Available online at www.elixirpublishers.com (Elixir International Journal)

Adoc Network

Elixir Adoc Network 42 (2012) 6429-6432

ISSN: 2229-712X

An improved energy efficient routing protocol for wireless sensor networks

Jayanthi K Murthy[1], Mahesh D[1] and Suthikshn Kumar[2]
[1]BMS College of Engineering,Bangalore,
[2]DIAT, Pune.

ARTICLE INFO

Article history:
Received: 3 December 2011;
Received in revised form:
15 January 2012;
Accepted: 27 January 2012;

Keywords
Wireless Sensor networks,
Clustering,
Energy efficient,
Network life time.

ABSTRACT
Wireless Sensor Networks consists of spatially distributed autonomous sensors called nodes which co-operatively monitor a physical or environmental condition. Due to the scarce energy reserves in the sensor networks it is necessary to design protocols which minimize the energy consumption. In this paper, we firstly analyze the LEACH protocol in a homogeneous environment and then present a novel clustering based routing protocol for sensor networks. The simulation results show that the proposed protocol prolongs the network lifetime with 70% of the nodes remaining alive when compared to LEACH.

Introduction

Wireless Sensor Networks (WSN) has evolved due to the development in the large scale integrated circuits and wireless technology. A WSN consists of autonomous sensor nodes that self-organize to form a multi-hop network. They are densely deployed nodes with capability of sensing, computation and communication. Due to their small size, these networks are characterized by limited computational capability, memory, bandwidth and battery power. The nature of deployment of nodes in harsh environment makes the replacement of battery impossible. Excessive computation and communication in the node causes the battery to dry up. Since communication plays an important role in draining the battery, protocols need to be developed which aim at the reduction of number of transmissions and receptions in these data centric networks. Thus energy conservation becomes a key issue in research.

Network lifetime is one of the basic performance metric of wireless sensor networks. The effective lifetime of a sensor node is directly determined by its power supply. Lifetime of a network is defined as the time at which the first node runs out of energy. Thus to maximize the network lifetime, the process of data transmission should be optimized. It is widely known that the energy consumed in one bit of data transfer can be used to perform a large number of arithmetic operations in the sensor processor. Moreover in a densely deployed sensor network the physical environment would produce very similar data in close-by sensor nodes and transmitting such data is more or less redundant. This encourages using some kind of grouping of nodes such that data from sensor nodes of a group can be combined or compressed together in an intelligent way and transmits only compact data. This can not only reduce the global data to be transmitted, but reduces the traffic and hence the power consumption. Energy efficiency in WSNs is determined by the architecture of networks, data aggregation mechanism employed and underlying routing protocol. Among the various architectures suggested in literature, for energy efficient techniques, clustering is widely used as it is a scalable approach that improves the network lifetime. The process of grouping of sensor nodes in a densely deployed large-scale sensor network is known as clustering [1]. Clustering is usually within a geographic neighborhood. Here, sensor nodes organize themselves into clusters with one node acting as a cluster head which co-ordinates the local activities of all its members. Since these cluster heads need to transmit the data over large distances to the sink, they expend a lot of energy and drain out soon.

This problem was first addressed in [2] by suggesting the rotation of cluster head role among all the members. As cluster head carries most of the communication burden in the cluster and consumes more power, being mainly responsible for data aggregation after the collection of data from the cluster members and transmitting the aggregated data to the sink [3, 4].

Further nodes on the cluster boundary expend more energy compared to the ones close to the cluster head. Hence, targeting the cluster head is expected to pay in terms of increased the life time. In our protocol, we device a new technique to select energy efficient node as cluster head for increasing the lifetime of the network.

The major contributions of this paper are as follows:
- Theoretical analysis of energy consumption during and after cluster formation is presented.
- A framework for novel energy saving cluster formation scheme is proposed.
- Simulated comparison of with LEACH and static clustering protocol to demonstrate the effectiveness of the new protocol.

The rest of the paper is organized as follows. The next section deals with the related work and discusses the advantages and disadvantages of the schemes proposed earlier.

Section III describes the network model and the simulated parameters used. In section IV, we propose an improvement about the choice of selecting the cluster head .The details of the protocol is elaborated. The theoretical analysis and simulation carried out is highlighted in section V and the paper concludes with a discussion on the work providing future work directions in the last section.

