Indonesian Journal of Electrical Engineering and Computer Science
Vol. 7, No. 2, August 2017, pp. 415 ~ 425
DOI: 10.11591/ijeecs.v7.i2.pp415-425

Energy Efficient WSN by Optimizing the Packet Failure in Network

Madhu Patil*[1], Chirag Sharma[2]
[1]Department of Electronics and Communication Engineering, NMIT, Bangalore, India
[2]Department of Electronics and Communication Engineering, NREA, UOM, Mysore
*Corresponding author, e-mail: pmadhu.nmit@gmail.com

Abstract

Wireless sensor network (WSN) has attained enormous growth in recent times due to availability of tiny and low cost sensor devices. The sensor network is been adopted by various organization for various application services such environment monitoring, surveillance etc. The WSN are powered by batteries and are deployed in non-rechargeable remote location. Preserving batteries of these devices is most desired. Many methodologies have been proposed in recent time to improve the lifespan of sensor network among them clustering technique is the most sorted out technique. The drawback of existing technique the cluster head energy degrades very fast due to long transmission which requires amplification as a result energy is lost to the node that is surrounding the cluster head. They did not consider the packet failure likelihood among inter and intra as a results there exist scheduling bottleneck and degrades the energy of sensor devices. To overcome this work present a packet failure estimation model and hop selection optimization model for inter cluster transmission. Experiments are conducted for lifetime efficiency for varied sensor devices for proposed and existing $\boldsymbol{LEACH}$. The result shows that the proposed model performs better than existing $\boldsymbol{LEACH}$ in term of network lifetime and energy efficiency.

Keywords: *WSN, Clustering, MAC, Packet failure*

1. Introduction

The WSN is composed of large density of small, low cost sensor device that are connected to a centralized devices namely sink/base station [1, 2]. The sensor devices are equipped and powered by battery which is remotely deployed. The sensor device can perform various sensory activities such as sensing, processing data and transmission [3, [4]. The WSN is adopted in various application services such as in military statistical operation, disaster management and environmental monitoring and so on [5, 6]. Due to low cost availability and ease of deployment of these devices has led to the growth of WSN in various industries and organization. The sensor device is battery powered and the deployed nature of these device pose a difficulty in recharging since these devices are deployed in an unattended environment. Therefore preserving the batter/energy is a key factor in prolonging the lifetime of sensor networks. There has been various model has been presented [7-9] to improve and prolong the lifetime of sensor network. But still the sensor network poses the following issues and challenges such as the data rate for communication, storage capacity, computation complexity and range of communication [10-12]. The transmission capacity of sensor devices is limited due to the communication range of these devices. Due to limited range of communication the data is transmitted multiple times through intermediate/hop nodes using certain routing path selected which results in flooding of packets which can cause collision of packets, data redundancy, and energy dissipation.

To address these short coming hierarchical based clustering technique is been adopted were the WSN is partitioned into several cluster and each portioned cluster contain a cluster head and set of member devices associated to one cluster head at a time. The cluster head collects data from its member and transmit it to base station/sink or nearby cluster head. This reduces data redundancy and improves the energy efficiency of sensor network. There has been various protocol has been developed to improve energy efficiency of sensor network among them the low energy adaptive clustering hierarchy ($LEACH$) strategy is a revolutionary protocol [13, 14]. The $LEACH$ strategy forms many clusters of sensor devices and assign a

Received May 9, 2017; Revised July 11, 2017; Accepted July 26, 2017

cluster head (CH) node for each cluster, with the aim of reducing the energy depletion of WSN. A centralized approach of $LEACH$ namely $LEACH - C$, where the base station takes the cluster formation decision using all composed information that provided better outcomes over the distributed approach in terms of the bandwidth utilization and lifetime of network [13]. Recently many approach have been developed by enhancing the $LEACH - C$. In [15], each cluster head sensor devices avoid the energy exhaustion in its roles by assigning a vice-cluster head sensor device in its cluster. $LEACH - CE$ [16] Considers the residual energy info of the candidate cluster head sensor devices more actively. In $LEACH - CKM$ [17] adopted a refined clustering technique based on K-mean clustering technique which is considered to be effective clustering methodologies. The problem with K-mean clustering is to find initial centroid vector which resulting in inappropriate size of clusters division resulting in loss of connectivity.

However, the benefit of these clustering protocols induces an overhead for formation of cluster and selection of cluster head. These issues can be overcome by utilizing a proper medium access control (MAC) design which can improve the reliability sleep scheduling of sensor devices. The MAC can be broadly classified into two types contention based and contention free based protocol. The MAC layer that adopts contention based protocol such as $CSMA/CA$ is not efficient due to long contention of nodes for channel access [18]. The $CSMA/CA$ protocol induces high collision due to concurrent channel access and the packet drop increase when the node density and network is increased as a result the contention based protocol is not suitable for large networks. To overcome this contention free based protocol such as $TDMA$ is been adopted by various clustering approach [19, 20], where each cluster member is assigned a time slot for transmission and based on this time slot scheduling is done. The adoption of $TDMA$ improves the sleep time of sensor nodes thus the reliability and energy efficiency of network is improved. The existing clustering methodology [19, 20] that adopted $TDMA$ did not consider hop selection [21, 22] and likelihood of packet loss in network channel as a result there induces a scheduling overhead among intra and inter cluster communication which degrades the energy consumption and reliability of network. This problem can be overcome by developing a packet failure estimation bounding model. To overcome these shortcoming this work propose an energy optimization technique for hop node/clusterhead selection based on connectivity and packet failure likelihood of sensor devices broadcasted by using a $TDMA$ based channel.

