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Research Article

K-SEP: A more stable SEP using K-Means Clustering and Probabilistic Transmission in WSN

Bharti Kandari[Á*] and Rajdeep Singh[Á]

[Á]Dept. of Computer Science, Punjab Technical University, Punjab India

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Abstract

A Wireless sensor network consists of large number of sensor nodes having different energy levels deployed for sensing and monitoring task. As energy is the major constraint in wireless sensor network these nodes are mostly organized into clusters to save energy. In this paper a modified approach for Stability Election Protocol called K-SEP is proposed which aimed at improving the stability period by balancing the energy consumption of the nodes. The proposed protocol uses K-means algorithm for uniform clustering and select cluster heads based on current energy levels and distance. Also transmission from cluster members to cluster head is made probabilistic. Simulation result shows that proposed protocol have better stability period than SEP.

Keywords: *wireless sensor network, stability period, K-means, heterogeneous.*

1. Introduction

A wireless sensor networks (WSN) is composed of a large number of tiny ,battery powered sensor nodes which are deployed in ad-hoc manner in an environment without infrastructure to monitor physical or environmental conditions and to cooperatively pass their data through the network to a main location via sink. Sensor nodes have limited battery which is difficult or impossible to recharge in contrast to the sink which have no energy constraint and the battery used is rechargeable. Sensor nodes sense and send their report to sink either directly or via multi-hop transmission. Protocols for such network should be designed so as the sensors efficiently utilizes their energy in order to maximize network lifetime as it is nearly impossible to charge their batteries once deployed.

The sensor nodes have three main tasks to perform- sensing, processing and communication. The most energy consuming task for senor node is communicating the sensed data. The more is the distance between communicating sensors more is the energy consumed. Many energy efficient protocols have been proposed which distribute the energy load to prolong the network lifetime. Among these cluster based protocols are much more efficient than others. In these sensors are organized into clusters headed by a cluster head which aggregate the data of its cluster member and is responsible for communicating the aggregated data to the sink.

2. Related Work

There are two types of sensor network according to sensor capabilities-homogenous and heterogeneous. Following are the different protocols that are applied to these networks:-

2.1 Low-Energy Adaptive Clustering Hierarchy (LEACH)

Low-Energy Adaptive Clustering Hierarchy (LEACH) which is one of the most fundamental protocol frameworks in the literature. LEACH is clustering based protocol architecture which utilizes randomized rotation of the Cluster-Heads (CHs) to uniformly distribute the energy across the network. The sensor nodes are grouped into several clusters and in each cluster, one of the sensor nodes is selected to be CH. The operation of LEACH is divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase. In steady-state phase nodes send their data to the cluster head which forwards the sensed data to the sink directly (Heinzelman et.al, 2000).

2.2 Power Efficient Gathering in Sensor Information Systems (PEGASIS)

In the PEGASIS (Lindsey et. al, 2002) protocol the sensors are organized into a chain which can be formed by the sensors by using greedy algorithm or by the sink which broadcast chain to all the sensors. Here only one node of the chain is allowed to aggregate all the data and transmit it to the sink. This protocol requires global knowledge of the network topology which is an add-on to the complexity of the protocol .Moreover discovering a new route is difficult, if a node fails, as it has a fixed path every time before it starts a new route towards the sink for the transmission. Though this protocol conserve energy, but it loose focus on maintaining quality-of-service factors. For instance, it cannot resist uneven traffic

*Corresponding author: **Bharti Kandari**

distribution for all those nodes, which are not in the single-hop range, but has to make a multi-hop structure for adding such nodes.

2.3 Stability Election Protocol (SEP)

In SEP (Smaragdakis et. al, 2004) every sensor node in a heterogeneous two-level hierarchical network independently elects itself as a cluster head based on its initial energy relative to that of other nodes. Here weighted probabilities are assigned to the sensors according to their energy. Variants of SEP are Z-SEP (Faisal et. al, 2013), DB-SEP (Benkirane *et al*, 2012), TSEP(Kashaf *et al*,2012).