Tele:
E-mail addresses: jayanthi.ece@bmsce.ac.in, suthikshn.kumar@gmail.com

Related Work

Interest in wireless sensor networks has prompted extensive research and development of different routing protocols. Here we will summarize a few of the studies related to the previous approaches to cluster based data gathering in wireless sensor networks.

Among the clustering protocols [5-10] are the most prominent and well referenced in literature.

LEACH (Low Energy Adaptive Clustering Hierarchy)

The algorithm, proposed by Heinzelman et al [5], is a self-organizing, adaptive clustering protocol. It uses randomization to distribute the energy load (associated with cluster-head activity) evenly among the sensor nodes but excludes the recently selected cluster-heads from the current selection of cluster-heads. LEACH has been a landmark in communication protocols with its simplicity and efficiency and has been shown to give far better performance than other prevalent protocols. In this protocol, a few nodes are randomly selected as Cluster Heads (CHs) and the role of cluster head is rotated amongst the cluster members so as to evenly distribute the energy dissipation across the cluster. The CH nodes compress the data arriving from the nodes that belong to a particular cluster and send an aggregated packet to the base station (BS), thus reducing the amount of information that must be transmitted. LEACH uses TDMA and CDMA MAC to reduce the intra and inter cluster collisions. The operation of LEACH consists of two phases such as the setup phase and the steady state phase. Selection of CH is done in the setup phase, by considering both, the desired percentage of nodes in the network and the history of node that has served as cluster-head. This decision is made by each node *n* based on the random number *r* (between 0 and 1) chosen by the node. If the generated random number is less than a threshold value

$$T(n) = \frac{p}{1-p(r \bmod 1/p)} \text{ if } n \in G \qquad (1)$$

Then, the corresponding nodes becomes cluster-head for that round.

Each CH elect broadcasts an advertisement to the rest of the nodes in the network. The non CHs decide which cluster to join depending on the signal strength of the message received and convey this information to the respective cluster heads. The CH creates a TDMA schedule and broadcasts it to all its members. During the steady state, the CH collects and aggregates the data and transmits it to the BS. After a fixed duration the cycle repeats again.

But, it has some severe limitations mainly due to the extreme assumptions it makes about the network topology. It assumes that all the nodes have the same initial energy and that the energy distribution remains more or less uniform as the protocol progresses in time. It is again a resource-blind protocol with the cluster-head selection being independent of node properties like residual energy. It totally depends on the random number generation for probability based cluster-head selection, in order to maintain the optimal number of cluster heads within the network. The deviations from this optimality lead to large inefficiencies like high energy dissipation and smaller system lifetime. With the death of a cluster head node all messages from the nodes within that cluster are lost leading to data losses. Energy-LEACH protocol improves the CH selection procedure. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round [11]. LEACH offers no guarantee about the placement and/or number of cluster heads. In [12], the authors consider both the energy and distance to elect the cluster head, which is the concept used in this paper.

Static Clustering Protocol

In this protocol [13], the network is divided into static clusters which eliminate the need for re-clustering hence conserving the energy of the nodes. The base station sends K-1 messages (where K refers to the number of clusters) with K-1 different powers. For each level, all nodes which receive the signal form the cluster and inform this to the base station. The base station randomly selects one node in each cluster as the cluster head and informs all the members the same followed by the TDMA schedule for the member nodes to transmit. At the beginning of each round the nodes send their energy level and the node with the highest energy is chosen as the cluster head. To facilitate energy conservation, the cluster members are put to sleep until their time to transmit.

The cluster head is burdened by the task of collecting the data from members, aggregating them and transmitting to the base station. This consumes a lot of energy. Since the cluster heads and clusters are fixed they get drained of energy and the network lifetime decreases.

System Model

Our energy model for the network is based on the *first order radio model* described in [2] as shown in figure 1. A fixed base station is located at the centre. The sensor nodes are energy constrained with a uniform initial energy allocation. They are equipped with power control capabilities to vary their transmitting power. Each node senses the environment at a fixed rate and always has data to send to the base station. All sensor nodes are immobile.