There have been several methodologies that have been proposed in recent time in order to improve the energy efficiency of wireless sensor network which are surveyed below. In [23] they proposed a hybrid hierarchical clustering approach ($HHCA$) by adopting a centralized gridding for the upper-level head selection and distributed clustering for the lower-level head selection. Their approach balances the communication load on sensor devices and increases the network lifetime and scalability. The experimental outcomes show that their approach achieves better efficiency than other distributed algorithms and is suitable for large-scale WSN.

In [24] presented a dynamic cluster head selection for WSN. They addressed the energy degradation issues due to overlapping region of cluster head. The cluster head is selected by adopting vernoi diagram. The experiment outcomes show 50% lifetime improvement over LEACH and 30% improvement is achieved for $DEEC$. They also improved node survival time in network over Energy-balanced deterministic clustering algorithm ($EBDC$) [25] and adaptive energy optimized clustering algorithm ($AEOC$) [26]. They did not consider re-division of the sensing region after the loss of all the redundant sensor devices under the same coverage area.

In [27] presented a Three-layer LEACH namely TL-LEACH, they addressed the issue pertaining to long transmission energy consumption of cluster head devices. The TL-LEACH is an extension of two level LEACH clustering protocol. Here the networks are divided into three layers as layer 0, layer 1 and layer 2. The data are transmitted from layer 0 cluster head to layer 1 cluster and finally to layer 2 cluster head and reach to destination/ base station. The layer 1 cluster head is selected as LEACH in setup phase. Then these layer 2 Cluster head is chosen from layer 1 cluster head based on energy condition and layer 2 cluster head communicate with base station. The experiment outcomes shows a significant improvement in lifetime efficiency but the drawback of these protocol is the node closer to the base station drains fast as a result the network coverage is not efficient.

In [28] presented a fuzzy based clustering namely Fuzzy c-mean (FCM) methodology for wireless sensor network. The FCM adopted a centralized based cluster formation approach. The cluster formation and cluster head selection is done based on sensor device location and its residual energy. It allocates degree of belonging to each sensor devices and adopt FCM algorithm in order to minimize the special distance among sensor devices to form an efficient cluster.The cluster formation is performed by minimizing an objective function, which consists of the degree of belongingness and the distance among the sensor devices and center point of the cluster. The principle used here is based on fuzzy logic in order to obtain the degree of belongingness after it has been calculated. Once the completion of first stage of clustering and data transmission, the present cluster head select a new CH for next phase which depends upon the energy received from every sensor device. The FCM strategy is an efficient way to distribute the sensor devices and the load of the network among the clusters. The experimental outcomes shows the FCM approach achieves better energy efficiency and improved the overall lifetime of network since the mean distance of every sensor device to cluster head is minimized which aid in optimizing the transmission power of non-cluster head sensor devices.

In [29] here the surveyed various hierarchical based protocols that have been developed in recent times in order to improve lifetime and energy efficiency of wireless sensor network. Here they surveyed atypical hierarchical based clustering protocol it pros and cons under various topological circumstances. They classified atypical hierarchical routing technique into following categories as follows chain based routing such as $PEGASIS$ (power-efficient gathering in sensor information systems) [30], $EBCRP$ (energy-balanced chain-cluster routing protocol) [31] and so on, tree based routing such as $EADAT$ (energy-aware data aggregation tree) [32], Power-efficient data gathering and aggregation protocol ($PEDAP$) [33] and so on, grid based routing such as $HGMR$ (hierarchical geographic multicast routing) [34], Grid-based Multipath with Congestion Avoidance Routing (GMCAR) [35] and so on and lastly area based routing such as $LBDD$ (Line-based Data Dissemination) [36]. Here they compared various protocol and its characteristics for various network performance parameter and lastly an open issues of WSN routing technique are discussed and highlighted.

It is seen from literature that the existing approach to improve the energy efficiency of WSN is not efficient and suffers from high overhead for cluster/hop selection and increase data transmission latency and data redundancy due to its cluster formation hierarchy. To overcome these issue here in this work a simplified energy consumption model considering packet failure likelihood is presented and also presented an energy minimization optimization technique for sleep active scheduling for inter cluster transmission. The proposed modified LEACH based on cross layer model is presented in next section.

The research contribution of this work is as follows, unlike existing clustering protocol this work consider large randomly distributed sensor network. Presented a simplified energy consumption model considering packet failure likelihood. Presented an energy minimization optimization technique for sleep active scheduling for inter cluster transmission.

The paper organization is as follows: The literature survey is presented in section two. The proposed models are presented in Section three. The simulation results and the experimental study are presented in the section four. The concluding remark is discussed in the last section.

