor networks. Because it is the first mature algorithm for cluster formation, LEACH becomes a baseline for successors. Since the birth of LEACH, more and more clustering algorithms have been proposed and show their advantages in energy efficiency and node management compared with flat routing protocols, such as directed diffusion[11]. HEED[6] is another classical clustering approach proposed in 2004, to achieve better load balance, HEED considers the residual energy as the criterion to choose clusterheads. On the other hand, HEED is too strict to destroy the randomness of the algorithm, which might lead to worse energy efficiency. In order to realize more load balancing, Cao presents a new adaptive backoff strategy in [4] to not only realize load balance among sensor node, but also ensure that the elected cluster-heads are evenly distributed. The Max-Min d-cluster algorithm proposed in [13] generates d-hop clusters which can achieve better load balance and generate fewer clusters than early algorithms. But this algorithm does not ensure that the total energy consumption is minimized. Moreover, the Max-Min d-cluster algorithm suffers high implement complexity, making it unsuitable for resource limited sensor networks. Assuming that sensors are distributed according to a homogeneous spatial poisson process, Bandyopadhyay et al.[8] first introduced a multi-hop hierarchical clustering algorithm for wireless sensor networks, they prove that the algorithm can work better than previous algorithms in multi-hop networks. But the random property of the algorithm, a lot of forced cluster-heads will appear in many cases, i.e., the node has no cluster to join and has to communicate directly with BS, which is often located far away from the node's vicinity. The resulting long-range transmission to the BS is very energy demanding. Also the residual battery energy has not been considered in their algorithm.

The rest of this paper is organized as follows. Section 2 briefly describes the applications of the WSN in various fields. Section 3 includes a detailed survey of the related research. The proposed algorithm is discussed in section 4.Section 5 discusses the simulation and its results Finally Section 6 concludes the paper.

Manuscript received on April 14, 2012.

Rajesh. P, Information technology, Anna University-Chennai, India, 9944981694, (e-mail: rajeshapce@gmail.com).

Priya. S, Information technology, Anna University-Chennai, India, 9843115384, (e-mail: priyasaishu@gmail.com).

Priyanka. R , Information technology, Anna University-Chennai , India, 8220605847, (e-mail: priyarbabur@gmail.com).

II. APPLICATIONS

This section describes a few areas where WSNs can be used effectively. According to Akyildiz, Su, Cayirci and Sankarasubramaniam, 2002[10] WNS are able to monitor wide range of applications which include Temperature, Humidity, Pressure, Lightning conditions, Soil makeup, Presence of objects, Mechanical stress, Speed, direction and size of objects, structural monitoring, water/waste water monitoring, data logging, machine health monitoring . Typical applications include forest fire detection. According to Mohamed Hefeeda and Majid Bagheri[14], they consider forest fire detection problem as a k-coverage problem in wireless sensor networks. In addition, they present a simple data aggregation scheme based on the FWI System. This data aggregation scheme significantly prolongs the network lifetime, because it only delivers the data that is of interest to the application. Other applications include forest fire detection, flood detection [Bonnet, Seshadri and Gehrke, 2000] etc.

III. RELATED WORK

Ad hoc networks (also referred to as packet radio net works) consist of nodes that move freely and communicate with other nodes via wireless links. One way to support efficient communication between nodes is to develop a wireless backbone architecture While all nodes are identical in their capabilities, certain nodes are elected to form the backbone. These nodes are called cluster heads and gateways. Cluster heads are nodes that are vested with the responsibility of routing messages for all the nodes within their cluster. Gateway nodes are nodes at the fringe of a cluster and typically communicate with gateway nodes of other clusters. The wireless backbone can be used either to route packets, or to disseminate routing information, or both.

In wireless sensor networks (WSN), communication band width and energy are significantly more limited than in a tethered network environment. These constraints require innovative design techniques to use the available bandwidth and energy efficiently. Clustering algorithms appeared from ad-hoc networks, which is inspired by wired networks, such as the Internet. LEACH [9] is the first typical clustering protocol designed for sensor networks. Because it is the first mature clustering algorithm, LEACH becomes a base-line for successors. Since the birth of LEACH, more and more clustering algorithms have been proposed and show their advantages in energy efficiency and node management compared with flat routing protocols, such as directed diffusion [11]. HEED [6] is another classical clustering approach proposed in 2004, to achieve better load balance, HEED considers the residual energy as the criterion to choose cluster-heads. On the other hand, HEED is too strict to destroy the randomness of the algorithm, which might lead to worse energy efficiency. In order to realize more load balancing, Cao presents a new adaptive backup strategy in [4] to not only realize load balance among sensor node, but also ensure that the elected cluster-heads are evenly distributed.

