Wireless Sensor Network with Energy Efficient Clustering

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ABSTRACT

The wireless sensor network has become a very essential and important part of communication world. In recent years there are extensive applications of wireless sensor networks in the field such as environment monitoring, surveillance, enemy tracking, automation etc. Since the available energy of sensor nodes are limited and hard to renew, energy supervision is critical for nodes in wireless sensor networks. In this paper, we propose a dynamic multi hop routing technique using residual energy based clustering algorithm to prolong network lifetime. Here, clusters are formed using certain suitable parameters such as remaining energy of the nodes, its centrality and cluster head selection frequency. After collecting all data within a cluster, the cluster head forward the data to the base station, if required via another cluster heads. In this way the proposed method generates an energy efficient routing path from each sensor to the base station. Simulation results show that our approach effectively conserves energy for cluster heads as well as cluster members and prolong their life time significantly. Thus the proposed algorithm improves the nodes life time.

Keywords

Cluster Head (CH), Base Station (BS), Wireless Sensor Network, Residual Energy, Energy Efficiency, Network Lifetime LEACH, Advertisement packet (ADV).

1. INTRODUCTION

In wireless sensor network Clustering is one of the conventional routing protocols. In clustering, nodes are organized into several clusters which consist of one cluster head (CH) and several others nodes known as member nodes. Cluster members send their data to the respective cluster head which is mainly responsible for sending the aggregated data to sink/ base station. This reduces energy consumption of nodes that are long way from sink and also balancing the load among the nodes. Hence, clustering is en energy efficient routing protocol for wireless network.

Instead of using direct routing from cluster head to base station, cluster heads follows multi hop routing path to send data to base station. This allows routing the data from cluster heads to base station and thus save the energy by reducing the long distance transmission occurrence. There exist several energy efficient routing protocols [13, 14] to maximize nodes' lifetimes, reduce bandwidth consumption by using local collaboration among the nodes, and tolerate node failures. LEACH [15] is a classic hierarchical cluster based routing protocol where cluster heads are selected randomly in each round, however, it may cause unbalanced energy consumption and can shorten network life time. HEED [16] elects cluster heads based on residual energy and node degree. PEGASIS [17] use chain topology with data fusion to reduce energy consumption. For such kind of networks, nodes far away from the base station exhaust their energy

rapidly and would die soon. In this paper we have proposed an energy efficient multi hop routing based on clustering to prolong the life time of nodes as well as network. The proposed routing protocol is divided into two phases: in first phase selection of cluster

heads, cluster formation and cluster maintenance and in second phase formation of energy aware multi hop routing tree. This protocol thus saves energy consumption among the nodes, minimize the latency and increase life time of network.

II. DESIGNING SYSTEM

A sensor network consisting of N homogeneous nodes, randomly deployed over a terrain to monitor continuously the targeted environment, is considered here. We denote the sensor node set as S = {s1,s2,….sN} where |S|=N and each node has an unique ID . The base station is assumed to be located far from the sensing field- this base station and all sensors nodes remain static after deployment. Further, links are considered to be symmetric. A node can compute the approximate distance to another node using the received signal strength if the transmitting power is known; a sensor is also capable of adjusting its transmission power using the distance from the receiver. Here, cluster range is assumed to be same as transmission range. We use a simplified model shown in [3] for the communication energy dissipation. Both the free space (*P*2 power loss) and the multi-path fading (*P*4 power loss) channel models are used, depending on the distance between the transmitter and receiver. The energy spent for transmission of an *l*-bit packet over distance *d* is:

E T*x*(*l*, *P*)= *lE*elec +*l P efs* = *lE*elec + *l P*2, *P* < *P*o
=*lE*elec + *l eamp P*4, *P* < *Po* (1)

The electronics energy, *E*elec, depends on factors such as the digital coding, and modulation, whereas the amplifier energy *ampd*4or *d* 2, depends on the transmission distance and the acceptable bit-error rate. We have *Po* = To receive this message, the radio expends energy: *ERx*(*l*) = *lE*elec.

