A Relay Node Based Hybrid Low Energy Adaptive Clustering Hierarchy for Wireless Sensor Networks

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Abstract

Due to the necessity of saving energy cost in low-powered devices, extending the lifetime of a sensor node powered by battery in both homogeneous and heterogeneous wireless sensor networks (WSNs) is area of interest. To save battery power in sensor networks, many research works including low energy adaptive clustering hierarchy (LEACH) and its variants use clustering techniques to reduce energy spent by keeping most of the nodes in sleeping mode but making a good quality of service (QoS). However, LEACH lacks on optimizing the network life time due to loosing huge energy of sensor nodes selected as cluster heads for communications. In contrast, relay node based schemes use independent powerful relay nodes as cluster heads to save energy of the low energy sensor nodes. These schemes also suffer from a number of problems such as relay node placement, blind spots and immature death of cluster heads. LEACH and its variants except fixed LEACH, suffer from the problem of accomplishing huge energy of sensor nodes due to forming repeated cluster at each fixed time interval. Fixed LEACH surmounts the repeated clustering formation problem by forming fixed clusters only once, but wastes huge energy and incurs loss of information due to the premature death of cluster heads before expire a constant amount of round time. The research work in this paper uses the relay nodes as the cluster heads in addition to LEACH, however uses fixed LEACH (LEACH-F) when all relay node dies, and the round time of fixed LEACH is adjusted dynamically to decrease the probability of premature death of cluster heads.

Keywords: *LEACH, sensor nodes, relay nodes, energy, clustering*

1. Introduction

A sensor network consists of multiple sensor nodes, each of which is tiny, lightweight and operated by rechargeable or non-rechargeable batteries depends on the type of applications. Due to the low cost simple structure, a large number of sensor devices [1] are prompted in a sensor network to employ widely. Once a sensor node collects information from the environment, it transmits the information to the base station (BS) of the network. The longer transmission in a WSN is the most energy consuming activity, diverts in shorter the network lifetime as expected. If the network is unable to operate due to quick drain of battery power, the system collapsed and the network needs to be reconfigured by either recharging/replacing batteries or replacing the sensor nodes. The solutions are complex, expensive, and sometimes become unfeasible. Such a condition demands for designing an energy efficient clustering technique which reduces the number of communications to converge the desired lifetime of a WSN.

Efficient clustering in sensor networks is required to save energy by forming efficient groups that communicate each other and process information in the network to send to the BS. Clustering is the process to select a set of cluster heads from the set of nodes in the network, and then group the remaining nodes with these heads. Cluster heads aggregates the data coming from different nodes of the related clusters and communication with other cluster heads or BS. Since, clusters are repeatedly broken and formed in a fixed time interval in LEACH and LEACH-C [2, 3, 4, 13], huge energy is wasted for electing cluster heads and non cluster heads repeatedly as well as premature death of cluster heads for fixed round time.

LEACH-F [2, 4] is an efficient centralized clustering technique where cluster is formed only once and then becomes fixed. BS broadcasts the schedule of future cluster heads and cluster heads rotates based on that schedule. LEACH-F solves the repeated cluster setup problem but couldn't solve the fixed round time problem. Therefore, energy and information is wasted due to pre-mature dead of cluster head before completing the round for energy limitation.

The fixed round time problem of LEACH-F can be alleviated by introducing a relationship between round time and current energy of sensor nodes. As a result round time adapts based on the energy loss of the sensor nodes. Therefore LEACH-F becomes out of the two serious problems of repeated cluster formation and fixed round time problem occurs in LEACH and LEACH-C.

The rest of the paper proceeds as follows: Section 2 presents details of LEACH, LEACH-C and LEACH-F. The proposed Modified LEACH-F scheme is described in section 3. Section 4 presents the relay node based scheme. Section 5 presents the performance comparison among existing schemes and proposed scheme along with the simulation parameters and assumptions. Finally some concluding remarks are given in section 6.