2. Research Method

Here the author proposes an energy efficient design for hop node/clusterhead selection based on connectivity and packet failure likelihood. The propose cluster formation is similar to $LEACH$ protocol. Selection of cluster head in $LEACH$ [13, 14] is as follows. In every round, for a particular sensor device d a random uniform value between 0 and 1 is obtained and the obtained value is compared with the threshold $H(d)$ of corresponded to this sensor devices. If the obtained value is less than $H(d)$, then this sensor devices elect himself as cluster-head in that particular round and the value of the threshold is updated in each and every round.

$$H(d) = \begin{cases} \frac{r}{1 - r \times [\varphi mod(1/r)]}, & if\ d\epsilon\bar{S}; \\ 0, & Otherwise. \end{cases} \quad (1)$$

Were r represent mean ratio of cluster head in every round to the total sensor devices, $\varphi, 0 \leq \varphi < \infty$, is the current round number, and $\bar{S}$ is the collection of sensor devices that has not elected as cluster head of period $1/r$ rounds, that is, rounds $0 \sim 1/r - 1$, rounds

$1/r \sim 2/r - 1, \ldots$ and so on. Based on the Equation (1) every sensor devices behaves as CH for a particular period in a round. In the next round this sensor devices is removed for cluster head selection candidate.

In the proposed model the nodes are randomly deployed over the network with density δ and each nodes has same radius S which has the overlapping section and the $LEACH$ threshold selection in Equation (1) and the parameter r is changed to be parameter proportional to a sensor devices normalized overlapping region, i.e. a particular sensor device d, we obtain the following value as follows:

$$r(d) = \propto \times \, \omega(d), \tag{2}$$

Were $\propto$ depict the mean amount of cluster head. Now the proposed threshold $H(d)$ considering sensor device d can be rewritten as follows:

$$H(d) = \begin{cases} \dfrac{r(d)}{1 - r(d) \times [\varphi mod(1/r(d))]}, & if \ d \in \bar{S}; \\ 0, & Otherwise. \end{cases} \tag{3}$$

Where $\bar{S}$ is a collection sensor device that has not yet been as a cluster head in the present round of period, d is the sensor node that behave as cluster head in round $1/r(d)$. Based on this every sensor devices are selected to be cluster head with varied likelihoods. The likelihood of cluster head neighbor can be obtained by following equation

$$\mathcal{F}_d(d) = (\delta \pi S^2)^d e^{-\gamma \pi S^2} / \delta!, \quad \delta = 0.1,2,3, \ldots \ldots \infty. \tag{4}$$

The transmission in cluster network is classified into following as inter clustering and intra clustering transmission which is shown in Figure 1.

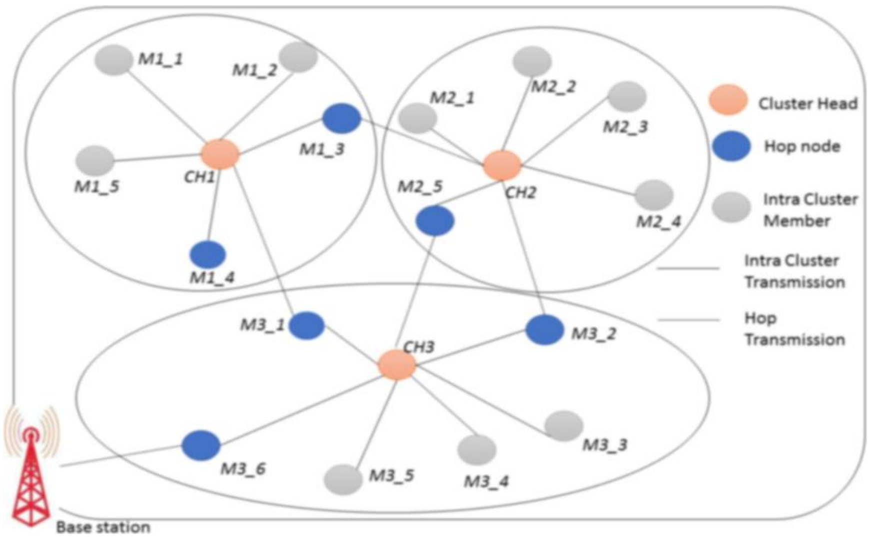

Figure 1. Architecture of Proposed Model

2.1. Packet Failure Evaluation in Intra Cluster Communication

To evaluate the likelihood of packet failure in intra cluster communication, let consider the all the member devices of a cluster will not decode the data correctly. We consider the Rayleigh fading channel based on which the received Signal to Noise Ratio (SNR) γ,which is at distance s from cluster head is obtained as follows:

$$\gamma_{,} = \mathcal{G}D_{,}|c|^2 / s^2 \mathcal{N}_0, \tag{5}$$

Where $\mathcal{G} = \frac{(\mathcal{G}_{trns}\mathcal{G}_{rcvr}\lambda^2)}{(L_m F_n (4\pi)^2)}$, where λ represent the carrier wavelength, F_n represent noise param of receiver, $\mathcal{G}_{trns}$ and $\mathcal{G}_{rcvr}$ represent the antenna gain of transmitter and receiver respectively and L_m is the additive background noise of hardware devices, $\mathcal{N}_0$ is the receiver end Gaussian noise power, $|c|$ represent Rayleigh distribution, $D_,$ is the intra cluster communication energy dissipation per bit and c is the wireless channel gain among sensor node of a cluster and its cluster head. Therefore for a particular $D_,$ and s, the mean bit error rate (BER) is obtained as follows:

$$L_,^b = D\big(\mathbb{Q}(2\gamma_,)\big) \cong {s^2\mathcal{N}_0}\big/{4\mathcal{G}D_,} \tag{6}$$