Consumption of energy among the nodes in a cluster to prolong the lifetime of WSN. Here we designed a protocol using three approaches,

1. Energy aware CH rotation policy
2. Data aggregation
3. Tunneling data to nodes in sleep mode cluster.

2. Leach Protocol

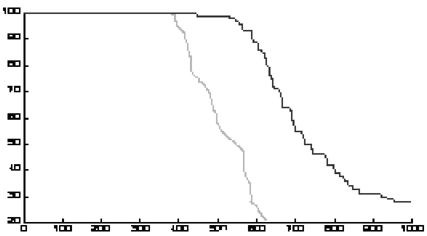
In LEACH, nodes organize themselves into clusters and all non-cluster head nodes transmit to the cluster-head. The cluster head performs data aggregation and transmits the data to the remote base station. Therefore a cluster-head node is much more energy intensive than a non-cluster head node.

During the setup phase in LEACH [2] the cluster heads are selected based on the suggested percentage of them for the network and the number of times the node has been a cluster-head so far. This decision is made by each node n choosing a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster-head for the current round. The threshold is set as follows:

$$T(n) = \begin{cases} \dfrac{P}{1 - P(r \bmod \frac{1}{P})}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases} \qquad (1)$$

where P is the desired cluster-head probability, r is the number of the current round and G is the set of nodes that have not been cluster-heads in the last 1/P rounds. Once a node has been elected to be the cluster head it will broadcast an advertisement message (ADV). Each non cluster-head node decides its cluster for this round by choosing the cluster head that requires minimum communication energy, based on the received signal strength of the advertisement from each cluster head. After each node decides to which cluster it belongs, it informs the cluster head by transmitting a join request message (Join-REQ) back to the cluster head. The cluster head node sets up a TDMA schedule and transmits this schedule to all the nodes in its cluster, completing the setup phase, which is then followed by a steady-state operation. This steady state operation is broken into frames, where nodes send their data to the cluster head at most once per frame during their allocated slot.
Energy efficiency

Fig.2.1 Alive nodes vs rounds



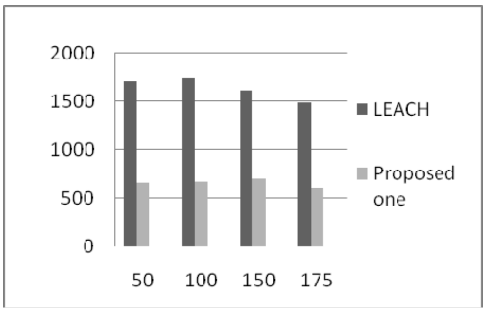


Fig2.2 number of cluster vs BS

3. Cluster Head Selection Policy

In our protocol architecture we implemented three strategies i.e CH rotation, data aggregation and tunneling of data to sleep mode cluster node. In designing the routing protocol, the primary goal is to
improve the life time of the network. In order to achieve this, energy consumption of the nodes should be well balanced so that no node drains its battery power rapidly. Therefore selection of cluster heads is an important issue in cluster based routing protocol. In proposed scheme, the cluster heads are selected based on four parameters namely:

• *Node Residual Energy:* Selected nodes must have a high residual energy because cluster heads are involved in high energy consumption operations. It is denoted in this paper by RE(si) and initial energy of each node is Eo.

• *Centrality:* The node centrality defines the node's importance based on how central the node is to the cluster. It is defines as number of active/ alive neighbor nodes of each node has after each round.
Centrality(C)= A_node(si)/ N_node(si) Where N_node(si) is total number of neighbor nodes of si at the time of deployment and A_node(si) is number of active neighbor nodes of si at each round. A low centrality value is desired.

• *Distance to neighbor nodes:* It is the sum of distances of each active neighbor nodes to node si itself. Lower value of this parameter is always desirable. It is defined by
d1= where d(si,sj) is distance between si and sj

• *Cluster head (CH) frequency:* A record of the number of times each node served as cluster head is kept to avoid electing the same nodes repeatedly. It is denoted in this

3.1 Motivation For CH Role Rotation Policy

In LEACH, a node becomes a cluster-head by a stochastic mechanism of tossing biased coins. This stochastic approach doesn't consider energy consumption of a cluster-heads. This will lead to more energy dissipation of cluster head and hence affect the reliability. Secondly, LEACH assumes that every time a node becomes a cluster-head, it dissipates an equal amount of energy. This is incorrect, as cluster-heads located far from the base station spend more energy in transmitting data to those located near the base station. Hence we need to focus of optimization of CH energy consumption to increase network lifetime.