2. Related Works

A large body of related work exists on LEACH and its variants. A node elects itself to become cluster head by some probability and broadcasts an advertisement message to all the other nodes in the network in LEACH. A non cluster head node then selects a cluster head to join based on the received signal strength. Since the cluster head needs to receive data from all cluster members in its cluster and then send the data to the BS, cluster head consumes more energy than being a non cluster head node. All nodes in the network become cluster head during some periods of time. After the set-up phase, non cluster heads send data to the corresponding cluster heads and cluster heads sends the aggregated data for a fixed amount of time which depends upon the initial energy. To avoid collusion all nodes have their transmission slots to send data. A node elects itself to become a cluster head by calculating probability in the following way,

$$P_i(r) = \begin{cases} \dfrac{k}{N - k * \left(r \bmod \dfrac{N}{k} \right)}, & C_i(t) = 1 \\ 0, & C_i(t) = 0 \end{cases} \tag{1}$$

where N is the number of nodes, k is the expected number of cluster heads, $C_i(t)=0$ if node i has already been a cluster head in the most recent $\left(r \bmod \frac{N}{k} \right)$ rounds and 1 otherwise.

LEACH is popular but has some limitations in the selection process of cluster heads. One of the weakest points of LEACH is the uneven distribution of cluster heads. Uneven distribution of cluster heads doesn't confirm all the nodes can be attached with clusters and optimum number of nodes within the cluster. So, the average energy consumption becomes higher. LEACH may produce too many cluster heads than expected and incurs huge energy loss due to sending data to BS. Setup phase repeats after certain time and energy loss due to setup phase becomes most significant when average energy of the nodes becomes lower. Lastly, the fixed round time of LEACH doesn't adapt the energy loss behaviour of the sensor nodes which incurs premature dead of cluster head when the cluster head energy is low. As a consequence information of the associated cluster becomes lost and energy of member nodes is wasted due to sending data to the dead cluster head. The fixed round time problem also exists in the works to improve LEACH [6, 7, 8, 9].

A centralized variation of LEACH (LEACH-C) uses a centralized cluster formation algorithm at the BS to form clusters. Steady state phase of LEACH-C is same as in LEACH. During the set-up phase, the BS receives information from each node about their location and energy in each round. After that, the BS runs an optimization algorithm to determine cluster heads and clusters for that round. Approximation algorithms such as taboo search or simulated annealing [5] can be used to find optimal clusters. Simulated annealing is based on thermodynamics principles. To ensure that energy is evenly distributed among the nodes, BS finds the eligible nodes to become cluster heads which have more than the average energy. Simulated annealing algorithm runs on these eligible nodes to find the best k nodes for the next round and the corresponding clusters. In each iteration *k*, if the set of cluster head nodes C has cost f(C) and the new state which is represented by the set of cluster heads C' with cost f(C'), then the current state probability,

$$p_k = \begin{cases} e^{-(f(C')-f(C))/\alpha_k} : & f(C') \geq f(C) \\ 1: & f(C') < f(C) \end{cases} \tag{2}$$

where α_k is the control parameter which is equivalent to temperature parameter of the thermodynamic model and depends upon the number of iterations (k). The cost function is defined by,

$$f(C) = \sum_{i=1}^{N} \min_{c \in C} d^2(i,c) \tag{3}$$

where *d(i,c)* is the distance between node i and node c. Once the optimal clusters are cluster heads are found, BS sends the information about cluster head IDs to all nodes in the network. If the node finds a match with the cluster head id then acts as the cluster head otherwise determines the TDMA slot for data transmission. The repeated cluster formation overhead also exists in LEACH-C. Since the steady state phase is same as LEACH, energy and information are also wasted due to fixed round time.

LEACH-F avoids repeated formation of clusters. When the cluster is formed once, cluster positions change among the nodes within the cluster. Clusters are created at the BS using the same way as in LEACH-C. BS uses simulated annealing algorithm to form efficient clusters and BS then broadcasts messages which includes cluster id for each node and the order to rotate the cluster head position. Nodes' position in the list indicates the order to become cluster heads in the upcoming rounds. The process of rotating reinitializes when all the nodes in the list becomes cluster heads. The steady state phase of LEACH-F is same like LEACH and LEACH-C. So, the fixed round time problem of LEACH and LEACH-C also occurs in LEACH-F. If this problem can be minimized then LEACH-F becomes more efficient for fixed networks.