3. Heterogeneous Network and Radio Energy Dissipation Model

3.1 Heterogeneous Network Model

In this study, we describe the network model. Assume that there are N sensor nodes, which are uniformly dispersed within a M x M square region. The nodes always have data to transmit to a base station, which is often far from the sensing area. The network is organized into a clustering hierarchy, and the cluster-heads execute fusion function to reduce correlated data produced by the sensor nodes within the clusters. The cluster-heads transmit the aggregated data to the base station directly. We assume that the nodes are stationary. In the two level heterogeneous networks, 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 Nm 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:

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

3.2 Radio Energy Dissipation Model

According to the radio energy dissipation model proposed in (Heinzelman *et al*,2002) (Figure 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:-

$$E_{Tx}(k, d) = \begin{cases} kE_{elec} + k\epsilon_{fs}d^2, & d < d_0 \\ kE_{elec} + k\epsilon_{mp}d^4, & d \geq d_0 \end{cases} \qquad (2)$$

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:

$$E_{Rx}(k) = kE_{elec} \qquad (3)$$

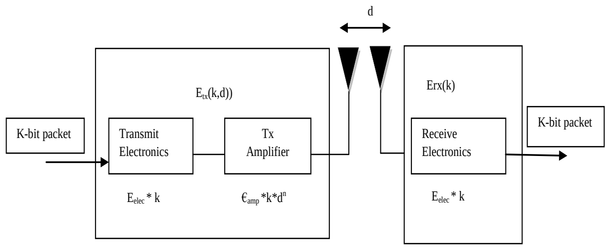

Fig. 1 Energy Dissipation Model

4. SEP Protocol

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

As we know in SEP total energy of system is increased by (1 + α.m) times. To make balanced utilization of this increased energy advanced nodes have to become the CH more often than normal nodes. To implement this new epoch is introduced which is equal to $1/p_{opt}$ (1 + α.m) because system has α.m times more nodes and α.m more energy. Initially, for each node the probability of becoming CH is p_{opt}.

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

$$p_{nrm} = \frac{p_{opt}}{(1+\alpha m)} \qquad (4)$$

If S is the normal node

$$p_{adv} = \frac{p_{opt}}{(1+\alpha m)} \times (1+\alpha) \qquad (5)$$

If S is the advanced node

The decision to become a CH is made at the beginning of each round by each node S_{nrm}€G' and S_{adv}€G" independently by 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 as:

$$T(S_{nrm}) = \begin{cases} p_{nrm}/(1-p_{nrm}(r.\text{mod}1/p_{nrm})) & \text{if } S€G' \\ 0 & \text{otherwise} \end{cases} \qquad (6)$$

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. $T(S_{nrm})$ and $T(S_{adv})$ is threshold for normal and advance nodes respectively.

$$T(S_{adv}) = \begin{cases} p_{adv}/(1-p_{adv}(r.\text{mod}1/p_{adv})) & \text{if } S€G" \\ 0 & \text{otherwise} \end{cases} \qquad (7)$$

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 $1/p_{adv}$. 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/popt.(1 + α.m) rounds per epoch.
- Each advanced node becomes a CH (1 + α) times every 1/popt.(1 + α.m) rounds per epoch.
- Average number of CH per round per epoch is equal to n × p_{opt}.

5. Modify presumption in SEP

We have modified the presumption in SEP that the cluster member nodes always have data to transmit to cluster head at their slot. But in reality, the cluster member may not always have data to transmit and also the nodes are close to each other and they have correlated data so there is no need that all nodes should transmit at their slot. So, in proposed protocol we assume that the non-cluster head nodes send data to cluster head at its transmission slot with probability P. With probability P, if the cluster member doesn't transmit data to cluster head, the cluster member should be in an idle or sleep state. The energy consumption can be neglected when the nodes are in idle or sleep state. If P's value is 1, the network model is the same with SEP. And if P 's value is other than between 0 and 1, the network model is the same as TEEN (Manjeshwar *et al*, 2001) and APTEEN (Manjeshwar *et al*, 2002). As we assumed that nodes send data randomly at report time, the nodes can be asleep when it has no data to send or receive, and the network's lifetime can be prolonged largely.

6. K-means Clustering Algorithm

The K-Means clustering algorithm is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem.

During every pass of the algorithm, each data is assigned to the nearest partition based upon some similarity parameter (such as Euclidean distance measure). After the completion of every successive pass, a data may switch partitions, thereby altering the values of the original partitions. Various steps of the standard K-Means clustering (Mac Queen *et al*, 1967) algorithm is as follows:

1) The number of clusters is first initialized and accordingly the initial cluster centers are randomly selected.
2) A new partition is then generated by assigning each data to the cluster that has the closest centroid.
3) When all objects have been assigned, the positions of the K centroids are recalculated.
4) Steps 2 and 3 are repeated until the centroids no longer move any cluster.