The above protocols share the commonality that only one-hop clusters are considered. One-hop clusters require any pair of sensor nodes in the same cluster to be able to communicate directly (i.e., the sensor nodes are within each other's transmission range).In large net-works, this constraint may lead to a large number of cluster-heads, potentially increasing the efforts of inter cluster control information flow, which consumes energy as well as network bandwidth. Moreover, even if sensor nodes in the same cluster can communicate directly, [9] proved that multi-hop communication is more energy-efficient than direct communication. In addition, one-hop clusters demand that all sensors are equipped with the capability of tuning the power for the variable-range communication. However, in some cases, sensors are very simple and all the sensors transmit at a fixed power level, so data between two communicating sensors who are not within each other's radio range is forwarded by other sensors in the network. Hence, it is desirable to find an effective solution for constructing multi-hop clusters, where the distance of sensor nodes is no longer limited to one hop.

The Max-Min *d*-cluster algorithm proposed in [13] Generates *d*-hop clusters which can achieve better load balance and generate fewer clusters than early algorithms. But this algorithm does not ensure that the total energy consumption is minimized. Moreover, the Max-Min *d*-cluster algorithm suffers high implement complexity, making it unsuitable for resource limited sensor networks. Assuming that sensors are distributed according to a homogeneous spatial poisson process, Bandyopadhyay *et al*.[8] first introduced a multi-hop hierarchical clustering algorithm for wireless sensor networks, they prove that the algorithm can work better than previous algorithms in multi-hop networks. But the random property of the algorithm, a lot of "forced cluster-head" will appear in many cases, i.e., the node has no cluster to join and has to communicate directly with BS, which is often located far away from the node's

vicinity. The resulting long-range transmission to the BS is very energy demanding. Also the residual battery energy has not been considered in their algorithm .

In the energy efficient backup clustering algorithm proposed in [5], achieves fairly uniform cluster head distribution across the network. Further it does not need any prior knowledge about the topology information, compared with Max-Min d-hop algorithm [13], the clustering process in this algorithm terminates in O(1) iterations and incurs low implementation complexity. The cluster head is mainly selected based on the residual energy, but it results in the failure of the entire cluster i.e. when a particular node say 'i' is elected as a cluster head then within particular time slot it will lose all its energy by continuously transferring the data from the nodes to the base station , then the entire cluster will be failed.

IV. MODIFIED ENERGY EFFICIENT BACKUP HIERARCHICAL CLUSTERING ALGORITHM

Taking into account sensor nodes' residual energy, our proposed algorithm in multi-hop sensor networks can achieve better dynamic load balance than. It also achieves uniform cluster head distribution in a dynamic manner across the network. compared with the Max-Min d-hop[13] algorithm, the clustering process in our algorithm terminates in O(1) iterations and incurs low implementation complexity. Although we borrow the backup idea of , the proposed algorithm in our paper is totally new because the backup strategy and the whole algorithm execution process have been redesigned so that it can work well in much complicated multi-hop networks. Both the theoretical and the simulation result shows that our algorithm works well even in a very complicated environment with large number of cluster nodes.

A. Algorithm description

The modified energy efficient backup hierarchical clustering algorithm comprise of two distinct phases, the setup phase and steady phase. During the setup phase Cluster Heads are elected , followed by the steady phase. The steady phase is the data transmission phase and is longer than the setup phase. In the setup phase, the algorithm first filters all the nodes in the network of which area coverage is covered by its neighbors. Sometimes the sensing area is also covered in case if two adjacent nodes have different sensing range due to its different battery power. But we are not considering this type of area coverage in this simulation.

B. *Cluster formation*

The cluster formation is based on the area concept which means that the following are done for the cluster formation. The following assumptions where made for the cluster formation.

```
Step1    : consider the area for simulation
                  Area = 100 m × 100 m
Step 2   :  to form the cluster
         Cluster formation= divide the area to 10m ×10m
Step 3   : the criteria to form the cluster
           If(number of nodes > 15)
           { Form the cluster}

            Else if

        { Get the remaining number of nodes from the
      neighboring area only if it have more than 15 nodes  }

            Else
         {Form the cluster with the available nodes}

  Step 4   : repeat step3 until all the nodes are joined in any
one  Of the cluster
```

Table 1: pseudo code for the formation of clusters.

C. *Cluster head formation*

Another most important problem in the wireless sensor network is the selection of cluster head. The cluster head usually consume lot of energy compared with the other nodes. Because the cluster head need to collect the sensed data from all the nodes, and need to transfer it to the base station, which is located far away from the cluster nodes. This normally consumes lot of energy, with in a particular time the cluster head will lose all its energy, leading to the failure of the cluster head, at last the entire cluster will be failed.