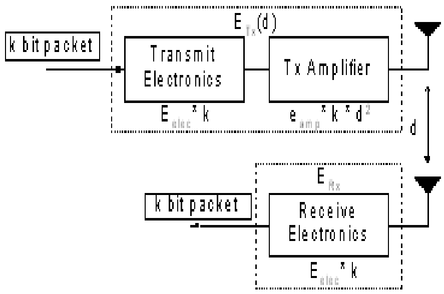

Figure 1: Model for the Network

According to the model, to reach an acceptable rate of Signal-to-Noise (SNR), the energy spent to send the message with the length of k-bit through the distance d is calculated through the relation:

$E_{TX}(k, d) = k.(E_{elec} + \epsilon_{fs} .d^2)$ if $d<d_o$ (2)

$E_{TX}(k, d) = k.(E_{elec} + \epsilon_{fs}.d^4)$ if $d>d_o$ (3)

E_{elec} is the consumed energy for each bit in the transmitter circuit or receiver circuit which is 50nJ/bit; ϵ_{amp}=0.0013PJ/bit/m^4, is the transmitter amplifier energy consumption and ϵ_{fs} = 10pJ/bit/m^4 which depends on the model boosting the transmitter circuit and d is the distance between the transmitter and receiver. Both the free space model (d^2) and multipath fading (d^4) channel model is used depending on the distance. If the distance is greater than the threshold, multi path model is used else free space model is used. The threshold is calculated as $d_o=\sqrt{(\epsilon_{fs}/\epsilon_{amp})}$. The energy for data aggregation is set to E_{DA} =5nJ/bit/signal. To receive the *k*-bit message the radio energy consumed is given by:

$E_{Rx}= k \times E_{elec}$ (4)

The energy required by the cluster member to send k bits of data to cluster head at a distance d_{CH} is

$E_{nonCH} = E_{elec}$ X k+ ϵ_{amp} X k X d^2_{CH} (5)

The energy consumed by the cluster head during each round is computed as

$E_{CH} = E_{elec}$ X k + ϵ_{amp}X k X d^2_{BS} X n + n X k X E_{DA} + E_{elec} X k X n. (6)

Proposed Protocol

This protocol, like in LEACH, is divided into rounds. Certain nodes may have more active participation in the sensing events or may be part of many routes in the event propagation trees. Hence, some nodes will deplete their energies faster than other nodes. The nodes organize themselves in to clusters and all non-cluster head transmit data to the cluster heads. The cluster head collects the data, aggregate them and sends it to the base station. Thus cluster head nodes are more energy intensive than the non cluster head counterparts.

Organization of clusters

It is assumed that each sensor node is equipped with the GPS and that the nodes transmit the information regarding their position and the initial energy to the base station. The optimum percentage of cluster heads is determined in advance .The base station selects the cluster head depending on two criteria:

- Nodes having maximum energy and
- Minimum distance between the cluster head as 2R, where R is the sensing range of the nodes.

The selected cluster head are notified which advertise their status. All nodes receive the advertisement and select the cluster they want to join depending on the signal strength of the advertisement received. This is the procedure for the cluster formation. Figure 2 shows the formation of 5 clusters in a network of 100 nodes. Since cluster head expends energy for transmission to base station, it needs to be rotated for uniform energy distribution in the cluster. The selection of cluster head is done as follows.

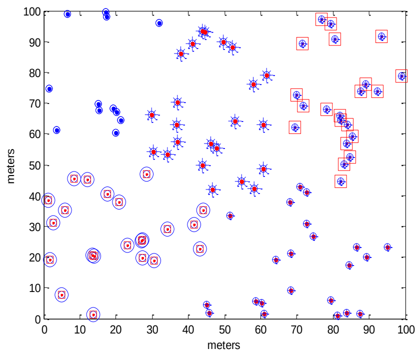

Figure 2: Cluster formation

Selection of Cluster Head Node for each Cluster:

Sensor nodes conduct a local election based on the distance and energy of neighboring nodes which form the part of the cluster. We define a parameter 'Y' as "the ratio of remaining energy in the sensor node to the square of the mean distance to all sensor nodes in that particular cluster". The sensor node which is having the highest value of parameter 'Y' above the threshold will be selected as the cluster head. If the same sensor node has the highest value of 'Y' then it will continued as the cluster head for the next round also. Mean distance sensor node 'i' is calculated using the equation

$$D_{i\,mean} = \frac{\sum_{j=1}^{clustm} d_{ij}}{clustm} \quad (7)$$

Where $D_{i\ mean}$ = mean distance of sensor node i from all other sensor nodes in the cluster,

d_{ij} = distance between sensor nodes i and j and clustm = number of sensor nodes in the cluster.

Each sensor node in the cluster maintains a table in its memory which helps in the process of cluster head selection as given in table 1.