The main objective of K-Means is the minimization of an objective function that determines the closeness between the data and the cluster centers, and is calculated as follows:

$$J = \sum_{j=1}^{K} \sum_{i=1}^{N} \| D(X_i, C_j) \| \tag{8}$$

Where, $\|D(X_i, C_j)\|$ is the distance between the data X_i and the cluster center C_j.

The downside of K-Means algorithm is that, the result of clustering mostly depends on the initially selected centroids. Spherical data sets cannot be efficiently clustered using K-Means. And only numerical values attributes can be ably clustered.

7. K-SEP Protocol

The proposed protocol improves the clustering and cluster head selection procedure. For the first round of communication, in setup phase we use the K-means algorithm for cluster formation, which ensures uniform clustering. The cluster formation by K-means algorithm ensures best clustering and selection of cluster head is done based on Euclidian distance from the cluster center and maximum residual energy in the cluster which gives most energy efficient solution in WSN. We perform K-means clustering till 50% of nodes die then we switch to random clustering. Proposed protocol is divided into many rounds, and each round contains cluster formation phase and Steady state phase

Cluster formation phase

1) For the first round clusters are formed using K-means clustering algorithm and cluster heads are selected as a node which is nearer to the sink using Euclidian distance and having maximum residual energy. For rest of the rounds nodes nearest to the sink and having maximum residual energy is chosen as cluster head.
2) Some nodes that turn into cluster heads as per above conditions send their cluster head announcement information to inform other nodes. The other nodes turn up as non-cluster head nodes send cluster joining information to cluster head
3) Cluster heads prepare their TDMA schedule.

Steady state phase

1) Nodes in a cluster, sends their data with transmission probability P according to TDMA schedule, and cluster head receives, and aggregates the data.
2) The cluster heads will send their data directly to the base station.

This way the limitation of random clustering of SEP protocol is addressed by uniform clustering to balance the load of entire network among all the nodes. The step by step flowchart of K-SEP protocol is shown as follows:

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
7	p_{opt}	0.1
8	m	0.1
9	α	1
10	P	0.7

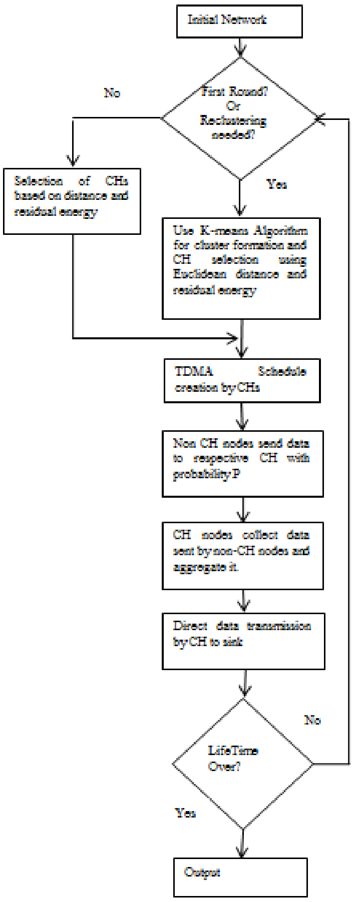

Fig. 2 Flowchart of K-SEP

8. Simulation and Results

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 K-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

In the simulation, we compared the performance of proposed K-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."
- **Network Lifetime:** is the time interval from the start of operation (of the sensor network) until the death of the last alive node.
- **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.
- **Residual energy of network per round:** This instantaneous measure reflects the residual energy of the network.

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 $\alpha=1$ and m=0.1.

The probability of transmission P is taken as 0.7 for the simulation. Smaller the value of P less is the energy consumption and hence more is the network lifetime.

The simulation has shown that the stability period has been increased for K-SEP as compared to SEP. Fig 3 shows alive nodes per round with transmission probability 0.7. Also the network lifetime for K-SEP is increased. First node dies for KSEP much later as compared to SEP which leads to greater stability period. Also lifetime of the network is also increased for K-SEP as compared to SEP. for both SEP and K-SEP node die earlier in case of former as compared to later.

