Position-Based Cluster Routing Protocol for Wireless Microsensor Networks

Dong-hwan Kim, Ho-seung Lee, Jung-woo Jin, Jae-min Son, Ki-jun Han
{iondh, leeho678, deux8, huntermin}netopia.knu.ac.kr,kjhan@bh.knu.ac.kr
Department of Computer Engineering,
Kyungpook National University, Taegu, KOREA
Phone number: +82-53-950-5557

Abstract:

Microsensor nodes is energy limited in sensor networks. If nodes had been stop in working, sensor network can't acquire sensing data in that area as well as routing path though the sensor can't be available. So, it's important to maximize the life of network in sensor network. In this paper, we look at communication protocol, which is modified by LEACH(Low-Energy Adaptive Clustering Hierarchy). We extend LEACH's stochastic cluster-head selection algorithm by a Position-based Selection (PB-Leach). This method is that the sink divides the topology into several areas and cluster head is only one in an area. PB-Leach can prevent that the variance of the number of Cluster-Head is large and Cluster-Heads are concentrated in specific area. Simulation results show that PB-Leach performs better than leach by about 100 to 250%.

Keywords: Microsensor, LEACH, data aggregation, energy efficient operation.

1. INTRODUCTION

Advances in processor, memory, and radio technology will enable small and cheap nodes capable of sensing, communication, and computation. Networking together hundreds or thousands of microsensor nodes allows users to accurately monitor a remote environment by intelligently combining the data from the individual nodes.

Since both device and battery technologies have only recently matured to the point where microsensor nodes are feasible, this is a fairly new field of study. Researchers have begun discussing not only the uses and challenges facing sensor networks, but have also been developing preliminary ideas as to how these networks should function as well as the appropriate low-energy architecture for the sensor nodes themselves [9].

There have been some application-specific protocols developed for microsensor networks. Clare et al. developed a time division multiple-access (TDMA)MAC protocol for low-energy operation [1]. Using a TDMA approach saves energy by allowing the nodes to remain in the sleep state, with radios powered-down, for a long time. Intanagonwiwat et al. developed directed diffusion, a protocol that employs a data-driven model to achieve low-energy routing [3]. The LEACH protocol presented in [12] is an elegant solution to this data collection problem where a small number of clusters are formed in a self-organized manner.

Recently, there has been much work on "power-aware" routing protocols for wireless networks [3]. In these protocols, optimal routes are chosen based on the energy at each node along the route. Routes that are longer, but which use nodes with more energy than the nodes along the shorter routes, are favored, helping avoid "hot spots" in the network.

This paper proposes a modification of LEACH's cluster-head selection algorithm to reduce energy consumption. For a microsensor network we make the following assumptions:

- The sink is located far from the sensors and immobile.
- All nodes in the network are homogenous and energy-constrained
- All nodes know their own locations.
- All nodes are able to reach Sink.
- Symmetric propagation channel
- Cluster-heads perform data compression.

These assumptions are reasonable due to technological advances in radio hardware and low-power computing.

The rest of the paper is organized as follows. Section 2 shows that xx. In section 3 a modification of LEACH that Position Based LEACH is proposed. Simulation results comparing original LEACH and Position Based LEACH are presented in section 4. Section 5 concludes the paper and discusses possible future research directions.

2. RELATED WORK

Low-energy adaptive clustering hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes. All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1.

The node becomes a cluster head for the current round if the number is less than the following particular threshold (Equations 1).

$$P_i(t) = \begin{cases} \dfrac{k}{N - k * (r \bmod \frac{N}{k})} & : C_i(t) = 1 \\ 0 & : C_i(t) = 0 \end{cases} \quad (1)$$

where $C_i(t)$ is the indicator function determining whether or not node i, N is the number of the nodes, and k is the number of cluster heads.[2][3]

So, the nodes die randomly and dynamic clustering increases lifetime of the system. While there are advantages to using LEACH's distributed cluster formation algorithm, this protocol offers no guarantee about the placement and/or number of cluster head nodes.