Table 1: Table maintained by each node of the cluster

Node	1	2	3	4	.	.	Clustm	Mean D	P_i	$Y=P_i/D$
1	D_{11}	D_{12}	D_{13}	D_{14}	.	.	Clustm	$D_{1\ Mean}$	P_1	Y_1
2	D_{21}	D_{22}	D_{23}	D_{24}	.	.	Clustm	$D_{2\ Mean}$	P_2	Y_2
3	D_{31}	D_{32}	D_{33}	D_{34}	.	.	Clustm	$D_{3\ Mean}$	P_3	Y_3
4	D_{41}	D_{42}	D_{43}	D_{44}	.	.	Clustm	$D_{4\ Mean}$	P_4	Y_4
. . .	.	.	.	.	.	.	.	.	.	.

Where, D_{11},D_{12},D_{13} are the distances of node 1 from nodes 1,2,3…

D_{21},D_{22},D_{23} are the distances of node 2 from nodes 1,2,3…

$D_{1\ Mean}$, $D_{2\ Mean}$, $D_{3\ Mean}$ are the mean distance to every other node in the cluster from node 1,2,3…. respectively.

P_1 P_2 , $P_{3\ldots}$ are the remaining energy in the nodes.

The parameter Y for each node is calculated using equation 8

$Y_i=P_{i\ Rem}/D^2_{i\ Mean.}$ (8)

Where, $P_{i\ Rem}$ is the remaining energy in the i^{th} node

And $D^2_{i\ Mean}$ = mean distance of the sensor node I from all other sensor nodes in the cluster.

$$Y_{Threshold} = \frac{\sum_{i=1}^{clustm} Y_i}{\text{clustm}} \quad (9)$$

Set-up Phase

The cluster heads act as local control centers to coordinate the data transmissions in their cluster. It sets up a TDMA schedule and transmits this schedule to the nodes in the cluster. This ensures that there are no collisions among data messages and also allows the radio components of each non cluster head node to be turned off at all times except during their transmit time, thus minimizing the energy dissipated by the individual sensors .After the TDMA schedule is known by all nodes in the cluster the set-up phase is complete and the steady-state operation (data transmission) can begin.

Steady state Phase:

In the steady state nodes send their data in the form of frames to the cluster head at most once per frame during their allocated transmission slot. The cluster head keeps its receiver on, to receive all the data from the nodes in the cluster. Once the cluster head receives all the data, it can aggregate data and send to the base station. This is a high energy transmission as the base station is at a large distance. The cluster head initiates an election if its current energy level falls below a threshold value of the energy level. Once an election is initiated, each node transmits special 'energy-level' messages, which are appended to its regularly scheduled transmission packet during its scheduled time slot.

Simulations and Results

In this paper the proposed protocol has been simulated in a network of size 100x100m consisting of 100 nodes and results compared with Static clustering and LEACH protocol. We use three metrics to evaluate the performance of the proposed protocol:

1. Total number of nodes alive: This metric indicates the overall lifetime of the network and this gives the idea of the area coverage of the network over time.

2. The time for first node to die: This metric, along with the time to network partition, gives an indication of network lifetime.
3. Energy dissipated: The dissipation of energy per node over time as the network performs the transmission, reception, sensing and aggregation of data is indicated by this metric.

Figure 3 shows the number of nodes alive over simulation time .Comparing the various protocols, it is seen that the nodes are alive for a longer duration. The life time of a network is defined as the time when the first node dies. Here in the proposed protocol, the first node dies at 1640 seconds as compared to LEACH where the node dies at 380 seconds.

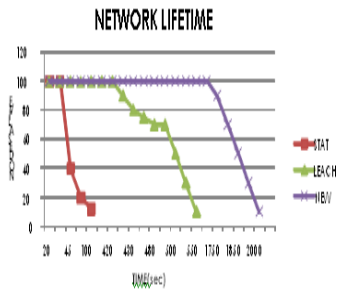

Figure 3 : Network lifetime

In the Figure 4,the total data messages received at the BS at the expense of specific amount of energy is shown.The graph shows that in the proposed protocol, an increase in the number of nodes in the network keeps the number of messages receivedhigh.

