International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

B-SEP: An Enhanced SEP Protocol for Wireless Sensor Network

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Accepted 10 July 2014, Available online 01 Aug 2014, **Vol.4, No.4 (Aug 2014)**

Abstract

Wireless sensor networks have high potential to be applied in almost every field of life. Lots of research is done which have led to many new protocols where energy efficiency is an essential consideration. Clustering is a significant technique to reduce energy consumption. In this sensors are organized into groups, so that sensors transfer information only to cluster-heads and then the cluster-heads transfer the aggregated information to the base station. In this paper we have modified SEP(Stability Election Protocol) by presenting efficient cluster head selection scheme based on current energy level of sensor nodes and applying second selection to modify the number of cluster heads to be near optimal and then using dual transmitting power levels for cluster members.

Keywords: *Balanced, Dual power level, Current energy, Stability Period.*

1. Introduction

Wireless sensors network consist of sensors which are small, low power devices deployed in a field in large number. These sensing nodes have many usages like observing physical or environmental conditions, such as temperature, humidity, sound, motion, etc. Wireless Sensor Networks (WSNs) enable us to use these small sensor nodes for multiple applications like military applications; manufacturing, end user applications, area monitoring, waste water monitoring, etc.

In WSNs, nodes sense data and send information to sink directly or indirectly. Wireless sensor nodes can be mobile or stationary and can be deployed in their environment randomly or with a proper deployment mechanism. Some of the energy of nodes is expended due to sensing and some part due to transmission and reception of data. But communication takes up major share of node’s energy. Practically, it is not possible to replace or renew batteries of nodes once deployed. WSN must operate without human involvement so the main focus is to increase network life in any way and for this purpose many protocols are introduced.

In routing protocols clustering reduces energy consumption in sensor nodes. When clusters are formed, CHs are elected on the basis of energy of nodes or on. After clusters formation each node transmits data during its time slot and as the last node transmits data, schedule is repeated.

2. Related Work

Data transmission in wireless sensor network should be as energy efficient as possible. Various techniques have been developed for this. One is direct transmission (DT), in which node sense data from its environment and sends it directly to base station. From this data security is assured but node’s life time is compromised due to excessive power consumption (if BS is far away). Hence, using direct transmission technique, nodes that are far away from BS die early as they require more power for communication.

Another technique called Minimum Transmission Energy (MTE) was introduced. In this technique, data is transmitted to base stations via multi hop. This leads to almost same problem as in direct transmission but here nodes near to base station die earlier as they have to route all the data from far end nodes to the base station. Moreover, transmitting large amount of sensed data from each node use more energy (Shepard, 1996).

Clustering protocol LEACH guarantees that well balanced energy loads by dynamically created clusters headed by dynamically chosen cluster heads according to optimal probability. Cluster heads aggregate data from their cluster-members and then forward it to the sink. Each node gets the role of cluster head uniformly which make each node to expend same energy over time. The operation of LEACH is divided into rounds. Each round consists of two phases- setup phase in which clusters are formed and steady state phase where data transmission takes place (Heinzelman et al, 2000). Other homogenous protocol is HEED (Younis et al, 2004).

Stability Election Protocol (SEP) (Smaragdakis et al, 2004) is like LEACH protocol but considers the fact that sensors will not have same energy level. Here every sensor node independently elects itself as a cluster head based on weighted probabilities.

3. SEP Protocol

SEP improves the stable region of a WSN by using the heterogeneity parameters such as fraction of advanced

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nodes m and additional energy factor α between the normal and advance nodes. To prolong the stability region of a network, SEP maintain the constraints of well balance energy consumption.

In SEP initially, advanced nodes have to become the CH more often than normal nodes. Suppose that E_0 is the initial energy of each normal node and $E_0(1 + \alpha)$ is the energy of advanced nodes in a WSN. Total energy of the system is increased by $(1 + \alpha.m)$ times. In order to increase the stability of the system, new epoch must equal to $1/p_{opt}\ (1 + \alpha.m)$ because system has α.m times more nodes and α.m more energy. Initially, for homogenous system each node has the probability of becoming CH as p_{opt}.