3. The Proposed Dynamic Round Time-based Fixed LEACH

A part of the contribution from our research is to propose an adaptive round time mathematical model. The motivation of the proposed adaptive round time based LEACH-F is to mitigate the fixed round time problem of LEACH-F. Since the round time adapts with the energy loss behaviour of the sensor nodes the possibility of premature death of cluster head becomes reduced. The detail scheme is presented below:

3.1. Proposed Scheme and Mathematical Model

In LEACH-F, each node sends location information and current energy prior to the cluster formation which is done only once. Then BS broadcasts the cluster head id and schedule to rotate the cluster head position. Then LEACH-F enters into steady state phase. In the proposed scheme, each round operates for a certain amount of time depends on the current energy of cluster head and all the member nodes are synchronized with the cluster head to become free after the end of cluster head service span and elect cluster head based on the schedule of future cluster heads. If there are $N_{frames/round}$ transmitted by the cluster head and non cluster head in each round and $E_{CH/frame}$ and $E_{non-CH/frame}$ are energy consumption per frame for cluster head and non-cluster head respectively. So the energy consumption of cluster head $E_{CH/round}$ and the energy consumption of non-cluster head $E_{non-CH/round}$ per round are,

$$E_{CH/round} = N_{frames/round} \times E_{CH/frame} \quad (4)$$

$$E_{non-CH/round} = N_{frames/round} \times E_{non-CH/frame} \quad (5)$$

The method to determine how often to rotate clusters is to ensure that each node's energy lasts long enough to allow the node to be cluster head once and non-cluster head in the other *(N/k-1)* rounds.

$$E_{CH/round} + (\frac{N}{k} - 1)E_{non-CH/round} = E_{start}$$

$$\Rightarrow N_{frames/round}((E_{CH/frame}) + (\frac{N}{k} - 1)(E_{non-CH/frame})) = E_{start}$$

$$\Rightarrow N_{frames/round} = \frac{E_{start}}{[(E_{CH/frame}) + (\frac{N}{k} - 1)(E_{non-CH/frame})]} \quad (6)$$

If R_b is the bit rate and l bit data message takes $t_{msg} = l/R_b$ seconds then the total frame time is $t_{frame} = \frac{l}{R_b}\frac{N}{k}$ seconds. So, the round time according to LEACH-F is,

$$\therefore t_{round} = N_{frames/round} \times t_{frame}$$

$$= \frac{l}{R_b}\frac{N}{k}\frac{E_{start}}{[(E_{CH/frame}) + (\frac{N}{k} - 1)(E_{non-CH/frame})]} \quad (7)$$

All of the above parameters are fixed for all nodes and as a result t_{round} becomes fixed.

Round time is same in each cluster but may be different in other clusters. In the proposed modified LEACH-F, round time t_{round} is calculated from current energy $E_{current}$ instead of initial energy E_{start}. In each round, the scheduled cluster head sends the current energy to the BS to calculate and broadcasts the round time to all nodes of the corresponding cluster. The round time t_{round} is calculated using the following equation,

$$t_{round} = \frac{l}{R_b}\frac{N}{k}\frac{E_{current}}{[(E_{CH/frame}) + (\frac{N}{k} - 1)(E_{non-CH/frame})]} \quad (8)$$

3.2. Algorithm

Two procedures exist for modified LEACH-F: one of which will run in the BS and other will run in the sensor nodes. The BS procedure receives the location and energy information to find the k optimal clusters using approximation algorithm such as simulated annealing and broadcasts the cluster id and rotation sequence to all of the nodes. Then it waits for the cluster head's energy information to calculate the steady state phase operation time (t_{round}) and broadcast that information to all of the members of the corresponding cluster. Then it waits for receiving data from the cluster heads and if it again gets energy information then the procedure from the calculation of t_{round} repeats.

The procedure at the sensor node starts with the sending of location and energy information to the BS. Then it waits for receiving the broadcast message from BS about the cluster head id and the sequence of future cluster heads. Then if cluster head id matches with the node id then it sends the current energy information to the BS to calculate t_{steady} . Then it receives data based on TDMA from the member nodes for t_{steady} amount of seconds. If the cluster head id doesn't match with the node id then the node sleeps until it's time slot comes to send data to the BS assigned cluster head. The node changes its position in the future cluster head list after t_{steady} amount of seconds and the whole process related to steady state phase repeats. Figure 1 presents two procedures of the proposed Modified LEACH-F algorithm, named as Procedure BS and Procedure Sensor_node.