The variance of the number of Cluster-Head is large at LEACH since each node elects itself to be a Cluster-Head at the beginning of a round. When the number of Cluster-Head is many, it is over 10% among all nodes and when the number of Cluster-Head is small, it is zero. Moreover, LEACH cause the problem that the Cluster-Heads are concentrated in specific area, so this problem cause a Cluster-Head to have many non-CH nodes and the distance from non-CH nodes to Cluster-Head is far in cluster.

As an example, consider the case of Fig.1. In the bad-case-scenario cluster-heads are selected many in (a), in (b) on the right-hand-side of the network.

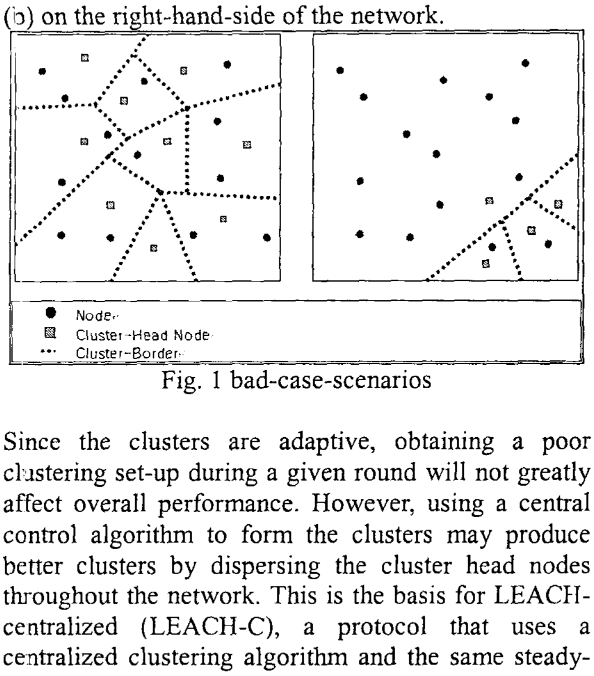

Fig. 1 bad-case-scenarios

Since the clusters are adaptive, obtaining a poor clustering set-up during a given round will not greatly affect overall performance. However, using a central control algorithm to form the clusters may produce better clusters by dispersing the cluster head nodes throughout the network. This is the basis for LEACH-centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH. LEACH-C requires location information of all nodes of the networks is only available through GPS or a location-sensing technique, such as triangulation which requires additional communication among the nodes [2].

3. ENERGY CONSUMPTION MODEL

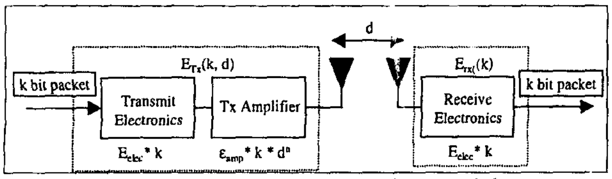

Fig. 2 Radio energy dissipation model.

We use the same radio model as discussed in [2]. The transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Fig. 2. For the experiments described here, both the free space (d2 power loss) and the multi-path fading (d4 power loss) channel models were used, depending on the distance between the transmitter and receiver. Power control can be used to invert this loss by appropriately setting the power amplifier—if the distance is less than a threshold d0, the free space (fs) model is used; otherwise, the multi-path (mp) model is used. Thus, to transmit an l-bit message a distance d, the radio expends

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d)$$

$$= \begin{cases} lE_{elec} + le_{fs}d^2, & d < d_0 \\ lE_{elec} + le_{mp}d^4 & d < d_0 \end{cases} \quad (2)$$

and to receive this message, the radio expends:

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} \quad (3)$$

The electronics energy, Eelec, depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, whereas the amplifier energy, Єfsd2 or Єmpd4, depends on the distance to the receiver and the acceptable bit-error rate.