But, for two-level heterogeneous networks as in SEP, p is defined as follow:-

$$p_{nrm} = \frac{p_{opt}}{(1+\alpha m)} \qquad (1)$$

If S is the normal node

$$p_{adv} = \frac{p_{opt}}{(1+\alpha m)} \times (1+\alpha) \qquad (2)$$

If S is the advanced node

The nodes that are elected to be CH in current round can no longer become CH in the same epoch. Nodes that are not elected CHs belong to set G in order to maintain a steady number of CHs per round. The probability of nodes S€G to become CH is increases after each round in same epoch. The decision is made at the beginning of each round by each node S€G independently choosing a random number between [0,1]. If random number is less than threshold then the node becomes a cluster head in current round. The threshold is set in as:-.

$$T(S_{nrm}) = \begin{cases} p_{nrm}/(1-p_{nrm}(r.\mathrm{mod}1/p_{nrm})) & \text{if } S€G' \\ 0 & \text{otherwise} \end{cases} \qquad (3)$$

Where G' is set of normal nodes not selected as CHs and G" is set of advanced nodes not selected as CHs, r is current round number. T(Snrm) and T(Sadv) is threshold for normal and advance nodes respectively.

$$T(S_{adv}) = \begin{cases} p_{adv}/(1-p_{adv}(r.\mathrm{mod}1/p_{adv})) & \text{if } S€G'' \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

The nodes that are elected to be CH in current round can no longer become CH in the same epoch. Advance nodes become CH again after Sub-epoch which is equal to 1/padv. The probability of nodes S€G to become CH is increases after each round in same epoch. SEP increase the stable region of a network, if fulfilling the following conditions.

- Each normal nodes becomes a CH once every $1/p_{opt}.(1 + \alpha.m)$ rounds per epoch.
- Each advanced node becomes a CH $(1 + \alpha)$ times every $1/p_{opt}.(1 + \alpha.m)$ rounds per epoch.
- Average number of CH per round per epoch is equal to $n \times p_{opt}$.

4. Proposed Approach

4.1 Heterogeneous Network Model

For our proposed model, we adopt a few reasonable assumptions of the network model as follows:

1. There are N sensor nodes, which are uniformly dispersed within a M x M square region.
2. The nodes are stationary and always have data to transmit to a base station.
3. The network is organized into a clustering hierarchy
4. The cluster-heads transmit the aggregated data to the base station directly.
5. There are two types of sensor nodes, i.e., the advanced nodes and normal nodes

Let E_0 the initial energy of the normal nodes, and m the fraction of the advanced nodes, which own α times more energy than the normal ones. Thus there are N.m advanced nodes equipped with initial energy of $E_0(1+\alpha)$, and N(1–m) normal nodes equipped with initial energy of E_0. The total initial energy of the two-level heterogeneous networks is given by

$$E_{total} = N(1-m)E_0 + NmE_0(1+\alpha) = NE_0(1+\alpha m) \qquad (5)$$

4.2 Radio Energy Dissipation Model

According to the radio energy dissipation model proposed in (Heinzelman et al, 2000) Fig.1 and in order to achieve an acceptable Signal-to Noise Ratio (SNR) in transmitting an k-bit message over a distance d, the energy expended by the radio is given by:-

$$E_{Tx}(k, d) = \begin{cases} kE_{elec} + k\epsilon_{fs}d2, & d < d_0 \\ kE_{elec} + k\epsilon_{mp}d4, & d \geq d_0 \end{cases} \qquad (6)$$

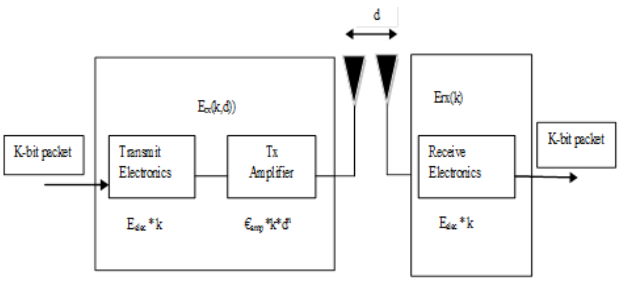

Fig. 1 Energy Dissipation Model

Where E_{elec} is the energy dissipated per bit to run the transmitter E_{Tx} or the receiver E_{Rx} circuit, and $\epsilon_{fs} d^2$ and $\epsilon_{mp}d^4$ depend on the transmitter amplifier model used and d is the distance between the sender and the receiver. To receive this message the radio expends energy:

$$E_{Rx}(k) = kE_{elec} \qquad (7)$$

4.3 Energy-efficient Cluster-head Selection

SEP randomly selects some nodes as cluster heads and rotates this role to balance the energy dissipation of the sensor nodes in the networks. Each node decides whether or not to become a cluster-head for the current round based on the probability i.e p_{nrm} or p_{adv} and the number of times the node has been a cluster-head so far. This decision is made by a node by choosing a random number between 0 and 1. If the number is less than a threshold $T(S_{nrm})$ or $T(S_{adv})$ depending whether node is normal or advance node respectively, the node becomes a cluster-head for the current round.