4. The Proposed Hybrid LEACH

The other part the contribution from our research is to propose a relay node based LEACH to reduce the energy load of the sensor nodes elected as cluster heads. The main motivation of the proposed hybrid LEACH is to maintain the network activities as long as energy exists even in a single node, resulting in a new robust clustering technique, called hybrid LEACH, through combining the concepts of relay node based scheme with EC-LEACH. The detail model and algorithms of the proposed scheme are given below.

```
Procedure Modified_LEACH-F:

Procedure Base_station:

Receive location and energy information from sensor nodes
Calculates the k-optimal clusters and cluster heads using
   simulated annealing algorithm
Broadcasts cluster head id and order to rotate cluster heads
Wait until get current energy information from cluster heads
calculate tround
Broadcast tround with the cluster head id to the
    corresponding cluster member nodes
Wait until receiving data

Procedure Sensor_node:

Send location and current energy to the base station
Wait until Receive broadcast messages from base station
If node i is a cluster head then
  Send current energy information to BS
   while (t < tround)
       do
        Receive data from cluster members (tschedule) seconds
         Compute on data (data fusion) and send result to BS
      done
else
   Sleep for tslot_for_node_i seconds
    while (t < tround)
      do
      Transmit data to cluster head
      Sleep for tschedule seconds
      done
Rotate the position in the order to become cluster head
```

Figure 1. Algorithm of the Proposed Modified LEACH-F

4.1. Hybrid LEACH Scheme

In Hybrid LEACH, it is assumed that the relay nodes are placed randomly within a WSN and the relay nodes, as like relay node based scheme, are design to act as cluster head. The maximum size of cluster is bounded by the limit of achieving the maximum expected network life time. This assumption creates possibilities that there exist some sensor nodes that cannot be accommodated within any cluster. Such sensor nodes, rather than being idle or wasting energy unnecessarily, form their own cluster using the remaining energy [14]. This concept is extended so that if any relay node dies, the active sensor nodes under the corresponding cluster may still operate by forming their own. If no relay node exists in the network, then the modified fixed LEACH is used to form clusters permanently.

It is likely that more than one relay nodes under the same cluster may be elected since the relay nodes are scattered randomly within the WSN network. In that case, each relay node calculates a probability to become elected as a cluster head. Let $P_i(t)$ be the probability that the relay node i with current energy $E_i(t)$ will be a cluster head. If k is the expected number of cluster heads and p is the total number of relay nodes then,

$$P_i(t) = \frac{E_i(t)}{E_{total}(t)} k \qquad \text{where, } E_{total}(t) = \sum_{i=1}^{P} E_i(t), \tag{9}$$

Once a relay node estimates its probability that is above a threshold P_{Th}^{U}, then it will broadcast a message claiming itself as a cluster head at a given power level. Any relay has its own probability to become cluster head and received broadcast messages from a number of other relay nodes with RSSI above the acceptable limit. If the calculated probability of a relay node to become cluster head is less than any of the received probability, then the relay node scheduled itself as redundant cluster head. However, if the calculated probability of the node itself is higher than the received probabilities from messages, then the relay start act as cluster head.

A sensor node elects its cluster head from the relay nodes that have sent messages to it with highest probabilities, if the RSSI is higher than the acceptable limit. If the sensor node does not receive any message and receive message having RSSI under the acceptable limit, then it estimates a probability to become cluster head using the Equation 10 as shown below:

$$P_i(t) = \frac{k}{N - k * \left(r \bmod \frac{N}{k}\right)} * \left[\frac{E_i(t) - E_c}{E_i(t)}\right] \tag{10}$$

As like relay nodes, if the value $P_i(t)$ is above P_{Th}^{U} then the sensor node broadcast a message to its neighbour declaring itself as cluster head. If a node receives messages from both the relay nodes and sensor nodes, then the node will select the relay node with the highest priority if RSSI of the relay node is above the acceptable limit, otherwise select sensor node as cluster head.

```
Procedure Hybrid_LEACH

If node = relay_node then
    Calculate the probability Pi(t) to become cluster head
    If Pi(t) ≥ P_Th^U then
          Send broadcast message to all neighboring nodes
    endif
    Receive messages from relay nodes having RSSI ≥ acceptable
       threshold
    If Pi(t)  > all probabilities claimed in received messages
          Change own status as cluster head
    else
          Find the relay node i with highest probability
          Mark relay node i as cluster head
     endif
else
     if the node receives messages from relay nodes with RSSI ≥
        acceptable  threshold
          select node i having highest  Pi(t)
          Join the cluster with head node i
     else
         Calculate the probability Pi(t) to become cluster head
          if Pi(t) ≥ P_Th^U then
               Send broadcast messages to all neighboring nodes
          endif
          Receive messages from all nodes having RSSI ≥ acceptable
              threshold
           If Pi(t)  > all probabilities claimed in received messages
               Change own status as cluster head
          else
               Find the node i with highest Pi(t)

               Join the cluster with head node i
          endif
     endif
endif

If all relay nodes are dead
   Procedure Modified LEACH-F
Else
   Procedure Hybrid_LEACH
```