To overcome this problem we have to elect the cluster head in the dynamic manner. The LEACH one of the most popular dynamic cluster forming algorithm, has elected the cluster head in the dynamic way by that the energy was saved. But in our algorithm the cluster head is elected based on the following steps.

```
  Step 1: the clusters are formed using the pseudo code
in
  Table1. the next step is to select the cluster head.

  Step 2: to select the initial cluster head

  Cluster head= node with higher residual energy

  This node will act as a cluster head for 20 seconds.

  Step 3:   to select the next cluster head

   If(time =10seconds)

    { Search the next node with higher          residual
Energy. }
      Again

      If(time=14seconds)

   { Sent the message to the next node with the
       higher residual energy(node Selected already).
      This is because in order to intimate that node
       Should act as the next cluster head }
       If(time=16seconds)

      {That node should send the acknowledgement For
the old cluster head.
   If(time=20seconds)
    {Then the new node will act as the cluster head}
   Step4: repeat step3 until all the nodes dead.
```

Table 2: pseudo code for selection of cluster head

V. SIMULATION AND DISCUSSION

In this section we evaluate the performance of the MODIFIED ENERGY EFFICIENT BACKUP HIERARCHICAL CLUSTERING ALGORITHM. The simulation results shows that the proposed algorithm performs better in terms of energy consumptions. Also from the graph it is obvious that the proposed algorithm's energy consumption is uniform compared to leach and its extended version it also means that unbalanced clusters have no effect on the consumption of energy in this model.

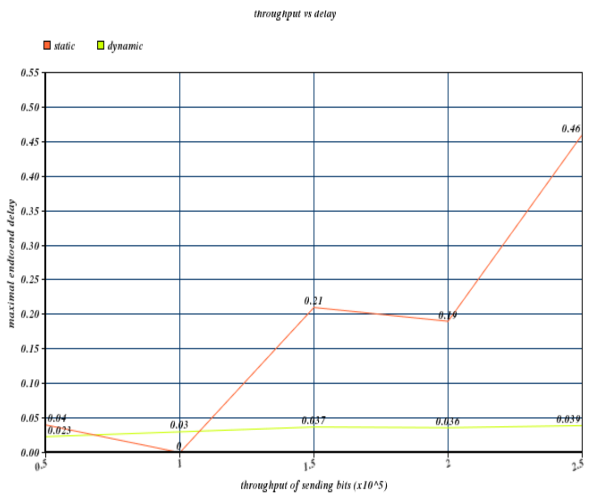

Fig1: the graph for showing the throughput vs delay

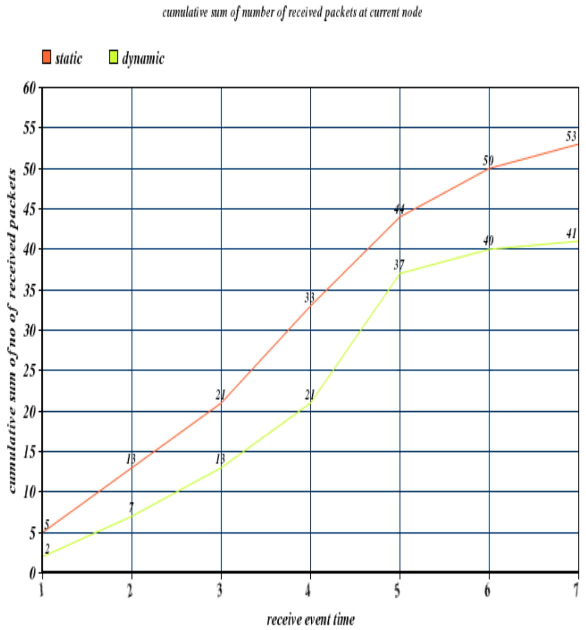

Fig2: the graph showing the cumulatve sum of received packets

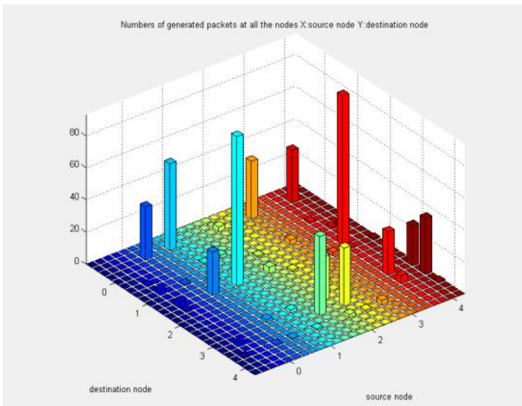

Fig3: the 3D view showing the cumulative sum of the generated packets for the static cluster head selection.