Where $D(\cdot)$ average param related to distribution of $|c|$, $\mathbb{Q}(y)$ is Q-function and is represented as $\mathbb{Q}(y) = \left(\frac{1}{\sqrt{2\pi}}\right)\int_y^\infty e^{-x^2/2}\,dx$. we consider the packet length to be B bit based on first order energy model. Therefore the likelihood of packet failure $L_,^p$ is defined as follows,

$$L_,^p = 1 - (1 - L_,^b)^B. \tag{7}$$

The distance s among cluster head and its adjacent neighbor within each cluster, the likelihood density function is obtained as follows

$$\mathcal{F}_s(s) = \frac{2s}{S_,^2}, S_, \geq s > 0 \tag{8}$$

The $L_,^b$ is trivial, therefore we obtain $1 - (1 - L_,^b)^B \cong BL_,^b$. Therefore using eq. (7) and (8) we obtain the mean likelihood of packet failure in a cluster is as follows

$$\vec{L}_,^p \cong \int_0^{S_1} B\left({s^2\mathcal{N}_0}\big/{4\mathcal{G}D_,}\right){2s}\big/{S_,^2}\,ds = {B\mathcal{N}_0S_,^2}\big/{8\mathcal{G}D_,}. \tag{9}$$

The hop nodes channel is consider being independent. Therefore likelihood of a devices that successfully decode packet is as follows

$$L_a(a) = \sum_{d=a}^{\infty}\binom{d}{a}{(\delta\pi S_,^2)^d e^{-\delta\pi S_,^2}}\big/{d!}\left(\vec{L}_,^p\right)^{d-a}\left(1 - \vec{L}_,^p\right)^a, \tag{10}$$

Where $a = 0,1,2,3\cdots$. Therefore the mean number of devices in the cluster that decode packet correctly is given as follows

$$\vec{a} = \sum_{a=0}^{\infty} a * L_a(a) = \delta\pi S_,^2\left(1 - \vec{L}_,^p\right). \tag{11}$$

2.2. Sub Section 2 Packet Failure Evaluation in Inter Cluster Communication

Similarly to intra cluster, obtain the likelihood of packet failure in inter clustering communication is obtained based on Equation (7). Which is follows:

$$L_{,,}^p = 1 - (1 - L_{,,}^b)^B \cong BL_{,,}^b \cdot \tag{12}$$

In inter cluster communications, cluster head transmit the message to its members with mean energy depletion $D_,/bit$, based on Equation (4) number of member device $\delta\pi S^2$ with in a cluster that is trying to obtain packet is obtained. Therefore the mean energy consumption of intra cluster transmission I_D' per packet is formulated as follows:

$$I'_D = B\big((1+\beta)D_{,} + D_{trns} + \delta\pi S^2 D_{rcvr}\big) \tag{13}$$

Where B represent the packet length bit size, D_{trns} represent the energy consumption per bit of transmitter, D_{rcvr} represent the energy consumption per bit of receiver circuit and β represent the power amplifier transmission efficiency. For simplicity here we consider that all nodes in the network has same D_{trns} andD_{rcvr}. To select the hop devices in inter cluster communication the mean of $\vec{a}+1$ devices including cluster head energy dissipation I''_D per packet is formulated as follows:

$$I''_D = B\big((1+\beta)(\vec{a}+1)D_2 + (\vec{a}+1)D_{trns} + D_{rcvr}\big) \tag{14}$$

2.3. Energy Consumption in Network

The overall energy consumption of proposed clusterhead/hop selection model is obtained as follows using Equation 13 and 14.

$$I_D = I'_D + I''_D \tag{15}$$

$$\begin{aligned} I_D = D\left((1+\beta)\big(D_{,} + \delta\pi S_{,}^2(1-\vec{L}_{,}^{p})D_{,,}\big)\right) + \\ B\left(\big(\delta\pi S_{,}^2(1-\vec{L}_{,}^{p}) + 2\big)D_{trns} + (\delta\pi S_{,}^2 + 1)D_{rcvr}\right). \end{aligned} \tag{16}$$

The Equation (16) shows the total energy dissipation of a wireless sensor network. Therefore the total energy dissipation depend on following parameters $B, \delta, S_{,}$, $D_{,}$, $D_{,,}$ and $\vec{L}_{,}^{p}$ depends on $D_{,}$. The Equation (16) is optimized to improve the lifetime of sensor network.