3.2 Data Aggregation

In a typical sensor network scenario, different nodes collect data from the environment and then send it to some central node or sink which analyzes and processes the data and then send it to the required application center. But in many cases, data produced by different nodes can be jointly processed while being forwarded to the sink node. So in-network aggregation deals with this distributed processing of data within the network. Data aggregation techniques explore how the data is to be routed in the network as well as the processing method that are applied on the packets received by a node. They have a great impact on the energy consumption of nodes and thus on network efficiency by reducing number of transmission or length of packet. Elena Fosolo et al in [7] defines the in-network aggregation process as follows: "In-network aggregation is the global process of gathering and routing information through a multi-hop network, processing data at intermediate nodes with the objective of reducing the resource consumption (in particular energy), thereby increasing network lifetime."

3.3. Data Tunneling To Sleep Mode Cluster Node

As we discussed earlier WSN is divided into clusters for better performance. Not necessarily, each cluster is performing the same type of recording. It is also not necessary for the cluster to record and report information to BS all the time but information is to be reported at specific times. In such scenario keeping cluster in active mode is simply the wastage of energy. Hence in such scenario we may put the cluster in sleep mode during idle times to save energy. But sometimes it is required for the sleep mode cluster to receive/transmit the data. And hence the data to/from the nodes in sleep mode cluster must be tunneled. This can be implemented using a data tunneling protocol.

4. Protocol Algorithm

4.1 In our protocol there are 4 phases in each round.

Phase I: Cluster Head Selection

1. The BS broadcast an ADV packet type 1 to know all the sensor nodes in the range.
2. Then nodes respond to the BS with RES packet type 2 with their energy.
3. The base station now calculates the distance of each node and selects the node with shortest distance as cluster head using packet type 3.

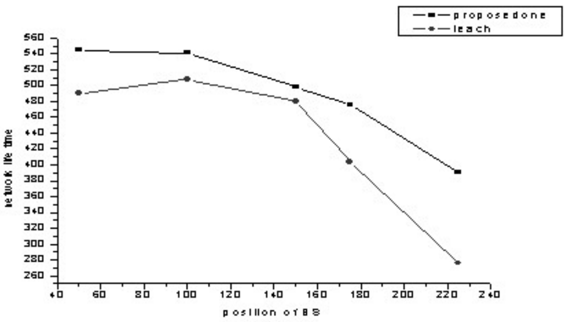


Fig3.1 Network life time vs. BS position

Phase II : **Cluster Formation.**

1. CH now broadcast JOIN-REQ packet type 4 to form the cluster.
2. After receiving the packet type 4, the neighboring nodes within the range respond by sending JOIN RES packet type 5 to CH.

Phase III : Data Reporting

1. CH now multicast START REPORTING packet type 6 to nodes in the cluster.
2. Nodes now start reporting to CH on TDM basis as allotted by CH with packet type 7.
3. Data aggregation is achieved at CH by setting counter to 30 for each node.
4. Then aggregated data is processed separately and transmitted to BS with packet type 8.

Phase IV : CH Alteration

1. CH now checks it residual energy and compares with threshold energy.
2. If finds energy equal to or below threshold level. It takes initiative itself to find new CH.
3. Now CH send EREQ packet type 1 to all other node and gets their residual energy in RES packet type 2 from them.
4. Now CH selects the node with highest residual energy as CH and multicast packet type 3 to all nodes.
5. Nodes update their CH information and start reporting to new CH now while CH old continues as normal node reporting to new CH.
6. New threshold level is set and same process is repeated.