Figure 2. Algorithm for Cluster Head Selection in Hybrid LEACH

4.2. Algorithm

The algorithm described in Figure 2 for cluster head selection in hybrid LEACH works as follows: the relay node calculates its probability using the equation 1 and checks whether it is the candidate for the cluster head. If the relay node is the candidate of cluster head then it sends broadcast message to all the remaining neighbouring nodes. The sensors node receives the broadcast messages from the relay nodes and selects the relay nodes with highest probability as cluster head. If the sensor node does not receive any messages with acceptable RSSI, then it calculates a probability to become cluster head by itself and receive messages from all the neighbouring sensor nodes too. In that case the sensor node with the highest probability is elected as the cluster head.

5. Experimental Results and Performance Study

Using a well-known robust discrete-event, open source and component based sensor network simulator and emulator J-sim [12, 13], comparative analysis among LEACH, EC-LEACH, relay node based scheme and proposed hybrid LEACH have been studied extensively. The advantages of the J-sim compared to ns-2 lies on its build-in WSN modules and the scalability in speed and memory usage [14]. The simulations were carried out for both the random and CRNSC topological placements of relay and sensor nodes. The parameters used in the experiments are listed in Table 1.

Table 1. Simulation Parameters

Parameters	Value
Number of the nodes	15 nodes ~ 100 nodes
Initial energy of the sensor node	0.40 unit
Transmission energy	0.016 unit
Amplifier energy	0.096 unit
Receiver energy	0.008 unit
Current Idle mode energy	0.002 unit
Sleep mode energy	0.000008 unit

5.1. Comparative Analysis of LEACH, LEACH-C and LEACH-F

A static fixed network of 15 homogeneous nodes were considered in the experiment to analyze the performance among LEACH, LEACH-C and LEACH-F. Simulation results in Figure 3 have shown that LEACH-C scheme is better than LEACH for better node lifetime due to the even distribution and optimum number of the cluster heads selected by the BS. We also found that LEACH-F outperforms LEACH by decreasing the energy consumption. Reasons behind this are the elimination of repetitive set up phase, optimum number of cluster heads and even distribution of the cluster heads.

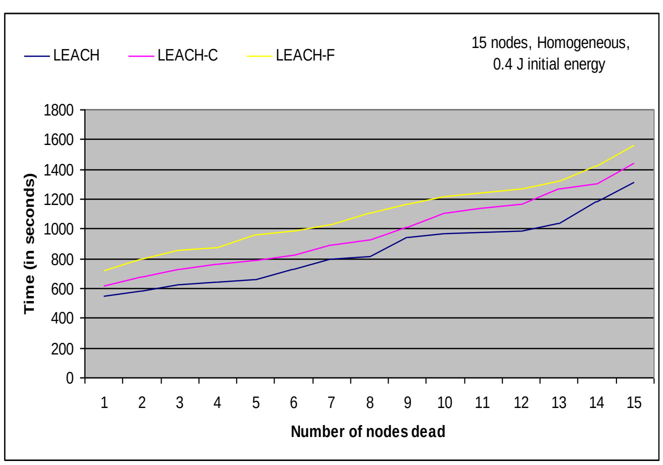

Figure 3. Number of Nodes Dead Vs Time Graph for Different Existing Schemes

5.2. Comparative analysis of Network life time for the modified LEACH-F

Figure 4 depicts the simulation results between existing LEACH-F and proposed modified LEACH-F. The results are found by the experiment that consist 15 homogeneous nodes with 0.4 J initial energy. The results have shown that node lifetime improves in the proposed scheme for varying the round time based on the energy.