2.3. Network Energy Optimization

Let consider a large cluster based sensor network. In such network there exist large density of cluster member, due to this the number of hop nodes involved in inter cluster transmission increases. Therefore the energy consumption of sensor increases due to number of sensor devices that actively participated in decoding data from cluster head devices. Considering sensor network characteristic it is not preferred to keep all sensor node active in satisfying packet failure rate. At the same time if we reduce the number of sensor node taking part in transmission it will aid in reducing energy consumption but it induces increase in energy consumption in hop devices due to amplification of power for longer transmission. Therefore a bounding is set to determine number of active device required to satisfy packet failure rate and minimize the energy consumption. The optimization of active nodes for energy minimization is presented below. Let the active sensor devices are κ. The I_D is minimized by optimizing $D_{,,}$ and κ.

$$\begin{aligned} O^{\downarrow}{}_{D_{,,}\kappa} D_T = B\left((1+\varphi)D_{,} + \big(\kappa\delta\pi S_{,}^2(1-\vec{L}_{,}^{p}) + 1\big)D_{,,}\right) + \\ B\left(\big(\kappa\delta\pi S_{,}^2(1-\vec{L}_{,}^{p}) + 2\big)D_{trns} + (\kappa\delta\pi S_{,}^2 + 1)D_{rcvr}\right), \end{aligned} \tag{17}$$

Such that $D_{\uparrow} \geq D_{,,} > 0, 1 \geq \kappa > 0, \vec{L} \geq L_T^p$,

where$D_{\uparrow}$ is the maximum energy consumption permitted to transmit at each node and $\vec{L}$ is the objective packet failure rate. Therefore the total packet failure likelihood L_T^p is obtained as follows,

$$L_T^p = e\left(\kappa\delta S_{,}^2(\vec{L}_{,}^{p} - 1)\right) * \sum_{a=0}^{\infty}\left(\left(\kappa\delta S_{,}^2 - \kappa\delta S_{,}^2\vec{L}_{,}^{p}\right)^a \Big/ a! * L_{,,}^{p}(D_{,,}, a)\right). \tag{18}$$

To find the optimized value of κ and $D_{,,}$ with respect to minD_T, we continuously find κ under condition $D_{,,}$. Therefore to compute optimization in Equation (17), $L_{,,}^{p}$ is upper bounded considering peak Signal-to-Noise-Ratio is as follows:

$$\left(\mathcal{N}_0 \jmath^2 \big/ \mathcal{G} D_{,,}\right)^a \geq \binom{2a-1}{m} \left(\mathcal{N}_0 \jmath^2 \big/ 4\mathcal{G} D_{,,}\right)^a \geq L_{,,}^p. \tag{19}$$

The packet failure rate L_T^p is upper bounded by utilizing sequence set of exponential function as follows:

$$\overrightarrow{L_T^p} = \mathcal{N}_0 \jmath^2 \big/ 4\mathcal{G} D_{,,} \, e^{\left(\kappa\delta\pi S_{,}^2 (L_{,}^p - 1) + \frac{(\kappa\delta\pi S_{,}^2 - \kappa\delta\pi S_{,}^2 L_{,}^p) \mathcal{N}_0 \jmath^2}{\mathcal{G} D_{,,}}\right)} \tag{20}$$

The κ is determined for a particular $D_{,,}$ by using Eq. (20) is as follows:

$$\kappa = \frac{ln\left(4\overrightarrow{L_T^p}\mathcal{G}D_{,,} \big/ B\,\mathcal{N}_0 \jmath^2\right)}{\left(\mathcal{N}_0 \jmath^2 \big/ \mathcal{G} D_{,,} - 1\right) \kappa\delta\pi S_{,}^2 \left(\overline{L}_{,}^p - 1\right)} \tag{21}$$

The value of κ is commonly greater than zero and is lesser than or equal to one i.e. $0 < \kappa \leq 1$. Considering Equation (17) and (21), $D_{,,}$ must fulfill

$$\begin{cases} 0 < D_{,,} \leq D_{\uparrow} \\ \mathcal{N}_0 \jmath^2 \big/ 4\mathcal{G} < D_{,,} < D_{\uparrow} 4\overrightarrow{L_T^p}\mathcal{G} \\ lnD_{,,} - \delta\pi S_{,}^2 \left(1 - \overline{L}_{,}^p\right) \left(\mathcal{N}_0 \jmath^2 \big/ 4\mathcal{G} D_{,,} + 1\right) ln\left(4\overrightarrow{L_T^p}\mathcal{G} \big/ \mathcal{N}_0 \jmath^2 B\right) \leq 0 \end{cases} \tag{22}$$

The simulation and experimental study of proposed packet failure optimization based energy model is evaluated and compared with existing methodology in next section.

3. Results and Analysis

The system environment used is windows 10 enterprises operating system, 64-bit Quad core processor, 2GB NVDIA CUDA Dedicated Graphic card, with 16GB of RAM. We have used sensoria simulator which is a dot net based simulator that uses C# as a programming language. We have conducted simulation study on following parameter for network lifetime and energy efficiency and compared our proposed model with existing $LEACH$ based protocol and we have varied node size by 1000, 1500 and 2000 and conducted simulation study and the simulation parameter is shown in Table 1.

The network lifetime is obtained for 40% of sensor node death. In Figure 2, 3 and 4, we can see that the proposed model performs better than the existing $LEACH$ algorithm in term of network lifetime efficiency. The experimental result shows that the energy efficiency of the proposed model over the existing $LEACH$.The proposed model improves the lifetime of sensor network by over 96.44%, 97.37% and 98.64% when sensor node equal to 1000, 1500 and 2000 respectively over $LEACH$. From the experimental result we can see that when we increase the sensor node the performance of proposed model get better but the performance of $LEACH$ protocol decreases with increasing number of nodes which is shown in figure 4. The result shows that $LEACH$ protocol is not suitable for large network and the proposed model is adaptive in nature with increase in node density.