4.2 Data Tunneling To Nodes In Sleep Mode Cluster

1. When data is to be sent to nodes in sleep mode cluster, a wakeup call is sent by BS to CH of cluster. Then CH will communicate that to the nodes in the cluster using wakeup call.
2. After completing the required task it again goes into sleeping mode.

4. Simulation Environment

Parameters	**Normal Scenario**
No. of nodes	29
Topographical area	1000 x 1000 sq. m.
Topology	Star
Max. internode distance	5.5 m
Antenna	Omni directional
Initial energy of node	5.0
Packet size	500 bytes
Energy consumption per packet	0.1 mJ
Packet Delay	1 ms
Throughput	98.69 %

Table 1: Simulation parameters

We used network simulator ns-2 for evaluating our protocol. For our experiments, we used a 29-node network as in fig. 1 where nodes are randomly distributed between (*x=0, y=0*) and (*x=1000, y=1000*) with a single BS at location (*x=500, y=500*). We have four clusters each having 7 nodes including CH. The bandwidth for the channel was set to 1Mb/s, each message 500 bytes long, and the packet header for each type was 25 bytes long.

5. Simulation Model

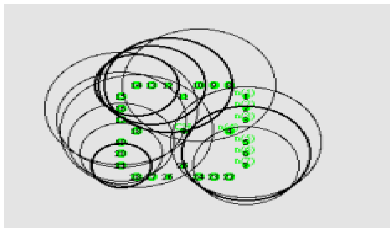


Figure 1 : Transmission & Reception scenario

Base station is located at the center of the network. Base station takes initiative towards CH selection and cluster formation by communicating appropriate packets. In our model we have used 9 different packets for proper WSN operation. Simulation model shows all 5 phases in the protocol. The above model is able to achieve systematic approach towards communication in WSN.

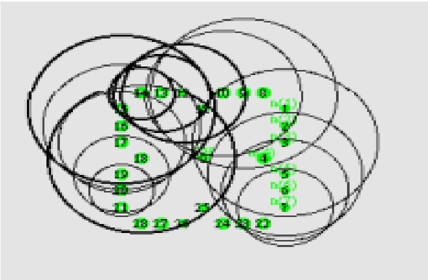


Fig. 2 Broadcasting of packets by BS

Figure 1 shows the snap shots of simulation process taken at different instants. Bubble in the figure shows the transmission and reception of packets taking place at the node. This model achieves
increase in lifetime of the WSN by saving energy of nodes. The results reported in the next section are an aggregate of 30 simulations.

5. Results & Conclusions

In this paper, we describe a modification of the LEACH's stochastic cluster-head selection algorithm by combining three strategies i.e. energy aware rotation of CH, data aggregation and data tunneling to node in sleep mode cluster. Hence this approach will save energy, increase data transmission reliability and prolong the lifetime and reduce the cost of the using WSN.

This will be helpful for the state like Chhattisgarh in deploying wireless sensor network for controlling the legal or illegal activities in remote areas surrounded by forest. Fig. 2 shows the packets received by different nodes during simulation time. As the CH role is change regularly depending on the threshold energy the nodes are receiving almost same number of packet.

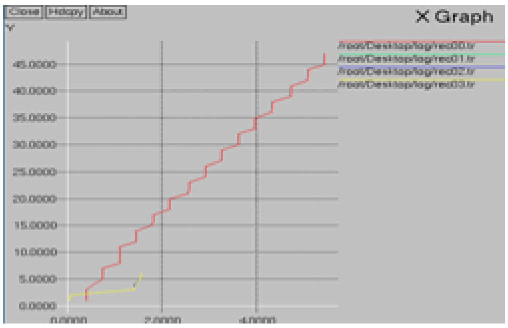


Fig. 3 : reception of packets by nodes

Fig. 3 shows the comparison of energy consumption by different nodes. The curve mark with CH_fix indicates the energy consumption by node 4 if we don't alter the CH role mean continue with the same CH. Other curves correspond to the energy consumption by nodes if the CH role is altered as a function of residual energy and threshold energy. From fig. 3 we can come to conclusion that alteration