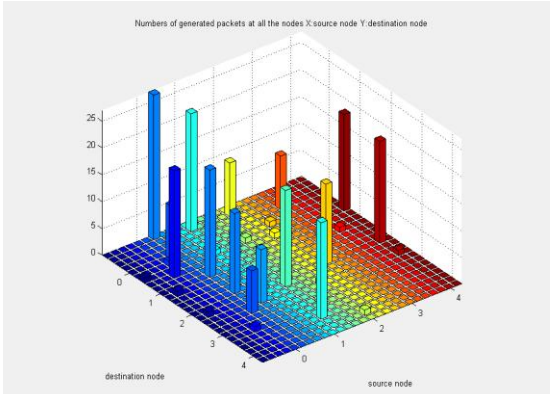

Fig4: the 3D view showing the cumulative sum of the generated packets for the dynamic cluster head selection.

VI. CONCLUSION AND FUTURE WORK

It is obvious from the simulation result that by exploiting the density property of the WSNs it is possible to enhance the network life time and also efficiently balance the energy consumption load across the network as well as the dynamic cluster head selection increases the network life time. Also the energy consumption of the network becomes uniform and it doesn't matter even if the cluster are balanced or unbalanced compared to leach. The future extension of the work include selection of the cluster head in the probability manner and possibly with some mobility in the network.

REFERENCES

[1] Wang J, Cao YT, Xie JY *et al.* Energy efficient backoff hierarchical clustering algorithms for multi-hop wireless sensor networks. JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY 26(2): 283{291 Mar. 2011. DOI 10.1007/s11390- 011-1131-x

[2] Yu M, Leung K K, Malvankar A. A dynamic clustering and energy efficient routing technique for sensor networks. *IEEE Transactions on Wireless Communications*, Aug. 2007, 6(8): 3069-3079.

[3] Chen Y P, Liestman A L, Liu J. A hierarchical energy efficient framework for data aggregation in wireless sensor networks. *IEEE Trans. VT*, May, 2006, 55(3): 789-796.

[4] Cao Y, He C. A distributed clustering algorithm with an adaptive backoff strategy for wireless sensor networks. *IEICE Transactions on Communications*., 2006, 89-B(2): 609-613.

[5] Sundararaman B, Buy U, Kshemkalyani A D. Clock synchronization for wireless sensor networks: A survey. *Ad Hoc Networks*, 2005, 3(3): 281-323.

[6] Younis O, Fahmy S. Distributed clustering in ad-hoc sensor networks: A hybrid, energy efficient approach. In *Proc. IEEE INFOCOM*, Hong Kong, China, Mar. 7-11, 2004.

[7] Zhao F, Guibas L. Wireless Sensor Networks: An Information Processing Approach. Morgan Kaufmann, 2004.

[8] Bandyopadhyay S, Coyle E J. An energy efficient hierarchical clustering algorithm for wireless sensor networks. In *Proc. IEEE INFOCOM2003*, San Francisco, USA, Mar. 30-Apr. 3, April 2003, pp.1713-1723.

[9] Heinzelman W B, Chandrakasan A P, Balakrishnan H. An application specific protocol architecture for wireless microsensor networks. *IEEE Tran. Wireless Communications*, Oct. 2002, 1(4): 660-670.

[10] Akyildiz I F, Su W, Sankarasubramaniam Y *et al.* A survey on sensor networks. *IEEE Communications Magazine*, 2002, 40(8): 102-114.

[11] Intanagonwiwat C, Govindan R, Estrin D. Directed diffusion: A scalable and robust communication paradigm for sensor networks. In *Proc. ACM/IEEE Int. Conf. Mobile Computing and Networking* (*MOBICOM*), Boston, USA, Aug. 6-11,2000, pp.56-67.

[12] Pottie G J, Kaiser W J. Wireless integrated network sensors.*Communications of the ACM*, 2000, 43(5): 51-58.

[13] Amis A D, Prakash R, Vuong T H P, Huynh D T. Max-Min *D*-cluster formation in wireless ad hoc networks. In *Proc. IEEEINFOCOM2000*, Tel Aviv, Israel, Mar. 26, 2000, pp.32-41.

[14] " Wireless Sensor Networks for Early Detection of Forest Fires " by Mohamed Hefeeda and Majid Bagheri.

P.Rajesh . B.E, M.Tech is working as an Assistant Professor in the Department of Information Technology at Pallavan college of Engineering in Kanchipuram. His area of interest in computer networks, wireless sensor Networks. He presented 2 papers in International Conference and 3 papers in National Conference and has attended several workshops.

S.Priya , B.Tech pursuing her degree in the Department of Information Technology at Pallavan college of Engineering in Kanchipuram . Her area of interest in wireless sensor networks and in all the network domains. She presented a paper in National conference and has attended 2 workshops.

R.Priyanka , B.Tech pursuing her degree in the Department of Information Technology at Pallavan college of Engineering in Kanchipuram . Her area of interest in wireless sensor networks and computer network . She presented a paper in National conference and several paper presentations.