Simulation parameter considered

Network Parameter	Value
Network Size	40m * 40m
Number of sensor nodes	1000, 1500, 2000
Number of Base station	1
Initial energy of sensor nodes	0.2 J
Radio energy dissipation	50 nj/bit
Data packets length	2000 bits
Transmission speed	100 bit/s
Bandwidth	5000 bit/s
Idle energy consumption (Eelec)	50 nj/bit
Data packet processing delay	0.1 ms
Amplification energy (Emp)	100 pJ/bit/m2

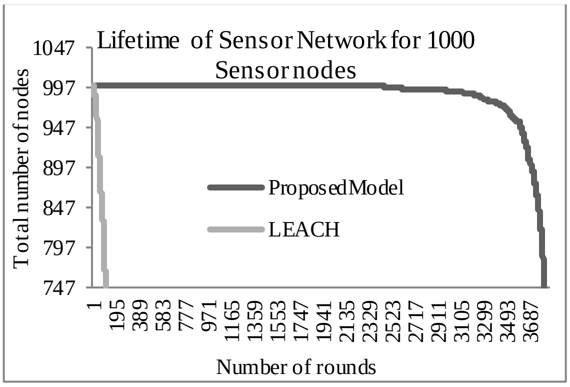

Figure 2. Network lifetime analysis for 1000 nodes

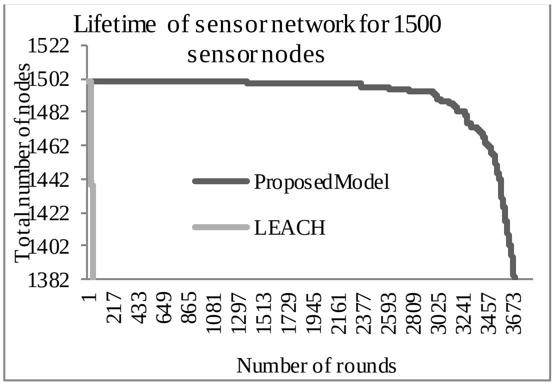

Figure 3. lifetime analysis for1500 nodes

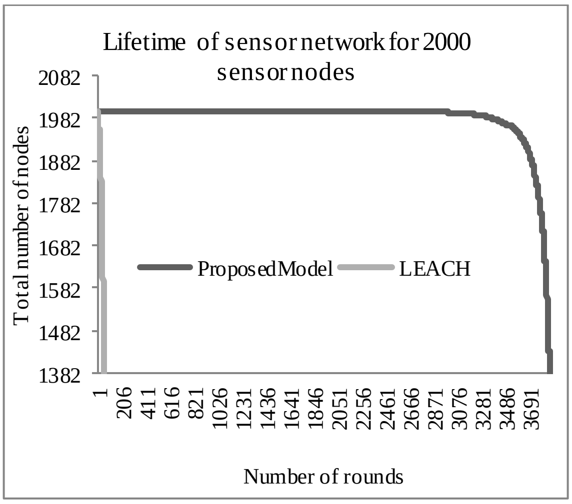

Figure 4. Network lifetime analysis for 2000 nodes

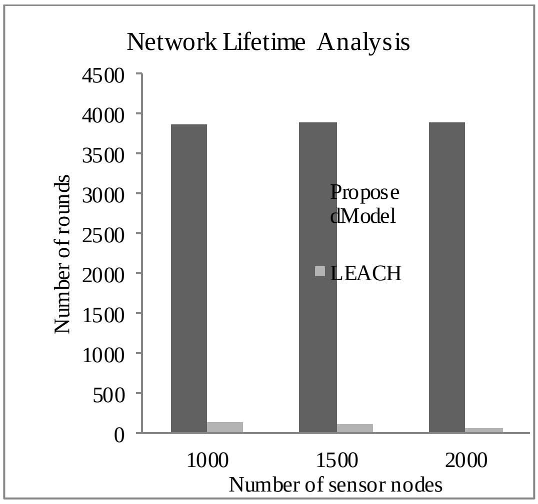

Figure 5. Network lifetime analysis

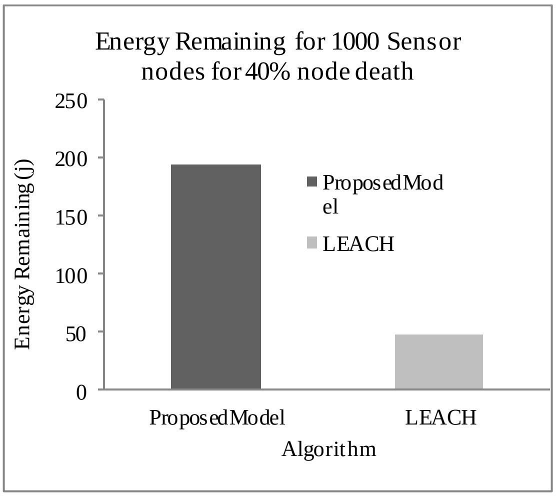

Figure 6. Energy remaining for 1000 sensor nodes for 40% sensor node death

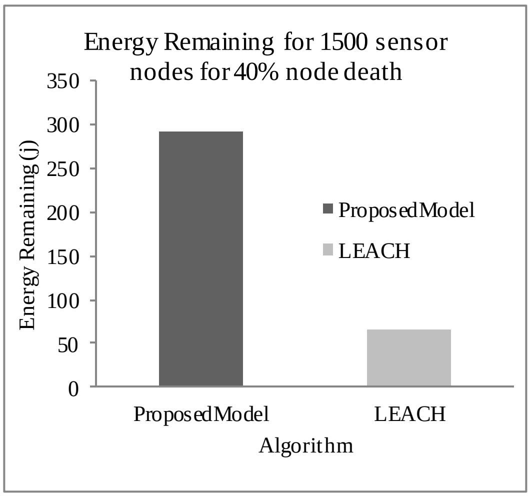

Figure 7. Energy remaining for 1500 sensor nodes for 40% sensor node death

The energy remaining is obtained for 40% of sensor node death. In Figure 6 and 7, we can see that the proposed model performs better than the existing $LEACH$ algorithm in term of energy remaining efficiency. The experimental result shows that the energy efficiency of the proposed model over the existing $LEACH$.The proposed model improves the energy efficiency of sensor network by over 76.16%, 77.75% and 79.12% when sensor node equal to 1000, 1500 and 2000 respectively over $LEACH$. From the experimental result we can see that when we increase the sensor node the performance of proposed model get better but the performance of $LEACH$ protocol decreases with increasing number of nodes.

4. Conclusion

Clustering methodology play a significant role in improving the lifetime of sensor network. There has been various hierarchical clustering that has been developed in recent time by enhancing the $LEACH$ protocol. The drawback of these protocols is energy of cluster head degrades very fast due to long distance transmission and packet failure likelihood is not considered for inter and intra cluster transmission. To address the energy efficiency issue of existing approach this work proposed packet failure likelihood estimation model and hop selection optimization model for inter cluster transmission. Our proposed model improves the lifetime of network by over 96.44%, 97.37% and 98.64% over $LEACH$ when sensor node equal to 1000, 1500 and 2000 respectively and the energy efficiency is improved by 76.16%, 77.75% and 79.12% over $LEACH$ when sensor node equal to 1000, 1500 and 2000 respectively. Experimental results show that the proposed