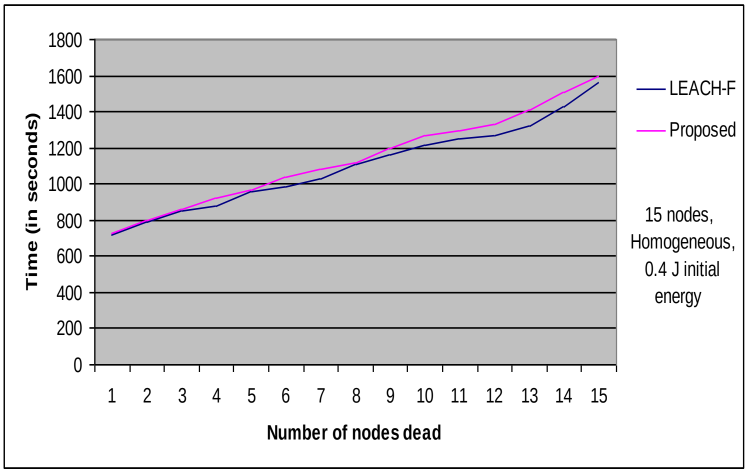

Figure 4. Number of Nodes Dead Vs Time Graph for Existing and Proposed LEACH-F

Due to the energy stage which is critical for death of cluster head before completing the round is same for the nodes starting with different energy level, the percentage increase of network lifetime of the proposed scheme over existing LEACH-F is almost same for different initial energy level of the nodes. Simulation results comprising 15 nodes with 0.4 J and 0.8 J, showing the significant network lifetime improvement for different energy levels are presented in Figure 5(a) and Figure 5(b), respectively. The network lifetime not only varies based on the number of nodes but also depends on the initial energy of nodes, number of clusters. The requirements of the network are usually based on the type of applications.

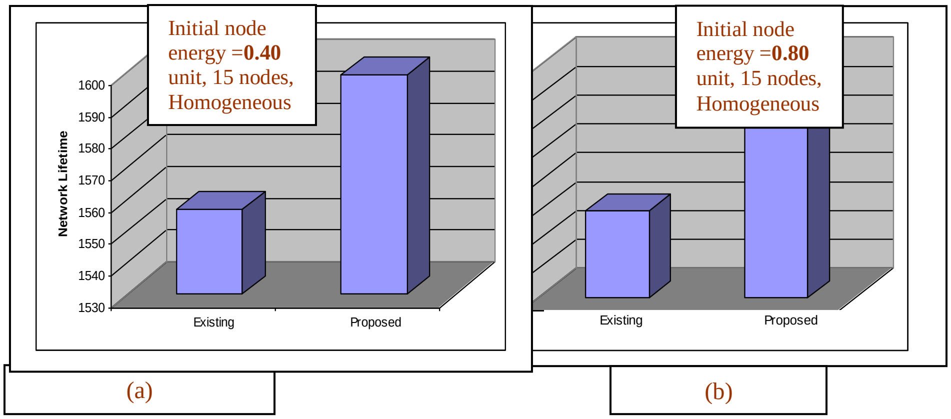

Figure 5. Network Lifetime Improvement of the Proposed Scheme Varying Node Energy

5.3. Comparative Analysis of Packet Loss for LEACH-F

Since premature death is one of major reasons of the packet loss, it can be reduced if the probability of pre-mature death can be reduced. Since the cluster head service time is not fixed and depends on the current energy in our proposed scheme, packet dropping rate is minimized. Figure 6 states that the packet dropping rate is significantly less in the proposed dynamic round time based scheme. It also dictates that the packet loss percentage is increased on behalf of the increasing number of nodes for collisions by placing 15 nodes to 100 nodes in the same area with same initial energy. The acceptable value for packet dropping varies based on the type of applications.