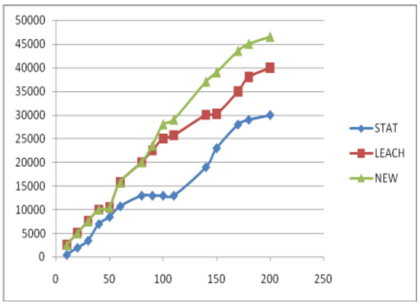

Figure 4: Total amount of data received at the base station per given amount of energy.

In the Figure 5, the energy dissipated by the nodes of the network over time is indicated for the three protocols.In static clustering, at the time of 45 seconds ,since all the nodes were dead,the network stopped working and the total energy dissipation of the network after 50 seconds remains constant at 60 J.Comparing LEACH and new protocol, initially the new protocol has a large amount of energy dissipation due to the calculation of the distances that has to be done in the clusters. In the following rounds, the selection of energy efficient cluster head causes lesser energy to be spent compared to LEACH .This shows that selection of cluster head can improve the energy efficiency and prolong the lifetime of the network.

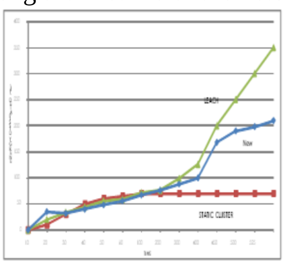

Figure 5: Energy dissipation of nodes with respect to time

Conclusion

Energy is one of the most important parameter in a WSN and an measure of the network lifetime. In this paper an indepth analysis of the classical protocols of WSN and the proposed protocol has been done.Here the cluster head is selected by considering both the distance of the nodes to all its neighbors in the cluster and the remaining energy. The simulation results prove that the protocol is superior to LEACH in terms of energy used and lifetime of the network.This work can be further enhanced to a multi level clustering to further reduce the burden on the clusterhead.

References

[1] I. F. Akylidiz, W. L. Su, Y. Sankarasubramaniam, and E. Cayirci, Wireless sensor network: A survey on sensor networks, IEEE Communications Magazine, 2002 August,Vol. 40, No. 8, pp. 102-114.
[2] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, Energy- Efficient Communication Protocol for Wireless Microsensor Networks, Proceedings of IEEE HICSS, January 2000.
[3] F.Xiangning,S Yulin,Improvement on LEACH Protocol of Wireless Sensor Networks, Proc.IEEE ICSTA,2007,pp 260-264.
[4] B.Kim amd I.Kim, Energy Aware routing Protocol in Wireless Sensor Networks, Int. J. Computer Science and Network Security, Jan 2006, 6[1]: pp 201-207.
[5] Heinzelman W , Chandrakasan A.,"An application specific protocol architecture for wireless micro sensor networks" [J],IEEE Transaction on Wireless Communication, 2002, I(4):660-670.
[6] K.Akkaya and M.Younis, "A Survey of Routing Protocols in Wireless Sensor Networks", Elsevier Ad Hoc Networks Journal, 2005,3(3), pp.325-349.
[7] Q. Wang, T. Zhang, and S. Peterson, "An effort to understand the optimal routing performance in wireless sensor network," Proc. IEEE 22nd Int. Conf. on Advanced Information Networking and Applications(AINA'08), Mar. 2008, pp. 279–286.
[8] Gao Yi , Sun Guiling ,Li Weixiang and Pan Yong," Recluster-LEACH: A recluster control algorithm based on density for wireless sensor network", Power Electronics and Intelligent Transportation System (PEITS), 2009 , Vol. 3,pp 198-202.
[9]O.Younis, M Krunz and S. Ramasubramanian, "Node clustering in wireless sensor networks: recent developments and deployment challenges," IEEE Network, 2006 May-June, 20[3], pp. 20-25.
[10] J. Al-Karaki and A.E. Kamal, "Routing techniques in wireless sensor networks: a survey," IEEE Wireless Communications, 2004,vol. 11, pp. 6- 28.
[11] P.Ding, J.Holliday and Celik," Distributed energy efficient hierarchical clustering for Wireless Sensor networks" Lecture Notes in Computer Science, 2005, pp 332-339.
[12] Md. Mehdi srimohammadi, Karim Faez and M.Chhardoli,"LELE: Leader Election with load balancing Energy in Wireless sensor Networks", International Conference on Communication and Mobile Computing, 2009.
[13] Amir Sepasi Zahmati, Bahman Abolhassani, Ali Asghar beheshti Shirazi ,Ali Shojaee Bakhtiari,"An Energy Efficient Protocol with Static Clustering For Wireless Sensor Networks",WASET,2007.