model performs better than $LEACH$ in term lifetime efficiency and energy efficiency. The outcome of proposed model achieved show that it achieves significance performance improvement when compared to E^2E^2 (energy-Efficiency and Reliable Routing) proposed by H. K. Deva Sarma et al and Fuzzy c-mean clustering model proposed by D. C. Hoang et al. In future work we would conduct simulation study to check the performance of other network parameter such node decay and active rate etc... The performance achieved of our model interm of energy efficiency will aid in providing security to these sensor devices. Our future work will embed security to sensor network and evaluate the performance and highlight its significance and energy overhead induced in providing security.

References

[1] G Anastasi, M Conti, M Di Francesco and A Passarella. "Energy conservation in wireless sensor networks: A survey". *Ad Hoc Netw*. 2009; 7(3): 537–568.

[2] Zhang Yu-Quan*, Wei Lei. A New Routing Protocol for Efficient and Secure Wireless Sensor Networks.*TELKOMNIKA*. 2013; 11(11): 6794~6801. ISSN: 2087-278X

[3] A Nayak and I Stojmenovic. *Wireless Sensor and Actuator Networks: Algorithms and Protocols for Scalable Coordination and Data Communication*. Hoboken, NJ, USA: Wiley. 2010.

[4] W Dargie. "Dynamic power management in wireless sensor networks: State-of-the-art". *IEEE Sensors J*. 2012; 12(5): 1518–1528.

[5] M Saleem, GA Di Caro and M Farooq. "Swarm intelligence based routing protocol for wireless sensor networks: Survey and future directions". *Inf. Sci*. 2011; 181(20): 4597–4624.

[6] Babak Namazi*, Karim Faez*. Energy-Efficient Multi-SPEED Routing Protocol for Wireless Sensor Networks. *International Journal of Electrical and Computer Engineering (IJECE)*. 2013; 3(2): 246~253. ISSN: 2088-8708

[7] C Schurgers and MB Srivastava. "*Energy efficient routing in wireless sensor networks*". In IEEE MILCOM. 2001; 1.

[8] J Ma, W Lou, Y Wu, M Li and G Chen. *"Energy efficient TDMA sleep scheduling in wireless sensor networks*". In IEEE INFOCOM. 2009.

[9] S Bandyopadhyay and EJ Coyle. "*An energy efficient hierarchical clustering algorithm for wireless sensor networks*". In IEEE INFOCOM. 2003; 3.

[10] J Cheng, Q Ye, H Jiang, D Wang and C Wang. "STCDG: an efficient data gathering algorithm based on matrix completion for wireless sensor networks". *IEEE Transactions on Wireless Communications.* 2013; 12(2): 850–861.

[11] Y Li, M Sheng, C Wang, X Wang, Y Shi and J Li. "Throughput-delay tradeoff in interference-free wireless networks with guaranteed energy efficiency". *IEEE Transactions on Wireless Communications.* 2015; 14(3): 1608–1621.