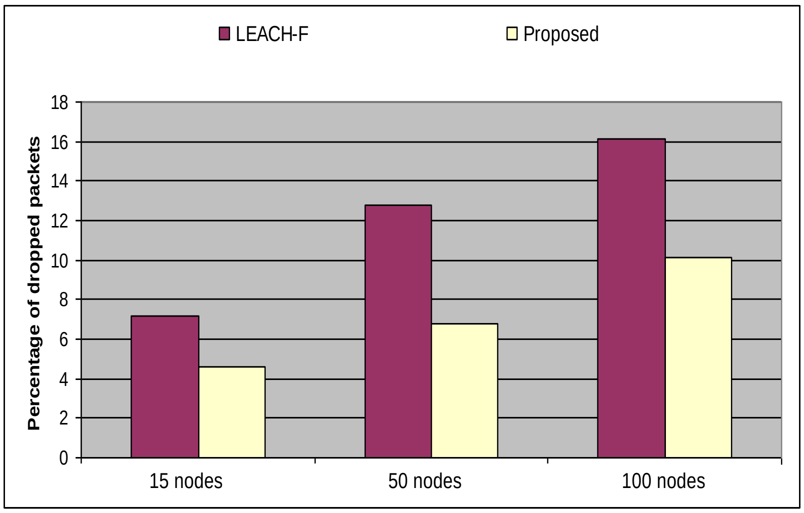

Figure 6. Percentage of Packet Loss Ratio between Existing and Proposed LEACH-F

5.4. Comparative Analysis of Remaining Energy for Hybrid LEACH without LEACH-F

Simulations have conducted for comparative analysis of remaining energy for Hybrid LEACH with the other schemes without using LEACH-F. The simulation results imply that the remaining energy, and hence the network operating time, using EC-LEACH scheme is higher than LEACH at a given time instance due to providing higher probability to the sensors nodes for becoming cluster heads. It is also observed that the difference is larger for the node die first as the EC-LEACH gives higher probability to the high energy node as cluster head. The graph also shows that the relay node based and the proposed schemes provide longer network life time as relay node performs communications activities. On the other hand, due to using energy efficient algorithm and sensor nodes as cluster heads besides relay nodes, the proposed hybrid LEACH provide 12% more network life time compared with relay node based scheme, which is significant.

5.5. Comparative Analysis of Nodes Life Time for Hybrid LEACH without LEACH-F

The number of nodes that become dead over time in simulations is shown in Figure 7. The first graph compares the nodes lifetime between LEACH and EC-LEACH for the network consisting 15 nodes with the initial sensor node energy of 0.4 units. From the experimental results it is found that the average lifetime of nodes in the EC-LEACH scheme is 5% higher than that is LEACH. The graphs in Figure 7(b)-7(d) explain the comparison between the relay nodes based scheme and the proposed scheme under the scenarios of random relay node placement with no failure, random relay node placement with failure and 1-connected relay node placement with failure.

In all of these experiments, the initial energy for sensor node used is 0.38. In Figure 7(b), the initial energy for relay node used was 0.7 unit while the value chosen in Figure 7(c) and Figure 7(d) to 0.42 for making the relay nodes to fail. So, the network fails when all relay node fails. Hence, curves of the relay node based scheme finishes earlier than hybrid LEACH in Figure 7(c) and Figure 7(d). The graphs show that under the random placement the proposed scheme provides about 6% improvement in network lifetime when no relay nodes fail, which is increased to about 15% in case of relay node failure. The proposed scheme provides about 30% improvement over the relay node based scheme under 1-connected placement of relay nodes. It is also observed that in all the graphs, the time required to die for a specific number of nodes in our proposed scheme is always higher than the relay node based scheme.