As clear from the threshold equations of SEP randomly elects cluster-head based on initial energy of nodes. But due to different amount of energy dissipation there are situation where a node having high initial energy have low energy levels as compared to nodes having less initial energy. Therefore selection of cluster-head based on initial energy needs to be modified. And for this we have adjusted the threshold equations of SEP by introducing node’s current energy level in it. Using this threshold each node decides whether or not to become a cluster-head in each round.

$$T(S) = \frac{p}{1 - p(r \bmod 1/p)} \frac{E_c}{E_i} k_{opt} \quad (8)$$

Where p can be p_{nrm} in case of normal node or p_{adv} in case of advance node, E_c is the current energy level of the node and E_i is the initial energy of the node before the transmission. To determine the optimal number of cluster for our network, we use following as shown in.

$$k_{opt} = \frac{\sqrt{n} \times M}{\sqrt{2\pi} \times d_{toBS}^2} \quad (9)$$

Where k_{opt} is the optimal cluster-head number, n is total number of sensor nodes, M is the length of nodes distributing fields, d_{toBS} is the distance between nodes and the base station.

4.3 Balancing Number of Clusters

This protocol also adds another selection of cluster heads to modify the number cluster-head in the set-up phase by using node’s residual energy per round.

Heinzelman et.al. in has proved that system having total 100 nodes in the network with 3 to 5 cluster are the most energy efficient system. That means the optimal percentage of cluster heads range from 3% to 5%.

This protocol introduce another competition for cluster-heads after the first selection of the cluster heads according to proposed threshold to make the number of cluster heads up to n×P, where P is the desired percentage of cluster heads and n is the number of total nodes. We have taken P as 5%.

The first-selected number and the residual energy of cluster heads can be learned by every node through the CHs' advertisement messages. If the number of cluster-heads is equal or less than n×P then these nodes become cluster-heads without any further selection. If the number of cluster heads is more than n×P , we select high energy cluster head to make the number of cluster head n×P if one cluster head’s energy is ranked below n×P, it is changed to normal node.

4.3 Dual Transmission Power Levels

In this protocol we also introduce two different levels of power to amplify signals according to nature of transmission. In SEP there can be two modes of transmission – intra cluster transmission and cluster head to base station transmission. Intra Cluster Transmission deals with all the communication within a cluster i.e. cluster member sense data and report sensed data to cluster head. The transmission of aggregated data from cluster heads to base station lies under the heading of cluster head to base station transmission.

Amplification energy required for intra cluster communication cannot be same with that cluster head to BS communication. In SEP, amplification energy is set same for both types of transmissions. Using low energy level for intra cluster transmissions as compared to cluster head to BS transmission leads in saving much amount of energy. Additionally, multi power levels also reduce the packet drop ratio, collisions and/ or interference for other signals. When a node act as a Cluster head, routing protocol informs it to use high power amplification and in next round, when that node becomes a cluster member, routing protocol switches it to low level power amplification.

4. Simulation and Results

To demonstrate B-SEP effect on communication energy consumption, we consider a network with 100-nodes randomly distribution in a field of size 100m×100m. In the simulation, we compared the performance of proposed B-SEP with SEP. Our performance metrics are:-

- **Stability Period:** is the time interval from the start of network operation until the death of the first sensor node. We also refer to this period as “stable region.”
- **Instability Period:** is the time interval from the death of the first node until the death of the last sensor node. We also refer to this period as “unstable region.”
- **Number of dead nodes per round:** This instantaneous measure reflects the total number of nodes that have expended all of their energy.
- **Number of alive nodes per round:** This instantaneous measure reflects the total number of nodes that have not yet expended all of their energy.

Here the simulation is performed in MATLAB and have collected the outputs till all the nodes die. The same simulation parameters are used for both SEP and B-SEP to simulate them. We ignore the effect caused by signal collision and interference in the wireless channel and the radio parameters used are shown in Table 1.

Table 1 Simulation Parameter

S.No.	Parameter	Value
1	E_{elec}	50nJ/bit
2	$€_{fs}$	10pJ/bit/m^2
3	$€_{mp}$	0.0013pJ/bit/m^4
4	E_{DA}	5nJ/bit/signal
5	Data packet size	4000 bytes
6	E_o	0.5J

The energy consumption due to communication will be calculated using the first order energy model. We assume that each sensor node generates one data packet per time unit to be transmitted to the BS. We have simulated the protocols by setting heterogeneity parameters as α=1 and m=0.1.