[12] HJ Lee and JT Lim. "Cross-layer congestion control for power efficiency over wireless multihop networks". *IEEE Transactions on Vehicular Technology*. 2009; 58(9): 5274–5278.

[13] WB Heinzelman et al. "An application-specific protocol architecture for wireless microsensor networks". *IEEE Trans. Wirel. Commun*. 2002; 1(4): 660-670.

[14] X Liu. "A survey on clustering routing protocols in wireless sensor networks". *Sensors*. 2012; 12(12): 11113-11153.

[15] F Zhao, Y Xu and R Li. "Improved leach routing communication protocol for a wireless sensor network". *Int. J. Distr. Sensor Netw*. 2012: 6. Article ID 649609.

[16] M Tripathi et al. "*Energy Efficient Clustered Routing for Wireless Sensor Network*". In Proc. IEEE MSN'13. 2013: 330-335.

[17] D Mechta, S Harous, I Alem and D Khebbab. "LEACH-CKM: Low energy adaptive clustering hierarchy protocol with K-means and MTE". in IIT'14, Al Ain. 2014: 99-103.

[18] Mao Ye, CLGC, Wu J. *EECS: An energy efficient clustering scheme in wireless sensor networks*. In Proceedings of the Performance, Computing, and Communications Conference (IPCCC 2005), Phoenix, AZ, USA. 2005: 535–540.

[19] Aboobeker Sidhik Koyamparambil Mammu*, Unai Hernandez-Jayo, Nekane Sainz and Idoia de la Iglesia. "Cross-Layer Cluster-Based Energy-Efficient Protocol for Wireless Sensor Networks". *Sensors*. 2015; 15: 8314-8336.

[20] HK Deva Sarma, R Mall and A Kar. "E2R2: Energy-Efficient and Reliable Routing for Mobile Wireless Sensor Networks". in *IEEE Systems Journal*. 2016; 10(2): 604-616.

[21] S Cui, AJ Goldsmith and A Bahai. "Energy-efficiency of MIMO and cooperative MIMO in sensor networks". *IEEE J. Select. Areas Commun*. 2004; 22(6): 1089–1098.

[22] Z Zhou, S Zhou, S Cui and JH Cui. "*Energy-efficient cooperative communication in clustered wireless sensor networks*". In Proc. IEEE Military Communications Conference. 2006: 1–7.

[23] JS Lee, TY Kao. "An Improved Three-Layer Low-Energy Adaptive Clustering Hierarchy for Wireless Sensor Networks". In *IEEE Internet of Things Journal*. 99: 1-1.

[24] D Jia, H Zhu, S Zou and P Hu. "Dynamic Cluster Head Selection Method for Wireless Sensor Network". in *IEEE Sensors Journal.* 2016; 16(8): 2746-2754.

[25] Liu H. Energy-balanced clustering algorithm for wireless sensor networks (EBCA). *Electronic Measurement Technology*. 2015.

[26] Yang Han, Yang Tianming. Adaptive energy optimized clustering algorithm for wireless sensor network routing. *Application Research of Computers*. 2015; 2.

[27] ZX Deng and BS Qi. "*Three-layered routing protocol for WSN based on LEACH algorithm*". In Proc. IET Conf. Wireless, Mobile & Sensor Networks, Shanghai, China. 2007: 72-75.

[28] DC Hoang, R Kumar and SK Panda. "*Fuzzy c-means clustering protocol for wireless sensor networks*". In Proc. IEEE Int. Symp. Industrial Electronics (ISIE), Bari, Italy. 2010: 3477-3482.

[29] X Liu. "Atypical Hierarchical Routing Protocols for Wireless Sensor Networks: A Review". In *IEEE Sensors Journal*. 2015; 15(10): 5372-5383.

[30] S Lindsey, C Raghavendra and KM Sivalingam. "Data gathering algorithms in sensor networks using energy metrics". *IEEE Transaction Parallel Distrib. Syst*. 2002; 13(9): 924–935.

[31] X Bao, S Zhang, D Xue and Z Qie. "*An energy-balanced chaincluster routing protocol for wireless sensor networks*". In Proc. 2nd Int. Conf. Netw. Security Wireless Commun. Trusted Comput. 2010: 79–84.

[32] M Ding, X Cheng and G Xue. “*Aggregation tree construction in sensor networks*”. In Proc. IEEE 58th Veh. Technol. Conf. 2003: 2168–2172.
[33] HÖ Tan and Í Körpeoˇglu. “Power efficient data gathering and aggregation in wireless sensor networks”. *ACM SIGMOD Rec*. 2003; 32(4): 66–71.
[34] D Koutsonikolas, SM Das, YC Hu and I Stojmenovic. “Hierarchical geographic multicast routing for wireless sensor networks”. *Wireless Netw*. 2010; 16(2): 449–466.
[35] O Banimelhem and S Khasawneh. “GMCAR: Grid-based multipath with congestion avoidance routing protocol in wireless sensor networks”. *Ad Hoc Netw*. 2012; 10(7): 1346–1361.
[36] EB Hamida and G Chelius. “*A line-based data dissemination protocol for wireless sensor networks with mobile sink*”. In Proc. IEEE Int. Conf. Commun. 2008: 2201–2205.