In LEACH, the cluster formation algorithm was created to ensure that the expected number of clusters per round is k, a system parameter. We can analytically determine the optimal value of k in LEACH using the computation and communication energy models. Assume that there are N nodes distributed uniformly in an M*M region. If there are k clusters, there are on average N/k nodes per cluster (one cluster head and (N/k)-1 non-cluster head nodes). Each cluster head dissipates energy receiving signals from the nodes, aggregating the signals, and transmitting the aggregate signal to the BS. Since the BS is far from the nodes, presumably the energy dissipation follows the multipath model (d4 power loss). Therefore, the energy dissipated in the cluster head node during a single frame is

$$E_{CH} = lE_{elec}\left(\frac{N}{k} - 1\right) + lE_{DA}\frac{N}{k} + lE_{elec} + lE_{mp}d^4_{toBS} \quad (4)$$

where dtoBS is the distance from the cluster head node to the BS and we have assumed perfect data aggregation.

Each non-cluster head node only needs to transmit its data to the cluster head once during a frame. Presumably the distance to the cluster head is small, so the energy dissipation follows the Friss free-space model (d2 power loss). Thus, the energy used in each non-cluster head node is

$$E_{non-CH} = lE_{elec} + lE_{fs}d^2_{toCH} \quad (5)$$

where dtoCH is the distance from the node to the cluster head..

4. POSITION BASED LEACH

In this paper, we propose the method solving two problems in order to increase the network lifetime. Fig 3 shows that the topology which is divided by 4 areas

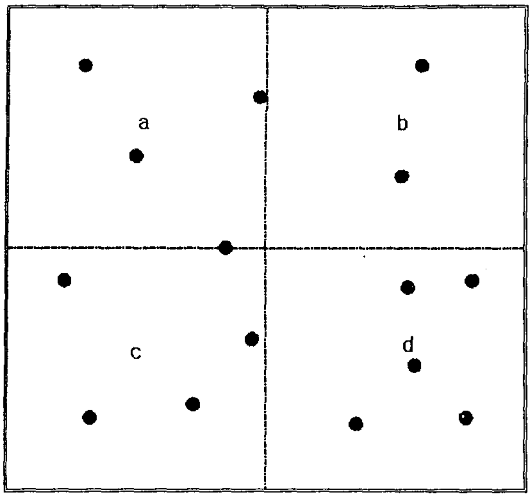

Fig. 3 The topology which is divided by 4 areas

The method is as follows.

- The sink divides the topology into several areas and advertising nodes of the area information.
- Each node memorizes information about its area.
- Nodes decide whether each node is the candidate of Cluster-Head at the beginning of a round.
- Cluster Head nodes advertising with its area.
- After the candidates of Cluster-Head are elected, the candidate of Cluster-Head which is first registered by Non-Cluster-Head node is Cluster-Head.
- Each node in the cluster will forward the data to head and the head relays the data to Sink.

PB-Leach can prevent that the variance of the number of Cluster-Head is large and Cluster-Heads are concentrated in specific area. Unlike LEACH-C, PB-Leach doesn't require information about all nodes of the networks at each round.

5. SIMULATION

We simulate to use energy consumption model in section 3. We compare the original LEACH algorithm with our PB-Leach. We used a 100-node network where nodes were randomly distributed between (x=0, y=0) and (x=100, y=100) with the BS at location (50, 175). Each data message was 500 bytes long and the packet header for each type of packet was 25 bytes long.

The communication energy parameters are set as: E_{elec} = 50nJ/bit, ϵ_{fs} = 10pJ/bit/m^2, and ϵ_{mp} = 0.0013pJ/bit/m^4. The energy for data aggregation is set as E_{DA} = 5nJ/bit/signal. The cluster-head probability k is set to 0.05 – about 5 nodes per round become cluster-heads.