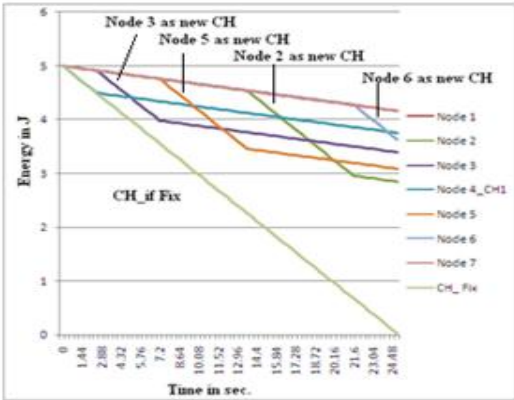


Fig. 3: Energy of CH vs other nodes

of CH role cause less energy consumption of the cluster and hence network. This will definitely prolong the lifetime of the network.

REFERENCES

[1] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," IEEE Transactions on Wireless Communications, vol. 1, no. 4, pp. 660–670, October 2002.

[2] Wendi Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan. Energy- Efficient Communicat ion Protocol for Wireless Microsensor Networks. Proceedings of the Hawaii International Conference on System Sciences, January 4-7, 2000 © 2000 IEEE.

[3] M. J. Handy, M. Haase, and D. Timmermann, "Low energy adaptive clustering hierarchy with deterministic cluster-head selection," in Proc. 4th IEEE International Workshop on Mobile and Wireless Communications Network (MWCN '02), pp. 368-372, Stockholm, Sweden, September 2002.

[4] I. Saha Misra, S. Dolui and A. Das, "Enhanced-Efficient Adaptive Clustering Protocol for distributed sensor networks", ICON 2005

[5] A. Manjeshwar and D. P. Agrawal, "An Efficient Sensor Network Routing Protocol (APTEEN) with Comprehensive Information Retrieval," Proc. Second Int'l Workshop Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, Apr. 2002.

[6] Ossama Younis, Sonia Fahmy, "HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks," *IEEE Transactions on Mobile Computing*, vol. 03, no. 4, pp. 366-379, Oct., 2004.

[7] Yongcai Wang, Qianchuan Zhao and Dazhong Zheng, "Energy-Driven Adaptive Clustering Data Collection Protocol in Wireless Sensor Networks", Proceedings of the 2004 International Conference on Intelligent

Mechatronics and Automation , Chengdu, China August 2004

[8] Loscri' V. , Marano S. , Morabito G. , " A Two-Levels Hierarchy for Low-Energy Adaptative Clustering Hierarchy (TL-LEACH).". Proceedings "VTC2005", Dallas (USA), pp. 1809-1813, Sept, 2005

[9] Junpei Kamimura and Naoki Wakamiya and Masayuki Murata, "Energy-efficient clustering method for data gathering in sensor networks," in Proceedings of First Workshop ON Broad-band Advanced Sensor Networks and October 2004

[10] Zengwei Zheng, Zhaohui Wu, and Huaizhong Lin. An Event-Driven Clustering Routing Algorithm for Wireless Sensor Networks. Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems. Sendai, Japan, Sep. 28 - Oct. 2, 2004.

[11] M. C. Vuran, O. B. Akan, I. F. Akyildiz, "Spatio-Temporal Correlation: Theory and Applications in Wireless Sensor Networks," Computer Networks Journal (Elsevier), vol. 45, no 3, pp. 245 -259, June 2004

[12] SunHee Yoon and Cyrus Shahabi, "Exploiting Spatial Correlation Towards an Energy Efficient Clustered AGgregation Technique (CAG)", IEEE International Conference on Communications (ICC), 16-20 May 2005, Seoul, Korea

[13] S. Singh, M. Woo and C.S. Raghavendra, "Power-Aware Routing in Mobile Ad Hoc Networks", in Proceedings ACM/IEEE Mobicom'98, 1998.

[14] Q. Jiang and D. Manivannan , "Routing Protocols for Sensor Networks," in proceedings 1st IEEE Consumer Comm. And Networking Conf. (CCNC 04), IEEE Press, pp. 93-98, 2004. Alive nodes LEACH Proposed Rounds.