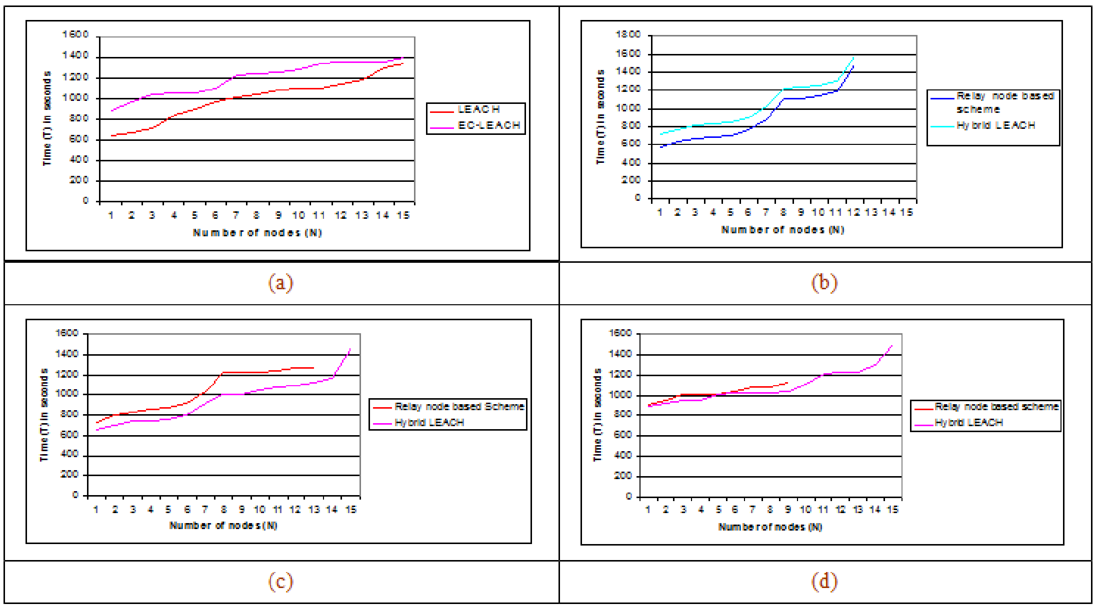

Figure 7. Nodes lifetime analysis (15 nodes): (a) LEACH and EC-LEACH with sensor node initial energy 0.4 unit; (b) relay node based scheme and hybrid LEACH with random placement of nodes with sensor node initial energy 0.38 unit and relay node energy 0.42 unit when relay nodes are not failed; (c) relay node based scheme and hybrid LEACH with random placement of nodes with sensor node initial energy 0.38 unit and relay node energy 0.42 unit when relay nodes failed; and (d) relay node based scheme and hybrid LEACH with 1 connected placement of nodes with sensor node initial energy 0.38 unit and relay node energy 0.42 unit when relay nodes failed.

5.6. Comparative Analysis for Percentage of Packet Loss for Hybrid LEACH without LEACH-F

Compared to the relay node based scheme, packet loss is significantly less in proposed Hybrid LEACH as shown in Figure 8, where simulations were carried out for

15, 50 and 75 nodes respectively. Since the proposed scheme supports communications even when some nodes are dead, the packet loss in the proposed scheme is significantly less.

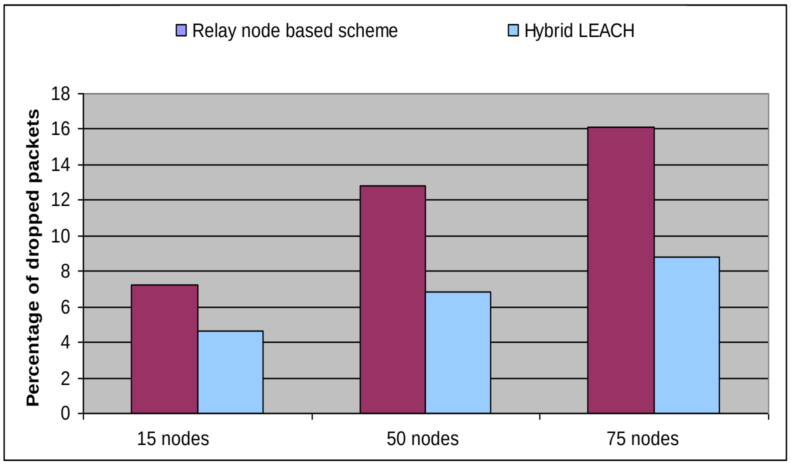

Figure 8. Percentage of Packet Loss Ratio between Existing and Proposed Scheme

5. Concluding Remarks

This paper presents a comparative analysis of LEACH-F over LEACH and LEACH-C for fixed static network and explored a significant problem of fixed round time. We have formulated a solution to alleviate the problem and this gives the improvement over energy and thus enhances the network lifetime. Significant number of packet dropping due to the pre-mature dead of cluster heads for the fixed round time is also minimized in the proposed scheme. The paper confirms its improvement by experimenting in a well known sensor network simulator by varying the different parameters.

This paper also proposes a new Hybrid LEACH scheme that reduces the packet loss and increases the network lifetime significantly. WSNs, having increasing demands in the emerging world, suffer from meeting its expected lifetime due to using tiny low power batteries. The 5%-30% improvement made by the proposed Hybrid LEACH without using LEACH-F compared with the relay node based scheme is therefore considered as significant improvement for meeting the targets of WSNs. If we use LEACH-F, the improvement will be no worse than that of Hybrid LEACH without LEACH-F. The comparative analysis and simulated results prove the superiority and acceptability of the proposed scheme in the applications of WSNs.

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