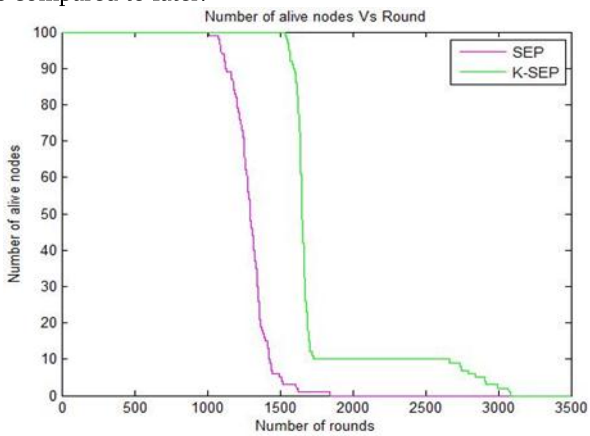

Fig. 3 Number of alive nodes per round for SEP and K-SEP

In fig 4 is shown number of dead nodes per round. It shows that in SEP nodes die earlier than K-SEP. it also shows that all nodes die later in K-SEP as compared to SEP.

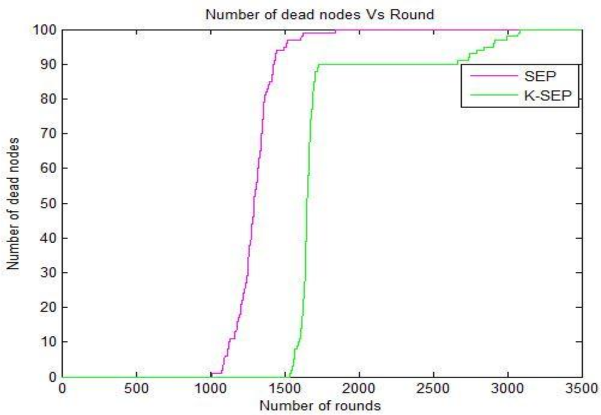

Fig. 4 Number of dead nodes per round for SEP and K-SEP

Fig 5 shows the comparison between all nodes in terms of FND(First Node Dead) and HNA(Half Node Alive), obviously we can remark that our protocol K-SEP contains a large period of stability time than SEP, that increases the efficiency of the network.

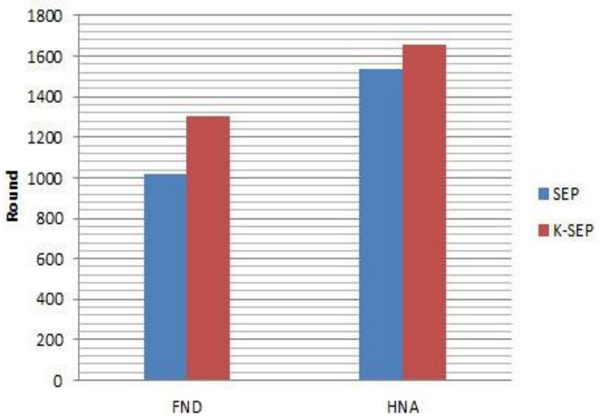

Fig. 5 FND and HNA for SEP and K-SEP

We notice the same results for HNA that K-SEP performs better than the SEP. When the half number of nodes have expended all of their energy, the network become inefficient.

Fig 6 shows the energy retention over time for SEP and K-SEP and it reveals that K-SEP consumes less energy in comparison to SEP which helps to extend the network lifetime. The technique used for KSEP reduces the energy consumption which leads to more energy retention.

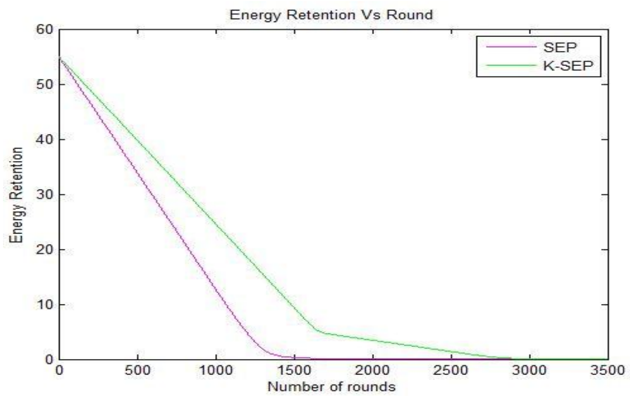

Fig. 6 Energy retention per round for SEP and K-SEP

Conclusions

In this we have defined an energy efficient protocol K-SEP and compared it with SEP. In this protocol uniform clustering is done using K-means clustering and probabilistic transmission of data from cluster members to cluster head is done. The simulation results show that the proposed algorithm K-SEP can maintain a balanced energy consumption distribution among nodes in a sensor network and thus prolong the network lifetime as well as stability period.

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