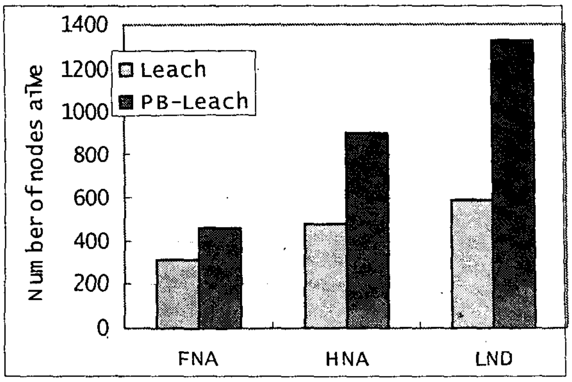

Fig. 4 System lifetime using Leach and PB-Leach with 2 J/node

Fig. 4 illustrates simulation results of our sample network. For FND (First Node Dies) a 200% improvement is accomplished comparing the algorithm of PB-Leach with LEACH. HNA (Half of the Nodes Alive) improves by 150%. Furthermore, LND(Last node dies) improves by 200%.

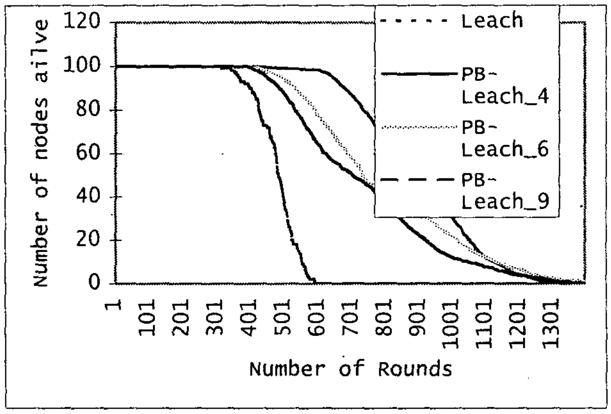

Fig. 5 System lifetime using Leach and PB-Leach(4,6,9 areas) with 2 J/node

we carried out the simulation by how the area is divided into 4, 6, and 9. Fig. 5 shows the number of the nodes alive over time. The more the area is divided, the slower the reduction of the nodes is and the longer the lifetime of the topology is. It can be compared how much the sensor nodes cover the area and how long the area covered by the sensor is last. Therefore, the PB-Leach divided into 4 areas has the best performance.

6. CONCLUSION

Microsensor nodes are energy limited in sensor networks. If nodes had been stop in working, sensor network can't acquire sensing data in that area as well as routing path though the sensor can't be available. So, it's important to maximize the life of network in sensor network.

This paper has discussed modifications of LEACH's cluster-head selection algorithm. PB-Leach solves the problems using simple method that the variance of the number of Cluster-Head is large and Cluster-Heads are concentrated in specific area. With that modification a 200% increase of lifetime of microsensor networks can be accomplished.

References

[1] L. Clare, G. Pottie, and J. Agre, "Self-Organizing Distributed Sensor Networks," Proc. SPIE Conf. Unattended Ground Sensor Technologies and Applications, pp. 229-237, 1999.

[2] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," Proc. Hawaii Conf. System Sciences, Jan. 2000.

[3] W. Heinzelman, "Application-specific protocol architectures for wireless networks", Ph.D. dissertstion, Mass. Inst. Technol., Cambridge, 2000.

[4] A. Manjeshwar, D.P. Agrawal, "TEEN: a protocol for enhanced efficiency in wireless sensor networks", in: Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[5] S. Lindsey, C.S. Raghavendra, "PEGASIS: power efficient gathering in sensor information systems", in: Proceedings of the IEEE Aerospace Conference, Big Sky, Montana, March 2002.

[6] S. Lindsey, C.S. Raghavendra, K. Sivalingam, "Data gathering in sensor networks using the energy delay metric", in: Proceedings of the IPDPS Workshop on Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[7] A. Manjeshwar, D.P. Agrawal, "APTEEN: a hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks", in: Proceedings of the 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile computing, Ft. Lauderdale, FL, April 2002.

[8] Handy, M.J.; Haase, M.; Timmermann, D., "Low energy adaptive clustering hierarchy with deterministic cluster-head selection", Mobile and Wireless Communications Network, 2002. 4th International Workshop on , 9-11 Sept. 2002 Pages:368 – 372

[9] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks", IEEE Communications Magazine, August 2002, pp102-114.