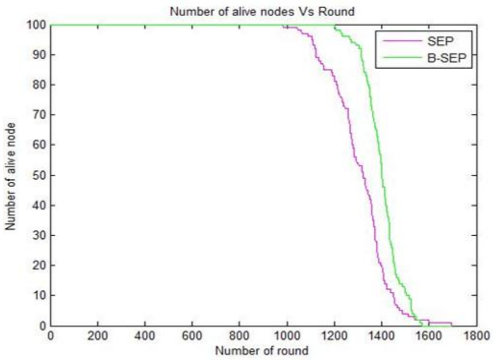

Fig. 3 Number of alive nodes per round for SEP and B-SEP

In Fig. 2 is shown, nodes in SEP protocol begin to die after about 983 rounds. While in B-SEP, nodes begin to die after about 1200 rounds. Therefore, the stability period of B-SEP is longer than the SEP protocol which proves that the proposed approach has extended the stability period effectively.

Fig. 3 shows number of dead nodes per round for both SEP and B-SEP for α=1 and m=0.1. Graph shows that nodes die earlier in SEP as compared to B-SEP. And it shows that instability period is less in B-SEP than SEP.

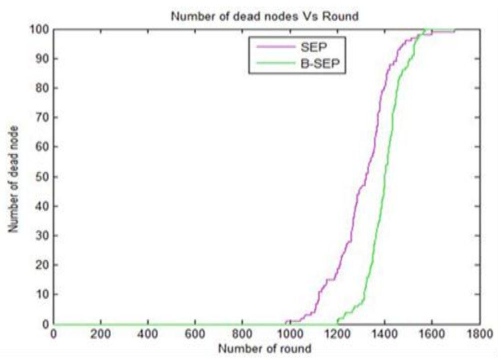

Fig. 3 Number of dead node per round for SEP and B-SEP

Fig. 4 shows number of alive nodes per round for m=0.1 and α=2 which also follows same trend as Fig. 2 follows.

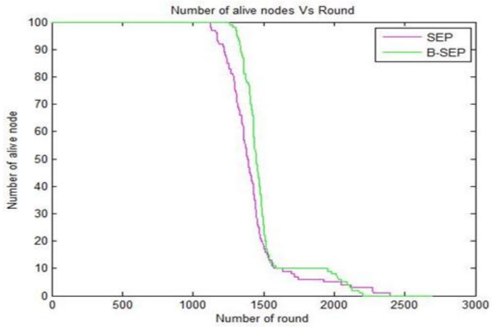

Fig. 4 Number of alive node per round for SEP and B-SEP (m=0.1 and α=2)

Table 2 shows the improvement that B-SEP has made over SEP for m=0.1 and α=1. If we look at FND (First Node Dead) which is also stability period the improvement is about 22%. Same is the result for HNA (Half Node Alive) where the improvement is about 6%. When the half number of nodes have expended all of their energy, the network become inefficient.

Table 2 Improvement of B-SEP over SEP

Protocol	FND	HNA	Instable Region
SEP	983	1320	712
B-SEP	1202	1400	251
Improvement	22.2%	6%	64.75%

Also one of the performances metric is instability region which needs to be decreased as reliability is decreased because there is no guarantee that there is at least one cluster head per round during the last rounds of the operation which prevents any reporting to sink.

Here instable region is less in B-SEP than SEP which has shown about 64% improvement. Fig. 5 shows the comparison between all nodes in terms of FND and HNA for different heterogeneity which shows that B-SEP is better than SEP in both cases.

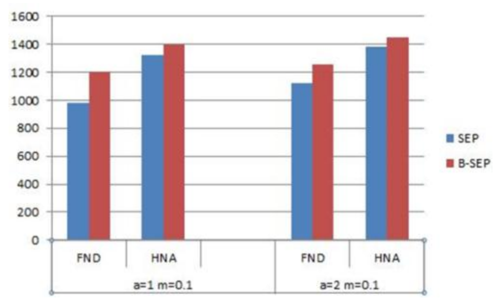

Fig. 5 FND and HNA of SEP and K-SEP

Conclusions

In this work we propose, a variant of SEP that can be utilized in other clustering routing protocols for better efficiency. B-SEP tends to increase the stability period by efficient cluster head selection, balancing the number of cluster-heads and dual transmitting power levels for intra-cluster and cluster head to base station communication.

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